深圳抽水蓄能电站

招标及施工图设计阶段水力过渡过程

计算分析报告

（采用D715A曲线计算结果）

武汉大学水利水电学院

水资源与水电工程科学国家重点实验室

2016年12月

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# 1.基本资料

## 1.1 水位

**表1-1 上、下水库水位**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 校核洪水位(m) | 设计洪水位(m) | 设计正常蓄水位 (m) | 死水位(m) |
| 上库 | 528.35 | 527.98 | 526.81 | 502.00 |
| 下库 | 84.26 | 83.29 | 80.00 | 60.00 |

注：下库水位为铜锣径水库扩建后的下库水位

## 1.2 水头／扬程及水头／扬程损失

正常最大毛水头(m) 466.81

正常最小毛水头(m) 431.78

极限最小毛水头 (m) 422.0

水轮机工况额定水头(m) 419.0

## 1.3 机组参数

**表1-2 电站机组参数表**

|  |  |  |
| --- | --- | --- |
| 机组参数 | 单位 | 数量 |
| 机组台数 | 台 | 4 |
| 单机容量 | MW | 300 |
| 额定转速 n0 | rpm | 428.6 |
| 发电机飞轮力矩GD2 | t-m2 | 6000 |
| 水泵-水轮机飞轮力矩GD2 | t-m2 | 257 |
| 转轮直径 D1 | m | 4.16 |
| 额定水头Hr | m | 419 |
| 额定流量 | m3/s | 83.53 |
| 水轮机额定出力 | MW | 306.1 |
| 水泵最大入力 | MW | 325 |
| 机组安装高程 | m | -5 |

## 1.4 水头

最大毛水头 466.81m

正常最小毛水头 431.78m

极限最小毛水头 422m

水轮机工况额定净水头 419m

引水水道水力损失计算式：

水轮机工况：

一台机运行，ΔH=0.3054×10-3QT2

两台机运行，ΔH=0.6408×10-3QT2

三台机运行，ΔH=1.1323×10-3QT2

四台机运行，ΔH=1.8051×10-3QT2

水泵工况：

一台机运行，ΔH=0.3016×10-3Qp2

两台机运行，ΔH=0.6341×10-3Qp2

三台机运行，ΔH=1.0898×10-3Qp2

四台机运行，ΔH=1.9118×10-3Qp2

其中Q为单机过流量（m3/s）

尾水水道水头损失计算式如下：

一台运行 发电工况 ΔH=0.1555×10-3QT2

抽水工况 ΔH=0.1249×10-3QT2

二台运行 发电工况 ΔH=0.2876×10-3QT2

抽水工况 ΔH=0.2299×10-3QT2

三台运行 发电工况 ΔH=0.5901×10-3QT2

抽水工况 ΔH=0.5511×10-3QT2

四台运行 发电工况 ΔH=0.7446×10-3QT2

抽水工况 ΔH= 0.5715×10-3QT2

其中Q为单机过流量（m3/s）

## 1.5 电网频率

额定频率 50Hz

正常频率变化范围 49.5Hz～50.5Hz

发电工况频率正常变化范围 49.5Hz～50.2Hz

水泵工况频率正常变化范围 49.8Hz～50.5Hz

短时允许频率变化范围 49Hz～51Hz

## 1.6 转轮特性曲线

《深圳水泵水轮机模型最终试验报告》中给出的D715A水泵水轮机四象限特性曲线如图1和图2所示。

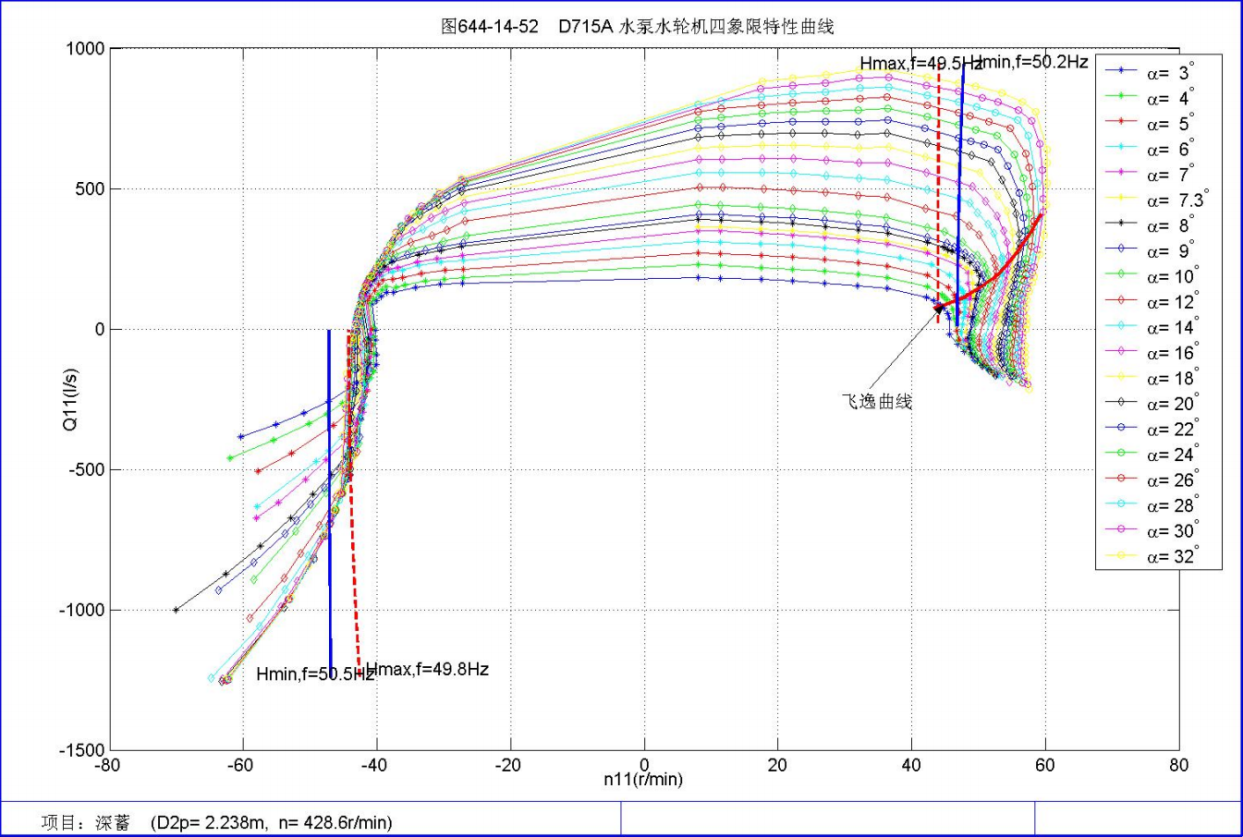
****

图1.1 D715A流量特性曲线

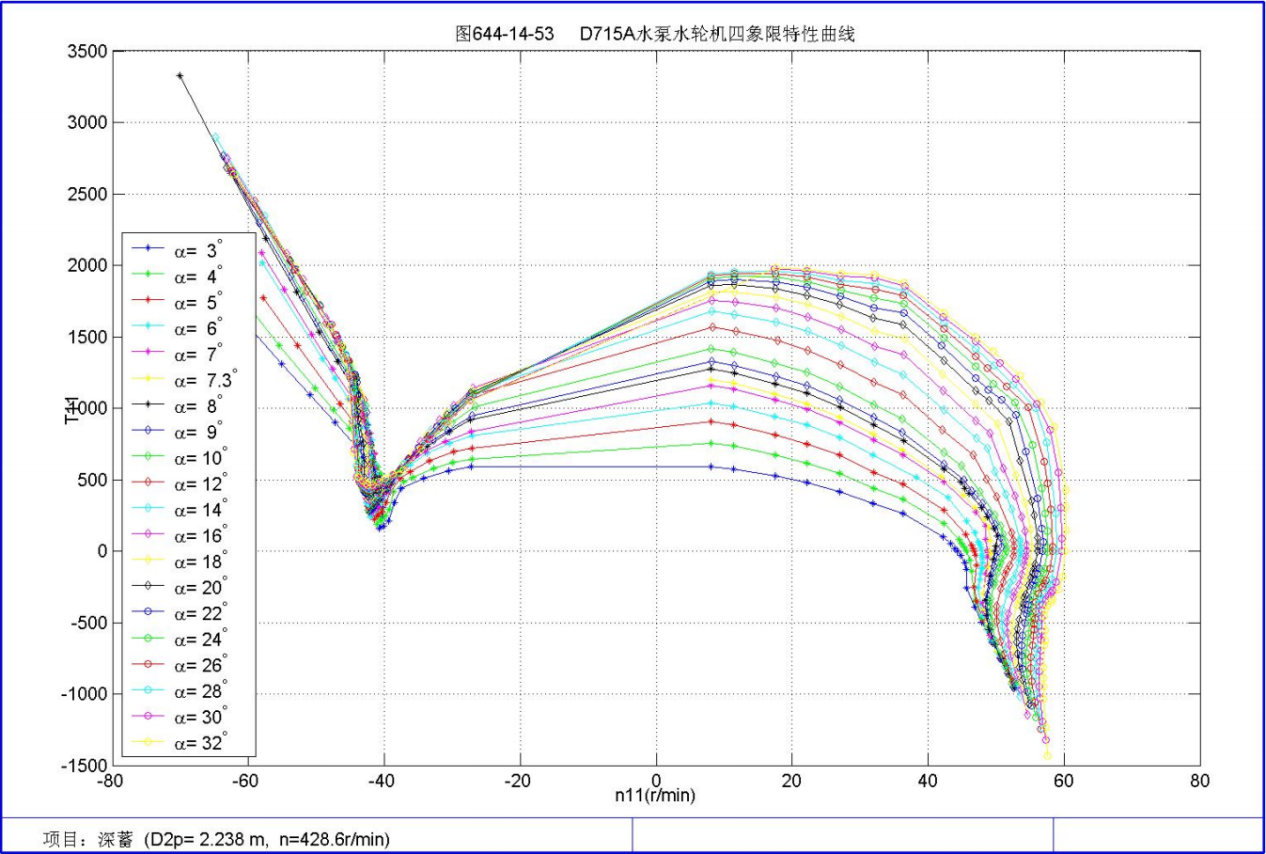
****

图1.2 D715A力矩特性曲线

# 2. 控制参数要求

## 2.1 修正量

压力脉动、计算误差等修正量按以下经验值选取：

(1) 压力脉动：

甩负荷工况时蜗壳最大压力——甩负荷前净水头的7%；

甩负荷工况时尾水管最小压力——甩负荷前净水头的3.5%；

甩入力工况时压力钢管最大压力——甩入力前净扬程的2%。

(2) 计算误差：

任何工况的压力——计算值与初始值差值的10%；

任何工况的转速——计算值与额定转速差值的5%；

调压室的涌浪——计算值与初始值差值的10%。

## 2.2 保证值

机组最大瞬态转速（含计算误差）应不大于1.45倍额定转速，蜗壳进口及进水阀前压力钢管中心线处的最大压力值（含压力脉动和计算误差）应不大于720mH2O，转轮出口处最大压力值不大于（含压力脉动和计算误差）应不大于160mH2O，转轮出口处最低水压值不少于12mH2O（绝对压力，含压力脉动和计算误差）。整个水道系统（上游侧引水管、下游侧尾水管）内的压力不得小于0.02MPa（相对压力）。

# 3. 研究内容

报告主要对深圳抽水蓄能电站招标及施工图设计阶段进行过渡过程计算分析，其主要内容如下：采用真机特性曲线进行水力-机械过渡过程进行详细计算，包括大波动过渡过程计算、小波动稳定计算和水力干扰过渡过程计算。给出大波动工况下的诸项极值，如机组突甩负荷或增加负荷时，水道系统的最大和最小压力，机组最大升速，上库和下库闸门井、引水调压室和尾水调压室的最高、最低涌浪等；寻求导叶的最优关闭规律；推荐调速器参数整定值，验证小波动稳定性；针对水轮机运行范围内有代表性的工况点进行部分机组正常运行，部分机组增减负荷的水力干扰计算，验证机组的出力摆动和运行的安全性和稳定性，为水轮发电机组设置最大出力或过载能力提供参考。

# 4. 计算理论与计算方法

4.1 有压管道非恒定流数学模型和特征线法

有压管道非恒定流基本方程为：

|  |  |
| --- | --- |
| 连续方程 | （4-1） |
| 动量方程 | （4-2） |

其中*H*为以某一水平面为基准的测压管水头；*V*为管道断面的平均流速；*A*为管道断面面积；管道断面面积随x轴线的变化率，若，则式（4-1）即简化为棱柱体管道中的水流连续性方程；为管道各断面形心的连线与水平面所成的夹角；*S*为湿周；*f*为Darcy-Weisbach摩阻系数；为水击波传播速度。

本报告数值计算采用当量管计算方法，因此式（4-1）中。

方程（4-1）和方程（4-2）是一组拟线性双曲型偏微分方程，可采用特征线法将其转化为两个在特征线上的常微分方程：

|  |  |
| --- | --- |
|  | （4-3） |
|  | （4-4） |

上述方程沿特征线C+和C－积分，其中摩阻损失项采取二阶精度数值积分，并用流量代替断面流速，经整理得：

|  |  |
| --- | --- |
| C+： | （4-5） |
| C－： | （4-6） |

式（4-5）和式（4-6）为二元一次方程组，十分便于求解管道内点的*Q*P和*H*P。计算中时间步长和空间步长的选取，需满足库朗稳定条件，否则计算结果不能收敛。

4.2 水轮发电机组边界条件

**4.2.1 机组事故甩负荷**

在甩负荷过渡过程计算中，机组边界共有九个未知数，分别为：转轮进口侧测压管水头、流量，转轮出口侧测压管水头、，单位转速，单位流量，单位力矩，水轮机力矩，转速。对应该九个变量的机组边界方程如下：水轮发电机组的边界条件包括九个方程：

|  |  |
| --- | --- |
|  | （4-7） |
|  | （4-8） |
|  | （4-9） |
|  | （4-10） |
|  | （4-11） |
|  | （4-12） |
|  | （4-13） |
|  | （4-14） |
|  | （4-15） |
| 式中, | （4-16） |

在上述公式中：转轮直径。下标0表示上一计算时段的已知值。式（4-12）和式（4-13）是以直线方程的型式分别代表水轮机瞬时工况点的流量特性和力矩特性。

|  |  |
| --- | --- |
| 令： |  |
|  |  |
|  |  |
|  |  |
|  |  |

上述九个方程可以化成：

|  |  |
| --- | --- |
|  | （4-17） |
|  | （4-18） |

用牛顿辛普生方法解上述两个方程。求出X，n后，将其回代，可依次求出各未知变量。

**4.2.2 机组增、减负荷**

4.2.2.1频率调节

在已知的机组边界方程（4-7）～（4-15）基础上，加入一个调速器方程。考虑测频微分环节（加速度回路）的辅助接力器型调速器方框图如图4-1所示，其调速器方程如下：

|  |  |
| --- | --- |
|  | （4-19） |



图4.1 辅助接力器型调速器方块图

式中y为接力器相对行程；为机组相对转速；、分别为暂态转差系数和永态转差系数；、、、分别为微分回路时间常数、测频微分时间常数、接力器反应时间常数和缓冲时间常数。

并且水轮发电机组的运动方程（4-15）改写为：

式中是机组加速时间常数，电网负荷自调节系数，下标t、g分别表示水轮机和发电机，下标 0表示上一计算时段的已知值，下标r表示额定值。随时间的变化需给定。

4.2.2.2功率调节

在无穷大电网条件下，增、减负荷时，机组未脱离电网，而且是在接到增、减负荷的脉冲信号后按正常规律操作的，所以可以认为在增、减负荷情况下，机组始终维持正常转速。因此，机组边界共有九个未知数，分别为：转轮进口侧测压管水头、流量，转轮出口侧测压管水头、，单位转速，单位流量，单位力矩，水轮机力矩，接力器行程。已知机组边界方程分别为式（4-7）～（4-14），共8个方程，需求解9个未知数，因此需要引入调速器方程。



图4.2 简化后直接式功率调节模式结构图

根据图4-2得出功率调节模式的调速器方程为：

|  |  |
| --- | --- |
|  | （4-21） |

式中，为开环放大系数，、、为调速器参数，为功率给定值，为机组实际功率测量值。

方程（4-21）与方程（4-7）～（4-14）联立，组成功率调节模式下的机组边界条件。

4.2.2.3开度调节

水轮机调速器工作于“功率调节”模式时，若检测出机组功率传感器有故障，则自动切换至“开度调节”模式下工作。此时开度随时间的变化关系曲线给定，机组转速为额定转速不变，则将方程（4-7）～（4-14）、（4-16）联立并简化为一元二次方程，用求根公式得出X后，将其回代，再求出各未知变量。

4.3 岔管边界条件

岔管的边界条件可表示为：

|  |  |
| --- | --- |
|  | （4-22） |
| ： | （4-23） |
| ： | （4-24） |

岔管流量连续方程

|  |  |
| --- | --- |
|  | （4-25） |



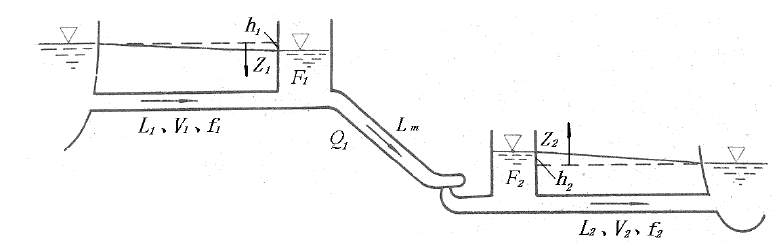
图4.3 岔管示意图

联立上面几个方程，在等时段网格中可求解。

4.4 上、下游调压室稳定断面积计算理论

在托马条件和Jaeger等人工作基础上，深入分析了上下游双调压室水位波动的稳定条件及稳定域变化规律。从理论上，导出了稳定域干涉点和共振点的解析公式，提出了上下游调压室稳定断面设计的准则和计算方法，指出上下游双调压室断面不能同时取托马断面。

**4.4.1 基本方程与波动稳定条件**



由如图所示的上下游双调压室水道系统，基本方程如下：

|  |  |
| --- | --- |
| 引水隧洞： |  |
| 连续性方程： | (4-26) |
| 动力方程： | (4-27) |
| 尾水隧洞： |  |
| 连续性方程： | (4-28) |
| 动力方程： | (4-29) |
| 调速方程： |  |
|  | (4-30) |
| 以托马假定为前提，并引入如下参数：每个调压室单独运行的稳定断面 | |
|  |  |
| 其中： | |
| 相应的托马周期为： |  |
|  |  |
| 调压室断面的放大系数： |  |
|  |  |
| 相应的实际周期为： |  |
|  |  |
| 相对水头损失系数为： |  |
|  |  |
| 由此导出下述上下游双调压室系统水位波动稳定性的四阶微分方程 | |
|  | (4-31) |
| 式中： | |
|  | |
| 其中： | |
|  | |
|  | |
|  | |
| 由常微分方程稳定性理论可知，当方程（4-31）的系数满足Routh-Hurwitz条件时，即满足： | |
|  | |
| 则方程（4-31）表示的波动是稳定的。 | |

**4.4.2 干涉点、共振点确定稳定域边界曲线**

由上下游双调压室水位波动稳定域的变化规律的具体分析（过程略）知，两条渐近线和三个特征点便可以确定两个调压室断面放大系数（）为坐标系下的上、下游双调压室稳定域边界。

其中，两条渐近线指的是。三个特征点：干涉点为的交点（成双存在），计算公式如下：

 （4-32）

|  |  |
| --- | --- |
|  |  |
|  | （4-33） |
| 其中：为上下游调压室的托马周期之比，，为相对水头损失比 | |

当上下游调压室的周期相等时，水位的波动将发生共振，故将稳定边界曲线上周期相等的点成为共振点，共振点计算公式如下：

|  |  |
| --- | --- |
| 两个调压室断面积放大系数应满足的关系： |  |
|  | （4-34） |
| 迭代求解共振点大小，将代入下式进行迭代计算： | |
|  | （4-35） |

一般情况下，迭代一次即可。

**4.4.3 稳定断面的设计准则与计算方法**

由前两节的内容，便可以描绘稳定边界的近似轮廓，在边界线以右，系统是稳定的。考虑到稳定性及裕度两方面的限制，建议双调压室稳定断面设计准则是：当，选取即可；当时，则选取。而，由下列公式近似表示：

 （4-36）

式中，，，是共振点的数值。这样的选择既有较大的安全裕度，又较经济合理。

# 5. 特征参数计算

5.1 计算简图及管道参数

根据深圳抽水蓄能电站引水发电管道系统布置方案，拟将管道系统分成32段，其过渡过程计算简图如图5.1，对应该计算简图的引水发电系统的计算参数见表5.1。其中图5.1中J21、J22、J23及J24分别代表1#、2#、3#及4#机组，J29、J30分别代表上、下游调压室。

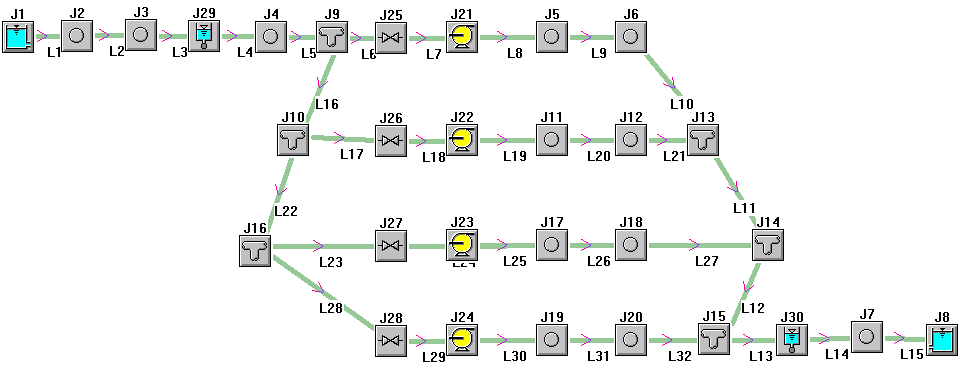


图5.1 深圳抽水蓄能电站过渡过程计算简图

**表5-1 深圳抽水蓄能电站过渡过程计算简图的管道系统参数**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 管段编号 | | 长度L(m) | 当量直径（m） | 波速(m/s) | 糙率 | 发电局部水头损失系数 | 抽水局部水头损失系数 | 发电岔管水头损失系数 | 抽水岔管水头损失系数 | 备注 |
| L1 | | 67.17 | 20.52 | 1000 | 0.014 | 0.8174 | 2.9016 | 0.0000 | 0.0000 | 上游进出水口扩散段 |
| L2 | | 146.51 | 10.12 | 1200 | 0.014 | 0.1506 | 0.2015 | 0.0000 | 0.0000 | 上游进出水口闸门井后渐变 |
| L3 | | 1404.29 | 9.50 | 1200 | 0.014 | 0.1391 | 0.1391 | 0.0000 | 0.0000 | 上游调压室 |
| L4 | | 1596.72 | 9.50 | 1200 | 0.014 | 0.3927 | 0.3927 | 0.0000 | 0.0000 | 上游9.5到8.5渐变始 |
| L5 | | 49.26 | 8.60 | 1200 | 0.014 | 0.1038 | 0.0953 | 0.0000 | 0.0000 | 1#上游岔点 |
| 1#机所在管线 | L6 | 151.23 | 3.56 | 1300 | 0.012 | 0.1404 | 0.1851 | 0.496 | 1.552 | 1#球阀 |
| L7 | 31.76 | 2.33 | 1400 | 0.0015 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1#蜗壳 |
| L8 | 25.59 | 3.31 | 1200 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 1#尾水管 |
| L9 | 102.84 | 4.50 | 1200 | 0.012 | 0.3528 | 0.3528 | 0.0000 | 0.0000 | 1#尾水钢衬末 |
| L10 | 16.74 | 7.52 | 1200 | 0.014 | 1.2480 | 0.3520 | 0.081 | 0.0450 | 1#/2#下游岔点 |
| L11 | 27.14 | 8.50 | 1200 | 0.014 | 0.0000 | 0.0000 | 0.237 | 0.0078 | 3#下游岔点 |
| L12 | 27.14 | 8.50 | 1200 | 0.014 | 0.0000 | 0.0000 | 0.24 | 0.0013 | 4#下游岔点 |
| L13 | | 25.00 | 9.17 | 1200 | 0.014 | 0.0219 | 0.0329 | 0.0000 | 0.0000 | 下游调压室 |
| L14 | | 994.85 | 9.50 | 1200 | 0.014 | 0.0679 | 0.0679 | 0.0000 | 0.0000 | 下游进出水口闸门井前渐变 |
| L15 | | 92.17 | 15.32 | 1000 | 0.014 | 1.3476 | 0.9404 | 0.0000 | 0.0000 | 下游进出水口扩散段 |
| 2#机所在管线 | L16 | 25.5 | 7.96 | 1200 | 0.014 | 0.0000 | 0.0000 | 0.0013 | 0.2 | 2#上游岔点 |
| L17 | 146.50 | 3.57 | 1300 | 0.012 | 0.1419 | 0.1806 | 0.354 | 2.224 | 2#球阀 |
| L18 | 31.76 | 2.33 | 1400 | 0.0015 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 2#蜗壳 |
| L19 | 25.59 | 3.31 | 1200 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 2#尾水管 |
| L20 | 97.95 | 4.50 | 1200 | 0.012 | 0.2445 | 0.2445 | 0.0000 | 0.0000 | 2#尾水钢衬末 |
| L21 | 10 | 4.50 | 1200 | 0.014 | 0.0000 | 0.0000 | 2.774 | 0.194 | 1#/2#下游岔点 |
| 3#机所在管线 | L22 | 25.5 | 6.61 | 1200 | 0.014 | 0.0000 | 0.0000 | 0.0078 | 0.179 | 3#/4#上游岔点 |
| L23 | 141.78 | 3.60 | 1300 | 0.012 | 0.1400 | 0.1782 | 0.219 | 2.599 | 3#球阀 |
| L24 | 31.76 | 2.33 | 1400 | 0.0015 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 3#蜗壳 |
| L25 | 25.59 | 3.31 | 1200 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 3#尾水管 |
| L26 | 111.52 | 4.50 | 1200 | 0.012 | 0.2444 | 0.2444 | 0.0000 | 0.0000 | 3#尾水钢衬末 |
| L27 | 10 | 4.50 | 1200 | 0.014 | 0.0000 | 0.0000 | 1.117 | 0.52 | 3#下游岔点 |
| 4#机所在管线 | L28 | 160.87 | 3.66 | 1300 | 0.012 | 0.1860 | 0.2175 | 0.0450 | 0.092 | 4#球阀 |
| L29 | 31.76 | 2.33 | 1400 | 0.0015 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 4#蜗壳 |
| L30 | 25.59 | 3.31 | 1200 | 0.0001 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 4#尾水管 |
| L31 | 125.09 | 4.50 | 1200 | 0.012 | 0.2436 | 0.2436 | 0.0000 | 0.0000 | 4#尾水钢衬末 |
| L32 | 10 | 4.50 | 1200 | 0.014 | 0.0000 | 0.0000 | 0.688 | 0.634 | 4#下游岔点 |

## 5.2 恒定流水头损失计算

引水发电系统的水头损失计算中钢筋混凝土的糙率取平均值0.014，钢管的糙率取平均值0.012。局部水头损失,为依据规范查得有关损失系数，A、Q分别为管道断面面积和流量，沿程损失，n、L、R分别为管道糙率、长度、水力半径，其它参数相同，总水头损失。计算结果并与设计院的结果对比见表5-2。

**表5-2 引水发电系统水头损失计算表**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 运行状态 | 运行方式 | 设计院参考值（m） | 计算值（m） | | | |
| 1# | 2# | 3# | 4# |
| 发电 | 四台机运行 | 17.790 | 12.674 | 13.107 | 12.635 | 12.269 |
| 抽水 | 四台机运行 | 11.523 | 9.284 | 9.575 | 10.194 | 8.685 |

注：1）引水隧洞和压力管道均取平均糙率计算，分别取0.014、0.012；

2）总水头损失发电按额定水头下发额定出力时的单机流量Qr=83.53m3/s计算，抽水按最小扬程时的单机流量Q=68.12m3/s计算；

3）水轮机工况时，四台机运行，按照设计院给的水力损失计算公式，水道四台机运行ΔH=1.8051×10-3QT2 ，尾水部分水力损失ΔH=0.7446×10-3QT2；

4）水泵工况时，四台机运行，按照设计院给的水力损失计算公式，水道四台机运行ΔH=1.9118×10-3Qp2，尾水部分水力损失ΔH= 0.5715×10-3QT2；

5.3 Tw值及Ta值计算

管线水流加速时间为，机组加速时间为，其中是管线上各管道长度，是引水管道中的最大流速，是重力加速度，是电站设计水头419.00（m）。为机组飞轮力矩6257，为机组额定转速428.6r/min，为机组额定力矩，为机组额定出力306.1MW。计算结果见表5-3。

**表5-3 值及值计算**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 管线代号 | Tw1值（s）(上游进水口到上游调压室) | Tw2值（s）(上游调压室到机组) | Tw3值（s）(机组到下游调压室) | Tw4值（s）(下游调压室到下游出口) | Ta值（s） | Tw2/Ta | Tw3/Ta |
| 1 | 1.775 | 2.359 | 0.279 | 1.182 | 10.288 | 0.229 | 0.027 |
| 2 | 1.775 | 2.379 | 0.278 | 1.182 | 10.288 | 0.231 | 0.027 |
| 3 | 1.775 | 2.402 | 0.275 | 1.182 | 10.288 | 0.233 | 0.027 |
| 4 | 1.775 | 2.423 | 0.264 | 1.182 | 10.288 | 0.236 | 0.026 |

5.4 上、下游调压室布置形式及稳定域校核

5.4.1 **上、下游调压室布置形式**

根据设计院图纸，上、下游调压室高程与断面关系如表5-4所示，阻抗孔口的位置在升管与第一段竖井连接处。

**表5-4 调压室高程—面积关系表**

|  |  |  |  |
| --- | --- | --- | --- |
| 上游调压室 | | 下游调压室 | |
| 高程(m) | 面积(m2) | 高程(m) | 面积(m2) |
| 398.00 | 242.065 | -11.25 | 260.115 |
| 402.75 | 70.88 | -6.5 | 70.88 |
| 462.575 | 70.88 | 31.65 | 70.88 |
| 463.5 | 26.42 | 33.5 | 26.42 |
| 465.00 | 201.06 | 34.99 | 26.42 |
| 535.999 | 201.06 | 35 | 201.06 |
| 536.00 | 1252.00 | 88.579 | 201.06 |
| 540.00 | 1252.00 | 88.58 | 876.60 |
| 541.20 | 1252.00 | 96.5 | 876.60 |

**5.4.2 稳定域校核**

由4.4节上、下游调压室稳定断面积计算理论：

以托马假定为前提，每个调压室单独运行的稳定断面计算下表5-5：

**表5-5 上、下游调压室托马断面计算表**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 调压室  (4#机管线) | (m) | (m2) | (s2/m) | (m) | (m) | (m) | (m) | (m2) | (s) | A  (m2) |
| 上游 | 1617.97 | 74.10 | 0.1189 | 422.0 | 7.952 | 2.407 | 1.680 | 91.328 | 89.58 | 201.06 |
| 下游 | 1087.02 | 74.78 | 0.0842 | 124.40 | 85.30 | 201.06 |

其中，和分别是压力引水道的长度与断面积，是自水库至游调压室的全部水头损失系数，是发电最小静水头,为压力管道的水头损失，、为压力引水道和压力尾水道水头损失，为调压室理论稳定断面面积，为理论稳定断面下调压室涌浪波动周期。

下面确定稳定域边界线，变量的含义见4.4.1节，如下表所示：

**表5-6 稳定域边界线计算表**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (m) | (m2) | (s2/m) | (m) | (m) | (m2) |  |  | 干涉点1 | 干涉点2 | 共振点 |
| 422.0 | 2.407 | 8.182 | 1.680 | 1.751E-2 | 8.541E-3 | 0.698 | 1.05 | 0.895  1.19 | 1.082  0.906 | 1.904  2.106 |

由上述计算结果，便可以大致绘出稳定域边界线。该电站上、下游调压室的实际断面积，实际断面放大倍数（2.202，1.616）。如下图所示，初步绘出稳定域边界线并在图中标出实际断面积放大倍数所在的位置。

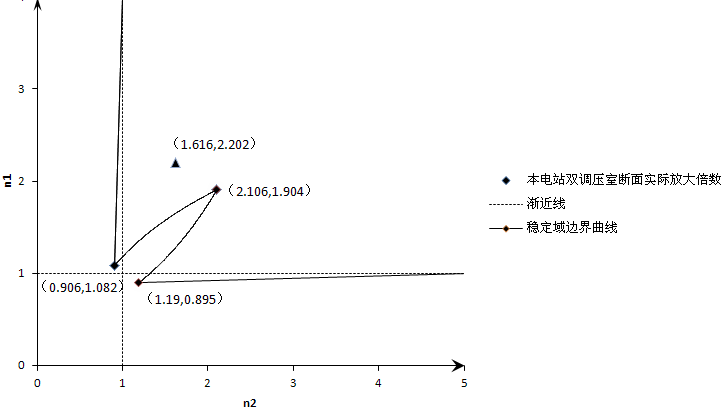


图5.2 稳定域边界曲线示意图

由图5.2可以看出，本电站上、下游双调压室的实际断面放大系数都在稳定域边界曲线以右，即在稳定域范围内，说明该电站的上、下游双调压室波动时稳定的。

又由4.4.3节稳定断面的设计准则计算知，由于表5.6中，，该电站推荐的双调压室断面积放大系数为：，。本电站实际的双调压室断面积放大系数的安全裕度较大。

# 6. 大波动过渡过程计算与分析

6.1 大波动过渡过程计算工况的拟定

根据设计院要求，本报告拟定了如下大波动过渡过程计算工况：

**6.1.1 水轮机工况**

1）设计工况

**表6-1 水轮机设计工况列表**

| 工况 | 上游水位  (m) | 下游水位  (m) | 工况描述 |
| --- | --- | --- | --- |
| SJT1 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，最大静水头，四台机组突甩全负荷，导叶正常关闭； |
| SJT2 | 509.50 | - | 上库水位509.50m，额定水头419.00m，四台机组突甩全负荷，导叶正常关闭； |
| SJT3 | 528.35 | 61.54 | 上库校核洪水位528.35m，最大静水头466.81m，四台机组突甩全负荷，导叶正常关闭 |
| SJT4 | 502.00 | - | 上库死水位502.00m，额定水头419.00m，四台机组突甩全负荷，导叶正常关闭； |
| SJT5 | 502.00 | - | 上库死水502.00m，额定水头419.00m，三台机组正常运行，第四台机组突增全负荷； |
| SJT6 | - | 78.40 | 下库水位78.40m，额定水头419.00m，四台机组突甩全负荷，导叶正常关闭； |
| SJT7 | - | 78.40 | 下库水位78.40m，额定水头419.00m，三台机组正常运行，第四台机组突增全负荷； |
| SJT8 | - | 71.90 | 下库水位71.90m，额定水头419.00m，四台机组突甩全负荷，导叶正常关闭； |
| SJT9 |  | 71.90 | 下库水位71.90m，额定水头419.00m，三台机组正常运行，第四台机组突增全负荷； |
| ZT1 | 526.81 | 60.00 | 三台机组正常工作，第四台机组启动增至满负荷后，在流入上游调压井流量最大时，四台机同时甩全部负荷；导叶正常关闭 |
| ZT2 | 509.50 | - | 额定水头419.00m，三台机组正常工作，第四台机组启动增至满负荷后，在流入上游调压井流量最大时，四台机同时甩全部负荷；导叶正常关闭 |
| ZT3 | 526.81 | 60.00 | 额定水头419.00m，三台机组正常运行，第四台机增至满负荷后，在流出下游调压室流量最大时，四台机同时甩全负荷，导叶正常关闭 |
| ZT4 | 502.00 | - | 额定水头419.00m，三台机组正常运行，第四台机增至满负荷后，在流出下游调压室流量最大时，四台机同时甩全负荷，导叶正常关闭 |

2）校核工况

**表6-2 水轮机校核工况列表**

| 工况 | 上游水位 (m) | 下游水位(m) | 工况描述 |
| --- | --- | --- | --- |
| JHT1 | 528.35 | 61.54 | 上库校核洪水位528.35 m，最大静水头466.81m，四台机组突甩全负荷，三台导叶正常关闭，一台导叶拒动； |
| JHT2 | 528.35 | 61.54 | 上库校核洪水位528.35 m，最大静水头466.81m，四台机组突甩全负荷，一台机球阀拒动；（蜗壳、阀前最大压力） |
| JHT3 | 509.50 | - | 上库水位509.50m，额定水头419.00m，四台机组突甩全负荷，三台导叶正常关闭，第四台延时关闭； |
| JHT4 | 509.50 | - | 上库正常蓄水位509.50m，额定水头419.00m，四台机组突甩全负荷，三台导叶正常关闭，一台导叶拒动； |
| JHT5 | 502.00 | - | 上库死水位502.00m，额定水头419.00m，四台机组突甩全负荷，一台机组导叶拒动； |
| JHT6 | 502.00 | - | 上库死水位502.00m，额定水头419.00m，四台机组突甩全负荷，三台导叶正常关闭，第四台延时关闭； |
| JHT7 | - | 78.40 | 下库水位78.40m，额定水头419.00m，四台机组突甩全负荷，一台机组导叶拒动； |
| JHT8 | - | 78.40 | 下库水位78.40m，额定水头419.00m，四台机组突甩全负荷，三台导叶正常关闭，第四台延时关闭； |
| JHT9 | - | 71.90 | 下库水位71.90m，额定水头419.00m，四台机突甩全负荷，一台机导叶拒动； |
| JHT10 | - | 71.90 | 下库水位71.90m，额定水头419.00m，四台机组突甩全负荷，三台导叶正常关闭，第四台延时关闭； |
| JHT11 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，最大静水头466.81m，四台机组突甩全负荷，一台机组导叶拒动 |
| JHT12 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，最大静水头466.81m，四台机组突甩全负荷，一台机组球阀拒动 |
| JHT13 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，两台机甩负荷，在最不利时刻，另外两台机组甩负荷；注：只能1#、2#一组3#、4#一组 |
| JHT14 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，四台机组发电运行，其中两台机组同时甩负荷，在最不利时刻，第三台机组甩负荷，第四台机组继续运行； |
| JHT15 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，三台机组发电运行，其中两台机组甩负荷，在最不利时刻，第三台机组甩负荷； |
| JHT16 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，三台机组发电运行，第一台机组甩负荷，在最不利时刻，剩下两台机组甩负荷； |
| JHT17 | 528.35 | 61.54 | 上库校核洪水位528.35m，最大静水头466.81m，四台机组突甩全负荷，三台导叶正常关闭，第四台延时关闭； |
| JHT18 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，最大静水头466.81m，四台机组突甩全负荷，三台导叶正常关闭，第四台延时关闭； |

3）极端工况

**表6-3 水轮机极端工况列表**

| 工况 | 上游水位 (m) | 下游水位(m) | 工况描述 |
| --- | --- | --- | --- |
| JDT1 | 528.35 | 61.54 | 上库校核洪水位528.35m，最大静水头466.81m，四台机组突甩全负荷，其中一台导叶、球阀均拒动； |
| JDT2 | 502.00 | - | 上库死水位502.00m，额定水头419.00m，四台机组突甩全负荷，其中一台导叶、球阀均拒动； |
| JDT3 | - | 78.40 | 下库水位78.40m，额定水头419.00m，四台机组突甩全负荷，其中一台机组导叶、球阀均拒动； |
| JDT4 | - | 71.90 | 下库水位71.90m，额定水头419.00m，四台机组突甩全负荷，其中一台机组导叶、球阀均拒动； |
| JDT5 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，四台机组突甩全负荷，其中一台机组导叶、球阀均拒动； |
| JDT6 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，三台机甩负荷，在最不利时刻，第四台机组甩负荷； |
| JDT7 | 528.35 | 61.54 | 上库校核洪水位528.35m，最大静水头466.81m，四台机组突甩全负荷，其中一台机组导叶延时2s关闭； |
| JDT10 | 526.81 | 60.00 | 上库正常蓄水位526.81m，下库死水位60.00m，四台机组发电运行，其中一台机组甩负荷，在最不利时刻，剩下三台机组甩负荷；转轮出口最小压力 |

6.1.2 **水泵工况**

1）设计工况

**表6-4 水泵设计工况列表**

| 工况 | 上游水位 (m) | 下游水位(m) | 工况描述 |
| --- | --- | --- | --- |
| SJP1 | 526.81 | 60.00 | 上库正常高水位526.81m，下库死水位60.00m，最大扬程，四台机组突然断电，导叶正常关闭； |
| SJP2 | 502.00 | 80.00 | 上库水位502.00m，下库水位80.00m，最小扬程422m，四台机组突然断电，导叶正常关闭； |
| SJP3 | 504.57 | 84.26 | 上库水位504.57m，下库校核洪水位84.26m，最小扬程422.00m，四台机组突然断电，导叶正常关闭； |
| SJP4 | 502.00 | 70.55 | 下库水位70.55m，上库死水位502.00m，四台机组突然断电，导叶正常关闭； |
| ZP2 | 502.00 | 80.00 | 三台机正常工作，第四台机启动，在流出上游调压井流量最大时四台机同时突然断电，导叶正常关闭； |
| ZP3 | 504.57 | 84.26 | 三台组正常工作，第四台机启动，在流出上游调压井流量最大时四台机同时突然断电，导叶正常关闭； |
| ZP4 | 502.00 | 80.00 | 三台机正常工作，第四台机启动，在流入下游调压井流量最大时四台机同时突然断电，导叶正常关闭； |

2）校核工况

**表6-5 水泵校核工况列表**

| 工况 | 上游水位 (m) | 下游水位(m) | 工况描述 |
| --- | --- | --- | --- |
| JHP1 | 502.00 | 80.00 | 上库水位502.00m，下库水位80.00m，最小扬程422m，四台机组突然断电，其中一台机组导叶拒动； |
| JHP2 | 502.00 | 80.00 | 上库水位502.00m，下库水位80.00m，最小扬程422m，四台机组突然断电，其中一台机组球阀拒动； |
| JHP3 | 502.00 | 70.55 | 下库水位70.55m，上库死水位502.00m，四台机组突然断电，其中一台机组导叶拒动； |
| JHP4 | 502.00 | 70.55 | 下库水位70.55m，上库死水位502.00m，四台机组突然断电，其中一台机组球阀拒动； |
| JHP5 | 526.81 | 60.00 | 上库正常蓄水位526.81m，最大扬程，四台机组突然断电，其中一台机组导叶拒动； |

3）极端工况

**表6-6 水泵极端工况列表**

| 工况 | 上游水位 (m) | 下游水位(m) | 工况描述 |
| --- | --- | --- | --- |
| JDP1 | 502.00 | 80.00 | 下库正常蓄水位80.00m，上库死水位502.00m，最小扬程422m，其中一台机组导叶、球阀均拒动； |
| JDP2 | 504.57 | 84.26 | 上库水位504.57m，下库校核洪水位84.26m，最小扬程422m，四台机组突然断电，其中一台机组导叶、球阀拒动；转轮出口最大压力 |
| JDP3 | 502.00 | 70.55 | 下库水位70.55m，，上库死水位502.00m，四台机组突然断电，其中一台机组导叶、球阀均拒动； |

6.2 球阀不参与调节导叶关闭规律优化

**6.2.1 控制工况选取**

对于深圳抽水蓄能电站，水泵工况较易满足要求，本章主要针对表6.7中的几个有可能产生水轮机设计工况及校核工况下蜗壳最大压力、设计工况下机组最大转速上升率、尾水管最小压力的水轮机工况，分以下2种情况进行导叶关闭规律优化：（1）导叶一段直线关闭；（2）导叶先快后慢两段关闭；

**表 6-7 控制工况列表**

| 工况 | 上游  水位 (m) | 下游水位(m) | 工况描述 | 计算目的 |
| --- | --- | --- | --- | --- |
| SJT2 | 509.50 | 79.00 | 上库水位509.50m，额定水头419.00m，四台机组突甩全负荷，导叶正常关闭； | 设计工况机组最大转速上升率 |
| SJT3 | 528.35 | 61.54 | 上库校核洪水位528.35 m，最大静水头466.81m，四台机组突甩全负荷，导叶正常关闭 | 设计工况蜗壳最大压力 |
| ZT2 | 509.50 | - | 额定水头419.00m，三台机组正常工作，第四台机组启动增至满负荷后，在流入上游调压井流量最大时，四台机同时甩全部负荷； | 设计工况机组最大转速上升率 |
| JHT3 | 509.50 | - | 上库水位509.50m，额定水头419.00m，四台机组突甩全负荷，三台导叶正常关闭，第四台（4#）延时4S关闭； | 校核工况蜗壳最大压力，机组最大转速上升率 |
| JHT13 | 526.81 | 60.00 | 上库正常蓄水位，下库死水位，两台机甩负荷，在最不利时刻，另外两台机组甩负荷；尾水压力 | 校核工况尾水管最小压力 |
| JDT6 | 526.81 | 60.00 | 上库正常蓄水位，下库死水位，三台机甩负荷，在最不利时刻，第四台机组甩负荷；尾水管最小压力 | 极端工况尾水管最小压力 |
| JDT10 | 526.81 | 60.00 | 不同水位组合下，四台机组发电运行，其中一台机组甩负荷，在最不利时刻，剩下三台机组甩负荷；转轮出口最小压力 | 极端工况尾水管最小压力 |

### 6.2.2 球阀关闭规律

根据公式就可求得球阀水头损失系数，式中A为球阀处管道面积，C为球阀流量系数C。C随角度的变化规律表如表6-8所示。

**表6-8 球阀流量系数C随角度的变化规律表**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 角度(°) | 0.01 | 1 | 4.48 | 10 | 15 | 20 | 25 |
| 流量系数C | 0 | 0.01 | 0.0351 | 0.0597 | 0.0811 | 0.10399 | 0.13501 |
| 角度(°) | 30 | 35 | 40 | 42.93 | 45 | 50 | 55 |
| 流量系数C | 0.17861 | 0.21347 | 0.25259 | 0.2824 | 0.3019 | 0.39937 | 0.46116 |
| 角度(°) | 60 | 62.5 | 65 | 70 | 75 | 80 | 82.5 |
| 流量系数C | 0.5648 | 0.79875 | 1 | 1.41421 | 2 | 3.16228 | 4.47214 |
| 角度(°) | 85 | 86.03 | 87.5 | 88.97 | 90 | \ | \ |
| 流量系数C | 10 | 14.14214 | 20 | 44.72136 | 100 | \ | \ |

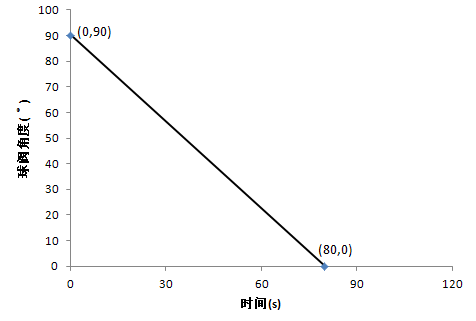
应设计院要求，导叶关闭的同时球阀联合关闭，球阀慢关截断水流、不起调保作用，球阀预先采用直线80s的关闭规律进行试算，在6.3节中再优化球阀的关闭规律，如图6.1所示。

图6.1 球阀关闭规律

### 6.2.3 一段直线关闭

一段直线关闭时，接力器行程从100%关到0，关闭时间分别按直线40s、直线50s、直线60s、直线70s对表6-7中的控制工况进行计算，结果如下。

**6.2.3.1 直线40s关闭计算结果**

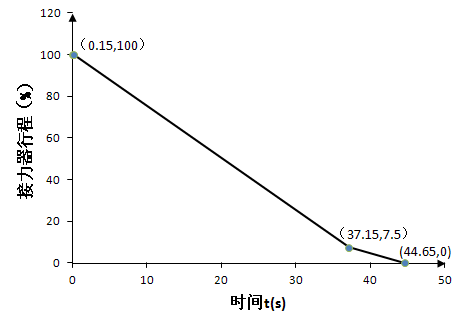


图6.2 水轮机工况导叶直线40s关闭规律

**表6-9 直线40s关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔(s) | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 654.31 | 9.83 | 662.25 | 9.93 | 50.18 | 12.29 | 42.57 | 7.80 |
| 0.00 | 2# | 656.26 | 10.08 | 663.44 | 9.70 | 49.19 | 11.81 | 42.72 | 7.79 |
| 0.00 | 3# | 656.48 | 9.84 | 663.69 | 10.03 | 48.71 | 11.90 | 42.85 | 7.82 |
| 0.00 | 4# | 659.26 | 9.55 | 667.64 | 10.05 | 49.75 | 11.90 | 42.91 | 7.81 |
| SJT3 | 0.00 | 1# | 673.23 | 9.55 | 680.42 | 9.55 | 34.24 | 10.63 | 40.14 | 7.41 |
| 0.00 | 2# | 674.34 | 9.58 | 681.03 | 9.70 | 34.29 | 10.63 | 40.26 | 7.41 |
| 0.00 | 3# | 674.33 | 9.61 | 681.05 | 9.58 | 34.52 | 10.65 | 40.36 | 7.44 |
| 0.00 | 4# | 677.05 | 9.55 | 683.52 | 10.05 | 34.48 | 10.63 | 40.41 | 7.44 |
| ZT2 | 76.76 | 1# | 654.31 | 86.55 | 660.98 | 86.60 | 49.84 | 88.44 | 43.12 | 84.62 |
| 76.76 | 2# | 655.34 | 86.59 | 662.22 | 86.52 | 49.75 | 88.35 | 43.26 | 84.61 |
| 76.76 | 3# | 656.37 | 86.64 | 663.22 | 86.66 | 49.71 | 88.56 | 43.39 | 84.65 |
| 76.76 | 4# | 657.90 | 86.74 | 664.61 | 86.77 | 49.78 | 88.59 | 43.44 | 84.63 |
| JHT3 | 0.00 | 1# | 654.31 | 9.83 | 662.25 | 9.93 | 50.18 | 12.29 | 42.57 | 7.80 |
| 0.00 | 2# | 656.26 | 10.08 | 663.44 | 9.70 | 49.19 | 11.81 | 42.72 | 7.79 |
| 0.00 | 3# | 656.48 | 9.84 | 663.69 | 10.03 | 48.71 | 11.90 | 42.85 | 7.82 |
| 0.00 | 4# | 659.26 | 9.55 | 667.64 | 10.05 | 49.75 | 11.90 | 42.91 | 7.81 |
| 1.00 | 1# | 653.81 | 9.83 | 661.13 | 9.93 | 49.25 | 12.29 | 42.44 | 7.83 |
| 1.00 | 2# | 655.32 | 10.08 | 662.25 | 9.70 | 48.93 | 11.81 | 42.59 | 7.84 |
| 1.00 | 3# | 655.86 | 10.30 | 662.76 | 10.11 | 47.75 | 11.90 | 42.73 | 7.89 |
| 1.00 | 4# | 660.19 | 10.05 | 670.07 | 10.05 | 50.78 | 11.90 | 43.92 | 7.83 |
| 2.00 | 1# | 652.64 | 10.23 | 659.56 | 9.93 | 49.29 | 12.29 | 42.26 | 7.85 |
| 2.00 | 2# | 654.34 | 10.08 | 660.78 | 10.06 | 49.20 | 11.81 | 42.41 | 7.87 |
| 2.00 | 3# | 654.94 | 10.30 | 661.58 | 10.11 | 47.75 | 11.90 | 42.54 | 7.87 |
| 2.00 | 4# | 660.99 | 10.05 | 671.40 | 10.05 | 50.32 | 11.00 | 44.84 | 7.80 |
| 3.00 | 1# | 651.06 | 10.23 | 658.07 | 9.93 | 49.38 | 12.29 | 42.03 | 7.87 |
| 3.00 | 2# | 652.84 | 10.08 | 659.17 | 10.06 | 49.43 | 12.36 | 42.18 | 7.90 |
| 3.00 | 3# | 653.56 | 10.30 | 660.10 | 10.11 | 48.37 | 11.90 | 42.31 | 7.88 |
| 3.00 | 4# | 660.95 | 10.05 | 672.22 | 10.05 | 47.87 | 30.77 | 45.62 | 7.88 |
| 4.00 | 1# | 649.51 | 10.23 | 656.66 | 9.93 | 50.25 | 12.29 | 41.81 | 7.85 |
| 4.00 | 2# | 651.55 | 10.08 | 657.69 | 10.06 | 50.20 | 12.36 | 41.95 | 7.88 |
| 4.00 | 3# | 652.24 | 10.30 | 658.57 | 10.11 | 49.39 | 11.90 | 42.08 | 7.91 |
| 4.00 | 4# | 659.59 | 10.05 | 671.09 | 10.05 | 47.83 | 30.77 | 46.19 | 8.00 |
| 5.00 | 1# | 648.17 | 9.83 | 655.60 | 9.93 | 51.34 | 12.29 | 41.66 | 7.80 |
| 5.00 | 2# | 650.39 | 10.08 | 656.53 | 10.06 | 51.35 | 12.36 | 41.79 | 7.81 |
| 5.00 | 3# | 650.65 | 10.30 | 657.19 | 10.11 | 50.68 | 11.90 | 41.90 | 7.84 |
| 5.00 | 4# | 656.73 | 10.05 | 668.10 | 10.05 | 46.72 | 30.77 | 46.69 | 8.22 |
| 6.00 | 1# | 647.46 | 9.80 | 655.23 | 9.93 | 52.99 | 11.09 | 41.59 | 7.77 |
| 6.00 | 2# | 649.35 | 10.08 | 656.02 | 9.70 | 52.41 | 11.81 | 41.72 | 7.76 |
| 6.00 | 3# | 649.42 | 10.30 | 656.33 | 10.11 | 51.87 | 11.90 | 41.82 | 7.79 |
| 6.00 | 4# | 652.11 | 9.55 | 661.89 | 10.05 | 45.05 | 30.91 | 46.96 | 8.33 |
| 7.00 | 1# | 647.23 | 9.83 | 655.32 | 9.93 | 52.35 | 11.09 | 41.57 | 7.72 |
| 7.00 | 2# | 649.13 | 10.08 | 656.30 | 9.70 | 52.17 | 11.17 | 41.70 | 7.74 |
| 7.00 | 3# | 649.02 | 10.30 | 656.27 | 10.11 | 51.97 | 11.90 | 41.80 | 7.76 |
| 7.00 | 4# | 647.75 | 9.55 | 654.32 | 10.05 | 42.71 | 31.31 | 47.02 | 8.42 |
| 8.00 | 1# | 647.07 | 9.83 | 655.34 | 9.93 | 51.83 | 11.09 | 41.57 | 7.72 |
| 8.00 | 2# | 648.72 | 10.08 | 656.47 | 9.70 | 51.57 | 11.17 | 41.71 | 7.73 |
| 8.00 | 3# | 648.49 | 9.94 | 656.27 | 10.11 | 51.28 | 11.35 | 41.80 | 7.76 |
| 8.00 | 4# | 644.32 | 9.55 | 650.29 | 31.70 | 37.82 | 14.08 | 47.00 | 8.39 |
| 9.00 | 1# | 646.79 | 9.83 | 655.42 | 9.93 | 51.22 | 11.09 | 41.57 | 7.72 |
| 9.00 | 2# | 648.52 | 10.08 | 656.41 | 9.70 | 50.88 | 11.17 | 41.71 | 7.73 |
| 9.00 | 3# | 648.37 | 9.94 | 656.46 | 10.11 | 50.62 | 11.35 | 41.80 | 7.76 |
| 9.00 | 4# | 642.14 | 9.55 | 648.33 | 31.77 | 33.16 | 14.44 | 47.00 | 8.41 |
| 10.00 | 1# | 646.62 | 9.83 | 655.38 | 9.93 | 50.87 | 11.09 | 41.57 | 7.72 |
| 10.00 | 2# | 648.29 | 10.08 | 656.37 | 9.70 | 50.43 | 11.17 | 41.71 | 7.73 |
| 10.00 | 3# | 648.17 | 9.94 | 656.41 | 10.11 | 50.13 | 11.35 | 41.80 | 7.76 |
| 10.00 | 4# | 641.21 | 9.55 | 646.77 | 31.77 | 32.04 | 14.44 | 47.00 | 8.41 |
| 11.00 | 1# | 646.62 | 9.83 | 655.38 | 9.93 | 50.70 | 11.09 | 41.57 | 7.72 |
| 11.00 | 2# | 648.29 | 10.08 | 656.37 | 9.70 | 50.23 | 11.17 | 41.71 | 7.73 |
| 11.00 | 3# | 648.17 | 9.94 | 656.41 | 10.11 | 49.82 | 11.35 | 41.80 | 7.76 |
| 11.00 | 4# | 641.21 | 9.55 | 647.90 | 31.70 | 32.82 | 14.44 | 47.00 | 8.41 |
| 12.00 | 1# | 646.62 | 9.83 | 655.38 | 9.93 | 50.70 | 11.09 | 41.57 | 7.72 |
| 12.00 | 2# | 648.29 | 10.08 | 656.37 | 9.70 | 50.23 | 11.17 | 41.71 | 7.73 |
| 12.00 | 3# | 648.17 | 9.94 | 656.41 | 10.11 | 49.82 | 11.35 | 41.80 | 7.76 |
| 12.00 | 4# | 641.21 | 9.55 | 646.91 | 31.70 | 33.00 | 14.74 | 47.00 | 8.41 |
| JHT13 | 0.00 | 1# | 671.68 | 9.55 | 678.79 | 9.55 | 32.65 | 10.63 | 40.14 | 7.41 |
| 0.00 | 2# | 672.80 | 9.58 | 679.47 | 9.70 | 32.77 | 10.63 | 40.26 | 7.41 |
| 0.00 | 3# | 672.91 | 9.61 | 679.71 | 9.58 | 32.92 | 10.65 | 40.36 | 7.45 |
| 0.00 | 4# | 675.46 | 9.55 | 681.85 | 10.05 | 33.02 | 10.63 | 40.42 | 7.46 |
| 1.00 | 1# | 668.24 | 10.46 | 674.85 | 10.36 | 35.23 | 27.03 | 39.21 | 7.74 |
| 1.00 | 2# | 668.73 | 10.34 | 675.46 | 10.41 | 35.44 | 11.17 | 39.34 | 7.78 |
| 1.00 | 3# | 673.95 | 10.73 | 682.57 | 10.69 | 32.35 | 11.26 | 40.90 | 8.14 |
| 1.00 | 4# | 674.85 | 10.59 | 683.86 | 10.96 | 32.53 | 11.15 | 40.97 | 8.15 |
| 2.00 | 1# | 662.31 | 11.46 | 668.50 | 10.96 | 31.94 | 27.52 | 37.92 | 7.86 |
| 2.00 | 2# | 664.11 | 11.03 | 670.21 | 10.95 | 31.85 | 27.50 | 38.04 | 7.88 |
| 2.00 | 3# | 675.87 | 11.48 | 685.55 | 11.58 | 31.92 | 28.91 | 41.14 | 9.00 |
| 2.00 | 4# | 676.11 | 11.63 | 685.55 | 11.58 | 31.26 | 28.88 | 41.23 | 8.99 |
| 3.00 | 1# | 653.10 | 11.46 | 656.92 | 11.56 | 30.83 | 14.45 | 36.57 | 7.62 |
| 3.00 | 2# | 654.64 | 11.52 | 658.29 | 11.42 | 30.20 | 14.36 | 36.65 | 7.71 |
| 3.00 | 3# | 672.82 | 12.13 | 684.63 | 12.13 | 30.85 | 12.26 | 41.26 | 9.85 |
| 3.00 | 4# | 674.17 | 12.23 | 684.88 | 12.08 | 30.57 | 12.34 | 41.36 | 9.86 |
| 4.00 | 1# | 636.44 | 11.46 | 640.69 | 11.56 | 23.97 | 15.73 | 35.51 | 7.28 |
| 4.00 | 2# | 638.86 | 12.12 | 641.31 | 11.42 | 19.26 | 15.28 | 35.55 | 7.34 |
| 4.00 | 3# | 672.39 | 12.80 | 686.49 | 12.73 | 26.53 | 12.91 | 41.48 | 10.73 |
| 4.00 | 4# | 672.85 | 12.92 | 687.28 | 12.85 | 25.28 | 12.88 | 41.59 | 10.75 |
| 5.00 | 1# | 632.00 | 9.55 | 636.32 | 9.46 | 17.55 | 16.34 | 34.87 | 6.93 |
| 5.00 | 2# | 632.77 | 9.58 | 636.01 | 9.70 | 13.15 | 16.24 | 34.88 | 6.93 |
| 5.00 | 3# | 667.42 | 13.20 | 686.30 | 13.20 | 18.54 | 13.16 | 41.90 | 11.51 |
| 5.00 | 4# | 668.31 | 13.29 | 687.37 | 13.21 | 18.27 | 13.25 | 42.01 | 11.54 |
| 6.00 | 1# | 628.74 | 9.37 | 634.21 | 9.33 | 24.63 | 16.62 | 34.67 | 6.64 |
| 6.00 | 2# | 628.44 | 9.28 | 633.85 | 8.82 | 22.89 | 16.84 | 34.66 | 6.67 |
| 6.00 | 3# | 656.18 | 13.43 | 680.47 | 13.48 | 13.74 | 13.35 | 41.88 | 12.06 |
| 6.00 | 4# | 657.34 | 13.52 | 681.19 | 13.58 | 12.47 | 13.48 | 42.02 | 12.12 |
| 7.00 | 1# | 630.99 | 9.37 | 637.61 | 8.86 | 25.55 | 18.25 | 34.67 | 6.60 |
| 7.00 | 2# | 631.25 | 9.28 | 637.38 | 8.82 | 24.03 | 18.14 | 34.66 | 6.60 |
| 7.00 | 3# | 635.55 | 13.95 | 661.27 | 13.85 | 14.73 | 13.81 | 40.41 | 12.51 |
| 7.00 | 4# | 637.68 | 13.98 | 662.50 | 14.04 | 13.09 | 13.78 | 40.59 | 12.57 |
| 8.00 | 1# | 631.11 | 8.88 | 640.51 | 8.86 | 22.64 | 18.12 | 34.67 | 6.60 |
| 8.00 | 2# | 631.27 | 8.93 | 640.39 | 8.82 | 21.47 | 18.62 | 34.66 | 6.60 |
| 8.00 | 3# | 625.13 | 9.41 | 639.06 | 14.74 | 20.79 | 14.47 | 37.66 | 13.15 |
| 8.00 | 4# | 627.62 | 9.55 | 642.06 | 14.78 | 20.85 | 14.44 | 37.89 | 13.23 |
| 9.00 | 1# | 636.63 | 17.18 | 639.75 | 8.86 | 19.41 | 19.61 | 34.67 | 6.60 |
| 9.00 | 2# | 636.55 | 17.22 | 639.79 | 8.82 | 18.71 | 19.62 | 34.66 | 6.60 |
| 9.00 | 3# | 620.45 | 16.83 | 623.44 | 16.04 | 24.19 | 22.98 | 34.81 | 14.15 |
| 9.00 | 4# | 624.17 | 16.96 | 626.92 | 16.12 | 28.39 | 26.86 | 35.10 | 14.25 |
| 10.00 | 1# | 628.85 | 8.88 | 639.75 | 8.86 | 25.89 | 27.15 | 34.67 | 6.60 |
| 10.00 | 2# | 628.31 | 8.77 | 639.79 | 8.82 | 25.63 | 27.14 | 34.66 | 6.60 |
| 10.00 | 3# | 605.54 | 9.41 | 616.10 | 24.12 | 18.90 | 23.61 | 32.33 | 15.24 |
| 10.00 | 4# | 606.09 | 9.55 | 610.97 | 37.59 | 30.84 | 23.50 | 32.67 | 15.29 |
| 11.00 | 1# | 628.85 | 8.88 | 639.75 | 8.86 | 31.10 | 26.49 | 34.67 | 6.60 |
| 11.00 | 2# | 628.31 | 8.77 | 639.79 | 8.82 | 30.42 | 26.50 | 34.66 | 6.60 |
| 11.00 | 3# | 625.18 | 24.49 | 634.48 | 24.47 | 30.73 | 23.77 | 31.97 | 19.66 |
| 11.00 | 4# | 621.87 | 24.59 | 629.13 | 24.67 | 32.90 | 23.72 | 31.98 | 19.42 |
| 12.00 | 1# | 628.85 | 8.88 | 639.75 | 8.86 | 31.98 | 26.34 | 34.67 | 6.60 |
| 12.00 | 2# | 628.31 | 8.77 | 639.79 | 8.82 | 31.42 | 26.35 | 34.66 | 6.60 |
| 12.00 | 3# | 637.79 | 24.67 | 647.00 | 24.47 | 32.13 | 24.08 | 34.02 | 20.67 |
| 12.00 | 4# | 637.90 | 24.52 | 646.56 | 24.50 | 31.83 | 24.24 | 34.04 | 20.53 |
| JDT6 | 0.00 | 1# | 671.68 | 9.55 | 678.79 | 9.55 | 32.65 | 10.63 | 40.14 | 7.41 |
| 0.00 | 2# | 672.80 | 9.58 | 679.47 | 9.70 | 32.77 | 10.63 | 40.26 | 7.41 |
| 0.00 | 3# | 672.91 | 9.61 | 679.71 | 9.58 | 32.92 | 10.65 | 40.36 | 7.45 |
| 0.00 | 4# | 675.46 | 9.55 | 681.85 | 10.05 | 33.02 | 10.63 | 40.42 | 7.46 |
| 1.00 | 1# | 668.36 | 10.46 | 676.16 | 10.30 | 34.75 | 10.63 | 39.65 | 7.55 |
| 1.00 | 2# | 669.75 | 10.08 | 676.69 | 9.70 | 35.07 | 10.63 | 39.77 | 7.56 |
| 1.00 | 3# | 670.61 | 10.30 | 678.42 | 10.33 | 35.32 | 10.45 | 39.88 | 7.56 |
| 1.00 | 4# | 674.54 | 10.59 | 684.75 | 10.96 | 30.74 | 28.29 | 41.33 | 8.03 |
| 2.00 | 1# | 664.67 | 10.46 | 672.31 | 10.36 | 34.16 | 27.38 | 39.00 | 7.55 |
| 2.00 | 2# | 665.01 | 10.61 | 672.81 | 10.58 | 33.90 | 27.39 | 39.11 | 7.56 |
| 2.00 | 3# | 666.94 | 10.73 | 674.69 | 10.41 | 33.90 | 27.50 | 39.22 | 7.57 |
| 2.00 | 4# | 675.64 | 11.43 | 687.93 | 11.50 | 25.91 | 11.90 | 41.97 | 8.85 |
| 3.00 | 1# | 657.79 | 10.78 | 665.55 | 10.30 | 31.65 | 27.52 | 38.38 | 7.46 |
| 3.00 | 2# | 659.20 | 10.94 | 666.29 | 10.58 | 31.88 | 27.52 | 38.47 | 7.46 |
| 3.00 | 3# | 660.74 | 10.84 | 668.06 | 10.41 | 31.94 | 27.50 | 38.56 | 7.48 |
| 3.00 | 4# | 674.15 | 11.57 | 692.58 | 12.08 | 18.06 | 12.19 | 42.63 | 9.88 |
| 4.00 | 1# | 654.34 | 9.54 | 660.83 | 9.93 | 31.01 | 27.61 | 37.90 | 7.33 |
| 4.00 | 2# | 655.09 | 9.50 | 661.23 | 9.69 | 31.06 | 27.61 | 37.98 | 7.34 |
| 4.00 | 3# | 655.07 | 10.21 | 661.47 | 10.32 | 31.36 | 27.65 | 38.04 | 7.42 |
| 4.00 | 4# | 672.35 | 12.53 | 695.27 | 12.45 | 8.77 | 12.50 | 43.49 | 10.76 |
| 5.00 | 1# | 652.48 | 9.54 | 658.98 | 9.46 | 33.76 | 27.61 | 37.55 | 7.22 |
| 5.00 | 2# | 653.25 | 9.50 | 658.91 | 9.69 | 34.14 | 27.61 | 37.63 | 7.24 |
| 5.00 | 3# | 652.72 | 9.56 | 658.29 | 9.58 | 33.03 | 27.65 | 37.66 | 7.28 |
| 5.00 | 4# | 669.24 | 12.92 | 697.16 | 12.76 | 2.44 | 12.81 | 44.27 | 11.48 |
| 6.00 | 1# | 649.46 | 9.82 | 656.56 | 9.46 | 32.67 | 27.61 | 37.40 | 7.10 |
| 6.00 | 2# | 650.27 | 9.79 | 657.15 | 9.69 | 32.54 | 27.62 | 37.45 | 7.11 |
| 6.00 | 3# | 650.09 | 10.21 | 656.18 | 10.05 | 31.74 | 27.58 | 37.47 | 7.12 |
| 6.00 | 4# | 658.43 | 10.05 | 688.74 | 13.21 | -2.24 | 13.25 | 44.45 | 11.99 |
| 7.00 | 1# | 650.73 | 9.45 | 657.77 | 9.46 | 30.63 | 27.52 | 37.38 | 7.04 |
| 7.00 | 2# | 651.41 | 9.50 | 657.23 | 9.69 | 30.70 | 27.50 | 37.43 | 7.05 |
| 7.00 | 3# | 650.76 | 9.41 | 656.69 | 9.43 | 30.53 | 27.50 | 37.45 | 7.06 |
| 7.00 | 4# | 650.28 | 10.59 | 674.48 | 13.58 | -1.67 | 13.62 | 43.43 | 12.48 |
| 8.00 | 1# | 652.41 | 9.45 | 659.56 | 9.46 | 27.20 | 27.52 | 37.38 | 7.04 |
| 8.00 | 2# | 653.34 | 9.50 | 659.17 | 9.56 | 26.55 | 27.50 | 37.43 | 7.05 |
| 8.00 | 3# | 652.59 | 9.41 | 658.81 | 9.43 | 27.12 | 27.50 | 37.45 | 7.06 |
| 8.00 | 4# | 648.18 | 9.55 | 655.76 | 14.18 | 4.41 | 14.14 | 41.26 | 13.00 |
| 9.00 | 1# | 651.75 | 9.54 | 659.72 | 9.46 | 33.39 | 27.61 | 37.38 | 7.04 |
| 9.00 | 2# | 652.67 | 9.50 | 659.96 | 9.69 | 34.18 | 27.61 | 37.43 | 7.05 |
| 9.00 | 3# | 652.19 | 9.56 | 659.49 | 9.49 | 33.96 | 27.50 | 37.45 | 7.06 |
| 9.00 | 4# | 645.61 | 10.05 | 651.67 | 10.05 | 7.52 | 15.11 | 38.08 | 13.73 |
| 10.00 | 1# | 651.10 | 9.45 | 659.68 | 9.46 | 36.66 | 20.35 | 37.38 | 7.04 |
| 10.00 | 2# | 651.99 | 9.50 | 659.52 | 9.56 | 36.93 | 20.52 | 37.43 | 7.05 |
| 10.00 | 3# | 651.16 | 9.56 | 659.11 | 9.43 | 36.51 | 20.54 | 37.45 | 7.06 |
| 10.00 | 4# | 633.91 | 10.36 | 638.39 | 10.47 | 7.05 | 16.16 | 34.69 | 14.80 |
| 11.00 | 1# | 651.10 | 9.45 | 659.68 | 9.46 | 32.24 | 20.50 | 37.38 | 7.04 |
| 11.00 | 2# | 651.99 | 9.50 | 659.52 | 9.56 | 32.44 | 20.52 | 37.43 | 7.05 |
| 11.00 | 3# | 651.16 | 9.56 | 659.11 | 9.43 | 32.21 | 20.54 | 37.45 | 7.06 |
| 11.00 | 4# | 633.51 | 9.55 | 632.67 | 10.05 | 13.41 | 17.06 | 31.97 | 15.94 |
| 12.00 | 1# | 651.10 | 9.45 | 659.68 | 9.46 | 33.58 | 21.47 | 37.38 | 7.04 |
| 12.00 | 2# | 651.99 | 9.50 | 659.52 | 9.56 | 34.04 | 22.00 | 37.43 | 7.05 |
| 12.00 | 3# | 651.16 | 9.56 | 659.11 | 9.43 | 33.48 | 21.97 | 37.45 | 7.06 |
| 12.00 | 4# | 633.51 | 9.55 | 638.10 | 27.05 | 23.11 | 26.34 | 29.81 | 16.85 |
| JDT10 | 0.00 | 1# | 671.68 | 9.55 | 678.79 | 9.55 | 32.65 | 10.63 | 40.14 | 7.41 |
| 0.00 | 2# | 672.80 | 9.58 | 679.47 | 9.70 | 32.77 | 10.63 | 40.26 | 7.41 |
| 0.00 | 3# | 672.91 | 9.61 | 679.71 | 9.58 | 32.92 | 10.65 | 40.36 | 7.45 |
| 0.00 | 4# | 675.46 | 9.55 | 681.85 | 10.05 | 33.02 | 10.63 | 40.42 | 7.46 |
| 1.00 | 1# | 667.54 | 10.46 | 673.65 | 10.36 | 34.28 | 26.95 | 38.85 | 7.94 |
| 1.00 | 2# | 672.06 | 10.94 | 679.75 | 10.95 | 33.29 | 11.17 | 40.47 | 8.26 |
| 1.00 | 3# | 673.32 | 10.73 | 681.58 | 10.87 | 32.96 | 11.35 | 40.60 | 8.28 |
| 1.00 | 4# | 674.35 | 10.59 | 682.82 | 10.96 | 34.21 | 11.52 | 40.66 | 8.29 |
| 2.00 | 1# | 660.66 | 11.35 | 664.52 | 11.56 | 29.12 | 13.55 | 37.11 | 8.57 |
| 2.00 | 2# | 673.38 | 11.58 | 680.39 | 11.42 | 34.27 | 29.05 | 40.46 | 9.17 |
| 2.00 | 3# | 674.36 | 11.67 | 682.82 | 11.58 | 34.40 | 12.26 | 40.59 | 9.17 |
| 2.00 | 4# | 674.84 | 11.49 | 682.96 | 11.58 | 34.42 | 12.34 | 40.67 | 9.17 |
| 3.00 | 1# | 651.02 | 12.24 | 651.31 | 12.08 | 16.93 | 14.87 | 34.92 | 8.96 |
| 3.00 | 2# | 671.41 | 12.67 | 678.11 | 12.31 | 34.12 | 29.60 | 40.26 | 10.02 |
| 3.00 | 3# | 670.85 | 12.65 | 679.51 | 12.58 | 34.78 | 29.52 | 40.42 | 10.04 |
| 3.00 | 4# | 671.91 | 12.53 | 680.41 | 12.68 | 34.31 | 13.18 | 40.50 | 10.06 |
| 4.00 | 1# | 645.43 | 15.70 | 673.35 | 15.69 | 3.32 | 15.73 | 33.45 | 14.88 |
| 4.00 | 2# | 667.06 | 13.24 | 676.27 | 13.22 | 33.93 | 30.60 | 39.99 | 10.84 |
| 4.00 | 3# | 668.74 | 13.31 | 677.00 | 13.31 | 34.01 | 30.50 | 40.16 | 10.85 |
| 4.00 | 4# | 669.61 | 13.44 | 677.88 | 13.44 | 34.34 | 30.60 | 40.27 | 10.90 |
| 5.00 | 1# | 658.94 | 14.32 | 676.39 | 16.38 | 1.56 | 16.42 | 33.14 | 15.64 |
| 5.00 | 2# | 668.25 | 13.84 | 675.79 | 13.58 | 34.07 | 12.36 | 39.85 | 11.55 |
| 5.00 | 3# | 669.25 | 13.97 | 676.57 | 13.85 | 34.19 | 11.90 | 40.04 | 11.59 |
| 5.00 | 4# | 669.25 | 14.10 | 676.89 | 14.04 | 34.00 | 12.34 | 40.17 | 11.63 |
| 6.00 | 1# | 663.62 | 14.80 | 668.03 | 14.94 | 4.64 | 17.14 | 31.98 | 6.11 |
| 6.00 | 2# | 665.32 | 14.40 | 672.18 | 14.10 | 32.61 | 13.08 | 39.57 | 12.15 |
| 6.00 | 3# | 665.54 | 14.58 | 671.87 | 14.15 | 32.88 | 13.13 | 39.80 | 12.19 |
| 6.00 | 4# | 666.29 | 14.55 | 672.84 | 14.40 | 33.41 | 13.25 | 39.95 | 12.26 |
| 7.00 | 1# | 640.99 | 18.28 | 657.25 | 18.45 | 21.65 | 18.55 | 31.98 | 6.11 |
| 7.00 | 2# | 635.72 | 14.95 | 640.04 | 14.94 | 35.23 | 10.63 | 37.33 | 12.80 |
| 7.00 | 3# | 637.36 | 15.11 | 642.68 | 15.21 | 34.66 | 10.65 | 37.61 | 12.86 |
| 7.00 | 4# | 639.25 | 14.91 | 645.73 | 14.94 | 33.73 | 10.78 | 37.82 | 12.91 |
| 8.00 | 1# | 641.16 | 19.44 | 653.49 | 19.84 | 25.84 | 19.98 | 31.98 | 6.11 |
| 8.00 | 2# | 631.76 | 18.73 | 634.61 | 18.30 | 35.09 | 34.59 | 35.62 | 14.52 |
| 8.00 | 3# | 633.13 | 18.58 | 637.31 | 18.56 | 34.78 | 34.59 | 35.92 | 14.48 |
| 8.00 | 4# | 633.84 | 18.56 | 638.88 | 18.46 | 35.52 | 11.22 | 36.14 | 14.50 |
| 9.00 | 1# | 645.92 | 20.75 | 655.74 | 20.85 | 31.06 | 21.06 | 31.98 | 6.11 |
| 9.00 | 2# | 640.06 | 19.29 | 644.33 | 19.28 | 35.54 | 35.60 | 35.53 | 16.70 |
| 9.00 | 3# | 640.94 | 19.42 | 645.42 | 19.32 | 35.76 | 35.57 | 35.67 | 16.60 |
| 9.00 | 4# | 641.41 | 19.26 | 646.11 | 19.42 | 36.34 | 35.99 | 35.77 | 16.51 |
| 10.00 | 1# | 644.87 | 21.15 | 651.87 | 21.20 | 34.39 | 21.69 | 31.98 | 6.11 |
| 10.00 | 2# | 642.16 | 20.66 | 648.16 | 20.56 | 35.95 | 36.74 | 36.38 | 17.94 |
| 10.00 | 3# | 643.42 | 20.59 | 649.30 | 20.58 | 36.30 | 36.61 | 36.48 | 17.91 |
| 10.00 | 4# | 644.55 | 20.73 | 651.27 | 20.84 | 36.54 | 36.61 | 36.54 | 17.86 |
| 11.00 | 1# | 642.67 | 21.87 | 649.46 | 22.03 | 35.66 | 22.24 | 31.98 | 6.11 |
| 11.00 | 2# | 647.17 | 22.39 | 655.37 | 21.96 | 33.74 | 22.25 | 37.19 | 18.82 |
| 11.00 | 3# | 648.34 | 22.12 | 656.67 | 22.01 | 32.85 | 22.33 | 37.29 | 18.84 |
| 11.00 | 4# | 649.28 | 22.04 | 657.77 | 22.10 | 33.91 | 22.38 | 37.36 | 18.82 |
| 12.00 | 1# | 643.70 | 22.50 | 649.74 | 22.40 | 37.46 | 25.89 | 31.98 | 6.11 |
| 12.00 | 2# | 656.16 | 23.20 | 664.34 | 22.94 | 31.80 | 22.98 | 37.99 | 19.72 |
| 12.00 | 3# | 657.00 | 23.17 | 665.43 | 23.08 | 32.34 | 22.76 | 38.11 | 19.72 |
| 12.00 | 4# | 657.68 | 23.17 | 666.67 | 22.94 | 32.51 | 22.68 | 38.18 | 19.75 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.3 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.4 JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.5 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.6 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.7 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.8 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.9 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.10 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.3.2 直线50s关闭计算结果**

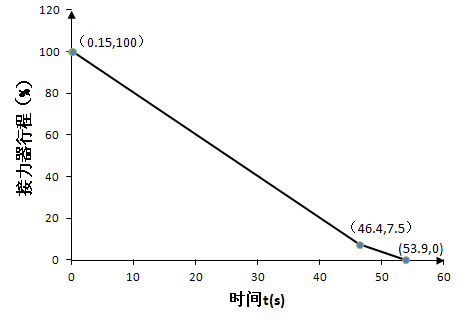


图6.11 水轮机工况导叶直线50s关闭规律

**表6-10 直线50s关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔(s) | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 646.05 | 9.83 | 653.04 | 9.93 | 51.85 | 11.09 | 42.81 | 7.86 |
| 0.00 | 2# | 647.30 | 10.08 | 653.82 | 10.06 | 51.99 | 11.17 | 42.96 | 7.86 |
| 0.00 | 3# | 647.84 | 10.21 | 654.73 | 10.32 | 51.44 | 11.90 | 43.09 | 7.86 |
| 0.00 | 4# | 650.10 | 9.55 | 658.62 | 10.05 | 51.90 | 11.90 | 43.15 | 7.88 |
| SJT3 | 0.00 | 1# | 659.83 | 9.45 | 666.20 | 9.46 | 34.70 | 11.09 | 40.47 | 7.50 |
| 0.00 | 2# | 660.81 | 9.50 | 666.33 | 9.56 | 34.41 | 11.17 | 40.59 | 7.52 |
| 0.00 | 3# | 661.32 | 9.41 | 666.70 | 9.43 | 34.77 | 11.26 | 40.69 | 7.55 |
| 0.00 | 4# | 663.26 | 9.55 | 668.44 | 9.40 | 34.41 | 11.00 | 40.74 | 7.54 |
| ZT2 | 76.76 | 1# | 645.34 | 86.59 | 651.45 | 86.60 | 52.45 | 87.92 | 43.35 | 84.70 |
| 76.76 | 2# | 646.21 | 86.57 | 652.45 | 86.63 | 52.42 | 87.93 | 43.50 | 84.68 |
| 76.76 | 3# | 646.94 | 86.59 | 653.28 | 86.80 | 52.50 | 88.02 | 43.63 | 84.70 |
| 76.76 | 4# | 648.29 | 86.84 | 654.55 | 86.77 | 52.45 | 89.12 | 43.67 | 84.72 |
| JHT3 | 0.00 | 1# | 646.05 | 9.83 | 653.04 | 9.93 | 51.85 | 11.09 | 42.81 | 7.86 |
| 0.00 | 2# | 647.30 | 10.08 | 653.82 | 10.06 | 51.99 | 11.17 | 42.96 | 7.86 |
| 0.00 | 3# | 647.84 | 10.21 | 654.73 | 10.32 | 51.44 | 11.90 | 43.09 | 7.86 |
| 0.00 | 4# | 650.10 | 9.55 | 658.62 | 10.05 | 51.90 | 11.90 | 43.15 | 7.88 |
| 1.00 | 1# | 644.30 | 10.23 | 652.15 | 9.93 | 52.14 | 12.29 | 42.70 | 7.88 |
| 1.00 | 2# | 646.47 | 10.08 | 652.94 | 10.06 | 52.13 | 12.36 | 42.85 | 7.89 |
| 1.00 | 3# | 647.26 | 10.21 | 654.25 | 10.32 | 51.57 | 11.90 | 42.98 | 7.93 |
| 1.00 | 4# | 651.35 | 9.55 | 660.28 | 10.05 | 52.61 | 11.00 | 43.92 | 7.87 |
| 2.00 | 1# | 642.94 | 10.23 | 650.56 | 9.93 | 52.45 | 12.29 | 42.54 | 7.89 |
| 2.00 | 2# | 645.24 | 10.08 | 651.51 | 10.06 | 52.38 | 12.36 | 42.69 | 7.91 |
| 2.00 | 3# | 645.87 | 10.21 | 652.84 | 10.32 | 51.94 | 11.90 | 42.83 | 7.96 |
| 2.00 | 4# | 651.01 | 9.55 | 660.57 | 10.05 | 47.99 | 33.23 | 44.58 | 7.90 |
| 3.00 | 1# | 642.03 | 9.83 | 649.26 | 9.93 | 52.78 | 12.29 | 42.37 | 7.94 |
| 3.00 | 2# | 644.10 | 10.08 | 650.21 | 10.06 | 52.73 | 12.36 | 42.51 | 7.93 |
| 3.00 | 3# | 644.46 | 10.21 | 651.22 | 10.32 | 52.05 | 11.90 | 42.64 | 7.95 |
| 3.00 | 4# | 650.16 | 9.55 | 660.23 | 10.05 | 45.54 | 33.39 | 45.12 | 7.98 |
| 4.00 | 1# | 641.22 | 10.23 | 648.46 | 9.93 | 53.38 | 12.29 | 42.20 | 7.90 |
| 4.00 | 2# | 643.19 | 10.08 | 649.17 | 10.06 | 53.27 | 12.36 | 42.34 | 7.89 |
| 4.00 | 3# | 643.91 | 10.21 | 650.42 | 10.32 | 52.76 | 11.90 | 42.46 | 7.92 |
| 4.00 | 4# | 649.92 | 9.55 | 660.24 | 10.05 | 46.96 | 33.52 | 45.66 | 8.15 |
| 5.00 | 1# | 640.07 | 10.23 | 647.65 | 9.93 | 54.17 | 11.09 | 42.07 | 7.84 |
| 5.00 | 2# | 642.19 | 10.08 | 648.39 | 10.06 | 54.08 | 11.17 | 42.21 | 7.87 |
| 5.00 | 3# | 642.84 | 10.21 | 649.46 | 10.32 | 53.83 | 11.90 | 42.32 | 7.89 |
| 5.00 | 4# | 647.10 | 9.55 | 656.91 | 10.05 | 50.75 | 11.90 | 46.08 | 8.28 |
| 6.00 | 1# | 639.72 | 9.83 | 647.20 | 9.93 | 53.66 | 11.09 | 42.01 | 7.81 |
| 6.00 | 2# | 641.42 | 10.08 | 647.92 | 10.06 | 53.87 | 11.17 | 42.14 | 7.82 |
| 6.00 | 3# | 641.74 | 10.21 | 648.83 | 10.32 | 53.83 | 11.35 | 42.25 | 7.85 |
| 6.00 | 4# | 643.48 | 9.55 | 651.23 | 10.05 | 49.85 | 12.34 | 46.30 | 8.35 |
| 7.00 | 1# | 639.79 | 9.88 | 647.40 | 9.93 | 53.38 | 11.09 | 42.00 | 7.80 |
| 7.00 | 2# | 641.41 | 10.08 | 648.17 | 10.06 | 53.52 | 11.17 | 42.13 | 7.82 |
| 7.00 | 3# | 641.61 | 10.21 | 648.96 | 10.32 | 53.20 | 11.35 | 42.23 | 7.82 |
| 7.00 | 4# | 640.51 | 9.55 | 646.45 | 10.05 | 47.28 | 14.44 | 46.35 | 8.42 |
| 8.00 | 1# | 639.69 | 9.83 | 647.58 | 9.93 | 53.36 | 11.09 | 42.00 | 7.79 |
| 8.00 | 2# | 641.39 | 10.08 | 648.34 | 10.06 | 53.39 | 11.17 | 42.13 | 7.81 |
| 8.00 | 3# | 641.54 | 10.21 | 649.05 | 10.32 | 53.06 | 11.90 | 42.23 | 7.83 |
| 8.00 | 4# | 638.64 | 9.55 | 642.72 | 10.05 | 42.92 | 14.74 | 46.34 | 8.39 |
| 9.00 | 1# | 639.63 | 9.83 | 647.74 | 9.93 | 53.09 | 11.09 | 42.00 | 7.79 |
| 9.00 | 2# | 641.20 | 10.08 | 648.40 | 10.06 | 53.09 | 11.17 | 42.13 | 7.81 |
| 9.00 | 3# | 641.49 | 10.21 | 649.11 | 10.32 | 52.74 | 11.35 | 42.23 | 7.83 |
| 9.00 | 4# | 636.61 | 9.55 | 640.51 | 10.05 | 40.42 | 14.74 | 46.34 | 8.41 |
| 10.00 | 1# | 639.51 | 9.83 | 647.67 | 9.93 | 52.84 | 11.09 | 42.00 | 7.79 |
| 10.00 | 2# | 641.02 | 10.08 | 648.32 | 10.06 | 52.83 | 11.17 | 42.13 | 7.81 |
| 10.00 | 3# | 641.22 | 10.21 | 648.99 | 10.03 | 52.37 | 11.90 | 42.23 | 7.83 |
| 10.00 | 4# | 635.88 | 9.55 | 638.24 | 9.57 | 38.94 | 14.74 | 46.34 | 8.41 |
| 11.00 | 1# | 639.51 | 9.83 | 647.67 | 9.93 | 52.68 | 11.09 | 42.00 | 7.79 |
| 11.00 | 2# | 641.02 | 10.08 | 648.32 | 10.06 | 52.66 | 11.17 | 42.13 | 7.81 |
| 11.00 | 3# | 641.22 | 10.21 | 648.99 | 10.03 | 52.04 | 11.90 | 42.23 | 7.83 |
| 11.00 | 4# | 635.88 | 9.55 | 638.24 | 9.57 | 39.07 | 14.74 | 46.34 | 8.41 |
| 12.00 | 1# | 639.51 | 9.83 | 647.67 | 9.93 | 52.68 | 11.09 | 42.00 | 7.79 |
| 12.00 | 2# | 641.02 | 10.08 | 648.32 | 10.06 | 52.66 | 11.17 | 42.13 | 7.81 |
| 12.00 | 3# | 641.22 | 10.21 | 648.99 | 10.03 | 51.95 | 11.90 | 42.23 | 7.83 |
| 12.00 | 4# | 635.88 | 9.55 | 638.24 | 9.57 | 39.63 | 14.74 | 46.34 | 8.41 |
| JHT13 | 0.00 | 1# | 658.29 | 9.45 | 664.66 | 9.46 | 33.16 | 11.09 | 40.47 | 7.50 |
| 0.00 | 2# | 659.27 | 9.50 | 664.79 | 9.56 | 32.87 | 11.17 | 40.59 | 7.52 |
| 0.00 | 3# | 659.78 | 9.41 | 665.16 | 9.43 | 33.23 | 11.26 | 40.69 | 7.55 |
| 0.00 | 4# | 661.72 | 9.55 | 666.90 | 9.40 | 32.87 | 11.00 | 40.74 | 7.54 |
| 1.00 | 1# | 653.43 | 9.54 | 659.07 | 9.46 | 37.47 | 12.29 | 39.59 | 7.91 |
| 1.00 | 2# | 654.40 | 9.58 | 659.59 | 9.56 | 37.02 | 11.81 | 39.72 | 7.92 |
| 1.00 | 3# | 660.07 | 10.59 | 668.79 | 10.41 | 31.91 | 11.35 | 41.20 | 8.24 |
| 1.00 | 4# | 660.87 | 10.34 | 669.45 | 10.82 | 33.13 | 11.52 | 41.27 | 8.24 |
| 2.00 | 1# | 645.66 | 11.46 | 650.48 | 10.36 | 31.59 | 13.93 | 38.32 | 8.09 |
| 2.00 | 2# | 647.66 | 11.52 | 651.66 | 10.95 | 29.76 | 13.79 | 38.44 | 8.15 |
| 2.00 | 3# | 663.71 | 11.56 | 673.88 | 11.58 | 31.97 | 11.90 | 41.41 | 9.07 |
| 2.00 | 4# | 663.57 | 11.63 | 673.50 | 11.58 | 32.70 | 11.90 | 41.50 | 9.09 |
| 3.00 | 1# | 636.51 | 11.46 | 639.09 | 11.56 | 25.75 | 15.16 | 37.00 | 7.78 |
| 3.00 | 2# | 638.49 | 11.52 | 640.22 | 11.42 | 24.00 | 15.00 | 37.09 | 7.86 |
| 3.00 | 3# | 662.76 | 12.23 | 674.88 | 12.13 | 31.56 | 11.90 | 41.53 | 9.94 |
| 3.00 | 4# | 663.11 | 12.24 | 674.40 | 12.08 | 31.58 | 12.34 | 41.63 | 9.98 |
| 4.00 | 1# | 627.86 | 9.45 | 630.68 | 9.46 | 20.91 | 15.73 | 36.02 | 7.40 |
| 4.00 | 2# | 628.18 | 9.49 | 630.75 | 9.32 | 16.77 | 15.87 | 36.06 | 7.45 |
| 4.00 | 3# | 660.37 | 12.62 | 674.56 | 12.58 | 28.78 | 30.33 | 41.65 | 10.71 |
| 4.00 | 4# | 661.74 | 12.70 | 675.53 | 12.76 | 28.25 | 12.64 | 41.76 | 10.77 |
| 5.00 | 1# | 622.11 | 9.55 | 625.41 | 9.46 | 23.80 | 16.24 | 35.37 | 7.09 |
| 5.00 | 2# | 622.72 | 9.49 | 625.36 | 9.32 | 16.09 | 16.36 | 35.38 | 7.10 |
| 5.00 | 3# | 653.11 | 13.03 | 672.78 | 12.95 | 23.90 | 13.05 | 41.69 | 11.41 |
| 5.00 | 4# | 654.28 | 13.29 | 672.53 | 13.21 | 23.08 | 13.25 | 41.83 | 11.49 |
| 6.00 | 1# | 619.54 | 9.37 | 624.98 | 8.86 | 26.65 | 17.02 | 35.14 | 6.80 |
| 6.00 | 2# | 619.40 | 9.24 | 624.58 | 8.82 | 20.65 | 17.12 | 35.13 | 6.78 |
| 6.00 | 3# | 644.41 | 13.75 | 667.54 | 13.68 | 17.57 | 13.62 | 41.64 | 12.14 |
| 6.00 | 4# | 646.16 | 13.73 | 667.11 | 13.81 | 16.45 | 13.78 | 41.79 | 12.18 |
| 7.00 | 1# | 621.58 | 9.37 | 627.24 | 8.86 | 24.01 | 19.01 | 35.13 | 6.73 |
| 7.00 | 2# | 621.31 | 9.49 | 626.94 | 8.82 | 23.43 | 18.72 | 35.12 | 6.77 |
| 7.00 | 3# | 632.22 | 14.24 | 656.84 | 14.15 | 14.61 | 14.11 | 40.79 | 12.73 |
| 7.00 | 4# | 633.43 | 14.36 | 656.96 | 14.31 | 13.78 | 14.14 | 40.97 | 12.79 |
| 8.00 | 1# | 624.03 | 9.37 | 630.15 | 9.33 | 21.86 | 19.32 | 35.13 | 6.73 |
| 8.00 | 2# | 624.07 | 9.49 | 630.24 | 9.32 | 19.54 | 19.08 | 35.12 | 6.77 |
| 8.00 | 3# | 619.48 | 14.93 | 639.50 | 14.86 | 18.96 | 14.62 | 38.65 | 13.30 |
| 8.00 | 4# | 622.80 | 15.08 | 642.32 | 14.94 | 18.34 | 14.74 | 38.87 | 13.37 |
| 9.00 | 1# | 623.18 | 17.33 | 629.21 | 9.25 | 18.67 | 19.80 | 35.13 | 6.73 |
| 9.00 | 2# | 622.38 | 17.22 | 629.11 | 9.22 | 16.78 | 19.62 | 35.12 | 6.77 |
| 9.00 | 3# | 611.63 | 9.93 | 620.19 | 15.92 | 27.24 | 15.17 | 35.82 | 14.15 |
| 9.00 | 4# | 612.65 | 16.14 | 623.82 | 16.04 | 27.54 | 15.26 | 36.09 | 14.21 |
| 10.00 | 1# | 620.46 | 9.37 | 629.21 | 9.25 | 30.73 | 20.29 | 35.13 | 6.73 |
| 10.00 | 2# | 620.41 | 9.24 | 629.18 | 9.30 | 29.70 | 20.34 | 35.12 | 6.77 |
| 10.00 | 3# | 602.14 | 17.40 | 608.51 | 25.30 | 29.50 | 23.60 | 33.10 | 15.12 |
| 10.00 | 4# | 603.64 | 17.40 | 602.65 | 17.32 | 25.89 | 27.33 | 33.43 | 15.19 |
| 11.00 | 1# | 620.46 | 9.37 | 629.21 | 9.25 | 33.16 | 23.57 | 35.13 | 6.73 |
| 11.00 | 2# | 620.41 | 9.24 | 629.18 | 9.30 | 33.87 | 23.51 | 35.12 | 6.77 |
| 11.00 | 3# | 599.51 | 9.41 | 614.31 | 26.62 | 23.92 | 26.77 | 30.89 | 20.00 |
| 11.00 | 4# | 601.22 | 9.55 | 613.42 | 27.37 | 25.36 | 27.55 | 31.26 | 16.43 |
| 12.00 | 1# | 626.15 | 24.79 | 632.22 | 24.58 | 35.67 | 24.17 | 35.13 | 6.73 |
| 12.00 | 2# | 625.73 | 24.75 | 632.73 | 24.66 | 35.86 | 24.25 | 35.12 | 6.77 |
| 12.00 | 3# | 614.87 | 25.07 | 615.24 | 24.77 | 26.60 | 27.50 | 33.42 | 21.15 |
| 12.00 | 4# | 614.57 | 24.99 | 614.92 | 24.80 | 26.44 | 27.55 | 33.35 | 21.09 |
| JDT6 | 0.00 | 1# | 658.29 | 9.45 | 664.66 | 9.46 | 33.16 | 11.09 | 40.47 | 7.50 |
| 0.00 | 2# | 659.27 | 9.50 | 664.79 | 9.56 | 32.87 | 11.17 | 40.59 | 7.52 |
| 0.00 | 3# | 659.78 | 9.41 | 665.16 | 9.43 | 33.23 | 11.26 | 40.69 | 7.55 |
| 0.00 | 4# | 661.72 | 9.55 | 666.90 | 9.40 | 32.87 | 11.00 | 40.74 | 7.54 |
| 1.00 | 1# | 655.76 | 9.54 | 661.91 | 9.46 | 36.09 | 11.09 | 40.00 | 7.71 |
| 1.00 | 2# | 656.56 | 9.50 | 662.02 | 9.56 | 35.87 | 11.28 | 40.12 | 7.72 |
| 1.00 | 3# | 657.01 | 9.41 | 662.53 | 9.43 | 35.53 | 11.35 | 40.24 | 7.72 |
| 1.00 | 4# | 662.25 | 9.55 | 671.44 | 10.96 | 30.63 | 11.00 | 41.60 | 8.12 |
| 2.00 | 1# | 649.49 | 9.54 | 656.02 | 9.93 | 38.40 | 10.63 | 39.36 | 7.70 |
| 2.00 | 2# | 650.59 | 9.58 | 656.77 | 9.69 | 38.43 | 11.17 | 39.48 | 7.70 |
| 2.00 | 3# | 651.59 | 10.30 | 658.46 | 10.32 | 38.42 | 13.62 | 39.58 | 7.78 |
| 2.00 | 4# | 665.82 | 11.43 | 678.22 | 11.58 | 28.99 | 11.52 | 42.19 | 8.96 |
| 3.00 | 1# | 645.51 | 9.37 | 651.52 | 9.46 | 36.20 | 14.45 | 38.77 | 7.57 |
| 3.00 | 2# | 646.50 | 9.50 | 651.83 | 9.32 | 36.06 | 14.36 | 38.87 | 7.59 |
| 3.00 | 3# | 647.19 | 9.41 | 652.27 | 9.30 | 36.46 | 14.19 | 38.94 | 7.65 |
| 3.00 | 4# | 667.12 | 12.02 | 681.99 | 12.02 | 24.07 | 11.90 | 42.80 | 9.92 |
| 4.00 | 1# | 643.43 | 9.37 | 648.56 | 9.46 | 36.31 | 14.74 | 38.33 | 7.47 |
| 4.00 | 2# | 644.17 | 9.50 | 648.71 | 9.30 | 35.40 | 14.68 | 38.41 | 7.48 |
| 4.00 | 3# | 644.36 | 9.41 | 648.82 | 9.30 | 34.46 | 14.62 | 38.46 | 7.50 |
| 4.00 | 4# | 665.29 | 12.63 | 683.20 | 12.45 | 19.00 | 12.34 | 43.45 | 10.67 |
| 5.00 | 1# | 641.22 | 9.37 | 646.29 | 9.46 | 36.85 | 15.73 | 38.01 | 7.33 |
| 5.00 | 2# | 642.01 | 9.50 | 646.37 | 9.32 | 35.26 | 15.56 | 38.07 | 7.34 |
| 5.00 | 3# | 641.72 | 9.56 | 646.14 | 9.30 | 34.93 | 15.17 | 38.11 | 7.38 |
| 5.00 | 4# | 662.15 | 12.94 | 684.17 | 12.92 | 13.80 | 13.01 | 43.92 | 11.36 |
| 6.00 | 1# | 638.70 | 9.54 | 644.63 | 9.46 | 30.69 | 19.98 | 37.83 | 7.21 |
| 6.00 | 2# | 639.56 | 9.50 | 644.91 | 9.30 | 26.50 | 19.88 | 37.89 | 7.21 |
| 6.00 | 3# | 639.12 | 9.41 | 644.56 | 9.30 | 36.02 | 23.40 | 37.91 | 7.27 |
| 6.00 | 4# | 652.98 | 13.51 | 678.53 | 13.44 | 5.14 | 13.55 | 44.00 | 12.08 |
| 7.00 | 1# | 639.86 | 9.54 | 646.08 | 9.46 | 28.05 | 20.58 | 37.81 | 7.18 |
| 7.00 | 2# | 640.49 | 9.50 | 645.73 | 9.30 | 32.68 | 24.24 | 37.86 | 7.18 |
| 7.00 | 3# | 639.84 | 9.41 | 645.27 | 9.30 | 36.18 | 23.98 | 37.88 | 7.16 |
| 7.00 | 4# | 640.24 | 10.96 | 667.48 | 14.04 | -2.06 | 14.07 | 43.40 | 12.76 |
| 8.00 | 1# | 641.25 | 9.54 | 647.61 | 9.46 | 31.93 | 31.36 | 37.81 | 7.18 |
| 8.00 | 2# | 642.17 | 9.50 | 647.70 | 9.30 | 31.03 | 31.43 | 37.86 | 7.18 |
| 8.00 | 3# | 641.84 | 9.41 | 647.42 | 9.30 | 31.38 | 31.54 | 37.88 | 7.16 |
| 8.00 | 4# | 638.37 | 9.55 | 652.58 | 14.48 | -0.71 | 14.61 | 41.98 | 13.33 |
| 9.00 | 1# | 640.65 | 9.54 | 647.61 | 9.46 | 31.12 | 32.05 | 37.81 | 7.18 |
| 9.00 | 2# | 641.47 | 9.50 | 647.49 | 9.56 | 31.89 | 32.02 | 37.86 | 7.18 |
| 9.00 | 3# | 640.82 | 9.41 | 647.23 | 9.49 | 33.38 | 31.76 | 37.88 | 7.16 |
| 9.00 | 4# | 634.42 | 9.55 | 639.76 | 10.05 | 4.76 | 15.26 | 39.48 | 13.94 |
| 10.00 | 1# | 639.96 | 9.54 | 647.50 | 9.46 | 32.10 | 32.25 | 37.81 | 7.18 |
| 10.00 | 2# | 640.82 | 9.50 | 647.40 | 9.30 | 32.77 | 32.26 | 37.86 | 7.18 |
| 10.00 | 3# | 640.22 | 9.41 | 647.11 | 9.30 | 36.74 | 32.14 | 37.88 | 7.16 |
| 10.00 | 4# | 625.51 | 10.44 | 630.01 | 10.96 | 6.02 | 16.24 | 36.25 | 14.82 |
| 11.00 | 1# | 639.96 | 9.54 | 647.50 | 9.46 | 31.03 | 32.40 | 37.81 | 7.18 |
| 11.00 | 2# | 640.82 | 9.50 | 647.40 | 9.30 | 31.84 | 32.26 | 37.86 | 7.18 |
| 11.00 | 3# | 640.22 | 9.41 | 647.11 | 9.30 | 33.28 | 32.22 | 37.88 | 7.16 |
| 11.00 | 4# | 625.03 | 9.55 | 623.53 | 9.57 | 8.69 | 17.13 | 33.18 | 15.86 |
| 12.00 | 1# | 639.96 | 9.54 | 647.50 | 9.46 | 32.49 | 22.16 | 37.81 | 7.18 |
| 12.00 | 2# | 640.82 | 9.50 | 647.40 | 9.30 | 32.76 | 22.13 | 37.86 | 7.18 |
| 12.00 | 3# | 640.22 | 9.41 | 647.11 | 9.30 | 32.36 | 21.97 | 37.88 | 7.16 |
| 12.00 | 4# | 625.03 | 9.55 | 623.53 | 9.57 | 17.73 | 28.89 | 30.62 | 16.81 |
| JDT10 | 0.00 | 1# | 658.29 | 9.45 | 664.66 | 9.46 | 33.16 | 11.09 | 40.47 | 7.50 |
| 0.00 | 2# | 659.27 | 9.50 | 664.79 | 9.56 | 32.87 | 11.17 | 40.59 | 7.52 |
| 0.00 | 3# | 659.78 | 9.41 | 665.16 | 9.43 | 33.23 | 11.26 | 40.69 | 7.55 |
| 0.00 | 4# | 661.72 | 9.55 | 666.90 | 9.40 | 32.87 | 11.00 | 40.74 | 7.54 |
| 1.00 | 1# | 652.80 | 10.46 | 656.99 | 10.36 | 34.16 | 13.18 | 39.27 | 8.13 |
| 1.00 | 2# | 658.41 | 10.48 | 666.11 | 10.58 | 32.70 | 11.81 | 40.80 | 8.36 |
| 1.00 | 3# | 659.77 | 10.73 | 667.38 | 10.69 | 32.12 | 11.90 | 40.92 | 8.40 |
| 1.00 | 4# | 660.79 | 10.59 | 668.26 | 10.67 | 32.86 | 11.90 | 40.98 | 8.43 |
| 2.00 | 1# | 644.91 | 11.46 | 645.66 | 10.96 | 21.34 | 14.53 | 37.62 | 8.83 |
| 2.00 | 2# | 660.79 | 11.52 | 667.69 | 11.42 | 34.10 | 12.35 | 40.77 | 9.24 |
| 2.00 | 3# | 661.61 | 11.56 | 669.76 | 11.58 | 34.15 | 12.46 | 40.91 | 9.23 |
| 2.00 | 4# | 661.91 | 11.49 | 670.10 | 11.50 | 33.74 | 12.64 | 40.99 | 9.29 |
| 3.00 | 1# | 636.69 | 12.72 | 650.99 | 15.47 | 11.74 | 15.34 | 35.49 | 9.46 |
| 3.00 | 2# | 659.74 | 12.67 | 666.67 | 12.68 | 35.93 | 13.07 | 40.59 | 10.10 |
| 3.00 | 3# | 658.80 | 12.13 | 667.38 | 12.13 | 35.23 | 13.16 | 40.74 | 10.14 |
| 3.00 | 4# | 659.66 | 12.23 | 667.94 | 12.08 | 34.71 | 13.25 | 40.83 | 10.14 |
| 4.00 | 1# | 638.78 | 13.79 | 663.04 | 16.20 | 6.77 | 16.24 | 34.94 | 15.07 |
| 4.00 | 2# | 656.52 | 13.48 | 663.98 | 13.22 | 37.78 | 11.17 | 40.29 | 10.93 |
| 4.00 | 3# | 657.76 | 13.43 | 664.77 | 13.31 | 37.02 | 11.35 | 40.46 | 10.95 |
| 4.00 | 4# | 657.96 | 13.44 | 665.59 | 13.44 | 37.43 | 14.44 | 40.57 | 11.00 |
| 5.00 | 1# | 645.10 | 14.71 | 669.08 | 16.90 | 7.02 | 16.94 | 35.08 | 15.88 |
| 5.00 | 2# | 654.22 | 13.84 | 661.26 | 13.58 | 36.86 | 12.52 | 39.94 | 11.66 |
| 5.00 | 3# | 654.77 | 13.86 | 661.97 | 13.85 | 36.16 | 11.90 | 40.14 | 11.71 |
| 5.00 | 4# | 655.89 | 13.93 | 662.98 | 13.51 | 36.39 | 12.34 | 40.27 | 11.70 |
| 6.00 | 1# | 650.32 | 15.10 | 665.61 | 17.69 | 8.39 | 17.65 | 33.96 | 16.75 |
| 6.00 | 2# | 653.42 | 14.68 | 659.35 | 14.10 | 33.87 | 24.33 | 39.66 | 12.27 |
| 6.00 | 3# | 654.02 | 14.66 | 659.69 | 14.43 | 35.04 | 13.13 | 39.88 | 12.35 |
| 6.00 | 4# | 654.98 | 14.55 | 661.02 | 14.40 | 35.29 | 13.25 | 40.04 | 12.36 |
| 7.00 | 1# | 640.92 | 18.75 | 660.88 | 18.87 | 17.87 | 18.92 | 32.47 | 6.23 |
| 7.00 | 2# | 635.41 | 14.96 | 639.74 | 14.94 | 34.98 | 35.95 | 38.08 | 12.87 |
| 7.00 | 3# | 636.69 | 14.93 | 641.46 | 14.86 | 35.31 | 32.22 | 38.35 | 12.92 |
| 7.00 | 4# | 638.29 | 14.91 | 644.17 | 14.94 | 34.58 | 10.78 | 38.55 | 13.02 |
| 8.00 | 1# | 638.39 | 20.04 | 656.81 | 20.02 | 21.96 | 19.98 | 32.47 | 6.23 |
| 8.00 | 2# | 613.95 | 16.11 | 618.83 | 16.67 | 33.33 | 22.99 | 35.98 | 14.25 |
| 8.00 | 3# | 616.00 | 16.04 | 621.22 | 17.21 | 34.29 | 33.26 | 36.30 | 14.25 |
| 8.00 | 4# | 617.97 | 17.47 | 624.09 | 16.66 | 33.70 | 29.70 | 36.53 | 14.29 |
| 9.00 | 1# | 638.85 | 21.15 | 653.19 | 21.14 | 26.68 | 21.10 | 32.47 | 6.23 |
| 9.00 | 2# | 619.51 | 19.30 | 623.03 | 19.28 | 36.47 | 23.51 | 35.41 | 16.71 |
| 9.00 | 3# | 620.19 | 19.30 | 623.86 | 19.32 | 38.66 | 23.61 | 35.58 | 16.57 |
| 9.00 | 4# | 621.49 | 19.28 | 625.22 | 19.42 | 38.62 | 37.57 | 35.72 | 16.44 |
| 10.00 | 1# | 637.67 | 21.84 | 650.13 | 21.82 | 30.44 | 21.78 | 32.47 | 6.23 |
| 10.00 | 2# | 624.52 | 19.82 | 629.05 | 19.94 | 38.43 | 24.40 | 36.16 | 18.13 |
| 10.00 | 3# | 626.02 | 19.93 | 629.81 | 20.00 | 38.93 | 24.28 | 36.24 | 18.08 |
| 10.00 | 4# | 626.07 | 20.05 | 631.02 | 19.94 | 38.88 | 24.46 | 36.29 | 18.02 |
| 11.00 | 1# | 643.78 | 22.99 | 653.31 | 22.94 | 32.39 | 22.67 | 32.47 | 6.23 |
| 11.00 | 2# | 633.38 | 23.19 | 637.22 | 22.65 | 38.37 | 22.25 | 37.07 | 19.10 |
| 11.00 | 3# | 634.09 | 23.18 | 638.14 | 22.67 | 38.01 | 22.34 | 37.16 | 19.11 |
| 11.00 | 4# | 634.51 | 23.11 | 639.94 | 22.64 | 38.13 | 25.53 | 37.20 | 19.07 |
| 12.00 | 1# | 649.78 | 23.81 | 656.99 | 23.61 | 34.39 | 23.27 | 32.47 | 6.23 |
| 12.00 | 2# | 641.98 | 23.75 | 646.62 | 23.30 | 36.96 | 22.98 | 37.97 | 20.03 |
| 12.00 | 3# | 643.20 | 23.84 | 647.46 | 23.36 | 37.49 | 22.62 | 38.07 | 20.03 |
| 12.00 | 4# | 643.75 | 23.70 | 649.26 | 23.31 | 37.52 | 22.60 | 38.13 | 20.03 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.12 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.13JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.14 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.15 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.16 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.17 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.18 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.19 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.3.3 直线60s关闭计算结果**

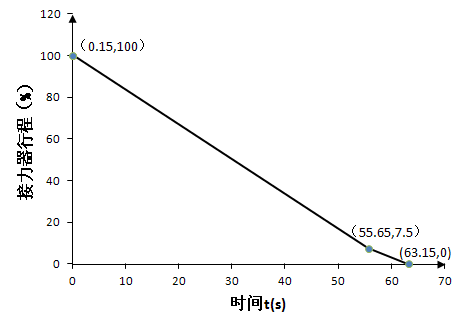


图6.20 水轮机工况导叶直线60s关闭规律

**表6-11 直线60s关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔(s) | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 639.23 | 9.83 | 646.28 | 9.46 | 53.32 | 11.09 | 42.95 | 7.89 |
| 0.00 | 2# | 640.68 | 10.08 | 646.90 | 9.70 | 53.44 | 11.17 | 43.09 | 7.89 |
| 0.00 | 3# | 641.30 | 10.21 | 648.03 | 10.11 | 53.26 | 11.35 | 43.22 | 7.92 |
| 0.00 | 4# | 644.18 | 9.55 | 651.74 | 10.05 | 53.87 | 11.90 | 43.28 | 7.94 |
| SJT3 | 0.00 | 1# | 654.26 | 9.45 | 660.55 | 9.46 | 36.41 | 11.09 | 40.69 | 7.60 |
| 0.00 | 2# | 655.39 | 9.50 | 660.27 | 9.56 | 36.24 | 11.17 | 40.80 | 7.60 |
| 0.00 | 3# | 655.30 | 9.56 | 660.87 | 9.49 | 36.45 | 11.26 | 40.91 | 7.63 |
| 0.00 | 4# | 658.07 | 9.55 | 662.67 | 9.57 | 36.54 | 11.00 | 40.96 | 7.64 |
| ZT2 | 76.76 | 1# | 638.83 | 86.61 | 644.58 | 86.60 | 53.83 | 88.43 | 43.49 | 84.72 |
| 76.76 | 2# | 639.76 | 86.57 | 645.57 | 86.63 | 53.78 | 88.00 | 43.63 | 84.71 |
| 76.76 | 3# | 640.41 | 86.55 | 646.54 | 86.66 | 53.86 | 88.30 | 43.76 | 84.74 |
| 76.76 | 4# | 641.29 | 86.85 | 647.58 | 86.77 | 54.17 | 88.29 | 43.80 | 84.76 |
| JHT3 | 0.00 | 1# | 639.23 | 9.83 | 646.28 | 9.46 | 53.32 | 11.09 | 42.95 | 7.89 |
| 0.00 | 2# | 640.68 | 10.08 | 646.90 | 9.70 | 53.44 | 11.17 | 43.09 | 7.89 |
| 0.00 | 3# | 641.30 | 10.21 | 648.03 | 10.11 | 53.26 | 11.35 | 43.22 | 7.92 |
| 0.00 | 4# | 644.18 | 9.55 | 651.74 | 10.05 | 53.87 | 11.90 | 43.28 | 7.94 |
| 1.00 | 1# | 638.14 | 9.55 | 645.43 | 9.46 | 53.81 | 11.09 | 42.85 | 7.90 |
| 1.00 | 2# | 639.90 | 10.08 | 646.20 | 10.06 | 53.62 | 11.17 | 43.00 | 7.94 |
| 1.00 | 3# | 640.43 | 10.21 | 647.27 | 10.32 | 53.35 | 11.90 | 43.12 | 7.92 |
| 1.00 | 4# | 643.89 | 9.55 | 652.34 | 10.05 | 53.59 | 11.00 | 43.85 | 7.95 |
| 2.00 | 1# | 637.48 | 9.55 | 644.51 | 9.46 | 53.92 | 11.09 | 42.72 | 7.92 |
| 2.00 | 2# | 639.04 | 10.08 | 645.22 | 10.06 | 53.81 | 11.17 | 42.87 | 7.94 |
| 2.00 | 3# | 639.42 | 10.21 | 646.16 | 10.32 | 53.60 | 11.35 | 43.00 | 7.96 |
| 2.00 | 4# | 643.68 | 9.55 | 651.91 | 10.05 | 52.98 | 11.00 | 44.31 | 7.97 |
| 3.00 | 1# | 636.84 | 9.54 | 643.73 | 9.46 | 54.42 | 11.09 | 42.58 | 7.94 |
| 3.00 | 2# | 638.39 | 10.08 | 644.32 | 9.70 | 54.37 | 11.17 | 42.72 | 7.96 |
| 3.00 | 3# | 638.81 | 10.21 | 645.20 | 10.32 | 53.85 | 11.90 | 42.85 | 7.97 |
| 3.00 | 4# | 644.19 | 9.55 | 653.04 | 10.05 | 52.20 | 11.00 | 44.81 | 8.08 |
| 4.00 | 1# | 635.65 | 9.83 | 642.55 | 9.46 | 54.94 | 11.09 | 42.44 | 7.92 |
| 4.00 | 2# | 637.48 | 10.08 | 643.34 | 10.06 | 54.79 | 11.17 | 42.58 | 7.92 |
| 4.00 | 3# | 638.13 | 10.21 | 644.45 | 10.32 | 54.30 | 11.90 | 42.70 | 7.95 |
| 4.00 | 4# | 642.83 | 9.55 | 651.98 | 10.05 | 52.85 | 11.00 | 45.31 | 8.21 |
| 5.00 | 1# | 634.68 | 9.55 | 641.77 | 9.46 | 54.82 | 11.09 | 42.33 | 7.89 |
| 5.00 | 2# | 636.48 | 10.08 | 642.49 | 10.06 | 54.85 | 11.17 | 42.46 | 7.89 |
| 5.00 | 3# | 636.91 | 10.21 | 643.56 | 10.32 | 54.74 | 11.35 | 42.58 | 7.92 |
| 5.00 | 4# | 640.40 | 9.55 | 648.39 | 10.05 | 52.77 | 11.90 | 45.66 | 8.25 |
| 6.00 | 1# | 634.30 | 9.55 | 641.49 | 9.46 | 54.65 | 11.09 | 42.27 | 7.85 |
| 6.00 | 2# | 635.89 | 10.08 | 642.30 | 9.70 | 54.62 | 11.17 | 42.41 | 7.87 |
| 6.00 | 3# | 636.19 | 10.21 | 643.08 | 10.32 | 54.47 | 11.35 | 42.52 | 7.86 |
| 6.00 | 4# | 638.22 | 9.55 | 644.46 | 10.05 | 51.90 | 36.75 | 45.84 | 8.37 |
| 7.00 | 1# | 634.30 | 9.55 | 641.67 | 9.46 | 54.49 | 11.09 | 42.26 | 7.86 |
| 7.00 | 2# | 635.80 | 10.08 | 642.37 | 9.70 | 54.40 | 11.17 | 42.40 | 7.85 |
| 7.00 | 3# | 636.33 | 10.21 | 643.40 | 10.32 | 54.17 | 11.35 | 42.50 | 7.85 |
| 7.00 | 4# | 636.18 | 9.55 | 641.33 | 10.05 | 49.13 | 14.08 | 45.88 | 8.44 |
| 8.00 | 1# | 634.32 | 9.83 | 641.77 | 9.93 | 54.42 | 11.09 | 42.26 | 7.83 |
| 8.00 | 2# | 635.96 | 10.08 | 642.64 | 9.70 | 54.46 | 11.17 | 42.40 | 7.84 |
| 8.00 | 3# | 636.17 | 10.21 | 643.39 | 10.32 | 54.19 | 11.35 | 42.50 | 7.87 |
| 8.00 | 4# | 634.91 | 9.55 | 639.16 | 10.05 | 46.77 | 14.74 | 45.88 | 8.42 |
| 9.00 | 1# | 634.21 | 9.83 | 641.88 | 9.93 | 54.21 | 11.09 | 42.26 | 7.83 |
| 9.00 | 2# | 635.81 | 10.08 | 642.65 | 9.70 | 54.32 | 11.17 | 42.40 | 7.84 |
| 9.00 | 3# | 636.09 | 10.21 | 643.55 | 10.32 | 54.03 | 11.35 | 42.50 | 7.87 |
| 9.00 | 4# | 633.12 | 9.55 | 636.95 | 10.05 | 44.55 | 14.74 | 45.88 | 8.40 |
| 10.00 | 1# | 634.07 | 9.83 | 641.79 | 9.93 | 54.02 | 11.09 | 42.26 | 7.83 |
| 10.00 | 2# | 635.68 | 10.08 | 642.62 | 9.70 | 54.07 | 11.17 | 42.40 | 7.84 |
| 10.00 | 3# | 635.85 | 10.21 | 643.47 | 10.32 | 53.77 | 11.35 | 42.50 | 7.87 |
| 10.00 | 4# | 632.51 | 9.55 | 634.89 | 10.05 | 43.49 | 14.74 | 45.88 | 8.40 |
| 11.00 | 1# | 634.07 | 9.83 | 641.79 | 9.93 | 53.89 | 11.09 | 42.26 | 7.83 |
| 11.00 | 2# | 635.68 | 10.08 | 642.62 | 9.70 | 53.93 | 11.17 | 42.40 | 7.84 |
| 11.00 | 3# | 635.85 | 10.21 | 643.47 | 10.32 | 53.57 | 11.35 | 42.50 | 7.87 |
| 11.00 | 4# | 632.51 | 9.55 | 634.89 | 10.05 | 43.40 | 14.74 | 45.88 | 8.40 |
| 12.00 | 1# | 634.07 | 9.83 | 641.79 | 9.93 | 53.89 | 11.09 | 42.26 | 7.83 |
| 12.00 | 2# | 635.68 | 10.08 | 642.62 | 9.70 | 53.93 | 11.17 | 42.40 | 7.84 |
| 12.00 | 3# | 635.85 | 10.21 | 643.47 | 10.32 | 53.57 | 11.35 | 42.50 | 7.87 |
| 12.00 | 4# | 632.51 | 9.55 | 634.89 | 10.05 | 43.94 | 14.74 | 45.88 | 8.40 |
| JHT13 | 0.00 | 1# | 652.72 | 9.45 | 659.01 | 9.46 | 34.87 | 11.09 | 40.69 | 7.60 |
| 0.00 | 2# | 653.85 | 9.50 | 658.73 | 9.56 | 34.70 | 11.17 | 40.80 | 7.60 |
| 0.00 | 3# | 653.76 | 9.56 | 659.33 | 9.49 | 34.91 | 11.26 | 40.91 | 7.63 |
| 0.00 | 4# | 656.53 | 9.55 | 661.13 | 9.57 | 35.00 | 11.00 | 40.96 | 7.64 |
| 1.00 | 1# | 646.53 | 9.54 | 652.46 | 9.46 | 36.70 | 13.18 | 39.83 | 7.99 |
| 1.00 | 2# | 647.58 | 9.58 | 652.84 | 9.69 | 35.63 | 13.25 | 39.96 | 8.00 |
| 1.00 | 3# | 654.22 | 10.59 | 661.83 | 10.32 | 33.94 | 11.35 | 41.39 | 8.31 |
| 1.00 | 4# | 654.62 | 10.44 | 663.54 | 10.05 | 34.80 | 11.90 | 41.47 | 8.31 |
| 2.00 | 1# | 638.14 | 10.46 | 643.04 | 10.30 | 28.46 | 14.53 | 38.58 | 8.26 |
| 2.00 | 2# | 639.75 | 10.94 | 643.83 | 10.58 | 28.10 | 14.44 | 38.71 | 8.27 |
| 2.00 | 3# | 656.05 | 11.67 | 666.55 | 11.58 | 34.20 | 11.90 | 41.58 | 9.12 |
| 2.00 | 4# | 656.54 | 11.49 | 666.33 | 11.58 | 34.12 | 12.34 | 41.68 | 9.10 |
| 3.00 | 1# | 628.87 | 9.45 | 632.67 | 9.46 | 25.95 | 15.34 | 37.27 | 7.89 |
| 3.00 | 2# | 629.72 | 11.57 | 633.28 | 9.32 | 22.52 | 15.27 | 37.36 | 7.91 |
| 3.00 | 3# | 654.16 | 12.02 | 666.48 | 12.13 | 32.53 | 11.90 | 41.64 | 9.98 |
| 3.00 | 4# | 655.07 | 12.16 | 666.78 | 12.08 | 32.98 | 11.90 | 41.75 | 9.97 |
| 4.00 | 1# | 623.43 | 9.45 | 625.70 | 9.46 | 24.06 | 16.24 | 36.34 | 7.47 |
| 4.00 | 2# | 623.88 | 9.50 | 626.05 | 9.32 | 21.17 | 15.99 | 36.37 | 7.48 |
| 4.00 | 3# | 652.85 | 12.70 | 666.48 | 12.65 | 30.49 | 12.62 | 41.70 | 10.75 |
| 4.00 | 4# | 653.22 | 12.92 | 667.10 | 12.76 | 30.03 | 12.81 | 41.81 | 10.81 |
| 5.00 | 1# | 618.79 | 9.55 | 622.10 | 9.46 | 25.45 | 16.52 | 35.73 | 7.18 |
| 5.00 | 2# | 619.37 | 9.49 | 621.56 | 9.32 | 19.97 | 16.47 | 35.74 | 7.19 |
| 5.00 | 3# | 649.17 | 13.40 | 666.91 | 13.30 | 24.64 | 13.13 | 41.78 | 11.48 |
| 5.00 | 4# | 649.76 | 13.44 | 665.83 | 13.44 | 24.15 | 13.25 | 41.92 | 11.51 |
| 6.00 | 1# | 614.76 | 9.46 | 619.72 | 8.86 | 26.45 | 18.49 | 35.49 | 6.92 |
| 6.00 | 2# | 614.95 | 9.49 | 619.54 | 8.82 | 23.71 | 17.16 | 35.49 | 6.90 |
| 6.00 | 3# | 641.05 | 13.86 | 662.56 | 13.85 | 19.30 | 13.62 | 41.65 | 12.17 |
| 6.00 | 4# | 642.05 | 13.82 | 663.36 | 13.96 | 17.98 | 13.78 | 41.80 | 12.24 |
| 7.00 | 1# | 616.34 | 9.46 | 621.55 | 8.86 | 23.31 | 19.09 | 35.48 | 6.82 |
| 7.00 | 2# | 616.21 | 9.49 | 621.30 | 8.82 | 21.31 | 19.08 | 35.47 | 6.82 |
| 7.00 | 3# | 629.13 | 14.32 | 652.30 | 14.38 | 16.78 | 14.19 | 40.79 | 12.82 |
| 7.00 | 4# | 631.09 | 14.47 | 653.28 | 14.41 | 16.86 | 14.27 | 40.97 | 12.87 |
| 8.00 | 1# | 618.20 | 9.46 | 624.04 | 9.46 | 21.98 | 19.61 | 35.48 | 6.82 |
| 8.00 | 2# | 618.37 | 9.49 | 623.96 | 9.30 | 20.02 | 19.62 | 35.47 | 6.82 |
| 8.00 | 3# | 616.59 | 15.11 | 637.52 | 14.94 | 19.73 | 14.62 | 39.04 | 13.45 |
| 8.00 | 4# | 619.42 | 15.08 | 639.32 | 15.07 | 18.45 | 14.74 | 39.26 | 13.52 |
| 9.00 | 1# | 617.55 | 17.33 | 623.12 | 9.46 | 21.12 | 20.21 | 35.48 | 6.82 |
| 9.00 | 2# | 616.50 | 17.37 | 623.14 | 9.32 | 18.63 | 19.98 | 35.47 | 6.82 |
| 9.00 | 3# | 608.97 | 16.04 | 620.60 | 15.92 | 19.60 | 34.46 | 36.51 | 14.20 |
| 9.00 | 4# | 611.58 | 16.14 | 623.89 | 16.04 | 22.01 | 37.87 | 36.78 | 14.28 |
| 10.00 | 1# | 615.09 | 9.45 | 623.48 | 9.33 | 29.13 | 31.19 | 35.48 | 6.82 |
| 10.00 | 2# | 614.78 | 9.24 | 623.38 | 9.32 | 27.58 | 31.22 | 35.47 | 6.82 |
| 10.00 | 3# | 601.12 | 17.32 | 602.13 | 17.21 | 24.59 | 26.59 | 33.82 | 15.11 |
| 10.00 | 4# | 603.08 | 17.47 | 603.32 | 17.32 | 26.15 | 27.63 | 34.14 | 15.17 |
| 11.00 | 1# | 615.09 | 9.45 | 623.48 | 9.33 | 30.29 | 23.79 | 35.48 | 6.82 |
| 11.00 | 2# | 614.78 | 9.24 | 623.38 | 9.32 | 30.38 | 23.70 | 35.47 | 6.82 |
| 11.00 | 3# | 602.98 | 27.91 | 617.94 | 27.83 | 22.30 | 27.59 | 31.33 | 16.18 |
| 11.00 | 4# | 604.48 | 28.16 | 618.30 | 28.18 | 25.78 | 27.33 | 31.70 | 16.27 |
| 12.00 | 1# | 627.51 | 25.20 | 635.54 | 25.18 | 32.89 | 31.60 | 35.48 | 6.82 |
| 12.00 | 2# | 626.64 | 25.16 | 635.45 | 25.10 | 32.60 | 31.68 | 35.47 | 6.82 |
| 12.00 | 3# | 604.39 | 25.47 | 618.00 | 28.44 | 23.22 | 28.23 | 32.77 | 21.72 |
| 12.00 | 4# | 605.58 | 28.85 | 618.43 | 28.68 | 24.38 | 28.22 | 32.64 | 21.39 |
| JDT6 | 0.00 | 1# | 652.72 | 9.45 | 659.01 | 9.46 | 34.87 | 11.09 | 40.69 | 7.60 |
| 0.00 | 2# | 653.85 | 9.50 | 658.73 | 9.56 | 34.70 | 11.17 | 40.80 | 7.60 |
| 0.00 | 3# | 653.76 | 9.56 | 659.33 | 9.49 | 34.91 | 11.26 | 40.91 | 7.63 |
| 0.00 | 4# | 656.53 | 9.55 | 661.13 | 9.57 | 35.00 | 11.00 | 40.96 | 7.64 |
| 1.00 | 1# | 649.05 | 9.54 | 655.46 | 9.46 | 37.82 | 12.29 | 40.23 | 7.79 |
| 1.00 | 2# | 650.24 | 9.50 | 655.96 | 9.70 | 37.39 | 11.81 | 40.35 | 7.81 |
| 1.00 | 3# | 650.57 | 9.56 | 656.01 | 9.58 | 37.23 | 11.90 | 40.46 | 7.81 |
| 1.00 | 4# | 657.19 | 9.55 | 665.48 | 10.05 | 32.64 | 11.15 | 41.79 | 8.13 |
| 2.00 | 1# | 642.78 | 9.54 | 649.46 | 9.93 | 38.50 | 13.55 | 39.59 | 7.78 |
| 2.00 | 2# | 644.15 | 10.08 | 650.43 | 9.69 | 37.80 | 13.79 | 39.71 | 7.80 |
| 2.00 | 3# | 645.01 | 10.30 | 651.34 | 10.32 | 36.53 | 13.62 | 39.81 | 7.84 |
| 2.00 | 4# | 657.65 | 11.49 | 669.39 | 11.42 | 30.74 | 11.22 | 42.34 | 8.96 |
| 3.00 | 1# | 639.80 | 9.37 | 644.91 | 9.46 | 34.79 | 14.53 | 39.01 | 7.62 |
| 3.00 | 2# | 640.31 | 9.50 | 645.26 | 9.32 | 34.51 | 14.36 | 39.11 | 7.69 |
| 3.00 | 3# | 640.58 | 9.41 | 645.55 | 9.43 | 34.36 | 14.47 | 39.18 | 7.72 |
| 3.00 | 4# | 658.89 | 12.10 | 673.25 | 12.02 | 26.29 | 11.90 | 42.83 | 9.90 |
| 4.00 | 1# | 638.09 | 9.37 | 642.66 | 9.46 | 35.92 | 15.16 | 38.59 | 7.52 |
| 4.00 | 2# | 638.58 | 9.50 | 642.75 | 9.32 | 34.37 | 15.27 | 38.67 | 7.54 |
| 4.00 | 3# | 638.91 | 9.41 | 642.66 | 9.43 | 33.27 | 15.17 | 38.72 | 7.58 |
| 4.00 | 4# | 657.65 | 12.53 | 676.62 | 12.68 | 21.35 | 12.81 | 43.39 | 10.68 |
| 5.00 | 1# | 636.45 | 9.37 | 641.06 | 9.46 | 37.22 | 19.09 | 38.28 | 7.45 |
| 5.00 | 2# | 636.88 | 9.50 | 641.26 | 9.69 | 30.93 | 26.24 | 38.36 | 7.44 |
| 5.00 | 3# | 636.86 | 9.60 | 640.97 | 9.43 | 33.07 | 15.67 | 38.39 | 7.46 |
| 5.00 | 4# | 654.99 | 13.06 | 675.81 | 13.05 | 14.57 | 13.25 | 43.86 | 11.39 |
| 6.00 | 1# | 633.52 | 9.54 | 639.38 | 9.46 | 26.70 | 23.48 | 38.12 | 7.31 |
| 6.00 | 2# | 634.16 | 9.58 | 639.58 | 9.30 | 17.90 | 23.64 | 38.18 | 7.34 |
| 6.00 | 3# | 634.09 | 9.41 | 639.43 | 9.30 | 30.54 | 30.79 | 38.20 | 7.34 |
| 6.00 | 4# | 647.06 | 13.51 | 671.29 | 13.58 | 7.15 | 13.78 | 43.91 | 12.13 |
| 7.00 | 1# | 634.35 | 9.37 | 640.15 | 9.46 | 29.30 | 31.28 | 38.09 | 7.25 |
| 7.00 | 2# | 634.60 | 9.50 | 640.01 | 9.30 | 31.26 | 31.43 | 38.14 | 7.24 |
| 7.00 | 3# | 634.54 | 9.41 | 639.71 | 9.30 | 36.01 | 23.99 | 38.15 | 7.26 |
| 7.00 | 4# | 635.35 | 10.87 | 661.38 | 14.11 | 0.98 | 14.27 | 43.37 | 12.88 |
| 8.00 | 1# | 635.51 | 9.37 | 641.20 | 9.46 | 33.08 | 31.88 | 38.09 | 7.25 |
| 8.00 | 2# | 635.70 | 9.50 | 641.27 | 9.30 | 32.58 | 32.00 | 38.14 | 7.24 |
| 8.00 | 3# | 635.69 | 9.41 | 640.96 | 9.30 | 35.56 | 32.33 | 38.15 | 7.26 |
| 8.00 | 4# | 632.20 | 9.55 | 649.68 | 14.78 | -1.69 | 14.74 | 42.17 | 13.51 |
| 9.00 | 1# | 634.32 | 9.54 | 641.12 | 9.46 | 30.70 | 32.45 | 38.09 | 7.25 |
| 9.00 | 2# | 635.09 | 9.58 | 641.03 | 9.56 | 31.91 | 32.32 | 38.14 | 7.24 |
| 9.00 | 3# | 634.71 | 9.41 | 640.62 | 9.30 | 32.68 | 28.79 | 38.15 | 7.26 |
| 9.00 | 4# | 628.53 | 9.55 | 634.78 | 30.34 | 2.63 | 15.45 | 40.15 | 14.15 |
| 10.00 | 1# | 634.06 | 9.37 | 641.04 | 9.46 | 30.80 | 32.80 | 38.09 | 7.25 |
| 10.00 | 2# | 634.32 | 9.50 | 640.88 | 9.30 | 32.28 | 32.71 | 38.14 | 7.24 |
| 10.00 | 3# | 634.13 | 9.41 | 640.60 | 9.30 | 33.82 | 29.35 | 38.15 | 7.26 |
| 10.00 | 4# | 627.13 | 30.41 | 636.78 | 30.34 | 5.11 | 16.24 | 37.32 | 14.89 |
| 11.00 | 1# | 634.06 | 9.37 | 641.04 | 9.46 | 34.35 | 33.29 | 38.09 | 7.25 |
| 11.00 | 2# | 634.32 | 9.50 | 640.88 | 9.30 | 32.50 | 32.85 | 38.14 | 7.24 |
| 11.00 | 3# | 634.13 | 9.41 | 640.60 | 9.30 | 33.79 | 32.71 | 38.15 | 7.26 |
| 11.00 | 4# | 619.69 | 9.55 | 629.79 | 30.11 | 8.60 | 17.13 | 34.22 | 15.82 |
| 12.00 | 1# | 634.06 | 9.37 | 641.04 | 9.46 | 35.89 | 21.47 | 38.09 | 7.25 |
| 12.00 | 2# | 634.32 | 9.50 | 640.88 | 9.30 | 33.64 | 33.23 | 38.14 | 7.24 |
| 12.00 | 3# | 634.13 | 9.41 | 640.60 | 9.30 | 35.67 | 33.11 | 38.15 | 7.26 |
| 12.00 | 4# | 619.69 | 9.55 | 621.26 | 29.89 | 16.69 | 29.98 | 31.46 | 16.84 |
| JDT10 | 0.00 | 1# | 652.72 | 9.45 | 664.66 | 9.46 | 33.16 | 11.09 | 40.47 | 7.50 |
| 0.00 | 2# | 653.85 | 9.50 | 664.79 | 9.56 | 32.87 | 11.17 | 40.59 | 7.52 |
| 0.00 | 3# | 653.76 | 9.56 | 665.16 | 9.43 | 33.23 | 11.26 | 40.69 | 7.55 |
| 0.00 | 4# | 656.53 | 9.55 | 666.90 | 9.40 | 32.87 | 11.00 | 40.74 | 7.54 |
| 1.00 | 1# | 645.79 | 10.46 | 656.99 | 10.36 | 34.16 | 13.18 | 39.27 | 8.13 |
| 1.00 | 2# | 652.36 | 10.60 | 666.11 | 10.58 | 32.70 | 11.81 | 40.80 | 8.36 |
| 1.00 | 3# | 653.70 | 10.59 | 667.38 | 10.69 | 32.12 | 11.90 | 40.92 | 8.40 |
| 1.00 | 4# | 654.36 | 10.59 | 668.26 | 10.67 | 32.86 | 11.90 | 40.98 | 8.43 |
| 2.00 | 1# | 638.72 | 11.55 | 645.66 | 10.96 | 21.34 | 14.53 | 37.62 | 8.83 |
| 2.00 | 2# | 653.90 | 11.57 | 667.69 | 11.42 | 34.10 | 12.35 | 40.77 | 9.24 |
| 2.00 | 3# | 654.83 | 11.56 | 669.76 | 11.58 | 34.15 | 12.46 | 40.91 | 9.23 |
| 2.00 | 4# | 654.97 | 11.43 | 670.10 | 11.50 | 33.74 | 12.64 | 40.99 | 9.29 |
| 3.00 | 1# | 630.67 | 12.24 | 650.99 | 15.47 | 11.74 | 15.34 | 35.49 | 9.46 |
| 3.00 | 2# | 651.94 | 12.67 | 666.67 | 12.68 | 35.93 | 13.07 | 40.59 | 10.10 |
| 3.00 | 3# | 651.79 | 12.51 | 667.38 | 12.13 | 35.23 | 13.16 | 40.74 | 10.14 |
| 3.00 | 4# | 652.51 | 12.63 | 667.94 | 12.08 | 34.71 | 13.25 | 40.83 | 10.14 |
| 4.00 | 1# | 631.40 | 13.79 | 663.04 | 16.20 | 6.77 | 16.24 | 34.94 | 15.07 |
| 4.00 | 2# | 649.49 | 13.48 | 663.98 | 13.22 | 37.78 | 11.17 | 40.29 | 10.93 |
| 4.00 | 3# | 650.64 | 13.43 | 664.77 | 13.31 | 37.02 | 11.35 | 40.46 | 10.95 |
| 4.00 | 4# | 651.22 | 13.44 | 665.59 | 13.44 | 37.43 | 14.44 | 40.57 | 11.00 |
| 5.00 | 1# | 638.59 | 17.33 | 669.08 | 16.90 | 7.02 | 16.94 | 35.08 | 15.88 |
| 5.00 | 2# | 648.16 | 14.12 | 661.26 | 13.58 | 36.86 | 12.52 | 39.94 | 11.66 |
| 5.00 | 3# | 648.88 | 14.14 | 661.97 | 13.85 | 36.16 | 11.90 | 40.14 | 11.71 |
| 5.00 | 4# | 649.91 | 14.01 | 662.98 | 13.51 | 36.39 | 12.34 | 40.27 | 11.70 |
| 6.00 | 1# | 641.60 | 15.10 | 665.61 | 17.69 | 8.39 | 17.65 | 33.96 | 16.75 |
| 6.00 | 2# | 644.97 | 14.56 | 659.35 | 14.10 | 33.87 | 24.33 | 39.66 | 12.27 |
| 6.00 | 3# | 646.08 | 14.75 | 659.69 | 14.43 | 35.04 | 13.13 | 39.88 | 12.35 |
| 6.00 | 4# | 647.05 | 14.63 | 661.02 | 14.40 | 35.29 | 13.25 | 40.04 | 12.36 |
| 7.00 | 1# | 634.29 | 19.06 | 660.88 | 18.87 | 17.87 | 18.92 | 32.47 | 6.23 |
| 7.00 | 2# | 630.87 | 14.96 | 639.74 | 14.94 | 34.98 | 35.95 | 38.08 | 12.87 |
| 7.00 | 3# | 632.58 | 15.31 | 641.46 | 14.86 | 35.31 | 32.22 | 38.35 | 12.92 |
| 7.00 | 4# | 634.05 | 15.08 | 644.17 | 14.94 | 34.58 | 10.78 | 38.55 | 13.02 |
| 8.00 | 1# | 626.72 | 20.19 | 656.81 | 20.02 | 21.96 | 19.98 | 32.47 | 6.23 |
| 8.00 | 2# | 610.36 | 16.04 | 618.83 | 16.67 | 33.33 | 22.99 | 35.98 | 14.25 |
| 8.00 | 3# | 612.69 | 16.04 | 621.22 | 17.21 | 34.29 | 33.26 | 36.30 | 14.25 |
| 8.00 | 4# | 614.67 | 16.06 | 624.09 | 16.66 | 33.70 | 29.70 | 36.53 | 14.29 |
| 9.00 | 1# | 628.34 | 21.35 | 653.19 | 21.14 | 26.68 | 21.10 | 32.47 | 6.23 |
| 9.00 | 2# | 610.45 | 19.30 | 623.03 | 19.28 | 36.47 | 23.51 | 35.41 | 16.71 |
| 9.00 | 3# | 611.64 | 19.30 | 623.86 | 19.32 | 38.66 | 23.61 | 35.58 | 16.57 |
| 9.00 | 4# | 612.71 | 19.28 | 625.22 | 19.42 | 38.62 | 37.57 | 35.72 | 16.44 |
| 10.00 | 1# | 634.48 | 22.50 | 650.13 | 21.82 | 30.44 | 21.78 | 32.47 | 6.23 |
| 10.00 | 2# | 616.43 | 19.94 | 629.05 | 19.94 | 38.43 | 24.40 | 36.16 | 18.13 |
| 10.00 | 3# | 617.64 | 19.93 | 629.81 | 20.00 | 38.93 | 24.28 | 36.24 | 18.08 |
| 10.00 | 4# | 617.82 | 20.05 | 631.02 | 19.94 | 38.88 | 24.46 | 36.29 | 18.02 |
| 11.00 | 1# | 646.96 | 23.39 | 653.31 | 22.94 | 32.39 | 22.67 | 32.47 | 6.23 |
| 11.00 | 2# | 623.31 | 23.19 | 637.22 | 22.65 | 38.37 | 22.25 | 37.07 | 19.10 |
| 11.00 | 3# | 623.29 | 23.09 | 638.14 | 22.67 | 38.01 | 22.34 | 37.16 | 19.11 |
| 11.00 | 4# | 623.89 | 23.31 | 639.94 | 22.64 | 38.13 | 25.53 | 37.20 | 19.07 |
| 12.00 | 1# | 652.77 | 24.08 | 656.99 | 23.61 | 34.39 | 23.27 | 32.47 | 6.23 |
| 12.00 | 2# | 632.79 | 23.81 | 646.62 | 23.30 | 36.96 | 22.98 | 37.97 | 20.03 |
| 12.00 | 3# | 633.70 | 23.84 | 647.46 | 23.36 | 37.49 | 22.62 | 38.07 | 20.03 |
| 12.00 | 4# | 634.36 | 23.81 | 649.26 | 23.31 | 37.52 | 22.60 | 38.13 | 20.03 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.21 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.22 JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.23 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.24 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.25 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.26 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.27 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.28 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.3.4 直线70s关闭计算结果**

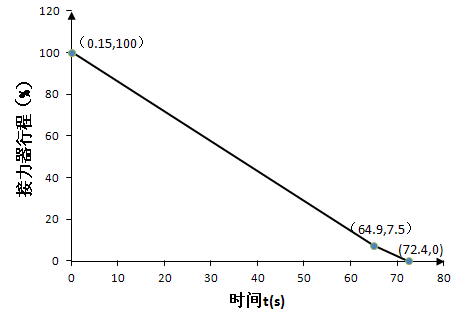


图6.29 水轮机工况导叶直线70s关闭规律

**表6-12 直线70s关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔(s) | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 634.40 | 9.54 | 641.11 | 9.46 | 53.51 | 11.09 | 42.97 | 7.96 |
| 0.00 | 2# | 635.74 | 9.50 | 641.33 | 9.70 | 53.56 | 11.17 | 43.12 | 7.94 |
| 0.00 | 3# | 635.63 | 10.21 | 642.31 | 10.11 | 53.66 | 11.26 | 43.24 | 7.97 |
| 0.00 | 4# | 638.89 | 9.55 | 645.59 | 10.05 | 53.74 | 11.00 | 43.30 | 7.95 |
| SJT3 | 0.00 | 1# | 650.38 | 9.54 | 656.36 | 9.46 | 37.42 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 651.57 | 9.50 | 656.28 | 9.56 | 37.53 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 651.22 | 9.56 | 656.39 | 9.58 | 37.83 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 653.84 | 9.55 | 658.24 | 9.57 | 37.54 | 11.00 | 41.16 | 7.67 |
| ZT2 | 76.76 | 1# | 633.51 | 86.59 | 638.81 | 86.60 | 54.09 | 88.02 | 43.52 | 84.76 |
| 76.76 | 2# | 634.40 | 86.58 | 639.84 | 86.52 | 53.98 | 88.01 | 43.66 | 84.77 |
| 76.76 | 3# | 635.14 | 86.59 | 640.88 | 86.39 | 54.03 | 88.02 | 43.79 | 84.79 |
| 76.76 | 4# | 635.90 | 86.53 | 641.74 | 86.44 | 54.57 | 87.96 | 43.82 | 84.78 |
| JHT3 | 0.00 | 1# | 634.40 | 9.54 | 641.11 | 9.46 | 53.51 | 11.09 | 42.97 | 7.96 |
| 0.00 | 2# | 635.74 | 9.50 | 641.33 | 9.70 | 53.56 | 11.17 | 43.12 | 7.94 |
| 0.00 | 3# | 635.63 | 10.21 | 642.31 | 10.11 | 53.66 | 11.26 | 43.24 | 7.97 |
| 0.00 | 4# | 638.89 | 9.55 | 645.59 | 10.05 | 53.74 | 11.00 | 43.30 | 7.95 |
| 1.00 | 1# | 633.88 | 9.45 | 640.59 | 9.46 | 53.98 | 11.09 | 42.88 | 7.96 |
| 1.00 | 2# | 635.10 | 9.50 | 640.92 | 9.70 | 53.82 | 11.17 | 43.03 | 7.97 |
| 1.00 | 3# | 635.06 | 10.21 | 641.73 | 10.32 | 54.11 | 11.35 | 43.15 | 7.97 |
| 1.00 | 4# | 639.23 | 9.55 | 645.90 | 10.05 | 53.69 | 11.00 | 43.71 | 7.99 |
| 2.00 | 1# | 633.08 | 9.54 | 639.91 | 9.46 | 54.39 | 11.09 | 42.78 | 7.96 |
| 2.00 | 2# | 634.50 | 9.50 | 640.23 | 9.70 | 54.29 | 11.17 | 42.92 | 7.95 |
| 2.00 | 3# | 634.51 | 9.56 | 641.15 | 10.32 | 54.41 | 11.35 | 43.05 | 7.98 |
| 2.00 | 4# | 639.26 | 9.55 | 646.81 | 10.05 | 52.90 | 11.00 | 44.13 | 8.11 |
| 3.00 | 1# | 632.70 | 9.45 | 639.35 | 9.46 | 54.56 | 11.09 | 42.66 | 7.96 |
| 3.00 | 2# | 634.11 | 9.50 | 639.49 | 9.70 | 54.54 | 11.17 | 42.81 | 7.97 |
| 3.00 | 3# | 633.85 | 9.56 | 640.21 | 10.32 | 54.63 | 11.35 | 42.93 | 7.96 |
| 3.00 | 4# | 638.86 | 9.55 | 646.58 | 10.05 | 53.36 | 11.00 | 44.61 | 8.16 |
| 4.00 | 1# | 631.61 | 9.54 | 638.28 | 9.46 | 54.80 | 11.09 | 42.54 | 7.95 |
| 4.00 | 2# | 632.97 | 9.50 | 638.57 | 9.70 | 54.75 | 11.17 | 42.68 | 7.98 |
| 4.00 | 3# | 633.07 | 10.21 | 639.55 | 10.32 | 54.60 | 11.35 | 42.80 | 7.99 |
| 4.00 | 4# | 637.09 | 9.55 | 644.43 | 10.05 | 53.87 | 11.00 | 45.04 | 8.24 |
| 5.00 | 1# | 630.83 | 9.45 | 637.56 | 9.46 | 54.84 | 11.09 | 42.44 | 7.93 |
| 5.00 | 2# | 632.13 | 9.50 | 637.77 | 9.70 | 54.81 | 11.17 | 42.58 | 7.96 |
| 5.00 | 3# | 632.05 | 10.21 | 638.65 | 10.32 | 54.95 | 11.35 | 42.69 | 7.98 |
| 5.00 | 4# | 635.66 | 9.55 | 641.95 | 10.05 | 53.82 | 11.90 | 45.34 | 8.27 |
| 6.00 | 1# | 630.59 | 9.45 | 637.21 | 9.46 | 54.56 | 11.09 | 42.39 | 7.90 |
| 6.00 | 2# | 631.70 | 9.50 | 637.35 | 9.70 | 54.63 | 11.17 | 42.53 | 7.90 |
| 6.00 | 3# | 631.54 | 9.56 | 638.23 | 10.32 | 54.77 | 11.35 | 42.64 | 7.94 |
| 6.00 | 4# | 634.32 | 9.55 | 639.76 | 10.05 | 51.58 | 14.08 | 45.49 | 8.38 |
| 7.00 | 1# | 630.41 | 9.45 | 637.30 | 9.46 | 54.39 | 11.09 | 42.38 | 7.89 |
| 7.00 | 2# | 631.62 | 9.50 | 637.58 | 9.70 | 54.52 | 11.17 | 42.51 | 7.90 |
| 7.00 | 3# | 631.50 | 10.21 | 638.27 | 10.32 | 54.61 | 11.35 | 42.62 | 7.88 |
| 7.00 | 4# | 633.03 | 9.55 | 637.31 | 10.05 | 50.05 | 14.08 | 45.53 | 8.40 |
| 8.00 | 1# | 630.26 | 9.54 | 637.33 | 9.46 | 54.41 | 11.09 | 42.38 | 7.90 |
| 8.00 | 2# | 631.53 | 9.50 | 637.71 | 9.70 | 54.51 | 11.17 | 42.52 | 7.90 |
| 8.00 | 3# | 631.71 | 10.21 | 638.68 | 10.32 | 54.66 | 11.35 | 42.62 | 7.93 |
| 8.00 | 4# | 631.70 | 9.55 | 635.96 | 10.05 | 48.61 | 14.08 | 45.53 | 8.42 |
| 9.00 | 1# | 629.99 | 9.45 | 637.18 | 9.46 | 54.29 | 11.09 | 42.38 | 7.90 |
| 9.00 | 2# | 631.31 | 9.50 | 637.77 | 9.70 | 54.37 | 11.17 | 42.52 | 7.90 |
| 9.00 | 3# | 631.54 | 10.21 | 638.69 | 10.32 | 54.60 | 11.35 | 42.62 | 7.93 |
| 9.00 | 4# | 630.13 | 9.55 | 633.87 | 10.05 | 47.37 | 14.44 | 45.53 | 8.42 |
| 10.00 | 1# | 629.99 | 9.45 | 637.19 | 9.46 | 54.05 | 11.09 | 42.38 | 7.90 |
| 10.00 | 2# | 631.28 | 9.50 | 637.71 | 9.70 | 54.17 | 11.17 | 42.52 | 7.90 |
| 10.00 | 3# | 631.33 | 10.21 | 638.62 | 10.32 | 54.41 | 11.35 | 42.62 | 7.93 |
| 10.00 | 4# | 629.60 | 9.55 | 632.17 | 9.40 | 46.23 | 14.74 | 45.53 | 8.42 |
| 11.00 | 1# | 629.99 | 9.45 | 637.19 | 9.46 | 53.97 | 11.09 | 42.38 | 7.90 |
| 11.00 | 2# | 631.28 | 9.50 | 637.71 | 9.70 | 54.07 | 11.17 | 42.52 | 7.90 |
| 11.00 | 3# | 631.33 | 10.21 | 638.62 | 10.32 | 54.25 | 11.35 | 42.62 | 7.93 |
| 11.00 | 4# | 629.60 | 9.55 | 632.17 | 9.40 | 46.09 | 14.74 | 45.53 | 8.42 |
| 12.00 | 1# | 629.99 | 9.45 | 637.19 | 9.46 | 53.97 | 11.09 | 42.38 | 7.90 |
| 12.00 | 2# | 631.28 | 9.50 | 637.71 | 9.70 | 54.07 | 11.17 | 42.52 | 7.90 |
| 12.00 | 3# | 631.33 | 10.21 | 638.62 | 10.32 | 54.25 | 11.35 | 42.62 | 7.93 |
| 12.00 | 4# | 629.60 | 9.55 | 632.17 | 9.40 | 46.66 | 14.74 | 45.53 | 8.42 |
| JHT13 | 0.00 | 1# | 648.84 | 9.54 | 654.82 | 9.46 | 35.88 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 650.03 | 9.50 | 654.74 | 9.56 | 35.99 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 649.68 | 9.56 | 654.85 | 9.58 | 36.29 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 652.30 | 9.55 | 656.70 | 9.57 | 36.00 | 11.00 | 41.16 | 7.67 |
| 1.00 | 1# | 642.39 | 9.54 | 647.99 | 9.46 | 36.61 | 14.45 | 40.04 | 8.05 |
| 1.00 | 2# | 643.42 | 9.50 | 648.42 | 9.69 | 36.24 | 13.79 | 40.17 | 8.08 |
| 1.00 | 3# | 649.76 | 10.59 | 657.23 | 10.32 | 35.32 | 11.90 | 41.58 | 8.34 |
| 1.00 | 4# | 650.67 | 9.55 | 659.55 | 10.05 | 35.81 | 11.90 | 41.66 | 8.39 |
| 2.00 | 1# | 634.28 | 10.71 | 638.53 | 10.30 | 30.63 | 14.53 | 38.81 | 8.31 |
| 2.00 | 2# | 635.98 | 11.58 | 639.59 | 10.58 | 29.71 | 14.73 | 38.94 | 8.35 |
| 2.00 | 3# | 650.93 | 11.48 | 660.97 | 11.58 | 35.84 | 11.90 | 41.77 | 9.13 |
| 2.00 | 4# | 652.11 | 11.43 | 661.10 | 11.50 | 35.24 | 12.34 | 41.87 | 9.14 |
| 3.00 | 1# | 625.46 | 9.26 | 628.50 | 9.46 | 28.06 | 15.34 | 37.52 | 7.86 |
| 3.00 | 2# | 626.18 | 11.41 | 629.26 | 9.32 | 25.34 | 15.71 | 37.60 | 7.98 |
| 3.00 | 3# | 649.52 | 12.13 | 660.91 | 12.13 | 32.12 | 33.50 | 41.79 | 9.98 |
| 3.00 | 4# | 650.19 | 12.23 | 661.21 | 12.08 | 34.62 | 11.90 | 41.90 | 9.99 |
| 4.00 | 1# | 620.27 | 9.46 | 622.69 | 9.46 | 26.04 | 16.24 | 36.61 | 7.52 |
| 4.00 | 2# | 621.09 | 9.49 | 622.91 | 9.32 | 21.92 | 16.36 | 36.65 | 7.55 |
| 4.00 | 3# | 648.24 | 12.74 | 661.76 | 12.95 | 27.77 | 34.08 | 41.81 | 10.77 |
| 4.00 | 4# | 649.54 | 12.92 | 661.51 | 12.76 | 30.11 | 34.05 | 41.92 | 10.81 |
| 5.00 | 1# | 616.07 | 9.55 | 619.12 | 9.46 | 27.26 | 16.94 | 36.01 | 7.23 |
| 5.00 | 2# | 616.86 | 9.58 | 618.83 | 9.32 | 22.38 | 17.00 | 36.03 | 7.25 |
| 5.00 | 3# | 646.37 | 13.43 | 662.83 | 13.30 | 25.82 | 34.69 | 41.88 | 11.54 |
| 5.00 | 4# | 646.32 | 13.52 | 662.22 | 13.44 | 26.21 | 13.25 | 42.01 | 11.58 |
| 6.00 | 1# | 610.78 | 8.88 | 615.87 | 8.86 | 25.99 | 18.62 | 35.76 | 6.94 |
| 6.00 | 2# | 611.15 | 9.49 | 615.81 | 8.82 | 24.38 | 18.24 | 35.75 | 6.95 |
| 6.00 | 3# | 638.87 | 13.97 | 658.83 | 13.85 | 22.10 | 13.62 | 41.60 | 12.19 |
| 6.00 | 4# | 639.38 | 14.10 | 659.27 | 14.04 | 21.05 | 13.78 | 41.76 | 12.26 |
| 7.00 | 1# | 612.10 | 9.46 | 617.18 | 9.33 | 23.07 | 19.32 | 35.74 | 6.90 |
| 7.00 | 2# | 612.19 | 9.24 | 617.15 | 9.32 | 19.91 | 19.08 | 35.73 | 6.89 |
| 7.00 | 3# | 626.59 | 14.58 | 649.31 | 14.43 | 19.33 | 14.47 | 40.79 | 12.89 |
| 7.00 | 4# | 628.46 | 14.70 | 648.70 | 14.58 | 18.59 | 14.44 | 40.97 | 12.95 |
| 8.00 | 1# | 613.49 | 9.55 | 619.23 | 9.46 | 23.22 | 19.80 | 35.74 | 6.90 |
| 8.00 | 2# | 613.94 | 9.49 | 619.38 | 9.32 | 20.34 | 19.62 | 35.73 | 6.89 |
| 8.00 | 3# | 615.62 | 15.21 | 635.31 | 15.13 | 21.30 | 15.09 | 39.17 | 13.53 |
| 8.00 | 4# | 618.60 | 15.39 | 636.71 | 15.30 | 20.03 | 14.74 | 39.39 | 13.61 |
| 9.00 | 1# | 611.96 | 9.55 | 619.12 | 9.46 | 22.54 | 20.35 | 35.74 | 6.90 |
| 9.00 | 2# | 612.40 | 9.58 | 618.63 | 9.56 | 20.02 | 20.29 | 35.73 | 6.89 |
| 9.00 | 3# | 607.22 | 16.12 | 619.64 | 16.12 | 24.40 | 34.46 | 36.82 | 14.25 |
| 9.00 | 4# | 609.28 | 16.29 | 621.93 | 16.12 | 17.62 | 38.31 | 37.08 | 14.33 |
| 10.00 | 1# | 611.05 | 9.46 | 619.19 | 9.46 | 28.79 | 31.45 | 35.74 | 6.90 |
| 10.00 | 2# | 611.02 | 9.49 | 618.82 | 9.32 | 27.46 | 31.59 | 35.73 | 6.89 |
| 10.00 | 3# | 597.75 | 17.46 | 599.57 | 17.21 | 22.44 | 26.86 | 34.13 | 15.13 |
| 10.00 | 4# | 599.15 | 17.40 | 600.95 | 17.48 | 28.58 | 27.98 | 34.45 | 15.22 |
| 11.00 | 1# | 611.05 | 9.46 | 619.19 | 9.46 | 30.59 | 34.06 | 35.74 | 6.90 |
| 11.00 | 2# | 611.02 | 9.49 | 618.82 | 9.32 | 32.19 | 33.60 | 35.73 | 6.89 |
| 11.00 | 3# | 601.97 | 28.28 | 617.65 | 28.36 | 24.82 | 27.64 | 31.87 | 26.66 |
| 11.00 | 4# | 601.38 | 28.71 | 615.79 | 28.68 | 27.07 | 28.89 | 32.00 | 16.28 |
| 12.00 | 1# | 620.22 | 25.77 | 625.44 | 25.76 | 31.70 | 35.25 | 35.74 | 6.90 |
| 12.00 | 2# | 619.47 | 25.76 | 625.41 | 25.57 | 31.77 | 34.86 | 35.73 | 6.89 |
| 12.00 | 3# | 601.04 | 25.76 | 612.49 | 29.40 | 30.39 | 28.77 | 32.72 | 23.32 |
| 12.00 | 4# | 600.42 | 25.69 | 611.87 | 29.74 | 30.54 | 29.78 | 32.39 | 23.20 |
| JDT6 | 0.00 | 1# | 648.84 | 9.54 | 654.82 | 9.46 | 35.88 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 650.03 | 9.50 | 654.74 | 9.56 | 35.99 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 649.68 | 9.56 | 654.85 | 9.58 | 36.29 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 652.30 | 9.55 | 656.70 | 9.57 | 36.00 | 11.00 | 41.16 | 7.67 |
| 1.00 | 1# | 645.61 | 9.45 | 651.11 | 9.46 | 39.07 | 32.70 | 40.43 | 7.82 |
| 1.00 | 2# | 646.56 | 9.50 | 651.74 | 9.70 | 38.50 | 32.76 | 40.55 | 7.84 |
| 1.00 | 3# | 646.60 | 9.56 | 651.54 | 9.58 | 38.46 | 11.90 | 40.67 | 7.90 |
| 1.00 | 4# | 653.19 | 9.55 | 661.06 | 10.05 | 34.22 | 11.15 | 41.97 | 8.18 |
| 2.00 | 1# | 638.88 | 9.54 | 645.15 | 9.46 | 36.82 | 14.45 | 39.81 | 7.82 |
| 2.00 | 2# | 640.00 | 9.79 | 646.12 | 9.69 | 36.79 | 14.08 | 39.92 | 7.90 |
| 2.00 | 3# | 640.64 | 10.30 | 646.88 | 10.32 | 35.96 | 13.62 | 40.02 | 7.88 |
| 2.00 | 4# | 652.59 | 11.43 | 664.45 | 10.96 | 31.69 | 11.90 | 42.50 | 8.94 |
| 3.00 | 1# | 635.92 | 9.37 | 641.15 | 9.46 | 35.59 | 14.53 | 39.23 | 7.71 |
| 3.00 | 2# | 636.74 | 9.50 | 641.31 | 9.32 | 35.35 | 14.36 | 39.33 | 7.73 |
| 3.00 | 3# | 637.04 | 9.41 | 641.44 | 9.30 | 32.39 | 14.47 | 39.41 | 7.77 |
| 3.00 | 4# | 653.44 | 12.23 | 667.96 | 12.08 | 26.99 | 12.34 | 42.95 | 9.90 |
| 4.00 | 1# | 634.61 | 9.45 | 639.27 | 9.46 | 36.15 | 33.86 | 38.83 | 7.58 |
| 4.00 | 2# | 635.55 | 9.50 | 639.22 | 9.32 | 35.20 | 25.96 | 38.91 | 7.59 |
| 4.00 | 3# | 635.40 | 9.41 | 639.27 | 9.43 | 33.64 | 15.37 | 38.96 | 7.62 |
| 4.00 | 4# | 652.66 | 12.63 | 671.38 | 12.68 | 21.85 | 12.89 | 43.45 | 10.69 |
| 5.00 | 1# | 633.15 | 9.45 | 637.67 | 9.46 | 36.51 | 30.53 | 38.54 | 7.49 |
| 5.00 | 2# | 633.73 | 9.50 | 637.68 | 9.32 | 20.41 | 37.24 | 38.60 | 7.48 |
| 5.00 | 3# | 633.62 | 9.41 | 637.59 | 9.43 | 34.70 | 15.67 | 38.64 | 7.50 |
| 5.00 | 4# | 649.32 | 13.06 | 670.82 | 13.21 | 15.16 | 13.25 | 43.86 | 11.42 |
| 6.00 | 1# | 629.78 | 9.37 | 635.62 | 9.46 | 30.33 | 30.79 | 38.36 | 7.40 |
| 6.00 | 2# | 630.41 | 9.50 | 635.76 | 9.30 | 26.70 | 37.24 | 38.42 | 7.38 |
| 6.00 | 3# | 630.44 | 9.41 | 635.78 | 9.30 | 32.10 | 30.78 | 38.44 | 7.38 |
| 6.00 | 4# | 640.78 | 13.59 | 666.35 | 13.74 | 8.07 | 13.78 | 43.85 | 12.14 |
| 7.00 | 1# | 630.32 | 9.37 | 635.79 | 9.46 | 35.82 | 31.58 | 38.32 | 7.29 |
| 7.00 | 2# | 630.53 | 9.50 | 635.96 | 9.30 | 34.06 | 34.88 | 38.38 | 7.30 |
| 7.00 | 3# | 630.63 | 9.41 | 635.75 | 9.30 | 37.50 | 31.32 | 38.39 | 7.32 |
| 7.00 | 4# | 631.54 | 10.96 | 657.37 | 14.40 | 3.32 | 14.37 | 43.27 | 12.92 |
| 8.00 | 1# | 631.06 | 9.37 | 636.60 | 9.46 | 36.80 | 31.88 | 38.32 | 7.32 |
| 8.00 | 2# | 631.45 | 9.50 | 636.62 | 9.30 | 36.70 | 32.00 | 38.38 | 7.28 |
| 8.00 | 3# | 631.28 | 9.41 | 636.29 | 9.30 | 37.45 | 35.58 | 38.39 | 7.31 |
| 8.00 | 4# | 627.85 | 9.55 | 646.42 | 14.94 | 0.44 | 14.90 | 42.13 | 13.60 |
| 9.00 | 1# | 630.09 | 9.45 | 636.69 | 9.46 | 36.93 | 29.04 | 38.32 | 7.32 |
| 9.00 | 2# | 630.86 | 9.50 | 636.66 | 9.69 | 36.75 | 29.05 | 38.38 | 7.28 |
| 9.00 | 3# | 630.48 | 9.41 | 636.02 | 9.30 | 36.14 | 29.07 | 38.39 | 7.31 |
| 9.00 | 4# | 624.48 | 9.55 | 629.84 | 15.49 | 2.60 | 15.63 | 40.30 | 14.25 |
| 10.00 | 1# | 629.78 | 9.37 | 636.65 | 9.46 | 36.90 | 29.41 | 38.32 | 7.32 |
| 10.00 | 2# | 630.25 | 9.50 | 636.36 | 9.30 | 36.60 | 29.60 | 38.38 | 7.28 |
| 10.00 | 3# | 629.93 | 9.41 | 636.02 | 9.30 | 35.43 | 29.44 | 38.39 | 7.31 |
| 10.00 | 4# | 616.09 | 10.52 | 620.83 | 10.96 | 5.34 | 16.35 | 37.75 | 15.00 |
| 11.00 | 1# | 629.78 | 9.37 | 636.65 | 9.46 | 35.80 | 33.86 | 38.32 | 7.32 |
| 11.00 | 2# | 630.25 | 9.50 | 636.36 | 9.30 | 34.63 | 33.76 | 38.38 | 7.28 |
| 11.00 | 3# | 629.93 | 9.41 | 636.02 | 9.30 | 37.78 | 30.33 | 38.39 | 7.31 |
| 11.00 | 4# | 616.14 | 31.44 | 623.36 | 31.55 | 8.81 | 17.13 | 34.84 | 15.90 |
| 12.00 | 1# | 629.78 | 9.37 | 636.65 | 9.46 | 36.07 | 21.47 | 38.32 | 7.32 |
| 12.00 | 2# | 630.25 | 9.50 | 636.36 | 9.30 | 31.94 | 33.52 | 38.38 | 7.28 |
| 12.00 | 3# | 629.93 | 9.41 | 636.02 | 9.30 | 31.27 | 33.31 | 38.39 | 7.31 |
| 12.00 | 4# | 616.31 | 31.00 | 628.31 | 30.93 | 17.92 | 17.88 | 32.38 | 28.95 |
| JDT10 | 0.00 | 1# | 648.84 | 9.54 | 654.82 | 9.46 | 35.88 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 650.03 | 9.50 | 654.74 | 9.56 | 35.99 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 649.68 | 9.56 | 654.85 | 9.58 | 36.29 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 652.30 | 9.55 | 656.70 | 9.57 | 36.00 | 11.00 | 41.16 | 7.67 |
| 1.00 | 1# | 641.54 | 10.46 | 645.63 | 10.36 | 31.36 | 14.45 | 39.73 | 8.28 |
| 1.00 | 2# | 648.23 | 10.60 | 655.21 | 10.58 | 36.41 | 11.81 | 41.20 | 8.48 |
| 1.00 | 3# | 649.55 | 10.30 | 656.71 | 10.32 | 35.44 | 11.90 | 41.32 | 8.51 |
| 1.00 | 4# | 650.23 | 10.44 | 657.86 | 10.05 | 36.21 | 11.90 | 41.38 | 8.50 |
| 2.00 | 1# | 634.84 | 11.55 | 636.20 | 10.96 | 22.99 | 15.34 | 38.18 | 9.12 |
| 2.00 | 2# | 649.58 | 11.58 | 655.34 | 11.42 | 37.41 | 12.53 | 41.16 | 9.34 |
| 2.00 | 3# | 650.35 | 11.56 | 657.74 | 11.58 | 36.95 | 12.62 | 41.30 | 9.36 |
| 2.00 | 4# | 650.54 | 11.49 | 657.60 | 10.96 | 36.57 | 12.64 | 41.38 | 9.37 |
| 3.00 | 1# | 628.38 | 12.24 | 635.02 | 16.20 | 16.60 | 16.34 | 36.25 | 10.01 |
| 3.00 | 2# | 647.54 | 12.67 | 653.72 | 12.31 | 37.87 | 13.78 | 40.95 | 10.20 |
| 3.00 | 3# | 647.32 | 12.56 | 654.72 | 12.13 | 37.48 | 13.62 | 41.10 | 10.22 |
| 3.00 | 4# | 648.30 | 12.53 | 655.51 | 12.02 | 36.65 | 13.78 | 41.20 | 10.23 |
| 4.00 | 1# | 626.51 | 13.51 | 647.81 | 16.98 | 14.63 | 17.02 | 36.40 | 15.38 |
| 4.00 | 2# | 643.90 | 13.24 | 651.46 | 12.84 | 39.36 | 11.17 | 40.62 | 11.00 |
| 4.00 | 3# | 645.20 | 13.31 | 652.28 | 12.95 | 38.66 | 11.26 | 40.80 | 11.07 |
| 4.00 | 4# | 646.38 | 13.44 | 653.32 | 12.92 | 38.26 | 14.74 | 40.91 | 11.07 |
| 5.00 | 1# | 633.29 | 17.68 | 655.85 | 17.55 | 12.30 | 17.65 | 36.84 | 16.23 |
| 5.00 | 2# | 643.52 | 13.84 | 650.20 | 13.58 | 35.85 | 24.08 | 40.33 | 11.80 |
| 5.00 | 3# | 644.22 | 13.86 | 651.03 | 13.85 | 37.69 | 11.90 | 40.52 | 11.83 |
| 5.00 | 4# | 645.20 | 14.01 | 652.26 | 13.88 | 37.68 | 11.82 | 40.66 | 11.89 |
| 6.00 | 1# | 637.32 | 15.30 | 657.18 | 18.16 | 14.19 | 18.25 | 36.45 | 16.94 |
| 6.00 | 2# | 640.88 | 14.68 | 646.02 | 14.10 | 29.93 | 24.76 | 39.87 | 12.45 |
| 6.00 | 3# | 641.69 | 14.83 | 647.56 | 14.38 | 35.64 | 35.50 | 40.10 | 12.52 |
| 6.00 | 4# | 642.88 | 14.70 | 648.48 | 14.40 | 35.30 | 27.98 | 40.25 | 12.55 |
| 7.00 | 1# | 631.24 | 19.26 | 650.25 | 19.13 | 20.45 | 19.32 | 34.91 | 17.72 |
| 7.00 | 2# | 630.14 | 15.36 | 635.08 | 14.94 | 33.03 | 25.14 | 38.72 | 13.08 |
| 7.00 | 3# | 631.60 | 15.49 | 635.77 | 15.21 | 34.01 | 36.49 | 38.99 | 13.14 |
| 7.00 | 4# | 633.34 | 15.39 | 638.40 | 14.94 | 34.50 | 36.58 | 39.18 | 13.22 |
| 8.00 | 1# | 622.13 | 20.38 | 640.77 | 20.47 | 22.67 | 20.35 | 33.14 | 6.35 |
| 8.00 | 2# | 609.72 | 16.11 | 613.42 | 38.64 | 31.30 | 37.63 | 36.63 | 14.06 |
| 8.00 | 3# | 611.76 | 16.04 | 615.64 | 16.04 | 31.46 | 37.60 | 36.96 | 14.08 |
| 8.00 | 4# | 613.37 | 16.06 | 618.34 | 15.91 | 29.67 | 40.93 | 37.20 | 14.21 |
| 9.00 | 1# | 621.19 | 21.64 | 635.72 | 21.65 | 27.41 | 21.69 | 33.14 | 6.35 |
| 9.00 | 2# | 604.90 | 19.38 | 607.31 | 19.28 | 34.44 | 34.95 | 35.41 | 16.49 |
| 9.00 | 3# | 605.84 | 19.30 | 609.20 | 19.32 | 33.01 | 39.40 | 35.65 | 16.36 |
| 9.00 | 4# | 607.30 | 19.28 | 610.42 | 19.42 | 31.33 | 42.42 | 35.85 | 16.22 |
| 10.00 | 1# | 626.19 | 22.93 | 638.82 | 22.71 | 25.73 | 32.56 | 33.14 | 6.35 |
| 10.00 | 2# | 610.35 | 20.12 | 614.04 | 19.94 | 36.64 | 25.83 | 36.00 | 18.37 |
| 10.00 | 3# | 611.48 | 19.93 | 614.71 | 20.00 | 38.35 | 25.70 | 36.08 | 18.26 |
| 10.00 | 4# | 611.63 | 20.05 | 615.79 | 20.02 | 36.00 | 43.77 | 36.12 | 18.11 |
| 11.00 | 1# | 634.04 | 23.91 | 644.20 | 23.92 | 24.60 | 33.23 | 33.14 | 6.35 |
| 11.00 | 2# | 617.79 | 23.21 | 621.50 | 22.94 | 36.21 | 41.47 | 37.01 | 19.53 |
| 11.00 | 3# | 617.71 | 23.17 | 621.71 | 22.67 | 36.55 | 41.34 | 37.06 | 19.49 |
| 11.00 | 4# | 618.31 | 23.31 | 623.09 | 22.64 | 36.81 | 44.75 | 37.09 | 19.40 |
| 12.00 | 1# | 638.44 | 24.42 | 647.36 | 24.50 | 33.55 | 33.98 | 33.14 | 6.35 |
| 12.00 | 2# | 628.32 | 23.81 | 631.68 | 23.30 | 36.82 | 42.12 | 38.02 | 20.53 |
| 12.00 | 3# | 629.05 | 23.84 | 632.44 | 23.56 | 36.61 | 42.10 | 38.10 | 20.51 |
| 12.00 | 4# | 629.25 | 23.92 | 633.42 | 23.31 | 36.79 | 26.79 | 38.14 | 20.51 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.30 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.31JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.32 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.33 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.34 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.35 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.36 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.37 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.3.5 一段直线关闭极值结果统计**

**表6-13 直线40s关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 659.26 | 9.55 | 703.88 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 667.64 | 10.05 | 715.05 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 48.71 | 11.90 | 32.37 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 42.91 | 7.81 | 45.06 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 677.05 | 9.55 | 724.10 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 683.52 | 10.05 | 732.78 |
| 尾水管最小动水压力 (m) | 457.35 | 51.93 | 0.00 | 2# | 34.29 | 10.63 | 16.52 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 40.41 | 7.44 | 42.43 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 0.00 | 4# | 657.90 | 86.74 | 702.37 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 663.22 | 86.66 | 710.15 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 49.78 | 88.59 | 31.31 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 43.44 | 84.63 | 45.61 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 2.00 | 4# | 660.99 | 10.05 | 705.78 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 3.00 | 4# | 672.22 | 10.05 | 720.09 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 10.00 | 4# | 32.04 | 14.44 | 14.06 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 7.00 | 4# | 47.02 | 8.42 | 49.37 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 2.00 | 4# | 676.11 | 11.63 | 723.22 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 687.37 | 13.21 | 737.17 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 6.00 | 4# | 12.47 | 13.48 | -7.30 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 42.02 | 12.12 | 44.12 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 2.00 | 4# | 675.64 | 11.43 | 722.71 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 697.16 | 12.76 | 747.94 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 6.00 | 4# | -2.24 | 13.25 | -23.48 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 44.45 | 11.99 | 46.67 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 0.00 | 4# | 675.46 | 9.55 | 722.51 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 682.96 | 11.58 | 732.32 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 1.56 | 16.42 | -19.27 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 40.67 | 9.17 | 42.70 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-14 直线50s关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 650.10 | 9.55 | 693.80 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 658.62 | 10.05 | 705.13 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 51.44 | 11.90 | 35.38 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 43.15 | 7.88 | 45.31 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 663.26 | 9.55 | 708.93 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 668.44 | 9.40 | 716.19 |
| 尾水管最小动水压力 (m) | 457.35 | 51.93 | 0.00 | 2# | 34.41 | 11.17 | 16.65 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 40.74 | 7.54 | 42.78 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 0.00 | 4# | 648.29 | 86.84 | 691.80 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 653.28 | 86.80 | 699.22 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 52.45 | 89.12 | 34.25 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 43.67 | 84.72 | 45.85 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 1.00 | 4# | 651.35 | 9.55 | 695.18 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 2.00 | 4# | 660.57 | 10.05 | 707.28 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 10.00 | 4# | 38.94 | 14.74 | 21.65 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 7.00 | 4# | 46.35 | 8.42 | 48.67 |
| JHT13 | 球阀上游侧最大动水压力（m） | 457.61 | 525.50 | 2.00 | 3# | 663.71 | 11.56 | 709.56 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 4.00 | 4# | 675.53 | 12.76 | 724.15 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 7.00 | 4# | 13.78 | 14.14 | -5.86 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 5.00 | 4# | 41.83 | 11.49 | 43.92 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 3.00 | 4# | 667.12 | 12.02 | 713.33 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 684.17 | 12.92 | 733.65 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 7.00 | 4# | -2.06 | 14.07 | -23.28 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 44.00 | 12.08 | 46.20 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 2.00 | 4# | 661.91 | 11.49 | 707.60 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 670.10 | 11.50 | 718.17 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 7.02 | 16.94 | -13.27 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 40.99 | 9.29 | 43.04 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-15 直线60s关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 644.18 | 9.55 | 687.29 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 651.74 | 10.05 | 697.56 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 53.26 | 11.35 | 37.38 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 43.28 | 7.94 | 45.44 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 658.07 | 9.55 | 703.23 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 662.67 | 9.57 | 709.85 |
| 尾水管最小动水压力 (m) | 457.35 | 51.93 | 0.00 | 2# | 36.24 | 11.17 | 18.66 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 40.96 | 7.64 | 43.01 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 0.00 | 4# | 641.29 | 86.85 | 684.10 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 646.54 | 86.66 | 691.80 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 54.17 | 88.29 | 36.14 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 43.80 | 84.76 | 45.99 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 3.00 | 4# | 644.19 | 9.55 | 687.30 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 3.00 | 4# | 653.04 | 10.05 | 698.99 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 12.00 | 4# | 43.40 | 14.74 | 26.56 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 7.00 | 4# | 45.88 | 8.44 | 48.17 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 2.00 | 4# | 656.54 | 11.49 | 701.70 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 4.00 | 4# | 667.10 | 12.76 | 714.87 |
| 尾水管最小动水压力 (m) | 457.61 | 50.22 | 7.00 | 3# | 16.78 | 14.19 | -2.58 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 5.00 | 4# | 41.92 | 11.51 | 44.02 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 2.00 | 4# | 658.89 | 12.10 | 704.28 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 4.00 | 4# | 676.62 | 12.68 | 725.35 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 8.00 | 4# | -1.69 | 14.74 | -22.88 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 43.91 | 12.13 | 46.11 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 0.00 | 4# | 656.53 | 9.55 | 701.69 |
| 蜗壳最大动水压力(m) | 457.68 | 509.46 | 12.00 | 1# | 664.06 | 24.06 | 711.56 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 11.90 | 17.31 | -7.90 |
| 机组最大转速上升率(%) | 458.06 | 510.00 | 2.00 | 4# | 41.19 | 9.33 | 43.25 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-16 直线70s关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 638.89 | 9.55 | 681.47 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 645.59 | 10.05 | 690.80 |
| 尾水管最小动水压力 (m) | 419.05 | 64.78 | 0.00 | 1# | 53.51 | 11.09 | 37.72 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 43.30 | 7.95 | 45.47 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 653.84 | 9.55 | 698.57 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 658.24 | 9.57 | 704.97 |
| 尾水管最小动水压力 (m) | 457.68 | 51.24 | 0.00 | 1# | 37.42 | 11.09 | 20.02 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 41.16 | 7.67 | 43.22 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 0.00 | 4# | 635.90 | 86.53 | 678.17 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 640.88 | 86.39 | 685.58 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 54.57 | 87.96 | 36.58 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 43.82 | 84.78 | 46.01 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 2.00 | 4# | 639.26 | 9.55 | 681.88 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 2.00 | 4# | 646.81 | 10.05 | 692.14 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 11.00 | 4# | 46.09 | 14.74 | 29.52 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 7.00 | 4# | 45.53 | 8.40 | 47.81 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 0.00 | 4# | 652.30 | 9.55 | 697.03 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 5.00 | 3# | 662.83 | 13.30 | 710.16 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 17.62 | 38.31 | -1.63 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 5.00 | 4# | 42.01 | 11.58 | 44.11 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 3.00 | 4# | 653.44 | 12.23 | 698.29 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 4.00 | 4# | 671.38 | 12.68 | 719.58 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 8.00 | 4# | 0.44 | 14.90 | -20.53 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 5.00 | 4# | 43.86 | 11.42 | 46.05 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 0.00 | 4# | 652.30 | 9.55 | 697.03 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 1.00 | 4# | 657.86 | 10.05 | 704.71 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 12.30 | 17.65 | -7.46 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 1.00 | 4# | 41.38 | 8.50 | 43.45 |

注；表中尾水管进口最小动水压力为相对压力值

**6.2.3.6 本节小结**

（1）采用直线40s、直线50s、直线60s、直线70s关闭规律，SJT2、ZT2、JHT3、JDT6工况的机组最大转速上升率修正值都超过了45%，不能满足控制在45%的要求。

（2）采用直线40s、直线50s、直线60s、直线70s关闭规律，JHT13、JDT6、JDT10工况尾水管最小水动压力都出现了负压，不满足控制要求。

（3）采用直线40s、直线50s、直线60s、直线70s关闭规律 ，JDT6工况蜗壳最大动水压力（修正值）均接近或超过720mH2O，不能满足要求。采用直线40s关闭规律SJT3、JHT13、JDT6、JDT10工况蜗壳最大动水压力（修正值）均超过720mH2O，不能满足要求。

### 6.2.4 先快后慢关闭

二段关闭表示方法用 a-g-c，其中a为第一段关闭时间（从100%开度至0），g为拐点位置（%），c为第二段关闭时间（从100%开度至0）。

**6.2.4.1 20s-(70%)-70s两段关闭规律计算结果**

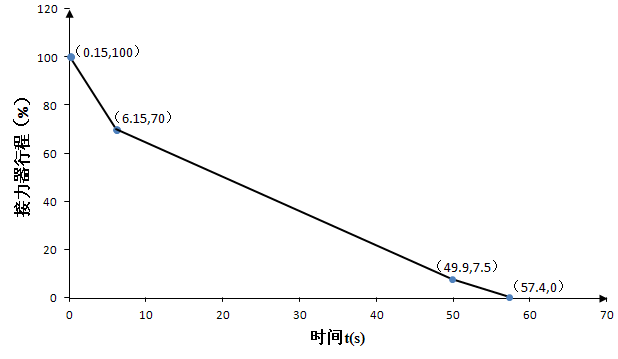


图6.38 水轮机工况导叶20s-(70%)-70s两段关闭规律

**表6-17 20s-(70%)-70s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 664.98 | 9.54 | 671.76 | 9.46 | 48.88 | 11.09 | 41.24 | 7.26 |
| 0.00 | 2# | 666.18 | 9.50 | 671.77 | 9.32 | 48.53 | 11.17 | 41.39 | 7.26 |
| 0.00 | 3# | 665.91 | 9.41 | 672.29 | 9.30 | 48.19 | 11.26 | 41.52 | 7.25 |
| 0.00 | 4# | 668.50 | 9.55 | 674.16 | 9.40 | 48.22 | 11.00 | 41.58 | 7.25 |
| SJT3 | 0.00 | 1# | 649.53 | 9.45 | 655.20 | 9.46 | 36.08 | 11.09 | 39.33 | 7.49 |
| 0.00 | 2# | 650.30 | 9.50 | 654.51 | 9.56 | 35.66 | 11.17 | 39.44 | 7.51 |
| 0.00 | 3# | 649.89 | 9.56 | 654.79 | 9.49 | 36.08 | 11.26 | 39.54 | 7.51 |
| 0.00 | 4# | 652.63 | 9.55 | 656.87 | 9.57 | 36.06 | 11.00 | 39.58 | 7.51 |
| ZT2 | 76.76 | 1# | 663.66 | 86.29 | 669.26 | 86.18 | 48.42 | 88.02 | 41.76 | 84.06 |
| 76.76 | 2# | 664.59 | 86.22 | 670.26 | 86.15 | 48.50 | 87.99 | 41.90 | 84.07 |
| 76.76 | 3# | 665.50 | 86.29 | 671.42 | 86.17 | 48.16 | 88.07 | 42.03 | 84.09 |
| 76.76 | 4# | 666.31 | 86.43 | 672.54 | 86.03 | 48.66 | 88.09 | 42.09 | 84.07 |
| JHT3 | 0.00 | 1# | 664.98 | 9.54 | 671.76 | 9.46 | 48.88 | 11.09 | 41.24 | 7.26 |
| 0.00 | 2# | 666.18 | 9.50 | 671.77 | 9.32 | 48.53 | 11.17 | 41.39 | 7.26 |
| 0.00 | 3# | 665.91 | 9.41 | 672.29 | 9.30 | 48.19 | 11.26 | 41.52 | 7.25 |
| 0.00 | 4# | 668.50 | 9.55 | 674.16 | 9.40 | 48.22 | 11.00 | 41.58 | 7.25 |
| 1.00 | 1# | 663.05 | 9.54 | 669.31 | 9.46 | 45.42 | 11.09 | 41.05 | 7.33 |
| 1.00 | 2# | 664.26 | 9.50 | 668.84 | 9.56 | 44.24 | 11.28 | 41.20 | 7.35 |
| 1.00 | 3# | 664.12 | 9.41 | 669.30 | 9.43 | 43.04 | 11.35 | 41.34 | 7.37 |
| 1.00 | 4# | 676.02 | 9.55 | 686.24 | 8.86 | 47.91 | 7.93 | 43.33 | 7.21 |
| 2.00 | 1# | 661.71 | 9.54 | 666.39 | 9.46 | 41.29 | 11.09 | 40.71 | 7.48 |
| 2.00 | 2# | 662.68 | 9.50 | 666.28 | 9.32 | 39.86 | 11.28 | 40.86 | 7.47 |
| 2.00 | 3# | 663.55 | 9.41 | 667.29 | 9.30 | 38.43 | 11.26 | 41.02 | 7.49 |
| 2.00 | 4# | 683.05 | 9.07 | 699.63 | 8.96 | 42.73 | 8.83 | 45.28 | 7.24 |
| 3.00 | 1# | 659.49 | 9.54 | 663.37 | 9.46 | 40.77 | 11.61 | 40.24 | 7.50 |
| 3.00 | 2# | 660.85 | 9.50 | 663.31 | 9.32 | 39.30 | 11.28 | 40.40 | 7.53 |
| 3.00 | 3# | 661.36 | 9.41 | 663.85 | 9.30 | 37.15 | 11.35 | 40.54 | 7.54 |
| 3.00 | 4# | 689.84 | 9.27 | 708.76 | 9.04 | 37.92 | 8.83 | 47.00 | 7.38 |
| 4.00 | 1# | 656.66 | 9.54 | 660.18 | 9.46 | 41.05 | 11.67 | 39.82 | 7.43 |
| 4.00 | 2# | 658.15 | 9.50 | 660.06 | 9.32 | 38.99 | 11.81 | 39.96 | 7.46 |
| 4.00 | 3# | 658.44 | 9.41 | 660.74 | 9.43 | 37.65 | 11.72 | 40.09 | 7.49 |
| 4.00 | 4# | 695.90 | 9.55 | 715.63 | 9.40 | 35.98 | 9.14 | 48.31 | 7.55 |
| 5.00 | 1# | 653.65 | 9.45 | 657.54 | 9.46 | 43.27 | 11.89 | 39.55 | 7.27 |
| 5.00 | 2# | 655.20 | 9.50 | 657.49 | 9.32 | 41.25 | 11.81 | 39.67 | 7.31 |
| 5.00 | 3# | 655.43 | 9.41 | 658.10 | 9.30 | 39.00 | 11.90 | 39.79 | 7.35 |
| 5.00 | 4# | 692.17 | 9.55 | 710.57 | 9.84 | 35.29 | 9.89 | 49.16 | 7.76 |
| 6.00 | 1# | 652.54 | 9.54 | 657.36 | 9.46 | 46.96 | 12.29 | 39.47 | 7.21 |
| 6.00 | 2# | 653.78 | 9.50 | 656.81 | 9.32 | 46.00 | 12.36 | 39.59 | 7.20 |
| 6.00 | 3# | 653.59 | 9.41 | 657.16 | 9.30 | 44.31 | 12.26 | 39.68 | 7.27 |
| 6.00 | 4# | 683.84 | 9.55 | 701.14 | 10.05 | 34.37 | 10.63 | 49.40 | 7.98 |
| 7.00 | 1# | 652.84 | 9.55 | 658.66 | 9.46 | 52.62 | 12.29 | 39.46 | 7.21 |
| 7.00 | 2# | 654.07 | 9.50 | 657.93 | 9.32 | 51.44 | 12.36 | 39.58 | 7.18 |
| 7.00 | 3# | 653.55 | 9.41 | 658.14 | 9.30 | 49.98 | 12.62 | 39.67 | 7.24 |
| 7.00 | 4# | 673.27 | 10.16 | 690.09 | 10.05 | 32.10 | 11.15 | 49.45 | 8.08 |
| 8.00 | 1# | 651.86 | 9.55 | 658.66 | 9.46 | 55.14 | 8.53 | 39.46 | 7.21 |
| 8.00 | 2# | 653.09 | 9.50 | 658.20 | 9.32 | 55.02 | 8.53 | 39.58 | 7.18 |
| 8.00 | 3# | 652.87 | 9.41 | 658.40 | 9.30 | 54.93 | 3.90 | 39.67 | 7.24 |
| 8.00 | 4# | 660.63 | 9.55 | 675.20 | 10.96 | 33.22 | 11.82 | 49.41 | 8.00 |
| 9.00 | 1# | 638.55 | 9.55 | 645.77 | 9.46 | 50.21 | 18.91 | 37.72 | 7.12 |
| 9.00 | 2# | 639.38 | 9.50 | 644.90 | 9.32 | 48.44 | 15.80 | 37.81 | 7.14 |
| 9.00 | 3# | 638.31 | 9.56 | 649.71 | 11.58 | 43.29 | 12.62 | 47.38 | 8.09 |
| 9.00 | 4# | 641.38 | 9.55 | 650.07 | 11.58 | 42.23 | 12.64 | 47.41 | 8.12 |
| 10.00 | 1# | 651.16 | 9.55 | 658.49 | 9.46 | 53.44 | 11.09 | 39.46 | 7.21 |
| 10.00 | 2# | 652.36 | 9.50 | 658.08 | 9.32 | 53.54 | 11.17 | 39.58 | 7.18 |
| 10.00 | 3# | 652.17 | 9.41 | 658.31 | 9.30 | 53.24 | 11.35 | 39.67 | 7.24 |
| 10.00 | 4# | 652.93 | 9.55 | 657.29 | 9.40 | 36.28 | 12.64 | 49.41 | 8.00 |
| 11.00 | 1# | 651.16 | 9.55 | 658.49 | 9.46 | 53.18 | 11.09 | 39.46 | 7.21 |
| 11.00 | 2# | 652.36 | 9.50 | 658.08 | 9.32 | 53.08 | 11.17 | 39.58 | 7.18 |
| 11.00 | 3# | 652.17 | 9.41 | 658.31 | 9.30 | 52.43 | 11.35 | 39.67 | 7.24 |
| 11.00 | 4# | 652.93 | 9.55 | 657.29 | 9.40 | 39.79 | 12.64 | 49.41 | 8.00 |
| 12.00 | 1# | 651.16 | 9.55 | 658.49 | 9.46 | 53.18 | 11.09 | 39.46 | 7.21 |
| 12.00 | 2# | 652.36 | 9.50 | 658.08 | 9.32 | 53.08 | 11.17 | 39.58 | 7.18 |
| 12.00 | 3# | 652.17 | 9.41 | 658.31 | 9.30 | 52.43 | 11.35 | 39.67 | 7.24 |
| 12.00 | 4# | 652.93 | 9.55 | 657.29 | 9.40 | 43.17 | 11.90 | 49.41 | 8.00 |
| JHT13 | 0.00 | 1# | 647.99 | 9.45 | 653.66 | 9.46 | 34.54 | 11.09 | 39.33 | 7.49 |
| 0.00 | 2# | 648.76 | 9.50 | 652.97 | 9.56 | 34.12 | 11.17 | 39.44 | 7.51 |
| 0.00 | 3# | 648.35 | 9.56 | 653.25 | 9.49 | 34.54 | 11.26 | 39.54 | 7.51 |
| 0.00 | 4# | 651.09 | 9.55 | 655.33 | 9.57 | 34.52 | 11.00 | 39.58 | 7.51 |
| 1.00 | 1# | 642.95 | 9.45 | 648.73 | 9.46 | 37.72 | 32.08 | 38.62 | 7.78 |
| 1.00 | 2# | 644.01 | 9.50 | 648.80 | 9.69 | 37.94 | 32.16 | 38.74 | 7.76 |
| 1.00 | 3# | 647.83 | 10.21 | 655.60 | 10.41 | 33.09 | 11.90 | 39.91 | 8.24 |
| 1.00 | 4# | 649.94 | 9.55 | 657.34 | 10.05 | 33.09 | 11.90 | 39.97 | 8.26 |
| 2.00 | 1# | 635.49 | 10.46 | 640.07 | 9.93 | 32.38 | 14.74 | 37.59 | 7.89 |
| 2.00 | 2# | 635.75 | 10.47 | 640.80 | 10.06 | 32.06 | 14.36 | 37.71 | 7.92 |
| 2.00 | 3# | 648.62 | 11.56 | 658.31 | 11.58 | 33.59 | 12.26 | 40.04 | 9.10 |
| 2.00 | 4# | 649.63 | 11.63 | 657.99 | 11.58 | 33.13 | 12.34 | 40.11 | 9.13 |
| 3.00 | 1# | 627.57 | 9.37 | 631.98 | 9.46 | 28.59 | 15.73 | 36.45 | 7.80 |
| 3.00 | 2# | 627.89 | 9.50 | 632.16 | 9.32 | 26.20 | 15.56 | 36.54 | 7.84 |
| 3.00 | 3# | 648.06 | 12.23 | 659.32 | 12.13 | 33.41 | 12.46 | 40.02 | 10.01 |
| 3.00 | 4# | 648.37 | 12.10 | 659.27 | 12.08 | 33.14 | 12.34 | 40.10 | 10.00 |
| 4.00 | 1# | 621.80 | 9.45 | 624.68 | 9.46 | 26.90 | 16.24 | 35.35 | 7.72 |
| 4.00 | 2# | 621.97 | 9.50 | 624.75 | 9.32 | 23.95 | 16.16 | 35.41 | 7.76 |
| 4.00 | 3# | 646.27 | 12.86 | 659.15 | 12.73 | 30.47 | 34.08 | 39.91 | 10.85 |
| 4.00 | 4# | 646.46 | 12.92 | 659.27 | 12.76 | 30.71 | 13.25 | 40.01 | 10.84 |
| 5.00 | 1# | 613.06 | 9.83 | 615.75 | 9.46 | 26.34 | 16.77 | 34.39 | 7.33 |
| 5.00 | 2# | 613.38 | 10.08 | 615.96 | 9.69 | 23.04 | 16.84 | 34.43 | 7.37 |
| 5.00 | 3# | 640.11 | 13.31 | 656.61 | 13.30 | 26.63 | 13.16 | 39.66 | 11.53 |
| 5.00 | 4# | 641.31 | 13.51 | 656.00 | 13.44 | 26.37 | 13.25 | 39.79 | 11.54 |
| 6.00 | 1# | 608.50 | 8.88 | 612.16 | 8.26 | 26.47 | 18.35 | 34.02 | 6.74 |
| 6.00 | 2# | 608.63 | 8.77 | 614.58 | 17.93 | 21.67 | 17.72 | 34.01 | 6.76 |
| 6.00 | 3# | 631.57 | 13.97 | 650.35 | 13.85 | 23.30 | 13.62 | 39.09 | 12.16 |
| 6.00 | 4# | 632.58 | 13.99 | 650.05 | 13.96 | 23.07 | 13.78 | 39.24 | 12.22 |
| 7.00 | 1# | 611.70 | 8.76 | 615.62 | 8.86 | 23.66 | 19.09 | 34.00 | 6.72 |
| 7.00 | 2# | 611.83 | 8.77 | 615.30 | 8.82 | 21.39 | 18.72 | 34.00 | 6.73 |
| 7.00 | 3# | 620.03 | 14.55 | 641.10 | 14.38 | 21.94 | 14.47 | 38.37 | 12.80 |
| 7.00 | 4# | 622.66 | 14.70 | 641.04 | 14.58 | 21.23 | 14.44 | 38.55 | 12.85 |
| 8.00 | 1# | 613.27 | 9.46 | 617.85 | 8.86 | 21.77 | 19.61 | 34.00 | 6.72 |
| 8.00 | 2# | 613.28 | 9.49 | 617.72 | 8.82 | 19.58 | 19.32 | 34.00 | 6.73 |
| 8.00 | 3# | 614.86 | 9.41 | 629.58 | 15.03 | 24.92 | 33.50 | 36.95 | 13.38 |
| 8.00 | 4# | 616.94 | 9.55 | 630.27 | 15.07 | 23.52 | 14.74 | 37.16 | 13.46 |
| 9.00 | 1# | 610.03 | 17.33 | 616.86 | 8.86 | 22.13 | 19.80 | 34.00 | 6.72 |
| 9.00 | 2# | 609.88 | 9.49 | 616.79 | 9.32 | 19.37 | 19.98 | 34.00 | 6.73 |
| 9.00 | 3# | 611.54 | 10.30 | 618.15 | 10.32 | 27.21 | 34.38 | 34.68 | 14.08 |
| 9.00 | 4# | 611.71 | 10.05 | 618.30 | 10.05 | 24.01 | 38.24 | 34.94 | 14.15 |
| 10.00 | 1# | 609.27 | 9.45 | 617.20 | 9.33 | 30.43 | 30.97 | 34.00 | 6.72 |
| 10.00 | 2# | 608.67 | 9.49 | 617.04 | 9.32 | 28.61 | 31.14 | 34.00 | 6.73 |
| 10.00 | 3# | 595.09 | 10.59 | 601.48 | 26.41 | 23.47 | 26.52 | 32.08 | 14.98 |
| 10.00 | 4# | 595.28 | 10.59 | 601.99 | 10.96 | 26.38 | 27.33 | 32.39 | 15.03 |
| 11.00 | 1# | 612.00 | 24.22 | 620.30 | 24.06 | 32.04 | 23.57 | 34.00 | 6.72 |
| 11.00 | 2# | 609.83 | 24.09 | 618.74 | 24.06 | 31.72 | 30.90 | 34.00 | 6.73 |
| 11.00 | 3# | 605.42 | 27.93 | 620.12 | 27.91 | 23.91 | 27.50 | 30.61 | 26.29 |
| 11.00 | 4# | 606.33 | 28.16 | 618.88 | 28.18 | 26.11 | 27.63 | 30.53 | 26.52 |
| 12.00 | 1# | 625.29 | 25.18 | 633.09 | 25.18 | 33.77 | 31.50 | 34.00 | 6.72 |
| 12.00 | 2# | 625.11 | 25.16 | 633.34 | 25.10 | 32.79 | 31.43 | 34.00 | 6.73 |
| 12.00 | 3# | 602.65 | 25.21 | 615.61 | 28.58 | 26.40 | 28.23 | 32.00 | 22.26 |
| 12.00 | 4# | 603.02 | 25.32 | 615.20 | 28.71 | 26.76 | 28.52 | 31.85 | 22.01 |
| JDT6 | 0.00 | 1# | 647.99 | 9.45 | 653.66 | 9.46 | 34.54 | 11.09 | 39.33 | 7.49 |
| 0.00 | 2# | 648.76 | 9.50 | 652.97 | 9.56 | 34.12 | 11.17 | 39.44 | 7.51 |
| 0.00 | 3# | 648.35 | 9.56 | 653.25 | 9.49 | 34.54 | 11.26 | 39.54 | 7.51 |
| 0.00 | 4# | 651.09 | 9.55 | 655.33 | 9.57 | 34.52 | 11.00 | 39.58 | 7.51 |
| 1.00 | 1# | 645.29 | 9.45 | 651.05 | 9.46 | 38.07 | 11.09 | 38.95 | 7.61 |
| 1.00 | 2# | 646.10 | 9.50 | 650.80 | 9.56 | 37.58 | 11.17 | 39.06 | 7.57 |
| 1.00 | 3# | 646.11 | 9.41 | 651.12 | 9.58 | 37.61 | 11.90 | 39.17 | 7.62 |
| 1.00 | 4# | 651.51 | 9.55 | 658.30 | 10.05 | 31.97 | 11.52 | 40.23 | 8.14 |
| 2.00 | 1# | 639.52 | 9.54 | 645.80 | 9.46 | 37.49 | 32.17 | 38.42 | 7.58 |
| 2.00 | 2# | 640.51 | 9.50 | 645.80 | 9.69 | 37.60 | 32.24 | 38.53 | 7.63 |
| 2.00 | 3# | 640.65 | 9.56 | 646.19 | 9.43 | 37.04 | 32.22 | 38.63 | 7.66 |
| 2.00 | 4# | 650.24 | 11.63 | 661.65 | 11.58 | 28.53 | 11.90 | 40.67 | 8.96 |
| 3.00 | 1# | 636.37 | 9.37 | 641.84 | 9.46 | 36.10 | 14.53 | 37.86 | 7.59 |
| 3.00 | 2# | 637.22 | 9.50 | 642.08 | 9.32 | 35.59 | 14.36 | 37.95 | 7.61 |
| 3.00 | 3# | 637.54 | 9.41 | 642.35 | 9.30 | 34.45 | 14.47 | 38.04 | 7.60 |
| 3.00 | 4# | 651.52 | 12.02 | 666.65 | 12.08 | 25.62 | 12.34 | 41.09 | 9.92 |
| 4.00 | 1# | 633.88 | 9.37 | 638.75 | 9.46 | 36.08 | 30.19 | 37.36 | 7.55 |
| 4.00 | 2# | 634.57 | 9.50 | 638.80 | 9.30 | 35.36 | 30.14 | 37.44 | 7.55 |
| 4.00 | 3# | 635.05 | 9.41 | 638.97 | 9.30 | 32.91 | 15.09 | 37.51 | 7.59 |
| 4.00 | 4# | 650.21 | 12.63 | 667.27 | 12.68 | 21.62 | 12.41 | 41.48 | 10.77 |
| 5.00 | 1# | 630.54 | 9.54 | 635.53 | 9.46 | 35.64 | 19.17 | 36.93 | 7.43 |
| 5.00 | 2# | 630.98 | 9.58 | 635.35 | 9.56 | 26.40 | 23.04 | 37.00 | 7.44 |
| 5.00 | 3# | 630.70 | 9.56 | 634.87 | 9.30 | 33.80 | 15.74 | 37.06 | 7.48 |
| 5.00 | 4# | 647.09 | 12.92 | 665.51 | 13.05 | 17.01 | 13.25 | 41.66 | 11.41 |
| 6.00 | 1# | 627.01 | 8.88 | 632.45 | 8.86 | 30.25 | 20.29 | 36.69 | 7.22 |
| 6.00 | 2# | 627.05 | 9.24 | 632.60 | 9.30 | 23.37 | 27.68 | 36.75 | 7.24 |
| 6.00 | 3# | 627.66 | 8.77 | 632.74 | 8.82 | 30.87 | 30.76 | 36.78 | 7.25 |
| 6.00 | 4# | 636.78 | 13.73 | 660.34 | 13.58 | 11.22 | 13.78 | 41.50 | 12.11 |
| 7.00 | 1# | 628.01 | 8.88 | 633.43 | 8.86 | 27.51 | 32.14 | 36.66 | 7.13 |
| 7.00 | 2# | 628.23 | 9.50 | 633.17 | 9.30 | 32.24 | 31.99 | 36.71 | 7.12 |
| 7.00 | 3# | 628.22 | 8.77 | 633.03 | 8.68 | 35.11 | 35.30 | 36.73 | 7.15 |
| 7.00 | 4# | 628.23 | 10.59 | 649.63 | 14.23 | 5.94 | 14.27 | 40.87 | 12.84 |
| 8.00 | 1# | 630.48 | 9.37 | 635.53 | 9.46 | 34.83 | 31.88 | 36.66 | 7.13 |
| 8.00 | 2# | 631.05 | 9.50 | 635.73 | 9.30 | 34.51 | 31.68 | 36.71 | 7.12 |
| 8.00 | 3# | 630.87 | 9.41 | 635.27 | 9.30 | 35.67 | 33.59 | 36.73 | 7.15 |
| 8.00 | 4# | 632.79 | 9.55 | 639.08 | 14.78 | 2.12 | 14.74 | 39.75 | 13.50 |
| 9.00 | 1# | 629.17 | 9.54 | 635.29 | 9.46 | 30.31 | 32.45 | 36.66 | 7.13 |
| 9.00 | 2# | 629.75 | 9.50 | 635.11 | 9.56 | 31.25 | 32.56 | 36.71 | 7.12 |
| 9.00 | 3# | 629.39 | 9.56 | 634.82 | 9.30 | 32.63 | 32.33 | 36.73 | 7.15 |
| 9.00 | 4# | 630.20 | 10.05 | 637.62 | 10.05 | 5.55 | 15.34 | 37.97 | 14.12 |
| 10.00 | 1# | 628.34 | 9.54 | 635.24 | 9.46 | 31.22 | 32.94 | 36.66 | 7.13 |
| 10.00 | 2# | 628.95 | 9.50 | 635.12 | 9.30 | 30.02 | 32.85 | 36.71 | 7.12 |
| 10.00 | 3# | 628.46 | 9.41 | 634.82 | 9.30 | 34.14 | 32.71 | 36.73 | 7.15 |
| 10.00 | 4# | 623.31 | 30.43 | 632.50 | 30.34 | 8.32 | 16.16 | 35.31 | 14.83 |
| 11.00 | 1# | 628.34 | 9.54 | 635.24 | 9.46 | 33.31 | 33.26 | 36.66 | 7.13 |
| 11.00 | 2# | 628.95 | 9.50 | 635.12 | 9.30 | 30.52 | 32.85 | 36.71 | 7.12 |
| 11.00 | 3# | 628.46 | 9.41 | 634.82 | 9.30 | 30.85 | 32.71 | 36.73 | 7.15 |
| 11.00 | 4# | 617.61 | 30.21 | 629.31 | 30.11 | 13.09 | 17.06 | 32.35 | 15.73 |
| 12.00 | 1# | 628.34 | 9.54 | 635.24 | 9.46 | 36.19 | 33.23 | 36.66 | 7.13 |
| 12.00 | 2# | 628.95 | 9.50 | 635.12 | 9.30 | 32.16 | 33.15 | 36.71 | 7.12 |
| 12.00 | 3# | 628.46 | 9.41 | 634.82 | 9.30 | 28.79 | 32.97 | 36.73 | 7.15 |
| 12.00 | 4# | 614.85 | 9.55 | 619.01 | 30.04 | 15.55 | 29.87 | 30.79 | 28.41 |
| JDT10 | 0.00 | 1# | 647.99 | 9.45 | 653.66 | 9.46 | 34.54 | 11.09 | 39.33 | 7.49 |
| 0.00 | 2# | 648.76 | 9.50 | 652.97 | 9.56 | 34.12 | 11.17 | 39.44 | 7.51 |
| 0.00 | 3# | 648.35 | 9.56 | 653.25 | 9.49 | 34.54 | 11.26 | 39.54 | 7.51 |
| 0.00 | 4# | 651.09 | 9.55 | 655.33 | 9.57 | 34.52 | 11.00 | 39.58 | 7.51 |
| 1.00 | 1# | 641.61 | 9.83 | 646.95 | 9.46 | 33.43 | 14.53 | 38.35 | 7.97 |
| 1.00 | 2# | 647.23 | 10.08 | 653.42 | 10.06 | 34.71 | 11.81 | 39.59 | 8.35 |
| 1.00 | 3# | 647.80 | 10.50 | 654.78 | 10.41 | 33.86 | 11.90 | 39.70 | 8.35 |
| 1.00 | 4# | 649.11 | 10.15 | 656.37 | 10.05 | 34.11 | 11.90 | 39.76 | 8.38 |
| 2.00 | 1# | 634.42 | 10.46 | 637.61 | 10.36 | 23.93 | 15.73 | 37.03 | 8.52 |
| 2.00 | 2# | 647.88 | 11.52 | 654.42 | 11.42 | 35.28 | 12.88 | 39.52 | 9.26 |
| 2.00 | 3# | 648.43 | 11.56 | 655.73 | 11.58 | 35.58 | 12.62 | 39.65 | 9.28 |
| 2.00 | 4# | 649.01 | 11.63 | 655.73 | 11.58 | 35.18 | 12.88 | 39.71 | 9.28 |
| 3.00 | 1# | 625.64 | 12.03 | 628.37 | 16.12 | 15.70 | 16.24 | 35.43 | 8.95 |
| 3.00 | 2# | 646.23 | 12.67 | 653.25 | 12.02 | 36.91 | 13.25 | 39.29 | 10.14 |
| 3.00 | 3# | 645.87 | 12.13 | 653.58 | 12.13 | 36.64 | 13.62 | 39.43 | 10.18 |
| 3.00 | 4# | 647.12 | 12.23 | 654.44 | 12.08 | 36.37 | 13.55 | 39.50 | 10.19 |
| 4.00 | 1# | 623.17 | 13.67 | 641.87 | 16.80 | 15.34 | 16.77 | 33.99 | 15.23 |
| 4.00 | 2# | 642.95 | 13.41 | 650.13 | 13.45 | 38.54 | 34.13 | 38.92 | 11.04 |
| 4.00 | 3# | 643.55 | 13.43 | 650.88 | 12.95 | 38.26 | 34.16 | 39.07 | 11.05 |
| 4.00 | 4# | 643.83 | 13.52 | 652.23 | 12.76 | 37.80 | 14.44 | 39.16 | 11.07 |
| 5.00 | 1# | 628.35 | 17.39 | 650.23 | 17.47 | 15.63 | 17.59 | 34.46 | 16.04 |
| 5.00 | 2# | 638.77 | 13.84 | 645.42 | 13.94 | 36.84 | 35.33 | 38.36 | 11.83 |
| 5.00 | 3# | 639.48 | 13.86 | 646.53 | 13.85 | 39.19 | 12.62 | 38.54 | 11.85 |
| 5.00 | 4# | 640.10 | 14.18 | 647.68 | 14.11 | 38.30 | 34.87 | 38.66 | 11.87 |
| 6.00 | 1# | 632.45 | 18.00 | 653.54 | 18.16 | 17.68 | 18.20 | 34.12 | 16.68 |
| 6.00 | 2# | 630.68 | 14.80 | 636.05 | 14.78 | 34.77 | 35.85 | 37.53 | 12.49 |
| 6.00 | 3# | 632.03 | 14.83 | 637.59 | 14.43 | 36.68 | 35.58 | 37.75 | 12.53 |
| 6.00 | 4# | 633.77 | 14.70 | 639.82 | 14.78 | 37.19 | 9.74 | 37.90 | 12.58 |
| 7.00 | 1# | 629.58 | 18.94 | 649.90 | 19.05 | 19.91 | 19.09 | 32.96 | 17.54 |
| 7.00 | 2# | 619.97 | 15.36 | 625.00 | 14.94 | 34.53 | 36.75 | 36.59 | 12.99 |
| 7.00 | 3# | 622.22 | 15.49 | 627.34 | 15.41 | 36.44 | 10.65 | 36.86 | 13.08 |
| 7.00 | 4# | 622.88 | 15.25 | 628.72 | 15.30 | 35.55 | 10.78 | 37.04 | 13.11 |
| 8.00 | 1# | 620.49 | 20.10 | 638.68 | 20.17 | 21.82 | 20.27 | 31.36 | 6.19 |
| 8.00 | 2# | 606.75 | 38.85 | 611.62 | 38.73 | 30.32 | 37.63 | 34.90 | 14.08 |
| 8.00 | 3# | 608.31 | 17.33 | 612.89 | 17.21 | 33.80 | 34.32 | 35.20 | 14.16 |
| 8.00 | 4# | 610.95 | 17.47 | 615.77 | 17.27 | 30.59 | 37.87 | 35.43 | 14.21 |
| 9.00 | 1# | 623.94 | 21.35 | 638.43 | 21.22 | 27.50 | 21.39 | 31.36 | 6.19 |
| 9.00 | 2# | 608.54 | 18.73 | 611.16 | 18.82 | 34.10 | 24.16 | 34.40 | 16.68 |
| 9.00 | 3# | 609.12 | 18.75 | 612.06 | 18.56 | 35.49 | 38.56 | 34.54 | 16.54 |
| 9.00 | 4# | 610.09 | 18.65 | 613.98 | 18.76 | 35.78 | 27.62 | 34.66 | 16.49 |
| 10.00 | 1# | 631.54 | 22.50 | 643.42 | 22.63 | 26.24 | 31.88 | 31.36 | 6.19 |
| 10.00 | 2# | 613.02 | 19.46 | 616.42 | 19.42 | 36.08 | 25.31 | 34.97 | 18.09 |
| 10.00 | 3# | 613.58 | 19.54 | 616.91 | 19.53 | 37.17 | 25.39 | 35.04 | 18.01 |
| 10.00 | 4# | 614.35 | 19.63 | 618.38 | 19.65 | 37.21 | 25.06 | 35.07 | 17.96 |
| 11.00 | 1# | 640.04 | 23.36 | 651.16 | 23.31 | 28.19 | 32.56 | 31.36 | 6.19 |
| 11.00 | 2# | 619.71 | 22.93 | 622.26 | 22.57 | 35.36 | 25.83 | 35.80 | 19.16 |
| 11.00 | 3# | 619.87 | 23.09 | 623.31 | 22.67 | 35.48 | 25.70 | 35.86 | 19.16 |
| 11.00 | 4# | 620.27 | 22.79 | 624.65 | 22.64 | 35.09 | 25.97 | 35.89 | 19.11 |
| 12.00 | 1# | 646.46 | 24.08 | 657.65 | 24.06 | 31.43 | 24.17 | 31.36 | 6.19 |
| 12.00 | 2# | 626.12 | 23.57 | 629.94 | 23.30 | 36.15 | 26.35 | 36.65 | 20.12 |
| 12.00 | 3# | 627.25 | 23.83 | 630.97 | 23.28 | 35.73 | 26.38 | 36.73 | 20.13 |
| 12.00 | 4# | 628.25 | 23.81 | 632.64 | 23.31 | 35.25 | 26.49 | 36.78 | 20.09 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.39 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.40 JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.41 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.42 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.43 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.44 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.45 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.46 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.4.2 20s-(70%)-80s两段关闭规律计算结果**

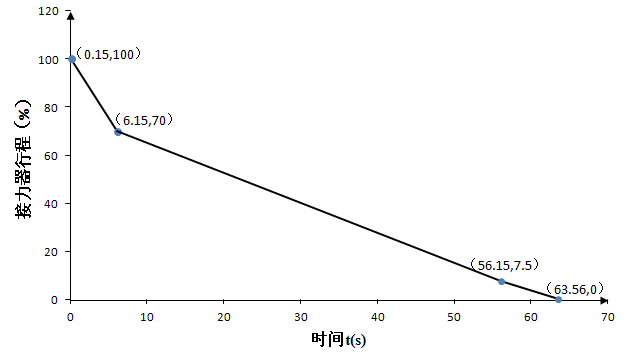


图6.47 水轮机工况导叶20s-(70%)-80s两段关闭规律

**表6-18 20s-(70%)-80s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 663.00 | 9.54 | 669.74 | 9.46 | 48.81 | 11.09 | 41.24 | 7.26 |
| 0.00 | 2# | 664.07 | 9.50 | 669.57 | 9.32 | 48.43 | 11.17 | 41.38 | 7.27 |
| 0.00 | 3# | 663.98 | 9.41 | 670.22 | 9.30 | 47.93 | 11.35 | 41.51 | 7.28 |
| 0.00 | 4# | 666.41 | 9.55 | 672.48 | 8.86 | 48.27 | 11.00 | 41.58 | 7.27 |
| SJT3 | 0.00 | 1# | 646.67 | 9.45 | 652.17 | 9.46 | 37.05 | 11.09 | 39.37 | 7.52 |
| 0.00 | 2# | 647.54 | 9.50 | 651.54 | 9.56 | 36.65 | 11.17 | 39.48 | 7.53 |
| 0.00 | 3# | 647.16 | 9.56 | 651.81 | 9.49 | 36.98 | 11.26 | 39.58 | 7.49 |
| 0.00 | 4# | 650.02 | 9.55 | 654.04 | 9.57 | 37.03 | 11.00 | 39.62 | 7.55 |
| ZT2 | 76.76 | 1# | 661.64 | 86.27 | 667.14 | 85.94 | 48.33 | 88.05 | 41.76 | 84.08 |
| 76.76 | 2# | 662.63 | 86.21 | 668.19 | 85.87 | 48.36 | 88.14 | 41.90 | 84.07 |
| 76.76 | 3# | 663.38 | 86.24 | 669.33 | 86.03 | 48.07 | 88.05 | 42.03 | 84.08 |
| 76.76 | 4# | 664.21 | 86.12 | 670.58 | 86.02 | 48.69 | 88.09 | 42.08 | 84.07 |
| JHT3 | 0.00 | 1# | 663.00 | 9.54 | 669.74 | 9.46 | 48.81 | 11.09 | 41.24 | 7.26 |
| 0.00 | 2# | 664.07 | 9.50 | 669.57 | 9.32 | 48.43 | 11.17 | 41.38 | 7.27 |
| 0.00 | 3# | 663.98 | 9.41 | 670.22 | 9.30 | 47.93 | 11.35 | 41.51 | 7.28 |
| 0.00 | 4# | 666.41 | 9.55 | 672.48 | 8.86 | 48.27 | 11.00 | 41.58 | 7.27 |
| 1.00 | 1# | 661.13 | 9.54 | 667.21 | 9.46 | 45.61 | 11.23 | 41.04 | 7.37 |
| 1.00 | 2# | 662.44 | 9.50 | 666.77 | 9.32 | 44.12 | 11.28 | 41.19 | 7.37 |
| 1.00 | 3# | 662.34 | 9.41 | 667.36 | 9.43 | 42.83 | 11.35 | 41.33 | 7.39 |
| 1.00 | 4# | 673.99 | 9.55 | 684.67 | 8.86 | 47.92 | 7.93 | 43.31 | 7.21 |
| 2.00 | 1# | 659.73 | 9.54 | 664.45 | 9.46 | 41.57 | 11.09 | 40.71 | 7.47 |
| 2.00 | 2# | 660.80 | 9.50 | 664.37 | 9.32 | 40.02 | 11.28 | 40.86 | 7.47 |
| 2.00 | 3# | 661.61 | 9.41 | 665.29 | 9.30 | 38.54 | 11.26 | 41.01 | 7.50 |
| 2.00 | 4# | 681.98 | 9.07 | 698.75 | 8.96 | 42.36 | 34.05 | 45.27 | 7.24 |
| 3.00 | 1# | 657.59 | 9.54 | 661.51 | 9.46 | 40.58 | 11.61 | 40.24 | 7.50 |
| 3.00 | 2# | 658.89 | 9.50 | 661.23 | 9.32 | 39.46 | 11.81 | 40.39 | 7.51 |
| 3.00 | 3# | 659.53 | 9.41 | 661.99 | 9.30 | 37.28 | 11.35 | 40.54 | 7.53 |
| 3.00 | 4# | 689.09 | 9.18 | 708.43 | 9.04 | 37.58 | 8.83 | 46.99 | 7.37 |
| 4.00 | 1# | 654.94 | 9.54 | 658.30 | 9.46 | 40.97 | 11.89 | 39.81 | 7.43 |
| 4.00 | 2# | 656.41 | 9.50 | 658.10 | 9.32 | 38.64 | 11.81 | 39.96 | 7.47 |
| 4.00 | 3# | 656.66 | 9.41 | 658.72 | 9.43 | 37.31 | 11.90 | 40.09 | 7.49 |
| 4.00 | 4# | 694.44 | 9.55 | 715.33 | 9.40 | 35.54 | 9.14 | 48.29 | 7.53 |
| 5.00 | 1# | 652.07 | 9.45 | 655.72 | 9.46 | 42.86 | 11.89 | 39.55 | 7.30 |
| 5.00 | 2# | 653.58 | 9.50 | 655.67 | 9.32 | 40.74 | 11.81 | 39.67 | 7.31 |
| 5.00 | 3# | 653.90 | 9.41 | 656.26 | 9.30 | 38.84 | 11.90 | 39.78 | 7.36 |
| 5.00 | 4# | 691.62 | 9.55 | 710.08 | 9.70 | 35.13 | 9.89 | 49.14 | 7.74 |
| 6.00 | 1# | 650.95 | 9.54 | 655.50 | 9.46 | 46.36 | 12.29 | 39.46 | 7.19 |
| 6.00 | 2# | 652.21 | 9.50 | 655.11 | 9.32 | 45.45 | 12.36 | 39.58 | 7.22 |
| 6.00 | 3# | 652.09 | 9.41 | 655.41 | 9.30 | 43.90 | 12.26 | 39.67 | 7.23 |
| 6.00 | 4# | 683.54 | 9.55 | 700.67 | 10.05 | 34.51 | 10.26 | 49.36 | 7.96 |
| 7.00 | 1# | 650.97 | 9.54 | 656.58 | 9.46 | 51.70 | 12.29 | 39.45 | 7.21 |
| 7.00 | 2# | 652.35 | 9.50 | 656.12 | 9.32 | 50.22 | 12.36 | 39.58 | 7.18 |
| 7.00 | 3# | 651.86 | 9.41 | 656.29 | 9.30 | 49.01 | 12.62 | 39.66 | 7.22 |
| 7.00 | 4# | 672.72 | 10.16 | 689.93 | 10.05 | 32.32 | 11.00 | 49.41 | 8.07 |
| 8.00 | 1# | 650.08 | 9.54 | 656.59 | 9.46 | 55.39 | 8.53 | 39.45 | 7.21 |
| 8.00 | 2# | 651.30 | 9.50 | 656.29 | 9.32 | 55.25 | 8.53 | 39.58 | 7.18 |
| 8.00 | 3# | 651.02 | 9.41 | 656.35 | 9.30 | 54.93 | 3.90 | 39.66 | 7.22 |
| 8.00 | 4# | 660.09 | 9.55 | 674.36 | 10.82 | 33.85 | 11.75 | 49.37 | 7.99 |
| 9.00 | 1# | 649.45 | 9.54 | 656.40 | 9.46 | 54.59 | 11.09 | 39.45 | 7.21 |
| 9.00 | 2# | 650.68 | 9.50 | 656.13 | 9.32 | 54.42 | 11.17 | 39.58 | 7.18 |
| 9.00 | 3# | 650.33 | 9.41 | 656.27 | 9.30 | 53.90 | 11.35 | 39.66 | 7.22 |
| 9.00 | 4# | 653.84 | 9.55 | 659.23 | 10.05 | 36.03 | 12.34 | 49.37 | 7.99 |
| 10.00 | 1# | 649.38 | 9.54 | 656.42 | 9.46 | 53.63 | 11.09 | 39.45 | 7.21 |
| 10.00 | 2# | 650.62 | 9.50 | 656.13 | 9.32 | 53.57 | 11.17 | 39.58 | 7.18 |
| 10.00 | 3# | 650.31 | 9.41 | 656.27 | 9.30 | 53.29 | 11.35 | 39.66 | 7.22 |
| 10.00 | 4# | 652.24 | 9.55 | 656.97 | 9.40 | 38.42 | 12.34 | 49.37 | 7.99 |
| 11.00 | 1# | 649.38 | 9.54 | 656.42 | 9.46 | 53.27 | 11.09 | 39.45 | 7.21 |
| 11.00 | 2# | 650.62 | 9.50 | 656.13 | 9.32 | 53.05 | 11.17 | 39.58 | 7.18 |
| 11.00 | 3# | 650.31 | 9.41 | 656.27 | 9.30 | 52.51 | 11.35 | 39.66 | 7.22 |
| 11.00 | 4# | 652.24 | 9.55 | 656.97 | 9.40 | 41.99 | 12.64 | 49.37 | 7.99 |
| 12.00 | 1# | 649.38 | 9.54 | 656.42 | 9.46 | 53.27 | 11.09 | 39.45 | 7.21 |
| 12.00 | 2# | 650.62 | 9.50 | 656.13 | 9.32 | 53.05 | 11.17 | 39.58 | 7.18 |
| 12.00 | 3# | 650.31 | 9.41 | 656.27 | 9.30 | 52.51 | 11.35 | 39.66 | 7.22 |
| 12.00 | 4# | 652.24 | 9.55 | 656.97 | 9.40 | 44.44 | 11.90 | 49.37 | 7.99 |
| JHT13 | 0.00 | 1# | 645.13 | 9.45 | 650.63 | 9.46 | 35.51 | 11.09 | 39.37 | 7.52 |
| 0.00 | 2# | 646.00 | 9.50 | 650.00 | 9.56 | 35.11 | 11.17 | 39.48 | 7.53 |
| 0.00 | 3# | 645.62 | 9.56 | 650.27 | 9.49 | 35.44 | 11.26 | 39.58 | 7.49 |
| 0.00 | 4# | 648.48 | 9.55 | 652.50 | 9.57 | 35.49 | 11.00 | 39.62 | 7.55 |
| 1.00 | 1# | 639.92 | 9.45 | 645.57 | 9.46 | 36.44 | 33.23 | 38.69 | 7.81 |
| 1.00 | 2# | 641.01 | 9.79 | 645.93 | 9.69 | 36.57 | 33.23 | 38.81 | 7.80 |
| 1.00 | 3# | 644.50 | 10.21 | 651.67 | 10.41 | 33.91 | 11.90 | 39.91 | 8.27 |
| 1.00 | 4# | 646.27 | 9.55 | 653.60 | 10.05 | 33.91 | 11.90 | 39.98 | 8.28 |
| 2.00 | 1# | 632.62 | 10.46 | 637.02 | 9.93 | 34.66 | 15.34 | 37.69 | 7.96 |
| 2.00 | 2# | 632.74 | 10.47 | 637.50 | 10.06 | 33.64 | 15.27 | 37.80 | 7.97 |
| 2.00 | 3# | 644.43 | 11.56 | 653.64 | 11.58 | 34.80 | 12.26 | 40.01 | 9.09 |
| 2.00 | 4# | 645.61 | 11.63 | 653.71 | 11.58 | 34.10 | 12.34 | 40.09 | 9.13 |
| 3.00 | 1# | 625.38 | 9.37 | 629.59 | 9.46 | 30.74 | 15.73 | 36.56 | 7.85 |
| 3.00 | 2# | 625.74 | 9.50 | 629.87 | 9.32 | 27.98 | 15.80 | 36.65 | 7.88 |
| 3.00 | 3# | 643.63 | 12.23 | 654.66 | 12.13 | 34.28 | 12.26 | 39.96 | 10.01 |
| 3.00 | 4# | 643.84 | 12.23 | 654.48 | 12.08 | 33.75 | 12.34 | 40.05 | 10.00 |
| 4.00 | 1# | 619.54 | 9.45 | 622.28 | 9.46 | 28.11 | 16.34 | 35.48 | 7.76 |
| 4.00 | 2# | 619.94 | 9.58 | 622.39 | 9.32 | 26.19 | 16.47 | 35.54 | 7.79 |
| 4.00 | 3# | 641.74 | 12.88 | 654.56 | 12.95 | 28.70 | 34.16 | 39.84 | 10.84 |
| 4.00 | 4# | 641.91 | 12.92 | 654.75 | 12.76 | 31.55 | 13.25 | 39.94 | 10.85 |
| 5.00 | 1# | 610.62 | 9.83 | 612.98 | 9.93 | 27.46 | 16.94 | 34.48 | 7.47 |
| 5.00 | 2# | 611.04 | 10.08 | 613.32 | 9.77 | 24.62 | 16.84 | 34.52 | 7.52 |
| 5.00 | 3# | 636.75 | 13.43 | 652.60 | 13.48 | 26.44 | 34.87 | 39.53 | 11.55 |
| 5.00 | 4# | 638.18 | 13.52 | 652.13 | 13.58 | 26.81 | 34.87 | 39.65 | 11.60 |
| 6.00 | 1# | 606.02 | 8.88 | 609.56 | 18.45 | 26.61 | 18.62 | 34.09 | 6.81 |
| 6.00 | 2# | 605.77 | 8.77 | 612.29 | 18.06 | 22.65 | 17.88 | 34.09 | 6.82 |
| 6.00 | 3# | 629.91 | 13.97 | 647.11 | 13.93 | 24.93 | 13.62 | 39.04 | 12.18 |
| 6.00 | 4# | 630.99 | 14.10 | 647.58 | 14.04 | 24.41 | 13.78 | 39.18 | 12.25 |
| 7.00 | 1# | 608.63 | 8.88 | 612.42 | 8.86 | 24.40 | 19.09 | 34.07 | 6.74 |
| 7.00 | 2# | 608.71 | 8.77 | 612.04 | 8.82 | 21.61 | 19.08 | 34.07 | 6.73 |
| 7.00 | 3# | 618.00 | 14.56 | 637.22 | 14.43 | 22.82 | 14.47 | 38.25 | 12.87 |
| 7.00 | 4# | 620.92 | 14.70 | 637.83 | 14.58 | 22.68 | 14.44 | 38.43 | 12.92 |
| 8.00 | 1# | 610.26 | 9.46 | 614.24 | 8.86 | 22.15 | 19.61 | 34.07 | 6.74 |
| 8.00 | 2# | 610.27 | 9.49 | 613.95 | 8.82 | 19.73 | 19.62 | 34.07 | 6.73 |
| 8.00 | 3# | 612.18 | 9.41 | 626.37 | 15.21 | 26.18 | 36.78 | 36.79 | 13.44 |
| 8.00 | 4# | 614.23 | 9.55 | 627.11 | 15.30 | 21.79 | 37.27 | 37.01 | 13.52 |
| 9.00 | 1# | 607.80 | 17.33 | 614.27 | 20.54 | 23.34 | 19.80 | 34.07 | 6.74 |
| 9.00 | 2# | 607.35 | 17.36 | 613.23 | 9.30 | 20.51 | 20.27 | 34.07 | 6.73 |
| 9.00 | 3# | 609.54 | 10.30 | 616.03 | 10.32 | 27.11 | 26.24 | 34.81 | 14.13 |
| 9.00 | 4# | 609.49 | 10.35 | 615.79 | 10.05 | 21.73 | 38.24 | 35.06 | 14.18 |
| 10.00 | 1# | 605.88 | 9.45 | 613.60 | 9.46 | 29.50 | 30.97 | 34.07 | 6.74 |
| 10.00 | 2# | 605.58 | 9.49 | 613.42 | 9.30 | 27.57 | 31.43 | 34.07 | 6.73 |
| 10.00 | 3# | 594.21 | 10.73 | 600.41 | 10.87 | 22.77 | 26.59 | 32.30 | 14.96 |
| 10.00 | 4# | 594.12 | 10.74 | 601.73 | 10.96 | 27.41 | 27.63 | 32.60 | 15.04 |
| 11.00 | 1# | 606.60 | 24.51 | 613.60 | 9.46 | 28.62 | 34.06 | 34.07 | 6.74 |
| 11.00 | 2# | 605.58 | 9.49 | 613.42 | 9.30 | 29.83 | 33.89 | 34.07 | 6.73 |
| 11.00 | 3# | 602.99 | 28.46 | 616.93 | 28.30 | 27.98 | 27.50 | 31.05 | 26.57 |
| 11.00 | 4# | 601.89 | 28.56 | 614.52 | 28.68 | 28.48 | 28.88 | 31.07 | 26.78 |
| 12.00 | 1# | 616.69 | 25.48 | 622.43 | 25.61 | 31.18 | 35.25 | 34.07 | 6.74 |
| 12.00 | 2# | 616.96 | 25.45 | 622.67 | 25.57 | 30.87 | 34.95 | 34.07 | 6.73 |
| 12.00 | 3# | 598.99 | 25.21 | 608.89 | 29.20 | 31.72 | 29.44 | 32.02 | 23.01 |
| 12.00 | 4# | 598.87 | 25.32 | 607.64 | 29.37 | 30.25 | 29.70 | 31.77 | 23.00 |
| JDT6 | 0.00 | 1# | 645.13 | 9.45 | 650.63 | 9.46 | 35.51 | 11.09 | 39.37 | 7.52 |
| 0.00 | 2# | 646.00 | 9.50 | 650.00 | 9.56 | 35.11 | 11.17 | 39.48 | 7.53 |
| 0.00 | 3# | 645.62 | 9.56 | 650.27 | 9.49 | 35.44 | 11.26 | 39.58 | 7.49 |
| 0.00 | 4# | 648.48 | 9.55 | 652.50 | 9.57 | 35.49 | 11.00 | 39.62 | 7.55 |
| 1.00 | 1# | 639.92 | 9.45 | 645.57 | 9.46 | 36.44 | 33.23 | 38.69 | 7.81 |
| 1.00 | 2# | 641.01 | 9.79 | 645.93 | 9.69 | 36.57 | 33.23 | 38.81 | 7.80 |
| 1.00 | 3# | 644.50 | 10.21 | 651.67 | 10.41 | 33.91 | 11.90 | 39.91 | 8.27 |
| 1.00 | 4# | 646.27 | 9.55 | 653.60 | 10.05 | 33.91 | 11.90 | 39.98 | 8.28 |
| 2.00 | 1# | 636.52 | 9.54 | 642.68 | 9.46 | 38.89 | 33.23 | 38.49 | 7.67 |
| 2.00 | 2# | 637.28 | 9.50 | 642.72 | 9.69 | 38.37 | 14.36 | 38.59 | 7.66 |
| 2.00 | 3# | 637.52 | 9.61 | 642.86 | 9.58 | 38.43 | 14.19 | 38.69 | 7.71 |
| 2.00 | 4# | 645.81 | 11.63 | 656.82 | 11.58 | 29.93 | 11.90 | 40.62 | 8.97 |
| 3.00 | 1# | 633.30 | 9.37 | 638.46 | 9.46 | 37.11 | 33.23 | 37.93 | 7.60 |
| 3.00 | 2# | 633.93 | 9.50 | 638.52 | 9.32 | 36.88 | 30.14 | 38.02 | 7.59 |
| 3.00 | 3# | 634.43 | 9.41 | 638.97 | 9.30 | 34.81 | 14.47 | 38.11 | 7.64 |
| 3.00 | 4# | 646.58 | 11.96 | 661.34 | 12.08 | 26.67 | 12.34 | 40.98 | 9.93 |
| 4.00 | 1# | 631.26 | 9.37 | 635.95 | 9.46 | 35.87 | 26.20 | 37.44 | 7.58 |
| 4.00 | 2# | 631.76 | 9.50 | 635.66 | 9.32 | 33.02 | 25.96 | 37.52 | 7.61 |
| 4.00 | 3# | 632.01 | 9.41 | 635.60 | 9.30 | 34.34 | 15.45 | 37.59 | 7.61 |
| 4.00 | 4# | 646.00 | 12.63 | 663.38 | 12.68 | 22.98 | 12.64 | 41.33 | 10.78 |
| 5.00 | 1# | 627.78 | 9.54 | 632.75 | 9.46 | 34.34 | 37.34 | 37.01 | 7.48 |
| 5.00 | 2# | 628.47 | 9.58 | 632.72 | 9.56 | 18.20 | 37.48 | 37.08 | 7.48 |
| 5.00 | 3# | 628.15 | 9.56 | 632.27 | 9.58 | 35.17 | 30.42 | 37.13 | 7.50 |
| 5.00 | 4# | 642.17 | 13.22 | 661.69 | 13.21 | 17.25 | 13.25 | 41.51 | 11.46 |
| 6.00 | 1# | 624.42 | 9.37 | 629.50 | 9.46 | 32.54 | 30.76 | 36.74 | 7.28 |
| 6.00 | 2# | 624.39 | 9.50 | 629.83 | 9.30 | 15.31 | 37.48 | 36.81 | 7.31 |
| 6.00 | 3# | 624.75 | 9.41 | 629.69 | 9.30 | 32.59 | 34.16 | 36.83 | 7.32 |
| 6.00 | 4# | 633.90 | 13.73 | 655.90 | 13.81 | 12.16 | 13.78 | 41.33 | 12.11 |
| 7.00 | 1# | 625.05 | 9.37 | 630.17 | 8.86 | 35.24 | 31.58 | 36.71 | 7.17 |
| 7.00 | 2# | 625.10 | 9.50 | 629.89 | 9.30 | 26.95 | 35.44 | 36.76 | 7.15 |
| 7.00 | 3# | 625.08 | 8.77 | 629.83 | 8.68 | 37.64 | 31.26 | 36.78 | 7.15 |
| 7.00 | 4# | 625.49 | 10.59 | 646.33 | 14.29 | 6.35 | 14.44 | 40.64 | 12.86 |
| 8.00 | 1# | 627.33 | 9.37 | 632.01 | 9.46 | 37.58 | 32.11 | 36.71 | 7.17 |
| 8.00 | 2# | 627.71 | 9.50 | 632.12 | 9.30 | 36.99 | 35.68 | 36.76 | 7.15 |
| 8.00 | 3# | 627.62 | 9.41 | 631.82 | 9.30 | 38.13 | 35.58 | 36.78 | 7.15 |
| 8.00 | 4# | 629.83 | 9.55 | 636.01 | 14.94 | 3.57 | 14.98 | 39.57 | 13.56 |
| 9.00 | 1# | 626.03 | 9.54 | 631.99 | 9.46 | 37.26 | 28.96 | 36.71 | 7.17 |
| 9.00 | 2# | 626.55 | 9.58 | 631.69 | 9.56 | 36.79 | 28.80 | 36.76 | 7.15 |
| 9.00 | 3# | 626.25 | 9.60 | 631.33 | 9.30 | 37.13 | 28.97 | 36.78 | 7.15 |
| 9.00 | 4# | 627.45 | 10.05 | 634.79 | 10.05 | 5.70 | 15.51 | 37.93 | 14.22 |
| 10.00 | 1# | 625.24 | 9.54 | 631.98 | 9.46 | 37.61 | 29.33 | 36.71 | 7.17 |
| 10.00 | 2# | 625.65 | 9.50 | 631.50 | 9.30 | 36.99 | 29.60 | 36.76 | 7.15 |
| 10.00 | 3# | 625.23 | 9.41 | 631.32 | 9.30 | 35.75 | 29.35 | 36.78 | 7.15 |
| 10.00 | 4# | 617.10 | 10.74 | 624.39 | 10.96 | 7.98 | 16.24 | 35.56 | 14.90 |
| 11.00 | 1# | 625.24 | 9.54 | 631.98 | 9.46 | 36.77 | 35.92 | 36.71 | 7.17 |
| 11.00 | 2# | 625.65 | 9.50 | 631.50 | 9.30 | 33.69 | 33.44 | 36.76 | 7.15 |
| 11.00 | 3# | 625.23 | 9.41 | 631.32 | 9.30 | 38.10 | 30.14 | 36.78 | 7.15 |
| 11.00 | 4# | 612.09 | 9.55 | 617.46 | 31.18 | 13.23 | 17.06 | 32.73 | 15.75 |
| 12.00 | 1# | 625.24 | 9.54 | 631.98 | 9.46 | 29.34 | 36.74 | 36.71 | 7.17 |
| 12.00 | 2# | 625.65 | 9.50 | 631.50 | 9.30 | 30.87 | 33.44 | 36.76 | 7.15 |
| 12.00 | 3# | 625.23 | 9.41 | 631.32 | 9.30 | 26.97 | 33.39 | 36.78 | 7.15 |
| 12.00 | 4# | 613.37 | 30.83 | 625.17 | 30.73 | 22.64 | 17.66 | 31.34 | 28.90 |
| JDT10 | 0.00 | 1# | 645.13 | 9.45 | 650.63 | 9.46 | 35.51 | 11.09 | 39.37 | 7.52 |
| 0.00 | 2# | 646.00 | 9.50 | 650.00 | 9.56 | 35.11 | 11.17 | 39.48 | 7.53 |
| 0.00 | 3# | 645.62 | 9.56 | 650.27 | 9.49 | 35.44 | 11.26 | 39.58 | 7.49 |
| 0.00 | 4# | 648.48 | 9.55 | 652.50 | 9.57 | 35.49 | 11.00 | 39.62 | 7.55 |
| 1.00 | 1# | 638.47 | 9.83 | 643.43 | 9.46 | 32.09 | 15.34 | 38.44 | 8.00 |
| 1.00 | 2# | 643.90 | 10.08 | 649.93 | 10.06 | 35.71 | 12.06 | 39.61 | 8.35 |
| 1.00 | 3# | 644.48 | 10.21 | 651.21 | 10.41 | 34.92 | 11.90 | 39.72 | 8.37 |
| 1.00 | 4# | 645.66 | 10.59 | 652.92 | 10.05 | 35.25 | 11.90 | 39.78 | 8.41 |
| 2.00 | 1# | 631.73 | 10.46 | 635.12 | 10.36 | 22.97 | 16.24 | 37.17 | 8.60 |
| 2.00 | 2# | 644.14 | 11.52 | 650.33 | 11.42 | 35.77 | 12.88 | 39.53 | 9.26 |
| 2.00 | 3# | 644.72 | 11.56 | 651.75 | 11.58 | 35.98 | 13.16 | 39.66 | 9.30 |
| 2.00 | 4# | 645.00 | 11.63 | 651.48 | 11.58 | 35.68 | 13.01 | 39.72 | 9.30 |
| 3.00 | 1# | 623.17 | 12.03 | 624.37 | 11.56 | 18.29 | 16.53 | 35.60 | 9.10 |
| 3.00 | 2# | 642.39 | 12.67 | 649.05 | 12.02 | 37.40 | 13.79 | 39.29 | 10.22 |
| 3.00 | 3# | 642.02 | 12.13 | 649.42 | 12.13 | 37.25 | 13.62 | 39.43 | 10.21 |
| 3.00 | 4# | 643.34 | 12.23 | 650.39 | 12.15 | 36.69 | 14.08 | 39.50 | 10.23 |
| 4.00 | 1# | 619.01 | 13.51 | 634.66 | 17.10 | 16.82 | 17.14 | 34.14 | 15.37 |
| 4.00 | 2# | 638.88 | 13.41 | 645.81 | 12.76 | 39.47 | 11.81 | 38.92 | 11.06 |
| 4.00 | 3# | 639.70 | 13.43 | 646.88 | 12.95 | 38.83 | 11.90 | 39.06 | 11.08 |
| 4.00 | 4# | 639.96 | 13.52 | 648.00 | 12.76 | 38.30 | 11.90 | 39.16 | 11.09 |
| 5.00 | 1# | 623.67 | 17.68 | 644.95 | 17.79 | 17.14 | 17.65 | 34.81 | 16.11 |
| 5.00 | 2# | 635.02 | 14.01 | 641.59 | 13.94 | 39.68 | 24.16 | 38.36 | 11.88 |
| 5.00 | 3# | 635.90 | 13.86 | 642.57 | 13.85 | 39.53 | 12.62 | 38.53 | 11.90 |
| 5.00 | 4# | 636.44 | 14.10 | 643.85 | 14.11 | 38.82 | 8.83 | 38.65 | 11.93 |
| 6.00 | 1# | 628.55 | 18.28 | 647.85 | 18.36 | 18.85 | 18.25 | 34.73 | 16.78 |
| 6.00 | 2# | 628.20 | 14.80 | 633.43 | 14.78 | 35.45 | 24.70 | 37.57 | 12.56 |
| 6.00 | 3# | 629.32 | 14.83 | 634.55 | 14.86 | 37.16 | 35.87 | 37.78 | 12.60 |
| 6.00 | 4# | 631.01 | 14.70 | 636.97 | 14.78 | 37.47 | 35.85 | 37.94 | 12.65 |
| 7.00 | 1# | 624.98 | 19.15 | 644.34 | 19.05 | 20.91 | 19.17 | 33.74 | 17.58 |
| 7.00 | 2# | 617.44 | 15.36 | 622.34 | 15.38 | 36.68 | 36.62 | 36.59 | 13.08 |
| 7.00 | 3# | 619.47 | 15.49 | 624.69 | 15.41 | 36.62 | 36.78 | 36.85 | 13.16 |
| 7.00 | 4# | 620.17 | 15.39 | 626.13 | 15.30 | 35.99 | 10.78 | 37.04 | 13.23 |
| 8.00 | 1# | 616.49 | 20.19 | 634.31 | 20.25 | 22.54 | 20.29 | 32.09 | 18.57 |
| 8.00 | 2# | 611.78 | 38.94 | 615.29 | 38.87 | 32.46 | 37.76 | 35.00 | 14.05 |
| 8.00 | 3# | 606.30 | 17.33 | 610.38 | 17.21 | 32.47 | 37.69 | 35.31 | 14.13 |
| 8.00 | 4# | 610.50 | 39.10 | 614.08 | 39.03 | 31.80 | 40.93 | 35.53 | 14.23 |
| 9.00 | 1# | 618.89 | 21.42 | 633.91 | 21.45 | 27.70 | 21.41 | 31.46 | 6.25 |
| 9.00 | 2# | 604.78 | 18.74 | 606.88 | 18.82 | 29.95 | 45.28 | 34.35 | 16.69 |
| 9.00 | 3# | 605.23 | 18.75 | 607.84 | 18.56 | 34.79 | 39.05 | 34.50 | 16.55 |
| 9.00 | 4# | 606.42 | 18.74 | 609.79 | 18.76 | 32.08 | 42.05 | 34.63 | 16.42 |
| 10.00 | 1# | 624.64 | 22.65 | 637.03 | 22.63 | 25.11 | 32.57 | 31.46 | 6.25 |
| 10.00 | 2# | 609.69 | 19.54 | 612.92 | 19.94 | 37.67 | 25.83 | 34.90 | 18.15 |
| 10.00 | 3# | 610.17 | 19.83 | 613.23 | 19.53 | 38.12 | 40.49 | 34.96 | 18.04 |
| 10.00 | 4# | 611.02 | 19.63 | 614.69 | 19.65 | 36.47 | 43.85 | 34.99 | 17.97 |
| 11.00 | 1# | 629.45 | 23.53 | 639.46 | 23.53 | 24.66 | 33.15 | 31.46 | 6.25 |
| 11.00 | 2# | 614.98 | 20.70 | 618.81 | 20.56 | 36.00 | 41.39 | 35.72 | 19.26 |
| 11.00 | 3# | 615.52 | 20.66 | 619.56 | 20.58 | 36.33 | 41.34 | 35.78 | 19.21 |
| 11.00 | 4# | 616.32 | 20.61 | 620.74 | 20.68 | 36.71 | 41.39 | 35.80 | 19.23 |
| 12.00 | 1# | 634.18 | 23.99 | 642.84 | 24.50 | 31.88 | 33.98 | 31.46 | 6.25 |
| 12.00 | 2# | 622.08 | 23.74 | 625.75 | 23.40 | 36.85 | 42.22 | 36.61 | 20.23 |
| 12.00 | 3# | 622.91 | 23.84 | 626.39 | 23.56 | 36.77 | 42.10 | 36.69 | 20.22 |
| 12.00 | 4# | 623.78 | 23.81 | 627.60 | 23.31 | 36.94 | 42.22 | 36.73 | 20.24 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.48 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.49 JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.50 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.51 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.52 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.53 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.54 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.55 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.4.3 30s-(70%)-70s两段关闭规律计算结果**

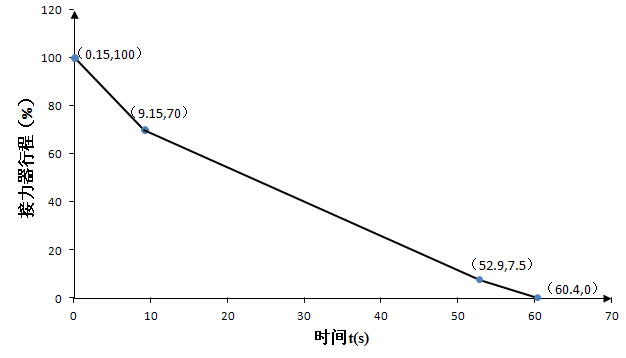


图6.56 水轮机工况导叶30s-(70%)-70s两段关闭规律

**表6-19 30s-(70%)-70s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 660.46 | 9.55 | 668.61 | 9.46 | 48.69 | 11.09 | 42.04 | 7.65 |
| 0.00 | 2# | 661.69 | 9.50 | 668.78 | 9.70 | 48.56 | 11.17 | 42.18 | 7.67 |
| 0.00 | 3# | 661.71 | 9.76 | 668.98 | 9.30 | 48.48 | 11.35 | 42.31 | 7.64 |
| 0.00 | 4# | 665.17 | 9.55 | 671.16 | 9.40 | 49.10 | 11.00 | 42.37 | 7.64 |
| SJT3 | 0.00 | 1# | 650.84 | 9.54 | 656.38 | 9.46 | 37.55 | 11.09 | 39.73 | 7.49 |
| 0.00 | 2# | 651.75 | 9.50 | 656.15 | 9.56 | 37.35 | 11.17 | 39.83 | 7.50 |
| 0.00 | 3# | 651.13 | 9.56 | 656.39 | 9.30 | 37.41 | 11.26 | 39.94 | 7.49 |
| 0.00 | 4# | 653.49 | 9.55 | 657.88 | 9.70 | 37.25 | 11.00 | 39.99 | 7.55 |
| ZT2 | 76.76 | 1# | 659.62 | 86.51 | 666.31 | 86.29 | 49.22 | 87.92 | 42.57 | 84.43 |
| 76.76 | 2# | 660.83 | 86.52 | 667.51 | 86.50 | 48.99 | 88.00 | 42.72 | 84.45 |
| 76.76 | 3# | 661.85 | 86.55 | 668.57 | 86.42 | 48.95 | 88.02 | 42.85 | 84.47 |
| 76.76 | 4# | 662.87 | 86.43 | 669.70 | 86.44 | 49.38 | 88.17 | 42.89 | 84.48 |
| JHT3 | 0.00 | 1# | 660.46 | 9.55 | 668.61 | 9.46 | 48.69 | 11.09 | 42.04 | 7.65 |
| 0.00 | 2# | 661.69 | 9.50 | 668.78 | 9.70 | 48.56 | 11.17 | 42.18 | 7.67 |
| 0.00 | 3# | 661.71 | 9.76 | 668.98 | 9.30 | 48.48 | 11.35 | 42.31 | 7.64 |
| 0.00 | 4# | 665.17 | 9.55 | 671.16 | 9.40 | 49.10 | 11.00 | 42.37 | 7.64 |
| 1.00 | 1# | 660.62 | 9.54 | 668.14 | 9.46 | 48.88 | 12.29 | 41.90 | 7.69 |
| 1.00 | 2# | 661.95 | 9.50 | 667.94 | 9.56 | 47.67 | 11.81 | 42.05 | 7.72 |
| 1.00 | 3# | 661.91 | 9.41 | 668.30 | 9.30 | 46.74 | 11.90 | 42.20 | 7.73 |
| 1.00 | 4# | 671.09 | 9.55 | 679.04 | 9.57 | 47.67 | 11.00 | 43.77 | 7.59 |
| 2.00 | 1# | 659.39 | 9.54 | 666.27 | 9.46 | 46.62 | 12.29 | 41.65 | 7.75 |
| 2.00 | 2# | 660.38 | 9.50 | 666.22 | 9.70 | 46.79 | 11.81 | 41.80 | 7.76 |
| 2.00 | 3# | 660.68 | 9.76 | 666.49 | 9.58 | 45.27 | 11.90 | 41.94 | 7.79 |
| 2.00 | 4# | 674.38 | 9.55 | 684.71 | 9.57 | 47.05 | 10.63 | 45.05 | 7.61 |
| 3.00 | 1# | 657.43 | 9.55 | 664.13 | 9.46 | 46.31 | 12.29 | 41.35 | 7.78 |
| 3.00 | 2# | 658.52 | 9.58 | 664.21 | 9.70 | 45.85 | 12.35 | 41.50 | 7.75 |
| 3.00 | 3# | 658.81 | 9.56 | 664.27 | 9.58 | 45.22 | 12.26 | 41.64 | 7.83 |
| 3.00 | 4# | 674.62 | 9.55 | 687.14 | 10.05 | 44.70 | 10.63 | 46.15 | 7.70 |
| 4.00 | 1# | 654.79 | 9.54 | 661.60 | 9.46 | 47.73 | 12.29 | 41.06 | 7.75 |
| 4.00 | 2# | 656.04 | 9.50 | 661.94 | 9.70 | 47.34 | 12.36 | 41.20 | 7.73 |
| 4.00 | 3# | 656.36 | 9.76 | 661.65 | 9.58 | 46.70 | 12.62 | 41.33 | 7.77 |
| 4.00 | 4# | 672.85 | 9.55 | 686.44 | 10.05 | 42.48 | 11.00 | 47.04 | 7.87 |
| 5.00 | 1# | 652.72 | 9.55 | 660.05 | 9.46 | 51.63 | 12.29 | 40.85 | 7.68 |
| 5.00 | 2# | 653.90 | 9.50 | 660.10 | 9.70 | 51.13 | 12.44 | 40.99 | 7.71 |
| 5.00 | 3# | 654.28 | 9.76 | 659.93 | 9.49 | 49.76 | 12.62 | 41.10 | 7.73 |
| 5.00 | 4# | 669.32 | 10.16 | 683.46 | 10.05 | 41.82 | 11.00 | 47.53 | 8.06 |
| 6.00 | 1# | 652.16 | 9.45 | 659.78 | 9.46 | 54.00 | 11.09 | 40.77 | 7.59 |
| 6.00 | 2# | 653.35 | 9.50 | 659.43 | 9.70 | 54.12 | 11.17 | 40.89 | 7.61 |
| 6.00 | 3# | 653.52 | 9.56 | 659.70 | 9.43 | 54.05 | 11.90 | 41.00 | 7.64 |
| 6.00 | 4# | 663.01 | 10.16 | 675.53 | 10.67 | 39.86 | 11.90 | 47.88 | 8.30 |
| 7.00 | 1# | 651.68 | 9.54 | 659.74 | 9.46 | 53.32 | 11.09 | 40.76 | 7.57 |
| 7.00 | 2# | 652.91 | 9.50 | 659.83 | 9.70 | 53.28 | 11.17 | 40.88 | 7.60 |
| 7.00 | 3# | 652.86 | 9.56 | 659.63 | 9.43 | 53.72 | 11.35 | 40.98 | 7.62 |
| 7.00 | 4# | 656.21 | 10.16 | 666.94 | 10.96 | 38.08 | 12.41 | 47.95 | 8.42 |
| 8.00 | 1# | 651.33 | 9.54 | 659.73 | 9.46 | 52.40 | 11.09 | 40.76 | 7.56 |
| 8.00 | 2# | 652.46 | 9.50 | 659.86 | 9.70 | 52.61 | 11.17 | 40.88 | 7.61 |
| 8.00 | 3# | 652.21 | 9.41 | 659.60 | 9.43 | 52.91 | 11.26 | 40.98 | 7.59 |
| 8.00 | 4# | 650.26 | 9.55 | 656.54 | 12.02 | 36.27 | 13.01 | 47.92 | 8.35 |
| 9.00 | 1# | 650.87 | 9.55 | 659.55 | 9.46 | 51.67 | 11.09 | 40.76 | 7.56 |
| 9.00 | 2# | 651.94 | 9.50 | 659.87 | 9.70 | 51.77 | 11.17 | 40.88 | 7.61 |
| 9.00 | 3# | 651.90 | 9.61 | 659.55 | 9.43 | 51.98 | 11.35 | 40.98 | 7.59 |
| 9.00 | 4# | 647.08 | 9.55 | 650.71 | 10.05 | 33.84 | 13.25 | 47.92 | 8.36 |
| 10.00 | 1# | 650.83 | 9.55 | 659.55 | 9.46 | 51.22 | 11.09 | 40.76 | 7.56 |
| 10.00 | 2# | 651.89 | 9.50 | 659.79 | 9.70 | 51.30 | 11.17 | 40.88 | 7.61 |
| 10.00 | 3# | 651.78 | 9.56 | 659.55 | 9.43 | 51.36 | 11.26 | 40.98 | 7.59 |
| 10.00 | 4# | 645.87 | 9.55 | 648.41 | 8.86 | 32.69 | 13.78 | 47.92 | 8.36 |
| 11.00 | 1# | 650.83 | 9.55 | 659.55 | 9.46 | 51.04 | 11.09 | 40.76 | 7.56 |
| 11.00 | 2# | 651.89 | 9.50 | 659.79 | 9.70 | 51.01 | 11.17 | 40.88 | 7.61 |
| 11.00 | 3# | 651.78 | 9.56 | 659.55 | 9.43 | 51.02 | 11.26 | 40.98 | 7.59 |
| 11.00 | 4# | 645.87 | 9.55 | 648.41 | 8.86 | 34.09 | 13.78 | 47.92 | 8.36 |
| 12.00 | 1# | 650.83 | 9.55 | 659.55 | 9.46 | 51.04 | 11.09 | 40.76 | 7.56 |
| 12.00 | 2# | 651.89 | 9.50 | 659.79 | 9.70 | 51.01 | 11.17 | 40.88 | 7.61 |
| 12.00 | 3# | 651.78 | 9.56 | 659.55 | 9.43 | 51.02 | 11.26 | 40.98 | 7.59 |
| 12.00 | 4# | 645.87 | 9.55 | 648.41 | 8.86 | 34.50 | 14.08 | 47.92 | 8.36 |
| JHT13 | 0.00 | 1# | 649.30 | 9.54 | 654.84 | 9.46 | 36.01 | 11.09 | 39.73 | 7.49 |
| 0.00 | 2# | 650.21 | 9.50 | 654.61 | 9.56 | 35.81 | 11.17 | 39.83 | 7.50 |
| 0.00 | 3# | 649.59 | 9.56 | 654.85 | 9.30 | 35.87 | 11.26 | 39.94 | 7.49 |
| 0.00 | 4# | 651.95 | 9.55 | 656.34 | 9.70 | 35.71 | 11.00 | 39.99 | 7.55 |
| 1.00 | 1# | 643.26 | 9.54 | 649.05 | 9.46 | 37.58 | 32.25 | 39.00 | 7.79 |
| 1.00 | 2# | 643.93 | 9.58 | 649.31 | 9.56 | 37.52 | 32.16 | 39.11 | 7.80 |
| 1.00 | 3# | 648.95 | 10.30 | 656.46 | 10.32 | 33.99 | 11.72 | 40.31 | 8.22 |
| 1.00 | 4# | 649.73 | 10.16 | 658.05 | 10.05 | 34.56 | 11.76 | 40.37 | 8.24 |
| 2.00 | 1# | 634.45 | 10.87 | 640.71 | 9.93 | 32.47 | 14.53 | 37.93 | 8.00 |
| 2.00 | 2# | 636.03 | 10.94 | 641.15 | 10.06 | 31.96 | 14.36 | 38.05 | 8.02 |
| 2.00 | 3# | 649.07 | 11.56 | 659.01 | 11.58 | 33.73 | 11.90 | 40.40 | 9.08 |
| 2.00 | 4# | 649.33 | 11.43 | 658.66 | 11.58 | 33.42 | 12.34 | 40.49 | 9.11 |
| 3.00 | 1# | 627.31 | 9.45 | 631.74 | 9.46 | 28.46 | 15.73 | 36.71 | 7.91 |
| 3.00 | 2# | 628.12 | 9.24 | 632.13 | 9.32 | 26.30 | 15.56 | 36.81 | 7.98 |
| 3.00 | 3# | 647.92 | 12.25 | 659.62 | 12.13 | 33.48 | 12.26 | 40.37 | 9.97 |
| 3.00 | 4# | 648.13 | 12.23 | 658.81 | 12.08 | 33.41 | 12.34 | 40.47 | 9.98 |
| 4.00 | 1# | 621.20 | 9.46 | 624.36 | 9.46 | 26.95 | 16.24 | 35.57 | 7.65 |
| 4.00 | 2# | 621.88 | 9.50 | 624.18 | 9.32 | 23.86 | 16.36 | 35.63 | 7.71 |
| 4.00 | 3# | 645.72 | 12.70 | 658.73 | 12.72 | 31.21 | 12.62 | 40.28 | 10.77 |
| 4.00 | 4# | 646.11 | 12.92 | 659.66 | 12.76 | 30.88 | 13.01 | 40.39 | 10.79 |
| 5.00 | 1# | 612.44 | 9.37 | 615.91 | 9.46 | 26.01 | 16.77 | 34.70 | 7.21 |
| 5.00 | 2# | 613.31 | 9.49 | 615.72 | 9.32 | 22.14 | 17.00 | 34.72 | 7.21 |
| 5.00 | 3# | 640.63 | 13.40 | 656.78 | 13.30 | 26.74 | 13.16 | 40.05 | 11.45 |
| 5.00 | 4# | 641.02 | 13.44 | 656.04 | 13.44 | 26.26 | 13.25 | 40.18 | 11.51 |
| 6.00 | 1# | 609.89 | 8.88 | 613.50 | 8.86 | 26.53 | 18.49 | 34.43 | 6.73 |
| 6.00 | 2# | 609.37 | 8.77 | 613.16 | 8.82 | 22.21 | 17.72 | 34.42 | 6.76 |
| 6.00 | 3# | 632.96 | 13.86 | 652.27 | 13.85 | 23.36 | 13.62 | 39.68 | 12.13 |
| 6.00 | 4# | 633.90 | 14.07 | 652.54 | 13.96 | 22.64 | 13.78 | 39.83 | 12.18 |
| 7.00 | 1# | 611.71 | 8.88 | 616.22 | 8.86 | 22.96 | 19.09 | 34.41 | 6.72 |
| 7.00 | 2# | 611.60 | 9.24 | 616.03 | 8.82 | 21.79 | 18.72 | 34.41 | 6.72 |
| 7.00 | 3# | 623.12 | 14.55 | 643.87 | 14.38 | 21.80 | 14.19 | 38.90 | 12.77 |
| 7.00 | 4# | 624.48 | 14.70 | 643.43 | 14.58 | 21.39 | 14.44 | 39.09 | 12.82 |
| 8.00 | 1# | 613.10 | 9.46 | 618.21 | 9.33 | 21.60 | 19.61 | 34.41 | 6.72 |
| 8.00 | 2# | 613.47 | 9.49 | 618.23 | 9.30 | 20.15 | 19.32 | 34.41 | 6.72 |
| 8.00 | 3# | 613.92 | 15.11 | 631.93 | 15.03 | 24.08 | 14.62 | 37.48 | 13.36 |
| 8.00 | 4# | 616.09 | 15.25 | 633.00 | 15.07 | 22.49 | 37.03 | 37.70 | 13.43 |
| 9.00 | 1# | 610.30 | 17.33 | 617.41 | 8.86 | 22.68 | 19.80 | 34.41 | 6.72 |
| 9.00 | 2# | 610.32 | 9.49 | 617.34 | 9.30 | 19.85 | 19.98 | 34.41 | 6.72 |
| 9.00 | 3# | 606.80 | 10.22 | 615.36 | 15.92 | 26.89 | 26.16 | 35.20 | 14.07 |
| 9.00 | 4# | 607.80 | 16.21 | 618.24 | 16.04 | 23.29 | 38.12 | 35.46 | 14.15 |
| 10.00 | 1# | 609.32 | 9.26 | 617.49 | 9.33 | 30.17 | 31.27 | 34.41 | 6.72 |
| 10.00 | 2# | 609.74 | 9.24 | 617.53 | 9.30 | 27.79 | 30.85 | 34.41 | 6.72 |
| 10.00 | 3# | 594.66 | 17.30 | 598.61 | 26.48 | 23.40 | 26.59 | 32.57 | 14.98 |
| 10.00 | 4# | 595.37 | 17.40 | 597.60 | 10.96 | 26.59 | 27.33 | 32.88 | 15.05 |
| 11.00 | 1# | 609.55 | 24.51 | 617.49 | 9.33 | 31.98 | 23.57 | 34.41 | 6.72 |
| 11.00 | 2# | 609.74 | 9.24 | 617.53 | 9.30 | 32.05 | 23.63 | 34.41 | 6.72 |
| 11.00 | 3# | 604.29 | 27.97 | 619.27 | 28.05 | 24.28 | 27.35 | 30.81 | 26.36 |
| 11.00 | 4# | 606.27 | 28.33 | 618.48 | 28.33 | 26.43 | 27.62 | 30.73 | 26.62 |
| 12.00 | 1# | 625.61 | 25.20 | 633.73 | 25.18 | 33.87 | 34.36 | 34.41 | 6.72 |
| 12.00 | 2# | 625.67 | 25.16 | 633.29 | 25.20 | 32.92 | 31.51 | 34.41 | 6.72 |
| 12.00 | 3# | 602.73 | 28.83 | 615.30 | 28.81 | 27.06 | 28.49 | 32.13 | 22.27 |
| 12.00 | 4# | 603.26 | 29.00 | 615.46 | 28.93 | 27.44 | 28.22 | 31.93 | 21.93 |
| JDT6 | 0.00 | 1# | 649.30 | 9.54 | 654.84 | 9.46 | 36.01 | 11.09 | 39.73 | 7.49 |
| 0.00 | 2# | 650.21 | 9.50 | 654.61 | 9.56 | 35.81 | 11.17 | 39.83 | 7.50 |
| 0.00 | 3# | 649.59 | 9.56 | 654.85 | 9.30 | 35.87 | 11.26 | 39.94 | 7.49 |
| 0.00 | 4# | 651.95 | 9.55 | 656.34 | 9.70 | 35.71 | 11.00 | 39.99 | 7.55 |
| 1.00 | 1# | 646.07 | 9.54 | 651.95 | 9.46 | 38.96 | 11.23 | 39.34 | 7.64 |
| 1.00 | 2# | 647.02 | 9.50 | 651.90 | 9.56 | 38.09 | 11.81 | 39.45 | 7.67 |
| 1.00 | 3# | 646.87 | 9.56 | 651.92 | 9.30 | 38.20 | 11.90 | 39.56 | 7.68 |
| 1.00 | 4# | 651.43 | 9.55 | 658.90 | 10.05 | 32.52 | 11.52 | 40.64 | 8.14 |
| 2.00 | 1# | 640.52 | 9.54 | 646.60 | 9.46 | 38.05 | 32.45 | 38.78 | 7.64 |
| 2.00 | 2# | 641.57 | 9.50 | 647.10 | 9.69 | 37.92 | 32.56 | 38.89 | 7.67 |
| 2.00 | 3# | 641.82 | 9.67 | 647.03 | 9.30 | 37.57 | 13.62 | 38.99 | 7.74 |
| 2.00 | 4# | 650.14 | 11.63 | 661.86 | 11.58 | 29.77 | 11.90 | 41.07 | 8.97 |
| 3.00 | 1# | 636.92 | 9.37 | 642.09 | 9.46 | 35.75 | 33.00 | 38.20 | 7.59 |
| 3.00 | 2# | 637.34 | 9.50 | 642.40 | 9.32 | 35.75 | 32.85 | 38.29 | 7.63 |
| 3.00 | 3# | 638.27 | 9.41 | 642.99 | 9.30 | 36.14 | 14.47 | 38.38 | 7.65 |
| 3.00 | 4# | 650.84 | 12.10 | 665.77 | 12.02 | 26.13 | 11.90 | 41.48 | 9.91 |
| 4.00 | 1# | 634.25 | 9.37 | 639.01 | 9.46 | 34.88 | 33.59 | 37.69 | 7.50 |
| 4.00 | 2# | 635.10 | 9.50 | 639.04 | 9.32 | 35.32 | 29.98 | 37.79 | 7.55 |
| 4.00 | 3# | 634.94 | 9.41 | 638.98 | 9.30 | 34.26 | 15.17 | 37.84 | 7.57 |
| 4.00 | 4# | 649.94 | 12.64 | 667.76 | 12.68 | 21.68 | 12.64 | 41.87 | 10.69 |
| 5.00 | 1# | 631.26 | 9.45 | 636.31 | 9.46 | 35.69 | 33.59 | 37.29 | 7.38 |
| 5.00 | 2# | 631.98 | 9.50 | 635.88 | 9.69 | 27.67 | 34.00 | 37.36 | 7.41 |
| 5.00 | 3# | 631.49 | 9.41 | 635.75 | 9.43 | 35.18 | 15.73 | 37.41 | 7.45 |
| 5.00 | 4# | 646.42 | 12.92 | 666.28 | 12.92 | 16.16 | 13.25 | 42.12 | 11.39 |
| 6.00 | 1# | 628.10 | 9.37 | 633.86 | 9.46 | 31.80 | 34.20 | 37.09 | 7.22 |
| 6.00 | 2# | 628.80 | 9.50 | 633.86 | 9.30 | 23.39 | 23.64 | 37.14 | 7.18 |
| 6.00 | 3# | 628.91 | 9.41 | 633.87 | 9.30 | 30.38 | 30.79 | 37.17 | 7.25 |
| 6.00 | 4# | 638.67 | 13.51 | 661.40 | 13.58 | 10.33 | 13.78 | 42.02 | 12.12 |
| 7.00 | 1# | 629.66 | 9.37 | 634.75 | 9.46 | 30.04 | 31.88 | 37.06 | 7.11 |
| 7.00 | 2# | 629.67 | 9.50 | 634.69 | 9.30 | 28.97 | 34.88 | 37.11 | 7.14 |
| 7.00 | 3# | 629.65 | 9.41 | 634.50 | 9.30 | 34.51 | 35.05 | 37.13 | 7.13 |
| 7.00 | 4# | 629.04 | 10.74 | 652.32 | 14.11 | 5.42 | 14.27 | 41.43 | 12.81 |
| 8.00 | 1# | 630.94 | 9.37 | 636.12 | 9.46 | 32.54 | 31.85 | 37.06 | 7.11 |
| 8.00 | 2# | 631.27 | 9.50 | 636.32 | 9.30 | 31.67 | 31.68 | 37.11 | 7.14 |
| 8.00 | 3# | 631.24 | 9.41 | 636.08 | 9.30 | 36.01 | 28.12 | 37.13 | 7.13 |
| 8.00 | 4# | 630.72 | 9.55 | 641.56 | 14.78 | 1.66 | 14.82 | 40.33 | 13.48 |
| 9.00 | 1# | 629.42 | 9.45 | 636.13 | 9.46 | 33.46 | 32.40 | 37.06 | 7.11 |
| 9.00 | 2# | 630.37 | 9.50 | 635.84 | 9.56 | 32.42 | 32.56 | 37.11 | 7.14 |
| 9.00 | 3# | 629.86 | 9.41 | 635.64 | 9.30 | 34.49 | 32.42 | 37.13 | 7.13 |
| 9.00 | 4# | 627.01 | 10.05 | 633.47 | 10.05 | 5.13 | 15.45 | 38.48 | 14.10 |
| 10.00 | 1# | 629.15 | 9.37 | 636.12 | 9.46 | 31.94 | 32.97 | 37.06 | 7.11 |
| 10.00 | 2# | 629.66 | 9.50 | 635.78 | 9.30 | 31.55 | 32.85 | 37.11 | 7.14 |
| 10.00 | 3# | 629.26 | 9.41 | 635.63 | 9.30 | 32.88 | 32.71 | 37.13 | 7.13 |
| 10.00 | 4# | 623.89 | 30.65 | 633.52 | 30.57 | 7.35 | 16.16 | 35.82 | 14.84 |
| 11.00 | 1# | 629.15 | 9.37 | 636.12 | 9.46 | 34.23 | 33.37 | 37.06 | 7.11 |
| 11.00 | 2# | 629.66 | 9.50 | 635.78 | 9.30 | 33.19 | 33.23 | 37.11 | 7.14 |
| 11.00 | 3# | 629.26 | 9.41 | 635.63 | 9.30 | 33.84 | 32.82 | 37.13 | 7.13 |
| 11.00 | 4# | 618.61 | 30.63 | 630.28 | 30.57 | 11.52 | 17.06 | 32.88 | 15.74 |
| 12.00 | 1# | 629.15 | 9.37 | 636.12 | 9.46 | 35.17 | 33.23 | 37.06 | 7.11 |
| 12.00 | 2# | 629.66 | 9.50 | 635.78 | 9.30 | 32.11 | 33.21 | 37.11 | 7.14 |
| 12.00 | 3# | 629.26 | 9.41 | 635.63 | 9.30 | 27.43 | 33.31 | 37.13 | 7.13 |
| 12.00 | 4# | 614.90 | 9.55 | 622.21 | 30.19 | 16.94 | 29.98 | 31.22 | 28.64 |
| JDT10 | 0.00 | 1# | 649.30 | 9.54 | 654.84 | 9.46 | 36.01 | 11.09 | 39.73 | 7.49 |
| 0.00 | 2# | 650.21 | 9.50 | 654.61 | 9.56 | 35.81 | 11.17 | 39.83 | 7.50 |
| 0.00 | 3# | 649.59 | 9.56 | 654.85 | 9.30 | 35.87 | 11.26 | 39.94 | 7.49 |
| 0.00 | 4# | 651.95 | 9.55 | 656.34 | 9.70 | 35.71 | 11.00 | 39.99 | 7.55 |
| 1.00 | 1# | 641.84 | 9.54 | 647.18 | 9.55 | 33.13 | 14.45 | 38.74 | 8.03 |
| 1.00 | 2# | 647.98 | 10.60 | 654.70 | 10.58 | 35.29 | 11.81 | 39.98 | 8.36 |
| 1.00 | 3# | 649.09 | 10.59 | 655.99 | 10.33 | 34.73 | 11.90 | 40.09 | 8.37 |
| 1.00 | 4# | 649.58 | 10.44 | 657.01 | 10.05 | 35.66 | 11.90 | 40.15 | 8.37 |
| 2.00 | 1# | 634.49 | 10.87 | 637.55 | 10.96 | 23.37 | 15.73 | 37.38 | 8.64 |
| 2.00 | 2# | 648.55 | 11.57 | 654.56 | 11.42 | 36.08 | 12.88 | 39.89 | 9.26 |
| 2.00 | 3# | 649.27 | 11.56 | 656.58 | 11.58 | 35.92 | 12.62 | 40.02 | 9.25 |
| 2.00 | 4# | 649.58 | 11.43 | 656.44 | 10.96 | 35.13 | 12.64 | 40.09 | 9.28 |
| 3.00 | 1# | 625.96 | 12.24 | 629.70 | 16.20 | 16.16 | 16.24 | 35.67 | 9.29 |
| 3.00 | 2# | 646.11 | 12.67 | 652.80 | 12.02 | 37.06 | 13.25 | 39.64 | 10.13 |
| 3.00 | 3# | 645.86 | 12.51 | 653.89 | 12.13 | 36.54 | 13.62 | 39.78 | 10.13 |
| 3.00 | 4# | 647.00 | 12.23 | 654.25 | 12.21 | 36.05 | 13.62 | 39.86 | 10.16 |
| 4.00 | 1# | 624.32 | 13.51 | 643.75 | 16.80 | 15.12 | 16.94 | 34.53 | 15.20 |
| 4.00 | 2# | 643.03 | 13.48 | 649.92 | 13.22 | 39.12 | 34.42 | 39.25 | 10.96 |
| 4.00 | 3# | 643.65 | 13.43 | 650.78 | 12.95 | 38.76 | 14.47 | 39.42 | 11.01 |
| 4.00 | 4# | 644.41 | 13.44 | 651.74 | 13.22 | 38.56 | 14.44 | 39.51 | 11.04 |
| 5.00 | 1# | 629.67 | 17.39 | 652.66 | 17.47 | 14.45 | 17.43 | 35.05 | 16.01 |
| 5.00 | 2# | 638.81 | 14.12 | 645.24 | 14.10 | 36.40 | 35.25 | 38.74 | 11.75 |
| 5.00 | 3# | 639.61 | 14.14 | 646.55 | 13.85 | 39.25 | 34.69 | 38.93 | 11.79 |
| 5.00 | 4# | 640.34 | 13.91 | 647.82 | 13.88 | 39.48 | 34.65 | 39.05 | 11.85 |
| 6.00 | 1# | 632.54 | 18.17 | 654.51 | 18.16 | 16.78 | 18.20 | 34.71 | 16.69 |
| 6.00 | 2# | 631.70 | 14.68 | 637.68 | 14.10 | 34.65 | 35.98 | 38.07 | 12.37 |
| 6.00 | 3# | 633.29 | 14.83 | 638.94 | 14.66 | 36.98 | 35.50 | 38.29 | 12.39 |
| 6.00 | 4# | 634.69 | 14.70 | 641.04 | 14.78 | 37.29 | 35.32 | 38.45 | 12.46 |
| 7.00 | 1# | 627.40 | 19.06 | 648.34 | 19.05 | 18.97 | 19.09 | 33.35 | 17.52 |
| 7.00 | 2# | 623.13 | 14.96 | 628.00 | 14.94 | 34.33 | 36.51 | 37.12 | 12.93 |
| 7.00 | 3# | 624.97 | 14.83 | 629.49 | 14.86 | 36.79 | 10.65 | 37.39 | 12.99 |
| 7.00 | 4# | 625.86 | 14.91 | 631.99 | 14.94 | 36.29 | 10.78 | 37.58 | 13.03 |
| 8.00 | 1# | 620.07 | 20.26 | 638.94 | 20.17 | 20.82 | 20.29 | 31.78 | 6.21 |
| 8.00 | 2# | 609.12 | 38.85 | 614.99 | 38.57 | 30.74 | 37.87 | 35.27 | 14.01 |
| 8.00 | 3# | 608.31 | 17.33 | 613.16 | 17.21 | 34.62 | 34.23 | 35.57 | 14.08 |
| 8.00 | 4# | 610.59 | 17.32 | 615.66 | 17.40 | 32.29 | 37.79 | 35.80 | 14.21 |
| 9.00 | 1# | 622.65 | 21.42 | 637.68 | 21.43 | 26.36 | 21.47 | 31.78 | 6.21 |
| 9.00 | 2# | 607.60 | 19.01 | 610.29 | 18.89 | 35.28 | 24.33 | 34.62 | 16.69 |
| 9.00 | 3# | 608.09 | 18.84 | 611.46 | 18.56 | 34.69 | 38.87 | 34.79 | 16.52 |
| 9.00 | 4# | 609.41 | 18.74 | 613.44 | 18.76 | 36.75 | 41.75 | 34.91 | 16.46 |
| 10.00 | 1# | 629.62 | 22.62 | 642.60 | 22.63 | 26.68 | 32.03 | 31.78 | 6.21 |
| 10.00 | 2# | 613.64 | 19.54 | 617.11 | 19.95 | 36.22 | 25.59 | 35.25 | 18.19 |
| 10.00 | 3# | 614.30 | 19.93 | 617.54 | 19.53 | 37.13 | 25.42 | 35.32 | 18.10 |
| 10.00 | 4# | 614.90 | 19.80 | 618.55 | 19.65 | 37.55 | 43.48 | 35.35 | 18.01 |
| 11.00 | 1# | 638.07 | 23.53 | 649.56 | 23.43 | 27.61 | 32.86 | 31.78 | 6.21 |
| 11.00 | 2# | 618.72 | 20.58 | 623.11 | 20.56 | 36.46 | 25.83 | 36.12 | 19.25 |
| 11.00 | 3# | 619.24 | 20.66 | 624.03 | 20.58 | 36.21 | 26.09 | 36.18 | 19.22 |
| 11.00 | 4# | 619.77 | 20.61 | 624.81 | 20.68 | 35.78 | 25.97 | 36.21 | 19.18 |
| 12.00 | 1# | 644.09 | 24.08 | 654.95 | 24.13 | 31.35 | 24.25 | 31.78 | 6.21 |
| 12.00 | 2# | 626.16 | 23.57 | 630.85 | 23.30 | 37.11 | 26.62 | 37.00 | 20.20 |
| 12.00 | 3# | 627.34 | 23.84 | 631.76 | 23.19 | 36.87 | 26.24 | 37.09 | 20.26 |
| 12.00 | 4# | 628.36 | 23.31 | 633.19 | 23.31 | 36.51 | 26.42 | 37.13 | 20.17 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.57 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.58 JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.59 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.60 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.61 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.62 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.63 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.64 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.4.4 30s-(70%)-80s两段关闭规律计算结果**

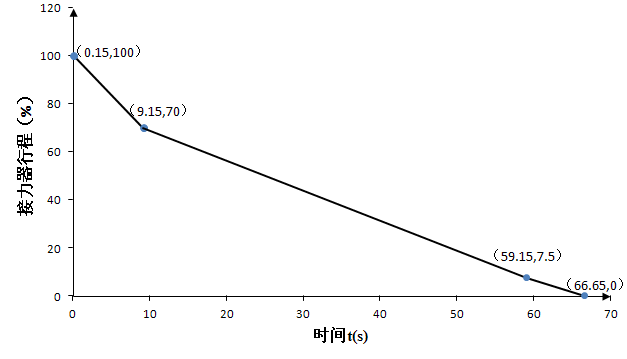


图6.65 水轮机工况导叶30s-(70%)-80s两段关闭规律

**表6-20 30s-(70%)-80s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 659.69 | 9.54 | 667.84 | 9.46 | 49.04 | 11.09 | 42.04 | 7.65 |
| 0.00 | 2# | 660.97 | 9.50 | 667.87 | 9.70 | 48.80 | 11.17 | 42.18 | 7.66 |
| 0.00 | 3# | 661.00 | 9.41 | 668.34 | 9.30 | 48.74 | 11.35 | 42.31 | 7.64 |
| 0.00 | 4# | 664.39 | 9.55 | 670.38 | 9.40 | 49.30 | 11.00 | 42.37 | 7.64 |
| SJT3 | 0.00 | 1# | 647.32 | 9.54 | 652.65 | 9.46 | 38.85 | 11.09 | 39.72 | 7.53 |
| 0.00 | 2# | 648.32 | 9.50 | 652.55 | 9.56 | 38.49 | 11.81 | 39.84 | 7.52 |
| 0.00 | 3# | 647.71 | 9.56 | 652.81 | 9.30 | 38.45 | 11.35 | 39.94 | 7.56 |
| 0.00 | 4# | 650.12 | 9.55 | 654.12 | 9.57 | 38.46 | 11.00 | 39.98 | 7.54 |
| ZT2 | 76.76 | 1# | 658.77 | 86.50 | 665.56 | 86.30 | 49.43 | 88.02 | 42.57 | 84.43 |
| 76.76 | 2# | 660.03 | 86.52 | 666.74 | 86.39 | 49.29 | 88.00 | 42.72 | 84.48 |
| 76.76 | 3# | 661.04 | 86.41 | 667.83 | 86.39 | 49.26 | 88.02 | 42.85 | 84.46 |
| 76.76 | 4# | 662.11 | 86.43 | 668.91 | 86.44 | 49.65 | 88.17 | 42.90 | 84.48 |
| JHT3 | 0.00 | 1# | 659.69 | 9.54 | 667.84 | 9.46 | 49.04 | 11.09 | 42.04 | 7.65 |
| 0.00 | 2# | 660.97 | 9.50 | 667.87 | 9.70 | 48.80 | 11.17 | 42.18 | 7.66 |
| 0.00 | 3# | 661.00 | 9.41 | 668.34 | 9.30 | 48.74 | 11.35 | 42.31 | 7.64 |
| 0.00 | 4# | 664.39 | 9.55 | 670.38 | 9.40 | 49.30 | 11.00 | 42.37 | 7.64 |
| 1.00 | 1# | 660.02 | 9.54 | 667.48 | 9.46 | 48.72 | 12.29 | 41.90 | 7.71 |
| 1.00 | 2# | 661.36 | 9.50 | 667.21 | 9.56 | 47.88 | 11.81 | 42.05 | 7.71 |
| 1.00 | 3# | 661.28 | 9.41 | 667.63 | 9.30 | 47.03 | 11.90 | 42.19 | 7.71 |
| 1.00 | 4# | 670.65 | 9.55 | 678.73 | 9.57 | 47.58 | 11.00 | 43.77 | 7.59 |
| 2.00 | 1# | 658.75 | 9.55 | 665.53 | 9.46 | 46.36 | 12.29 | 41.65 | 7.74 |
| 2.00 | 2# | 659.68 | 9.50 | 665.38 | 9.70 | 46.67 | 12.35 | 41.80 | 7.78 |
| 2.00 | 3# | 659.93 | 9.76 | 665.71 | 9.58 | 45.45 | 11.90 | 41.94 | 7.79 |
| 2.00 | 4# | 674.22 | 9.55 | 684.64 | 9.57 | 46.88 | 10.63 | 45.05 | 7.61 |
| 3.00 | 1# | 656.78 | 9.55 | 663.40 | 9.46 | 46.18 | 12.29 | 41.35 | 7.75 |
| 3.00 | 2# | 657.90 | 9.58 | 663.47 | 9.70 | 45.69 | 12.35 | 41.50 | 7.78 |
| 3.00 | 3# | 658.11 | 9.56 | 663.50 | 9.58 | 45.17 | 12.26 | 41.64 | 7.79 |
| 3.00 | 4# | 674.40 | 9.55 | 686.96 | 10.05 | 44.37 | 10.63 | 46.15 | 7.70 |
| 4.00 | 1# | 654.14 | 9.54 | 660.90 | 9.46 | 47.65 | 12.29 | 41.06 | 7.74 |
| 4.00 | 2# | 655.37 | 9.50 | 661.13 | 9.70 | 47.18 | 12.36 | 41.21 | 7.77 |
| 4.00 | 3# | 655.67 | 9.76 | 660.99 | 9.49 | 46.30 | 12.62 | 41.33 | 7.78 |
| 4.00 | 4# | 672.73 | 9.55 | 686.44 | 10.05 | 42.43 | 11.00 | 47.04 | 7.87 |
| 5.00 | 1# | 652.15 | 9.55 | 659.38 | 9.46 | 51.42 | 12.78 | 40.85 | 7.67 |
| 5.00 | 2# | 653.31 | 9.50 | 659.36 | 9.70 | 50.90 | 12.36 | 40.99 | 7.66 |
| 5.00 | 3# | 653.52 | 9.76 | 659.18 | 9.43 | 49.40 | 12.62 | 41.10 | 7.70 |
| 5.00 | 4# | 669.11 | 10.16 | 683.49 | 10.05 | 41.39 | 11.00 | 47.53 | 8.05 |
| 6.00 | 1# | 651.52 | 9.45 | 659.01 | 9.46 | 54.53 | 11.09 | 40.77 | 7.59 |
| 6.00 | 2# | 652.80 | 9.50 | 658.78 | 9.70 | 54.60 | 11.17 | 40.89 | 7.61 |
| 6.00 | 3# | 652.87 | 9.56 | 658.99 | 9.43 | 54.13 | 13.16 | 41.00 | 7.64 |
| 6.00 | 4# | 662.83 | 10.16 | 675.49 | 10.67 | 39.69 | 11.90 | 47.88 | 8.31 |
| 7.00 | 1# | 651.05 | 9.54 | 659.06 | 9.46 | 53.72 | 11.09 | 40.76 | 7.57 |
| 7.00 | 2# | 652.33 | 9.50 | 659.02 | 9.70 | 53.80 | 11.17 | 40.88 | 7.60 |
| 7.00 | 3# | 652.24 | 9.56 | 658.94 | 9.43 | 54.21 | 11.35 | 40.98 | 7.62 |
| 7.00 | 4# | 655.97 | 10.16 | 667.11 | 11.04 | 37.97 | 12.41 | 47.95 | 8.43 |
| 8.00 | 1# | 650.65 | 9.54 | 659.03 | 9.46 | 52.85 | 11.09 | 40.76 | 7.56 |
| 8.00 | 2# | 651.89 | 9.50 | 659.02 | 9.70 | 52.98 | 11.17 | 40.88 | 7.61 |
| 8.00 | 3# | 651.74 | 9.41 | 659.05 | 9.43 | 53.29 | 11.26 | 40.98 | 7.59 |
| 8.00 | 4# | 650.08 | 9.55 | 656.42 | 12.02 | 36.88 | 12.89 | 47.92 | 8.35 |
| 9.00 | 1# | 650.19 | 9.55 | 658.87 | 9.46 | 52.00 | 11.09 | 40.76 | 7.56 |
| 9.00 | 2# | 651.36 | 9.50 | 659.02 | 9.70 | 52.03 | 11.17 | 40.88 | 7.61 |
| 9.00 | 3# | 651.24 | 9.56 | 658.87 | 9.43 | 52.25 | 11.35 | 40.98 | 7.59 |
| 9.00 | 4# | 646.83 | 9.55 | 650.51 | 10.05 | 34.81 | 13.25 | 47.92 | 8.36 |
| 10.00 | 1# | 650.15 | 9.55 | 658.90 | 9.46 | 51.49 | 11.09 | 40.76 | 7.56 |
| 10.00 | 2# | 651.31 | 9.50 | 658.94 | 9.70 | 51.52 | 11.17 | 40.88 | 7.61 |
| 10.00 | 3# | 651.13 | 9.41 | 658.87 | 9.43 | 51.60 | 11.26 | 40.98 | 7.59 |
| 10.00 | 4# | 645.65 | 9.55 | 648.33 | 8.86 | 34.04 | 13.78 | 47.92 | 8.36 |
| 11.00 | 1# | 650.15 | 9.55 | 658.90 | 9.46 | 51.31 | 11.09 | 40.76 | 7.56 |
| 11.00 | 2# | 651.31 | 9.50 | 658.94 | 9.70 | 51.22 | 11.17 | 40.88 | 7.61 |
| 11.00 | 3# | 651.13 | 9.41 | 658.87 | 9.43 | 51.27 | 11.26 | 40.98 | 7.59 |
| 11.00 | 4# | 645.65 | 9.55 | 648.33 | 8.86 | 35.24 | 13.78 | 47.92 | 8.36 |
| 12.00 | 1# | 650.15 | 9.55 | 658.90 | 9.46 | 51.31 | 11.09 | 40.76 | 7.56 |
| 12.00 | 2# | 651.31 | 9.50 | 658.94 | 9.70 | 51.22 | 11.17 | 40.88 | 7.61 |
| 12.00 | 3# | 651.13 | 9.41 | 658.87 | 9.43 | 51.27 | 11.26 | 40.98 | 7.59 |
| 12.00 | 4# | 645.65 | 9.55 | 648.33 | 8.86 | 35.38 | 14.08 | 47.92 | 8.36 |
| JHT13 | 0.00 | 1# | 645.78 | 9.54 | 651.11 | 9.46 | 37.31 | 11.09 | 39.72 | 7.53 |
| 0.00 | 2# | 646.78 | 9.50 | 651.01 | 9.56 | 36.95 | 11.81 | 39.84 | 7.52 |
| 0.00 | 3# | 646.17 | 9.56 | 651.27 | 9.30 | 36.91 | 11.35 | 39.94 | 7.56 |
| 0.00 | 4# | 648.58 | 9.55 | 652.58 | 9.57 | 36.92 | 11.00 | 39.98 | 7.54 |
| 1.00 | 1# | 639.98 | 9.54 | 645.62 | 9.46 | 37.65 | 14.45 | 39.03 | 7.88 |
| 1.00 | 2# | 640.80 | 9.58 | 646.12 | 9.69 | 38.44 | 14.36 | 39.15 | 7.86 |
| 1.00 | 3# | 645.40 | 10.30 | 652.68 | 10.32 | 35.50 | 11.72 | 40.29 | 8.26 |
| 1.00 | 4# | 646.32 | 10.16 | 654.28 | 10.05 | 35.86 | 11.69 | 40.35 | 8.26 |
| 2.00 | 1# | 631.74 | 10.87 | 637.07 | 9.93 | 34.38 | 15.34 | 37.98 | 8.07 |
| 2.00 | 2# | 633.45 | 10.94 | 637.79 | 10.06 | 33.73 | 15.27 | 38.09 | 8.07 |
| 2.00 | 3# | 645.33 | 11.56 | 654.68 | 11.58 | 35.12 | 11.90 | 40.36 | 9.07 |
| 2.00 | 4# | 645.49 | 11.43 | 654.54 | 10.96 | 34.38 | 12.34 | 40.44 | 9.10 |
| 3.00 | 1# | 624.47 | 9.45 | 628.63 | 9.46 | 30.38 | 15.73 | 36.77 | 7.96 |
| 3.00 | 2# | 625.26 | 9.24 | 629.04 | 9.32 | 28.44 | 15.87 | 36.87 | 8.04 |
| 3.00 | 3# | 643.70 | 12.02 | 655.28 | 12.13 | 32.06 | 33.59 | 40.30 | 9.94 |
| 3.00 | 4# | 644.09 | 12.23 | 654.48 | 12.08 | 33.58 | 33.52 | 40.39 | 10.00 |
| 4.00 | 1# | 618.41 | 9.46 | 621.36 | 9.46 | 28.00 | 16.24 | 35.64 | 7.71 |
| 4.00 | 2# | 619.07 | 9.50 | 621.24 | 9.56 | 25.23 | 16.36 | 35.70 | 7.76 |
| 4.00 | 3# | 641.27 | 12.70 | 654.18 | 12.95 | 27.19 | 34.16 | 40.15 | 10.77 |
| 4.00 | 4# | 642.00 | 12.92 | 654.60 | 12.76 | 29.21 | 34.35 | 40.26 | 10.77 |
| 5.00 | 1# | 609.73 | 9.37 | 613.13 | 9.46 | 27.04 | 16.94 | 34.77 | 7.26 |
| 5.00 | 2# | 610.59 | 9.50 | 612.85 | 9.32 | 23.03 | 17.00 | 34.80 | 7.32 |
| 5.00 | 3# | 637.32 | 13.40 | 652.35 | 13.48 | 25.23 | 34.80 | 39.90 | 11.47 |
| 5.00 | 4# | 637.37 | 13.52 | 651.91 | 13.58 | 26.14 | 34.87 | 40.03 | 11.53 |
| 6.00 | 1# | 607.24 | 8.88 | 610.70 | 8.86 | 25.15 | 39.00 | 34.48 | 6.77 |
| 6.00 | 2# | 606.88 | 8.77 | 610.55 | 8.20 | 23.23 | 18.24 | 34.48 | 6.81 |
| 6.00 | 3# | 630.59 | 13.95 | 648.89 | 13.95 | 22.68 | 35.58 | 39.54 | 12.17 |
| 6.00 | 4# | 632.00 | 14.10 | 649.06 | 13.96 | 24.16 | 13.78 | 39.69 | 12.21 |
| 7.00 | 1# | 608.82 | 8.88 | 613.14 | 8.86 | 22.97 | 19.09 | 34.47 | 6.74 |
| 7.00 | 2# | 608.66 | 9.24 | 612.92 | 8.82 | 21.54 | 19.08 | 34.46 | 6.77 |
| 7.00 | 3# | 622.21 | 14.56 | 640.55 | 14.43 | 23.77 | 14.47 | 38.70 | 12.77 |
| 7.00 | 4# | 623.91 | 14.70 | 640.29 | 14.58 | 23.08 | 14.44 | 38.88 | 12.83 |
| 8.00 | 1# | 610.31 | 9.46 | 615.23 | 9.33 | 22.66 | 19.61 | 34.47 | 6.74 |
| 8.00 | 2# | 610.63 | 9.49 | 615.13 | 9.30 | 19.83 | 19.62 | 34.46 | 6.77 |
| 8.00 | 3# | 613.18 | 15.18 | 629.21 | 15.03 | 25.90 | 14.62 | 37.36 | 13.40 |
| 8.00 | 4# | 614.97 | 15.32 | 629.90 | 15.30 | 24.48 | 37.03 | 37.58 | 13.46 |
| 9.00 | 1# | 608.07 | 17.33 | 614.51 | 9.46 | 23.80 | 20.35 | 34.47 | 6.74 |
| 9.00 | 2# | 607.91 | 9.58 | 614.18 | 9.32 | 21.56 | 20.27 | 34.46 | 6.77 |
| 9.00 | 3# | 604.97 | 10.22 | 613.65 | 16.04 | 25.97 | 26.24 | 35.18 | 14.11 |
| 9.00 | 4# | 606.48 | 16.56 | 615.43 | 16.04 | 20.72 | 38.01 | 35.44 | 14.16 |
| 10.00 | 1# | 606.70 | 9.46 | 614.69 | 9.46 | 29.46 | 31.06 | 34.47 | 6.74 |
| 10.00 | 2# | 606.73 | 9.49 | 614.40 | 9.32 | 26.67 | 31.22 | 34.46 | 6.77 |
| 10.00 | 3# | 592.69 | 17.21 | 596.39 | 10.69 | 22.17 | 26.86 | 32.69 | 14.97 |
| 10.00 | 4# | 593.93 | 17.40 | 597.09 | 10.96 | 27.46 | 27.01 | 33.00 | 15.06 |
| 11.00 | 1# | 606.70 | 9.46 | 614.69 | 9.46 | 28.94 | 34.12 | 34.47 | 6.74 |
| 11.00 | 2# | 606.73 | 9.49 | 614.40 | 9.32 | 29.29 | 33.94 | 34.46 | 6.77 |
| 11.00 | 3# | 603.19 | 28.46 | 616.97 | 28.44 | 27.66 | 27.59 | 31.31 | 26.71 |
| 11.00 | 4# | 602.35 | 28.58 | 614.74 | 28.71 | 28.41 | 28.89 | 31.33 | 26.92 |
| 12.00 | 1# | 615.13 | 25.77 | 620.68 | 25.61 | 30.30 | 35.25 | 34.47 | 6.74 |
| 12.00 | 2# | 615.48 | 25.45 | 620.92 | 25.57 | 30.48 | 35.25 | 34.46 | 6.77 |
| 12.00 | 3# | 598.26 | 25.21 | 607.27 | 29.56 | 32.18 | 29.44 | 32.14 | 23.16 |
| 12.00 | 4# | 597.92 | 25.34 | 606.73 | 29.74 | 30.53 | 29.78 | 31.88 | 23.11 |
| JDT6 | 0.00 | 1# | 645.78 | 9.54 | 651.11 | 9.46 | 37.31 | 11.09 | 39.72 | 7.53 |
| 0.00 | 2# | 646.78 | 9.50 | 651.01 | 9.56 | 36.95 | 11.81 | 39.84 | 7.52 |
| 0.00 | 3# | 646.17 | 9.56 | 651.27 | 9.30 | 36.91 | 11.35 | 39.94 | 7.56 |
| 0.00 | 4# | 648.58 | 9.55 | 652.58 | 9.57 | 36.92 | 11.00 | 39.98 | 7.54 |
| 1.00 | 1# | 642.68 | 9.54 | 648.31 | 9.46 | 39.34 | 12.29 | 39.35 | 7.65 |
| 1.00 | 2# | 643.58 | 9.50 | 648.40 | 9.56 | 38.96 | 11.81 | 39.46 | 7.67 |
| 1.00 | 3# | 643.44 | 9.56 | 648.23 | 9.43 | 39.17 | 11.90 | 39.57 | 7.70 |
| 1.00 | 4# | 648.34 | 9.55 | 655.40 | 10.05 | 34.10 | 11.52 | 40.62 | 8.15 |
| 2.00 | 1# | 637.25 | 9.54 | 643.14 | 9.46 | 38.87 | 14.45 | 38.79 | 7.70 |
| 2.00 | 2# | 638.14 | 9.50 | 643.72 | 9.69 | 38.57 | 14.36 | 38.91 | 7.75 |
| 2.00 | 3# | 638.54 | 9.67 | 643.42 | 9.58 | 37.37 | 14.19 | 39.01 | 7.77 |
| 2.00 | 4# | 646.21 | 11.34 | 657.21 | 10.96 | 31.16 | 11.90 | 41.00 | 8.93 |
| 3.00 | 1# | 633.66 | 9.37 | 638.81 | 9.46 | 37.81 | 25.54 | 38.22 | 7.62 |
| 3.00 | 2# | 634.15 | 9.50 | 638.87 | 9.32 | 37.35 | 14.68 | 38.32 | 7.65 |
| 3.00 | 3# | 634.76 | 9.41 | 639.26 | 9.30 | 35.76 | 14.62 | 38.40 | 7.69 |
| 3.00 | 4# | 646.81 | 12.10 | 661.11 | 12.08 | 27.07 | 12.34 | 41.34 | 9.88 |
| 4.00 | 1# | 631.24 | 9.45 | 635.95 | 9.46 | 36.07 | 26.20 | 37.72 | 7.57 |
| 4.00 | 2# | 632.13 | 9.50 | 635.73 | 9.32 | 33.27 | 25.96 | 37.81 | 7.58 |
| 4.00 | 3# | 631.97 | 9.41 | 635.95 | 9.43 | 36.05 | 15.45 | 37.87 | 7.61 |
| 4.00 | 4# | 645.61 | 12.63 | 663.59 | 12.76 | 22.63 | 12.64 | 41.69 | 10.72 |
| 5.00 | 1# | 628.22 | 9.45 | 633.03 | 9.46 | 32.89 | 37.34 | 37.32 | 7.43 |
| 5.00 | 2# | 628.96 | 9.50 | 632.72 | 9.69 | 16.59 | 37.48 | 37.39 | 7.42 |
| 5.00 | 3# | 628.40 | 9.41 | 632.60 | 9.43 | 35.93 | 30.50 | 37.44 | 7.45 |
| 5.00 | 4# | 641.39 | 12.92 | 662.12 | 13.21 | 17.02 | 13.25 | 41.90 | 11.42 |
| 6.00 | 1# | 625.12 | 9.45 | 630.69 | 9.46 | 31.32 | 34.20 | 37.12 | 7.21 |
| 6.00 | 2# | 625.87 | 9.50 | 630.70 | 9.30 | 4.89 | 37.48 | 37.18 | 7.24 |
| 6.00 | 3# | 626.01 | 9.41 | 630.74 | 9.30 | 32.89 | 30.78 | 37.20 | 7.26 |
| 6.00 | 4# | 634.16 | 13.51 | 657.23 | 13.74 | 11.02 | 13.78 | 41.79 | 12.12 |
| 7.00 | 1# | 626.49 | 9.37 | 631.47 | 9.46 | 36.02 | 20.81 | 37.09 | 7.15 |
| 7.00 | 2# | 626.65 | 9.50 | 631.37 | 9.30 | 35.88 | 36.32 | 37.15 | 7.18 |
| 7.00 | 3# | 626.64 | 9.41 | 631.32 | 9.30 | 37.15 | 31.29 | 37.16 | 7.18 |
| 7.00 | 4# | 626.56 | 10.74 | 648.79 | 14.34 | 7.10 | 14.27 | 41.18 | 12.82 |
| 8.00 | 1# | 627.70 | 9.37 | 632.75 | 9.46 | 37.81 | 31.88 | 37.09 | 7.15 |
| 8.00 | 2# | 628.16 | 9.50 | 632.90 | 9.30 | 37.64 | 32.00 | 37.15 | 7.18 |
| 8.00 | 3# | 628.14 | 9.41 | 632.83 | 9.30 | 39.17 | 31.86 | 37.16 | 7.18 |
| 8.00 | 4# | 627.91 | 9.55 | 637.42 | 14.86 | 3.33 | 14.82 | 40.07 | 13.51 |
| 9.00 | 1# | 626.21 | 9.45 | 632.60 | 9.46 | 35.83 | 32.45 | 37.09 | 7.15 |
| 9.00 | 2# | 627.01 | 9.50 | 632.23 | 9.30 | 36.86 | 32.26 | 37.15 | 7.18 |
| 9.00 | 3# | 626.65 | 9.41 | 632.30 | 9.30 | 37.09 | 29.07 | 37.16 | 7.18 |
| 9.00 | 4# | 624.15 | 10.05 | 630.56 | 10.05 | 5.38 | 15.51 | 38.37 | 14.16 |
| 10.00 | 1# | 625.87 | 9.37 | 632.55 | 9.46 | 37.03 | 33.00 | 37.09 | 7.15 |
| 10.00 | 2# | 626.30 | 9.50 | 632.27 | 9.30 | 36.80 | 29.35 | 37.15 | 7.18 |
| 10.00 | 3# | 626.06 | 9.41 | 632.29 | 9.30 | 35.40 | 29.35 | 37.16 | 7.18 |
| 10.00 | 4# | 615.16 | 10.87 | 621.76 | 10.96 | 7.81 | 16.24 | 35.99 | 14.90 |
| 11.00 | 1# | 625.87 | 9.37 | 632.55 | 9.46 | 34.08 | 35.92 | 37.09 | 7.15 |
| 11.00 | 2# | 626.30 | 9.50 | 632.27 | 9.30 | 34.64 | 33.44 | 37.15 | 7.18 |
| 11.00 | 3# | 626.06 | 9.41 | 632.29 | 9.30 | 37.91 | 30.14 | 37.16 | 7.18 |
| 11.00 | 4# | 612.18 | 9.55 | 615.74 | 31.18 | 11.66 | 17.06 | 33.18 | 15.75 |
| 12.00 | 1# | 625.87 | 9.37 | 632.55 | 9.46 | 27.84 | 36.76 | 37.09 | 7.15 |
| 12.00 | 2# | 626.30 | 9.50 | 632.27 | 9.30 | 31.11 | 33.44 | 37.15 | 7.18 |
| 12.00 | 3# | 626.06 | 9.41 | 632.29 | 9.30 | 25.06 | 33.31 | 37.16 | 7.18 |
| 12.00 | 4# | 614.33 | 31.09 | 623.83 | 30.93 | 21.30 | 17.66 | 31.58 | 28.92 |
| JDT10 | 0.00 | 1# | 645.78 | 9.54 | 651.11 | 9.46 | 37.31 | 11.09 | 39.72 | 7.53 |
| 0.00 | 2# | 646.78 | 9.50 | 651.01 | 9.56 | 36.95 | 11.81 | 39.84 | 7.52 |
| 0.00 | 3# | 646.17 | 9.56 | 651.27 | 9.30 | 36.91 | 11.35 | 39.94 | 7.56 |
| 0.00 | 4# | 648.58 | 9.55 | 652.58 | 9.57 | 36.92 | 11.00 | 39.98 | 7.54 |
| 1.00 | 1# | 638.95 | 10.46 | 643.50 | 9.93 | 34.33 | 14.74 | 38.79 | 8.05 |
| 1.00 | 2# | 644.69 | 10.60 | 650.99 | 10.58 | 36.46 | 11.81 | 39.97 | 8.39 |
| 1.00 | 3# | 645.68 | 10.59 | 652.28 | 10.33 | 35.94 | 11.90 | 40.08 | 8.39 |
| 1.00 | 4# | 646.08 | 10.44 | 653.40 | 10.05 | 37.12 | 11.90 | 40.14 | 8.41 |
| 2.00 | 1# | 631.63 | 10.97 | 634.69 | 10.96 | 24.12 | 15.87 | 37.49 | 8.73 |
| 2.00 | 2# | 644.93 | 11.58 | 650.70 | 11.42 | 37.17 | 12.88 | 39.87 | 9.25 |
| 2.00 | 3# | 645.66 | 11.56 | 652.64 | 11.58 | 36.91 | 12.62 | 40.00 | 9.27 |
| 2.00 | 4# | 645.96 | 11.43 | 652.67 | 10.96 | 36.03 | 12.64 | 40.07 | 9.30 |
| 3.00 | 1# | 623.89 | 12.24 | 625.01 | 11.56 | 18.86 | 16.53 | 35.85 | 9.48 |
| 3.00 | 2# | 642.01 | 12.67 | 648.76 | 12.02 | 38.19 | 13.25 | 39.61 | 10.17 |
| 3.00 | 3# | 642.18 | 12.23 | 649.94 | 12.13 | 37.45 | 13.62 | 39.75 | 10.18 |
| 3.00 | 4# | 643.35 | 12.23 | 650.22 | 12.21 | 37.24 | 13.62 | 39.83 | 10.18 |
| 4.00 | 1# | 620.55 | 13.51 | 636.51 | 17.09 | 16.90 | 17.14 | 34.66 | 15.30 |
| 4.00 | 2# | 639.09 | 13.48 | 645.79 | 12.76 | 40.10 | 12.35 | 39.22 | 11.00 |
| 4.00 | 3# | 639.70 | 13.43 | 646.73 | 12.95 | 39.36 | 14.47 | 39.38 | 11.04 |
| 4.00 | 4# | 640.48 | 13.44 | 647.69 | 12.92 | 39.38 | 14.44 | 39.47 | 11.06 |
| 5.00 | 1# | 626.40 | 17.68 | 646.33 | 17.79 | 16.55 | 17.65 | 35.37 | 16.07 |
| 5.00 | 2# | 635.10 | 14.12 | 641.47 | 14.10 | 39.05 | 34.78 | 38.70 | 11.81 |
| 5.00 | 3# | 635.83 | 14.14 | 642.52 | 13.85 | 39.16 | 35.22 | 38.88 | 11.82 |
| 5.00 | 4# | 636.39 | 13.91 | 643.80 | 13.88 | 38.64 | 34.87 | 39.00 | 11.82 |
| 6.00 | 1# | 628.39 | 18.46 | 649.43 | 18.30 | 17.49 | 18.40 | 35.24 | 16.79 |
| 6.00 | 2# | 628.60 | 14.68 | 634.20 | 14.10 | 36.02 | 24.69 | 38.03 | 12.42 |
| 6.00 | 3# | 629.95 | 14.66 | 635.59 | 14.66 | 36.86 | 35.87 | 38.25 | 12.52 |
| 6.00 | 4# | 631.33 | 14.91 | 637.92 | 14.78 | 37.30 | 28.15 | 38.41 | 12.53 |
| 7.00 | 1# | 624.99 | 19.15 | 643.91 | 19.13 | 19.79 | 19.09 | 34.13 | 17.57 |
| 7.00 | 2# | 620.18 | 14.92 | 625.16 | 14.94 | 36.52 | 36.51 | 37.09 | 13.00 |
| 7.00 | 3# | 621.74 | 14.83 | 626.67 | 14.86 | 36.07 | 36.48 | 37.35 | 13.04 |
| 7.00 | 4# | 622.79 | 14.91 | 629.01 | 14.94 | 36.28 | 36.58 | 37.55 | 13.10 |
| 8.00 | 1# | 615.48 | 20.19 | 634.26 | 20.25 | 21.80 | 20.35 | 32.44 | 18.57 |
| 8.00 | 2# | 613.04 | 39.02 | 618.28 | 38.87 | 32.86 | 37.93 | 35.36 | 14.01 |
| 8.00 | 3# | 608.88 | 38.98 | 611.18 | 38.84 | 34.17 | 37.76 | 35.67 | 14.12 |
| 8.00 | 4# | 612.01 | 39.13 | 614.83 | 39.03 | 32.85 | 40.93 | 35.89 | 14.14 |
| 9.00 | 1# | 617.55 | 21.44 | 632.50 | 21.45 | 27.29 | 21.47 | 31.84 | 6.24 |
| 9.00 | 2# | 603.81 | 18.74 | 605.87 | 18.82 | 32.96 | 45.51 | 34.56 | 16.65 |
| 9.00 | 3# | 604.30 | 18.58 | 607.49 | 18.56 | 33.86 | 39.24 | 34.73 | 16.45 |
| 9.00 | 4# | 605.97 | 18.74 | 609.81 | 18.76 | 34.30 | 42.59 | 34.88 | 16.39 |
| 10.00 | 1# | 623.54 | 22.65 | 636.45 | 22.63 | 26.30 | 32.40 | 31.84 | 6.24 |
| 10.00 | 2# | 609.72 | 19.94 | 613.07 | 19.95 | 38.00 | 25.66 | 35.14 | 18.23 |
| 10.00 | 3# | 610.32 | 19.83 | 613.04 | 19.82 | 38.68 | 35.58 | 35.19 | 18.09 |
| 10.00 | 4# | 610.53 | 19.80 | 613.78 | 19.65 | 37.25 | 43.93 | 35.23 | 18.03 |
| 11.00 | 1# | 629.49 | 23.91 | 639.50 | 23.83 | 25.10 | 33.37 | 31.84 | 6.24 |
| 11.00 | 2# | 615.42 | 20.58 | 619.27 | 20.56 | 37.07 | 41.59 | 36.04 | 19.34 |
| 11.00 | 3# | 615.82 | 20.66 | 620.01 | 20.58 | 37.87 | 44.71 | 36.09 | 19.30 |
| 11.00 | 4# | 616.40 | 20.73 | 620.88 | 20.68 | 37.46 | 44.97 | 36.11 | 19.31 |
| 12.00 | 1# | 633.26 | 24.08 | 642.16 | 24.50 | 33.20 | 34.06 | 31.84 | 6.24 |
| 12.00 | 2# | 622.52 | 23.81 | 626.85 | 23.30 | 37.96 | 42.35 | 36.96 | 20.38 |
| 12.00 | 3# | 623.22 | 23.84 | 627.49 | 23.19 | 37.49 | 42.38 | 37.04 | 20.32 |
| 12.00 | 4# | 624.16 | 23.81 | 628.76 | 23.31 | 37.48 | 42.35 | 37.07 | 20.30 |

|  |  |
| --- | --- |
| 图6.66 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.67 JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.68 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.69 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.70 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.71 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.72 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.73 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.4.5 30s-(80%)-70s两段关闭规律计算结果**

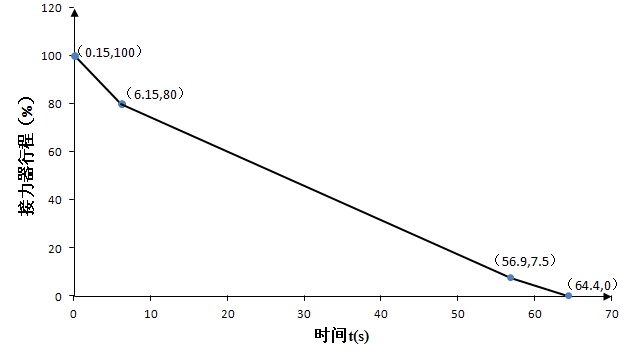


图6.74 水轮机工况导叶30s-(80%)-70s两段关闭规律

**表6-21 30s-(80%)-70s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 646.11 | 9.55 | 653.07 | 9.46 | 51.86 | 11.09 | 41.86 | 7.61 |
| 0.00 | 2# | 647.08 | 9.50 | 653.88 | 9.70 | 51.70 | 11.17 | 42.00 | 7.61 |
| 0.00 | 3# | 647.41 | 9.76 | 653.38 | 9.58 | 51.50 | 11.35 | 42.13 | 7.61 |
| 0.00 | 4# | 650.05 | 9.55 | 655.85 | 10.05 | 52.02 | 11.15 | 42.19 | 7.61 |
| SJT3 | 0.00 | 1# | 650.38 | 9.54 | 656.36 | 9.46 | 37.42 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 651.57 | 9.50 | 656.28 | 9.56 | 37.53 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 651.22 | 9.56 | 656.39 | 9.58 | 37.83 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 653.84 | 9.55 | 658.24 | 9.57 | 37.54 | 11.00 | 41.16 | 7.67 |
| ZT2 | 76.76 | 1# | 645.01 | 86.58 | 650.83 | 86.48 | 52.18 | 88.13 | 42.39 | 84.44 |
| 76.76 | 2# | 646.31 | 86.59 | 652.41 | 86.50 | 52.20 | 88.12 | 42.53 | 84.41 |
| 76.76 | 3# | 647.24 | 86.55 | 653.32 | 86.54 | 52.07 | 87.96 | 42.66 | 84.44 |
| 76.76 | 4# | 648.22 | 86.62 | 654.25 | 86.55 | 52.15 | 87.96 | 42.71 | 84.44 |
| JHT3 | 0.00 | 1# | 646.11 | 9.55 | 653.07 | 9.46 | 51.86 | 11.09 | 41.86 | 7.61 |
| 0.00 | 2# | 647.08 | 9.50 | 653.88 | 9.70 | 51.70 | 11.17 | 42.00 | 7.61 |
| 0.00 | 3# | 647.41 | 9.76 | 653.38 | 9.58 | 51.50 | 11.35 | 42.13 | 7.61 |
| 0.00 | 4# | 650.05 | 9.55 | 655.85 | 10.05 | 52.02 | 11.15 | 42.19 | 7.61 |
| 1.00 | 1# | 645.49 | 9.54 | 651.77 | 9.46 | 49.78 | 12.29 | 41.81 | 7.71 |
| 1.00 | 2# | 646.68 | 9.50 | 652.98 | 9.70 | 49.22 | 12.36 | 41.96 | 7.75 |
| 1.00 | 3# | 646.91 | 9.61 | 652.51 | 10.03 | 49.22 | 11.90 | 42.10 | 7.75 |
| 1.00 | 4# | 655.58 | 9.55 | 663.29 | 9.40 | 51.20 | 34.87 | 43.42 | 7.44 |
| 2.00 | 1# | 643.35 | 9.54 | 649.16 | 9.46 | 47.41 | 12.29 | 41.58 | 7.79 |
| 2.00 | 2# | 644.50 | 9.50 | 649.85 | 9.70 | 47.11 | 12.36 | 41.74 | 7.83 |
| 2.00 | 3# | 644.68 | 9.76 | 649.86 | 10.11 | 46.72 | 12.62 | 41.89 | 7.86 |
| 2.00 | 4# | 659.39 | 9.55 | 669.65 | 9.40 | 40.21 | 19.69 | 44.69 | 7.45 |
| 3.00 | 1# | 641.78 | 9.55 | 646.97 | 9.46 | 46.55 | 12.29 | 41.29 | 7.80 |
| 3.00 | 2# | 642.99 | 9.50 | 647.36 | 9.70 | 45.99 | 12.35 | 41.45 | 7.85 |
| 3.00 | 3# | 643.18 | 9.56 | 647.16 | 9.30 | 45.14 | 12.62 | 41.60 | 7.89 |
| 3.00 | 4# | 663.15 | 9.55 | 675.40 | 9.40 | 35.78 | 19.69 | 45.78 | 7.54 |
| 4.00 | 1# | 639.81 | 9.54 | 644.80 | 9.46 | 47.07 | 12.29 | 41.00 | 7.80 |
| 4.00 | 2# | 641.13 | 9.50 | 645.29 | 9.70 | 46.38 | 12.44 | 41.15 | 7.82 |
| 4.00 | 3# | 641.19 | 9.56 | 644.88 | 9.30 | 44.99 | 12.62 | 41.28 | 7.85 |
| 4.00 | 4# | 665.22 | 9.55 | 678.63 | 9.40 | 36.57 | 19.98 | 46.60 | 7.66 |
| 5.00 | 1# | 638.30 | 9.55 | 643.57 | 9.46 | 48.99 | 12.78 | 40.79 | 7.71 |
| 5.00 | 2# | 639.50 | 9.79 | 644.10 | 9.70 | 48.16 | 12.88 | 40.92 | 7.73 |
| 5.00 | 3# | 640.12 | 9.76 | 643.55 | 10.03 | 47.00 | 12.62 | 41.04 | 7.75 |
| 5.00 | 4# | 664.04 | 9.55 | 677.19 | 9.70 | 42.37 | 19.98 | 47.03 | 7.84 |
| 6.00 | 1# | 638.08 | 9.55 | 643.70 | 9.46 | 52.31 | 13.10 | 40.71 | 7.64 |
| 6.00 | 2# | 639.09 | 10.08 | 644.15 | 9.70 | 50.74 | 13.25 | 40.83 | 7.65 |
| 6.00 | 3# | 639.43 | 9.84 | 643.44 | 10.03 | 49.39 | 13.16 | 40.94 | 7.67 |
| 6.00 | 4# | 659.49 | 10.05 | 675.03 | 10.05 | 44.46 | 11.00 | 47.30 | 8.01 |
| 7.00 | 1# | 637.88 | 9.55 | 644.04 | 9.46 | 53.29 | 14.45 | 40.69 | 7.61 |
| 7.00 | 2# | 639.24 | 10.08 | 644.94 | 9.70 | 53.22 | 14.36 | 40.82 | 7.60 |
| 7.00 | 3# | 639.38 | 9.84 | 644.43 | 10.03 | 53.39 | 14.47 | 40.92 | 7.64 |
| 7.00 | 4# | 650.64 | 10.16 | 662.44 | 10.05 | 44.72 | 11.00 | 47.32 | 8.04 |
| 8.00 | 1# | 637.95 | 9.55 | 644.56 | 9.46 | 55.22 | 11.09 | 40.69 | 7.63 |
| 8.00 | 2# | 638.70 | 9.79 | 645.16 | 9.70 | 55.41 | 11.17 | 40.82 | 7.62 |
| 8.00 | 3# | 638.92 | 9.76 | 644.44 | 10.11 | 55.21 | 11.26 | 40.92 | 7.63 |
| 8.00 | 4# | 642.50 | 9.55 | 651.48 | 10.05 | 46.68 | 12.64 | 47.30 | 8.01 |
| 9.00 | 1# | 637.51 | 9.55 | 644.37 | 9.46 | 54.41 | 11.09 | 40.69 | 7.63 |
| 9.00 | 2# | 638.34 | 9.79 | 645.27 | 9.70 | 54.51 | 11.17 | 40.82 | 7.62 |
| 9.00 | 3# | 638.60 | 9.84 | 644.50 | 10.03 | 54.33 | 11.26 | 40.92 | 7.63 |
| 9.00 | 4# | 639.16 | 9.55 | 644.85 | 10.05 | 46.98 | 12.64 | 47.30 | 8.01 |
| 10.00 | 1# | 637.47 | 9.55 | 644.39 | 9.46 | 53.76 | 11.09 | 40.69 | 7.63 |
| 10.00 | 2# | 638.20 | 9.58 | 645.20 | 9.70 | 53.82 | 11.17 | 40.82 | 7.62 |
| 10.00 | 3# | 638.39 | 9.76 | 644.37 | 10.03 | 53.51 | 11.35 | 40.92 | 7.63 |
| 10.00 | 4# | 638.13 | 9.55 | 643.30 | 8.86 | 48.11 | 12.64 | 47.30 | 8.01 |
| 11.00 | 1# | 637.47 | 9.55 | 644.39 | 9.46 | 53.58 | 11.09 | 40.69 | 7.63 |
| 11.00 | 2# | 638.20 | 9.58 | 645.20 | 9.70 | 53.57 | 11.17 | 40.82 | 7.62 |
| 11.00 | 3# | 638.39 | 9.76 | 644.37 | 10.03 | 53.10 | 11.35 | 40.92 | 7.63 |
| 11.00 | 4# | 638.13 | 9.55 | 643.30 | 8.86 | 47.75 | 14.74 | 47.30 | 8.01 |
| 12.00 | 1# | 637.47 | 9.55 | 644.39 | 9.46 | 53.58 | 11.09 | 40.69 | 7.63 |
| 12.00 | 2# | 638.20 | 9.58 | 645.20 | 9.70 | 53.57 | 11.17 | 40.82 | 7.62 |
| 12.00 | 3# | 638.39 | 9.76 | 644.37 | 10.03 | 53.10 | 11.35 | 40.92 | 7.63 |
| 12.00 | 4# | 638.13 | 9.55 | 643.30 | 8.86 | 48.51 | 14.74 | 47.30 | 8.01 |
| JHT13 | 0.00 | 1# | 648.84 | 9.54 | 654.82 | 9.46 | 35.88 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 650.03 | 9.50 | 654.74 | 9.56 | 35.99 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 649.68 | 9.56 | 654.85 | 9.58 | 36.29 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 652.30 | 9.55 | 656.70 | 9.57 | 36.00 | 11.00 | 41.16 | 7.67 |
| 1.00 | 1# | 642.39 | 9.54 | 647.99 | 9.46 | 36.61 | 14.45 | 40.04 | 8.05 |
| 1.00 | 2# | 643.42 | 9.50 | 648.42 | 9.69 | 36.24 | 13.79 | 40.17 | 8.08 |
| 1.00 | 3# | 649.76 | 10.59 | 657.23 | 10.32 | 35.32 | 11.90 | 41.58 | 8.34 |
| 1.00 | 4# | 650.67 | 9.55 | 659.55 | 10.05 | 35.81 | 11.90 | 41.66 | 8.39 |
| 2.00 | 1# | 634.28 | 10.71 | 638.53 | 10.30 | 30.63 | 14.53 | 38.81 | 8.31 |
| 2.00 | 2# | 635.98 | 11.58 | 639.59 | 10.58 | 29.71 | 14.73 | 38.94 | 8.35 |
| 2.00 | 3# | 650.93 | 11.48 | 660.97 | 11.58 | 35.84 | 11.90 | 41.77 | 9.13 |
| 2.00 | 4# | 652.11 | 11.43 | 661.10 | 11.50 | 35.24 | 12.34 | 41.87 | 9.14 |
| 3.00 | 1# | 625.46 | 9.26 | 628.50 | 9.46 | 28.06 | 15.34 | 37.52 | 7.86 |
| 3.00 | 2# | 626.18 | 11.41 | 629.26 | 9.32 | 25.34 | 15.71 | 37.60 | 7.98 |
| 3.00 | 3# | 649.52 | 12.13 | 660.91 | 12.13 | 32.12 | 33.50 | 41.79 | 9.98 |
| 3.00 | 4# | 650.19 | 12.23 | 661.21 | 12.08 | 34.62 | 11.90 | 41.90 | 9.99 |
| 4.00 | 1# | 620.27 | 9.46 | 622.69 | 9.46 | 26.04 | 16.24 | 36.61 | 7.52 |
| 4.00 | 2# | 621.09 | 9.49 | 622.91 | 9.32 | 21.92 | 16.36 | 36.65 | 7.55 |
| 4.00 | 3# | 648.24 | 12.74 | 661.76 | 12.95 | 27.77 | 34.08 | 41.81 | 10.77 |
| 4.00 | 4# | 649.54 | 12.92 | 661.51 | 12.76 | 30.11 | 34.05 | 41.92 | 10.81 |
| 5.00 | 1# | 616.07 | 9.55 | 619.12 | 9.46 | 27.26 | 16.94 | 36.01 | 7.23 |
| 5.00 | 2# | 616.86 | 9.58 | 618.83 | 9.32 | 22.38 | 17.00 | 36.03 | 7.25 |
| 5.00 | 3# | 646.37 | 13.43 | 662.83 | 13.30 | 25.82 | 34.69 | 41.88 | 11.54 |
| 5.00 | 4# | 646.32 | 13.52 | 662.22 | 13.44 | 26.21 | 13.25 | 42.01 | 11.58 |
| 6.00 | 1# | 610.78 | 8.88 | 615.87 | 8.86 | 25.99 | 18.62 | 35.76 | 6.94 |
| 6.00 | 2# | 611.15 | 9.49 | 615.81 | 8.82 | 24.38 | 18.24 | 35.75 | 6.95 |
| 6.00 | 3# | 638.87 | 13.97 | 658.83 | 13.85 | 22.10 | 13.62 | 41.60 | 12.19 |
| 6.00 | 4# | 639.38 | 14.10 | 659.27 | 14.04 | 21.05 | 13.78 | 41.76 | 12.26 |
| 7.00 | 1# | 612.10 | 9.46 | 617.18 | 9.33 | 23.07 | 19.32 | 35.74 | 6.90 |
| 7.00 | 2# | 612.19 | 9.24 | 617.15 | 9.32 | 19.91 | 19.08 | 35.73 | 6.89 |
| 7.00 | 3# | 626.59 | 14.58 | 649.31 | 14.43 | 19.33 | 14.47 | 40.79 | 12.89 |
| 7.00 | 4# | 628.46 | 14.70 | 648.70 | 14.58 | 18.59 | 14.44 | 40.97 | 12.95 |
| 8.00 | 1# | 613.49 | 9.55 | 619.23 | 9.46 | 23.22 | 19.80 | 35.74 | 6.90 |
| 8.00 | 2# | 613.94 | 9.49 | 619.38 | 9.32 | 20.34 | 19.62 | 35.73 | 6.89 |
| 8.00 | 3# | 615.62 | 15.21 | 635.31 | 15.13 | 21.30 | 15.09 | 39.17 | 13.53 |
| 8.00 | 4# | 618.60 | 15.39 | 636.71 | 15.30 | 20.03 | 14.74 | 39.39 | 13.61 |
| 9.00 | 1# | 611.96 | 9.55 | 619.12 | 9.46 | 22.54 | 20.35 | 35.74 | 6.90 |
| 9.00 | 2# | 612.40 | 9.58 | 618.63 | 9.56 | 20.02 | 20.29 | 35.73 | 6.89 |
| 9.00 | 3# | 607.22 | 16.12 | 619.64 | 16.12 | 24.40 | 34.46 | 36.82 | 14.25 |
| 9.00 | 4# | 609.28 | 16.29 | 621.93 | 16.12 | 17.62 | 38.31 | 37.08 | 14.33 |
| 10.00 | 1# | 611.05 | 9.46 | 619.19 | 9.46 | 28.79 | 31.45 | 35.74 | 6.90 |
| 10.00 | 2# | 611.02 | 9.49 | 618.82 | 9.32 | 27.46 | 31.59 | 35.73 | 6.89 |
| 10.00 | 3# | 597.75 | 17.46 | 599.57 | 17.21 | 22.44 | 26.86 | 34.13 | 15.13 |
| 10.00 | 4# | 599.15 | 17.40 | 600.95 | 17.48 | 28.58 | 27.98 | 34.45 | 15.22 |
| 11.00 | 1# | 611.05 | 9.46 | 619.19 | 9.46 | 30.59 | 34.06 | 35.74 | 6.90 |
| 11.00 | 2# | 611.02 | 9.49 | 618.82 | 9.32 | 32.19 | 33.60 | 35.73 | 6.89 |
| 11.00 | 3# | 601.97 | 28.28 | 617.65 | 28.36 | 24.82 | 27.64 | 31.87 | 26.66 |
| 11.00 | 4# | 601.38 | 28.71 | 615.79 | 28.68 | 27.07 | 28.89 | 32.00 | 16.28 |
| 12.00 | 1# | 620.22 | 25.77 | 625.44 | 25.76 | 31.70 | 35.25 | 35.74 | 6.90 |
| 12.00 | 2# | 619.47 | 25.76 | 625.41 | 25.57 | 31.77 | 34.86 | 35.73 | 6.89 |
| 12.00 | 3# | 601.04 | 25.76 | 612.49 | 29.40 | 30.39 | 28.77 | 32.72 | 23.32 |
| 12.00 | 4# | 600.42 | 25.69 | 611.87 | 29.74 | 30.54 | 29.78 | 32.39 | 23.20 |
| JDT6 | 0.00 | 1# | 648.84 | 9.54 | 654.82 | 9.46 | 35.88 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 650.03 | 9.50 | 654.74 | 9.56 | 35.99 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 649.68 | 9.56 | 654.85 | 9.58 | 36.29 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 652.30 | 9.55 | 656.70 | 9.57 | 36.00 | 11.00 | 41.16 | 7.67 |
| 1.00 | 1# | 645.61 | 9.45 | 651.11 | 9.46 | 39.07 | 32.70 | 40.43 | 7.82 |
| 1.00 | 2# | 646.56 | 9.50 | 651.74 | 9.70 | 38.50 | 32.76 | 40.55 | 7.84 |
| 1.00 | 3# | 646.60 | 9.56 | 651.54 | 9.58 | 38.46 | 11.90 | 40.67 | 7.90 |
| 1.00 | 4# | 653.19 | 9.55 | 661.06 | 10.05 | 34.22 | 11.15 | 41.97 | 8.18 |
| 2.00 | 1# | 638.88 | 9.54 | 645.15 | 9.46 | 36.82 | 14.45 | 39.81 | 7.82 |
| 2.00 | 2# | 640.00 | 9.79 | 646.12 | 9.69 | 36.79 | 14.08 | 39.92 | 7.90 |
| 2.00 | 3# | 640.64 | 10.30 | 646.88 | 10.32 | 35.96 | 13.62 | 40.02 | 7.88 |
| 2.00 | 4# | 652.59 | 11.43 | 664.45 | 10.96 | 31.69 | 11.90 | 42.50 | 8.94 |
| 3.00 | 1# | 635.92 | 9.37 | 641.15 | 9.46 | 35.59 | 14.53 | 39.23 | 7.71 |
| 3.00 | 2# | 636.74 | 9.50 | 641.31 | 9.32 | 35.35 | 14.36 | 39.33 | 7.73 |
| 3.00 | 3# | 637.04 | 9.41 | 641.44 | 9.30 | 32.39 | 14.47 | 39.41 | 7.77 |
| 3.00 | 4# | 653.44 | 12.23 | 667.96 | 12.08 | 26.99 | 12.34 | 42.95 | 9.90 |
| 4.00 | 1# | 634.61 | 9.45 | 639.27 | 9.46 | 36.15 | 33.86 | 38.83 | 7.58 |
| 4.00 | 2# | 635.55 | 9.50 | 639.22 | 9.32 | 35.20 | 25.96 | 38.91 | 7.59 |
| 4.00 | 3# | 635.40 | 9.41 | 639.27 | 9.43 | 33.64 | 15.37 | 38.96 | 7.62 |
| 4.00 | 4# | 652.66 | 12.63 | 671.38 | 12.68 | 21.85 | 12.89 | 43.45 | 10.69 |
| 5.00 | 1# | 633.15 | 9.45 | 637.67 | 9.46 | 36.51 | 30.53 | 38.54 | 7.49 |
| 5.00 | 2# | 633.73 | 9.50 | 637.68 | 9.32 | 20.41 | 37.24 | 38.60 | 7.48 |
| 5.00 | 3# | 633.62 | 9.41 | 637.59 | 9.43 | 34.70 | 15.67 | 38.64 | 7.50 |
| 5.00 | 4# | 649.32 | 13.06 | 670.82 | 13.21 | 15.16 | 13.25 | 43.86 | 11.42 |
| 6.00 | 1# | 629.78 | 9.37 | 635.62 | 9.46 | 30.33 | 30.79 | 38.36 | 7.40 |
| 6.00 | 2# | 630.41 | 9.50 | 635.76 | 9.30 | 26.70 | 37.24 | 38.42 | 7.38 |
| 6.00 | 3# | 630.44 | 9.41 | 635.78 | 9.30 | 32.10 | 30.78 | 38.44 | 7.38 |
| 6.00 | 4# | 640.78 | 13.59 | 666.35 | 13.74 | 8.07 | 13.78 | 43.85 | 12.14 |
| 7.00 | 1# | 630.32 | 9.37 | 635.79 | 9.46 | 35.82 | 31.58 | 38.32 | 7.29 |
| 7.00 | 2# | 630.53 | 9.50 | 635.96 | 9.30 | 34.06 | 34.88 | 38.38 | 7.30 |
| 7.00 | 3# | 630.63 | 9.41 | 635.75 | 9.30 | 37.50 | 31.32 | 38.39 | 7.32 |
| 7.00 | 4# | 631.54 | 10.96 | 657.37 | 14.40 | 3.32 | 14.37 | 43.27 | 12.92 |
| 8.00 | 1# | 631.06 | 9.37 | 636.60 | 9.46 | 36.80 | 31.88 | 38.32 | 7.32 |
| 8.00 | 2# | 631.45 | 9.50 | 636.62 | 9.30 | 36.70 | 32.00 | 38.38 | 7.28 |
| 8.00 | 3# | 631.28 | 9.41 | 636.29 | 9.30 | 37.45 | 35.58 | 38.39 | 7.31 |
| 8.00 | 4# | 627.85 | 9.55 | 646.42 | 14.94 | 0.44 | 14.90 | 42.13 | 13.60 |
| 9.00 | 1# | 630.09 | 9.45 | 636.69 | 9.46 | 36.93 | 29.04 | 38.32 | 7.32 |
| 9.00 | 2# | 630.86 | 9.50 | 636.66 | 9.69 | 36.75 | 29.05 | 38.38 | 7.28 |
| 9.00 | 3# | 630.48 | 9.41 | 636.02 | 9.30 | 36.14 | 29.07 | 38.39 | 7.31 |
| 9.00 | 4# | 624.48 | 9.55 | 629.84 | 15.49 | 2.60 | 15.63 | 40.30 | 14.25 |
| 10.00 | 1# | 629.78 | 9.37 | 636.65 | 9.46 | 36.90 | 29.41 | 38.32 | 7.32 |
| 10.00 | 2# | 630.25 | 9.50 | 636.36 | 9.30 | 36.60 | 29.60 | 38.38 | 7.28 |
| 10.00 | 3# | 629.93 | 9.41 | 636.02 | 9.30 | 35.43 | 29.44 | 38.39 | 7.31 |
| 10.00 | 4# | 616.09 | 10.52 | 620.83 | 10.96 | 5.34 | 16.35 | 37.75 | 15.00 |
| 11.00 | 1# | 629.78 | 9.37 | 636.65 | 9.46 | 35.80 | 33.86 | 38.32 | 7.32 |
| 11.00 | 2# | 630.25 | 9.50 | 636.36 | 9.30 | 34.63 | 33.76 | 38.38 | 7.28 |
| 11.00 | 3# | 629.93 | 9.41 | 636.02 | 9.30 | 37.78 | 30.33 | 38.39 | 7.31 |
| 11.00 | 4# | 616.14 | 31.44 | 623.36 | 31.55 | 8.81 | 17.13 | 34.84 | 15.90 |
| 12.00 | 1# | 629.78 | 9.37 | 636.65 | 9.46 | 36.07 | 21.47 | 38.32 | 7.32 |
| 12.00 | 2# | 630.25 | 9.50 | 636.36 | 9.30 | 31.94 | 33.52 | 38.38 | 7.28 |
| 12.00 | 3# | 629.93 | 9.41 | 636.02 | 9.30 | 31.27 | 33.31 | 38.39 | 7.31 |
| 12.00 | 4# | 616.31 | 31.00 | 628.31 | 30.93 | 17.92 | 17.88 | 32.38 | 28.95 |
| JDT10 | 0.00 | 1# | 648.84 | 9.54 | 654.82 | 9.46 | 35.88 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 650.03 | 9.50 | 654.74 | 9.56 | 35.99 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 649.68 | 9.56 | 654.85 | 9.58 | 36.29 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 652.30 | 9.55 | 656.70 | 9.57 | 36.00 | 11.00 | 41.16 | 7.67 |
| 1.00 | 1# | 641.54 | 10.46 | 645.63 | 10.36 | 31.36 | 14.45 | 39.73 | 8.28 |
| 1.00 | 2# | 648.23 | 10.60 | 655.21 | 10.58 | 36.41 | 11.81 | 41.20 | 8.48 |
| 1.00 | 3# | 649.55 | 10.30 | 656.71 | 10.32 | 35.44 | 11.90 | 41.32 | 8.51 |
| 1.00 | 4# | 650.23 | 10.44 | 657.86 | 10.05 | 36.21 | 11.90 | 41.38 | 8.50 |
| 2.00 | 1# | 634.84 | 11.55 | 636.20 | 10.96 | 22.99 | 15.34 | 38.18 | 9.12 |
| 2.00 | 2# | 649.58 | 11.58 | 655.34 | 11.42 | 37.41 | 12.53 | 41.16 | 9.34 |
| 2.00 | 3# | 650.35 | 11.56 | 657.74 | 11.58 | 36.95 | 12.62 | 41.30 | 9.36 |
| 2.00 | 4# | 650.54 | 11.49 | 657.60 | 10.96 | 36.57 | 12.64 | 41.38 | 9.37 |
| 3.00 | 1# | 628.38 | 12.24 | 635.02 | 16.20 | 16.60 | 16.34 | 36.25 | 10.01 |
| 3.00 | 2# | 647.54 | 12.67 | 653.72 | 12.31 | 37.87 | 13.78 | 40.95 | 10.20 |
| 3.00 | 3# | 647.32 | 12.56 | 654.72 | 12.13 | 37.48 | 13.62 | 41.10 | 10.22 |
| 3.00 | 4# | 648.30 | 12.53 | 655.51 | 12.02 | 36.65 | 13.78 | 41.20 | 10.23 |
| 4.00 | 1# | 626.51 | 13.51 | 647.81 | 16.98 | 14.63 | 17.02 | 36.40 | 15.38 |
| 4.00 | 2# | 643.90 | 13.24 | 651.46 | 12.84 | 39.36 | 11.17 | 40.62 | 11.00 |
| 4.00 | 3# | 645.20 | 13.31 | 652.28 | 12.95 | 38.66 | 11.26 | 40.80 | 11.07 |
| 4.00 | 4# | 646.38 | 13.44 | 653.32 | 12.92 | 38.26 | 14.74 | 40.91 | 11.07 |
| 5.00 | 1# | 633.29 | 17.68 | 655.85 | 17.55 | 12.30 | 17.65 | 36.84 | 16.23 |
| 5.00 | 2# | 643.52 | 13.84 | 650.20 | 13.58 | 35.85 | 24.08 | 40.33 | 11.80 |
| 5.00 | 3# | 644.22 | 13.86 | 651.03 | 13.85 | 37.69 | 11.90 | 40.52 | 11.83 |
| 5.00 | 4# | 645.20 | 14.01 | 652.26 | 13.88 | 37.68 | 11.82 | 40.66 | 11.89 |
| 6.00 | 1# | 637.32 | 15.30 | 657.18 | 18.16 | 14.19 | 18.25 | 36.45 | 16.94 |
| 6.00 | 2# | 640.88 | 14.68 | 646.02 | 14.10 | 29.93 | 24.76 | 39.87 | 12.45 |
| 6.00 | 3# | 641.69 | 14.83 | 647.56 | 14.38 | 35.64 | 35.50 | 40.10 | 12.52 |
| 6.00 | 4# | 642.88 | 14.70 | 648.48 | 14.40 | 35.30 | 27.98 | 40.25 | 12.55 |
| 7.00 | 1# | 631.24 | 19.26 | 650.25 | 19.13 | 20.45 | 19.32 | 34.91 | 17.72 |
| 7.00 | 2# | 630.14 | 15.36 | 635.08 | 14.94 | 33.03 | 25.14 | 38.72 | 13.08 |
| 7.00 | 3# | 631.60 | 15.49 | 635.77 | 15.21 | 34.01 | 36.49 | 38.99 | 13.14 |
| 7.00 | 4# | 633.34 | 15.39 | 638.40 | 14.94 | 34.50 | 36.58 | 39.18 | 13.22 |
| 8.00 | 1# | 622.13 | 20.38 | 640.77 | 20.47 | 22.67 | 20.35 | 33.14 | 6.35 |
| 8.00 | 2# | 609.72 | 16.11 | 613.42 | 38.64 | 31.30 | 37.63 | 36.63 | 14.06 |
| 8.00 | 3# | 611.76 | 16.04 | 615.64 | 16.04 | 31.46 | 37.60 | 36.96 | 14.08 |
| 8.00 | 4# | 613.37 | 16.06 | 618.34 | 15.91 | 29.67 | 40.93 | 37.20 | 14.21 |
| 9.00 | 1# | 621.19 | 21.64 | 635.72 | 21.65 | 27.41 | 21.69 | 33.14 | 6.35 |
| 9.00 | 2# | 604.90 | 19.38 | 607.31 | 19.28 | 34.44 | 34.95 | 35.41 | 16.49 |
| 9.00 | 3# | 605.84 | 19.30 | 609.20 | 19.32 | 33.01 | 39.40 | 35.65 | 16.36 |
| 9.00 | 4# | 607.30 | 19.28 | 610.42 | 19.42 | 31.33 | 42.42 | 35.85 | 16.22 |
| 10.00 | 1# | 626.19 | 22.93 | 638.82 | 22.71 | 25.73 | 32.56 | 33.14 | 6.35 |
| 10.00 | 2# | 610.35 | 20.12 | 614.04 | 19.94 | 36.64 | 25.83 | 36.00 | 18.37 |
| 10.00 | 3# | 611.48 | 19.93 | 614.71 | 20.00 | 38.35 | 25.70 | 36.08 | 18.26 |
| 10.00 | 4# | 611.63 | 20.05 | 615.79 | 20.02 | 36.00 | 43.77 | 36.12 | 18.11 |
| 11.00 | 1# | 634.04 | 23.91 | 644.20 | 23.92 | 24.60 | 33.23 | 33.14 | 6.35 |
| 11.00 | 2# | 617.79 | 23.21 | 621.50 | 22.94 | 36.21 | 41.47 | 37.01 | 19.53 |
| 11.00 | 3# | 617.71 | 23.17 | 621.71 | 22.67 | 36.55 | 41.34 | 37.06 | 19.49 |
| 11.00 | 4# | 618.31 | 23.31 | 623.09 | 22.64 | 36.81 | 44.75 | 37.09 | 19.40 |
| 12.00 | 1# | 638.44 | 24.42 | 647.36 | 24.50 | 33.55 | 33.98 | 33.14 | 6.35 |
| 12.00 | 2# | 628.32 | 23.81 | 631.68 | 23.30 | 36.82 | 42.12 | 38.02 | 20.53 |
| 12.00 | 3# | 629.05 | 23.84 | 632.44 | 23.56 | 36.61 | 42.10 | 38.10 | 20.51 |
| 12.00 | 4# | 629.25 | 23.92 | 633.42 | 23.31 | 36.79 | 26.79 | 38.14 | 20.51 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.75 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.76 JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.77 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.78 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.79 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.80 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.81 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.82 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.4.6 30s-(80%)-80s两段关闭规律计算结果**

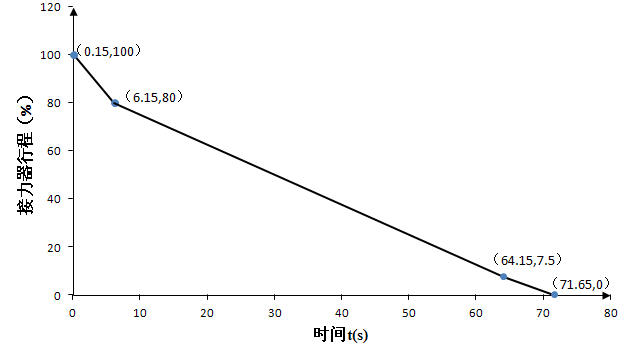


图6.83 水轮机工况导叶30s-(80%)-80s两段关闭规律

**表6-22 30s-(80%)-80s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 643.75 | 9.55 | 650.60 | 9.46 | 52.26 | 11.09 | 41.84 | 7.61 |
| 0.00 | 2# | 644.64 | 9.50 | 651.45 | 9.70 | 52.23 | 11.17 | 41.98 | 7.59 |
| 0.00 | 3# | 644.98 | 9.76 | 650.81 | 9.78 | 52.03 | 11.26 | 42.11 | 7.62 |
| 0.00 | 4# | 647.66 | 9.55 | 653.45 | 10.05 | 52.34 | 11.15 | 42.16 | 7.61 |
| SJT3 | 0.00 | 1# | 647.45 | 9.54 | 652.98 | 9.46 | 38.90 | 11.09 | 41.02 | 7.72 |
| 0.00 | 2# | 648.25 | 9.50 | 652.94 | 9.56 | 38.77 | 11.17 | 41.14 | 7.71 |
| 0.00 | 3# | 647.90 | 9.56 | 653.12 | 9.30 | 38.78 | 11.26 | 41.24 | 7.70 |
| 0.00 | 4# | 650.26 | 9.55 | 654.92 | 9.40 | 38.64 | 11.00 | 41.29 | 7.73 |
| ZT2 | 76.76 | 1# | 642.70 | 86.58 | 648.47 | 86.48 | 52.78 | 88.13 | 42.37 | 84.42 |
| 76.76 | 2# | 643.77 | 86.57 | 649.74 | 86.50 | 52.64 | 87.92 | 42.51 | 84.42 |
| 76.76 | 3# | 644.69 | 86.56 | 650.63 | 86.54 | 52.49 | 87.99 | 42.63 | 84.42 |
| 76.76 | 4# | 645.69 | 86.64 | 651.54 | 86.64 | 52.63 | 87.97 | 42.68 | 84.41 |
| JHT3 | 0.00 | 1# | 643.75 | 9.55 | 650.60 | 9.46 | 52.26 | 11.09 | 41.84 | 7.61 |
| 0.00 | 2# | 644.64 | 9.50 | 651.45 | 9.70 | 52.23 | 11.17 | 41.98 | 7.59 |
| 0.00 | 3# | 644.98 | 9.76 | 650.81 | 9.78 | 52.03 | 11.26 | 42.11 | 7.62 |
| 0.00 | 4# | 647.66 | 9.55 | 653.45 | 10.05 | 52.34 | 11.15 | 42.16 | 7.61 |
| 1.00 | 1# | 643.38 | 9.54 | 649.54 | 9.46 | 50.38 | 12.29 | 41.80 | 7.69 |
| 1.00 | 2# | 644.62 | 9.50 | 650.42 | 9.70 | 50.15 | 12.36 | 41.95 | 7.72 |
| 1.00 | 3# | 644.65 | 9.61 | 650.12 | 10.11 | 49.75 | 11.90 | 42.09 | 7.76 |
| 1.00 | 4# | 653.76 | 9.55 | 661.54 | 9.40 | 52.89 | 19.69 | 43.39 | 7.44 |
| 2.00 | 1# | 641.63 | 9.54 | 647.05 | 9.46 | 48.10 | 12.29 | 41.58 | 7.78 |
| 2.00 | 2# | 642.72 | 9.50 | 647.55 | 9.70 | 47.75 | 12.36 | 41.73 | 7.82 |
| 2.00 | 3# | 642.67 | 9.41 | 647.28 | 10.11 | 47.22 | 11.90 | 41.88 | 7.83 |
| 2.00 | 4# | 657.80 | 9.55 | 668.78 | 8.86 | 39.11 | 19.69 | 44.66 | 7.42 |
| 3.00 | 1# | 639.88 | 9.55 | 645.00 | 9.46 | 47.00 | 12.29 | 41.28 | 7.82 |
| 3.00 | 2# | 641.32 | 9.50 | 645.21 | 9.70 | 46.51 | 12.36 | 41.44 | 7.82 |
| 3.00 | 3# | 641.55 | 9.41 | 645.45 | 9.43 | 45.77 | 12.62 | 41.58 | 7.89 |
| 3.00 | 4# | 661.86 | 9.55 | 674.32 | 9.40 | 34.85 | 19.69 | 45.75 | 7.52 |
| 4.00 | 1# | 638.07 | 9.54 | 642.97 | 9.46 | 47.23 | 12.29 | 40.99 | 7.80 |
| 4.00 | 2# | 639.56 | 9.50 | 643.03 | 9.70 | 46.63 | 12.36 | 41.13 | 7.84 |
| 4.00 | 3# | 639.74 | 9.56 | 643.28 | 9.43 | 45.60 | 12.62 | 41.27 | 7.86 |
| 4.00 | 4# | 664.29 | 9.55 | 677.96 | 9.40 | 35.07 | 19.98 | 46.56 | 7.65 |
| 5.00 | 1# | 636.61 | 9.55 | 641.54 | 9.46 | 49.62 | 12.29 | 40.78 | 7.73 |
| 5.00 | 2# | 637.73 | 9.50 | 641.89 | 9.70 | 48.80 | 12.88 | 40.92 | 7.74 |
| 5.00 | 3# | 638.14 | 9.76 | 641.45 | 9.30 | 47.54 | 12.62 | 41.03 | 7.78 |
| 5.00 | 4# | 663.76 | 9.55 | 676.93 | 9.57 | 40.71 | 19.98 | 46.99 | 7.85 |
| 6.00 | 1# | 636.11 | 9.54 | 641.78 | 9.46 | 51.84 | 14.45 | 40.69 | 7.67 |
| 6.00 | 2# | 637.32 | 9.50 | 641.86 | 9.70 | 51.24 | 13.25 | 40.82 | 7.66 |
| 6.00 | 3# | 637.40 | 9.84 | 641.04 | 9.43 | 49.82 | 13.16 | 40.92 | 7.67 |
| 6.00 | 4# | 658.63 | 10.16 | 674.46 | 10.05 | 44.44 | 11.00 | 47.25 | 7.98 |
| 7.00 | 1# | 635.68 | 9.55 | 641.93 | 9.46 | 53.19 | 14.53 | 40.67 | 7.61 |
| 7.00 | 2# | 636.90 | 10.08 | 642.48 | 9.70 | 53.05 | 14.36 | 40.80 | 7.62 |
| 7.00 | 3# | 637.18 | 10.21 | 642.00 | 10.03 | 52.40 | 14.47 | 40.91 | 7.66 |
| 7.00 | 4# | 649.89 | 10.16 | 662.06 | 10.05 | 44.89 | 11.00 | 47.26 | 8.04 |
| 8.00 | 1# | 635.46 | 9.55 | 642.05 | 9.46 | 55.67 | 11.09 | 40.67 | 7.61 |
| 8.00 | 2# | 636.51 | 9.79 | 642.73 | 9.70 | 55.82 | 11.17 | 40.80 | 7.64 |
| 8.00 | 3# | 636.60 | 9.84 | 642.24 | 10.03 | 55.49 | 14.47 | 40.91 | 7.66 |
| 8.00 | 4# | 641.83 | 10.05 | 651.43 | 10.05 | 47.07 | 11.90 | 47.25 | 8.00 |
| 9.00 | 1# | 635.11 | 9.55 | 641.93 | 9.46 | 54.87 | 11.09 | 40.67 | 7.61 |
| 9.00 | 2# | 636.21 | 9.79 | 642.84 | 9.70 | 55.13 | 11.17 | 40.80 | 7.64 |
| 9.00 | 3# | 636.41 | 9.84 | 642.21 | 10.03 | 54.98 | 11.26 | 40.91 | 7.66 |
| 9.00 | 4# | 638.50 | 9.55 | 644.52 | 10.05 | 47.90 | 12.64 | 47.25 | 8.00 |
| 10.00 | 1# | 635.06 | 9.55 | 641.93 | 9.46 | 54.19 | 11.09 | 40.67 | 7.61 |
| 10.00 | 2# | 636.08 | 9.50 | 642.76 | 9.70 | 54.34 | 11.17 | 40.80 | 7.64 |
| 10.00 | 3# | 636.16 | 9.84 | 642.10 | 10.03 | 54.19 | 11.26 | 40.91 | 7.66 |
| 10.00 | 4# | 637.43 | 9.55 | 642.93 | 8.86 | 49.44 | 11.90 | 47.25 | 8.00 |
| 11.00 | 1# | 635.06 | 9.55 | 641.93 | 9.46 | 54.03 | 11.09 | 40.67 | 7.61 |
| 11.00 | 2# | 636.08 | 9.50 | 642.76 | 9.70 | 54.07 | 11.17 | 40.80 | 7.64 |
| 11.00 | 3# | 636.16 | 9.84 | 642.10 | 10.03 | 53.69 | 11.35 | 40.91 | 7.66 |
| 11.00 | 4# | 637.43 | 9.55 | 642.93 | 8.86 | 50.15 | 14.74 | 47.25 | 8.00 |
| 12.00 | 1# | 635.06 | 9.55 | 641.93 | 9.46 | 54.03 | 11.09 | 40.67 | 7.61 |
| 12.00 | 2# | 636.08 | 9.50 | 642.76 | 9.70 | 54.07 | 11.17 | 40.80 | 7.64 |
| 12.00 | 3# | 636.16 | 9.84 | 642.10 | 10.03 | 53.69 | 11.35 | 40.91 | 7.66 |
| 12.00 | 4# | 637.43 | 9.55 | 642.93 | 8.86 | 51.28 | 14.74 | 47.25 | 8.00 |
| JHT13 | 0.00 | 1# | 645.91 | 9.54 | 651.44 | 9.46 | 37.36 | 11.09 | 41.02 | 7.72 |
| 0.00 | 2# | 646.71 | 9.50 | 651.40 | 9.56 | 37.23 | 11.17 | 41.14 | 7.71 |
| 0.00 | 3# | 646.36 | 9.56 | 651.58 | 9.30 | 37.24 | 11.26 | 41.24 | 7.70 |
| 0.00 | 4# | 648.72 | 9.55 | 653.38 | 9.40 | 37.10 | 11.00 | 41.29 | 7.73 |
| 1.00 | 1# | 639.14 | 9.45 | 644.79 | 9.46 | 35.97 | 14.45 | 40.20 | 8.12 |
| 1.00 | 2# | 640.22 | 9.50 | 645.09 | 10.06 | 36.27 | 14.36 | 40.32 | 8.10 |
| 1.00 | 3# | 646.31 | 10.21 | 654.13 | 10.32 | 35.76 | 11.90 | 41.72 | 8.38 |
| 1.00 | 4# | 647.67 | 9.55 | 656.32 | 10.05 | 36.20 | 11.90 | 41.79 | 8.39 |
| 2.00 | 1# | 631.73 | 11.46 | 635.60 | 10.30 | 32.02 | 15.16 | 38.99 | 8.37 |
| 2.00 | 2# | 633.25 | 11.41 | 636.67 | 10.95 | 31.49 | 15.27 | 39.11 | 8.49 |
| 2.00 | 3# | 648.05 | 11.48 | 657.30 | 11.58 | 36.44 | 12.46 | 41.90 | 9.16 |
| 2.00 | 4# | 648.86 | 11.49 | 657.81 | 11.50 | 36.03 | 12.34 | 42.00 | 9.18 |
| 3.00 | 1# | 623.11 | 9.27 | 625.64 | 8.86 | 29.15 | 16.24 | 37.68 | 7.95 |
| 3.00 | 2# | 623.79 | 9.24 | 626.66 | 9.32 | 26.96 | 15.80 | 37.78 | 8.04 |
| 3.00 | 3# | 646.53 | 12.13 | 657.63 | 12.13 | 34.59 | 33.79 | 41.90 | 10.00 |
| 3.00 | 4# | 647.34 | 12.23 | 657.90 | 12.08 | 34.40 | 13.25 | 42.01 | 10.02 |
| 4.00 | 1# | 618.07 | 9.37 | 620.28 | 9.46 | 28.17 | 16.24 | 36.81 | 7.56 |
| 4.00 | 2# | 618.84 | 9.50 | 620.42 | 9.32 | 23.99 | 16.36 | 36.84 | 7.56 |
| 4.00 | 3# | 644.91 | 12.80 | 658.16 | 12.95 | 31.87 | 34.69 | 41.89 | 10.79 |
| 4.00 | 4# | 645.26 | 12.92 | 657.63 | 12.68 | 32.37 | 13.25 | 42.01 | 10.83 |
| 5.00 | 1# | 613.95 | 9.45 | 616.69 | 9.46 | 27.67 | 16.94 | 36.21 | 7.29 |
| 5.00 | 2# | 614.69 | 9.58 | 616.35 | 9.32 | 24.37 | 17.00 | 36.23 | 7.32 |
| 5.00 | 3# | 642.88 | 13.43 | 658.36 | 13.48 | 27.58 | 35.42 | 41.93 | 11.55 |
| 5.00 | 4# | 642.74 | 13.52 | 657.90 | 13.50 | 27.93 | 13.25 | 42.06 | 11.61 |
| 6.00 | 1# | 608.49 | 8.88 | 613.64 | 8.86 | 26.04 | 19.01 | 35.95 | 6.99 |
| 6.00 | 2# | 608.69 | 9.24 | 613.29 | 8.82 | 24.66 | 18.43 | 35.95 | 7.00 |
| 6.00 | 3# | 636.59 | 13.97 | 655.20 | 13.95 | 23.14 | 35.95 | 41.63 | 12.23 |
| 6.00 | 4# | 637.39 | 14.18 | 655.80 | 14.04 | 23.36 | 13.78 | 41.79 | 12.29 |
| 7.00 | 1# | 610.02 | 9.37 | 615.08 | 9.33 | 24.08 | 19.61 | 35.93 | 6.95 |
| 7.00 | 2# | 609.85 | 9.28 | 614.90 | 9.32 | 20.37 | 40.14 | 35.92 | 6.91 |
| 7.00 | 3# | 625.35 | 14.66 | 645.30 | 14.66 | 16.96 | 36.49 | 40.83 | 12.96 |
| 7.00 | 4# | 627.34 | 14.79 | 647.21 | 14.78 | 20.27 | 36.75 | 41.02 | 13.00 |
| 8.00 | 1# | 610.99 | 9.37 | 616.60 | 9.33 | 24.20 | 20.13 | 35.93 | 6.95 |
| 8.00 | 2# | 611.00 | 9.49 | 616.66 | 9.32 | 21.52 | 19.98 | 35.92 | 6.91 |
| 8.00 | 3# | 613.62 | 15.21 | 634.11 | 15.21 | 17.44 | 37.08 | 39.33 | 13.62 |
| 8.00 | 4# | 617.59 | 15.45 | 635.38 | 15.41 | 19.83 | 37.27 | 39.55 | 13.68 |
| 9.00 | 1# | 609.06 | 9.55 | 616.09 | 9.46 | 23.10 | 20.29 | 35.93 | 6.95 |
| 9.00 | 2# | 609.77 | 9.58 | 615.86 | 9.32 | 20.90 | 20.51 | 35.92 | 6.91 |
| 9.00 | 3# | 605.53 | 16.12 | 619.29 | 16.12 | 25.75 | 37.38 | 37.15 | 14.31 |
| 9.00 | 4# | 608.71 | 16.42 | 620.99 | 16.19 | 18.46 | 38.31 | 37.41 | 14.37 |
| 10.00 | 1# | 608.19 | 9.46 | 616.15 | 9.46 | 29.05 | 31.88 | 35.93 | 6.95 |
| 10.00 | 2# | 608.30 | 9.49 | 616.09 | 9.32 | 26.11 | 31.78 | 35.92 | 6.91 |
| 10.00 | 3# | 595.83 | 17.54 | 598.76 | 17.21 | 21.95 | 27.14 | 34.48 | 15.14 |
| 10.00 | 4# | 597.48 | 17.47 | 599.90 | 17.32 | 29.95 | 27.63 | 34.79 | 15.22 |
| 11.00 | 1# | 608.19 | 9.46 | 616.15 | 9.46 | 29.60 | 34.26 | 35.93 | 6.95 |
| 11.00 | 2# | 608.30 | 9.49 | 616.09 | 9.32 | 28.79 | 33.60 | 35.92 | 6.91 |
| 11.00 | 3# | 599.48 | 28.58 | 615.90 | 28.55 | 24.97 | 28.49 | 32.71 | 26.87 |
| 11.00 | 4# | 597.68 | 29.08 | 612.33 | 29.15 | 25.96 | 29.04 | 32.49 | 27.23 |
| 12.00 | 1# | 610.77 | 25.79 | 616.15 | 9.46 | 29.67 | 35.61 | 35.93 | 6.95 |
| 12.00 | 2# | 610.40 | 25.85 | 616.09 | 9.32 | 28.23 | 35.62 | 35.92 | 6.91 |
| 12.00 | 3# | 597.37 | 25.87 | 603.67 | 30.09 | 31.07 | 30.20 | 32.79 | 23.95 |
| 12.00 | 4# | 596.75 | 26.03 | 602.77 | 30.43 | 29.11 | 30.47 | 32.41 | 23.94 |
| JDT6 | 0.00 | 1# | 645.91 | 9.54 | 651.44 | 9.46 | 37.36 | 11.09 | 41.02 | 7.72 |
| 0.00 | 2# | 646.71 | 9.50 | 651.40 | 9.56 | 37.23 | 11.17 | 41.14 | 7.71 |
| 0.00 | 3# | 646.36 | 9.56 | 651.58 | 9.30 | 37.24 | 11.26 | 41.24 | 7.70 |
| 0.00 | 4# | 648.72 | 9.55 | 653.38 | 9.40 | 37.10 | 11.00 | 41.29 | 7.73 |
| 1.00 | 1# | 642.83 | 9.54 | 647.98 | 9.46 | 39.55 | 14.45 | 40.59 | 7.90 |
| 1.00 | 2# | 643.46 | 9.50 | 648.25 | 9.56 | 39.50 | 11.81 | 40.71 | 7.91 |
| 1.00 | 3# | 643.30 | 9.56 | 648.29 | 9.58 | 39.42 | 11.90 | 40.81 | 7.94 |
| 1.00 | 4# | 649.70 | 9.55 | 657.58 | 10.05 | 35.17 | 11.00 | 42.10 | 8.25 |
| 2.00 | 1# | 636.08 | 9.45 | 642.03 | 9.93 | 37.16 | 14.53 | 39.96 | 7.94 |
| 2.00 | 2# | 637.01 | 9.50 | 642.72 | 9.69 | 36.43 | 14.36 | 40.07 | 7.91 |
| 2.00 | 3# | 637.47 | 9.84 | 643.51 | 10.32 | 36.69 | 14.19 | 40.18 | 7.96 |
| 2.00 | 4# | 649.65 | 11.49 | 661.06 | 10.96 | 30.34 | 34.87 | 42.62 | 8.97 |
| 3.00 | 1# | 633.24 | 9.45 | 638.28 | 9.46 | 34.85 | 25.54 | 39.39 | 7.75 |
| 3.00 | 2# | 633.81 | 9.50 | 638.25 | 9.32 | 35.49 | 25.60 | 39.48 | 7.78 |
| 3.00 | 3# | 634.28 | 9.41 | 638.78 | 9.30 | 34.25 | 14.47 | 39.56 | 7.83 |
| 3.00 | 4# | 649.88 | 12.02 | 663.58 | 12.08 | 27.81 | 12.34 | 43.03 | 9.91 |
| 4.00 | 1# | 631.97 | 9.45 | 636.38 | 9.46 | 35.31 | 26.20 | 39.00 | 7.63 |
| 4.00 | 2# | 632.77 | 9.50 | 636.30 | 9.32 | 32.16 | 25.96 | 39.08 | 7.63 |
| 4.00 | 3# | 632.58 | 9.41 | 636.06 | 9.43 | 34.28 | 15.37 | 39.13 | 7.64 |
| 4.00 | 4# | 649.21 | 12.65 | 667.16 | 12.68 | 22.89 | 12.89 | 43.48 | 10.71 |
| 5.00 | 1# | 630.33 | 9.45 | 634.93 | 9.46 | 36.72 | 33.86 | 38.71 | 7.56 |
| 5.00 | 2# | 631.13 | 9.50 | 634.72 | 9.30 | 32.76 | 34.00 | 38.77 | 7.54 |
| 5.00 | 3# | 631.09 | 9.41 | 634.68 | 9.49 | 35.66 | 15.73 | 38.81 | 7.56 |
| 5.00 | 4# | 646.04 | 13.20 | 666.84 | 13.22 | 16.50 | 13.25 | 43.83 | 11.45 |
| 6.00 | 1# | 627.07 | 9.37 | 632.71 | 9.46 | 34.51 | 34.49 | 38.54 | 7.42 |
| 6.00 | 2# | 627.53 | 9.50 | 632.86 | 9.30 | 35.03 | 23.64 | 38.59 | 7.42 |
| 6.00 | 3# | 627.74 | 9.41 | 632.89 | 9.30 | 35.20 | 34.16 | 38.62 | 7.45 |
| 6.00 | 4# | 637.43 | 13.64 | 662.92 | 13.81 | 9.69 | 13.78 | 43.78 | 12.18 |
| 7.00 | 1# | 627.48 | 9.37 | 632.82 | 9.46 | 34.10 | 31.50 | 38.49 | 7.38 |
| 7.00 | 2# | 627.79 | 9.50 | 633.08 | 9.30 | 34.58 | 31.43 | 38.55 | 7.36 |
| 7.00 | 3# | 627.86 | 9.41 | 632.89 | 9.30 | 34.21 | 31.60 | 38.56 | 7.36 |
| 7.00 | 4# | 628.61 | 11.06 | 655.04 | 14.41 | 4.11 | 14.44 | 43.20 | 12.94 |
| 8.00 | 1# | 628.09 | 9.37 | 633.49 | 9.46 | 32.04 | 32.14 | 38.49 | 7.34 |
| 8.00 | 2# | 628.72 | 9.50 | 633.78 | 9.30 | 31.46 | 32.24 | 38.55 | 7.35 |
| 8.00 | 3# | 628.42 | 9.41 | 633.39 | 9.30 | 31.99 | 32.14 | 38.56 | 7.36 |
| 8.00 | 4# | 624.93 | 9.55 | 643.91 | 14.94 | 1.32 | 14.98 | 42.16 | 13.65 |
| 9.00 | 1# | 627.27 | 9.45 | 633.58 | 9.46 | 31.16 | 32.68 | 38.49 | 7.34 |
| 9.00 | 2# | 628.10 | 9.50 | 633.58 | 9.69 | 30.75 | 32.56 | 38.55 | 7.35 |
| 9.00 | 3# | 627.66 | 9.41 | 633.13 | 9.43 | 31.43 | 32.71 | 38.56 | 7.36 |
| 9.00 | 4# | 621.71 | 9.55 | 628.01 | 15.60 | 2.72 | 15.63 | 40.49 | 14.30 |
| 10.00 | 1# | 626.91 | 9.45 | 633.49 | 9.46 | 32.68 | 33.23 | 38.49 | 7.34 |
| 10.00 | 2# | 627.49 | 9.50 | 633.43 | 9.30 | 31.99 | 33.15 | 38.55 | 7.35 |
| 10.00 | 3# | 627.12 | 9.41 | 633.13 | 9.30 | 32.75 | 32.97 | 38.56 | 7.36 |
| 10.00 | 4# | 613.54 | 9.55 | 617.85 | 10.96 | 6.99 | 16.40 | 38.02 | 15.04 |
| 11.00 | 1# | 626.91 | 9.45 | 633.49 | 9.46 | 39.42 | 33.60 | 38.49 | 7.34 |
| 11.00 | 2# | 627.49 | 9.50 | 633.43 | 9.30 | 37.45 | 33.44 | 38.55 | 7.35 |
| 11.00 | 3# | 627.12 | 9.41 | 633.13 | 9.30 | 35.38 | 33.59 | 38.56 | 7.36 |
| 11.00 | 4# | 613.54 | 9.55 | 612.14 | 9.57 | 11.09 | 17.13 | 35.09 | 15.89 |
| 12.00 | 1# | 626.91 | 9.45 | 633.49 | 9.46 | 20.72 | 36.82 | 38.49 | 7.34 |
| 12.00 | 2# | 627.49 | 9.50 | 633.43 | 9.30 | 27.25 | 34.60 | 38.55 | 7.35 |
| 12.00 | 3# | 627.12 | 9.41 | 633.13 | 9.30 | 22.85 | 33.59 | 38.56 | 7.36 |
| 12.00 | 4# | 613.54 | 9.55 | 615.96 | 31.27 | 17.79 | 17.88 | 32.44 | 28.79 |
| JDT10 | 0.00 | 1# | 645.91 | 9.54 | 651.44 | 9.46 | 37.36 | 11.09 | 41.02 | 7.72 |
| 0.00 | 2# | 646.71 | 9.50 | 651.40 | 9.56 | 37.23 | 11.17 | 41.14 | 7.71 |
| 0.00 | 3# | 646.36 | 9.56 | 651.58 | 9.30 | 37.24 | 11.26 | 41.24 | 7.70 |
| 0.00 | 4# | 648.72 | 9.55 | 653.38 | 9.40 | 37.10 | 11.00 | 41.29 | 7.73 |
| 1.00 | 1# | 638.81 | 10.46 | 642.59 | 10.36 | 33.24 | 14.45 | 39.90 | 8.37 |
| 1.00 | 2# | 645.02 | 10.60 | 651.64 | 10.58 | 37.30 | 11.81 | 41.33 | 8.54 |
| 1.00 | 3# | 646.33 | 10.30 | 653.44 | 10.32 | 36.42 | 11.90 | 41.45 | 8.58 |
| 1.00 | 4# | 646.79 | 10.44 | 654.46 | 10.05 | 37.23 | 11.90 | 41.52 | 8.56 |
| 2.00 | 1# | 631.42 | 11.46 | 632.79 | 11.56 | 22.27 | 15.79 | 38.38 | 9.17 |
| 2.00 | 2# | 646.26 | 11.58 | 652.38 | 11.42 | 37.95 | 12.88 | 41.30 | 9.37 |
| 2.00 | 3# | 646.92 | 11.58 | 654.40 | 11.58 | 37.35 | 13.16 | 41.44 | 9.37 |
| 2.00 | 4# | 647.31 | 11.49 | 654.25 | 11.50 | 37.86 | 12.64 | 41.52 | 9.41 |
| 3.00 | 1# | 626.49 | 12.61 | 630.86 | 16.38 | 17.04 | 16.53 | 36.49 | 10.13 |
| 3.00 | 2# | 645.25 | 12.67 | 650.98 | 12.31 | 38.32 | 13.79 | 41.07 | 10.23 |
| 3.00 | 3# | 644.57 | 12.56 | 651.94 | 12.13 | 38.15 | 13.81 | 41.23 | 10.27 |
| 3.00 | 4# | 645.59 | 12.53 | 652.92 | 12.02 | 37.17 | 13.78 | 41.32 | 10.26 |
| 4.00 | 1# | 624.55 | 13.51 | 643.19 | 17.18 | 15.49 | 17.23 | 36.94 | 15.39 |
| 4.00 | 2# | 641.33 | 13.24 | 648.70 | 12.84 | 37.80 | 35.98 | 40.74 | 11.04 |
| 4.00 | 3# | 642.16 | 13.43 | 649.69 | 12.95 | 39.15 | 11.26 | 40.91 | 11.08 |
| 4.00 | 4# | 643.01 | 13.44 | 650.48 | 12.92 | 38.91 | 14.74 | 41.02 | 11.11 |
| 5.00 | 1# | 629.73 | 14.63 | 652.89 | 17.87 | 15.69 | 17.92 | 37.39 | 16.31 |
| 5.00 | 2# | 639.92 | 14.12 | 646.72 | 13.58 | 35.65 | 24.16 | 40.43 | 11.83 |
| 5.00 | 3# | 641.05 | 13.95 | 647.57 | 13.85 | 37.31 | 35.30 | 40.63 | 11.86 |
| 5.00 | 4# | 641.69 | 14.10 | 648.82 | 13.96 | 37.48 | 35.32 | 40.75 | 11.89 |
| 6.00 | 1# | 633.83 | 15.30 | 653.58 | 18.58 | 16.99 | 18.49 | 37.18 | 17.03 |
| 6.00 | 2# | 636.72 | 14.76 | 642.77 | 14.10 | 33.64 | 35.85 | 39.96 | 12.51 |
| 6.00 | 3# | 638.12 | 14.66 | 643.91 | 14.43 | 35.90 | 35.88 | 40.19 | 12.54 |
| 6.00 | 4# | 638.84 | 14.80 | 645.20 | 14.40 | 35.10 | 28.22 | 40.35 | 12.61 |
| 7.00 | 1# | 629.86 | 19.44 | 649.24 | 19.28 | 19.87 | 19.40 | 35.98 | 17.80 |
| 7.00 | 2# | 628.23 | 15.48 | 632.53 | 14.94 | 30.71 | 25.00 | 38.89 | 13.15 |
| 7.00 | 3# | 630.05 | 15.39 | 634.61 | 15.21 | 34.74 | 36.78 | 39.15 | 13.23 |
| 7.00 | 4# | 630.84 | 15.52 | 636.02 | 14.94 | 32.23 | 39.81 | 39.34 | 13.29 |
| 8.00 | 1# | 619.99 | 20.47 | 638.93 | 20.54 | 23.56 | 20.43 | 34.29 | 18.71 |
| 8.00 | 2# | 615.83 | 39.66 | 622.52 | 39.27 | 34.11 | 37.93 | 36.95 | 14.02 |
| 8.00 | 3# | 615.65 | 39.81 | 618.18 | 39.67 | 35.65 | 37.84 | 37.26 | 14.08 |
| 8.00 | 4# | 613.50 | 15.89 | 618.34 | 15.91 | 27.71 | 41.23 | 37.50 | 14.19 |
| 9.00 | 1# | 616.17 | 21.73 | 632.29 | 21.82 | 27.81 | 21.78 | 33.33 | 6.40 |
| 9.00 | 2# | 604.52 | 40.20 | 602.76 | 39.83 | 24.87 | 46.24 | 35.44 | 16.20 |
| 9.00 | 3# | 606.82 | 40.25 | 606.89 | 40.18 | 33.54 | 38.96 | 35.72 | 16.12 |
| 9.00 | 4# | 604.62 | 40.54 | 618.35 | 43.00 | 20.49 | 42.65 | 35.95 | 15.98 |
| 10.00 | 1# | 620.47 | 22.93 | 632.58 | 22.94 | 25.73 | 32.86 | 33.33 | 6.40 |
| 10.00 | 2# | 605.72 | 20.10 | 608.92 | 19.94 | 37.14 | 36.22 | 35.93 | 18.44 |
| 10.00 | 3# | 606.44 | 19.93 | 609.68 | 20.00 | 37.32 | 35.95 | 36.00 | 18.25 |
| 10.00 | 4# | 607.04 | 20.05 | 611.04 | 20.02 | 37.75 | 36.23 | 36.05 | 18.19 |
| 11.00 | 1# | 627.91 | 23.91 | 637.41 | 23.92 | 22.19 | 33.46 | 33.33 | 6.40 |
| 11.00 | 2# | 613.12 | 23.21 | 616.59 | 22.94 | 40.37 | 44.61 | 36.99 | 19.71 |
| 11.00 | 3# | 612.91 | 20.66 | 616.94 | 22.01 | 39.53 | 36.73 | 37.03 | 19.63 |
| 11.00 | 4# | 613.37 | 23.31 | 618.36 | 22.64 | 37.76 | 36.58 | 37.03 | 19.55 |
| 12.00 | 1# | 631.75 | 24.51 | 639.25 | 24.67 | 28.24 | 34.18 | 33.33 | 6.40 |
| 12.00 | 2# | 623.41 | 23.86 | 627.09 | 23.83 | 38.90 | 37.58 | 38.04 | 20.66 |
| 12.00 | 3# | 624.15 | 23.94 | 627.69 | 23.56 | 39.17 | 37.38 | 38.11 | 20.68 |
| 12.00 | 4# | 624.72 | 23.83 | 628.55 | 23.31 | 37.79 | 37.57 | 38.14 | 20.60 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.84 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.85 JHT3尾水管最小压力随延时关闭时间间隔变化图 |
| 图6.86 JHT13蜗壳最大压力随甩负荷时间间隔变化图 | 图6.87 JHT13尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.88 JDT6蜗壳最大压力随甩负荷时间间隔变化图 | 图6.89 JDT6尾水管最小压力随甩负荷时间间隔变化图 |
| 图6.90 JDT10蜗壳最大压力随甩负荷时间间隔变化图 | 图6.91 JDT10尾水管最小压力随甩负荷时间间隔变化图 |

**6.2.4.7 30s-(85%)-70s两段关闭规律计算结果**

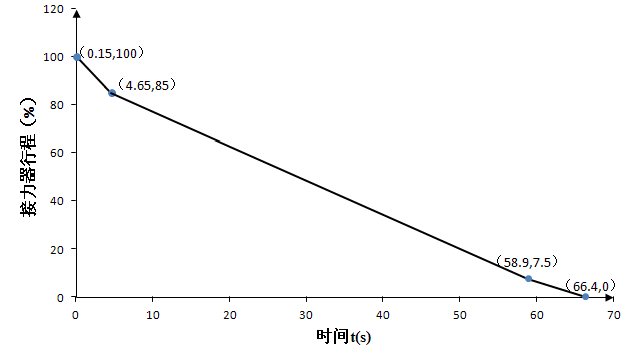


图6.92 水轮机工况导叶30s-(85%)-70s两段关闭规律

**表6-23 30s-(85%)-70s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 637.88 | 9.83 | 645.29 | 9.93 | 54.29 | 12.29 | 41.82 | 7.68 |
| 0.00 | 2# | 640.01 | 10.08 | 646.22 | 10.06 | 54.10 | 12.36 | 41.96 | 7.71 |
| 0.00 | 3# | 640.43 | 10.21 | 646.82 | 10.11 | 53.81 | 11.90 | 42.09 | 7.70 |
| 0.00 | 4# | 641.37 | 10.05 | 650.01 | 10.05 | 53.72 | 12.64 | 42.14 | 7.75 |
| SJT3 | 0.00 | 1# | 650.38 | 9.54 | 656.36 | 9.46 | 37.42 | 11.09 | 40.89 | 7.65 |
| 0.00 | 2# | 651.57 | 9.50 | 656.28 | 9.56 | 37.53 | 11.17 | 41.00 | 7.68 |
| 0.00 | 3# | 651.22 | 9.56 | 656.39 | 9.58 | 37.83 | 11.26 | 41.10 | 7.69 |
| 0.00 | 4# | 653.84 | 9.55 | 658.24 | 9.57 | 37.54 | 11.00 | 41.16 | 7.67 |
| ZT2 | 76.76 | 1# | 637.63 | 86.61 | 643.65 | 86.60 | 54.42 | 89.28 | 42.36 | 84.52 |
| 76.76 | 2# | 638.74 | 86.62 | 644.84 | 86.64 | 54.51 | 89.19 | 42.51 | 84.54 |
| 76.76 | 3# | 639.69 | 86.59 | 645.85 | 86.74 | 54.33 | 89.25 | 42.63 | 84.52 |
| 76.76 | 4# | 640.80 | 86.64 | 647.03 | 86.66 | 54.40 | 89.33 | 42.67 | 84.54 |
| JHT3 | 0.00 | 1# | 637.88 | 9.83 | 645.29 | 9.93 | 54.29 | 12.29 | 41.82 | 7.68 |
| 0.00 | 2# | 640.01 | 10.08 | 646.22 | 10.06 | 54.10 | 12.36 | 41.96 | 7.71 |
| 0.00 | 3# | 640.43 | 10.21 | 646.82 | 10.11 | 53.81 | 11.90 | 42.09 | 7.70 |
| 0.00 | 4# | 641.37 | 10.05 | 650.01 | 10.05 | 53.72 | 12.64 | 42.14 | 7.75 |
| 1.00 | 1# | 638.31 | 9.83 | 645.40 | 9.93 | 52.75 | 12.29 | 41.87 | 7.77 |
| 1.00 | 2# | 640.10 | 10.08 | 646.18 | 10.06 | 52.65 | 12.36 | 42.02 | 7.79 |
| 1.00 | 3# | 640.68 | 10.21 | 647.12 | 10.11 | 52.29 | 12.62 | 42.16 | 7.80 |
| 1.00 | 4# | 645.38 | 9.55 | 653.12 | 10.05 | 55.21 | 26.42 | 42.98 | 7.52 |
| 2.00 | 1# | 637.92 | 9.83 | 644.17 | 9.93 | 51.20 | 12.78 | 41.76 | 7.86 |
| 2.00 | 2# | 639.44 | 10.08 | 645.00 | 10.06 | 51.07 | 12.36 | 41.92 | 7.86 |
| 2.00 | 3# | 639.94 | 10.21 | 645.86 | 10.11 | 50.13 | 12.62 | 42.07 | 7.92 |
| 2.00 | 4# | 649.21 | 9.55 | 657.47 | 9.57 | 47.36 | 19.69 | 43.95 | 7.44 |
| 3.00 | 1# | 636.11 | 9.55 | 642.25 | 9.46 | 49.92 | 12.29 | 41.54 | 7.95 |
| 3.00 | 2# | 637.90 | 10.08 | 643.45 | 9.70 | 49.37 | 12.36 | 41.70 | 7.96 |
| 3.00 | 3# | 638.47 | 9.84 | 643.71 | 10.32 | 48.37 | 12.62 | 41.85 | 8.03 |
| 3.00 | 4# | 652.74 | 9.55 | 662.39 | 9.40 | 40.44 | 19.98 | 44.93 | 7.47 |
| 4.00 | 1# | 634.32 | 9.83 | 639.91 | 9.46 | 49.61 | 12.78 | 41.25 | 7.94 |
| 4.00 | 2# | 635.95 | 10.08 | 641.06 | 9.70 | 49.08 | 12.88 | 41.40 | 7.98 |
| 4.00 | 3# | 636.56 | 9.84 | 641.22 | 10.03 | 48.03 | 12.62 | 41.56 | 8.00 |
| 4.00 | 4# | 654.88 | 9.55 | 666.02 | 9.57 | 38.09 | 19.98 | 45.72 | 7.61 |
| 5.00 | 1# | 632.67 | 9.83 | 638.39 | 9.46 | 50.93 | 24.17 | 41.02 | 7.85 |
| 5.00 | 2# | 634.61 | 10.08 | 639.35 | 9.70 | 50.49 | 12.88 | 41.17 | 7.88 |
| 5.00 | 3# | 635.00 | 9.84 | 639.44 | 10.03 | 49.47 | 13.16 | 41.30 | 7.92 |
| 5.00 | 4# | 654.02 | 9.55 | 666.19 | 10.05 | 42.70 | 20.58 | 46.16 | 7.86 |
| 6.00 | 1# | 632.20 | 9.83 | 638.26 | 9.46 | 52.75 | 14.45 | 40.92 | 7.77 |
| 6.00 | 2# | 634.23 | 10.08 | 638.80 | 9.70 | 52.61 | 14.36 | 41.06 | 7.77 |
| 6.00 | 3# | 634.52 | 10.21 | 639.09 | 10.32 | 51.99 | 13.16 | 41.18 | 7.83 |
| 6.00 | 4# | 650.31 | 10.05 | 664.35 | 10.05 | 48.30 | 21.10 | 46.43 | 8.03 |
| 7.00 | 1# | 632.16 | 9.83 | 638.83 | 9.93 | 54.94 | 14.53 | 40.90 | 7.76 |
| 7.00 | 2# | 634.56 | 10.08 | 639.48 | 10.06 | 55.08 | 14.36 | 41.04 | 7.73 |
| 7.00 | 3# | 635.17 | 10.21 | 640.22 | 10.11 | 54.82 | 14.47 | 41.15 | 7.80 |
| 7.00 | 4# | 645.49 | 10.16 | 656.57 | 10.05 | 49.59 | 11.00 | 46.44 | 8.04 |
| 8.00 | 1# | 631.87 | 9.83 | 639.06 | 9.93 | 56.47 | 11.09 | 40.90 | 7.75 |
| 8.00 | 2# | 634.04 | 10.08 | 639.66 | 10.06 | 56.59 | 11.17 | 41.04 | 7.75 |
| 8.00 | 3# | 634.31 | 10.21 | 640.41 | 10.11 | 56.55 | 11.90 | 41.15 | 7.78 |
| 8.00 | 4# | 637.18 | 10.16 | 645.88 | 10.05 | 50.19 | 11.90 | 46.42 | 8.03 |
| 9.00 | 1# | 631.48 | 9.83 | 639.05 | 9.93 | 55.70 | 11.09 | 40.90 | 7.75 |
| 9.00 | 2# | 633.55 | 10.08 | 639.68 | 10.06 | 55.69 | 11.17 | 41.04 | 7.75 |
| 9.00 | 3# | 633.97 | 10.21 | 640.55 | 10.32 | 55.62 | 11.35 | 41.15 | 7.78 |
| 9.00 | 4# | 633.01 | 9.55 | 639.52 | 10.05 | 49.89 | 12.64 | 46.42 | 8.03 |
| 10.00 | 1# | 631.30 | 9.83 | 639.01 | 9.93 | 55.09 | 11.09 | 40.90 | 7.75 |
| 10.00 | 2# | 633.34 | 10.08 | 639.63 | 10.06 | 55.04 | 11.17 | 41.04 | 7.75 |
| 10.00 | 3# | 633.57 | 10.21 | 640.38 | 10.32 | 54.93 | 11.35 | 41.15 | 7.78 |
| 10.00 | 4# | 631.99 | 9.55 | 637.12 | 8.86 | 49.75 | 14.08 | 46.42 | 8.03 |
| 11.00 | 1# | 631.30 | 9.83 | 639.01 | 9.93 | 54.90 | 11.09 | 40.90 | 7.75 |
| 11.00 | 2# | 633.34 | 10.08 | 639.63 | 10.06 | 54.78 | 11.17 | 41.04 | 7.75 |
| 11.00 | 3# | 633.57 | 10.21 | 640.38 | 10.32 | 54.53 | 11.35 | 41.15 | 7.78 |
| 11.00 | 4# | 631.99 | 9.55 | 637.12 | 8.86 | 47.97 | 14.74 | 46.42 | 8.03 |
| 12.00 | 1# | 631.30 | 9.83 | 639.01 | 9.93 | 54.90 | 11.09 | 40.90 | 7.75 |
| 12.00 | 2# | 633.34 | 10.08 | 639.63 | 10.06 | 54.78 | 11.17 | 41.04 | 7.75 |
| 12.00 | 3# | 633.57 | 10.21 | 640.38 | 10.32 | 54.48 | 11.90 | 41.15 | 7.78 |
| 12.00 | 4# | 631.99 | 9.55 | 637.12 | 8.86 | 48.24 | 14.74 | 46.42 | 8.03 |

|  |  |
| --- | --- |
| 图6.93 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.94 JHT3尾水管最小压力随延时关闭时间间隔变化图 |

**6.2.4.8 30s-(85%)-80s两段关闭规律计算结果**

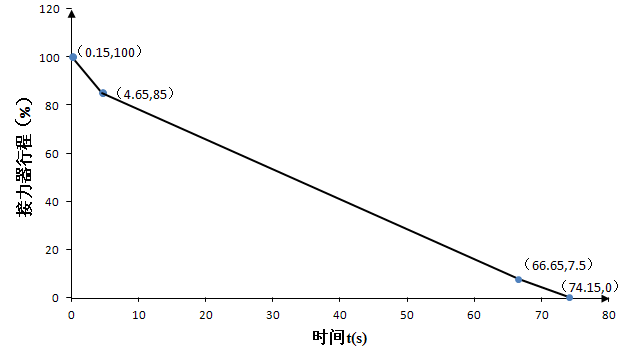


图6.95 水轮机工况导叶30s-(85%)-80s两段关闭规律

**表6-24 30s-(85%)-80s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 635.06 | 9.83 | 642.38 | 9.93 | 54.94 | 12.29 | 41.78 | 7.70 |
| 0.00 | 2# | 637.10 | 10.08 | 643.23 | 10.06 | 54.89 | 11.17 | 41.93 | 7.71 |
| 0.00 | 3# | 637.51 | 10.21 | 643.90 | 10.03 | 54.58 | 11.35 | 42.05 | 7.72 |
| 0.00 | 4# | 638.64 | 9.55 | 647.35 | 10.05 | 54.80 | 12.64 | 42.11 | 7.73 |
| SJT3 | 0.00 | 1# | 647.45 | 9.54 | 652.98 | 9.46 | 38.90 | 11.09 | 41.02 | 7.72 |
| 0.00 | 2# | 648.25 | 9.50 | 652.94 | 9.56 | 38.77 | 11.17 | 41.14 | 7.71 |
| 0.00 | 3# | 647.90 | 9.56 | 653.12 | 9.30 | 38.78 | 11.26 | 41.24 | 7.70 |
| 0.00 | 4# | 650.26 | 9.55 | 654.92 | 9.40 | 38.64 | 11.00 | 41.29 | 7.73 |
| ZT2 | 76.76 | 1# | 634.70 | 86.71 | 640.54 | 86.61 | 55.27 | 88.04 | 42.33 | 84.53 |
| 76.76 | 2# | 635.73 | 86.68 | 641.69 | 86.64 | 55.15 | 88.12 | 42.46 | 84.52 |
| 76.76 | 3# | 636.79 | 86.59 | 642.69 | 86.56 | 55.13 | 88.12 | 42.59 | 84.54 |
| 76.76 | 4# | 637.79 | 86.64 | 643.71 | 86.66 | 54.91 | 89.33 | 42.64 | 84.55 |
| JHT3 | 0.00 | 1# | 635.06 | 9.83 | 642.38 | 9.93 | 54.94 | 12.29 | 41.78 | 7.70 |
| 0.00 | 2# | 637.10 | 10.08 | 643.23 | 10.06 | 54.89 | 11.17 | 41.93 | 7.71 |
| 0.00 | 3# | 637.51 | 10.21 | 643.90 | 10.03 | 54.58 | 11.35 | 42.05 | 7.72 |
| 0.00 | 4# | 638.64 | 9.55 | 647.35 | 10.05 | 54.80 | 12.64 | 42.11 | 7.73 |
| 1.00 | 1# | 635.30 | 9.54 | 641.53 | 9.46 | 51.79 | 12.29 | 41.76 | 7.89 |
| 1.00 | 2# | 636.94 | 10.08 | 642.56 | 9.70 | 51.69 | 12.36 | 41.93 | 7.91 |
| 1.00 | 3# | 637.27 | 9.76 | 643.03 | 10.11 | 50.87 | 12.62 | 42.07 | 7.94 |
| 1.00 | 4# | 646.80 | 9.55 | 654.82 | 9.57 | 46.88 | 19.69 | 43.85 | 7.42 |
| 2.00 | 1# | 635.30 | 9.54 | 641.53 | 9.46 | 51.79 | 12.29 | 41.76 | 7.89 |
| 2.00 | 2# | 636.94 | 10.08 | 642.56 | 9.70 | 51.69 | 12.36 | 41.93 | 7.91 |
| 2.00 | 3# | 637.27 | 9.76 | 643.03 | 10.11 | 50.87 | 12.62 | 42.07 | 7.94 |
| 2.00 | 4# | 646.80 | 9.55 | 654.82 | 9.57 | 46.88 | 19.69 | 43.85 | 7.42 |
| 3.00 | 1# | 633.80 | 9.55 | 640.04 | 9.46 | 50.31 | 12.29 | 41.55 | 7.97 |
| 3.00 | 2# | 635.26 | 9.58 | 640.99 | 9.70 | 50.02 | 12.36 | 41.71 | 7.99 |
| 3.00 | 3# | 636.21 | 9.84 | 641.14 | 10.03 | 49.10 | 12.62 | 41.86 | 7.99 |
| 3.00 | 4# | 650.60 | 9.55 | 660.28 | 9.40 | 39.61 | 19.98 | 44.81 | 7.46 |
| 4.00 | 1# | 632.11 | 9.83 | 637.89 | 9.46 | 50.07 | 12.78 | 41.26 | 7.99 |
| 4.00 | 2# | 633.60 | 10.08 | 638.50 | 9.70 | 49.62 | 12.88 | 41.41 | 8.00 |
| 4.00 | 3# | 634.31 | 9.76 | 638.77 | 10.11 | 48.42 | 12.62 | 41.57 | 8.02 |
| 4.00 | 4# | 653.09 | 9.55 | 664.27 | 9.57 | 36.56 | 19.98 | 45.60 | 7.62 |
| 5.00 | 1# | 630.59 | 9.83 | 636.16 | 9.46 | 50.74 | 24.17 | 41.03 | 7.87 |
| 5.00 | 2# | 632.18 | 10.08 | 636.92 | 9.70 | 50.39 | 24.33 | 41.17 | 7.87 |
| 5.00 | 3# | 632.67 | 9.84 | 636.93 | 10.03 | 50.01 | 12.62 | 41.30 | 7.95 |
| 5.00 | 4# | 652.15 | 9.55 | 663.60 | 9.57 | 40.58 | 20.58 | 46.04 | 7.81 |
| 6.00 | 1# | 629.95 | 9.83 | 635.66 | 9.46 | 51.81 | 24.94 | 40.92 | 7.79 |
| 6.00 | 2# | 631.74 | 10.08 | 636.53 | 9.70 | 52.23 | 24.76 | 41.06 | 7.82 |
| 6.00 | 3# | 631.98 | 9.84 | 636.39 | 10.03 | 52.35 | 24.87 | 41.18 | 7.81 |
| 6.00 | 4# | 649.14 | 9.55 | 662.84 | 10.05 | 45.05 | 21.10 | 46.29 | 8.01 |
| 7.00 | 1# | 629.61 | 9.83 | 635.96 | 9.93 | 55.10 | 14.53 | 40.91 | 7.76 |
| 7.00 | 2# | 632.04 | 10.08 | 636.69 | 9.70 | 55.21 | 14.36 | 41.04 | 7.76 |
| 7.00 | 3# | 632.41 | 10.21 | 637.13 | 10.32 | 54.46 | 14.47 | 41.16 | 7.77 |
| 7.00 | 4# | 644.01 | 10.16 | 655.69 | 10.05 | 49.61 | 11.00 | 46.30 | 8.04 |
| 8.00 | 1# | 629.28 | 9.83 | 636.14 | 9.93 | 57.12 | 11.09 | 40.90 | 7.76 |
| 8.00 | 2# | 631.43 | 10.08 | 636.78 | 10.06 | 57.16 | 26.24 | 41.04 | 7.74 |
| 8.00 | 3# | 631.73 | 10.21 | 637.60 | 10.32 | 56.98 | 0.27 | 41.15 | 7.78 |
| 8.00 | 4# | 635.89 | 10.16 | 645.01 | 10.05 | 50.55 | 11.90 | 46.28 | 8.00 |
| 9.00 | 1# | 628.98 | 9.83 | 636.27 | 9.93 | 56.34 | 11.09 | 40.90 | 7.76 |
| 9.00 | 2# | 631.06 | 10.08 | 636.94 | 10.06 | 56.39 | 11.17 | 41.04 | 7.74 |
| 9.00 | 3# | 631.49 | 10.21 | 637.72 | 10.32 | 56.17 | 11.35 | 41.15 | 7.78 |
| 9.00 | 4# | 631.64 | 9.55 | 638.35 | 10.05 | 50.26 | 12.64 | 46.28 | 8.00 |
| 10.00 | 1# | 628.78 | 9.83 | 636.22 | 9.93 | 55.74 | 11.09 | 40.90 | 7.76 |
| 10.00 | 2# | 630.82 | 10.08 | 636.86 | 10.06 | 55.70 | 11.17 | 41.04 | 7.74 |
| 10.00 | 3# | 631.13 | 10.21 | 637.52 | 10.32 | 55.46 | 11.35 | 41.15 | 7.78 |
| 10.00 | 4# | 630.63 | 9.55 | 636.04 | 8.86 | 50.49 | 13.25 | 46.28 | 8.00 |
| 11.00 | 1# | 628.78 | 9.83 | 636.22 | 9.93 | 55.57 | 11.09 | 40.90 | 7.76 |
| 11.00 | 2# | 630.82 | 10.08 | 636.86 | 10.06 | 55.44 | 11.17 | 41.04 | 7.74 |
| 11.00 | 3# | 631.13 | 10.21 | 637.52 | 10.32 | 55.10 | 11.35 | 41.15 | 7.78 |
| 11.00 | 4# | 630.63 | 9.55 | 636.04 | 8.86 | 50.83 | 14.74 | 46.28 | 8.00 |
| 12.00 | 1# | 628.78 | 9.83 | 636.22 | 9.93 | 55.57 | 11.09 | 40.90 | 7.76 |
| 12.00 | 2# | 630.82 | 10.08 | 636.86 | 10.06 | 55.44 | 11.17 | 41.04 | 7.74 |
| 12.00 | 3# | 631.13 | 10.21 | 637.52 | 10.32 | 55.10 | 11.35 | 41.15 | 7.78 |
| 12.00 | 4# | 630.63 | 9.55 | 636.04 | 8.86 | 51.00 | 14.74 | 46.28 | 8.00 |

|  |  |
| --- | --- |
| 图6.96 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.97 JHT3尾水管最小压力随延时关闭时间间隔变化图 |

**6.2.4.9 20s-(85%)-80s两段关闭规律计算结果**

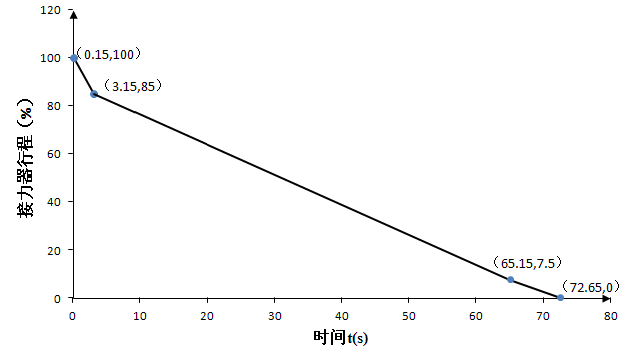


图6.98 水轮机工况导叶20s-(85%)-80s两段关闭规律

**表6-25 20s-(85%)-80s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 635.67 | 9.83 | 641.97 | 9.46 | 53.17 | 12.29 | 41.22 | 7.67 |
| 0.00 | 2# | 637.13 | 9.79 | 643.12 | 9.70 | 53.22 | 11.81 | 41.36 | 7.70 |
| 0.00 | 3# | 637.53 | 9.84 | 642.82 | 9.78 | 52.71 | 11.90 | 41.48 | 7.71 |
| 0.00 | 4# | 640.12 | 9.55 | 646.01 | 10.05 | 53.53 | 11.90 | 41.54 | 7.72 |
| SJT3 | 0.00 | 1# | 647.45 | 9.54 | 652.98 | 9.46 | 38.90 | 11.09 | 41.02 | 7.72 |
| 0.00 | 2# | 648.25 | 9.50 | 652.94 | 9.56 | 38.77 | 11.17 | 41.14 | 7.71 |
| 0.00 | 3# | 647.90 | 9.56 | 653.12 | 9.30 | 38.78 | 11.26 | 41.24 | 7.70 |
| 0.00 | 4# | 650.26 | 9.55 | 654.92 | 9.40 | 38.64 | 11.00 | 41.29 | 7.73 |
| ZT2 | 0.00 | 1# | 635.10 | 86.59 | 640.31 | 86.60 | 53.96 | 89.28 | 41.77 | 84.52 |
| 76.76 | 2# | 636.12 | 86.57 | 641.37 | 86.53 | 53.90 | 89.18 | 41.91 | 84.52 |
| 76.76 | 3# | 637.02 | 86.58 | 642.36 | 86.54 | 53.82 | 89.05 | 42.03 | 84.53 |
| 76.76 | 4# | 637.74 | 86.64 | 642.98 | 86.66 | 53.96 | 89.12 | 42.07 | 84.50 |
| JHT3 | 0.00 | 1# | 635.67 | 9.83 | 641.97 | 9.46 | 53.17 | 12.29 | 41.22 | 7.67 |
| 0.00 | 2# | 637.13 | 9.79 | 643.12 | 9.70 | 53.22 | 11.81 | 41.36 | 7.70 |
| 0.00 | 3# | 637.53 | 9.84 | 642.82 | 9.78 | 52.71 | 11.90 | 41.48 | 7.71 |
| 0.00 | 4# | 640.12 | 9.55 | 646.01 | 10.05 | 53.53 | 11.90 | 41.54 | 7.72 |
| 1.00 | 1# | 635.30 | 9.83 | 642.02 | 9.93 | 53.16 | 12.29 | 41.31 | 7.74 |
| 1.00 | 2# | 636.85 | 10.08 | 643.11 | 9.70 | 52.93 | 12.36 | 41.46 | 7.74 |
| 1.00 | 3# | 637.37 | 9.84 | 643.18 | 10.03 | 52.48 | 11.90 | 41.59 | 7.76 |
| 1.00 | 4# | 640.99 | 9.55 | 647.65 | 10.05 | 56.19 | 11.90 | 42.14 | 7.55 |
| 2.00 | 1# | 635.93 | 9.83 | 641.67 | 9.93 | 51.02 | 12.29 | 41.35 | 7.86 |
| 2.00 | 2# | 637.37 | 9.79 | 642.86 | 9.70 | 50.91 | 12.36 | 41.50 | 7.85 |
| 2.00 | 3# | 637.66 | 9.84 | 642.87 | 10.03 | 50.45 | 11.90 | 41.65 | 7.89 |
| 2.00 | 4# | 646.31 | 9.55 | 652.75 | 9.40 | 49.69 | 19.62 | 43.09 | 7.34 |
| 3.00 | 1# | 635.93 | 9.83 | 641.67 | 9.93 | 51.02 | 12.29 | 41.35 | 7.86 |
| 3.00 | 2# | 637.37 | 9.79 | 642.86 | 9.70 | 50.91 | 12.36 | 41.50 | 7.85 |
| 3.00 | 3# | 637.66 | 9.84 | 642.87 | 10.03 | 50.45 | 11.90 | 41.65 | 7.89 |
| 3.00 | 4# | 646.31 | 9.55 | 652.75 | 9.40 | 49.69 | 19.62 | 43.09 | 7.34 |
| 4.00 | 1# | 633.20 | 9.55 | 638.05 | 9.46 | 47.13 | 12.29 | 40.87 | 8.09 |
| 4.00 | 2# | 634.40 | 9.50 | 638.90 | 9.70 | 46.70 | 12.44 | 41.03 | 8.12 |
| 4.00 | 3# | 635.15 | 9.76 | 638.77 | 10.03 | 46.27 | 12.62 | 41.19 | 8.12 |
| 4.00 | 4# | 652.72 | 9.55 | 664.03 | 9.40 | 32.60 | 19.69 | 45.29 | 7.40 |
| 5.00 | 1# | 631.05 | 9.54 | 635.56 | 9.46 | 48.10 | 12.29 | 40.53 | 8.01 |
| 5.00 | 2# | 632.43 | 9.50 | 636.41 | 9.70 | 47.54 | 12.44 | 40.68 | 8.00 |
| 5.00 | 3# | 632.80 | 9.76 | 636.17 | 9.43 | 46.83 | 12.62 | 40.83 | 8.11 |
| 5.00 | 4# | 655.55 | 9.55 | 668.12 | 9.40 | 33.52 | 19.98 | 45.96 | 7.61 |
| 6.00 | 1# | 630.58 | 9.55 | 635.01 | 9.46 | 50.52 | 24.17 | 40.37 | 7.84 |
| 6.00 | 2# | 631.63 | 9.50 | 635.34 | 9.70 | 50.42 | 12.44 | 40.51 | 7.85 |
| 6.00 | 3# | 632.04 | 9.76 | 635.13 | 9.43 | 49.56 | 12.62 | 40.63 | 7.90 |
| 6.00 | 4# | 654.07 | 9.55 | 665.35 | 9.57 | 39.54 | 20.58 | 46.18 | 7.89 |
| 7.00 | 1# | 630.44 | 9.55 | 635.41 | 9.46 | 52.41 | 24.94 | 40.33 | 7.77 |
| 7.00 | 2# | 631.55 | 9.79 | 635.85 | 9.70 | 53.39 | 24.99 | 40.47 | 7.82 |
| 7.00 | 3# | 632.13 | 9.76 | 635.30 | 9.58 | 52.97 | 12.62 | 40.59 | 7.77 |
| 7.00 | 4# | 648.83 | 9.55 | 661.94 | 10.05 | 47.62 | 21.24 | 46.19 | 7.99 |
| 8.00 | 1# | 629.58 | 9.83 | 635.35 | 9.93 | 55.99 | 12.29 | 40.33 | 7.76 |
| 8.00 | 2# | 631.47 | 10.08 | 636.32 | 9.70 | 55.94 | 12.44 | 40.47 | 7.81 |
| 8.00 | 3# | 631.61 | 10.21 | 636.43 | 10.11 | 55.41 | 11.90 | 40.59 | 7.84 |
| 8.00 | 4# | 641.40 | 10.16 | 652.09 | 10.05 | 49.65 | 11.90 | 46.16 | 7.90 |
| 9.00 | 1# | 628.94 | 9.83 | 635.33 | 9.93 | 56.69 | 12.29 | 40.33 | 7.76 |
| 9.00 | 2# | 630.50 | 10.08 | 636.24 | 9.70 | 56.22 | 11.81 | 40.47 | 7.81 |
| 9.00 | 3# | 630.61 | 9.84 | 636.27 | 10.03 | 55.61 | 11.90 | 40.59 | 7.84 |
| 9.00 | 4# | 632.59 | 9.55 | 639.45 | 10.05 | 50.18 | 11.90 | 46.16 | 7.90 |
| 10.00 | 1# | 628.66 | 9.83 | 635.23 | 9.93 | 56.05 | 12.29 | 40.33 | 7.76 |
| 10.00 | 2# | 630.18 | 10.08 | 636.17 | 9.70 | 55.30 | 11.81 | 40.47 | 7.81 |
| 10.00 | 3# | 630.33 | 9.84 | 636.11 | 10.03 | 54.81 | 11.90 | 40.59 | 7.84 |
| 10.00 | 4# | 631.08 | 9.55 | 635.14 | 9.40 | 51.29 | 12.34 | 46.16 | 7.90 |
| 11.00 | 1# | 628.66 | 9.83 | 635.23 | 9.93 | 55.38 | 12.29 | 40.33 | 7.76 |
| 11.00 | 2# | 630.18 | 10.08 | 636.17 | 9.70 | 54.38 | 11.81 | 40.47 | 7.81 |
| 11.00 | 3# | 630.33 | 9.84 | 636.11 | 10.03 | 53.70 | 11.90 | 40.59 | 7.84 |
| 11.00 | 4# | 631.08 | 9.55 | 635.14 | 9.40 | 51.04 | 14.74 | 46.16 | 7.90 |
| 12.00 | 1# | 628.66 | 9.83 | 635.23 | 9.93 | 54.65 | 12.29 | 40.33 | 7.76 |
| 12.00 | 2# | 630.18 | 10.08 | 636.17 | 9.70 | 54.17 | 11.81 | 40.47 | 7.81 |
| 12.00 | 3# | 630.33 | 9.84 | 636.11 | 10.03 | 53.40 | 11.90 | 40.59 | 7.84 |
| 12.00 | 4# | 631.08 | 9.55 | 635.14 | 9.40 | 50.15 | 14.74 | 46.16 | 7.90 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.99 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.100 JHT3尾水管最小压力随延时关闭时间间隔变化图 |

**6.2.4.10 40s-(85%)-80s两段关闭规律计算结果**

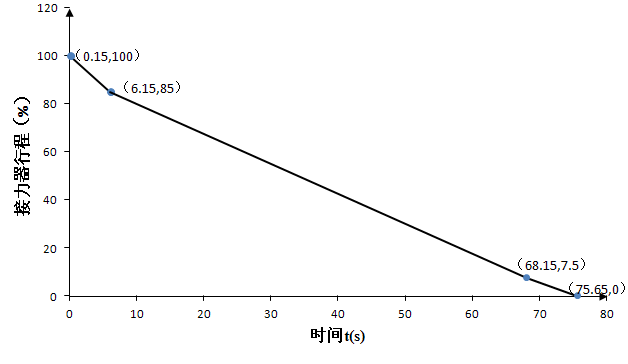


图6.101 水轮机工况导叶40s-(85%)-80s两段关闭规律

**表6-26 40s-(85%)-80s两段关闭规律计算结果**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 时间间隔（s） | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| SJT2 | 0.00 | 1# | 637.70 | 9.54 | 644.60 | 9.46 | 53.60 | 11.09 | 42.41 | 7.74 |
| 0.00 | 2# | 638.98 | 9.50 | 645.38 | 9.70 | 53.86 | 11.17 | 42.55 | 7.73 |
| 0.00 | 3# | 639.20 | 9.41 | 645.05 | 10.03 | 53.86 | 11.90 | 42.67 | 7.74 |
| 0.00 | 4# | 642.60 | 9.55 | 648.80 | 10.05 | 53.91 | 11.15 | 42.73 | 7.73 |
| SJT3 | 0.00 | 1# | 647.45 | 9.54 | 652.98 | 9.46 | 38.90 | 11.09 | 41.02 | 7.72 |
| 0.00 | 2# | 648.25 | 9.50 | 652.94 | 9.56 | 38.77 | 11.17 | 41.14 | 7.71 |
| 0.00 | 3# | 647.90 | 9.56 | 653.12 | 9.30 | 38.78 | 11.26 | 41.24 | 7.70 |
| 0.00 | 4# | 650.26 | 9.55 | 654.92 | 9.40 | 38.64 | 11.00 | 41.29 | 7.73 |
| ZT2 | 76.76 | 1# | 637.14 | 86.49 | 642.72 | 86.49 | 54.04 | 87.82 | 42.94 | 84.57 |
| 76.76 | 2# | 638.01 | 86.44 | 643.83 | 86.52 | 54.02 | 87.82 | 43.09 | 84.59 |
| 76.76 | 3# | 638.73 | 86.55 | 644.49 | 86.39 | 54.01 | 87.88 | 43.20 | 84.55 |
| 76.76 | 4# | 639.50 | 86.25 | 645.69 | 86.32 | 53.95 | 87.96 | 43.25 | 84.56 |
| JHT3 | 0.00 | 1# | 637.70 | 9.54 | 644.60 | 9.46 | 53.60 | 11.09 | 42.41 | 7.74 |
| 0.00 | 2# | 638.98 | 9.50 | 645.38 | 9.70 | 53.86 | 11.17 | 42.55 | 7.73 |
| 0.00 | 3# | 639.20 | 9.41 | 645.05 | 10.03 | 53.86 | 11.90 | 42.67 | 7.74 |
| 0.00 | 4# | 642.60 | 9.55 | 648.80 | 10.05 | 53.91 | 11.15 | 42.73 | 7.73 |
| 1.00 | 1# | 637.79 | 9.55 | 644.27 | 9.46 | 53.52 | 11.09 | 42.37 | 7.81 |
| 1.00 | 2# | 639.03 | 9.58 | 645.14 | 9.70 | 53.56 | 11.17 | 42.52 | 7.80 |
| 1.00 | 3# | 639.16 | 9.56 | 644.71 | 9.58 | 52.70 | 11.90 | 42.65 | 7.81 |
| 1.00 | 4# | 645.58 | 9.55 | 653.19 | 10.05 | 54.70 | 11.00 | 43.53 | 7.66 |
| 2.00 | 1# | 636.81 | 9.55 | 643.05 | 9.46 | 53.19 | 12.29 | 42.22 | 7.87 |
| 2.00 | 2# | 637.96 | 9.58 | 643.58 | 9.70 | 52.91 | 12.36 | 42.37 | 7.90 |
| 2.00 | 3# | 638.22 | 9.84 | 643.45 | 9.43 | 52.04 | 11.90 | 42.51 | 7.88 |
| 2.00 | 4# | 648.75 | 9.55 | 656.83 | 10.05 | 51.92 | 19.98 | 44.35 | 7.62 |
| 3.00 | 1# | 635.85 | 9.55 | 641.65 | 9.46 | 52.56 | 24.39 | 42.01 | 7.92 |
| 3.00 | 2# | 637.06 | 9.58 | 642.04 | 9.70 | 51.90 | 24.33 | 42.16 | 7.92 |
| 3.00 | 3# | 637.40 | 9.41 | 642.10 | 9.43 | 51.64 | 11.90 | 42.30 | 7.95 |
| 3.00 | 4# | 651.81 | 9.55 | 660.54 | 9.57 | 46.90 | 19.98 | 45.12 | 7.71 |
| 4.00 | 1# | 634.28 | 9.55 | 640.02 | 9.46 | 51.89 | 24.46 | 41.79 | 7.84 |
| 4.00 | 2# | 635.56 | 9.58 | 640.54 | 9.70 | 51.78 | 24.33 | 41.94 | 7.87 |
| 4.00 | 3# | 635.87 | 9.41 | 640.38 | 9.43 | 52.25 | 13.62 | 42.06 | 7.91 |
| 4.00 | 4# | 652.41 | 9.55 | 662.61 | 10.05 | 46.55 | 20.88 | 45.66 | 7.84 |
| 5.00 | 1# | 633.28 | 9.55 | 638.97 | 9.46 | 52.40 | 14.45 | 41.63 | 7.79 |
| 5.00 | 2# | 634.47 | 9.58 | 639.41 | 9.70 | 52.92 | 14.36 | 41.77 | 7.83 |
| 5.00 | 3# | 634.60 | 9.41 | 639.09 | 9.43 | 52.28 | 14.19 | 41.88 | 7.83 |
| 5.00 | 4# | 650.43 | 9.55 | 662.11 | 10.05 | 49.00 | 20.95 | 46.13 | 8.04 |
| 6.00 | 1# | 632.45 | 9.55 | 638.41 | 9.46 | 53.82 | 14.53 | 41.55 | 7.72 |
| 6.00 | 2# | 633.62 | 9.58 | 639.05 | 9.70 | 54.41 | 14.36 | 41.69 | 7.75 |
| 6.00 | 3# | 633.85 | 9.41 | 638.75 | 9.43 | 53.51 | 14.47 | 41.80 | 7.78 |
| 6.00 | 4# | 645.30 | 9.55 | 657.27 | 10.05 | 49.37 | 11.15 | 46.34 | 8.13 |
| 7.00 | 1# | 632.33 | 9.55 | 638.50 | 9.46 | 55.84 | 11.09 | 41.54 | 7.73 |
| 7.00 | 2# | 633.42 | 9.58 | 639.22 | 9.70 | 55.96 | 11.17 | 41.67 | 7.71 |
| 7.00 | 3# | 633.43 | 9.41 | 638.66 | 9.43 | 56.23 | 14.47 | 41.78 | 7.75 |
| 7.00 | 4# | 639.90 | 9.55 | 648.85 | 10.05 | 49.72 | 11.15 | 46.37 | 8.17 |
| 8.00 | 1# | 632.17 | 9.55 | 638.68 | 9.46 | 55.67 | 11.09 | 41.54 | 7.72 |
| 8.00 | 2# | 633.27 | 9.58 | 639.37 | 9.70 | 55.83 | 11.17 | 41.67 | 7.71 |
| 8.00 | 3# | 633.07 | 9.41 | 638.66 | 9.58 | 56.00 | 11.35 | 41.78 | 7.76 |
| 8.00 | 4# | 636.44 | 9.55 | 642.41 | 10.05 | 49.24 | 12.34 | 46.35 | 8.16 |
| 9.00 | 1# | 631.88 | 9.55 | 638.54 | 9.46 | 55.06 | 11.09 | 41.54 | 7.72 |
| 9.00 | 2# | 632.96 | 9.58 | 639.34 | 9.70 | 55.32 | 11.17 | 41.67 | 7.71 |
| 9.00 | 3# | 632.69 | 9.41 | 638.80 | 10.11 | 55.39 | 11.35 | 41.78 | 7.76 |
| 9.00 | 4# | 634.14 | 9.55 | 638.76 | 10.05 | 49.31 | 13.25 | 46.35 | 8.16 |
| 10.00 | 1# | 631.85 | 9.55 | 638.55 | 9.46 | 54.68 | 11.09 | 41.54 | 7.72 |
| 10.00 | 2# | 632.90 | 9.58 | 639.32 | 9.70 | 54.86 | 11.17 | 41.67 | 7.71 |
| 10.00 | 3# | 632.68 | 9.41 | 638.75 | 10.11 | 54.89 | 11.26 | 41.78 | 7.76 |
| 10.00 | 4# | 633.26 | 9.55 | 637.23 | 9.40 | 49.41 | 14.08 | 46.35 | 8.16 |
| 11.00 | 1# | 631.85 | 9.55 | 638.55 | 9.46 | 54.58 | 11.09 | 41.54 | 7.72 |
| 11.00 | 2# | 632.90 | 9.58 | 639.32 | 9.70 | 54.67 | 11.17 | 41.67 | 7.71 |
| 11.00 | 3# | 632.68 | 9.41 | 638.75 | 10.11 | 54.62 | 11.35 | 41.78 | 7.76 |
| 11.00 | 4# | 633.26 | 9.55 | 637.23 | 9.40 | 49.19 | 14.74 | 46.35 | 8.16 |
| 12.00 | 1# | 631.85 | 9.55 | 638.55 | 9.46 | 54.58 | 11.09 | 41.54 | 7.72 |
| 12.00 | 2# | 632.90 | 9.58 | 639.32 | 9.70 | 54.67 | 11.17 | 41.67 | 7.71 |
| 12.00 | 3# | 632.68 | 9.41 | 638.75 | 10.11 | 54.62 | 11.35 | 41.78 | 7.76 |
| 12.00 | 4# | 633.26 | 9.55 | 637.23 | 9.40 | 49.96 | 14.74 | 46.35 | 8.16 |

注；表中尾水管进口最小动水压力为相对压力值

|  |  |
| --- | --- |
| 图6.102 JHT3蜗壳最大压力随延时关闭时间间隔变化图 | 图6.103 JHT3尾水管最小压力随延时关闭时间间隔变化图 |

注：1) JHT13、JDT6、JTT10的初始开度为73.56%，接力器行程为76.24%，采用30s-(85%)-70s两段关闭规律时，JHT13、JDT6、JTT10计算结果与30s-(80%)-70s两段关闭规律计算结果相同，不复述；

2)采用30s-(85%)-80s、30s-(85%)-80s、30s-(85%)-80s两段关闭规律时，JHT13、JDT6、JTT10计算结果与30s-(80%)-80s两段关闭规律计算结果相同，不复述；

3)当JHT3、JHT13、JDT6、JTT10工况甩负荷时导叶延迟关闭或者相距甩负荷时，图中所示的是蜗壳最大压力及尾水管最小压力极值发生的机组随时间间隔的变化情况；

**6.2.4.11 先快后慢关闭极值结果统计**

**表6-27 20s-(70%)-70s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 668.50 | 9.55 | 714.04 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 674.16 | 9.40 | 722.23 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 48.19 | 11.26 | 31.80 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 41.58 | 7.25 | 43.66 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 652.63 | 9.55 | 697.24 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 656.87 | 9.57 | 703.47 |
| 尾水管最小动水压力 (m) | 457.35 | 51.93 | 0.00 | 2# | 35.66 | 11.17 | 18.03 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 39.58 | 7.51 | 41.56 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 666.31 | 86.43 | 711.62 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 671.42 | 86.17 | 719.17 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 48.66 | 88.09 | 30.08 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.09 | 84.07 | 44.19 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 4.00 | 4# | 695.90 | 9.55 | 744.18 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 4.00 | 4# | 715.63 | 9.40 | 767.84 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 7.00 | 4# | 32.10 | 11.15 | 14.13 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 7.00 | 4# | 49.45 | 8.08 | 51.92 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 0.00 | 4# | 651.09 | 9.55 | 695.70 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 3.00 | 3# | 659.32 | 12.13 | 706.29 |
| 尾水管最小动水压力 (m) | 457.35 | 50.39 | 9.00 | 2# | 19.37 | 19.98 | 0.26 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 40.11 | 9.13 | 42.12 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 3.00 | 4# | 651.52 | 12.02 | 696.17 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 4.00 | 4# | 667.27 | 12.68 | 715.06 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 8.00 | 4# | 2.12 | 14.74 | -18.68 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 5.00 | 4# | 41.66 | 11.41 | 43.74 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 0.00 | 4# | 651.09 | 9.55 | 695.70 |
| 蜗壳最大动水压力(m) | 457.68 | 509.46 | 12.00 | 1# | 657.65 | 24.06 | 704.51 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 4.00 | 1# | 15.34 | 16.77 | -4.11 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 1.00 | 4# | 39.76 | 8.38 | 41.75 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-28 20s-(70%)-80s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 666.41 | 9.55 | 711.74 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 672.48 | 8.86 | 720.38 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 47.93 | 11.35 | 31.52 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 41.58 | 7.27 | 43.66 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 650.02 | 9.55 | 694.37 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 654.04 | 9.57 | 700.35 |
| 尾水管最小动水压力 (m) | 457.35 | 51.93 | 0.00 | 2# | 36.65 | 11.17 | 19.12 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 39.62 | 7.55 | 41.60 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 664.21 | 86.12 | 709.31 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 669.33 | 86.03 | 716.87 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 48.69 | 88.09 | 30.12 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.08 | 84.07 | 44.18 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 4.00 | 4# | 694.44 | 9.55 | 742.58 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 4.00 | 4# | 715.33 | 9.40 | 767.51 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 7.00 | 4# | 32.32 | 11.00 | 14.37 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 7.00 | 4# | 49.41 | 8.07 | 51.88 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 0.00 | 4# | 648.48 | 9.55 | 692.83 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 4.00 | 4# | 654.75 | 12.76 | 701.29 |
| 尾水管最小动水压力 (m) | 457.35 | 50.39 | 8.00 | 2# | 19.73 | 19.62 | 0.66 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 40.09 | 9.13 | 42.09 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.48 | 9.55 | 692.83 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 663.38 | 12.68 | 710.78 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 3.57 | 14.98 | -17.09 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 41.51 | 11.46 | 43.59 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.48 | 9.55 | 692.83 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 652.92 | 10.05 | 699.28 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 16.82 | 17.14 | -2.49 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 39.78 | 8.41 | 41.77 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-29 30s-(70%)-70s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 665.17 | 9.55 | 710.38 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 671.16 | 9.40 | 718.93 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 48.48 | 11.35 | 32.12 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 42.37 | 7.64 | 44.49 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 653.49 | 9.55 | 698.19 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 657.88 | 9.70 | 704.58 |
| 尾水管最小动水压力 (m) | 458.06 | 51.38 | 0.00 | 4# | 37.25 | 11.00 | 19.80 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 39.99 | 7.55 | 41.99 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 662.87 | 86.43 | 707.84 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 668.57 | 86.42 | 716.04 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 49.38 | 88.17 | 30.87 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.89 | 84.48 | 45.03 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 4.00 | 4# | 674.62 | 9.55 | 720.78 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 4.00 | 4# | 687.14 | 10.05 | 736.50 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 11.00 | 4# | 32.69 | 13.78 | 14.78 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 8.00 | 4# | 47.95 | 8.42 | 50.35 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 651.95 | 9.55 | 696.65 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 659.66 | 12.76 | 706.69 |
| 尾水管最小动水压力 (m) | 457.35 | 50.39 | 10.00 | 2# | 19.85 | 19.98 | 0.79 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 3.00 | 4# | 40.49 | 9.11 | 42.51 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 651.95 | 9.55 | 696.65 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 667.76 | 12.68 | 715.60 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 1.66 | 14.82 | -19.19 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 42.12 | 11.39 | 44.23 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 651.95 | 9.55 | 696.65 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 657.01 | 10.05 | 703.78 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 6.00 | 1# | 14.45 | 17.43 | -5.09 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 40.15 | 8.37 | 42.16 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-30 30s-(70%)-80s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 664.39 | 9.55 | 709.52 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 670.38 | 9.40 | 718.07 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 48.74 | 11.35 | 32.41 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 42.37 | 7.64 | 44.49 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 650.12 | 9.55 | 694.48 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 654.12 | 9.57 | 700.44 |
| 尾水管最小动水压力 (m) | 457.61 | 51.76 | 0.00 | 3# | 38.45 | 11.35 | 21.10 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 39.98 | 7.54 | 41.98 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 662.11 | 86.43 | 707.00 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 667.83 | 86.39 | 715.22 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 49.65 | 88.17 | 31.17 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.90 | 84.48 | 45.05 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 4.00 | 4# | 674.40 | 9.55 | 720.53 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 4.00 | 4# | 686.96 | 10.05 | 736.31 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 11.00 | 4# | 34.04 | 13.78 | 16.26 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 8.00 | 4# | 47.95 | 8.43 | 50.35 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.58 | 9.55 | 692.94 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 4.00 | 3# | 655.28 | 12.13 | 701.85 |
| 尾水管最小动水压力 (m) | 457.35 | 50.39 | 9.00 | 2# | 19.83 | 19.62 | 0.77 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 3.00 | 4# | 40.44 | 9.10 | 42.46 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.58 | 9.55 | 692.94 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 663.59 | 12.76 | 711.01 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 3.33 | 14.82 | -17.35 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 41.90 | 11.42 | 44.00 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.58 | 9.55 | 692.94 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 653.40 | 10.05 | 699.80 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 6.00 | 1# | 16.55 | 17.65 | -2.78 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 40.14 | 8.41 | 42.15 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-31 30s-(80%)-70s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 650.05 | 9.55 | 693.75 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 655.85 | 10.05 | 702.09 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 51.50 | 11.35 | 35.44 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 42.19 | 7.61 | 44.30 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 653.84 | 9.55 | 698.57 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 658.24 | 9.57 | 704.97 |
| 尾水管最小动水压力 (m) | 457.68 | 51.24 | 0.00 | 1# | 37.42 | 11.09 | 20.02 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 41.16 | 7.67 | 43.22 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 648.22 | 86.62 | 691.72 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 653.32 | 86.54 | 699.26 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 52.15 | 87.96 | 33.92 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.71 | 84.44 | 44.85 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 5.00 | 4# | 665.22 | 9.55 | 710.44 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 5.00 | 4# | 678.63 | 9.40 | 727.14 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 4.00 | 4# | 35.78 | 19.69 | 18.18 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 8.00 | 4# | 47.32 | 8.04 | 49.69 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 652.30 | 9.55 | 697.03 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 6.00 | 3# | 662.83 | 13.30 | 710.16 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 10.00 | 4# | 17.62 | 38.31 | -1.63 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 42.01 | 11.58 | 44.11 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 4.00 | 4# | 653.44 | 12.23 | 698.29 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 671.38 | 12.68 | 719.58 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 0.44 | 14.90 | -20.53 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 43.86 | 11.42 | 46.05 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 652.30 | 9.55 | 697.03 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 657.86 | 10.05 | 704.71 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 6.00 | 1# | 12.30 | 17.65 | -7.46 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 41.38 | 8.50 | 43.45 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-32 30s-(80%)-80s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 647.66 | 9.55 | 691.12 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 653.45 | 10.05 | 699.45 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 0.00 | 3# | 52.34 | 11.15 | 36.39 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 42.16 | 7.61 | 44.27 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 650.26 | 9.55 | 694.63 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 654.92 | 9.40 | 701.32 |
| 尾水管最小动水压力 (m) | 458.06 | 51.38 | 0.00 | 4# | 38.64 | 11.00 | 21.33 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 41.29 | 7.73 | 43.35 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 645.69 | 86.64 | 688.94 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 650.63 | 86.54 | 696.30 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 52.63 | 87.97 | 34.45 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.68 | 84.41 | 44.81 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 5.00 | 4# | 664.29 | 9.55 | 709.41 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 5.00 | 4# | 677.96 | 9.40 | 726.41 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 4.00 | 4# | 34.85 | 19.69 | 17.16 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 8.00 | 4# | 47.26 | 8.04 | 49.62 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 3.00 | 4# | 648.86 | 11.49 | 693.25 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 6.00 | 3# | 658.36 | 13.48 | 705.24 |
| 尾水管最小动水压力 (m) | 457.61 | 50.22 | 8.00 | 3# | 16.96 | 36.49 | -2.38 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 42.06 | 11.61 | 44.16 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 4.00 | 4# | 649.88 | 12.02 | 694.37 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 667.16 | 12.68 | 714.94 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 1.32 | 14.98 | -19.56 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 43.83 | 11.45 | 46.02 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.72 | 9.55 | 693.09 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 654.46 | 10.05 | 700.97 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 15.49 | 17.23 | -3.95 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 41.52 | 8.56 | 43.60 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-33 30s-(85%)-70s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 638.64 | 9.55 | 681.20 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 647.35 | 10.05 | 692.74 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 54.58 | 11.35 | 38.83 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 42.11 | 7.73 | 44.22 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 650.26 | 9.55 | 694.63 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 654.92 | 9.40 | 701.32 |
| 尾水管最小动水压力 (m) | 458.06 | 51.38 | 0.00 | 4# | 38.64 | 11.00 | 21.33 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 41.29 | 7.73 | 43.35 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 637.79 | 86.64 | 680.25 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 642.69 | 86.56 | 687.57 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 54.91 | 89.33 | 36.96 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.64 | 84.55 | 44.77 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 5.00 | 4# | 653.09 | 9.55 | 697.09 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 5.00 | 4# | 664.27 | 9.57 | 711.35 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 5.00 | 4# | 36.56 | 19.98 | 19.04 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 8.00 | 4# | 46.30 | 8.04 | 48.62 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 3.00 | 4# | 648.86 | 11.49 | 693.25 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 6.00 | 3# | 658.36 | 13.48 | 705.24 |
| 尾水管最小动水压力 (m) | 457.61 | 50.22 | 8.00 | 3# | 16.96 | 36.49 | -2.38 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 42.06 | 11.61 | 44.16 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 4.00 | 4# | 649.88 | 12.02 | 694.37 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 667.16 | 12.68 | 714.94 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 1.32 | 14.98 | -19.56 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 43.83 | 11.45 | 46.02 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.72 | 9.55 | 693.09 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 654.46 | 10.05 | 700.97 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 15.49 | 17.23 | -3.95 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 41.52 | 8.56 | 43.60 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-34 30s-(85%)-80s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 641.37 | 10.05 | 684.20 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 650.01 | 10.05 | 695.66 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 0.00 | 4# | 53.72 | 12.64 | 37.91 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 42.14 | 7.75 | 44.25 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 653.84 | 9.55 | 698.57 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 658.24 | 9.57 | 704.97 |
| 尾水管最小动水压力 (m) | 457.68 | 51.24 | 0.00 | 1# | 37.42 | 11.09 | 20.02 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 41.16 | 7.67 | 43.22 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 640.80 | 86.64 | 683.56 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 645.85 | 86.74 | 691.05 |
| 尾水管最小动水压力 (m) | 421.50 | 64.80 | 76.76 | 2# | 54.51 | 89.19 | 38.73 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.67 | 84.54 | 44.80 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 5.00 | 4# | 654.88 | 9.55 | 699.06 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 6.00 | 4# | 666.19 | 10.05 | 713.46 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 5.00 | 4# | 38.09 | 19.98 | 20.72 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 8.00 | 4# | 46.44 | 8.04 | 48.76 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 652.30 | 9.55 | 697.03 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 6.00 | 3# | 662.83 | 13.30 | 710.16 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 10.00 | 4# | 17.62 | 38.31 | -1.63 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 42.01 | 11.58 | 44.11 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 4.00 | 4# | 653.44 | 12.23 | 698.29 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 671.38 | 12.68 | 719.58 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 0.44 | 14.90 | -20.53 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 43.86 | 11.42 | 46.05 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 652.30 | 9.55 | 697.03 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 657.86 | 10.05 | 704.71 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 6.00 | 1# | 12.30 | 17.65 | -7.46 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 41.38 | 8.50 | 43.45 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-35 20s-(85%)-80s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 640.12 | 9.55 | 682.83 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 646.01 | 10.05 | 691.26 |
| 尾水管最小动水压力 (m) | 418.96 | 65.43 | 0.00 | 3# | 52.71 | 11.90 | 36.77 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 41.54 | 7.72 | 43.62 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 650.26 | 9.55 | 694.63 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 654.92 | 9.40 | 701.32 |
| 尾水管最小动水压力 (m) | 458.06 | 51.38 | 0.00 | 4# | 38.64 | 11.00 | 21.33 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 41.29 | 7.73 | 43.35 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 637.74 | 86.64 | 680.19 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 642.36 | 86.54 | 687.21 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 53.96 | 89.12 | 35.91 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 42.07 | 84.50 | 44.17 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 6.00 | 4# | 655.55 | 9.55 | 699.80 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 6.00 | 4# | 668.12 | 9.40 | 715.58 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 5.00 | 4# | 32.60 | 19.69 | 14.68 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 8.00 | 4# | 46.19 | 7.99 | 48.50 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 3.00 | 4# | 648.86 | 11.49 | 693.25 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 6.00 | 3# | 658.36 | 13.48 | 705.24 |
| 尾水管最小动水压力 (m) | 457.61 | 50.22 | 8.00 | 3# | 16.96 | 36.49 | -2.38 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 42.06 | 11.61 | 44.16 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 4.00 | 4# | 649.88 | 12.02 | 694.37 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 667.16 | 12.68 | 714.94 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 1.32 | 14.98 | -19.56 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 43.83 | 11.45 | 46.02 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.72 | 9.55 | 693.09 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 654.46 | 10.05 | 700.97 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 15.49 | 17.23 | -3.95 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 41.52 | 8.56 | 43.60 |

注；表中尾水管进口最小动水压力为相对压力值

**表6-36 40s-(85%)-80s两段关闭规律极值统计**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 关机  时间 | 控制参数 | 净水头 | 初始值 | 间隔时间(s) | 发生机组 | 计算  极值 | 极值发生时间(s) | 修正值 |
| SJT2 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 0.00 | 4# | 642.60 | 9.55 | 685.55 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 0.00 | 4# | 648.80 | 10.05 | 694.33 |
| 尾水管最小动水压力 (m) | 419.05 | 64.78 | 0.00 | 1# | 53.60 | 11.09 | 37.82 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 0.00 | 4# | 42.73 | 7.73 | 44.87 |
| SJT3 | 球阀上游侧最大动水压力（m） | 458.06 | 527.15 | 0.00 | 4# | 650.26 | 9.55 | 694.63 |
| 蜗壳最大动水压力(m) | 458.06 | 511.54 | 0.00 | 4# | 654.92 | 9.40 | 701.32 |
| 尾水管最小动水压力 (m) | 458.06 | 51.38 | 0.00 | 4# | 38.64 | 11.00 | 21.33 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 0.00 | 4# | 41.29 | 7.73 | 43.35 |
| ZT2 | 球阀上游侧最大动水压力（m） | 425.59 | 511.10 | 76.76 | 4# | 639.50 | 86.25 | 682.13 |
| 蜗壳最大动水压力(m) | 421.83 | 489.17 | 76.76 | 3# | 644.49 | 86.39 | 689.55 |
| 尾水管最小动水压力 (m) | 425.59 | 85.48 | 76.76 | 4# | 53.95 | 87.96 | 35.90 |
| 机组最大转速上升率(%) | 425.59 | 428.60 | 76.76 | 4# | 43.25 | 84.56 | 45.41 |
| JHT3 | 球阀上游侧最大动水压力（m） | 419.53 | 506.74 | 5.00 | 4# | 652.41 | 9.55 | 696.34 |
| 蜗壳最大动水压力(m) | 419.53 | 487.17 | 5.00 | 4# | 662.61 | 10.05 | 709.52 |
| 尾水管最小动水压力 (m) | 419.53 | 64.96 | 5.00 | 4# | 46.55 | 20.88 | 30.03 |
| 机组最大转速上升率(%) | 419.53 | 428.60 | 8.00 | 4# | 46.37 | 8.17 | 48.69 |
| JHT13 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 3.00 | 4# | 648.86 | 11.49 | 693.25 |
| 蜗壳最大动水压力(m) | 457.61 | 509.91 | 6.00 | 3# | 658.36 | 13.48 | 705.24 |
| 尾水管最小动水压力 (m) | 457.61 | 50.22 | 8.00 | 3# | 16.96 | 36.49 | -2.38 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 42.06 | 11.61 | 44.16 |
| JDT6 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 4.00 | 4# | 649.88 | 12.02 | 694.37 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 5.00 | 4# | 667.16 | 12.68 | 714.94 |
| 尾水管最小动水压力 (m) | 458.06 | 49.84 | 9.00 | 4# | 1.32 | 14.98 | -19.56 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 6.00 | 4# | 43.83 | 11.45 | 46.02 |
| JDT10 | 球阀上游侧最大动水压力（m） | 458.06 | 525.61 | 1.00 | 4# | 648.72 | 9.55 | 693.09 |
| 蜗壳最大动水压力(m) | 458.06 | 510.00 | 2.00 | 4# | 654.46 | 10.05 | 700.97 |
| 尾水管最小动水压力 (m) | 457.68 | 49.70 | 5.00 | 1# | 15.49 | 17.23 | -3.95 |
| 机组最大转速上升率(%) | 458.06 | 428.60 | 2.00 | 4# | 41.52 | 8.56 | 43.60 |

注；表中尾水管进口最小动水压力为相对压力值

**6.2.4.8 本节小结**

（1）工况JHT3采用20s-(70%)-70s、20s-(70%)-80s、30s-(70%)-70s、30s-(70%)-80s、30s-(80%)-70s、30s-(80%)-80s关闭规律都使蜗壳压力修正后大于720mH2O，不满足控制要求。

（2）采用40s-(85%)-80s关闭规律将使ZT2工况4#机组最大转速上升率修正值达45.41%，不满足机组最大瞬态转速不超过1.45倍额定转速的要求。

（3） 采用30s-(85%)-80s关闭规律与30s-(85%)-70s关闭规律时，JHT13、JDT6、JDT10工况尾水管最小压力（相对压力）有可能低于1.66mH2O，不满足控制的要求，但除了JDT6工况外，其余工况尾水管最小压力（绝对压力）都超过1.66m，此外采用30s-(85%)-80s关闭规律尾水管最小压力变化情况较30s-(85%)-70s关闭规律好。

（4）采用30s-(85%)-80s关闭规律时，JDT6工况4#相距甩6s时机组最大转速上升率计算值为43.86%，修正后为46.05%，不满足控制要求。

（5）综上所述，考虑各方面的因素，选取30s-(85%)-80s两段关闭为宜。

## 6.3 球阀关闭规律的优化

### 6.3.1 球阀关闭关闭的优化结果

选取SJT2、SJT3两个工况，导叶的关闭规律为6.2节中优化的最优结果30s-(85%)-80s先快后慢两段直线关闭，球阀关闭规律如图6.104～6.110所示，计算球阀不关和直线关闭时球阀进口压力、蜗壳进口压力、尾水管进口压力、机组转速等控制参数变化情况，结果如表6-37～6-39所示：

|  |  |
| --- | --- |
| 图6.104 球阀不关规律 | 图6.105 球阀直线70s关闭规律 |
| 图6.106 球阀直线80s关闭规律 | 图6.107 球阀直线90s关闭规律 |
| 图6.108 球阀直线100s关闭规律 | 图6.109 球阀直线110s关闭规律 |
| 图6.110 球阀直线120s关闭规律 |  |

**表6-37 SJT2工况的优化结果**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 球阀关闭时间(s) | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| 不关 | 1# | 635.04 | 9.83 | 642.39 | 9.93 | 54.96 | 12.29 | 41.78 | 7.72 |
| 2# | 637.11 | 10.08 | 643.27 | 10.06 | 54.87 | 11.17 | 41.93 | 7.71 |
| 3# | 637.55 | 10.21 | 643.95 | 10.03 | 54.57 | 11.35 | 42.06 | 7.70 |
| 4# | 638.65 | 9.55 | 647.39 | 10.05 | 54.79 | 12.64 | 42.11 | 7.73 |
| 直线70s | 1# | 635.06 | 9.83 | 642.38 | 9.93 | 54.94 | 12.29 | 41.78 | 7.70 |
| 2# | 637.10 | 10.08 | 643.23 | 10.06 | 54.89 | 11.17 | 41.93 | 7.71 |
| 3# | 637.51 | 10.21 | 643.90 | 10.03 | 54.58 | 11.35 | 42.05 | 7.72 |
| 4# | 638.64 | 9.55 | 647.35 | 10.05 | 54.80 | 12.64 | 42.11 | 7.73 |
| 直线80s | 1# | 635.04 | 9.83 | 642.36 | 9.93 | 54.91 | 12.29 | 41.78 | 7.69 |
| 2# | 637.12 | 10.08 | 643.26 | 10.06 | 54.86 | 11.17 | 41.93 | 7.71 |
| 3# | 637.55 | 10.21 | 643.95 | 10.03 | 54.57 | 11.35 | 42.06 | 7.72 |
| 4# | 638.67 | 9.55 | 647.43 | 10.05 | 54.79 | 12.64 | 42.11 | 7.71 |
| 直线90s | 1# | 634.98 | 9.83 | 642.32 | 9.93 | 54.92 | 12.29 | 41.78 | 7.71 |
| 2# | 637.12 | 10.08 | 643.26 | 10.06 | 54.84 | 11.17 | 41.93 | 7.71 |
| 3# | 637.60 | 10.21 | 644.03 | 10.03 | 54.55 | 11.35 | 42.06 | 7.70 |
| 4# | 638.64 | 9.55 | 647.35 | 10.05 | 54.81 | 12.64 | 42.11 | 7.73 |
| 直线100s | 1# | 635.02 | 9.83 | 642.35 | 9.93 | 54.96 | 12.29 | 41.78 | 7.71 |
| 2# | 637.06 | 10.08 | 643.19 | 10.06 | 54.89 | 11.17 | 41.93 | 7.71 |
| 3# | 637.57 | 10.21 | 644.00 | 10.03 | 54.54 | 11.35 | 42.06 | 7.70 |
| 4# | 638.66 | 9.55 | 647.40 | 10.05 | 54.81 | 11.00 | 42.11 | 7.73 |
| 直线110s | 1# | 635.09 | 9.83 | 642.45 | 9.93 | 54.97 | 12.29 | 41.78 | 7.71 |
| 2# | 637.09 | 10.08 | 643.22 | 10.06 | 54.88 | 11.17 | 41.93 | 7.71 |
| 3# | 637.51 | 10.21 | 643.88 | 10.03 | 54.59 | 11.35 | 42.06 | 7.70 |
| 4# | 638.67 | 9.55 | 647.46 | 10.05 | 54.78 | 11.00 | 42.11 | 7.73 |
| 直线120s | 1# | 635.00 | 9.83 | 642.33 | 9.93 | 54.93 | 12.29 | 41.78 | 7.71 |
| 2# | 637.10 | 10.08 | 643.22 | 10.06 | 54.89 | 11.17 | 41.93 | 7.71 |
| 3# | 637.63 | 10.21 | 644.07 | 10.03 | 54.55 | 11.35 | 42.06 | 7.70 |
| 4# | 638.68 | 9.55 | 647.43 | 10.05 | 54.78 | 12.64 | 42.11 | 7.73 |

|  |  |
| --- | --- |
| 图6.111 SJT2 1#球阀进口动水压力波动图 | 图6.112 SJT2 1#球阀进口动水压力波动图 |
| 图6.113 SJT2 1#尾水管进口动水压力波动图 | 图6.114 SJT2 1#机组转速波动图 |

**表6-38 SJT3工况的优化结果**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 球阀关闭时间(s) | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| 不关 | 1# | 647.55 | 9.54 | 653.08 | 9.46 | 38.87 | 11.09 | 41.03 | 7.72 |
| 2# | 648.32 | 9.50 | 653.04 | 9.56 | 38.74 | 11.17 | 41.14 | 7.71 |
| 3# | 647.96 | 9.56 | 653.19 | 9.30 | 38.71 | 11.26 | 41.24 | 7.70 |
| 4# | 650.23 | 9.55 | 654.90 | 9.40 | 38.70 | 11.00 | 41.29 | 7.71 |
| 直线70s | 1# | 647.45 | 9.54 | 652.98 | 9.46 | 38.90 | 11.09 | 41.02 | 7.72 |
| 2# | 648.25 | 9.50 | 652.94 | 9.56 | 38.77 | 11.17 | 41.14 | 7.71 |
| 3# | 647.90 | 9.56 | 653.12 | 9.30 | 38.78 | 11.26 | 41.24 | 7.70 |
| 4# | 650.26 | 9.55 | 654.92 | 9.40 | 38.64 | 11.00 | 41.29 | 7.73 |
| 直线80s | 1# | 647.47 | 9.54 | 652.98 | 9.46 | 38.89 | 11.09 | 41.03 | 7.73 |
| 2# | 648.33 | 9.50 | 653.03 | 9.56 | 38.76 | 11.17 | 41.14 | 7.74 |
| 3# | 647.93 | 9.56 | 653.16 | 9.30 | 38.69 | 11.26 | 41.24 | 7.70 |
| 4# | 650.21 | 9.55 | 654.85 | 9.40 | 38.67 | 11.00 | 41.29 | 7.73 |
| 直线90s | 1# | 647.51 | 9.54 | 653.01 | 9.46 | 38.87 | 11.09 | 41.03 | 7.71 |
| 2# | 648.34 | 9.50 | 653.03 | 9.56 | 38.72 | 11.17 | 41.14 | 7.71 |
| 3# | 647.99 | 9.56 | 653.19 | 9.30 | 38.71 | 11.26 | 41.24 | 7.75 |
| 4# | 650.23 | 9.55 | 654.89 | 9.40 | 38.71 | 11.00 | 41.29 | 7.72 |
| 直线100s | 1# | 647.54 | 9.54 | 653.08 | 9.46 | 38.88 | 11.09 | 41.03 | 7.72 |
| 2# | 648.28 | 9.50 | 652.99 | 9.56 | 38.78 | 11.17 | 41.14 | 7.71 |
| 3# | 647.92 | 9.56 | 653.14 | 9.30 | 38.73 | 11.26 | 41.24 | 7.74 |
| 4# | 650.24 | 9.55 | 654.90 | 9.40 | 38.65 | 11.00 | 41.29 | 7.71 |
| 直线110s | 1# | 647.46 | 9.54 | 652.97 | 9.46 | 38.88 | 11.09 | 41.03 | 7.73 |
| 2# | 648.29 | 9.50 | 652.98 | 9.56 | 38.76 | 11.17 | 41.14 | 7.71 |
| 3# | 647.91 | 9.56 | 653.16 | 9.30 | 38.69 | 11.26 | 41.24 | 7.74 |
| 4# | 650.15 | 9.55 | 654.82 | 9.40 | 38.68 | 11.00 | 41.29 | 7.71 |
| 直线120s | 1# | 647.48 | 9.54 | 652.99 | 9.46 | 38.93 | 11.09 | 41.03 | 7.71 |
| 2# | 648.28 | 9.50 | 652.98 | 9.56 | 38.80 | 11.17 | 41.14 | 7.70 |
| 3# | 647.91 | 9.56 | 653.14 | 9.30 | 38.72 | 11.26 | 41.24 | 7.70 |
| 4# | 650.24 | 9.55 | 654.90 | 9.40 | 38.62 | 11.00 | 41.29 | 7.71 |

|  |  |
| --- | --- |
| 图6.115 SJT3 1#球阀进口动水压力波动图 | 图6.116 SJT3 1#蜗壳进口动水压力波动图 |
| 图6.117 SJT3 1#尾水管进口动水压力波动图 | 图6.118 SJT3 1#机组转速波动图 |

**表6-39 JHT4工况的优化结果**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 球阀关闭时间(s) | 机组 | 球阀上游侧最大动水压力（m） | 极值发生时间（s） | 蜗壳进口最大动水压力（m） | 极值发生时间（s） | 尾水管进口最小动水压力（m） | 极值发生时间（s） | 机组最大转速上升（%） | 极值发生时间（s） |
| 不关 | 1# | 628.78 | 9.83 | 636.23 | 9.93 | 55.55 | 11.09 | 40.91 | 7.77 |
| 2# | 630.83 | 10.08 | 636.89 | 10.06 | 55.43 | 11.17 | 41.04 | 7.74 |
| 3# | 631.13 | 10.21 | 637.56 | 10.32 | 55.04 | 11.35 | 41.16 | 7.78 |
| 4# | 630.67 | 9.55 | 636.09 | 8.86 | 49.08 | 26.72 | 46.28 | 8.02 |
| 直线70s | 1# | 628.72 | 9.83 | 636.13 | 9.93 | 55.52 | 11.09 | 40.90 | 7.76 |
| 2# | 630.79 | 10.08 | 636.80 | 10.06 | 55.43 | 11.17 | 41.04 | 7.76 |
| 3# | 631.05 | 10.21 | 637.46 | 10.11 | 55.08 | 11.35 | 41.16 | 7.77 |
| 4# | 630.62 | 9.55 | 635.97 | 8.86 | 49.61 | 26.72 | 46.27 | 8.00 |
| 直线80s | 1# | 628.78 | 9.83 | 636.18 | 9.93 | 55.55 | 11.09 | 40.91 | 7.76 |
| 2# | 630.79 | 10.08 | 636.84 | 10.06 | 55.41 | 11.17 | 41.04 | 7.74 |
| 3# | 631.12 | 10.21 | 637.57 | 10.11 | 55.06 | 11.35 | 41.15 | 7.80 |
| 4# | 630.64 | 9.55 | 636.01 | 8.86 | 49.07 | 26.72 | 46.27 | 8.00 |
| 直线90s | 1# | 628.81 | 9.83 | 636.25 | 9.93 | 55.55 | 11.09 | 40.91 | 7.78 |
| 2# | 630.87 | 10.08 | 636.91 | 10.06 | 55.41 | 11.17 | 41.04 | 7.74 |
| 3# | 631.16 | 10.21 | 637.59 | 10.32 | 55.04 | 11.35 | 41.16 | 7.78 |
| 4# | 630.67 | 9.55 | 636.03 | 8.86 | 49.13 | 26.72 | 46.28 | 7.98 |
| 直线100s | 1# | 628.80 | 9.83 | 636.23 | 9.93 | 55.54 | 11.09 | 40.91 | 7.77 |
| 2# | 630.84 | 10.08 | 636.90 | 10.06 | 55.41 | 11.17 | 41.04 | 7.74 |
| 3# | 631.13 | 10.21 | 637.58 | 10.32 | 55.02 | 11.35 | 41.16 | 7.77 |
| 4# | 630.67 | 9.55 | 636.04 | 8.86 | 49.11 | 26.72 | 46.28 | 8.02 |
| 直线110s | 1# | 628.78 | 9.83 | 636.22 | 9.93 | 55.52 | 11.09 | 40.91 | 7.77 |
| 2# | 630.82 | 10.08 | 636.87 | 10.06 | 55.39 | 11.17 | 41.04 | 7.74 |
| 3# | 631.07 | 10.21 | 637.48 | 10.11 | 55.06 | 11.35 | 41.16 | 7.78 |
| 4# | 630.66 | 9.55 | 636.04 | 8.86 | 49.18 | 26.72 | 46.28 | 8.00 |
| 直线120s | 1# | 628.77 | 9.83 | 636.21 | 9.93 | 55.54 | 11.09 | 40.91 | 7.78 |
| 2# | 630.88 | 10.08 | 636.95 | 10.06 | 55.41 | 11.17 | 41.04 | 7.74 |
| 3# | 631.10 | 10.21 | 637.54 | 10.32 | 55.05 | 11.35 | 41.16 | 7.78 |
| 4# | 630.62 | 9.55 | 636.04 | 8.86 | 49.14 | 26.72 | 46.28 | 8.02 |

|  |  |
| --- | --- |
| 图6.119 JHT4 4#球阀进口动水压力波动图 | 图6.120 JHT4 4#蜗壳进口动水压力波动图 |
| 图6.121 JHT4 4#尾水管进口动水压力波动图 | 图6.122 JHT4 4#机组转速波动 |

### 6.3.2 本节小结

由表6-37～6-39和图6.111～6.122可知，球阀不关闭和球阀70s、80s、90s、100s、110s、120s关闭时对球阀进口压力、蜗壳进口压力、尾水管进口压力和机组转速参数的影响并不大，各参数极值基本上相同，导叶正常关闭时四台机组同时甩负荷采用不同的关闭规律各参数的变化曲线基本重合，当四台机组同时甩负荷并且其中一台机组导叶拒动时，球阀关闭时间不同，波形图虽有所差异，但各曲线图的第一、第二峰值基本上相同，球阀不关时波形是振荡的，不能稳定下来。球阀关后，除尾水管压力外各参数的稳定值基本相同。设计院推荐导叶关闭的同时球阀随动关闭，考虑到导叶的关闭规律为30s-(85%)-80s两段直线关闭，关闭时间为74.15s，故选球阀关闭时间为直线80s。

## 6.4 优化后球阀关闭规律

经过优化，最终选择直线80s的关闭规律，如图6.122所示。

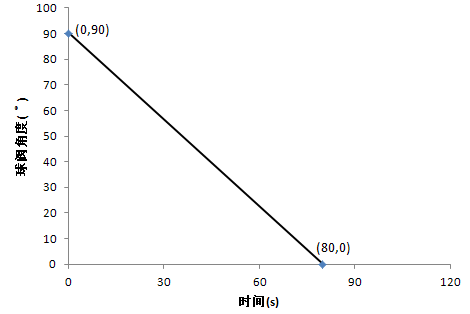


图6.122 球阀关闭规律

## 6.5 优化后水轮机工况导叶关闭规律

经过优化，最终确定折线关闭规律，选取图6.123所示100%开度下的折线关闭规律，折点坐标（4.65s，85%）。

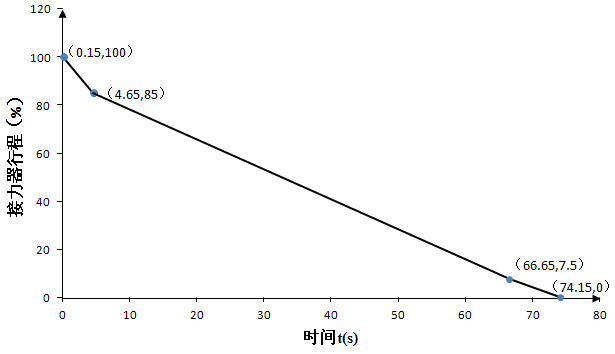


图6.123 水轮机工况导叶关闭规律

## 6.6 优化后水轮机工况导叶开启规律

导叶开启规律见图6.124，有效开启时间Ts=30s，从0％增加到满开度100.00％。

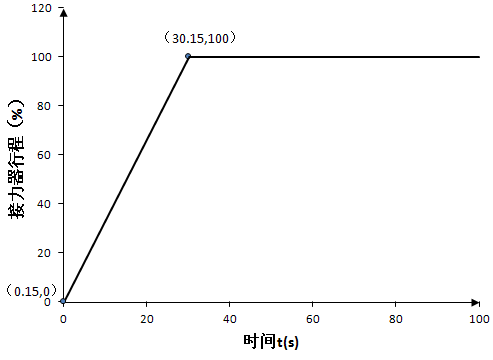


图6.124 水轮机工况导叶开启规律

## 6.7 优化后水泵工况导叶关闭规律

水泵工况导叶关闭规律如图6.125所示，直线30s关闭，从100％开度减小到0%。

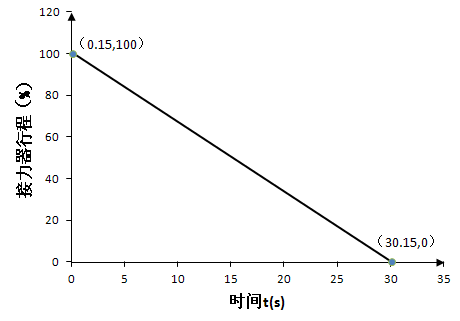


图6.125 水泵工况导叶关闭规律

## 6.8 优化后水泵工况导叶开启规律

水泵启动时采用导叶30s直线开启规律，使0增至100%开度，如图6.126所示。

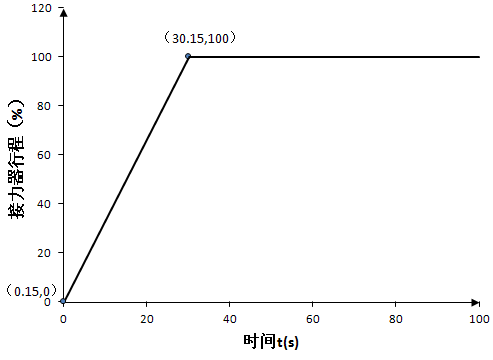


图6.126 水泵工况导叶开启规律

## 6.9 **大波动过渡过程计算结果及分析**

### 6.9.1 恒定流计算结果

GD2为6257，调压室阻抗孔口取给定面积26.42m2，流入、流出调压室的流速系数为0.6、0.8，采用图6.122、图6.123、图6.124、图6.125和图6.126所示的导叶及球阀的启闭规律进行大波动过渡过程计算，各工况参数及计算结果见表6-40～表6-41。

**表6-40** **大波动水轮机工况参数表**

| 工况 | 上游水位 (m) | 下游水位(m) | 机组 | 开度(%) | 净水头(m) | 流量(m3/s) | 出力(MW) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SJT1 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| SJT2 | 509.50 | 79.00 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| SJT3 | 528.35 | 61.54 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| SJT4 | 502.00 | 71.50 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| SJT5 | 502.00 | 71.50 | 1# | 94.43 | 421.99 | 83.91 | 309.62 |
| 2# | 94.43 | 421.50 | 83.85 | 309.04 |
| 3# | 94.43 | 421.83 | 83.89 | 309.43 |
| 4# | 15.87 | 425.59 | 10.60 | 0.00 |
| SJT6 | 508.90 | 78.40 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| SJT7 | 508.90 | 78.40 | 1# | 94.43 | 421.99 | 83.91 | 309.62 |
| 2# | 94.43 | 421.50 | 83.85 | 309.04 |
| 3# | 94.43 | 421.83 | 83.89 | 309.43 |
| 4# | 15.87 | 425.59 | 10.60 | 0.00 |
| SJT8 | 502.40 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| SJT9 | 502.40 | 71.90 | 1# | 94.43 | 421.99 | 83.91 | 309.62 |
| 2# | 94.43 | 421.50 | 83.85 | 309.04 |
| 3# | 94.43 | 421.83 | 83.89 | 309.43 |
| 4# | 15.87 | 425.59 | 10.60 | 0.00 |
| ZT1 | 526.81 | 60.00 | 1# | 73.56 | 460.24 | 74.93 | 309.16 |
| 2# | 73.56 | 459.86 | 74.89 | 308.71 |
| 3# | 73.56 | 460.12 | 74.92 | 309.01 |
| 4# | 10.58 | 463.03 | 9.25 | 0.00 |
| ZT2 | 509.5 | 79.00 | 1# | 94.43 | 421.99 | 83.91 | 309.62 |
| 2# | 94.43 | 421.50 | 83.85 | 309.04 |
| 3# | 94.43 | 421.83 | 83.89 | 309.43 |
| 4# | 15.87 | 425.59 | 10.60 | 0.00 |
| ZT3 | 526.81 | 60.00 | 1# | 73.56 | 460.24 | 74.93 | 309.16 |
| 2# | 73.56 | 459.86 | 74.89 | 308.71 |
| 3# | 73.56 | 460.12 | 74.92 | 309.01 |
| 4# | 10.58 | 463.03 | 9.25 | 0.00 |
| ZT4 | 502.00 | 71.50 | 1# | 94.43 | 421.99 | 83.91 | 309.62 |
| 2# | 94.43 | 421.50 | 83.85 | 309.04 |
| 3# | 94.43 | 421.83 | 83.89 | 309.43 |
| 4# | 15.87 | 425.59 | 10.60 | 0.00 |
| JHT1 | 528.35 | 61.54 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JHT2 | 528.35 | 61.54 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JHT3 | 509.50 | 79.00 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JHT4 | 509.50 | 79.00 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JHT5 | 502.00 | 71.50 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JHT6 | 502.00 | 71.50 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JHT7 | 508.90 | 78.40 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JHT8 | 508.90 | 78.40 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JHT9 | 502.40 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JHT10 | 502.40 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JHT11 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JHT12 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JHT13 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JHT14 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JHT15 | 526.81 | 60.00 | 1# | 72.43 | 460.66 | 74.12 | 306.34 |
| 2# | 72.43 | 460.29 | 74.07 | 305.89 |
| 3# | 72.43 | 460.53 | 74.10 | 306.18 |
| JHT16 | 526.81 | 60.00 | 1# | 72.25 | 460.88 | 74.00 | 306.04 |
| 2# | 72.25 | 460.94 | 74.01 | 306.11 |
| 3# | 72.25 | 461.09 | 74.03 | 306.29 |
| JHT17 | 528.35 | 61.54 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JHT18 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JDT1 | 528.35 | 61.54 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JDT2 | 502.00 | 71.50 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JDT3 | 508.90 | 78.40 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JDT4 | 502.40 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| JDT5 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JDT6 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JDT7 | 528.35 | 61.54 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| JDT10 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |

**表6-41 大波动水泵工况机组参数表**

| 工况 | 上游水位 (m) | 下游水位(m) | 机组 | 开度(%) | 净扬程(m) | 流量(m3/s) | 出力(MW) |
| --- | --- | --- | --- | --- | --- | --- | --- |
| SJP1 | 526.81 | 60.00 | 1# | 60.40 | 472.61 | -56.69 | -290.42 |
| 2# | 60.40 | 472.79 | -56.64 | -290.27 |
| 3# | 60.40 | 473.22 | -56.51 | -289.91 |
| 4# | 60.40 | 472.06 | -56.86 | -290.89 |
| SJP2 | 502.00 | 80.00 | 1# | 63.20 | 430.35 | -67.06 | -312.92 |
| 2# | 63.20 | 430.60 | -67.00 | -312.82 |
| 3# | 63.20 | 431.21 | -66.85 | -312.57 |
| 4# | 63.20 | 429.55 | -67.25 | -313.24 |
| SJP3 | 504.57 | 84.26 | 1# | 63.20 | 428.75 | -67.45 | -313.57 |
| 2# | 63.20 | 429.01 | -67.38 | -313.46 |
| 3# | 63.20 | 429.63 | -67.23 | -313.21 |
| 4# | 63.20 | 427.95 | -67.63 | -313.87 |
| SJP4 | 502.00 | 70.55 | 1# | 59.94 | 439.34 | -65.22 | -310.37 |
| 2# | 59.94 | 439.58 | -65.16 | -310.29 |
| 3# | 59.94 | 440.16 | -65.04 | -310.10 |
| 4# | 59.94 | 438.58 | -65.38 | -310.62 |
| ZP2 | 502.00 | 80.00 | 1# | 63.20 | 427.58 | -67.71 | -313.99 |
| 2# | 63.20 | 427.45 | -67.74 | -314.04 |
| 3# | 63.20 | 427.49 | -67.73 | -314.02 |
| 4# | 0.02 | 425.02 | -0.06 | -38.15 |
| ZP3 | 504.57 | 84.26 | 1# | 63.20 | 425.95 | -68.07 | -314.55 |
| 2# | 63.20 | 425.82 | -68.10 | -314.59 |
| 3# | 63.20 | 425.86 | -68.09 | -314.58 |
| 4# | 0.02 | 423.36 | -0.06 | -38.15 |
| ZP4 | 502.00 | 80.00 | 1# | 63.20 | 427.58 | -67.71 | -313.99 |
| 2# | 63.20 | 427.45 | -67.74 | -314.04 |
| 3# | 63.20 | 427.49 | -67.73 | -314.02 |
| 4# | 0.02 | 425.02 | -0.06 | -38.15 |
| JHP1 | 502.00 | 80.00 | 1# | 63.20 | 430.35 | -67.06 | -312.92 |
| 2# | 63.20 | 430.60 | -67.00 | -312.82 |
| 3# | 63.20 | 431.21 | -66.85 | -312.57 |
| 4# | 63.20 | 429.55 | -67.25 | -313.24 |
| JHP2 | 502.00 | 80.00 | 1# | 63.20 | 430.35 | -67.06 | -312.92 |
| 2# | 63.20 | 430.60 | -67.00 | -312.82 |
| 3# | 63.20 | 431.21 | -66.85 | -312.57 |
| 4# | 63.20 | 429.55 | -67.25 | -313.24 |
| JHP3 | 502.00 | 70.55 | 1# | 59.94 | 439.34 | -65.22 | -310.37 |
| 2# | 59.94 | 439.58 | -65.16 | -310.29 |
| 3# | 59.94 | 440.16 | -65.04 | -310.10 |
| 4# | 59.94 | 438.58 | -65.38 | -310.62 |
| JHP4 | 502.00 | 70.55 | 1# | 59.94 | 439.34 | -65.22 | -310.37 |
| 2# | 59.94 | 439.58 | -65.16 | -310.29 |
| 3# | 59.94 | 440.16 | -65.04 | -310.10 |
| 4# | 59.94 | 438.58 | -65.38 | -310.62 |
| JHP5 | 526.81 | 60.00 | 1# | 60.40 | 472.61 | -56.69 | -290.42 |
| 2# | 60.40 | 472.79 | -56.64 | -290.27 |
| 3# | 60.40 | 473.22 | -56.51 | -289.91 |
| 4# | 60.40 | 472.06 | -56.86 | -290.89 |
| JDP1 | 502.00 | 80.00 | 1# | 63.20 | 430.35 | -67.06 | -312.92 |
| 2# | 63.20 | 430.60 | -67.00 | -312.82 |
| 3# | 63.20 | 431.21 | -66.85 | -312.57 |
| 4# | 63.20 | 429.55 | -67.25 | -313.24 |
| JDP2 | 504.57 | 84.26 | 1# | 63.20 | 428.75 | -67.45 | -313.57 |
| 2# | 63.20 | 429.01 | -67.38 | -313.46 |
| 3# | 63.20 | 429.63 | -67.23 | -313.21 |
| 4# | 63.20 | 427.95 | -67.63 | -313.87 |
| JDP3 | 502.00 | 70.55 | 1# | 59.94 | 439.34 | -65.22 | -310.37 |
| 2# | 59.94 | 439.58 | -65.16 | -310.29 |
| 3# | 59.94 | 440.16 | -65.04 | -310.10 |
| 4# | 59.94 | 438.58 | -65.38 | -310.62 |

### 6.9.2 大波动过渡过程计算结果

#### 6.9.2.1 水轮机设计工况计算结果

大波动水轮机设计工况机组参数极值计算结果见表6-42（含脉动压力和计算误差）。

**表6-42 大波动水轮机设计工况机组参数计算结果**

| 工况 | 控制参数 | 机组 | 净水头（m） | 初始值 | 计算  极值 | 极值发生时间(s) | 压力脉动(%) | 计算误差(%) | 修正值 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|
|
| SJT1 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 645.91 | 9.54 | 7 | 10 | 690.03 |
| 2# | 457.35 | 525.38 | 646.71 | 9.50 | 7 | 10 | 690.86 |
| 3# | 457.61 | 525.50 | 646.36 | 9.56 | 7 | 10 | 690.48 |
| 4# | 458.06 | 525.61 | 648.72 | 9.55 | 7 | 10 | 693.09 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 651.44 | 9.46 | 7 | 10 | 697.68 |
| 2# | 457.35 | 509.80 | 651.40 | 9.56 | 7 | 10 | 697.57 |
| 3# | 457.61 | 509.91 | 651.58 | 9.30 | 7 | 10 | 697.78 |
| 4# | 458.06 | 510.00 | 653.38 | 9.40 | 7 | 10 | 699.78 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 37.36 | 11.09 | 3.5 | 10 | 20.11 |
| 2# | 457.35 | 50.39 | 37.23 | 11.17 | 3.5 | 10 | 19.91 |
| 3# | 457.61 | 50.22 | 37.24 | 11.26 | 3.5 | 10 | 19.93 |
| 4# | 458.06 | 49.84 | 37.10 | 11.00 | 3.5 | 10 | 19.79 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 41.02 | 7.72 | 0 | 5 | 43.07 |
| 2# | 457.35 | 428.60 | 41.14 | 7.71 | 0 | 5 | 43.20 |
| 3# | 457.61 | 428.60 | 41.24 | 7.70 | 0 | 5 | 43.30 |
| 4# | 458.06 | 428.60 | 41.29 | 7.73 | 0 | 5 | 43.35 |
| SJT2 | 球阀最大动水压力(m) | 1# | 419.05 | 506.04 | 635.06 | 9.83 | 7 | 10 | 677.30 |
| 2# | 418.64 | 506.45 | 637.10 | 10.08 | 7 | 10 | 679.47 |
| 3# | 418.96 | 506.59 | 637.51 | 10.21 | 7 | 10 | 679.93 |
| 4# | 419.53 | 506.74 | 638.64 | 9.55 | 7 | 10 | 681.20 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 486.50 | 642.38 | 9.93 | 7 | 10 | 687.30 |
| 2# | 418.64 | 486.93 | 643.23 | 10.06 | 7 | 10 | 688.16 |
| 3# | 418.96 | 487.06 | 643.90 | 10.03 | 7 | 10 | 688.91 |
| 4# | 419.53 | 487.17 | 647.35 | 10.05 | 7 | 10 | 692.74 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 64.78 | 54.94 | 12.29 | 3.5 | 10 | 39.29 |
| 2# | 418.64 | 65.65 | 54.89 | 11.17 | 3.5 | 10 | 39.16 |
| 3# | 418.96 | 65.43 | 54.58 | 11.35 | 3.5 | 10 | 38.83 |
| 4# | 419.53 | 64.96 | 54.80 | 12.64 | 3.5 | 10 | 39.10 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 41.78 | 7.70 | 0 | 5 | 43.87 |
| 2# | 418.64 | 428.60 | 41.93 | 7.71 | 0 | 5 | 44.03 |
| 3# | 418.96 | 428.60 | 42.05 | 7.72 | 0 | 5 | 44.15 |
| 4# | 419.53 | 428.60 | 42.11 | 7.73 | 0 | 5 | 44.22 |
| SJT3 | 球阀最大动水压力(m) | 1# | 457.68 | 526.59 | 647.45 | 9.54 | 7 | 10 | 691.57 |
| 2# | 457.35 | 526.92 | 648.25 | 9.50 | 7 | 10 | 692.40 |
| 3# | 457.61 | 527.04 | 647.90 | 9.56 | 7 | 10 | 692.02 |
| 4# | 458.06 | 527.15 | 650.26 | 9.55 | 7 | 10 | 694.63 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 511.00 | 652.98 | 9.46 | 7 | 10 | 699.22 |
| 2# | 457.35 | 511.34 | 652.94 | 9.56 | 7 | 10 | 699.11 |
| 3# | 457.61 | 511.45 | 653.12 | 9.30 | 7 | 10 | 699.32 |
| 4# | 458.06 | 511.54 | 654.92 | 9.40 | 7 | 10 | 701.32 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 51.24 | 38.90 | 11.09 | 3.5 | 10 | 21.65 |
| 2# | 457.35 | 51.93 | 38.77 | 11.17 | 3.5 | 10 | 21.45 |
| 3# | 457.61 | 51.76 | 38.78 | 11.26 | 3.5 | 10 | 21.47 |
| 4# | 458.06 | 51.38 | 38.64 | 11.00 | 3.5 | 10 | 21.33 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 41.02 | 7.72 | 0 | 5 | 43.07 |
| 2# | 457.35 | 428.60 | 41.14 | 7.71 | 0 | 5 | 43.20 |
| 3# | 457.61 | 428.60 | 41.24 | 7.70 | 0 | 5 | 43.30 |
| 4# | 458.06 | 428.60 | 41.29 | 7.73 | 0 | 5 | 43.35 |
| SJT4 | 球阀最大动水压力(m) | 1# | 419.05 | 498.54 | 627.56 | 9.83 | 7 | 10 | 669.80 |
| 2# | 418.64 | 498.95 | 629.60 | 10.08 | 7 | 10 | 671.97 |
| 3# | 418.96 | 499.09 | 630.01 | 10.21 | 7 | 10 | 672.43 |
| 4# | 419.53 | 499.24 | 631.14 | 9.55 | 7 | 10 | 673.70 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 479.00 | 634.88 | 9.93 | 7 | 10 | 679.80 |
| 2# | 418.64 | 479.43 | 635.73 | 10.06 | 7 | 10 | 680.66 |
| 3# | 418.96 | 479.56 | 636.40 | 10.03 | 7 | 10 | 681.41 |
| 4# | 419.53 | 479.67 | 639.85 | 10.05 | 7 | 10 | 685.24 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 57.28 | 47.44 | 12.29 | 3.5 | 10 | 31.79 |
| 2# | 418.64 | 58.15 | 47.39 | 11.17 | 3.5 | 10 | 31.66 |
| 3# | 418.96 | 57.93 | 47.08 | 11.35 | 3.5 | 10 | 31.33 |
| 4# | 419.53 | 57.46 | 47.30 | 12.64 | 3.5 | 10 | 31.60 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 41.78 | 7.70 | 0 | 5 | 43.87 |
| 2# | 418.64 | 428.60 | 41.93 | 7.71 | 0 | 5 | 44.03 |
| 3# | 418.96 | 428.60 | 42.05 | 7.72 | 0 | 5 | 44.15 |
| 4# | 419.53 | 428.60 | 42.11 | 7.73 | 0 | 5 | 44.22 |
| SJT5 | 球阀最大动水压力(m) | 1# | 421.99 | 500.89 | 508.03 | 0.25 | 7 | 10 | 538.28 |
| 2# | 421.50 | 501.23 | 507.23 | 0.23 | 7 | 10 | 537.33 |
| 3# | 421.83 | 501.38 | 505.33 | 0.23 | 7 | 10 | 535.25 |
| 4# | 425.59 | 503.60 | 503.98 | 0.56 | 7 | 10 | 533.81 |
| 蜗壳最大动水压力(m) | 1# | 421.99 | 481.18 | 505.10 | 0.37 | 7 | 10 | 537.03 |
| 2# | 421.50 | 481.55 | 504.58 | 0.76 | 7 | 10 | 536.39 |
| 3# | 421.83 | 481.67 | 507.05 | 0.25 | 7 | 10 | 539.12 |
| 4# | 425.59 | 503.29 | 506.87 | 0.33 | 7 | 10 | 537.02 |
| 尾水管最小动水压力 (m) | 1# | 421.99 | 56.42 | 52.78 | 0.01 | 3.5 | 10 | 37.65 |
| 2# | 421.50 | 57.30 | 53.66 | 0.01 | 3.5 | 10 | 38.54 |
| 3# | 421.83 | 57.08 | 52.34 | 0.27 | 3.5 | 10 | 37.10 |
| 4# | 425.59 | 77.98 | 57.95 | 91.75 | 3.5 | 10 | 41.05 |
| 机组最大转速上升率(%) | 1# | 421.99 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 2# | 421.50 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 3# | 421.83 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 4# | 425.59 | 428.60 | 0.17 | 300.01 | 0 | 5 | 0.18 |
| SJT6 | 球阀最大动水压力(m) | 1# | 419.05 | 505.44 | 634.46 | 9.83 | 7 | 10 | 676.70 |
| 2# | 418.64 | 505.85 | 636.50 | 10.08 | 7 | 10 | 678.87 |
| 3# | 418.96 | 505.99 | 636.91 | 10.21 | 7 | 10 | 679.33 |
| 4# | 419.53 | 506.14 | 638.04 | 9.55 | 7 | 10 | 680.60 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 485.90 | 641.78 | 9.93 | 7 | 10 | 686.70 |
| 2# | 418.64 | 486.33 | 642.63 | 10.06 | 7 | 10 | 687.56 |
| 3# | 418.96 | 486.46 | 643.30 | 10.03 | 7 | 10 | 688.31 |
| 4# | 419.53 | 486.57 | 646.75 | 10.05 | 7 | 10 | 692.14 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 64.18 | 54.34 | 12.29 | 3.5 | 10 | 38.69 |
| 2# | 418.64 | 65.05 | 54.29 | 11.17 | 3.5 | 10 | 38.56 |
| 3# | 418.96 | 64.83 | 53.98 | 11.35 | 3.5 | 10 | 38.23 |
| 4# | 419.53 | 64.36 | 54.20 | 12.64 | 3.5 | 10 | 38.50 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 41.78 | 7.70 | 0 | 5 | 43.87 |
| 2# | 418.64 | 428.60 | 41.93 | 7.71 | 0 | 5 | 44.03 |
| 3# | 418.96 | 428.60 | 42.05 | 7.72 | 0 | 5 | 44.15 |
| 4# | 419.53 | 428.60 | 42.11 | 7.73 | 0 | 5 | 44.22 |
| SJT7 | 球阀最大动水压力(m) | 1# | 421.99 | 507.79 | 514.93 | 0.25 | 7 | 10 | 545.18 |
| 2# | 421.50 | 508.13 | 514.13 | 0.23 | 7 | 10 | 544.23 |
| 3# | 421.83 | 508.28 | 512.23 | 0.23 | 7 | 10 | 542.15 |
| 4# | 425.59 | 510.50 | 510.88 | 0.56 | 7 | 10 | 540.71 |
| 蜗壳最大动水压力(m) | 1# | 421.99 | 488.08 | 512.00 | 0.37 | 7 | 10 | 543.93 |
| 2# | 421.50 | 488.45 | 511.48 | 0.76 | 7 | 10 | 543.29 |
| 3# | 421.83 | 488.57 | 513.95 | 0.25 | 7 | 10 | 546.02 |
| 4# | 425.59 | 510.19 | 513.77 | 0.33 | 7 | 10 | 543.92 |
| 尾水管最小动水压力 (m) | 1# | 421.99 | 63.32 | 59.68 | 0.01 | 3.5 | 10 | 44.55 |
| 2# | 421.50 | 64.20 | 60.56 | 0.01 | 3.5 | 10 | 45.44 |
| 3# | 421.83 | 63.98 | 59.24 | 0.27 | 3.5 | 10 | 44.00 |
| 4# | 425.59 | 84.88 | 64.85 | 91.75 | 3.5 | 10 | 47.95 |
| 机组最大转速上升率(%) | 1# | 421.99 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 2# | 421.50 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 3# | 421.83 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 4# | 425.59 | 428.60 | 0.17 | 300.01 | 0 | 5 | 0.18 |
| SJT8 | 球阀最大动水压力(m) | 1# | 419.05 | 498.94 | 627.96 | 9.83 | 7 | 10 | 670.20 |
| 2# | 418.64 | 499.35 | 630.00 | 10.08 | 7 | 10 | 672.37 |
| 3# | 418.96 | 499.49 | 630.41 | 10.21 | 7 | 10 | 672.83 |
| 4# | 419.53 | 499.64 | 631.54 | 9.55 | 7 | 10 | 674.10 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 479.40 | 635.28 | 9.93 | 7 | 10 | 680.20 |
| 2# | 418.64 | 479.83 | 636.13 | 10.06 | 7 | 10 | 681.06 |
| 3# | 418.96 | 479.96 | 636.80 | 10.03 | 7 | 10 | 681.81 |
| 4# | 419.53 | 480.07 | 640.25 | 10.05 | 7 | 10 | 685.64 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 57.68 | 47.84 | 12.29 | 3.5 | 10 | 32.19 |
| 2# | 418.64 | 58.55 | 47.79 | 11.17 | 3.5 | 10 | 32.06 |
| 3# | 418.96 | 58.33 | 47.48 | 11.35 | 3.5 | 10 | 31.73 |
| 4# | 419.53 | 57.86 | 47.70 | 12.64 | 3.5 | 10 | 32.00 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 41.78 | 7.70 | 0 | 5 | 43.87 |
| 2# | 418.64 | 428.60 | 41.93 | 7.71 | 0 | 5 | 44.03 |
| 3# | 418.96 | 428.60 | 42.05 | 7.72 | 0 | 5 | 44.15 |
| 4# | 419.53 | 428.60 | 42.11 | 7.73 | 0 | 5 | 44.22 |
| SJT9 | 球阀最大动水压力(m) | 1# | 421.99 | 501.29 | 508.43 | 0.25 | 7 | 10 | 538.68 |
| 2# | 421.50 | 501.63 | 507.63 | 0.23 | 7 | 10 | 537.73 |
| 3# | 421.83 | 501.78 | 505.73 | 0.23 | 7 | 10 | 535.65 |
| 4# | 425.59 | 504.00 | 504.38 | 0.56 | 7 | 10 | 534.21 |
| 蜗壳最大动水压力(m) | 1# | 421.99 | 481.58 | 505.50 | 0.37 | 7 | 10 | 537.43 |
| 2# | 421.50 | 481.95 | 504.98 | 0.76 | 7 | 10 | 536.79 |
| 3# | 421.83 | 482.07 | 507.45 | 0.25 | 7 | 10 | 539.52 |
| 4# | 425.59 | 503.69 | 507.27 | 0.33 | 7 | 10 | 537.42 |
| 尾水管最小动水压力 (m) | 1# | 421.99 | 56.82 | 53.18 | 0.01 | 3.5 | 10 | 38.05 |
| 2# | 421.50 | 57.70 | 54.06 | 0.01 | 3.5 | 10 | 38.94 |
| 3# | 421.83 | 57.48 | 52.74 | 0.27 | 3.5 | 10 | 37.50 |
| 4# | 425.59 | 78.38 | 58.35 | 91.75 | 3.5 | 10 | 41.45 |
| 机组最大转速上升率(%) | 1# | 421.99 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 2# | 421.50 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 3# | 421.83 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| 4# | 425.59 | 428.60 | 0.17 | 300.01 | 0 | 5 | 0.18 |
| ZT1 | 球阀最大动水压力(m) | 1# | 460.24 | 526.94 | 644.20 | 83.71 | 7 | 10 | 688.14 |
| 2# | 459.86 | 527.21 | 645.04 | 83.73 | 7 | 10 | 689.01 |
| 3# | 460.12 | 527.33 | 645.58 | 83.74 | 7 | 10 | 689.61 |
| 4# | 463.03 | 529.11 | 646.19 | 83.82 | 7 | 10 | 690.31 |
| 蜗壳最大动水压力(m) | 1# | 460.24 | 511.22 | 649.07 | 83.68 | 7 | 10 | 695.07 |
| 2# | 459.86 | 511.51 | 650.02 | 83.74 | 7 | 10 | 696.06 |
| 3# | 460.12 | 511.62 | 650.66 | 83.82 | 7 | 10 | 696.77 |
| 4# | 463.03 | 528.87 | 651.76 | 83.92 | 7 | 10 | 696.46 |
| 尾水管最小动水压力 (m) | 1# | 460.24 | 49.02 | 37.14 | 84.98 | 3.5 | 10 | 19.84 |
| 2# | 459.86 | 49.72 | 37.04 | 85.39 | 3.5 | 10 | 19.68 |
| 3# | 460.12 | 49.55 | 37.15 | 85.34 | 3.5 | 10 | 19.81 |
| 4# | 463.03 | 66.23 | 37.36 | 85.24 | 3.5 | 10 | 18.27 |
| 机组最大转速上升率(%) | 1# | 460.24 | 428.60 | 41.46 | 81.98 | 0 | 5 | 43.53 |
| 2# | 459.86 | 428.60 | 41.58 | 81.95 | 0 | 5 | 43.66 |
| 3# | 460.12 | 428.60 | 41.67 | 81.94 | 0 | 5 | 43.75 |
| 4# | 463.03 | 428.60 | 41.72 | 81.98 | 0 | 5 | 43.81 |
| ZT2 | 球阀最大动水压力(m) | 1# | 421.99 | 508.39 | 634.70 | 86.71 | 7 | 10 | 676.87 |
| 2# | 421.50 | 508.73 | 635.73 | 86.68 | 7 | 10 | 677.93 |
| 3# | 421.83 | 508.88 | 636.79 | 86.59 | 7 | 10 | 679.11 |
| 4# | 425.59 | 511.10 | 637.79 | 86.64 | 7 | 10 | 680.25 |
| 蜗壳最大动水压力(m) | 1# | 421.99 | 488.68 | 640.54 | 86.61 | 7 | 10 | 685.27 |
| 2# | 421.50 | 489.05 | 641.69 | 86.64 | 7 | 10 | 686.46 |
| 3# | 421.83 | 489.17 | 642.69 | 86.56 | 7 | 10 | 687.57 |
| 4# | 425.59 | 510.79 | 643.71 | 86.66 | 7 | 10 | 686.79 |
| 尾水管最小动水压力 (m) | 1# | 421.99 | 63.92 | 55.27 | 88.04 | 3.5 | 10 | 39.64 |
| 2# | 421.50 | 64.80 | 55.15 | 88.12 | 3.5 | 10 | 39.43 |
| 3# | 421.83 | 64.58 | 55.13 | 88.12 | 3.5 | 10 | 39.42 |
| 4# | 425.59 | 85.48 | 54.91 | 89.33 | 3.5 | 10 | 36.96 |
| 机组最大转速上升率(%) | 1# | 421.99 | 428.60 | 42.33 | 84.53 | 0 | 5 | 44.45 |
| 2# | 421.50 | 428.60 | 42.46 | 84.52 | 0 | 5 | 44.58 |
| 3# | 421.83 | 428.60 | 42.59 | 84.54 | 0 | 5 | 44.72 |
| 4# | 425.59 | 428.60 | 42.64 | 84.55 | 0 | 5 | 44.77 |
| ZT3 | 球阀最大动水压力(m) | 1# | 460.24 | 526.94 | 639.45 | 71.87 | 7 | 10 | 682.92 |
| 2# | 459.86 | 527.21 | 640.22 | 71.88 | 7 | 10 | 683.71 |
| 3# | 460.12 | 527.33 | 640.79 | 71.89 | 7 | 10 | 684.34 |
| 4# | 463.03 | 529.11 | 641.38 | 71.97 | 7 | 10 | 685.02 |
| 蜗壳最大动水压力(m) | 1# | 460.24 | 511.22 | 644.31 | 71.88 | 7 | 10 | 689.84 |
| 2# | 459.86 | 511.51 | 645.16 | 71.88 | 7 | 10 | 690.72 |
| 3# | 460.12 | 511.62 | 646.00 | 71.97 | 7 | 10 | 691.65 |
| 4# | 463.03 | 528.87 | 646.96 | 72.04 | 7 | 10 | 691.18 |
| 尾水管最小动水压力 (m) | 1# | 460.24 | 49.02 | 37.82 | 73.20 | 3.5 | 10 | 20.59 |
| 2# | 459.86 | 49.72 | 37.80 | 73.62 | 3.5 | 10 | 20.51 |
| 3# | 460.12 | 49.55 | 37.76 | 73.47 | 3.5 | 10 | 20.48 |
| 4# | 463.03 | 66.23 | 38.02 | 73.37 | 3.5 | 10 | 18.99 |
| 机组最大转速上升率(%) | 1# | 460.24 | 428.60 | 40.82 | 70.15 | 0 | 5 | 42.86 |
| 2# | 459.86 | 428.60 | 40.93 | 70.14 | 0 | 5 | 42.98 |
| 3# | 460.12 | 428.60 | 41.04 | 70.18 | 0 | 5 | 43.09 |
| 4# | 463.03 | 428.60 | 41.09 | 70.19 | 0 | 5 | 43.14 |
| ZT4 | 球阀最大动水压力(m) | 1# | 421.99 | 500.89 | 621.00 | 72.22 | 7 | 10 | 662.55 |
| 2# | 421.50 | 501.23 | 621.95 | 72.21 | 7 | 10 | 663.53 |
| 3# | 421.83 | 501.38 | 622.99 | 72.19 | 7 | 10 | 664.68 |
| 4# | 425.59 | 503.60 | 623.89 | 72.20 | 7 | 10 | 665.71 |
| 蜗壳最大动水压力(m) | 1# | 421.99 | 481.18 | 626.63 | 72.20 | 7 | 10 | 670.71 |
| 2# | 421.50 | 481.55 | 627.71 | 72.25 | 7 | 10 | 671.83 |
| 3# | 421.83 | 481.67 | 628.85 | 72.14 | 7 | 10 | 673.10 |
| 4# | 425.59 | 503.29 | 629.67 | 72.27 | 7 | 10 | 672.10 |
| 尾水管最小动水压力 (m) | 1# | 421.99 | 56.42 | 48.26 | 74.85 | 3.5 | 10 | 32.67 |
| 2# | 421.50 | 57.30 | 48.20 | 75.01 | 3.5 | 10 | 32.54 |
| 3# | 421.83 | 57.08 | 48.14 | 74.83 | 3.5 | 10 | 32.48 |
| 4# | 425.59 | 77.98 | 47.96 | 74.93 | 3.5 | 10 | 30.06 |
| 机组最大转速上升率(%) | 1# | 421.99 | 428.60 | 41.48 | 70.15 | 0 | 5 | 43.55 |
| 2# | 421.50 | 428.60 | 41.61 | 70.12 | 0 | 5 | 43.69 |
| 3# | 421.83 | 428.60 | 41.74 | 70.15 | 0 | 5 | 43.83 |
| 4# | 425.59 | 428.60 | 41.78 | 70.13 | 0 | 5 | 43.87 |

注：表中尾水管进口最小动水压力为相对压力值

#### 6.9.2.2 水轮机校核工况计算结果

**表6-43 大波动水轮机校核工况机组参数计算结果**

| 工况 | 控制参数 | 机组 | 净水头（m） | 初始值 | 计算  极值 | 极值发生时间(s) | 压力脉动(%) | 计算误差(%) | 修正值 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|
|
| JHT1 | 球阀最大动水压力(m) | 1# | 457.68 | 526.59 | 637.46 | 9.54 | 7 | 10 | 680.58 |
| 2# | 457.35 | 526.92 | 644.70 | 9.5 | 7 | 10 | 688.49 |
| 3# | 457.61 | 527.04 | 644.39 | 9.56 | 7 | 10 | 688.16 |
| 4# | 458.06 | 527.15 | 646.64 | 9.55 | 7 | 10 | 690.65 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 511.00 | 640.99 | 9.46 | 7 | 10 | 686.03 |
| 2# | 457.35 | 511.34 | 649.78 | 9.56 | 7 | 10 | 695.64 |
| 3# | 457.61 | 511.45 | 649.94 | 9.3 | 7 | 10 | 695.82 |
| 4# | 458.06 | 511.54 | 651.34 | 9.57 | 7 | 10 | 697.38 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 51.24 | 28.95 | 36.15 | 3.5 | 10 | 10.70 |
| 2# | 457.35 | 51.93 | 38.94 | 11.17 | 3.5 | 10 | 21.63 |
| 3# | 457.61 | 51.76 | 39.10 | 11.26 | 3.5 | 10 | 21.82 |
| 4# | 458.06 | 51.38 | 38.90 | 11 | 3.5 | 10 | 21.62 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 43.29 | 8.13 | 0 | 5 | **45.45** |
| 2# | 457.35 | 428.60 | 40.67 | 7.71 | 0 | 5 | 42.70 |
| 3# | 457.61 | 428.60 | 40.78 | 7.74 | 0 | 5 | 42.82 |
| 4# | 458.06 | 428.60 | 40.83 | 7.75 | 0 | 5 | 42.87 |
| JHT2 | 球阀最大动水压力(m) | 1# | 457.68 | 526.59 | 647.48 | 9.54 | 7 | 10 | 691.61 |
| 2# | 457.35 | 526.92 | 648.32 | 9.5 | 7 | 10 | 692.47 |
| 3# | 457.61 | 527.04 | 647.97 | 9.56 | 7 | 10 | 692.10 |
| 4# | 458.06 | 527.15 | 650.17 | 9.55 | 7 | 10 | 694.54 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 511.00 | 653.00 | 9.46 | 7 | 10 | 699.24 |
| 2# | 457.35 | 511.34 | 653.02 | 9.56 | 7 | 10 | 699.20 |
| 3# | 457.61 | 511.45 | 653.17 | 9.3 | 7 | 10 | 699.38 |
| 4# | 458.06 | 511.54 | 654.79 | 9.4 | 7 | 10 | 701.18 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 51.24 | 38.88 | 11.09 | 3.5 | 10 | 21.63 |
| 2# | 457.35 | 51.93 | 38.76 | 11.17 | 3.5 | 10 | 21.44 |
| 3# | 457.61 | 51.76 | 38.66 | 11.26 | 3.5 | 10 | 21.33 |
| 4# | 458.06 | 51.38 | 38.73 | 11 | 3.5 | 10 | 21.43 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 41.03 | 7.73 | 0 | 5 | 43.08 |
| 2# | 457.35 | 428.60 | 41.14 | 7.72 | 0 | 5 | 43.20 |
| 3# | 457.61 | 428.60 | 41.24 | 7.71 | 0 | 5 | 43.30 |
| 4# | 458.06 | 428.60 | 41.29 | 7.72 | 0 | 5 | 43.35 |
| JHT3 | 球阀最大动水压力(m) | 1# | 419.05 | 506.04 | 629.61 | 9.83 | 7 | 10 | 671.30 |
| 2# | 418.64 | 506.45 | 632.04 | 10.08 | 7 | 10 | 673.90 |
| 3# | 418.96 | 506.59 | 632.41 | 10.21 | 7 | 10 | 674.32 |
| 4# | 419.53 | 506.74 | 644.01 | 10.16 | 7 | 10 | 687.10 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 486.50 | 635.96 | 9.93 | 7 | 10 | 680.24 |
| 2# | 418.64 | 486.93 | 636.69 | 9.70 | 7 | 10 | 680.97 |
| 3# | 418.96 | 487.06 | 637.13 | 10.32 | 7 | 10 | 681.46 |
| 4# | 419.53 | 487.17 | 655.69 | 10.05 | 7 | 10 | 701.91 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 64.78 | 55.10 | 14.53 | 3.5 | 10 | 39.47 |
| 2# | 418.64 | 65.65 | 55.21 | 14.36 | 3.5 | 10 | 39.51 |
| 3# | 418.96 | 65.43 | 54.46 | 14.47 | 3.5 | 10 | 38.70 |
| 4# | 419.53 | 64.96 | 49.61 | 11.00 | 3.5 | 10 | 33.39 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.6 | 40.91 | 7.76 | 0 | 5 | 42.96 |
| 2# | 418.64 | 428.6 | 41.04 | 7.76 | 0 | 5 | 43.09 |
| 3# | 418.96 | 428.6 | 41.16 | 7.77 | 0 | 5 | 43.22 |
| 4# | 419.53 | 428.6 | 46.30 | 8.04 | 0 | 5 | **48.62** |
| JHT4 | 球阀最大动水压力(m) | 1# | 419.05 | 506.04 | 628.72 | 9.83 | 7 | 10 | 670.32 |
| 2# | 418.64 | 506.45 | 630.79 | 10.08 | 7 | 10 | 672.53 |
| 3# | 418.96 | 506.59 | 631.05 | 10.21 | 7 | 10 | 672.82 |
| 4# | 419.53 | 506.74 | 630.62 | 9.55 | 7 | 10 | 672.38 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 486.50 | 636.13 | 9.93 | 7 | 10 | 680.43 |
| 2# | 418.64 | 486.93 | 636.80 | 10.06 | 7 | 10 | 681.09 |
| 3# | 418.96 | 487.06 | 637.46 | 10.11 | 7 | 10 | 681.83 |
| 4# | 419.53 | 487.17 | 635.97 | 8.86 | 7 | 10 | 680.22 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 64.78 | 55.52 | 11.09 | 3.5 | 10 | 39.93 |
| 2# | 418.64 | 65.65 | 55.43 | 11.17 | 3.5 | 10 | 39.76 |
| 3# | 418.96 | 65.43 | 55.08 | 11.35 | 3.5 | 10 | 39.38 |
| 4# | 419.53 | 64.96 | 49.61 | 26.72 | 3.5 | 10 | 33.39 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 40.90 | 7.76 | 0 | 5 | 42.95 |
| 2# | 418.64 | 428.60 | 41.04 | 7.76 | 0 | 5 | 43.09 |
| 3# | 418.96 | 428.60 | 41.16 | 7.77 | 0 | 5 | 43.22 |
| 4# | 419.53 | 428.60 | 46.27 | 8 | 0 | 5 | **48.58** |
| JHT5 | 球阀最大动水压力(m) | 1# | 419.05 | 498.54 | 621.28 | 9.83 | 7 | 10 | 662.89 |
| 2# | 418.64 | 498.95 | 623.32 | 10.08 | 7 | 10 | 665.06 |
| 3# | 418.96 | 499.09 | 620.04 | 9.41 | 7 | 10 | 661.46 |
| 4# | 419.53 | 499.24 | 625.22 | 9.55 | 7 | 10 | 667.19 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 479.00 | 628.68 | 9.93 | 7 | 10 | 672.98 |
| 2# | 418.64 | 479.43 | 629.43 | 10.06 | 7 | 10 | 673.73 |
| 3# | 418.96 | 479.56 | 626.80 | 8.31 | 7 | 10 | 670.85 |
| 4# | 419.53 | 479.67 | 633.27 | 10.05 | 7 | 10 | 678.00 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 57.28 | 48.09 | 11.09 | 3.5 | 10 | 32.50 |
| 2# | 418.64 | 58.15 | 48.00 | 11.17 | 3.5 | 10 | 32.33 |
| 3# | 418.96 | 57.93 | 42.66 | 38.2 | 3.5 | 10 | 26.47 |
| 4# | 419.53 | 57.46 | 47.83 | 11 | 3.5 | 10 | 32.18 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 40.91 | 7.76 | 0 | 5 | 42.96 |
| 2# | 418.64 | 428.60 | 41.04 | 7.74 | 0 | 5 | 43.09 |
| 3# | 418.96 | 428.60 | 46.21 | 7.99 | 0 | 5 | **48.52** |
| 4# | 419.53 | 428.60 | 41.21 | 7.77 | 0 | 5 | 43.27 |
| JHT6 | 球阀最大动水压力(m) | 1# | 419.05 | 498.54 | 622.11 | 9.83 | 7 | 10 | 663.80 |
| 2# | 418.64 | 498.95 | 624.54 | 10.08 | 7 | 10 | 666.40 |
| 3# | 418.96 | 499.09 | 624.91 | 10.21 | 7 | 10 | 666.82 |
| 4# | 419.53 | 499.24 | 636.51 | 10.16 | 7 | 10 | 679.60 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 479.00 | 628.46 | 9.93 | 7 | 10 | 672.74 |
| 2# | 418.64 | 479.43 | 629.19 | 9.7 | 7 | 10 | 673.47 |
| 3# | 418.96 | 479.56 | 629.63 | 10.32 | 7 | 10 | 673.96 |
| 4# | 419.53 | 479.67 | 648.19 | 10.05 | 7 | 10 | 694.41 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 57.28 | 47.60 | 14.53 | 3.5 | 10 | 31.97 |
| 2# | 418.64 | 58.15 | 47.71 | 14.36 | 3.5 | 10 | 32.01 |
| 3# | 418.96 | 57.93 | 46.96 | 14.47 | 3.5 | 10 | 31.20 |
| 4# | 419.53 | 57.46 | 42.11 | 11 | 3.5 | 10 | 25.89 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 40.91 | 7.76 | 0 | 5 | 42.96 |
| 2# | 418.64 | 428.60 | 41.04 | 7.76 | 0 | 5 | 43.09 |
| 3# | 418.96 | 428.60 | 41.16 | 7.77 | 0 | 5 | 43.22 |
| 4# | 419.53 | 428.60 | 46.30 | 8.04 | 0 | 5 | **48.62** |
| JHT7 | 球阀最大动水压力(m) | 1# | 419.05 | 505.44 | 628.36 | 9.83 | 7 | 10 | 669.99 |
| 2# | 418.64 | 505.85 | 626.87 | 9.5 | 7 | 10 | 668.28 |
| 3# | 418.96 | 505.99 | 630.69 | 10.21 | 7 | 10 | 672.49 |
| 4# | 419.53 | 506.14 | 632.25 | 9.55 | 7 | 10 | 674.23 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 485.90 | 635.69 | 9.93 | 7 | 10 | 680.00 |
| 2# | 418.64 | 486.33 | 633.27 | 8.2 | 7 | 10 | 677.27 |
| 3# | 418.96 | 486.46 | 637.14 | 10.32 | 7 | 10 | 681.54 |
| 4# | 419.53 | 486.57 | 640.39 | 10.05 | 7 | 10 | 685.14 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 64.18 | 55.17 | 11.09 | 3.5 | 10 | 39.60 |
| 2# | 418.64 | 65.05 | 49.43 | 38.3 | 3.5 | 10 | 33.22 |
| 3# | 418.96 | 64.83 | 54.61 | 11.35 | 3.5 | 10 | 38.92 |
| 4# | 419.53 | 64.36 | 54.82 | 11 | 3.5 | 10 | 39.18 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 40.91 | 7.78 | 0 | 5 | 42.96 |
| 2# | 418.64 | 428.60 | 46.09 | 7.97 | 0 | 5 | **48.39** |
| 3# | 418.96 | 428.60 | 41.17 | 7.78 | 0 | 5 | 43.23 |
| 4# | 419.53 | 428.60 | 41.23 | 7.76 | 0 | 5 | 43.29 |
| JHT8 | 球阀最大动水压力(m) | 1# | 419.05 | 505.44 | 629.01 | 9.83 | 7 | 10 | 670.70 |
| 2# | 418.64 | 505.85 | 631.44 | 10.08 | 7 | 10 | 673.30 |
| 3# | 418.96 | 505.99 | 631.81 | 10.21 | 7 | 10 | 673.72 |
| 4# | 419.53 | 506.14 | 643.41 | 10.16 | 7 | 10 | 686.50 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 485.90 | 635.36 | 9.93 | 7 | 10 | 679.64 |
| 2# | 418.64 | 486.33 | 636.09 | 9.7 | 7 | 10 | 680.37 |
| 3# | 418.96 | 486.46 | 636.53 | 10.32 | 7 | 10 | 680.86 |
| 4# | 419.53 | 486.57 | 655.09 | 10.05 | 7 | 10 | 701.31 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 64.18 | 54.50 | 14.53 | 3.5 | 10 | 38.87 |
| 2# | 418.64 | 65.05 | 54.61 | 14.36 | 3.5 | 10 | 38.91 |
| 3# | 418.96 | 64.83 | 53.86 | 14.47 | 3.5 | 10 | 38.10 |
| 4# | 419.53 | 64.36 | 49.01 | 11 | 3.5 | 10 | 32.79 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 40.91 | 7.76 | 0 | 5 | 42.96 |
| 2# | 418.64 | 428.60 | 41.04 | 7.76 | 0 | 5 | 43.09 |
| 3# | 418.96 | 428.60 | 41.16 | 7.77 | 0 | 5 | 43.22 |
| 4# | 419.53 | 428.60 | 46.30 | 8.04 | 0 | 5 | **48.62** |
| JHT9 | 球阀最大动水压力(m) | 1# | 419.05 | 498.94 | 619.15 | 9.54 | 7 | 10 | 660.51 |
| 2# | 418.64 | 499.35 | 623.82 | 10.08 | 7 | 10 | 665.57 |
| 3# | 418.96 | 499.49 | 624.53 | 10.21 | 7 | 10 | 666.36 |
| 4# | 419.53 | 499.64 | 625.81 | 9.55 | 7 | 10 | 667.79 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 479.40 | 625.70 | 9.46 | 7 | 10 | 669.66 |
| 2# | 418.64 | 479.83 | 630.00 | 10.06 | 7 | 10 | 674.32 |
| 3# | 418.96 | 479.96 | 630.97 | 10.11 | 7 | 10 | 675.40 |
| 4# | 419.53 | 480.07 | 634.02 | 10.05 | 7 | 10 | 678.78 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 57.68 | 43.12 | 27.61 | 3.5 | 10 | 27.00 |
| 2# | 418.64 | 58.55 | 48.37 | 11.28 | 3.5 | 10 | 32.70 |
| 3# | 418.96 | 58.33 | 47.97 | 11.35 | 3.5 | 10 | 32.27 |
| 4# | 419.53 | 57.86 | 48.38 | 11 | 3.5 | 10 | 32.75 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 45.94 | 7.97 | 0 | 5 | **48.24** |
| 2# | 418.64 | 428.60 | 41.05 | 7.78 | 0 | 5 | 43.10 |
| 3# | 418.96 | 428.60 | 41.18 | 7.81 | 0 | 5 | 43.24 |
| 4# | 419.53 | 428.60 | 41.24 | 7.8 | 0 | 5 | 43.30 |
| JHT10 | 球阀最大动水压力(m) | 1# | 419.05 | 498.94 | 622.51 | 9.83 | 7 | 10 | 664.20 |
| 2# | 418.64 | 499.35 | 624.94 | 10.08 | 7 | 10 | 666.80 |
| 3# | 418.96 | 499.49 | 625.31 | 10.21 | 7 | 10 | 667.22 |
| 4# | 419.53 | 499.64 | 636.91 | 10.16 | 7 | 10 | 680.00 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 479.40 | 628.86 | 9.93 | 7 | 10 | 673.14 |
| 2# | 418.64 | 479.83 | 629.59 | 9.7 | 7 | 10 | 673.87 |
| 3# | 418.96 | 479.96 | 630.03 | 10.32 | 7 | 10 | 674.36 |
| 4# | 419.53 | 480.07 | 648.59 | 10.05 | 7 | 10 | 694.81 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 57.68 | 48.00 | 14.53 | 3.5 | 10 | 32.37 |
| 2# | 418.64 | 58.55 | 48.11 | 14.36 | 3.5 | 10 | 32.41 |
| 3# | 418.96 | 58.33 | 47.36 | 14.47 | 3.5 | 10 | 31.60 |
| 4# | 419.53 | 57.86 | 42.51 | 11 | 3.5 | 10 | 26.29 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 40.91 | 7.76 | 0 | 5 | 42.96 |
| 2# | 418.64 | 428.60 | 41.04 | 7.76 | 0 | 5 | 43.09 |
| 3# | 418.96 | 428.60 | 41.16 | 7.77 | 0 | 5 | 43.22 |
| 4# | 419.53 | 428.60 | 46.30 | 8.04 | 0 | 5 | **48.62** |
| JHT11 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 641.98 | 9.45 | 7 | 10 | 685.71 |
| 2# | 457.35 | 525.38 | 642.91 | 9.5 | 7 | 10 | 686.68 |
| 3# | 457.61 | 525.50 | 642.40 | 9.56 | 7 | 10 | 686.12 |
| 4# | 458.06 | 525.61 | 639.02 | 9.55 | 7 | 10 | 682.42 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 648.20 | 9.46 | 7 | 10 | 694.11 |
| 2# | 457.35 | 509.80 | 647.91 | 9.56 | 7 | 10 | 693.74 |
| 3# | 457.61 | 509.91 | 648.13 | 9.3 | 7 | 10 | 693.99 |
| 4# | 458.06 | 510.00 | 641.39 | 8.86 | 7 | 10 | 686.59 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 37.47 | 11.09 | 3.5 | 10 | 20.23 |
| 2# | 457.35 | 50.39 | 37.09 | 11.17 | 3.5 | 10 | 19.75 |
| 3# | 457.61 | 50.22 | 37.37 | 11.26 | 3.5 | 10 | 20.07 |
| 4# | 458.06 | 49.84 | 27.06 | 36.21 | 3.5 | 10 | 8.75 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 40.56 | 7.69 | 0 | 5 | 42.59 |
| 2# | 457.35 | 428.60 | 40.68 | 7.71 | 0 | 5 | 42.71 |
| 3# | 457.61 | 428.60 | 40.76 | 7.71 | 0 | 5 | 42.80 |
| 4# | 458.06 | 428.60 | 43.55 | 8.2 | 0 | 5 | **45.73** |
| JHT12 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 645.94 | 9.54 | 7 | 10 | 690.07 |
| 2# | 457.35 | 525.38 | 646.76 | 9.5 | 7 | 10 | 690.91 |
| 3# | 457.61 | 525.50 | 646.46 | 9.56 | 7 | 10 | 690.59 |
| 4# | 458.06 | 525.61 | 648.70 | 9.55 | 7 | 10 | 693.07 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 651.45 | 9.46 | 7 | 10 | 697.69 |
| 2# | 457.35 | 509.80 | 651.45 | 9.56 | 7 | 10 | 697.63 |
| 3# | 457.61 | 509.91 | 651.67 | 9.3 | 7 | 10 | 697.88 |
| 4# | 458.06 | 510.00 | 653.36 | 9.4 | 7 | 10 | 699.76 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 37.39 | 11.09 | 3.5 | 10 | 20.14 |
| 2# | 457.35 | 50.39 | 37.24 | 11.17 | 3.5 | 10 | 19.92 |
| 3# | 457.61 | 50.22 | 37.19 | 11.26 | 3.5 | 10 | 19.87 |
| 4# | 458.06 | 49.84 | 37.10 | 11 | 3.5 | 10 | 19.79 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 41.03 | 7.69 | 0 | 5 | 43.08 |
| 2# | 457.35 | 428.60 | 41.14 | 7.72 | 0 | 5 | 43.20 |
| 3# | 457.61 | 428.60 | 41.24 | 7.71 | 0 | 5 | 43.30 |
| 4# | 458.06 | 428.60 | 41.29 | 7.75 | 0 | 5 | 43.35 |
| JHT13 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 610.02 | 9.37 | 7 | 10 | 650.55 |
| 2# | 457.35 | 525.38 | 609.85 | 9.28 | 7 | 10 | 650.31 |
| 3# | 457.61 | 525.50 | 625.35 | 14.66 | 7 | 10 | 667.37 |
| 4# | 458.06 | 525.61 | 627.34 | 14.79 | 7 | 10 | 669.58 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 615.08 | 9.33 | 7 | 10 | 657.68 |
| 2# | 457.35 | 509.80 | 614.90 | 9.32 | 7 | 10 | 657.42 |
| 3# | 457.61 | 509.91 | 645.30 | 14.66 | 7 | 10 | 690.87 |
| 4# | 458.06 | 510.00 | 647.21 | 14.78 | 7 | 10 | 693.00 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 24.08 | 19.61 | 3.5 | 10 | 5.50 |
| 2# | 457.35 | 50.39 | 20.37 | 40.14 | 3.5 | 10 | 1.36 |
| 3# | 457.61 | 50.22 | 16.96 | 36.49 | 3.5 | 10 | -2.38 |
| 4# | 458.06 | 49.84 | 20.27 | 36.75 | 3.5 | 10 | 1.28 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 35.93 | 6.95 | 0 | 5 | 37.73 |
| 2# | 457.35 | 428.60 | 35.92 | 6.91 | 0 | 5 | 37.72 |
| 3# | 457.61 | 428.60 | 40.83 | 12.96 | 0 | 5 | 42.87 |
| 4# | 458.06 | 428.60 | 41.02 | 13 | 0 | 5 | 43.07 |
| JHT14 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 608.95 | 9.37 | 7 | 10 | 649.38 |
| 2# | 457.35 | 525.38 | 608.81 | 9.28 | 7 | 10 | 649.17 |
| 3# | 457.61 | 525.50 | 608.02 | 10.73 | 7 | 10 | 648.30 |
| 4# | 458.06 | 525.61 | 595.60 | 9.55 | 7 | 10 | 634.66 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 615.39 | 9.33 | 7 | 10 | 658.02 |
| 2# | 457.35 | 509.80 | 615.38 | 9.32 | 7 | 10 | 657.95 |
| 3# | 457.61 | 509.91 | 633.93 | 14.15 | 7 | 10 | 678.37 |
| 4# | 458.06 | 510.00 | 594.74 | 10.05 | 7 | 10 | 635.28 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 33.81 | 31.88 | 3.5 | 10 | 16.20 |
| 2# | 457.35 | 50.39 | 30.85 | 31.72 | 3.5 | 10 | 12.89 |
| 3# | 457.61 | 50.22 | 14.77 | 14.11 | 3.5 | 10 | -4.79 |
| 4# | 458.06 | 49.84 | 33.04 | 34.87 | 3.5 | 10 | 15.33 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 35.93 | 6.95 | 0 | 5 | 37.73 |
| 2# | 457.35 | 428.60 | 35.92 | 6.91 | 0 | 5 | 37.72 |
| 3# | 457.61 | 428.60 | 39.75 | 12.67 | 0 | 5 | 41.74 |
| 4# | 458.06 | 428.60 | 0.06 | 300.01 | 0 | 5 | 0.06 |
| JHT15 | 球阀最大动水压力(m) | 1# | 460.66 | 527.28 | 614.10 | 9.34 | 7 | 10 | 655.03 |
| 2# | 460.29 | 527.53 | 614.06 | 9.26 | 7 | 10 | 654.93 |
| 3# | 460.53 | 527.64 | 610.91 | 10.59 | 7 | 10 | 651.47 |
| 4# | \ | \ | \ | \ | \ | \ | \ |
| 蜗壳最大动水压力(m) | 1# | 460.66 | 511.90 | 620.65 | 9.25 | 7 | 10 | 663.77 |
| 2# | 460.29 | 512.17 | 619.41 | 9.33 | 7 | 10 | 662.35 |
| 3# | 460.53 | 512.27 | 634.21 | 13.95 | 7 | 10 | 678.64 |
| 4# | \ | \ | \ | \ | \ | \ | \ |
| 尾水管最小动水压力 (m) | 1# | 460.66 | 49.31 | 29.07 | 31.62 | 3.5 | 10 | 10.92 |
| 2# | 460.29 | 49.99 | 29.69 | 31.4 | 3.5 | 10 | 11.55 |
| 3# | 460.53 | 49.83 | 13.64 | 14 | 3.5 | 10 | -6.10 |
| 4# | \ | \ | \ | \ | \ | \ | \ |
| 机组最大转速上升率(%) | 1# | 460.66 | 428.60 | 36.17 | 6.96 | 0 | 5 | 37.98 |
| 2# | 460.29 | 428.60 | 36.18 | 6.93 | 0 | 5 | 37.99 |
| 3# | 460.53 | 428.60 | 39.65 | 12.61 | 0 | 5 | 41.63 |
| 4# | \ | \ | \ | \ | \ | \ | \ |
| JHT16 | 球阀最大动水压力(m) | 1# | 460.88 | 527.29 | 612.76 | 15.20 | 7 | 10 | 653.56 |
| 2# | \ | \ | \ | \ | \ | \ | \ |
| 3# | 460.94 | 527.46 | 626.54 | 14.24 | 7 | 10 | 665.31 |
| 4# | 461.09 | 527.58 | 628.47 | 14.40 | 7 | 10 | 667.24 |
| 蜗壳最大动水压力(m) | 1# | 460.88 | 511.96 | 618.31 | 18.15 | 7 | 10 | 661.21 |
| 2# | \ | \ | \ | \ | \ | \ | \ |
| 3# | 460.94 | 512.13 | 640.04 | 14.05 | 7 | 10 | 685.10 |
| 4# | 461.09 | 512.24 | 640.99 | 14.13 | 7 | 10 | 686.14 |
| 尾水管最小动水压力 (m) | 1# | 460.88 | 49.15 | 16.73 | 18.1 | 3.5 | 10 | -2.64 |
| 2# | \ | \ | \ | \ | \ | \ | \ |
| 3# | 460.94 | 49.26 | 31.91 | 13.37 | 3.5 | 10 | 14.04 |
| 4# | 461.09 | 49.20 | 31.37 | 13.27 | 3.5 | 10 | 13.45 |
| 机组最大转速上升率(%) | 1# | 460.88 | 428.60 | 33.38 | 6.44 | 0 | 5 | 35.05 |
| 2# | \ | \ | \ | \ | \ | \ | \ |
| 3# | 460.94 | 428.60 | 38.66 | 12.22 | 0 | 5 | 40.59 |
| 4# | 461.09 | 428.60 | 38.85 | 12.28 | 0 | 5 | 40.79 |
| JHT17 | 球阀最大动水压力(m) | 1# | 457.68 | 526.59 | 643.91 | 9.45 | 7 | 10 | 687.68 |
| 2# | 457.35 | 526.92 | 644.98 | 9.5 | 7 | 10 | 688.80 |
| 3# | 457.61 | 527.04 | 644.49 | 9.41 | 7 | 10 | 688.27 |
| 4# | 458.06 | 527.15 | 647.20 | 9.55 | 7 | 10 | 691.27 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 511.00 | 649.60 | 9.46 | 7 | 10 | 695.50 |
| 2# | 457.35 | 511.34 | 649.48 | 9.56 | 7 | 10 | 695.31 |
| 3# | 457.61 | 511.45 | 649.62 | 9.3 | 7 | 10 | 695.47 |
| 4# | 458.06 | 511.54 | 652.04 | 10.05 | 7 | 10 | 698.15 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 51.24 | 40.19 | 11.09 | 3.5 | 10 | 23.07 |
| 2# | 457.35 | 51.93 | 40.03 | 11.17 | 3.5 | 10 | 22.83 |
| 3# | 457.61 | 51.76 | 40.38 | 11.26 | 3.5 | 10 | 23.23 |
| 4# | 458.06 | 51.38 | 36.73 | 35.32 | 3.5 | 10 | 19.23 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 40.57 | 7.7 | 0 | 5 | 42.60 |
| 2# | 457.35 | 428.60 | 40.69 | 7.72 | 0 | 5 | 42.72 |
| 3# | 457.61 | 428.60 | 40.77 | 7.73 | 0 | 5 | 42.81 |
| 4# | 458.06 | 428.60 | 43.58 | 8.11 | 0 | 5 | **45.76** |
| JHT18 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 642.37 | 9.45 | 7 | 10 | 686.14 |
| 2# | 457.35 | 525.38 | 643.44 | 9.5 | 7 | 10 | 687.26 |
| 3# | 457.61 | 525.50 | 642.95 | 9.41 | 7 | 10 | 686.73 |
| 4# | 458.06 | 525.61 | 645.66 | 9.55 | 7 | 10 | 689.73 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 648.06 | 9.46 | 7 | 10 | 693.96 |
| 2# | 457.35 | 509.80 | 647.94 | 9.56 | 7 | 10 | 693.77 |
| 3# | 457.61 | 509.91 | 648.08 | 9.3 | 7 | 10 | 693.93 |
| 4# | 458.06 | 510.00 | 650.50 | 10.05 | 7 | 10 | 696.61 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 38.65 | 11.09 | 3.5 | 10 | 21.53 |
| 2# | 457.35 | 50.39 | 38.49 | 11.17 | 3.5 | 10 | 21.29 |
| 3# | 457.61 | 50.22 | 38.84 | 11.26 | 3.5 | 10 | 21.69 |
| 4# | 458.06 | 49.84 | 34.95 | 35.32 | 3.5 | 10 | 17.43 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 40.57 | 7.7 | 0 | 5 | 42.60 |
| 2# | 457.35 | 428.60 | 40.69 | 7.72 | 0 | 5 | 42.72 |
| 3# | 457.61 | 428.60 | 40.77 | 7.73 | 0 | 5 | 42.81 |
| 4# | 458.06 | 428.60 | 43.58 | 8.11 | 0 | 5 | **45.76** |

注：表中尾水管进口最小动水压力为相对压力值

#### 6.9.2.3 水轮机极端工况计算结果

**表6-44 大波动水轮机极端工况机组参数计算结果**

| 工况 | 控制参数 | 机组 | 净水头(m) | 初始值 | 计算  极值 | 极值发生时间(s) | 压力脉动(%) | 计算误差(%) | 修正值 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|
|
| JDT1 | 球阀最大动水压力(m) | 1# | 457.68 | 526.59 | 637.45 | 9.54 | 7 | 10 | 680.57 |
| 2# | 457.35 | 526.92 | 644.74 | 9.5 | 7 | 10 | 688.54 |
| 3# | 457.61 | 527.04 | 644.44 | 9.56 | 7 | 10 | 688.21 |
| 4# | 458.06 | 527.15 | 646.61 | 9.55 | 7 | 10 | 690.62 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 511.00 | 641.04 | 9.46 | 7 | 10 | 686.08 |
| 2# | 457.35 | 511.34 | 649.83 | 9.56 | 7 | 10 | 695.69 |
| 3# | 457.61 | 511.45 | 649.98 | 9.43 | 7 | 10 | 695.87 |
| 4# | 458.06 | 511.54 | 651.32 | 9.57 | 7 | 10 | 697.36 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 51.24 | 29.64 | 36.21 | 3.5 | 10 | 11.46 |
| 2# | 457.35 | 51.93 | 38.90 | 11.17 | 3.5 | 10 | 21.59 |
| 3# | 457.61 | 51.76 | 39.17 | 11.26 | 3.5 | 10 | 21.89 |
| 4# | 458.06 | 51.38 | 38.89 | 11 | 3.5 | 10 | 21.61 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 43.30 | 8.18 | 0 | 5 | 45.47 |
| 2# | 457.35 | 428.60 | 40.67 | 7.71 | 0 | 5 | 42.70 |
| 3# | 457.61 | 428.60 | 40.78 | 7.72 | 0 | 5 | 42.82 |
| 4# | 458.06 | 428.60 | 40.83 | 7.73 | 0 | 5 | 42.87 |
| JDT2 | 球阀最大动水压力(m) | 1# | 419.05 | 498.54 | 621.26 | 9.83 | 7 | 10 | 662.87 |
| 2# | 418.64 | 498.95 | 623.33 | 10.08 | 7 | 10 | 665.07 |
| 3# | 418.96 | 499.09 | 620.05 | 9.41 | 7 | 10 | 661.47 |
| 4# | 419.53 | 499.24 | 625.26 | 9.55 | 7 | 10 | 667.23 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 479.00 | 628.63 | 9.93 | 7 | 10 | 672.93 |
| 2# | 418.64 | 479.43 | 629.45 | 10.06 | 7 | 10 | 673.76 |
| 3# | 418.96 | 479.56 | 626.90 | 8.31 | 7 | 10 | 670.96 |
| 4# | 419.53 | 479.67 | 633.33 | 10.05 | 7 | 10 | 678.06 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 57.28 | 48.12 | 11.09 | 3.5 | 10 | 32.54 |
| 2# | 418.64 | 58.15 | 48.00 | 11.17 | 3.5 | 10 | 32.33 |
| 3# | 418.96 | 57.93 | 41.87 | 26.86 | 3.5 | 10 | 25.60 |
| 4# | 419.53 | 57.46 | 47.86 | 11 | 3.5 | 10 | 32.22 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 40.90 | 7.76 | 0 | 5 | 42.95 |
| 2# | 418.64 | 428.60 | 41.04 | 7.79 | 0 | 5 | 43.09 |
| 3# | 418.96 | 428.60 | 46.23 | 7.98 | 0 | 5 | 48.54 |
| 4# | 419.53 | 428.60 | 41.21 | 7.77 | 0 | 5 | 43.27 |
| JDT3 | 球阀最大动水压力(m) | 1# | 419.05 | 505.44 | 628.33 | 9.83 | 7 | 10 | 669.95 |
| 2# | 418.64 | 505.85 | 626.89 | 9.5 | 7 | 10 | 668.30 |
| 3# | 418.96 | 505.99 | 630.74 | 10.21 | 7 | 10 | 672.54 |
| 4# | 419.53 | 506.14 | 632.20 | 9.55 | 7 | 10 | 674.17 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 485.90 | 635.63 | 9.93 | 7 | 10 | 679.94 |
| 2# | 418.64 | 486.33 | 633.36 | 8.2 | 7 | 10 | 677.37 |
| 3# | 418.96 | 486.46 | 637.23 | 10.32 | 7 | 10 | 681.63 |
| 4# | 419.53 | 486.57 | 640.30 | 10.05 | 7 | 10 | 685.04 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 64.18 | 55.14 | 11.09 | 3.5 | 10 | 39.57 |
| 2# | 418.64 | 65.05 | 49.07 | 27.02 | 3.5 | 10 | 32.82 |
| 3# | 418.96 | 64.83 | 54.58 | 11.35 | 3.5 | 10 | 38.89 |
| 4# | 419.53 | 64.36 | 54.85 | 11 | 3.5 | 10 | 39.22 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 40.90 | 7.78 | 0 | 5 | 42.95 |
| 2# | 418.64 | 428.60 | 46.11 | 7.96 | 0 | 5 | 48.42 |
| 3# | 418.96 | 428.60 | 41.17 | 7.78 | 0 | 5 | 43.23 |
| 4# | 419.53 | 428.60 | 41.22 | 7.76 | 0 | 5 | 43.28 |
| JDT4 | 球阀最大动水压力(m) | 1# | 419.05 | 498.94 | 619.18 | 9.54 | 7 | 10 | 660.54 |
| 2# | 418.64 | 499.35 | 623.75 | 10.08 | 7 | 10 | 665.49 |
| 3# | 418.96 | 499.49 | 624.43 | 10.21 | 7 | 10 | 666.25 |
| 4# | 419.53 | 499.64 | 625.76 | 9.55 | 7 | 10 | 667.74 |
| 蜗壳最大动水压力(m) | 1# | 419.05 | 479.40 | 625.81 | 9.46 | 7 | 10 | 669.78 |
| 2# | 418.64 | 479.83 | 629.89 | 10.06 | 7 | 10 | 674.20 |
| 3# | 418.96 | 479.96 | 630.87 | 10.11 | 7 | 10 | 675.29 |
| 4# | 419.53 | 480.07 | 633.96 | 10.05 | 7 | 10 | 678.72 |
| 尾水管最小动水压力 (m) | 1# | 419.05 | 57.68 | 42.15 | 27.61 | 3.5 | 10 | 25.93 |
| 2# | 418.64 | 58.55 | 48.44 | 11.28 | 3.5 | 10 | 32.78 |
| 3# | 418.96 | 58.33 | 48.00 | 11.35 | 3.5 | 10 | 32.30 |
| 4# | 419.53 | 57.86 | 48.37 | 11 | 3.5 | 10 | 32.74 |
| 机组最大转速上升率(%) | 1# | 419.05 | 428.60 | 45.95 | 7.96 | 0 | 5 | 48.25 |
| 2# | 418.64 | 428.60 | 41.05 | 7.8 | 0 | 5 | 43.10 |
| 3# | 418.96 | 428.60 | 41.17 | 7.79 | 0 | 5 | 43.23 |
| 4# | 419.53 | 428.60 | 41.24 | 7.8 | 0 | 5 | 43.30 |
| JDT5 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 641.87 | 9.45 | 7 | 10 | 685.59 |
| 2# | 457.35 | 525.38 | 642.83 | 9.5 | 7 | 10 | 686.59 |
| 3# | 457.61 | 525.50 | 642.41 | 9.56 | 7 | 10 | 686.13 |
| 4# | 458.06 | 525.61 | 639.08 | 9.55 | 7 | 10 | 682.49 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 648.06 | 9.46 | 7 | 10 | 693.96 |
| 2# | 457.35 | 509.80 | 647.84 | 9.56 | 7 | 10 | 693.66 |
| 3# | 457.61 | 509.91 | 648.18 | 9.3 | 7 | 10 | 694.04 |
| 4# | 458.06 | 510.00 | 641.50 | 8.86 | 7 | 10 | 686.71 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 37.55 | 11.09 | 3.5 | 10 | 20.32 |
| 2# | 457.35 | 50.39 | 37.13 | 11.17 | 3.5 | 10 | 19.80 |
| 3# | 457.61 | 50.22 | 37.23 | 32.97 | 3.5 | 10 | 19.91 |
| 4# | 458.06 | 49.84 | 27.61 | 36.38 | 3.5 | 10 | 9.35 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 40.56 | 7.7 | 0 | 5 | 42.59 |
| 2# | 457.35 | 428.60 | 40.67 | 7.71 | 0 | 5 | 42.70 |
| 3# | 457.61 | 428.60 | 40.76 | 7.71 | 0 | 5 | 42.80 |
| 4# | 458.06 | 428.60 | 43.55 | 8.21 | 0 | 5 | 45.73 |
| JDT6 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 628.09 | 9.37 | 7 | 10 | 670.43 |
| 2# | 457.35 | 525.38 | 628.72 | 9.5 | 7 | 10 | 671.07 |
| 3# | 457.61 | 525.50 | 628.42 | 9.41 | 7 | 10 | 670.74 |
| 4# | 458.06 | 525.61 | 624.93 | 9.55 | 7 | 10 | 666.93 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 633.49 | 9.46 | 7 | 10 | 677.93 |
| 2# | 457.35 | 509.80 | 633.78 | 9.3 | 7 | 10 | 678.19 |
| 3# | 457.61 | 509.91 | 633.39 | 9.3 | 7 | 10 | 677.77 |
| 4# | 458.06 | 510.00 | 643.91 | 14.94 | 7 | 10 | 689.37 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 32.04 | 32.14 | 3.5 | 10 | 14.26 |
| 2# | 457.35 | 50.39 | 31.46 | 32.24 | 3.5 | 10 | 13.56 |
| 3# | 457.61 | 50.22 | 31.99 | 32.14 | 3.5 | 10 | 14.15 |
| 4# | 458.06 | 49.84 | 1.32 | 14.98 | 3.5 | 10 | -19.56 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 38.49 | 7.34 | 0 | 5 | 40.41 |
| 2# | 457.35 | 428.60 | 38.55 | 7.35 | 0 | 5 | 40.48 |
| 3# | 457.61 | 428.60 | 38.56 | 7.36 | 0 | 5 | 40.49 |
| 4# | 458.06 | 428.60 | 42.16 | 13.65 | 0 | 5 | 44.27 |
| JDT7 | 球阀最大动水压力(m) | 1# | 457.66 | 526.57 | 643.20 | 9.49 | 7 | 10 | 686.90 |
| 2# | 457.35 | 526.92 | 644.47 | 9.53 | 7 | 10 | 688.24 |
| 3# | 457.51 | 527.04 | 644.69 | 9.53 | 7 | 10 | 688.48 |
| 4# | 458.06 | 527.15 | 646.76 | 9.55 | 7 | 10 | 690.78 |
| 蜗壳最大动水压力(m) | 1# | 457.66 | 510.98 | 647.86 | 9.48 | 7 | 10 | 693.58 |
| 2# | 457.35 | 511.34 | 648.49 | 9.56 | 7 | 10 | 694.22 |
| 3# | 457.51 | 511.45 | 650.14 | 9.55 | 7 | 10 | 696.03 |
| 4# | 458.06 | 511.54 | 653.69 | 9.56 | 7 | 10 | 699.97 |
| 尾水管最小动水压力 (m) | 1# | 457.66 | 53.73 | 38.55 | 11.3 | 3.5 | 10 | 21.01 |
| 2# | 457.35 | 54.41 | 38.68 | 11.3 | 3.5 | 10 | 21.10 |
| 3# | 457.51 | 54.35 | 36.61 | 11.32 | 3.5 | 10 | 18.82 |
| 4# | 458.06 | 53.87 | 35.89 | 35 | 3.5 | 10 | 18.06 |
| 机组最大转速上升率(%) | 1# | 457.66 | 428.60 | 39.73 | 7.66 | 0 | 5 | 41.72 |
| 2# | 457.35 | 428.60 | 39.85 | 7.67 | 0 | 5 | 41.84 |
| 3# | 457.51 | 428.60 | 40.13 | 7.73 | 0 | 5 | 42.14 |
| 4# | 458.06 | 428.60 | 41.02 | 7.29 | 0 | 5 | 43.07 |
| JDT10 | 球阀最大动水压力(m) | 1# | 457.68 | 525.05 | 624.55 | 13.51 | 7 | 10 | 666.54 |
| 2# | 457.35 | 525.38 | 641.33 | 13.24 | 7 | 10 | 684.94 |
| 3# | 457.61 | 525.50 | 642.16 | 13.43 | 7 | 10 | 685.86 |
| 4# | 458.06 | 525.61 | 643.01 | 13.44 | 7 | 10 | 686.81 |
| 蜗壳最大动水压力(m) | 1# | 457.68 | 509.46 | 643.19 | 17.18 | 7 | 10 | 688.60 |
| 2# | 457.35 | 509.80 | 648.70 | 12.84 | 7 | 10 | 694.60 |
| 3# | 457.61 | 509.91 | 649.69 | 12.95 | 7 | 10 | 695.70 |
| 4# | 458.06 | 510.00 | 650.48 | 12.92 | 7 | 10 | 696.59 |
| 尾水管最小动水压力 (m) | 1# | 457.68 | 49.70 | 15.49 | 17.23 | 3.5 | 10 | -3.95 |
| 2# | 457.35 | 50.39 | 37.80 | 35.98 | 3.5 | 10 | 20.53 |
| 3# | 457.61 | 50.22 | 39.15 | 11.26 | 3.5 | 10 | 22.03 |
| 4# | 458.06 | 49.84 | 38.91 | 14.74 | 3.5 | 10 | 21.78 |
| 机组最大转速上升率(%) | 1# | 457.68 | 428.60 | 36.94 | 15.39 | 0 | 5 | 38.79 |
| 2# | 457.35 | 428.60 | 40.74 | 11.04 | 0 | 5 | 42.78 |
| 3# | 457.61 | 428.60 | 40.91 | 11.08 | 0 | 5 | 42.96 |
| 4# | 458.06 | 428.60 | 41.02 | 11.11 | 0 | 5 | 43.07 |

注：表中尾水管进口最小动水压力为相对压力值

#### 6.9.2.4 水泵设计工况计算结果

**表6-45 大波动水泵设计工况机组参数计算结果**

| 工况 | 控制参数 | 机组 | 净扬程(m) | 初始值 | 计算  极值 | 极值发生时间(s) | 压力脉动(%) | 计算误差(%) | 修正值 |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|
|
| SJP1 | 球阀最大动水压力(m) | 1# | 472.61 | 536.67 | 598.53 | 19.44 | 2 | 10 | 614.17 |
| 2# | 472.79 | 536.91 | 600.81 | 19.44 | 2 | 10 | 616.66 |
| 3# | 473.22 | 537.15 | 603.17 | 19.44 | 2 | 10 | 619.24 |
| 4# | 472.06 | 535.78 | 601.48 | 19.45 | 2 | 10 | 617.49 |
| 蜗壳最大动水压力(m) | 1# | 472.61 | 527.71 | 609.41 | 19.42 | 2 | 10 | 627.03 |
| 2# | 472.79 | 527.97 | 612.52 | 19.42 | 2 | 10 | 630.43 |
| 3# | 473.22 | 528.25 | 615.85 | 19.42 | 2 | 10 | 634.07 |
| 4# | 472.06 | 526.77 | 613.28 | 19.43 | 2 | 10 | 631.37 |
| 尾水管最小动水压力 (m) | 1# | 472.61 | 53.52 | 52.04 | 0.01 | 3.5 | 10 | 35.35 |
| 2# | 472.79 | 53.60 | 52.12 | 0.01 | 3.5 | 10 | 35.42 |
| 3# | 473.22 | 53.43 | 51.97 | 0.01 | 3.5 | 10 | 35.26 |
| 4# | 472.06 | 53.15 | 51.65 | 0.01 | 3.5 | 10 | 34.98 |
| SJP2 | 球阀最大动水压力(m) | 1# | 430.35 | 513.80 | 567.39 | 20.14 | 2 | 10 | 581.36 |
| 2# | 430.60 | 514.14 | 567.41 | 20.13 | 2 | 10 | 581.35 |
| 3# | 431.21 | 514.47 | 568.04 | 19.84 | 2 | 10 | 582.02 |
| 4# | 429.55 | 512.56 | 569.22 | 20.07 | 2 | 10 | 583.48 |
| 蜗壳最大动水压力(m) | 1# | 430.35 | 501.26 | 574.48 | 20.15 | 2 | 10 | 590.41 |
| 2# | 430.60 | 501.63 | 571.89 | 20.14 | 2 | 10 | 587.53 |
| 3# | 431.21 | 502.01 | 580.47 | 19.82 | 2 | 10 | 596.94 |
| 4# | 429.55 | 499.95 | 578.56 | 20.09 | 2 | 10 | 595.01 |
| 尾水管最小动水压力 (m) | 1# | 430.35 | 68.85 | 66.65 | 0.01 | 3.5 | 10 | 51.37 |
| 2# | 430.60 | 68.96 | 66.76 | 0.01 | 3.5 | 10 | 51.47 |
| 3# | 431.21 | 68.74 | 66.55 | 0.01 | 3.5 | 10 | 51.24 |
| 4# | 429.55 | 68.35 | 66.12 | 0.01 | 3.5 | 10 | 50.86 |
| SJP3 | 球阀最大动水压力(m) | 1# | 428.75 | 516.44 | 565.22 | 20.16 | 2 | 10 | 578.67 |
| 2# | 429.01 | 516.79 | 564.96 | 20.18 | 2 | 10 | 578.36 |
| 3# | 429.63 | 517.13 | 570.89 | 20.14 | 2 | 10 | 584.86 |
| 4# | 427.95 | 515.19 | 570.74 | 19.88 | 2 | 10 | 584.85 |
| 蜗壳最大动水压力(m) | 1# | 428.75 | 503.76 | 572.89 | 20.20 | 2 | 10 | 588.38 |
| 2# | 429.01 | 504.13 | 574.33 | 20.10 | 2 | 10 | 589.93 |
| 3# | 429.63 | 504.52 | 579.13 | 20.14 | 2 | 10 | 595.18 |
| 4# | 427.95 | 502.44 | 578.09 | 19.90 | 2 | 10 | 594.21 |
| 尾水管最小动水压力 (m) | 1# | 428.75 | 72.92 | 71.01 | 0.02 | 3.5 | 10 | 55.81 |
| 2# | 429.01 | 73.03 | 71.12 | 0.02 | 3.5 | 10 | 55.91 |
| 3# | 429.63 | 72.81 | 70.90 | 0.02 | 3.5 | 10 | 55.67 |
| 4# | 427.95 | 72.41 | 70.50 | 0.02 | 3.5 | 10 | 55.33 |
| SJP4 | 球阀最大动水压力(m) | 1# | 439.34 | 513.43 | 576.16 | 19.32 | 2 | 10 | 591.22 |
| 2# | 439.58 | 513.75 | 567.94 | 19.34 | 2 | 10 | 582.15 |
| 3# | 440.16 | 514.07 | 576.39 | 19.11 | 2 | 10 | 591.43 |
| 4# | 438.58 | 512.26 | 569.70 | 18.87 | 2 | 10 | 584.22 |
| 蜗壳最大动水压力(m) | 1# | 439.34 | 501.57 | 582.00 | 19.32 | 2 | 10 | 598.83 |
| 2# | 439.58 | 501.91 | 588.61 | 19.16 | 2 | 10 | 606.07 |
| 3# | 440.16 | 502.27 | 587.90 | 19.13 | 2 | 10 | 605.27 |
| 4# | 438.58 | 500.34 | 582.85 | 18.88 | 2 | 10 | 599.87 |
| 尾水管最小动水压力 (m) | 1# | 439.34 | 60.29 | 58.26 | 0.01 | 3.5 | 10 | 42.68 |
| 2# | 439.58 | 60.39 | 58.36 | 0.01 | 3.5 | 10 | 42.77 |
| 3# | 440.16 | 60.16 | 58.15 | 0.01 | 3.5 | 10 | 42.54 |
| 4# | 438.58 | 59.82 | 57.77 | 0.01 | 3.5 | 10 | 42.21 |
| ZP2 | 球阀最大动水压力(m) | 1# | 427.58 | 511.60 | 561.25 | 90.46 | 2 | 10 | 574.77 |
| 2# | 427.45 | 511.55 | 562.19 | 90.46 | 2 | 10 | 575.80 |
| 3# | 427.49 | 511.28 | 563.82 | 90.50 | 2 | 10 | 577.62 |
| 4# | 425.02 | 509.26 | 565.77 | 90.50 | 2 | 10 | 579.92 |
| 蜗壳最大动水压力(m) | 1# | 427.58 | 498.82 | 574.43 | 90.44 | 2 | 10 | 590.54 |
| 2# | 427.45 | 498.76 | 574.29 | 90.44 | 2 | 10 | 590.39 |
| 3# | 427.49 | 498.49 | 575.28 | 90.48 | 2 | 10 | 591.51 |
| 4# | 425.02 | 509.26 | 575.96 | 90.48 | 2 | 10 | 591.13 |
| 尾水管最小动水压力 (m) | 1# | 427.58 | 69.02 | 66.32 | 0.02 | 3.5 | 10 | 51.08 |
| 2# | 427.45 | 69.09 | 66.39 | 0.02 | 3.5 | 10 | 51.16 |
| 3# | 427.49 | 68.79 | 66.09 | 0.02 | 3.5 | 10 | 50.86 |
| 4# | 425.02 | 84.27 | 67.45 | 31.36 | 3.5 | 10 | 50.89 |
| ZP3 | 球阀最大动水压力(m) | 1# | 425.95 | 514.22 | 562.03 | 90.92 | 2 | 10 | 575.33 |
| 2# | 425.82 | 514.17 | 564.11 | 90.92 | 2 | 10 | 577.62 |
| 3# | 425.86 | 513.90 | 565.50 | 90.92 | 2 | 10 | 579.18 |
| 4# | 423.36 | 511.86 | 567.26 | 90.92 | 2 | 10 | 581.27 |
| 蜗壳最大动水压力(m) | 1# | 425.95 | 501.31 | 573.79 | 90.90 | 2 | 10 | 589.56 |
| 2# | 425.82 | 501.24 | 575.48 | 90.90 | 2 | 10 | 591.42 |
| 3# | 425.86 | 500.97 | 574.50 | 90.90 | 2 | 10 | 590.37 |
| 4# | 423.36 | 511.86 | 578.37 | 90.90 | 2 | 10 | 593.49 |
| 尾水管最小动水压力 (m) | 1# | 425.95 | 73.11 | 70.42 | 0.02 | 3.5 | 10 | 55.24 |
| 2# | 425.82 | 73.18 | 70.48 | 0.02 | 3.5 | 10 | 55.31 |
| 3# | 425.86 | 72.88 | 70.18 | 0.02 | 3.5 | 10 | 55.01 |
| 4# | 423.36 | 88.52 | 71.53 | 31.52 | 3.5 | 10 | 55.01 |
| ZP4 | 球阀最大动水压力(m) | 1# | 427.58 | 511.60 | 564.27 | 78.17 | 2 | 10 | 578.09 |
| 2# | 427.45 | 511.55 | 567.33 | 78.19 | 2 | 10 | 581.46 |
| 3# | 427.49 | 511.28 | 566.56 | 78.17 | 2 | 10 | 580.64 |
| 4# | 425.02 | 509.26 | 567.95 | 78.17 | 2 | 10 | 582.32 |
| 蜗壳最大动水压力(m) | 1# | 427.58 | 498.82 | 574.99 | 78.15 | 2 | 10 | 591.16 |
| 2# | 427.45 | 498.76 | 575.63 | 78.17 | 2 | 10 | 591.87 |
| 3# | 427.49 | 498.49 | 576.02 | 78.15 | 2 | 10 | 592.32 |
| 4# | 425.02 | 509.26 | 579.31 | 78.15 | 2 | 10 | 594.82 |
| 尾水管最小动水压力 (m) | 1# | 427.58 | 69.02 | 66.32 | 0.01 | 3.5 | 10 | 51.08 |
| 2# | 427.45 | 69.09 | 66.39 | 0.01 | 3.5 | 10 | 51.16 |
| 3# | 427.49 | 68.79 | 66.09 | 0.01 | 3.5 | 10 | 50.86 |
| 4# | 425.02 | 84.27 | 66.89 | 13.61 | 3.5 | 10 | 50.28 |

注：表中尾水管进口最小动水压力为相对压力值

#### 6.9.2.5 水泵校核工况计算结果

**表6-46 大波动水泵校核工况机组参数计算结果**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 控制参数 | 机组 | 净扬程(m) | 初始值 | 计算  极值 | 极值发生时间(s) | 压力脉动(%) | 计算误差(%) | 修正值 |
|
|
| JHP1 | 球阀最大动水压力(m) | 1# | 430.35 | 513.80 | 541.43 | 20.19 | 2 | 10 | 552.80 |
| 2# | 430.60 | 514.14 | 540.43 | 20.21 | 2 | 10 | 551.67 |
| 3# | 431.21 | 514.47 | 541.00 | 20.21 | 2 | 10 | 552.28 |
| 4# | 429.55 | 512.56 | 534.74 | 20.47 | 2 | 10 | 545.55 |
| 蜗壳最大动水压力(m) | 1# | 430.35 | 501.26 | 557.19 | 20.18 | 2 | 10 | 571.39 |
| 2# | 430.60 | 501.63 | 551.83 | 20.19 | 2 | 10 | 565.46 |
| 3# | 431.21 | 502.01 | 553.19 | 20.2 | 2 | 10 | 566.93 |
| 4# | 429.55 | 499.95 | 526.31 | 20.51 | 2 | 10 | 537.54 |
| 尾水管最小动水压力 (m) | 1# | 430.35 | 68.85 | 66.65 | 0.01 | 3.5 | 10 | 51.37 |
| 2# | 430.60 | 68.96 | 66.76 | 0.01 | 3.5 | 10 | 51.47 |
| 3# | 431.21 | 68.74 | 66.55 | 0.01 | 3.5 | 10 | 51.24 |
| 4# | 429.55 | 68.35 | 66.12 | 0.01 | 3.5 | 10 | 50.86 |
| JHP2 | 球阀最大动水压力(m) | 1# | 430.35 | 513.80 | 567.29 | 20.14 | 2 | 10 | 581.25 |
| 2# | 430.60 | 514.14 | 567.52 | 20.13 | 2 | 10 | 581.47 |
| 3# | 431.21 | 514.47 | 568.03 | 19.84 | 2 | 10 | 582.01 |
| 4# | 429.55 | 512.56 | 569.14 | 20.07 | 2 | 10 | 583.39 |
| 蜗壳最大动水压力(m) | 1# | 430.35 | 501.26 | 573.87 | 20.15 | 2 | 10 | 589.74 |
| 2# | 430.60 | 501.63 | 572.04 | 20.15 | 2 | 10 | 587.69 |
| 3# | 431.21 | 502.01 | 580.40 | 19.82 | 2 | 10 | 596.86 |
| 4# | 429.55 | 499.95 | 578.58 | 20.09 | 2 | 10 | 595.03 |
| 尾水管最小动水压力 (m) | 1# | 430.35 | 68.85 | 66.65 | 0.01 | 3.5 | 10 | 51.37 |
| 2# | 430.60 | 68.96 | 66.76 | 0.01 | 3.5 | 10 | 51.47 |
| 3# | 431.21 | 68.74 | 66.55 | 0.01 | 3.5 | 10 | 51.24 |
| 4# | 429.55 | 68.35 | 66.12 | 0.01 | 3.5 | 10 | 50.86 |
| JHP3 | 球阀最大动水压力(m) | 1# | 439.34 | 513.43 | 536.82 | 98.19 | 2 | 10 | 547.95 |
| 2# | 439.58 | 513.75 | 535.08 | 19.33 | 2 | 10 | 546.00 |
| 3# | 440.16 | 514.07 | 536.54 | 91.88 | 2 | 10 | 547.59 |
| 4# | 438.58 | 512.26 | 537.93 | 92.03 | 2 | 10 | 549.27 |
| 蜗壳最大动水压力(m) | 1# | 439.34 | 501.57 | 566.66 | 87.03 | 2 | 10 | 581.96 |
| 2# | 439.58 | 501.91 | 569.85 | 92.66 | 2 | 10 | 585.44 |
| 3# | 440.16 | 502.27 | 565.10 | 92.58 | 2 | 10 | 580.19 |
| 4# | 438.58 | 500.34 | 526.77 | 30.2 | 2 | 10 | 538.18 |
| 尾水管最小动水压力 (m) | 1# | 439.34 | 60.29 | 47.57 | 81.48 | 3.5 | 10 | 30.92 |
| 2# | 439.58 | 60.39 | 45.50 | 81.87 | 3.5 | 10 | 28.63 |
| 3# | 440.16 | 60.16 | 44.85 | 87.42 | 3.5 | 10 | 27.91 |
| 4# | 438.58 | 59.82 | 48.74 | 87.84 | 3.5 | 10 | 32.28 |
| JHP4 | 球阀最大动水压力(m) | 1# | 439.34 | 513.43 | 576.11 | 19.31 | 2 | 10 | 591.17 |
| 2# | 439.58 | 513.75 | 568.51 | 19.34 | 2 | 10 | 582.78 |
| 3# | 440.16 | 514.07 | 576.39 | 19.11 | 2 | 10 | 591.43 |
| 4# | 438.58 | 512.26 | 572.00 | 19.11 | 2 | 10 | 586.75 |
| 蜗壳最大动水压力(m) | 1# | 439.34 | 501.57 | 584.09 | 19.29 | 2 | 10 | 601.13 |
| 2# | 439.58 | 501.91 | 588.62 | 19.16 | 2 | 10 | 606.08 |
| 3# | 440.16 | 502.27 | 587.91 | 19.13 | 2 | 10 | 605.28 |
| 4# | 438.58 | 500.34 | 582.86 | 18.88 | 2 | 10 | 599.88 |
| 尾水管最小动水压力 (m) | 1# | 439.34 | 60.29 | 58.26 | 0.01 | 3.5 | 10 | 42.68 |
| 2# | 439.58 | 60.39 | 58.36 | 0.01 | 3.5 | 10 | 42.77 |
| 3# | 440.16 | 60.16 | 58.15 | 0.01 | 3.5 | 10 | 42.54 |
| 4# | 438.58 | 59.82 | 57.77 | 0.01 | 3.5 | 10 | 42.21 |
| JHP5 | 球阀最大动水压力(m) | 1# | 472.61 | 536.67 | 569.33 | 19.3 | 2 | 10 | 582.05 |
| 2# | 472.79 | 536.91 | 572.79 | 19.31 | 2 | 10 | 585.83 |
| 3# | 473.22 | 537.15 | 572.09 | 19.32 | 2 | 10 | 585.05 |
| 4# | 472.06 | 535.78 | 561.90 | 19.67 | 2 | 10 | 573.95 |
| 蜗壳最大动水压力(m) | 1# | 472.61 | 527.71 | 580.95 | 19.19 | 2 | 10 | 595.73 |
| 2# | 472.79 | 527.97 | 582.46 | 19.2 | 2 | 10 | 597.37 |
| 3# | 473.22 | 528.25 | 583.22 | 19.25 | 2 | 10 | 598.18 |
| 4# | 472.06 | 526.77 | 559.77 | 19.67 | 2 | 10 | 572.51 |
| 尾水管最小动水压力 (m) | 1# | 472.61 | 53.52 | 52.04 | 0.01 | 3.5 | 10 | 35.35 |
| 2# | 472.79 | 53.60 | 52.12 | 0.01 | 3.5 | 10 | 35.42 |
| 3# | 473.22 | 53.43 | 51.97 | 0.01 | 3.5 | 10 | 35.26 |
| 4# | 472.06 | 53.15 | 49.84 | 64.04 | 3.5 | 10 | 32.99 |

注：表中尾水管进口最小动水压力为相对压力值

#### 6.9.2.6 水泵极端工况计算结果

**表6-47 大波动水泵极端工况机组参数计算结果**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 控制参数 | 机组 | 净扬程(m) | 初始值 | 计算  极值 | 极值发生时间(s) | 压力脉动(%) | 计算误差(%) | 修正值 |
|
|
| JDP1 | 球阀最大动水压力(m) | 1# | 430.35 | 513.80 | 541.47 | 20.19 | 2 | 10 | 552.84 |
| 2# | 430.60 | 514.14 | 540.35 | 20.21 | 2 | 10 | 551.58 |
| 3# | 431.21 | 514.47 | 541.31 | 20.21 | 2 | 10 | 552.62 |
| 4# | 429.55 | 512.56 | 543.08 | 105.36 | 2 | 10 | 554.72 |
| 蜗壳最大动水压力(m) | 1# | 430.35 | 501.26 | 557.33 | 20.19 | 2 | 10 | 571.54 |
| 2# | 430.60 | 501.63 | 551.59 | 20.19 | 2 | 10 | 565.20 |
| 3# | 431.21 | 502.01 | 552.62 | 20.19 | 2 | 10 | 566.30 |
| 4# | 429.55 | 499.95 | 545.57 | 105.41 | 2 | 10 | 558.72 |
| 尾水管最小动水压力 (m) | 1# | 430.35 | 68.85 | 66.65 | 0.01 | 3.5 | 10 | 51.37 |
| 2# | 430.60 | 68.96 | 66.76 | 0.01 | 3.5 | 10 | 51.47 |
| 3# | 431.21 | 68.74 | 66.55 | 0.01 | 3.5 | 10 | 51.24 |
| 4# | 429.55 | 68.35 | 64.77 | 84.54 | 3.5 | 10 | 49.38 |
| JDP2 | 球阀最大动水压力(m) | 1# | 428.75 | 516.44 | 545.83 | 20.20 | 2 | 10 | 557.34 |
| 2# | 429.01 | 516.79 | 543.30 | 20.22 | 2 | 10 | 554.53 |
| 3# | 429.63 | 517.13 | 543.24 | 20.22 | 2 | 10 | 554.44 |
| 4# | 427.95 | 515.19 | 544.45 | 105.76 | 2 | 10 | 555.93 |
| 蜗壳最大动水压力(m) | 1# | 428.75 | 503.76 | 558.47 | 20.20 | 2 | 10 | 572.52 |
| 2# | 429.01 | 504.13 | 555.88 | 20.20 | 2 | 10 | 569.64 |
| 3# | 429.63 | 504.52 | 552.82 | 20.20 | 2 | 10 | 566.24 |
| 4# | 427.95 | 502.44 | 547.07 | 105.82 | 2 | 10 | 560.09 |
| 尾水管最小动水压力 (m) | 1# | 428.75 | 72.92 | 71.01 | 0.02 | 3.5 | 10 | 55.81 |
| 2# | 429.01 | 73.03 | 71.12 | 0.02 | 3.5 | 10 | 55.91 |
| 3# | 429.63 | 72.81 | 70.90 | 0.02 | 3.5 | 10 | 55.67 |
| 4# | 427.95 | 72.41 | 69.91 | 104.06 | 3.5 | 10 | 54.68 |
| JDP3 | 球阀最大动水压力(m) | 1# | 439.34 | 513.43 | 576.16 | 19.32 | 2 | 10 | 591.22 |
| 2# | 439.58 | 513.75 | 567.94 | 19.34 | 2 | 10 | 582.15 |
| 3# | 440.16 | 514.07 | 576.39 | 19.11 | 2 | 10 | 591.43 |
| 4# | 438.58 | 512.26 | 569.70 | 18.87 | 2 | 10 | 584.22 |
| 蜗壳最大动水压力(m) | 1# | 439.34 | 501.57 | 582.00 | 19.32 | 2 | 10 | 598.83 |
| 2# | 439.58 | 501.91 | 588.61 | 19.16 | 2 | 10 | 606.07 |
| 3# | 440.16 | 502.27 | 587.90 | 19.13 | 2 | 10 | 605.27 |
| 4# | 438.58 | 500.34 | 582.85 | 18.88 | 2 | 10 | 599.87 |
| 尾水管最小动水压力 (m) | 1# | 439.34 | 60.29 | 58.26 | 0.01 | 3.5 | 10 | 42.68 |
| 2# | 439.58 | 60.39 | 58.36 | 0.01 | 3.5 | 10 | 42.77 |
| 3# | 440.16 | 60.16 | 58.15 | 0.01 | 3.5 | 10 | 42.54 |
| 4# | 438.58 | 59.82 | 57.77 | 0.01 | 3.5 | 10 | 42.21 |

注；表中尾水管进口最小动水压力为相对压力值

#### 6.9.2.7 调压室最高最低涌浪计算结果

**表6-48 大波动上游调压室最高最低涌浪水位计算结果**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 调压室初始水位(m) | 最高涌浪(m) | 修正值(m) | 极值发生时间（s） | 最低涌浪(m) | 修正值(m) | 极值发生时间（s） | 底板向下最大压差(m) | 极值发生时间（s） | 底板向上最大压差(m) | 极值发生时间（s） |
| SJT1 | 524.89 | 537.81 | 539.10 | 41.40 | 513.93 | 512.83 | 130.88 | 2.62 | 93.54 | 16.74 | 13.55 |
| SJT2 | 507.09 | 528.50 | 530.64 | 42.35 | 497.94 | 497.03 | 112.93 | 1.93 | 77.54 | 18.39 | 13.55 |
| SJT3 | 526.43 | 538.35 | 539.54 | 60.71 | 515.46 | 514.36 | 140.72 | 2.58 | 104.87 | 16.74 | 13.55 |
| SJT4 | 499.59 | 521.00 | 523.14 | 42.35 | 490.44 | 489.53 | 112.93 | 1.93 | 77.55 | 18.39 | 13.55 |
| SJT5 | 500.52 | 503.11 | 503.37 | 113.59 | 493.80 | 493.13 | 45.13 | 0.31 | 23.66 | 0.38 | 74.17 |
| SJT6 | 506.49 | 527.90 | 530.04 | 42.35 | 497.34 | 496.43 | 112.93 | 1.93 | 77.55 | 18.39 | 13.55 |
| SJT7 | 507.42 | 510.01 | 510.27 | 113.59 | 500.70 | 500.03 | 45.13 | 0.31 | 23.66 | 0.38 | 74.17 |
| SJT8 | 499.99 | 521.40 | 523.54 | 42.35 | 490.84 | 489.93 | 112.93 | 1.93 | 77.55 | 18.39 | 13.55 |
| SJT9 | 500.92 | 503.51 | 503.77 | 113.59 | 494.20 | 493.53 | 45.13 | 0.31 | 23.66 | 0.38 | 74.17 |
| ZT1 | 525.63 | 538.36 | 539.63 | 132.23 | 512.86 | 511.58 | 209.81 | 3.10 | 173.41 | 19.20 | 87.67 |
| ZT2 | 508.02 | 530.68 | 532.95 | 119.00 | 496.75 | 495.62 | 188.71 | 2.39 | 152.96 | 21.02 | 89.98 |
| ZT3 | 525.63 | 538.23 | 539.49 | 121.03 | 513.11 | 511.86 | 198.38 | 3.00 | 161.58 | 19.44 | 75.87 |
| ZT4 | 500.52 | 522.72 | 524.94 | 105.35 | 489.27 | 488.15 | 176.23 | 2.41 | 139.78 | 21.37 | 75.71 |
| JHT1 | 526.43 | 537.93 | 539.08 | 42.86 | 515.71 | 514.64 | 136.48 | 2.11 | 98.78 | 15.43 | 13.55 |
| JHT2 | 526.43 | 538.35 | 539.54 | 60.89 | 515.46 | 514.36 | 140.70 | 2.58 | 104.87 | 16.75 | 13.55 |
| JHT3 | 507.09 | 528.41 | 530.54 | 43.22 | 498.11 | 497.21 | 112.47 | 1.93 | 81.18 | 17.77 | 13.63 |
| JHT4 | 507.09 | 526.66 | 528.62 | 42.21 | 498.72 | 497.88 | 113.21 | 1.72 | 47.34 | 17.01 | 14.17 |
| JHT5 | 499.59 | 519.16 | 521.12 | 42.13 | 491.27 | 490.44 | 113.35 | 1.70 | 47.04 | 16.99 | 14.17 |
| JHT6 | 499.59 | 520.91 | 523.04 | 43.22 | 490.61 | 489.71 | 112.47 | 1.93 | 81.18 | 17.77 | 13.63 |
| JHT7 | 506.49 | 526.06 | 528.02 | 42.12 | 498.17 | 497.34 | 113.28 | 1.69 | 46.99 | 16.99 | 14.18 |
| JHT8 | 506.49 | 527.81 | 529.94 | 43.22 | 497.51 | 496.61 | 112.47 | 1.93 | 81.18 | 17.77 | 13.63 |
| JHT9 | 499.99 | 519.57 | 521.53 | 42.15 | 491.67 | 490.84 | 113.33 | 1.71 | 47.09 | 16.98 | 14.17 |
| JHT10 | 499.99 | 521.31 | 523.44 | 43.22 | 491.01 | 490.11 | 112.47 | 1.93 | 81.18 | 17.77 | 13.63 |
| JHT11 | 524.89 | 537.53 | 538.79 | 42.61 | 514.34 | 513.29 | 128.12 | 2.07 | 92.58 | 15.46 | 13.55 |
| JHT12 | 524.89 | 537.80 | 539.09 | 41.38 | 513.93 | 512.83 | 130.86 | 2.62 | 93.54 | 16.74 | 13.55 |
| JHT13 | 524.89 | 538.11 | 539.43 | 63.17 | 513.33 | 512.17 | 140.11 | 2.79 | 99.94 | 9.96 | 16.48 |
| JHT14 | 524.89 | 536.83 | 538.02 | 54.47 | 515.89 | 514.99 | 126.04 | 1.57 | 88.29 | 6.25 | 13.56 |
| JHT15 | 525.74 | 537.04 | 538.17 | 54.06 | 515.52 | 514.50 | 127.04 | 1.88 | 87.82 | 6.59 | 13.54 |
| JHT16 | 525.75 | 537.02 | 538.15 | 42.24 | 515.63 | 514.62 | 128.41 | 1.85 | 93.64 | 8.55 | 16.28 |
| JHT17 | 526.43 | 538.31 | 539.50 | 61.72 | 515.52 | 514.43 | 140.72 | 2.54 | 104.74 | 16.16 | 13.63 |
| JHT18 | 524.89 | 537.79 | 539.08 | 42.09 | 514.03 | 512.94 | 132.06 | 2.53 | 93.09 | 16.16 | 13.63 |
| JDT1 | 526.43 | 537.93 | 539.08 | 42.96 | 515.84 | 514.78 | 135.68 | 3.21 | 96.34 | 15.44 | 13.55 |
| JDT2 | 499.59 | 519.12 | 521.07 | 42.12 | 490.81 | 489.93 | 106.96 | 2.85 | 82.57 | 16.99 | 14.17 |
| JDT3 | 506.49 | 526.02 | 527.97 | 42.10 | 497.77 | 496.90 | 106.66 | 2.90 | 82.30 | 16.99 | 14.18 |
| JDT4 | 499.99 | 519.53 | 521.48 | 42.15 | 491.27 | 490.40 | 106.69 | 2.91 | 82.32 | 16.98 | 14.17 |
| JDT5 | 524.89 | 537.54 | 538.81 | 42.69 | 514.62 | 513.59 | 122.69 | 2.97 | 81.32 | 15.46 | 13.55 |
| JDT6 | 524.89 | 538.01 | 539.32 | 60.01 | 513.48 | 512.34 | 137.22 | 2.67 | 101.41 | 11.43 | 13.84 |
| JDT7 | 526.43 | 538.17 | 539.34 | 42.28 | 515.98 | 514.94 | 140.19 | 2.24 | 104.82 | 16.17 | 13.54 |
| JDT10 | 524.89 | 537.90 | 539.20 | 61.29 | 513.71 | 512.59 | 136.34 | 2.71 | 97.25 | 14.34 | 17.09 |
| SJP1 | 527.99 | 536.52 | 537.37 | 102.64 | 506.50 | 504.35 | 30.96 | 13.16 | 8.68 | 6.16 | 55.81 |
| SJP2 | 503.65 | 515.23 | 516.39 | 99.20 | 479.11 | 476.66 | 31.89 | 14.77 | 10.05 | 7.06 | 56.34 |
| SJP3 | 506.24 | 517.83 | 518.99 | 99.46 | 481.59 | 479.13 | 31.94 | 19.03 | 10.10 | 8.28 | 56.70 |
| SJP4 | 502.95 | 515.89 | 517.18 | 170.26 | 476.97 | 474.37 | 102.42 | 22.04 | 80.34 | 9.21 | 127.04 |
| ZP2 | 505.53 | 518.49 | 519.79 | 170.68 | 479.42 | 476.81 | 102.82 | 22.22 | 80.74 | 9.24 | 127.42 |
| ZP3 | 505.52 | 518.42 | 519.71 | 174.61 | 479.94 | 477.38 | 107.03 | 11.36 | 79.57 | 6.99 | 132.98 |
| ZP4 | 502.95 | 515.50 | 516.76 | 161.32 | 478.30 | 475.84 | 90.34 | 17.23 | 68.00 | 7.35 | 120.32 |
| JHP1 | 503.65 | 516.25 | 517.51 | 99.37 | 475.57 | 472.76 | 31.62 | 14.98 | 10.05 | 7.68 | 55.92 |
| JHP2 | 503.65 | 515.23 | 516.39 | 99.20 | 479.11 | 476.66 | 31.89 | 14.77 | 10.05 | 7.06 | 56.34 |
| JHP3 | 503.56 | 516.15 | 517.41 | 99.66 | 475.95 | 473.19 | 31.58 | 14.66 | 9.89 | 7.40 | 55.99 |
| JHP4 | 503.56 | 514.98 | 516.12 | 98.71 | 479.76 | 477.38 | 31.21 | 14.45 | 9.62 | 6.82 | 61.39 |
| JHP5 | 527.99 | 536.79 | 537.67 | 101.60 | 502.95 | 500.45 | 30.03 | 13.28 | 8.97 | 6.62 | 54.34 |
| JDP1 | 503.65 | 516.01 | 517.25 | 98.26 | 475.55 | 472.74 | 31.58 | 14.98 | 10.05 | 8.76 | 55.92 |
| JDP2 | 506.24 | 518.56 | 519.79 | 98.40 | 478.03 | 475.21 | 31.62 | 19.31 | 10.10 | 10.33 | 56.22 |
| JDP3 | 503.56 | 514.98 | 516.12 | 98.71 | 479.76 | 477.38 | 31.21 | 14.45 | 9.62 | 6.83 | 61.39 |

**表6-49 大波动下游调压室最高最低涌浪水位计算结果**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 调压室号 | 调压室初始水位(m) | 最高涌浪(m) | 修正值(m) | 极值发生时间（s） | 最低涌浪(m) | 修正值(m) | 极值发生时间（s） | 底板向下最大压差(m) | 极值发生时间（s） | 底板向上最大压差(m) | 极值发生时间（s） |
| SJT1 | J30 | 61.34 | 67.70 | 68.34 | 93.24 | 45.36 | 43.76 | 38.37 | 8.25 | 12.62 | 3.58 | 44.59 |
| SJT2 | J30 | 80.68 | 85.87 | 86.39 | 94.29 | 63.37 | 61.64 | 22.62 | 9.56 | 13.05 | 5.94 | 47.53 |
| SJT3 | J30 | 62.88 | 69.24 | 69.88 | 93.21 | 46.93 | 45.34 | 38.39 | 8.25 | 12.62 | 3.58 | 44.67 |
| SJT4 | J30 | 73.18 | 78.37 | 78.89 | 94.29 | 55.87 | 54.14 | 22.62 | 9.56 | 13.05 | 5.94 | 47.53 |
| SJT5 | J30 | 72.54 | 77.73 | 78.25 | 38.27 | 70.21 | 69.98 | 92.21 | 0.23 | 62.35 | 0.42 | 20.19 |
| SJT6 | J30 | 80.08 | 85.27 | 85.79 | 94.27 | 62.77 | 61.04 | 22.62 | 9.56 | 13.05 | 5.94 | 47.53 |
| SJT7 | J30 | 79.44 | 84.63 | 85.15 | 38.27 | 77.11 | 76.88 | 92.21 | 0.23 | 62.35 | 0.42 | 20.19 |
| SJT8 | J30 | 73.58 | 78.77 | 79.29 | 94.29 | 56.27 | 54.54 | 22.62 | 9.56 | 13.05 | 5.94 | 47.53 |
| SJT9 | J30 | 72.94 | 78.13 | 78.65 | 38.27 | 70.61 | 70.38 | 92.21 | 0.23 | 62.35 | 0.42 | 20.19 |
| ZT1 | J30 | 60.82 | 68.15 | 68.88 | 164.99 | 43.20 | 41.44 | 96.41 | 8.32 | 86.84 | 5.10 | 118.89 |
| ZT2 | J30 | 80.04 | 86.23 | 86.85 | 168.22 | 60.74 | 58.81 | 99.19 | 9.46 | 89.80 | 7.57 | 124.25 |
| ZT3 | J30 | 60.82 | 68.40 | 69.16 | 154.76 | 43.62 | 41.90 | 100.34 | 9.18 | 74.98 | 4.61 | 107.15 |
| ZT4 | J30 | 72.54 | 79.08 | 79.73 | 155.81 | 53.93 | 52.07 | 85.59 | 10.55 | 75.36 | 7.09 | 110.18 |
| JHT1 | J30 | 62.88 | 68.64 | 69.22 | 93.12 | 47.98 | 46.49 | 22.52 | 7.60 | 12.62 | 4.17 | 45.68 |
| JHT2 | J30 | 62.88 | 69.24 | 69.88 | 93.22 | 46.93 | 45.34 | 38.38 | 8.25 | 12.62 | 3.58 | 44.59 |
| JHT3 | J30 | 80.68 | 85.65 | 86.15 | 94.84 | 63.54 | 61.83 | 23.23 | 9.11 | 13.28 | 5.87 | 48.42 |
| JHT4 | J30 | 80.68 | 85.16 | 85.61 | 94.10 | 63.94 | 62.27 | 22.87 | 8.78 | 13.28 | 5.45 | 48.77 |
| JHT5 | J30 | 73.18 | 77.60 | 78.04 | 94.20 | 56.46 | 54.79 | 22.86 | 8.78 | 13.28 | 5.53 | 48.42 |
| JHT6 | J30 | 73.18 | 78.15 | 78.65 | 94.84 | 56.04 | 54.33 | 23.23 | 9.11 | 13.28 | 5.87 | 48.42 |
| JHT7 | J30 | 80.08 | 84.51 | 84.95 | 94.20 | 63.36 | 61.69 | 22.85 | 8.78 | 13.28 | 5.55 | 48.42 |
| JHT8 | J30 | 80.08 | 85.05 | 85.55 | 94.84 | 62.94 | 61.23 | 23.23 | 9.11 | 13.28 | 5.87 | 48.42 |
| JHT9 | J30 | 73.58 | 78.01 | 78.45 | 94.21 | 56.88 | 55.21 | 22.82 | 8.77 | 13.28 | 5.50 | 48.42 |
| JHT10 | J30 | 73.58 | 78.55 | 79.05 | 94.84 | 56.44 | 54.73 | 23.24 | 9.11 | 13.28 | 5.87 | 48.42 |
| JHT11 | J30 | 61.34 | 67.13 | 67.71 | 93.04 | 46.45 | 44.96 | 22.50 | 7.61 | 12.62 | 4.23 | 45.68 |
| JHT12 | J30 | 61.34 | 67.70 | 68.34 | 93.27 | 45.35 | 43.75 | 38.36 | 8.25 | 12.62 | 3.59 | 44.59 |
| JHT13 | J30 | 61.34 | 68.09 | 68.77 | 97.70 | 45.00 | 43.37 | 41.52 | 4.84 | 15.13 | 2.83 | 69.77 |
| JHT14 | J30 | 61.34 | 66.76 | 67.30 | 96.20 | 48.22 | 46.91 | 37.17 | 3.12 | 14.15 | 1.78 | 67.06 |
| JHT15 | J30 | 60.74 | 67.13 | 67.77 | 95.52 | 47.31 | 45.97 | 37.20 | 3.36 | 12.52 | 2.01 | 66.21 |
| JHT16 | J30 | 61.34 | 67.04 | 67.61 | 96.93 | 47.49 | 46.10 | 39.90 | 3.88 | 18.13 | 2.04 | 67.85 |
| JHT17 | J30 | 62.88 | 69.07 | 69.69 | 93.66 | 47.16 | 45.59 | 38.88 | 7.92 | 12.62 | 3.80 | 45.07 |
| JHT18 | J30 | 61.34 | 67.53 | 68.15 | 93.70 | 45.59 | 44.02 | 38.85 | 7.92 | 12.62 | 3.80 | 45.07 |
| JDT1 | J30 | 62.88 | 68.96 | 69.57 | 87.80 | 47.98 | 46.49 | 22.51 | 7.60 | 12.62 | 4.56 | 45.84 |
| JDT2 | J30 | 73.18 | 78.45 | 78.98 | 89.59 | 56.46 | 54.79 | 22.86 | 8.78 | 13.28 | 6.07 | 48.77 |
| JDT3 | J30 | 80.08 | 85.31 | 85.83 | 89.39 | 63.37 | 61.70 | 22.82 | 8.78 | 13.28 | 6.11 | 48.77 |
| JDT4 | J30 | 73.58 | 78.80 | 79.32 | 89.39 | 56.87 | 55.20 | 22.81 | 8.77 | 13.28 | 6.08 | 48.96 |
| JDT5 | J30 | 61.34 | 67.45 | 68.06 | 88.10 | 46.45 | 44.96 | 22.49 | 7.61 | 12.62 | 4.57 | 45.84 |
| JDT6 | J30 | 61.34 | 68.07 | 68.74 | 96.54 | 44.43 | 42.74 | 38.27 | 5.68 | 12.62 | 2.76 | 66.65 |
| JDT7 | J30 | 62.88 | 68.03 | 68.55 | 92.65 | 47.45 | 45.91 | 22.14 | 8.10 | 12.37 | 4.67 | 45.99 |
| JDT10 | J30 | 61.34 | 67.90 | 68.56 | 96.99 | 45.00 | 43.37 | 41.07 | 7.32 | 15.89 | 3.31 | 47.89 |
| SJP1 | J30 | 59.26 | 75.22 | 76.82 | 21.70 | 49.50 | 48.52 | 76.71 | 2.52 | 45.56 | 16.58 | 8.83 |
| SJP2 | J30 | 78.96 | 90.72 | 91.90 | 27.83 | 69.26 | 68.29 | 89.22 | 2.67 | 58.98 | 18.81 | 9.02 |
| SJP3 | J30 | 83.21 | 92.15 | 93.04 | 33.94 | 74.51 | 73.64 | 104.28 | 2.69 | 74.04 | 21.99 | 9.26 |
| SJP4 | J30 | 69.57 | 86.79 | 88.51 | 23.56 | 59.58 | 58.58 | 78.60 | 2.82 | 47.40 | 18.15 | 8.83 |
| ZP2 | J30 | 79.40 | 91.29 | 92.48 | 98.12 | 68.60 | 67.52 | 161.26 | 3.98 | 130.72 | 23.24 | 79.30 |
| ZP3 | J30 | 83.66 | 92.76 | 93.67 | 104.14 | 73.96 | 72.99 | 176.34 | 3.08 | 146.28 | 23.65 | 79.74 |
| ZP4 | J30 | 79.40 | 91.07 | 92.24 | 86.93 | 68.85 | 67.80 | 149.31 | 2.93 | 118.92 | 21.70 | 66.92 |
| JHP1 | J30 | 78.96 | 91.46 | 92.71 | 30.02 | 68.35 | 67.29 | 90.94 | 3.35 | 59.07 | 19.31 | 9.33 |
| JHP2 | J30 | 78.96 | 90.72 | 91.90 | 27.83 | 69.26 | 68.29 | 89.22 | 2.67 | 58.98 | 18.81 | 9.02 |
| JHP3 | J30 | 69.57 | 88.78 | 90.70 | 26.43 | 57.96 | 56.80 | 79.46 | 3.73 | 52.45 | 18.82 | 9.10 |
| JHP4 | J30 | 69.57 | 86.79 | 88.51 | 23.57 | 59.58 | 58.58 | 78.60 | 2.82 | 47.40 | 18.15 | 8.83 |
| JHP5 | J30 | 59.26 | 77.59 | 79.42 | 24.93 | 47.84 | 46.70 | 77.50 | 3.32 | 51.31 | 17.42 | 9.10 |
| JDP1 | J30 | 78.96 | 91.46 | 92.71 | 30.00 | 68.63 | 67.60 | 93.10 | 3.58 | 57.63 | 19.31 | 9.33 |
| JDP2 | J30 | 81.53 | 92.30 | 93.38 | 32.08 | 71.81 | 70.84 | 97.56 | 2.99 | 72.33 | 19.33 | 9.34 |
| JDP3 | J30 | 69.57 | 86.79 | 88.51 | 23.56 | 59.58 | 58.58 | 78.60 | 2.82 | 47.40 | 18.15 | 8.83 |

#### 6.9.2.8 极值统计

**表6-50 水轮机设计工况极值统计表**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 控制参数 | 工况 | 机组 | 计算  极值 | 极值发生时间(s) | 修正结果 | 控制值 | 是否满足要求 |
| 球阀进口最大动水压力(m) | SJT3 | 4# | 647.45 | 9.54 | 691.57 | ≤ 720 | 是 |
| 蜗壳进口最大动水压力(m) | SJT3 | 4# | 654.92 | 9.40 | 701.32 | ≤ 720 | 是 |
| 尾水管进口最小动水压力 (m) | ZT1 | 4# | 37.36 | 85.24 | 18.27 | ≥ 1.66 | 是 |
| 水轮机方向机组最大转速升高率(%) | ZT2 | 4# | 42.64 | 84.55 | 44.77 | ≤ 45.0 | 是 |

注：表中尾水管进口最小动水压力为相对压力值

**表6-51 水轮机校核工况极值统计表**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 控制参数 | 工况 | 机组 | 计算  极值 | 极值发生时间(s) | 修正结果 | 控制值 | 是否满足要求 |
| 球阀进口最大动水压力(m) | JHT2 | 4# | 650.17 | 9.55 | 694.54 | ≤ 720 | 是 |
| 蜗壳进口最大动水压力(m) | JHT3 | 4# | 655.69 | 10.05 | 701.91 | ≤ 720 | 是 |
| 尾水管进口最小动水压力 (m) | JHT15 | 3# | 13.64 | 14 | -6.10 | ≥ 1.66 | 否 |
| 水轮机方向机组最大转速升高率(%) | JHT3 | 4# | 46.30 | 8.04 | 48.62 | ≤ 45.0 | 否 |
| JHT6 | 4# | 46.30 | 8.04 | 48.62 | ≤ 45.0 | 否 |
| JHT8 | 4# | 46.30 | 8.04 | 48.62 | ≤ 45.0 | 否 |
| JHT10 | 4# | 46.30 | 8.04 | 48.62 | ≤ 45.0 | 否 |

注：表中尾水管进口最小动水压力为相对压力值

**表6-52 水轮机极端工况极值统计表**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 控制参数 | 工况 | 机组 | 计算  极值 | 极值发生时间(s) | 修正结果 | 控制值 | 是否满足要求 |
| 球阀进口最大动水压力(m) | JDT7 | 4# | 646.76 | 9.55 | 690.78 | ≤ 720 | 是 |
| 蜗壳进口最大动水压力(m) | JDT7 | 4# | 653.69 | 9.56 | 699.97 | ≤ 720 | 是 |
| 尾水管进口最小动水压力 (m) | JDT6 | 4# | 1.32 | 14.98 | -19.56 | ≥ 1.66 | 否 |
| 水轮机方向机组最大转速升高率(%) | JDT2 | 4# | 46.23 | 8.04 | 48.54 | ≤ 45.0 | 否 |

注：表中尾水管进口最小动水压力为相对压力值

**表6-53 水泵设计工况极值统计表**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 控制参数 | 工况 | 机组 | 计算极值 | 极值发生时间(s) | 修正结果 | 控制值 | 是否满足要求 |
| 球阀进口最大动水压力(m) | SJP1 | 3# | 603.17 | 19.44 | 619.24 | ≤ 720 | 是 |
| 蜗壳进口最大动水压力(m) | SJP1 | 3# | 615.85 | 19.42 | 634.07 | ≤ 720 | 是 |
| 尾水管进口最小动水压力 (m) | SJP1 | 4# | 51.65 | 0.01 | 34.98 | ≥ 1.66 | 是 |

注：表中尾水管进口最小动水压力为相对压力值

**表6-54 水泵校核工况极值统计表**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 控制参数 | 工况 | 机组 | 计算极值 | 极值发生时间(s) | 修正结果 | 控制值 | 是否满足要求 |
| 球阀进口最大动水压力(m) | JHP4 | 3# | 576.39 | 19.11 | 591.43 | ≤ 720 | 是 |
| 蜗壳进口最大动水压力(m) | JHP4 | 2# | 588.62 | 19.16 | 606.08 | ≤ 720 | 是 |
| 尾水管进口最小动水压力 (m) | JHP3 | 3# | 44.85 | 87.42 | 27.91 | ≥ 1.66 | 是 |

注：表中尾水管进口最小动水压力为相对压力值

**表6-55 水泵极端工况极值统计表**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 控制参数 | 工况 | 机组 | 计算极值 | 极值发生时间(s) | 修正结果 | 控制值 | 是否满足要求 |
| 球阀进口最大动水压力(m) | JDP3 | 3# | 576.39 | 19.11 | 591.43 | ≤ 720 | 是 |
| 蜗壳进口最大动水压力(m) | JDP3 | 2# | 588.61 | 19.16 | 606.07 | ≤ 720 | 是 |
| 尾水管进口最小动水压力 (m) | JDP3 | 4# | 57.77 | 0.01 | 42.21 | ≥ 1.66 | 是 |

注：表中尾水管进口最小动水压力为相对压力值

**表6-56 上游调压室极值统计表**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 控制参数 | 工况 | 调压室号 | 计算极值 | 极值发生时间(s) | 修正结果 |
| 调压室最高涌浪(m) | ZT1 | J29 | 538.36 | 132.23 | 539.63 |
| 调压室最低涌浪(m) | JDP1 | J29 | 475.55 | 31.58 | 472.74 |
| 底板向下最大压差(m) | ZP2 | J29 | 22.22 | 80.74 | \ |
| 底板向上最大压差(m) | ZT4 | J29 | 21.37 | 75.71 | \ |

**表6-57 下游调压室极值统计表**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 控制参数 | 工况 | 调压室号 | 计算极值 | 极值发生时间(s) | 修正结果 |
| 调压室最高涌浪(m) | ZP3 | J30 | 92.76 | 104.14 | 93.67 |
| 调压室最低涌浪(m) | ZT1 | J30 | 43.20 | 96.41 | 41.44 |
| 底板向下最大压差(m) | ZT4 | J30 | 10.55 | 75.36 | \ |
| 底板向上最大压差(m) | ZP3 | J30 | 23.65 | 79.74 | \ |

### 6.9.3 大波动过渡过程计算结果分析

**（1）大波动水轮机设计工况计算结果及分析：**

1）对于水轮机设计工况，修正前后的球阀进口最大动水压力、蜗壳进口最大动水压力、尾水管进口最小动水压力及机组转速最大上升率均满足控制要求。

2）球阀进口最大动水压力发生在工况SJT3。工况SJT3球阀进口最大动水压力为647.45m ，修正后球阀进口最大动水压力值为691.57m，满足小于720.00m的限制值要求。

3）蜗壳进口最大动水压力发生在工况SJT3。工况SJT3蜗壳进口最大动水压力为654.92m，修正后蜗壳进口最大动水压力值为701.32m，满足小于720.00m的限制值要求。

4）尾水管进口最小动水压力发生在工况ZT1。ZT1的尾水管的压力值为37.36m，修正后尾水管进口最小动水压力值为18.27m，满足大于1.66m（相对压力）控制要求。

5）机组最大转速上升的控制工况是ZT2。机组转速上升率为42.64%，修正后机组最大转速上升率为44.77%，能满足控制在45%的要求。

**（2）大波动水轮机校核工况计算结果及分析：**

1）对于水轮机校核工况，修正前后的球阀进口最大动水压力、蜗壳进口最大动水压力满足控制要求，有个别工况尾水管进口最小动水压力及机组转速最大上升率不能满足控制要求，但是所有校核工况尾水管进口最小动水压力均大于-8m，并且所有校核工况的机组转速最大上升率修正值均小于50%。

2）球阀进口最大动水压力发生在工况JHT2。工况JHT3球阀进口最大动水压力为650.17m，修正后球阀进口最大动水压力值为694.54m，满足小于720.00m的限制值要求。

3）蜗壳进口最大动水压力发生在工况JHT3。工况JHT3蜗壳进口最大动水压力为655.69m，修正后蜗壳进口最大动水压力值为701.91m，满足小于720.00m的限制值要求。

4） 尾水管进口最小动水压力不满足大于1.66m的控制要求的工况有JHT13、JHT14、JHT15、JHT16,其中工况JHT15尾水管进口最小动水压力为所有控制工况中最小。JHT15的尾水管的压力值为13.64m，修正后尾水管进口最小动水压力值为-6.10m，不满足大于1.66m（相对压力）控制要求。

5） 机组最大转速上升超过45%的工况包含一台机组导叶拒动工况（JHT1、JHT4、JHT5、JHT7、JHT9、JHT11）和第四台延时关闭的工况（JHT3、JHT6、JHT8、JHT10、JHT17、JHT18），其中JHT3、JHT6、JHT8、JHT10工况的最大转速上升率为所有工况中最大，机组最大转速上升率都为46.30%，修正后机组最大转速上升率为48.62%，不能满足控制在45%的要求。

**（3）大波动水轮机极端工况计算结果及分析：**

1）对于水轮机极端工况，修正前后的球阀进口最大动水压力、蜗壳进口最大动水压力满足控制要求，个别工况尾水管进口最小动水压力及机组转速最大上升率不能满足控制要求，但是除工况JDT6外，所有极端工况的尾水管最小动水压力（相对压力）均大于-8m，所有工况最大转速上升率均小于45%，而且工况JDT6是极端工况，发生的概率较小。

2）球阀进口最大动水压力发生在工况JDT7。工况JDT7球阀进口最大动水压力为646.76m ，修正后球阀进口最大动水压力值为690.78m，满足小于720.00m的限制值要求。

3）蜗壳进口最大动水压力发生在工况JDT7。工况JDT7蜗壳进口最大动水压力为653.69m，修正后蜗壳进口最大动水压力值为699.97m，满足小于720.00m的限制值要求。

4） 尾水管进口最小动水压力不满足大于1.66m的控制要求的工况有JDT6、JDT10，这两个工况尾水管压力均出现了一定的负压，其中尾水管进口最小动水压力控制工况为JDT6。JDT6的尾水管的压力值为1.32m，修正后尾水管进口最小动水压力值为-19.56m，不满足大于1.66m（相对压力）控制要求，JDT10的尾水管的压力值为17.23m，修正后尾水管进口最小动水压力值为-3.95m，不满足大于1.66m（相对压力）控制要求。

5）机组最大转速上升超过45%的工况包含一台机组导叶、球阀均拒动工况（JDT1、JDT2、JDT3、JDT4、JDT5）。其中机组最大转速上升的控制工况是JDT2。机组转速上升率为46.23%，修正后机组最大转速上升率为48.54%，不能满足控制在45%的要求。

**（4）大波动水泵设计工况计算结果及分析：**

1）球阀进口最大动水压力发生在工况SJP1。工况SJP1球阀进口最大动水压力为603.17m ，修正后球阀进口最大动水压力值为619.24m，满足小于720.00m的限制值要求。

2）蜗壳进口最大动水压力发生在工况SJP1。工况SJP1蜗壳进口最大动水压力为615.85m，修正后蜗壳进口最大动水压力值为699.97m，满足小于720.00m的限制值要求。

3）尾水管进口最小动水压力发生在工况SJP1。SJP1的尾水管的压力值为51.65m，修正后尾水管进口最小动水压力值为34.98m，满足大于1.66m（相对压力）控制要求。

（5）大波动水泵校核工况计算结果及分析：

1）球阀进口最大动水压力发生在工况JHP4。工况JHP4球阀进口最大动水压力为576.39m，修正后球阀进口最大动水压力值为591.43m，满足小于720.00m的限制值要求。

2）蜗壳进口最大动水压力发生在工况JHP4。工况JHP4蜗壳进口最大动水压力为588.62m，修正后蜗壳进口最大动水压力值为606.08 m，满足小于720.00m的限制值要求。

3）尾水管进口最小动水压力发生在工况JHP3。JHP3的尾水管的压力值为44.85m，修正后尾水管进口最小动水压力值为27.91m，满足大于1.66m（相对压力）控制要求。

**（6）大波动水泵极端工况计算结果及分析：**

1）球阀进口最大动水压力发生在工况JDP3。工况JDP3球阀进口最大动水压力为576.39m，修正后球阀进口最大动水压力值为591.43m，满足小于720.00m的限制值要求。

2）蜗壳进口最大动水压力发生在工况JDP3。工况JDP3蜗壳进口最大动水压力为588.61m，修正后蜗壳进口最大动水压力值为606.07m，满足小于720.00m的限制值要求。

3）尾水管进口最小动水压力发生在工况JDP3。JDP3的尾水管的压力值为57.77m，修正后尾水管进口最小动水压力值为42.21m，满足大于1.66m（相对压力）控制要求。

（7）上游调压室最高涌浪的控制工况为ZT1。该工况下调压室最高涌浪水位计算值为538.36m，修正后为539.63m，挡水墙高度（541.20m）低1.57m；调压室最低涌浪的控制工况为JDP1。此时调压室最低涌浪水位计算值为475.55m，修正后472.74m，比调压室底板高程（465.00m）高12.74m。调压室向下最大压差的控制工况为ZP2，为22.22m；向上最大压差的控制工况为ZT4，为21.37m。

（8）下游调压室最高涌浪的控制工况为ZP3。此时该工况下调压室最高涌浪水位计算值为92.76m，修正后93.67m，比挡水墙高度（96.5m）低2.83m；调压室最低涌浪的控制工况为ZT1。此时调压室最低涌浪水位为43.20m，分别比调压室底板高程（35.0m）高8.2m。调压室向下最大压差的控制工况为ZT4，为10.55m；向上最大压差的控制工况为ZP3，分别为23.65m，均满足要求。

各调保参数及调压室涌浪水位极值发生工况的参数变化过程图如下：

|  |  |
| --- | --- |
| 图6.127 SJT3 球阀进口动水压力波动图 | 图6.128 SJT3 蜗壳进口动水压力波动图 |
| 图6.129 ZT1 尾水管进口动水压力波动图 | 图6.130 ZT2 机组转速波动图 |

|  |  |
| --- | --- |
| 图6.131 JHT2 球阀进口动水压力波动图 | 图6.132 JHT3 蜗壳进口动水压力波动图 |
| 图6.133 JHT15 尾水管进口动水压力波动图 | 图6.134 JHT3 机组转速波动图 |
| 图6.135 JHT6 机组转速波动图 | 图6.136 JHT8 机组转速波动图 |
| 图6.137 JHT10 机组转速波动图 |  |

|  |  |
| --- | --- |
| 图6.138 JDT7球阀进口动水压力波动图 | 图6.139 JDT7蜗壳进口动水压力波动图 |
| 图6.140 JDT6 尾水管进口动水压力波动图 | 图6.141 JDT2 机组转速波动图 |

|  |  |
| --- | --- |
| 图6.142 SJP1球阀进口动水压力波动图 | 图6.143 SJP1蜗壳进口动水压力波动图 |
| 图6.144 SJP1 尾水管进口动水压力波动图 |  |

|  |  |
| --- | --- |
| 图6.145 JHP4球阀进口动水压力波动图 | 图6.146 JHP4蜗壳进口动水压力波动图 |
| 图6.147 JHP3 尾水管进口动水压力波动图 |  |

|  |  |
| --- | --- |
| 图6.148 JDP3球阀进口动水压力波动图 | 图6.149 JDP3蜗壳进口动水压力波动图 |
| 图6.150 JDP3 尾水管进口动水压力波动图 |  |

|  |  |
| --- | --- |
| 图6.151 ZT1上游调压室水位波动图 | 图6.152 JDP1上游调压室水位波动图 |
| 图6.153 ZP3下游调压室水位波动图 | 图6.154 ZT1下游调压室水位波动图 |

（9）以4#机组为例，上、下游侧沿程测压管水头最大、最小压力包络线见图6.155～6.156。其中，4#机组上游侧第一个上弯头起点处（距进水口的距离为1680.25m）的最小压力值为470.71m，相应管道顶部压力值为67.96m（470.71m- 398.00m- 9.5/2m），满足2m正压的要求；上游段最小压力发生在进水口附近67.17米处，相应管道顶部压力值为7.81m（501.56m- 489.00m- 9.5/2m），满足要求；下游侧最小压力值发生在出水口处，为59.16m，相应管道顶部压力值为6.41m（59.16m- 48.00m- 9.5/2m），满足2m正压的要求。可知，沿线最大、最小压力均满足控制要求。

**表6-58 4#机组上游侧沿线压力**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 与进水口的距离(m) | 桩号 | 管道中心线高程(m) | 最大压力包络线(m) | 最小压力包络线(m) | 管道顶部最大压力(m) | 管道顶部最小压力值(m) | |
| 67.170 | Y0+000.000 | 489 | 528.75 | 501.56 | 35.00 | 7.81 |  |
| 192.265 | Y0+125.095 | 481.508 | 531.10 | 499.05 | 44.85 | 12.79 |
| 1617.97 | Y1+550.800 | 398 | 557.26 | 474.59 | 154.51 | 71.84 | |
| 1680.250 | Y1+613.080 | 398 | 558.09 | 470.71 | 155.34 | 67.96 | |
| 2060.526 | Y1+993.356 | 130 | 580.82 | 448.32 | 446.07 | 313.57 |  |
| 3014.907 | Y2+947.737 | 100 | 616.95 | 362.49 | 512.20 | 257.74 |
| 3125.015 | Y3+192.185 | -1.965 | 622.37 | 354.44 | 620.08 | 352.15 | |
| 3326.617 | Y3+259.447 | -4.215 | 633.82 | 338.47 | 635.13 | 339.78 | |
| 3468.16 | 4Y0+141.543 | -5 | 644.54 | 302.33 | 648.39 | 306.18 | |

**表6-59 4#机组下游侧沿线压力**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 与进水口的距离(m) | 桩号 | 管道中心线高程(m) | 最大压力包络线(m) | 最小压力包络线(m) | 管道顶部最大压力(m) | 管道顶部最小压力值(m) |
| 3531.51 | 4W0+135.087 | -13.750 | 123.26 | 8.29 | 134.76 | 19.79 |
| 3699.349 | W1+009.852 | -11.250 | 111.25 | 38.65 | 117.75 | 45.15 |
| 3738.187 | W0+971.014 | -11.250 | 110.10 | 39.37 | 116.60 | 45.87 |
| 4709.201 | W0+000.000 | 48.000 | 83.52 | 59.16 | 30.77 | 6.41 |

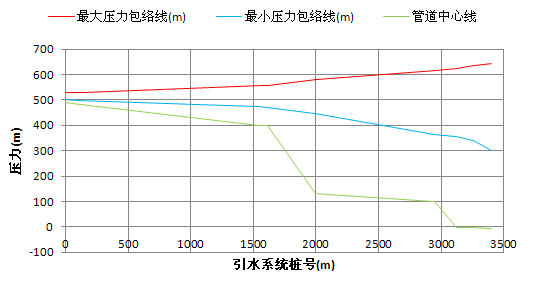


图6.155 4#机上游侧引水系统沿线压力包络线

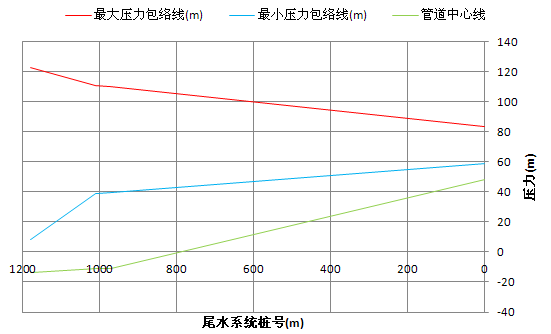


图6.156 4#机下游侧尾水系统沿线压力包络线

7. 小波动过渡过程计算与分析

为了保证水电站机组的稳定安全运行和供电品质，本报告对深圳抽水蓄能电站的水力－机械调节系统进行小波动过渡过程计算与分析，以判断小波动过程的稳定性和调节品质，并整定出合理的调速器参数。

## 7.1 小波动过渡过程计算工况的拟定

**表7-1 小波动计算工况列表**

| 工况  编号 | 上库水位(m) | 下库水位(m) | 工况说明 |
| --- | --- | --- | --- |
| X1 | 526.81 | 60.00 | 最大静水头466.81m，四台发电机组在满负荷运行时，突然丢弃10%负荷； |
| X2 | 526.81 | 60.00 | 最大静水头466.81m，一台发电机组在满负荷运行时，突然丢弃10%负荷； |
| X3 | - | 71.90 | 额定水头419.00m，四台发电机组在满负荷运行时，突然丢弃10%负荷； |
| X4 | - | 71.90 | 额定水头419.00m，三台发电机组（2#、3#、4#）在满负荷运行时，突然丢弃10%负荷； |
| X5 | - | 71.90 | 额定水头419.00m，两台发电机组（3#、4#）在满负荷运行时，突然丢弃10%负荷； |
| X6 | - | 71.90 | 额定水头419.00m，一台发电机组（4#）在满负荷运行时，突然丢弃10%负荷； |

**表7-2 小波动工况参数表**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 上游水位（m) | 下游水位(m) | 机组号 | 开度（%） | 净水头(m) | 流量(m3/s) | 出力(MW) | 工况说明 |
| X1 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 | 最大静水头466.81m，四台发电机组在满负荷运行时，突然丢弃10%负荷； |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| X2 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 | 最大静水头466.81m，一台发电机组在满负荷运行时，突然丢弃10%负荷； |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| X3 | 502.40 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 | 额定水头419.00m,四台发电机组在满负荷运行时，突然丢弃10%负荷； |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| X4 | 502.40 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 | 额定水头419.00m,三台发电机组（2#、3#、4#)在满负荷运行时，突然丢弃10%负荷； |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| X5 | 502.40 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 | 额定水头419.00m,两台发电机组（3#、4#)在满负荷运行时，突然丢弃10%负荷； |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| X6 | 502.40 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 | 额定水头419.00m,一台发电机组(4#)在满负荷运行时，突然丢弃10%负荷； |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |

## 7.2 小波动过渡过程计算结果及分析

调速器参数首先按照斯坦因建议公式取值，即，，其中为水流加速时间常数，为机组加速时间常数。按照斯坦因推荐值，，，，,对工况X3进行计算，并对调速器参数进行整定，结果如表7-3所示。分析表7-3中数据可得到最佳的调速器参数如表7-4所示。

**表7-3 调速器参数整定**

| 工况 | 机组号 | Nmax或Nmin（r/min） | 极值发生时间（s） | N1  (r/min) | 极值发生时间（s） | N2  (r/min) | 极值发生时间（s） | ±0.4％调节时间（s） | 最大偏差（r/min） | 振荡次数 | 衰减度 | 超调量σ |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tn=1.2s,bt=0.34,Td=7.2s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.10 | 5.68 | 427.65 | 70.22 | 430.87 | 132.30 | 149.02 | 21.50 | 1.50 | 0.89 | 0.04 |
| 2# | 450.41 | 5.66 | 427.67 | 70.44 | 430.85 | 133.02 | 148.94 | 21.81 | 1.50 | 0.90 | 0.04 |
| 3# | 450.34 | 5.68 | 427.69 | 70.40 | 430.85 | 132.54 | 148.90 | 21.74 | 1.50 | 0.90 | 0.04 |
| 4# | 450.21 | 5.68 | 427.68 | 70.24 | 430.88 | 131.24 | 149.14 | 21.61 | 1.50 | 0.89 | 0.04 |
| Tn=0.8s,bt=0.3,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 451.41 | 5.54 | 421.78 | 13.28 | 435.56 | 20.36 | 36.24 | 22.81 | 2.50 | 0.69 | 0.30 |
| 2# | 451.65 | 5.52 | 421.77 | 13.28 | 435.56 | 20.34 | 36.20 | 23.05 | 2.50 | 0.70 | 0.30 |
| 3# | 451.66 | 5.54 | 421.61 | 13.28 | 435.65 | 20.34 | 36.24 | 23.06 | 2.50 | 0.69 | 0.30 |
| 4# | 451.57 | 5.54 | 421.46 | 13.28 | 435.71 | 20.36 | 36.28 | 22.97 | 2.50 | 0.69 | 0.31 |
| Tn=0.8s,bt=0.3,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 451.03 | 5.54 | 426.16 | 13.16 | 434.04 | 19.50 | 33.82 | 22.43 | 2.50 | 0.76 | 0.11 |
| 2# | 451.27 | 5.52 | 426.19 | 13.14 | 434.04 | 19.46 | 33.82 | 22.67 | 2.50 | 0.76 | 0.11 |
| 3# | 451.27 | 5.50 | 426.05 | 13.16 | 434.08 | 19.50 | 33.84 | 22.67 | 2.50 | 0.76 | 0.11 |
| 4# | 451.18 | 5.50 | 425.90 | 13.16 | 434.10 | 19.54 | 33.92 | 22.58 | 2.50 | 0.76 | 0.12 |
| Tn=0.8s,bt=0.3,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.78 | 5.54 | 427.64 | 67.10 | 430.40 | 130.78 | 137.58 | 22.18 | 1.50 | 0.92 | 0.04 |
| 2# | 451.03 | 5.52 | 427.65 | 67.34 | 430.41 | 131.38 | 137.58 | 22.43 | 1.50 | 0.92 | 0.04 |
| 3# | 451.01 | 5.50 | 427.64 | 67.06 | 430.40 | 131.00 | 137.74 | 22.41 | 1.50 | 0.92 | 0.04 |
| 4# | 450.91 | 5.50 | 427.64 | 67.14 | 430.41 | 130.56 | 137.30 | 22.31 | 1.50 | 0.92 | 0.04 |
| Tn=0.9s,bt=0.3,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 451.30 | 5.50 | 423.33 | 13.20 | 434.00 | 20.06 | 34.36 | 22.70 | 2.50 | 0.76 | 0.23 |
| 2# | 451.57 | 5.50 | 423.34 | 13.18 | 434.00 | 20.04 | 34.42 | 22.97 | 2.50 | 0.76 | 0.23 |
| 3# | 451.54 | 5.48 | 423.18 | 13.18 | 434.06 | 20.06 | 34.50 | 22.94 | 2.50 | 0.76 | 0.24 |
| 4# | 451.47 | 5.48 | 423.04 | 13.18 | 434.11 | 20.10 | 34.48 | 22.87 | 2.50 | 0.76 | 0.24 |
| Tn=0.9s,bt=0.3,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.93 | 5.48 | 427.52 | 13.02 | 433.17 | 19.02 | 22.86 | 22.33 | 1.50 | 0.80 | 0.05 |
| 2# | 451.19 | 5.48 | 427.54 | 13.04 | 433.20 | 18.98 | 22.86 | 22.59 | 1.50 | 0.80 | 0.05 |
| 3# | 451.18 | 5.48 | 427.40 | 13.02 | 433.21 | 19.02 | 22.86 | 22.58 | 1.50 | 0.80 | 0.05 |
| 4# | 451.07 | 5.48 | 427.29 | 13.00 | 433.21 | 19.02 | 22.86 | 22.47 | 1.50 | 0.80 | 0.06 |
| Tn=0.9s,bt=0.3,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.68 | 5.48 | 427.69 | 69.22 | 430.48 | 130.66 | 139.96 | 22.08 | 1.50 | 0.91 | 0.04 |
| 2# | 450.95 | 5.48 | 427.70 | 68.72 | 430.47 | 131.20 | 139.76 | 22.35 | 1.50 | 0.92 | 0.04 |
| 3# | 450.92 | 5.48 | 427.69 | 68.60 | 430.46 | 130.48 | 139.76 | 22.32 | 1.50 | 0.92 | 0.04 |
| 4# | 450.81 | 5.48 | 427.69 | 68.46 | 430.48 | 130.34 | 140.22 | 22.21 | 1.50 | 0.92 | 0.04 |
| Tn=1.0s,bt=0.3,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 451.21 | 5.46 | 424.82 | 13.08 | 432.67 | 19.76 | 23.04 | 22.61 | 1.50 | 0.82 | 0.17 |
| 2# | 451.49 | 5.46 | 424.84 | 13.10 | 432.67 | 19.70 | 23.02 | 22.89 | 1.50 | 0.82 | 0.16 |
| 3# | 451.45 | 5.46 | 424.68 | 13.04 | 432.71 | 19.72 | 23.04 | 22.85 | 1.50 | 0.82 | 0.17 |
| 4# | 451.36 | 5.46 | 424.58 | 13.04 | 432.73 | 19.76 | 23.06 | 22.76 | 1.50 | 0.82 | 0.18 |
| Tn=1.0s,bt=0.3,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.85 | 5.46 | 427.81 | 67.20 | 430.30 | 129.46 | 22.40 | 22.25 | 0.50 | 0.92 | 0.04 |
| 2# | 451.13 | 5.44 | 427.83 | 67.64 | 430.30 | 129.72 | 22.40 | 22.53 | 0.50 | 0.92 | 0.03 |
| 3# | 451.07 | 5.44 | 427.81 | 67.06 | 430.31 | 129.64 | 22.38 | 22.47 | 0.50 | 0.92 | 0.03 |
| 4# | 450.98 | 5.46 | 427.81 | 67.04 | 430.32 | 129.16 | 130.20 | 22.38 | 1.50 | 0.92 | 0.04 |
| Tn=1.0s,bt=0.3,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.60 | 5.46 | 427.75 | 68.70 | 430.52 | 130.02 | 141.48 | 22.00 | 1.50 | 0.91 | 0.04 |
| 2# | 450.88 | 5.44 | 427.76 | 69.30 | 430.53 | 130.32 | 141.06 | 22.28 | 1.50 | 0.91 | 0.04 |
| 3# | 450.83 | 5.44 | 427.75 | 68.84 | 430.52 | 130.22 | 141.26 | 22.23 | 1.50 | 0.91 | 0.04 |
| 4# | 450.72 | 5.46 | 427.75 | 68.50 | 430.52 | 129.62 | 141.46 | 22.12 | 1.50 | 0.91 | 0.04 |
| Tn=1.1s,bt=0.3,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 451.11 | 5.44 | 426.25 | 13.00 | 431.54 | 19.44 | 22.38 | 22.51 | 1.50 | 0.87 | 0.10 |
| 2# | 451.41 | 5.42 | 426.27 | 13.02 | 431.54 | 19.42 | 22.34 | 22.81 | 1.50 | 0.87 | 0.10 |
| 3# | 451.34 | 5.40 | 426.13 | 13.00 | 431.57 | 19.48 | 22.40 | 22.74 | 1.50 | 0.87 | 0.11 |
| 4# | 451.26 | 5.40 | 426.02 | 12.98 | 431.57 | 19.48 | 22.40 | 22.66 | 1.50 | 0.87 | 0.11 |
| Tn=1.1s,bt=0.3,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.75 | 5.44 | 427.86 | 67.12 | 430.35 | 128.68 | 133.36 | 22.15 | 1.50 | 0.92 | 0.03 |
| 2# | 451.06 | 5.42 | 427.88 | 67.32 | 430.35 | 129.96 | 133.84 | 22.46 | 1.50 | 0.92 | 0.03 |
| 3# | 450.98 | 5.40 | 427.87 | 67.62 | 430.35 | 129.20 | 133.94 | 22.38 | 1.50 | 0.92 | 0.03 |
| 4# | 450.89 | 5.40 | 427.88 | 66.94 | 430.36 | 128.90 | 133.68 | 22.29 | 1.50 | 0.92 | 0.03 |
| Tn=1.1s,bt=0.3,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.50 | 5.44 | 427.80 | 68.72 | 430.60 | 128.76 | 142.90 | 21.90 | 1.50 | 0.91 | 0.04 |
| 2# | 450.81 | 5.44 | 427.81 | 69.22 | 430.57 | 130.62 | 142.42 | 22.21 | 1.50 | 0.91 | 0.04 |
| 3# | 450.74 | 5.42 | 427.82 | 68.84 | 430.57 | 130.22 | 142.44 | 22.14 | 1.50 | 0.91 | 0.04 |
| 4# | 450.63 | 5.40 | 427.81 | 68.50 | 430.57 | 130.34 | 142.68 | 22.03 | 1.50 | 0.91 | 0.04 |
| Tn=0.8s,bt=0.4,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.76 | 6.14 | 426.46 | 16.56 | 431.15 | 25.00 | 121.26 | 22.16 | 7.00 | 0.88 | 0.10 |
| 2# | 451.05 | 6.08 | 426.45 | 16.54 | 431.16 | 24.98 | 28.46 | 22.45 | 1.50 | 0.89 | 0.10 |
| 3# | 451.02 | 6.08 | 426.35 | 16.56 | 431.18 | 24.98 | 119.60 | 22.42 | 7.00 | 0.89 | 0.10 |
| 4# | 450.88 | 6.10 | 426.26 | 16.56 | 431.18 | 25.00 | 121.76 | 22.28 | 7.00 | 0.88 | 0.10 |
| Tn=0.8s,bt=0.4,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.45 | 6.22 | 427.29 | 69.98 | 430.57 | 121.94 | 141.92 | 21.85 | 1.50 | 0.91 | 0.06 |
| 2# | 450.76 | 6.18 | 427.29 | 69.98 | 430.54 | 133.36 | 141.76 | 22.16 | 1.50 | 0.91 | 0.06 |
| 3# | 450.72 | 6.18 | 427.29 | 69.90 | 430.55 | 122.00 | 141.72 | 22.12 | 1.50 | 0.91 | 0.06 |
| 4# | 450.56 | 6.22 | 427.28 | 69.80 | 430.59 | 121.86 | 142.02 | 21.96 | 1.50 | 0.91 | 0.06 |
| Tn=0.8s,bt=0.4,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.21 | 6.22 | 427.17 | 72.16 | 430.82 | 133.82 | 148.30 | 21.61 | 1.50 | 0.90 | 0.07 |
| 2# | 450.53 | 6.20 | 427.18 | 72.32 | 430.81 | 134.00 | 147.86 | 21.93 | 1.50 | 0.90 | 0.06 |
| 3# | 450.49 | 6.24 | 427.18 | 71.80 | 430.81 | 133.84 | 148.08 | 21.89 | 1.50 | 0.90 | 0.07 |
| 4# | 450.32 | 6.22 | 427.16 | 71.82 | 430.83 | 133.06 | 148.18 | 21.72 | 1.50 | 0.90 | 0.07 |
| Tn=0.9s,bt=0.4,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.69 | 6.08 | 427.12 | 16.80 | 430.74 | 25.22 | 123.32 | 22.09 | 7.00 | 0.90 | 0.07 |
| 2# | 450.98 | 6.08 | 427.11 | 16.80 | 430.74 | 25.20 | 121.68 | 22.38 | 7.00 | 0.90 | 0.07 |
| 3# | 450.95 | 6.08 | 427.02 | 16.76 | 430.75 | 25.26 | 122.22 | 22.35 | 7.00 | 0.90 | 0.07 |
| 4# | 450.81 | 6.06 | 426.95 | 16.74 | 430.76 | 25.44 | 124.42 | 22.21 | 7.00 | 0.90 | 0.07 |
| Tn=0.9s,bt=0.4,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.36 | 6.16 | 427.35 | 70.10 | 430.64 | 122.50 | 143.16 | 21.76 | 1.50 | 0.91 | 0.06 |
| 2# | 450.68 | 6.10 | 427.35 | 69.96 | 430.60 | 132.96 | 142.84 | 22.08 | 1.50 | 0.91 | 0.06 |
| 3# | 450.63 | 6.12 | 427.35 | 69.92 | 430.61 | 122.50 | 143.14 | 22.03 | 1.50 | 0.91 | 0.06 |
| 4# | 450.48 | 6.14 | 427.34 | 69.92 | 430.66 | 122.44 | 143.24 | 21.88 | 1.50 | 0.91 | 0.06 |
| Tn=0.9s,bt=0.4,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.14 | 6.16 | 427.23 | 72.16 | 430.88 | 133.52 | 149.14 | 21.54 | 1.50 | 0.89 | 0.06 |
| 2# | 450.45 | 6.18 | 427.21 | 72.28 | 430.86 | 135.04 | 149.02 | 21.85 | 1.50 | 0.90 | 0.06 |
| 3# | 450.39 | 6.18 | 427.22 | 71.88 | 430.87 | 133.30 | 149.08 | 21.79 | 1.50 | 0.90 | 0.06 |
| 4# | 450.24 | 6.14 | 427.22 | 71.82 | 430.89 | 133.06 | 149.20 | 21.64 | 1.50 | 0.89 | 0.06 |
| Tn=1.0s,bt=0.4,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.60 | 6.08 | 427.55 | 67.62 | 430.43 | 119.62 | 134.80 | 22.00 | 1.50 | 0.92 | 0.05 |
| 2# | 450.91 | 6.04 | 427.56 | 68.48 | 430.38 | 119.70 | 134.02 | 22.31 | 1.50 | 0.92 | 0.05 |
| 3# | 450.86 | 6.04 | 427.55 | 68.40 | 430.41 | 119.54 | 134.36 | 22.26 | 1.50 | 0.92 | 0.05 |
| 4# | 450.73 | 6.04 | 427.54 | 67.84 | 430.44 | 119.74 | 133.74 | 22.13 | 1.50 | 0.92 | 0.05 |
| Tn=1.0s,bt=0.4,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.28 | 6.10 | 427.39 | 69.32 | 430.70 | 122.92 | 144.06 | 21.68 | 1.50 | 0.90 | 0.06 |
| 2# | 450.59 | 6.08 | 427.40 | 69.86 | 430.65 | 133.36 | 143.92 | 21.99 | 1.50 | 0.91 | 0.05 |
| 3# | 450.55 | 6.08 | 427.38 | 69.76 | 430.67 | 123.10 | 144.16 | 21.95 | 1.50 | 0.91 | 0.06 |
| 4# | 450.40 | 6.06 | 427.39 | 69.80 | 430.73 | 122.70 | 144.22 | 21.80 | 1.50 | 0.90 | 0.06 |
| Tn=1.0s,bt=0.4,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.05 | 6.14 | 427.28 | 71.92 | 430.93 | 133.10 | 150.18 | 21.45 | 1.50 | 0.89 | 0.06 |
| 2# | 450.36 | 6.10 | 427.29 | 72.14 | 430.92 | 135.88 | 150.04 | 21.76 | 1.50 | 0.89 | 0.06 |
| 3# | 450.31 | 6.10 | 427.27 | 72.24 | 430.92 | 133.64 | 150.08 | 21.71 | 1.50 | 0.89 | 0.06 |
| 4# | 450.15 | 6.10 | 427.29 | 71.82 | 430.94 | 133.06 | 150.18 | 21.55 | 1.50 | 0.89 | 0.06 |
| Tn=1.1s,bt=0.4,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.53 | 6.04 | 427.56 | 67.64 | 430.49 | 119.80 | 137.18 | 21.93 | 1.50 | 0.91 | 0.05 |
| 2# | 450.83 | 6.02 | 427.58 | 68.38 | 430.43 | 119.88 | 136.46 | 22.23 | 1.50 | 0.92 | 0.05 |
| 3# | 450.79 | 6.02 | 427.59 | 67.20 | 430.45 | 119.68 | 136.74 | 22.19 | 1.50 | 0.92 | 0.05 |
| 4# | 450.66 | 6.04 | 427.60 | 67.24 | 430.50 | 119.92 | 137.56 | 22.06 | 1.50 | 0.91 | 0.05 |
| Tn=1.1s,bt=0.4,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.20 | 6.08 | 427.45 | 69.98 | 430.73 | 122.56 | 144.92 | 21.60 | 1.50 | 0.90 | 0.05 |
| 2# | 450.51 | 6.08 | 427.45 | 69.96 | 430.71 | 132.36 | 144.84 | 21.91 | 1.50 | 0.90 | 0.05 |
| 3# | 450.47 | 6.04 | 427.44 | 69.80 | 430.72 | 132.20 | 144.48 | 21.87 | 1.50 | 0.90 | 0.05 |
| 4# | 450.31 | 6.04 | 427.44 | 69.26 | 430.75 | 122.48 | 144.98 | 21.71 | 1.50 | 0.90 | 0.05 |
| Tn=1.1s,bt=0.4,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 449.96 | 6.08 | 427.35 | 72.44 | 431.01 | 133.00 | 151.20 | 21.36 | 1.50 | 0.89 | 0.06 |
| 2# | 450.28 | 6.08 | 427.36 | 72.46 | 430.99 | 134.86 | 150.96 | 21.68 | 1.50 | 0.89 | 0.06 |
| 3# | 450.23 | 6.06 | 427.37 | 72.36 | 430.99 | 133.48 | 151.14 | 21.63 | 1.50 | 0.89 | 0.06 |
| 4# | 450.06 | 6.04 | 427.35 | 71.86 | 431.00 | 132.68 | 151.32 | 21.46 | 1.50 | 0.89 | 0.06 |
| Tn=0.8s,bt=0.5,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.58 | 6.74 | 427.09 | 69.98 | 430.70 | 122.98 | 142.22 | 21.98 | 1.50 | 0.90 | 0.07 |
| 2# | 450.92 | 6.74 | 427.10 | 70.34 | 430.63 | 122.94 | 142.20 | 22.32 | 1.50 | 0.91 | 0.07 |
| 3# | 450.86 | 6.74 | 427.11 | 69.92 | 430.68 | 123.18 | 142.28 | 22.26 | 1.50 | 0.91 | 0.07 |
| 4# | 450.68 | 6.74 | 427.09 | 69.90 | 430.72 | 122.84 | 142.34 | 22.08 | 1.50 | 0.90 | 0.07 |
| Tn=0.8s,bt=0.5,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.34 | 6.82 | 426.89 | 72.22 | 430.98 | 126.62 | 149.26 | 21.74 | 1.50 | 0.89 | 0.08 |
| 2# | 450.69 | 6.82 | 426.91 | 72.48 | 430.91 | 127.88 | 148.90 | 22.09 | 1.50 | 0.90 | 0.08 |
| 3# | 450.62 | 6.80 | 426.90 | 72.36 | 430.95 | 126.58 | 149.04 | 22.02 | 1.50 | 0.89 | 0.08 |
| 4# | 450.42 | 6.80 | 426.89 | 72.40 | 430.99 | 126.52 | 149.20 | 21.82 | 1.50 | 0.89 | 0.08 |
| Tn=0.8s,bt=0.5,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.17 | 6.88 | 426.74 | 74.54 | 431.19 | 135.48 | 154.78 | 21.57 | 1.50 | 0.88 | 0.09 |
| 2# | 450.53 | 6.82 | 426.76 | 75.12 | 431.16 | 137.46 | 154.64 | 21.93 | 1.50 | 0.88 | 0.08 |
| 3# | 450.45 | 6.82 | 426.74 | 75.08 | 431.17 | 136.58 | 154.64 | 21.85 | 1.50 | 0.88 | 0.08 |
| 4# | 450.25 | 6.80 | 426.75 | 74.44 | 431.20 | 135.64 | 154.88 | 21.65 | 1.50 | 0.88 | 0.09 |
| Tn=0.9s,bt=0.5,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.51 | 6.74 | 427.13 | 69.96 | 430.77 | 123.14 | 143.32 | 21.91 | 1.50 | 0.90 | 0.07 |
| 2# | 450.85 | 6.74 | 427.15 | 69.98 | 430.69 | 123.24 | 143.14 | 22.25 | 1.50 | 0.91 | 0.07 |
| 3# | 450.80 | 6.74 | 427.14 | 69.92 | 430.73 | 123.04 | 143.06 | 22.20 | 1.50 | 0.90 | 0.07 |
| 4# | 450.62 | 6.74 | 427.13 | 69.80 | 430.78 | 123.14 | 143.48 | 22.02 | 1.50 | 0.90 | 0.07 |
| Tn=0.9s,bt=0.5,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.27 | 6.82 | 426.95 | 72.48 | 431.02 | 128.14 | 150.16 | 21.67 | 1.50 | 0.89 | 0.08 |
| 2# | 450.62 | 6.80 | 426.95 | 72.58 | 430.97 | 132.34 | 150.00 | 22.02 | 1.50 | 0.89 | 0.07 |
| 3# | 450.55 | 6.78 | 426.96 | 72.50 | 431.00 | 127.78 | 149.92 | 21.95 | 1.50 | 0.89 | 0.07 |
| 4# | 450.36 | 6.78 | 426.94 | 72.48 | 431.04 | 127.08 | 150.08 | 21.76 | 1.50 | 0.89 | 0.08 |
| Tn=0.9s,bt=0.5,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.17 | 6.88 | 426.74 | 74.54 | 431.19 | 135.48 | 154.78 | 21.57 | 1.50 | 0.88 | 0.09 |
| 2# | 450.53 | 6.82 | 426.76 | 75.12 | 431.16 | 137.46 | 154.64 | 21.93 | 1.50 | 0.88 | 0.08 |
| 3# | 450.45 | 6.82 | 426.74 | 75.08 | 431.17 | 136.58 | 154.64 | 21.85 | 1.50 | 0.88 | 0.08 |
| 4# | 450.25 | 6.80 | 426.75 | 74.44 | 431.20 | 135.64 | 154.88 | 21.65 | 1.50 | 0.88 | 0.09 |
| Tn=1.0s,bt=0.5,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.45 | 6.72 | 427.18 | 70.10 | 430.81 | 123.28 | 143.94 | 21.85 | 1.50 | 0.90 | 0.06 |
| 2# | 450.79 | 6.72 | 427.18 | 69.96 | 430.75 | 123.18 | 143.82 | 22.19 | 1.50 | 0.90 | 0.06 |
| 3# | 450.73 | 6.66 | 427.17 | 69.90 | 430.77 | 123.10 | 143.92 | 22.13 | 1.50 | 0.90 | 0.06 |
| 4# | 450.55 | 6.68 | 427.17 | 69.92 | 430.81 | 123.18 | 144.10 | 21.95 | 1.50 | 0.90 | 0.07 |
| Tn=1.0s,bt=0.5,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.21 | 6.82 | 426.99 | 72.32 | 431.09 | 126.72 | 150.94 | 21.61 | 1.50 | 0.88 | 0.07 |
| 2# | 450.55 | 6.76 | 427.01 | 72.60 | 431.04 | 130.04 | 150.64 | 21.95 | 1.50 | 0.89 | 0.07 |
| 3# | 450.49 | 6.78 | 427.00 | 72.36 | 431.06 | 127.64 | 150.78 | 21.89 | 1.50 | 0.89 | 0.07 |
| 4# | 450.29 | 6.78 | 426.99 | 72.38 | 431.11 | 127.20 | 151.08 | 21.69 | 1.50 | 0.88 | 0.07 |
| Tn=1.0s,bt=0.5,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.17 | 6.88 | 426.74 | 74.54 | 431.19 | 135.48 | 154.78 | 21.57 | 1.50 | 0.88 | 0.09 |
| 2# | 450.53 | 6.82 | 426.76 | 75.12 | 431.16 | 137.46 | 154.64 | 21.93 | 1.50 | 0.88 | 0.08 |
| 3# | 450.45 | 6.82 | 426.74 | 75.08 | 431.17 | 136.58 | 154.64 | 21.85 | 1.50 | 0.88 | 0.08 |
| 4# | 450.25 | 6.80 | 426.75 | 74.44 | 431.20 | 135.64 | 154.88 | 21.65 | 1.50 | 0.88 | 0.09 |
| Tn=1.1s,bt=0.5,Td=5.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.39 | 6.68 | 427.21 | 70.36 | 430.85 | 123.26 | 144.70 | 21.79 | 1.50 | 0.90 | 0.06 |
| 2# | 450.73 | 6.66 | 427.22 | 70.42 | 430.80 | 123.36 | 144.40 | 22.13 | 1.50 | 0.90 | 0.06 |
| 3# | 450.66 | 6.66 | 427.21 | 69.92 | 430.83 | 123.32 | 144.60 | 22.06 | 1.50 | 0.90 | 0.06 |
| 4# | 450.49 | 6.66 | 427.22 | 69.82 | 430.87 | 123.34 | 144.78 | 21.89 | 1.50 | 0.90 | 0.06 |
| Tn=1.1s,bt=0.5,Td=6.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.21 | 6.82 | 426.99 | 72.32 | 431.09 | 126.72 | 150.94 | 21.61 | 1.50 | 0.88 | 0.07 |
| 2# | 450.55 | 6.76 | 427.01 | 72.60 | 431.04 | 130.04 | 150.64 | 21.95 | 1.50 | 0.89 | 0.07 |
| 3# | 450.49 | 6.78 | 427.00 | 72.36 | 431.06 | 127.64 | 150.78 | 21.89 | 1.50 | 0.89 | 0.07 |
| 4# | 450.29 | 6.78 | 426.99 | 72.38 | 431.11 | 127.20 | 151.08 | 21.69 | 1.50 | 0.88 | 0.07 |
| Tn=1.1s,bt=0.5,Td=7.0s,Ty=0.02s | | | | | | | | | | | | |
| X3 | 1# | 450.17 | 6.88 | 426.74 | 74.54 | 431.19 | 135.48 | 154.78 | 21.57 | 1.50 | 0.88 | 0.09 |
| 2# | 450.53 | 6.82 | 426.76 | 75.12 | 431.16 | 137.46 | 154.64 | 21.93 | 1.50 | 0.88 | 0.08 |
| 3# | 450.45 | 6.82 | 426.74 | 75.08 | 431.17 | 136.58 | 154.64 | 21.85 | 1.50 | 0.88 | 0.08 |
| 4# | 450.25 | 6.80 | 426.75 | 74.44 | 431.20 | 135.64 | 154.88 | 21.65 | 1.50 | 0.88 | 0.09 |

**表7-4 调速器参数取值**

|  |  |
| --- | --- |
| 调速器参数 | 取值 |
| Tn(s) | 1.1 |
| bt | 0.3 |
| Td(s) | 5.0 |
| Ty(s) | 0.02 |

### 7.2.1 小波动过渡过程计算结果

整个引水发电系统的管道采用平均糙率（钢衬为0.012，混凝土为0.014）进行计算，且调速器参数按照表7-4取值，小波动过渡过程计算结果如表7-5～表7-7所示：

**表7-5 小波动过渡过程机组转速特征值计算结果**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 机组号 | Nmax或Nmin（r/min） | 极值发生时间（s） | N1  (r/min) | 极值发生时间（s） | N2  (r/min) | 极值发生时间（s） | ±0.4％调节时间（s） | 最大偏差（r/min） | 振荡次数 | 衰减度 | 超调量σ |
|
| X1 | 1# | 445.10 | 4.48 | 426.84 | 9.88 | 433.06 | 13.92 | 24.30 | 16.50 | 2.50 | 0.73 | 0.11 |
| 2# | 445.29 | 4.48 | 426.89 | 9.88 | 433.10 | 13.92 | 24.30 | 16.69 | 2.50 | 0.73 | 0.10 |
| 3# | 445.25 | 4.46 | 426.76 | 9.86 | 433.11 | 13.92 | 24.32 | 16.65 | 2.50 | 0.73 | 0.11 |
| 4# | 445.20 | 4.48 | 426.65 | 9.86 | 433.10 | 13.94 | 24.32 | 16.60 | 2.50 | 0.73 | 0.12 |
| X2 | 4# | 438.77 | 3.96 | 428.43 | 25.36 | 429.00 | 28.32 | 16.88 | 10.17 | 0.50 | 0.96 | 0.02 |
| X3 | 1# | 451.11 | 5.44 | 426.25 | 13.00 | 431.54 | 19.44 | 22.38 | **22.51** | 1.50 | 0.87 | 0.10 |
| 2# | 451.41 | 5.42 | 426.27 | 13.02 | 431.54 | 19.42 | 22.34 | **22.81** | 1.50 | 0.87 | 0.10 |
| 3# | 451.34 | 5.40 | 426.13 | 13.00 | 431.57 | 19.48 | 22.40 | **22.74** | 1.50 | 0.87 | 0.11 |
| 4# | 451.26 | 5.40 | 426.02 | 12.98 | 431.57 | 19.48 | 22.40 | **22.66** | 1.50 | 0.87 | 0.11 |
| X4 | 2# | 447.74 | 5.14 | 428.26 | 65.40 | 429.77 | 128.08 | 13.66 | 19.14 | 0.50 | 0.94 | 0.02 |
| 3# | 447.84 | 5.14 | 428.27 | 65.32 | 429.78 | 129.50 | 13.44 | 19.24 | 0.50 | 0.94 | 0.02 |
| 4# | 447.85 | 5.12 | 428.26 | 65.58 | 429.79 | 115.12 | 13.28 | 19.25 | 0.50 | 0.94 | 0.02 |
| X5 | 3# | 444.71 | 4.90 | 428.55 | 67.16 | 429.52 | 127.76 | 14.92 | 16.11 | 0.50 | 0.94 | 0.00 |
| 4# | 444.78 | 4.90 | 428.55 | 67.16 | 429.51 | 128.26 | 14.84 | 16.18 | 0.50 | 0.94 | 0.00 |
| X6 | 4# | 442.15 | 4.72 | 428.45 | 68.00 | 428.95 | 127.40 | 15.92 | 13.55 | 0.50 | 0.97 | 0.01 |

**表7-6 小波动过渡过程上游调压室水位特征值计算结果**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 调压室号 | 初始水位(m) | 最高涌浪水位(m) | 最高涌浪水位发生时间(s) | 最低涌浪水位(m) | 最低涌浪水位发生时间(s) | 波动周期 | 向上最大振幅(m) | 向下最大振幅(m) |
| X1 | J29 | 524.89 | 528.43 | 34.70 | 522.25 | 101.20 | 66.24 | 3.54 | 2.63 |
| X2 | J29 | 526.69 | 527.52 | 35.76 | 525.91 | 100.92 | 60.32 | 0.83 | 0.78 |
| X3 | J29 | 499.99 | 504.69 | 36.16 | 496.34 | 101.53 | 69.16 | 4.70 | 3.65 |
| X4 | J29 | 501.03 | 504.45 | 36.09 | 498.20 | 101.74 | 69.00 | 3.42 | 2.83 |
| X5 | J29 | 501.79 | 503.99 | 35.99 | 499.85 | 101.83 | 68.84 | 2.21 | 1.94 |
| X6 | J29 | 502.25 | 503.33 | 36.10 | 501.23 | 101.94 | 68.32 | 1.08 | 1.01 |

**表7-7 小波动过渡过程下游调压室水位特征值计算结果**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 调压室号 | 初始水位(m) | 最高涌浪水位(m) | 最高涌浪水位发生时间(s) | 最低涌浪水位(m) | 最低涌浪水位发生时间(s) | 波动周期 | 向上最大振幅(m) | 向下最大振幅(m) |
| X1 | J30 | 61.34 | 63.50 | 84.25 | 58.43 | 27.19 | 114.12 | 2.16 | 2.92 |
| X2 | J30 | 60.09 | 60.72 | 83.14 | 59.40 | 29.06 | 110.16 | 0.64 | 0.68 |
| X3 | J30 | 73.58 | 76.49 | 85.51 | 69.70 | 28.80 | 115.30 | 2.91 | 3.88 |
| X4 | J30 | 72.86 | 75.11 | 84.75 | 70.04 | 29.68 | 110.16 | 2.26 | 2.82 |
| X5 | J30 | 72.33 | 73.89 | 84.38 | 70.51 | 29.54 | 109.68 | 1.56 | 1.82 |
| X6 | J30 | 72.01 | 72.83 | 84.04 | 71.12 | 29.56 | 108.96 | 0.82 | 0.89 |

### 7.2.1 小波动过渡过程计算结果分析

由小波动计算结果表7-5～表7-7可以得到以下结论：

（1）对调速器参数进行整定后小波动的调节品质较好，±0.4%调节时间比较短，所有工况都能在24.32s内稳定下来。

（2）工况X3的机组转速最大偏差分别为22.51r/min（1#机）、22.81r/min（2#机）、22.74 r/min（3#机）和22.66 r/min（4#机），且越少机组参与小波动调节，机组转速最大偏差越小。

（3）四台机组同时运行时，超调量较大，X3工况超调量达0.11。

（4）最大水头4台机组同时运行突减10%负荷的X1工况，四台机转速进入±0.4%带宽的振荡次数均为2.5次；一台机运行突减10%负荷振荡次数较小，X2工况振荡次数为0.5次。

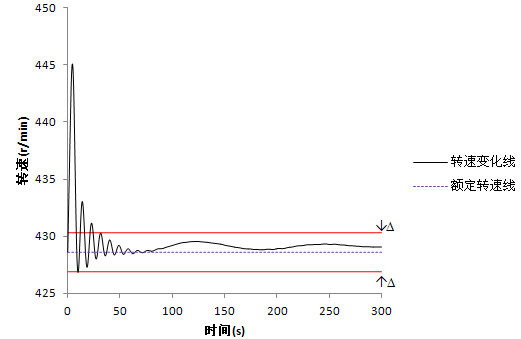


图7.1 工况X1 1#机组转速波动过程

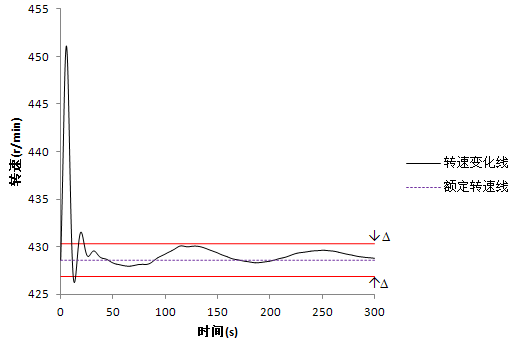


图7.2 工况X3 1#机组转速波动过程

# 8. 水力干扰过渡过程计算结果及分析

## 8.1 计算参数及内容

水力干扰过渡过程计算的参数和小波动过渡过程计算的参数相同，对如图5.1所示的管道系统单元进行分析计算。

在水力干扰过渡过程的计算中考虑了两种情况：（1）机组联入无穷大的电网条件下，机组的频率保持不变，系统中负荷的波动由电网承担，数值计算的目的是研究正常运行机组在受扰动情况下的出力摆动对电网的冲击和对机组自身的影响；（2）机组联入有限电网，在电网中担负调频的任务，其能力将影响电网的供电质量，数值计算的目的就是研究运行机组在受扰动情况下的调节品质。

但是，联合供水单元内机组的水力干扰问题要比小波动问题剧烈得多，因此不能要求调频调峰机组的调节品质达到和小波动一样的良好品质，而只能以波动是否衰减为判断条件，以保证事故不进一步扩大，导致运行机组接踵甩负荷。

## 8.2 水力干扰过渡过程计算工况的拟定

在小波动过渡过程计算的基础上，为了研究深圳抽水蓄能电站在水力干扰过渡过程情况下的机组运行稳定性和出力的波动幅度，进行水力干扰过渡过程计算。对于参与调频和不参与调频两种条件下的机组出力变化和机组的调节品质进行了如下表8-1中6种工况的水力干扰过渡过程计算。

**表8-1 水力干扰计算工况列表**

| 工况  编号 | 上库  水位(m) | 下库  水位(m) | 工况说明 |
| --- | --- | --- | --- |
| GR1 | 526.81 | 60.00 | 最大静水头466.81m，四台发电机组在满负荷运行时，一台(4#)机组突然丢弃负荷，对其他三台机运行形成的干扰 |
| GR2 | 526.81 | 60.00 | 最大静水头466.81m，四台发电机组在满负荷运行时，两机(3#、4#)组突然丢弃负荷，对其他两台机运行形成的干扰 |
| GR3 | 526.81 | 60.00 | 最大静水头466.81m，四台发电机组在满负荷运行时，（2#、3#、4#）三机组突然丢弃负荷，对剩下一台机运行形成的干扰 |
| GR4 | - | 71.90 | 额定水头419.00m，四台发电机组在满负荷运行时，一台机组（4#）突然丢弃负荷，对其他三台机运行形成的干扰； |
| GR5 | - | 71.90 | 额定水头419.00m，四台发电机组在满负荷运行时，两台机组（3#、4#）突然丢弃负荷，对其他两台机运行形成的干扰； |
| GR6 | - | 71.90 | 额定水头419.00m，四台发电机组在满负荷运行时，三台机组（2#、3#、4#）突然丢弃负荷，对剩下一台机运行形成的干扰 |

**表8-2 水力干扰工况参数表**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 上游水位（m) | 下游水位(m) | 机组号 | 开度（%） | 净水头(m) | 流量(m3/s) | 出力(MW) | 工况说明 |
| GR1 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 | 最大静水头466.81m，四台发电机组在满负荷运行时，一台(4#)机组突然丢弃负荷，对其他三台机运行形成的干扰 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| GR2 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 | 最大静水头466.81m，四台发电机组在满负荷运行时，两机(3#、4#)组突然丢弃负荷，对其他两台机运行形成的干扰 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| GR3 | 526.81 | 60.00 | 1# | 73.56 | 457.68 | 74.63 | 306.13 | 最大静水头466.81m，四台发电机组在满负荷运行时（2#、3#、4#）三机组突然丢弃负荷，对剩下一台机运行形成的干扰 |
| 2# | 73.56 | 457.35 | 74.60 | 305.74 |
| 3# | 73.56 | 457.61 | 74.63 | 306.04 |
| 4# | 73.56 | 458.06 | 74.68 | 306.58 |
| GR4 | 502.4 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 | 额定水头419.00m，四台发电机组在满负荷运行时，一台机组（4#）突然丢弃负荷，对其他三台机运行形成的干扰； |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| GR5 | 502.4 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 | 额定水头419.00m，四台发电机组在满负荷运行时，两台机组（3#、4#）突然丢弃负荷，对其他两台机运行形成的干扰； |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |
| GR6 | 502.4 | 71.90 | 1# | 94.43 | 419.05 | 83.54 | 306.15 | 额定水头419.00m，四台发电机组在满负荷运行时，三台机组（2#、3#、4#）突然丢弃负荷，对剩下一台机运行形成的干扰； |
| 2# | 94.43 | 418.64 | 83.48 | 305.65 |
| 3# | 94.43 | 418.96 | 83.52 | 306.04 |
| 4# | 94.43 | 419.53 | 83.60 | 306.71 |

## 8.3 水力干扰过渡过程计算结果及分析

### 8.3.1 水力干扰过渡过程计算结果

(1) 运行机组参与频率调节

运行机组调速器参与频率调节即机组联入有限电网，在电网中担负调频的任务，其能力将影响电网的供电质量，调速器跟踪运行机组频率进行调节。计算选取与小波动相同的调速器参数s，，，s，。运行机组调速器参与频率调节条件下水力干扰的计算结果如表8-3、表8-4。

**表8-3 参与频率调节水力干扰机组计算结果表**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 运行机组 | 初始  出力（MW) | 最大  出力(MW) | 最小  出力(MW) | 向上最大偏差(MW) | 向下最大偏差(MW) | 最大摆动幅度(MW) | 最大摆动幅度(%) | ±0.4％调节时间（s） | 振荡次数 |
| GR1 | 1# | 306.13 | 386.67 | 244.22 | 80.54 | 61.91 | 142.45 | 46.53 | 63.24 | 4.50 |
| 2# | 305.74 | 386.80 | 243.76 | 81.06 | 61.98 | 143.04 | 46.78 | 63.26 | 4.50 |
| 3# | 306.04 | 388.23 | 243.62 | 82.19 | 62.42 | 144.61 | 47.25 | 63.30 | 4.50 |
| GR2 | 1# | 306.13 | 386.92 | 242.61 | 80.79 | 63.52 | 144.31 | 47.14 | 137.46 | 10.00 |
| 2# | 305.74 | 386.69 | 241.94 | 80.95 | 63.80 | 144.75 | 47.34 | 136.30 | 10.00 |
| GR3 | 1# | 306.13 | 388.37 | 254.34 | 82.24 | 51.79 | 134.03 | 43.78 | 146.90 | 9.50 |
| GR4 | 1# | 306.15 | 365.00 | 242.77 | 58.86 | 63.38 | 122.23 | 39.92 | 146.16 | 7.00 |
| 2# | 305.65 | 365.12 | 241.34 | 59.47 | 64.31 | 123.78 | 40.50 | 145.48 | 7.50 |
| 3# | 306.04 | 366.19 | 241.76 | 60.15 | 64.28 | 124.43 | 40.66 | 145.64 | 7.00 |
| GR5 | 1# | 306.15 | 385.10 | 238.81 | 78.95 | 67.34 | 146.29 | 47.78 | 150.06 | 7.50 |
| 2# | 305.65 | 385.50 | 238.08 | 79.84 | 67.57 | 147.42 | 48.23 | 149.30 | 7.50 |
| GR6 | 1# | 306.15 | 390.74 | 247.21 | 84.59 | 58.94 | 143.54 | 46.89 | 152.72 | 8.00 |

注：表中机组为正常运行机组。

**表8-4 参与频率调节水力干扰上游调压室计算结果表**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况代号 | 上游调压室号 | 初始  水位 （m） | 最高  水位（m） | 最高水位发生时间  (s) | 最低  水位（m） | 最低水位发生时间  (s) | 向上最  大振幅 (m) | 向下最大振幅(m) |
| GR1 | J29 | 524.89 | 531.4 | 32.65 | 521.05 | 109.57 | 6.52 | 3.84 |
| GR2 | J29 | 524.89 | 536.08 | 35.67 | 518.36 | 110.09 | 11.19 | 6.53 |
| GR3 | J29 | 524.89 | 536.89 | 38.6 | 515.73 | 119.21 | 12.01 | 9.16 |
| GR4 | J29 | 499.99 | 507.76 | 35.68 | 496.11 | 108.64 | 7.77 | 3.88 |
| GR5 | J29 | 499.99 | 513.26 | 38.15 | 493.9 | 109.61 | 13.27 | 6.09 |
| GR6 | J29 | 499.99 | 517.64 | 40.33 | 492.04 | 111.15 | 17.65 | 7.95 |

**表8-5 参与频率调节水力干扰下游调压室计算结果表**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况  代号 | 上游调压室号 | 初始  水位（m） | 最高  水位（m） | 最高水位发生时间 (s) | 最低  水位（m） | 最低水位发生时间 (s) | 向上最大振幅(m) | 向下最大振幅(m) |
| GR1 | J29 | 61.34 | 64.1 | 92.14 | 55.73 | 31.79 | 2.76 | 5.61 |
| GR2 | J29 | 61.34 | 65.81 | 92.26 | 51.41 | 34.41 | 4.47 | 9.93 |
| GR3 | J29 | 61.34 | 67.02 | 92.76 | 48.04 | 36.74 | 5.68 | 13.3 |
| GR4 | J29 | 73.58 | 76.23 | 91.03 | 67.16 | 34.63 | 2.65 | 6.42 |
| GR5 | J29 | 73.58 | 77.51 | 91.98 | 62.85 | 36.79 | 3.92 | 10.73 |
| GR6 | J29 | 73.58 | 78.32 | 93.06 | 59.71 | 38.68 | 4.74 | 13.87 |

(2) 运行机组参与功率调节

对调速器参数进行整定，GR3工况计算结果如表8-6，选取最优的调速器参数，如表8-7。运行机组调速器参与功率调节条件下水力干扰的计算结果如表8-8、表8-9和表8-10。

**表8-6 参与功率调节水力干扰机组调速器参数整定**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况 | 机组号 | bt | Td (s) | 初始  出力(MW) | 最大  出力(MW) | 时间  (s) | 最小  出力(MW) | 时间(s) | 最大超出力(MW) |
| GR3 | 1# | 0.30 | 2.00 | 306.13 | 398.09 | 6.01 | 215.63 | 18.81 | 91.96 |
| GR3 | 1# | 0.30 | 3.00 | 306.13 | 411.69 | 9.54 | 222.97 | 18.81 | 105.56 |
| GR3 | 1# | 0.30 | 4.00 | 306.13 | 417.54 | 9.85 | 228.20 | 18.81 | 111.41 |
| GR3 | 1# | 0.30 | 5.00 | 306.13 | 420.56 | 9.85 | 231.86 | 18.81 | 114.43 |
| GR3 | 1# | 0.30 | 6.00 | 306.13 | 422.71 | 9.90 | 234.08 | 18.81 | 116.58 |
| GR3 | 1# | 0.30 | 7.00 | 306.13 | 424.36 | 9.90 | 236.27 | 18.81 | 118.23 |
| GR3 | 1# | 0.30 | 8.00 | 306.13 | 425.61 | 9.90 | 238.08 | 18.81 | 119.48 |
| GR3 | 1# | 0.40 | 2.00 | 306.13 | 408.21 | 9.48 | 220.64 | 18.81 | 102.08 |
| GR3 | 1# | 0.40 | 3.00 | 306.13 | 417.54 | 9.85 | 228.20 | 18.81 | 111.41 |
| GR3 | 1# | 0.40 | 4.00 | 306.13 | 421.37 | 9.85 | 232.62 | 18.81 | 115.24 |
| GR3 | 1# | 0.40 | 5.00 | 306.13 | 423.85 | 9.85 | 235.62 | 18.81 | 117.72 |
| GR3 | 1# | 0.40 | 6.00 | 306.13 | 425.61 | 9.90 | 238.08 | 18.81 | 119.48 |
| GR3 | 1# | 0.40 | 7.00 | 306.13 | 426.85 | 9.90 | 239.97 | 18.81 | 120.72 |
| GR3 | 1# | 0.40 | 8.00 | 306.13 | 427.72 | 9.90 | 241.44 | 18.81 | 121.59 |
| GR3 | 1# | 0.50 | 2.00 | 306.13 | 414.26 | 9.57 | 224.94 | 18.81 | 108.13 |
| GR3 | 1# | 0.50 | 3.00 | 306.13 | 420.56 | 9.85 | 231.86 | 18.81 | 114.43 |
| GR3 | 1# | 0.50 | 4.00 | 306.13 | 423.85 | 9.85 | 235.62 | 18.81 | 117.72 |
| GR3 | 1# | 0.50 | 5.00 | 306.13 | 425.94 | 9.90 | 238.57 | 18.81 | 119.81 |
| GR3 | 1# | 0.50 | 6.00 | 306.13 | 427.34 | 9.90 | 240.67 | 18.81 | 121.21 |
| GR3 | 1# | 0.50 | 7.00 | 306.13 | 428.29 | 9.90 | 242.28 | 18.81 | 122.16 |
| GR3 | 1# | 0.50 | 8.00 | 306.13 | 429.01 | 9.90 | 243.42 | 18.81 | 122.88 |
| GR3 | 1# | 0.60 | 2.00 | 306.13 | 417.54 | 9.85 | 228.20 | 18.81 | 111.41 |
| GR3 | 1# | 0.60 | 3.00 | 306.13 | 422.71 | 9.90 | 234.08 | 18.81 | 116.58 |
| GR3 | 1# | 0.60 | 4.00 | 306.13 | 425.61 | 9.90 | 238.08 | 18.81 | 119.48 |
| GR3 | 1# | 0.60 | 5.00 | 306.13 | 427.34 | 9.90 | 240.67 | 18.81 | 121.21 |
| GR3 | 1# | 0.60 | 6.00 | 306.13 | 428.48 | 9.90 | 242.51 | 18.81 | 122.35 |
| GR3 | 1# | 0.60 | 7.00 | 306.13 | 429.30 | 9.90 | 243.84 | 18.81 | 123.17 |
| GR3 | 1# | 0.60 | 8.00 | 306.13 | 429.86 | 9.90 | 244.68 | 18.81 | 123.73 |

**表8-7 调速器参数取值**

|  |  |
| --- | --- |
| 调速器参数 | 取值 |
|  | 0.04 |
|  | 0.3 |
| Td(s) | 2 |
| Ty(s) | 0.02 |

**表8-8 参与功率调节水力干扰机组计算结果表**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况代号 | 运行机组 | 初始  出力(MW） | 最大出力(MW) | 最小出力(MW) | 向上最大偏差(MW) | 向下最大偏差(MW) | 最大摆动幅度(MW) | 向上最大振幅（%） | 最大摆动幅度(%) | 进入110%出力限制线时间(s) |
| GR1 | 1# | 306.13 | 355.46 | 264.27 | 49.33 | 41.86 | 91.19 | 16.11 | 29.79 | 26.88 |
| 2# | 305.74 | 356.04 | 263.27 | 50.30 | 42.47 | 92.77 | 16.45 | 30.34 | 26.86 |
| 3# | 306.04 | 357.13 | 262.06 | 51.09 | 43.98 | 95.07 | 16.69 | 31.06 | 26.87 |
| GR2 | 1# | 306.13 | 379.31 | 236.14 | 73.18 | 69.99 | 143.17 | 23.90 | 46.77 | 30.34 |
| 2# | 305.74 | 379.97 | 234.95 | 74.23 | 70.79 | 145.02 | 24.28 | 47.43 | 30.34 |
| GR3 | 1# | 306.13 | 398.09 | 215.63 | 91.96 | 90.50 | 182.46 | 30.04 | 59.60 | 43.96 |
| GR4 | 1# | 306.15 | 360.99 | 269.00 | 54.84 | 37.15 | 91.99 | 17.91 | 30.05 | 43.30 |
| 2# | 305.65 | 361.82 | 268.07 | 56.17 | 37.58 | 93.75 | 18.38 | 30.67 | 43.30 |
| 3# | 306.04 | 362.82 | 266.90 | 56.78 | 39.14 | 95.92 | 18.55 | 31.34 | 43.30 |
| GR5 | 1# | 306.15 | 391.51 | 244.44 | 85.36 | 61.71 | 147.07 | 27.88 | 48.04 | 48.72 |
| 2# | 305.65 | 393.08 | 242.74 | 87.43 | 62.91 | 150.34 | 28.60 | 49.19 | 48.72 |
| GR6 | 1# | 306.15 | 419.83 | 228.02 | 113.68 | 78.13 | 191.81 | 37.13 | 62.65 | 52.08 |

**表8-9 参与功率调节水力干扰上游调压室计算结果表**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况代号 | 上游调压室号 | 初始  水位 （m） | 最高  水位  （m） | 最高水位发生时间 (s) | 最低  水位（m） | 最低水位发生时间 (s) | 向上最大振幅(m) | 向下最大振幅(m) |
| GR1 | J29 | 524.89 | 531.43 | 45.98 | 520.71 | 117.03 | 6.54 | 4.18 |
| GR2 | J29 | 524.89 | 536.07 | 36.47 | 517.78 | 114.23 | 11.18 | 7.11 |
| GR3 | J29 | 524.89 | 536.92 | 39.13 | 515.34 | 122.04 | 12.03 | 9.55 |
| GR4 | J29 | 499.99 | 506.98 | 47.99 | 496.31 | 121.48 | 6.99 | 3.68 |
| GR5 | J29 | 499.99 | 512.83 | 38.06 | 493.54 | 116.31 | 12.84 | 6.45 |
| GR6 | J29 | 499.99 | 517.84 | 40.66 | 491.57 | 113.92 | 17.85 | 8.42 |

**表8-10 参与功率调节水力干扰下游调压室计算结果表**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 工况代号 | 上游调压室号 | 初始  水位 （m） | 最高水位（m） | 最高水位发生时间 (s) | 最低  水位  （m） | 最低水位发生时间 (s) | 向上最大振幅(m) | 向下最大振幅(m) |
| GR1 | J30 | 61.34 | 64.10 | 97.53 | 56.18 | 33.20 | 2.76 | 5.16 |
| GR2 | J30 | 61.34 | 65.94 | 94.78 | 51.45 | 35.21 | 4.60 | 9.89 |
| GR3 | J30 | 61.34 | 67.15 | 93.59 | 47.89 | 37.05 | 5.81 | 13.45 |
| GR4 | J30 | 73.58 | 75.65 | 99.98 | 68.13 | 33.68 | 2.07 | 5.45 |
| GR5 | J30 | 73.58 | 77.38 | 96.32 | 63.04 | 36.64 | 3.80 | 10.54 |
| GR6 | J30 | 73.58 | 78.44 | 94.79 | 59.52 | 38.80 | 4.86 | 14.06 |

### 8.3.2 水力干扰过渡过程计算分析

(1) 由参与频率调节条件下的水力干扰计算结果(表8-3～8-5)分析可知：

1) 水力干扰调速器参与频率调节的条件下，各工况下转速进入±0.4％带宽最大调节时间为152.72s左右，振荡次数达10次，但转速波动是衰减的。因此，同一水力单元部分机组甩负荷时，不会造成事故进一步扩大，导致运行机组随之甩负荷。

2) 三台机组同时甩负荷时，超出力最大，超出力最大工况为GR6，1号机最大出力摆动为143.54MW，最大超出力为84.59MW，超出力幅度为27.6%，进入110%额定出力带宽范围持续时间为65.04s，如图8.1所示。

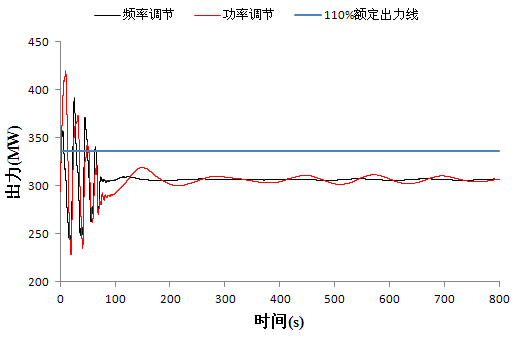


图8.1 工况GR6 1#机组出力变化过程线

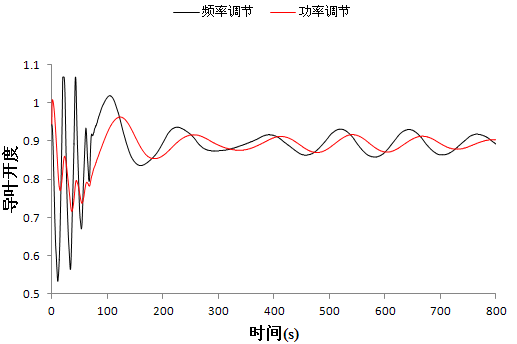


图8.2 工况GR6 1#机组开度变化过程线

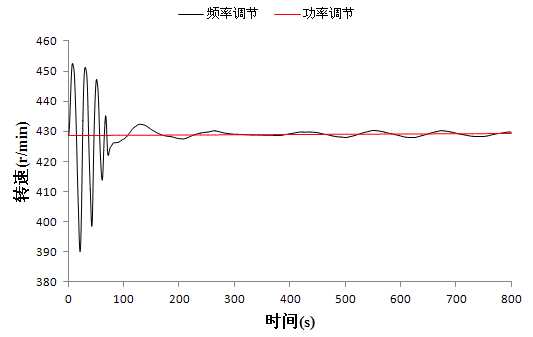


图8.3 工况GR6 1#转速波动变化图

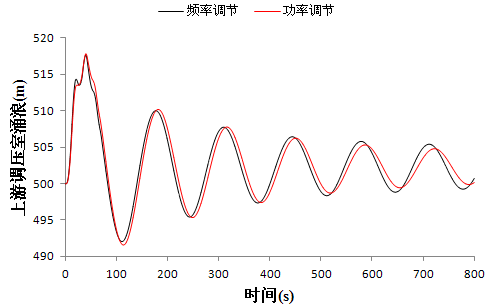


图8.4 工况GR6上游J29调压室水位变化过程线

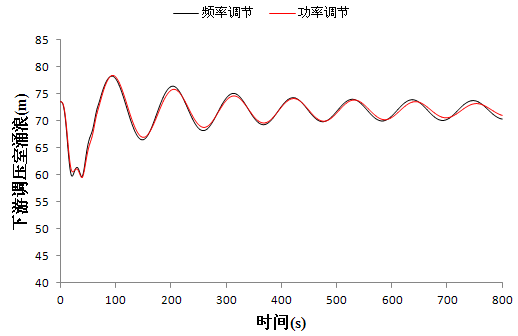


图8.5 工况GR6 下游J30调压室水位变化过程线

(2) 由参与功率调节条件下的水力干扰计算结果(表8-8～8-10)分析可知：功率调节下水力干扰过渡过程得出的基本规律与频率调节下的相同，只是幅值大小不同。额定水头工况GR6，1号机最大出力摆动为191.81MW，最大超出力为113.68MW，超出力幅度为37.13 %，进入110%出力限制线时间为52.08s，如图8.1所示。

(3) 两种调节模式下，水力干扰过渡过程计算结果对比：

将两种条件下6工况最大出力摆幅及上、下游调压室水位计算结果进行对比如下表：

**表8-11 水力干扰机组及调压室计算结果对比表**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 工况代号 | 调速器参与频率调节 | | | 调速器参与功率调节 | | |
| 最大出力摆幅(MW) | 上游调压室最大振幅 (m) | 下游调压室最大振幅 (m) | 最大出力摆幅(MW) | 上游调压室最大振幅 (m) | 下游调压室最大振幅 (m) |
| GR1 | 144.61 | 6.52 | 5.61 | 95.07 | 6.54 | 5.16 |
| GR2 | 144.75 | 11.19 | 9.93 | 145.02 | 11.18 | 9.89 |
| GR3 | 134.03 | 12.01 | 13.3 | 182.46 | 12.03 | 13.45 |
| GR4 | 124.43 | 7.77 | 6.42 | 95.92 | 6.99 | 5.45 |
| GR5 | 147.42 | 13.27 | 10.73 | 150.34 | 12.84 | 10.54 |
| GR6 | 143.54 | 17.65 | 13.87 | 191.81 | 17.85 | 14.06 |

由表8-11可以看出：调速器参与功率调节时运行机组的最大出力摆幅比调速器参与频率调节时基本上要大，而调压室室涌浪的振幅基本接近。

两种调节模式下，机组出力及调压室涌浪有所差别，主要是由不同调节模式下调速器参数不同，而且导叶开度变化过程也不同导致的（如图8.2中开度线所示）。

# 9. 总结

本报告采用的是《深圳水泵水轮机模型最终试验报告》中给出的D715A水泵水轮机四象限特性曲线，针对设计院提供的最新的管道和调压室布置方案，进行了大波动、小波动和水力干扰过渡过程计算分析，得到结论如下：

1. **恒定流计算结论**

1）深圳抽水蓄能电站的引水隧洞长1618.0m，尾水隧洞长度为1087.0m。四台机额定开度运行，上库至上游调压室水头损失为2.41m，上游调压室至尾水支管出口处水头损失为8.18m，上库至尾水隧洞出口处水头损失为12.27m（4#机组）。

2）四台机额定开度运行，上库至上游调压室的Tw1值为1.775s，上游调压室至机组的Tw2值为2.42s，机组至下游调压室的Tw3值为0.26s，下游调压室至尾水洞出口的Tw4值为1.18s，Ta值为10.29s，上游调压室至下游调压室的（Tw2+Tw3）/Ta值为0.26。

3）由托马稳定断面复核计算可知，每个调压室单独运行时，上游调压室的托马稳定断面积为91.33，下游调压室的托马稳定断面积为124.40，上、下游调压室的实际断面积、，实际断面放大倍数为（2.202，1.616）；通过绘制稳定域边界线可知，本电站上、下游双调压室的实际断面放大系数在稳定域范围内，说明该电站的上、下游双调压室波动时稳定的。

1. **大波动过渡过程计算结论**

对于水轮机工况，采用30s-(85%)-80s两段折线关闭规律与有效时间为30s的导叶直线开启规律，对于水泵工况，采用有效时间为30s的导叶直线关闭规律与开启规律，大波动过渡过程计算结果如下:

1）对于水轮机设计工况，修正前后的球阀进口最大动水压力、蜗壳进口最大动水压力、尾水管进口最小动水压力及机组转速最大上升率均满足控制要求。

2）对于水轮机校核工况，修正前后的球阀进口最大动水压力、蜗壳进口最大动水压力满足控制要求，有个别工况尾水管进口最小动水压力及机组转速最大上升率不能满足控制要求，但是所有校核工况尾水管进口最小动水压力均大于-8m，并且所有校核工况的机组转速最大上升率修正值均小于50%。

尾水管进口最小动水压力不满足大于1.66m的控制要求的工况有JHT13、JHT14、JHT15、JHT16,其中工况JHT15尾水管进口最小动水压力为所有控制工况中最小。JHT15的尾水管的压力值为13.64m，修正后尾水管进口最小动水压力值为-6.10m，不满足大于1.66m（相对压力）控制要求。

机组最大转速上升超过45%的工况包含一台机组导叶拒动工况（JHT1、JHT4、JHT5、JHT7、JHT9、JHT11）和第四台延时关闭的工况（JHT3、JHT6、JHT8、JHT10、JHT17、JHT18），其中JHT3、JHT6、JHT8、JHT10工况的最大转速上升率为所有工况中最大，机组最大转速上升率都为46.30%，修正后机组最大转速上升率为48.62%，不能满足控制在45%的要求。

3）对于水轮机极端工况，修正前后的球阀进口最大动水压力、蜗壳进口最大动水压力满足控制要求，个别工况尾水管进口最小动水压力及机组转速最大上升率不能满足控制要求，但是除工况JDT6外，所有极端工况的尾水管最小动水压力（相对压力）均大于-8m，所有工况最大转速上升率均小于50%，而且工况JDT6是极端工况，发生的概率较小。

尾水管进口最小动水压力不满足大于1.66m的控制要求的工况有JDT6、JDT10，这两个工况尾水管压力均出现了一定的负压，尾水管进口最小动水压力控制工况为JDT6。JDT6的尾水管的压力值为1.32m，修正后尾水管进口最小动水压力值为-19.56m，不满足大于1.66m（相对压力）控制要求。

机组最大转速上升超过45%的工况包含一台机组导叶、球阀均拒动工况（JDT1、JDT2、JDT3、JDT4、JDT5）。其中机组最大转速上升的控制工况是JDT2。机组转速上升率为46.23%，修正后机组最大转速上升率为48.54%，不能满足控制在45%的要求。

4）水泵设计工况、校核工况与极端工况的修正前后的球阀进口最大动水压力、蜗壳进口最大动水压力、尾水管进口最小动水压力及机组转速最大上升率均满足控制要求。

5）上、下游调压室最高最低涌浪水位均满足控制要求。上游调压室向下最大压差的控制工况为ZP2，极值结果为22.22m；向上最大压差的控制工况为ZT4，为21.37m；下游调压室向下最大压差的控制工况为ZT4，为10.55m；向上最大压差的控制工况为ZP3，分别为23.65m。

6）4#机组上游侧沿线最小压力发生在进水口附近67.17米处，相应管道顶部压力值为7.81m（501.56m- 489.00m- 9.5/2m），满足要求；下游侧最小压力值发生在出水口处，为59.16m，相应管道顶部压力值为6.41m（59.16m- 48.00m- 9.5/2m），满足2m正压的要求。可知，整个水道系统（上游侧引水管、下游侧尾水管）内的压力满足不小于2.0m的控制要求。

1. **小波动过渡过程计算结论**

在调速器参数=1.1，=0，=0.3、=5.0s、=0.02s，电网自调节系数=0.0的条件下，小波动工况的机组转速均可在24.32s内进入±0.4%的转速波动带宽；四台机机组转速最大偏差分别为22.51r/min（1#机）、22.81r/min（2#机）、22.74 r/min（3#机）和22.66 r/min（4#机）；四台机转速进入±0.4%带宽的振荡次数小于等于2.5次；上述结果表明，采用报告提出的调速器参数可使本电站的小波动过渡过程同时具有较好的稳定性和调节品质。

1. **水力干扰过渡过程计算结论**

1） 在调速器参与频率调节的条件下，在调速器参数取=1.1，=0.0，=0.3、=5.0s、=0.02s，电网自调节系数=0.0时，调速器参与频率调节的条件下， 各工况下转速进入±0.4％带宽最大调节时间为152.72s左右，振荡次数达10次，但转速波动是衰减的；额定水头工况GR6，运行机组（1#机）最大超出力为84.59MW，超出力幅度为27.60%，出力进入110%额定出力带宽范围持续时间为65.04s。

2）在调速器参与功率调节条件下，在调速器参数取=0.04，，，s，电网自调节系数=0.0时，额定水头工况GR6，运行机组（1#机）最大超出力为113.68MW，超出力幅度为37.13%，进入110%出力限制线时间为52.08s。

3）从水力干扰过渡过程来看，频率调节和功率调节模式下，机组出力均能进入110%出力限制线内，调速器参与功率调节时运行机组的最大出力摆幅比调速器参与频率调节时基本上要大，而调压室室涌浪的振幅基本接近。两种调节模式下，机组出力及调压室涌浪有所差别，主要是由不同调节模式下调速器参数不同，而且导叶开度变化过程也不同导致的。