

武汉理工大学课程设计计算说明书

课程名称：卷筒 $d=340\text{mm}$ 带速 $v=0.75\text{ m/s}$ $T=450\text{ N}\cdot\text{m}$

Day 1

1. 传动方案拟定
2. 电机选型
3. 传动比分配
4. 运动和动力参数计算
5. V带
6. 参数修正

① 课本 P_9 图 2-3 (a)

② 电动机的选择

1. 工作机所需功率

$$(P_w = Fv = \frac{T}{\frac{d}{2}} = \frac{2T}{d} = 2647.058824 \text{ kW}) \times$$

验证：工作机转速：

$$n = \frac{60v}{\pi D} = \frac{60 \times 0.75}{\pi \times 0.340} = 42.12924964 \text{ r/min}$$

书 P_6

$$P'_w = T \cdot n / 9550 = 1.985147889 \text{ kW} \leftarrow \text{这个没算滚筒}$$

2. $\eta = \eta_v \eta_{\text{齿轮}}^2 \eta_{\text{轴承}}^3 \eta_{\text{联轴器}}$

$$P_w = \frac{P'_w}{\eta_{\text{滚筒}}} = 2.067862384 \text{ kW}$$

$$= 0.95 \times 0.97^2 \times 0.98^3 \times 0.99$$

8级精度
油润滑

$$= 0.832876283$$

3. 电动机所需功率

$$P_d' = P'_w / \eta = \frac{1.985147889 \text{ kW}}{0.832876283} = 2.383484714 \text{ kW}$$

(未计滚筒)

$$P_d = P_d' / \eta_{\text{滚筒}} = 2.482796576 \text{ kW}$$

选取 $Y100 L 2-4$ 的电机

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课程名称：

4. 电动机数据 / 传动比

型号	额定功率/kW	满载转速/(r/min)	额定转矩	最大转矩
Y100L2	3	1430	2.2	2.3

$$\text{总传动比} = \frac{\text{满载转速}}{\text{泵同转速}} = \frac{1430 \text{ r/min}}{42.12924964 \text{ r/min}} = 33.94316329$$

$$5. \quad i_{\text{高}} = (1.3 - 1.4) i_{\text{低}}$$

* 二个大齿轮直径相差小于(60-70)

$$i_v = 3 \text{ 左右}$$

Plan A:

$$i = i_v \cdot i_{\text{高}} \cdot i_{\text{低}}$$

其中 $i_v = 3$

$$i = 3 \cdot 1.3 i_{\text{低}}^2$$

$$i_{\text{低}} = \sqrt{\frac{i}{3 \cdot 1.3}} = 2.950148336$$

$$i_{\text{高}} = 1.3 i_{\text{低}} = 3.835192836$$

6. 运动和动力参数计算

① 转速计算 $n_m \rightarrow n_v \rightarrow n_{\text{高}} \rightarrow n_{\text{低}}$

$$n_0 = n_m = 1430 \text{ r/min}$$

$$n_I = n_m / i_v = 476.6666667 \text{ r/min}$$

$$n_{II} = n_I / i_{\text{高}} = 124.2875357 \text{ r/min}$$

$$n_{III} = n_{II} / i_{\text{低}} = 42.12924965 \text{ r/min}$$

$$n_{IV} = n_{III}$$

② 功率计算

$$P_I = P_d / \eta_v = 2.61347008 \text{ kW}$$

$$P_{II} = P_I / (\eta_v \eta_{\text{高}}) = 2.694299052 \text{ kW} = 2.749284746 \text{ kW}$$

$$P_{III} = P_{II} / (\eta_{\text{低}} \eta_{\text{高}}) = 2.777627888 \text{ kW} = 2.892157318 \text{ kW}$$

$$P_{IV} = P_{III} / (\eta_{\text{低}} \eta_{\text{高}}) = 2.980490845 \text{ kW}$$

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$$P_I = P_d \cdot \eta_v = 2.358656744 \text{ kW}$$

$$P_{II} = P_I \cdot \eta_{\text{轴承}} \cdot \eta_{\text{联轴器}} = \cancel{2.360464221} \text{ kW} \quad 2.242139101 \text{ kW}$$

$$P_{III} = P_{II} \cdot \eta_{\text{低}} \cdot \eta_{\text{轴承}} = \cancel{2.3604} \text{ kW} \quad 2.13137743 \text{ kW}$$

$$P_{IV} = P_{III} \cdot \eta_{\text{联轴器}} \cdot \eta_{\text{轴承}} = 2.067862382 \text{ kW}$$

转矩

$$T_I = 9550 P / n = 47.25560 \text{ N} \cdot \text{m}$$

$$T_{II} = \dots = 172.281381 \text{ N} \cdot \text{m}$$

$$T_{III} = \dots = 483.147804 \text{ N} \cdot \text{m}$$

$$T_{IV} = \dots = 468.749999 \text{ N} \cdot \text{m}$$

工况信息：

双班制 (16 h/天)

轻微振动 寿命10年

轴承寿命 3年

V带 $P = 3 \text{ kW}$, $n_1 = 1430 \text{ r/min}$, $n_2 = 476.666667 \text{ r/min}$

工况系数 K_A | 课本 P103 表 4-1 | 1.2

计算功率 $P_c (\text{kW})$ | $P_c = K_A \cdot P$ | 3.6 kW

V带型号 | 课本 P104 表 4-8/9 | Z型 | A型

小轮直径 d_1 | 课本 P104 表 4-12 | 80 mm | 100 mm

验算带速 v | $v = \pi d_1 n_1 / 60000$ | $\cancel{6.1156} \text{ m/s}$ | $\cancel{7.6445} \text{ m/s}$

大轮直径 d_2 | $d_2 = d_1 n_1 / n_2$ | $\cancel{250} \text{ mm}$ | 300 mm

从动轮转速 n_2' | $n_2' = n_1 d_1 / d_2$ | 484.746 r/min | 476.667 r/min

从动轮误差 | $(n_2' - n_2) / n_2$ | +0.01695 | 0

初定中心距 a_0 | $a_0 = (0.75 \sim 0.80)(d_1 + d_2)$ | 252.8 mm | 320 mm

初算带长 L_c | 见课本公式 | 1026.038 mm | 1299.569 mm

选定基准长度 L | 表 4-8/9 | 1080 mm | 1250 mm

定中心距 a | $a \approx a_0 + (L_d - L_c) / 2$ | 280 mm | 295 mm

a_{\min} | $a_{\min} = a - 0.015 L_d$ | 263.8 mm | 276.25 mm

a_{\max} | $a_{\max} = a + 0.03 L_d$ | 312.4 mm | 332.5 mm

验算包角 α_1 | | 148.076° | 141.15°

单根带基本额
定功率 P_0 | | 1.346 kW | 1.3056 kW

传动比 i | 12.95 | 3

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课程名称：	Z型	A型
功率增量 ΔP_0	0.0261 kW	0.173 0.227 kW
长度系数 K_L	1.07	0.93
包角系数 K_a	0.914	0.893
单根带许用 $[P_0]$	0.3639 kW	11.228 1.273 kW
V带根数 z	10 (9.893)	3 (2.9312 2.828)
V带单位长度质量 q	0.06 kg/m	0.105 kg/m
初拉力 F_0	54.2966 N	150.09 N
轴上压力 F_Q	1044.063	849.279

8. 参数修正

$$\left(\begin{array}{l} n_0 = n_m = 1430 \\ n_I = n_m / i_v = \\ n_{II} = n_I / i_{II} \\ n_{III} = n_{II} / i_{III} \end{array} \right)$$

$$\times i_v' = i_v$$

不用修正

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<p>课程名称: Day 2</p>	<p>双班工作 16h/天, 300天/年 轻微振动 寿命10年 轴承寿命3年</p>
<p>通用要求:</p> <p>小. 调质 240 HBS , 大正火 200 HBS , 工作10年, 45钢</p> <p>高速级齿轮: 寿命系数 \rightarrow 许用应力 \rightarrow 接触设计 \rightarrow 弯曲校核</p> <p>\rightarrow 几何尺寸确定 \rightarrow 结构设计</p> <p>低速</p>	
<p>① 高速级齿轮 (软) 1年工作 48000h</p> <p>1. 寿命系数</p> <p>小齿轮: 工作次数 $N = \frac{4800h \cdot 60 \text{ min/h} \times 10}{\frac{1}{\frac{1}{476.6666667} \text{ r/min}}} = 1.3728 \times 10^8$</p> <p>$Y_{N1} = 1$ $Z_{N1} = 1$</p> <p>大齿轮: 工作次数 $N = 4800 \cdot 60 \cdot 10 = 3.5 \times 10^8$</p> <p>$Y_{N2} = 1$ $Z_{N2} = 1.05$</p> <p>2. 许用应力</p> <p>小齿轮: $\sigma_{Flim1} = 250 \text{ MPa}$, $\sigma_{FP1} = \frac{\sigma_{Flim1}^{(2)} Y_{St1}}{S_{Fmin1}} = 312.5 \text{ MPa}$</p> <p>$\sigma_{Hlim1} = 600 \text{ MPa}$, $\sigma_{HP1} = \frac{\sigma_{Hlim1}^{(1)} Z_R^{(1)} Z_W^{(1)}}{S_{Hmin1}} = 461.5 \text{ MPa}$</p> <p>大齿轮: $\sigma_{Flim2} = 200 \text{ MPa}$, $\sigma_{FP2} = \frac{\sigma_{Flim2}^{(2)} Y_{St2}}{S_{Fmin2}} = 250 \text{ MPa}$</p> <p>$\sigma_{Hlim2} = 400 \text{ MPa}$, $\sigma_{HP2} = \frac{\sigma_{Hlim2}^{(1.08)} Z_R^{(1.08)} Z_W^{(1.08)}}{S_{Hmin2}} = 332.3 \text{ MPa}$</p> <p>3. 接触设计</p> <p>\Rightarrow 小齿轮 $[\sigma_{F1}] = 312.5 \text{ MPa}$ $[\sigma_{H1}] = 332.3 \text{ MPa}$</p> <p>大齿轮 $[\sigma_{F2}] = 250 \text{ MPa}$ $[\sigma_{H2}] = 332.3 \text{ MPa}$</p>	

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课程名称：

3. 接触设计 (两齿轮都是钢制)

$$\text{计算公式: } d_1 \geq 753 \sqrt[3]{\frac{KT_L}{\psi_{HP}^2} \cdot \frac{u+1}{u}} \quad (Z_E = 189.8 \sqrt{\text{MPa}})$$

① 名义转矩

$$T_L = 47.25560 \text{ N} \cdot \text{m}$$

② $\psi_H = 1.0$

③ 斜齿轮, 8级

$$K = K_A \cdot K_V \cdot K_\beta \cdot K_\alpha = 1.66$$

1.25 1.1 1.1 1.1

④ $\beta = 8^\circ$

⑤ $u = i_L = 3.835192836$

$$\Rightarrow d_1 \geq \cancel{502.75 \text{ mm}} = 72.58 \text{ mm}$$

⑥ 确定模数、齿数

$$\text{取 } Z_1 = 24, Z_2 = i_L Z_1 = 92$$

$$m_n = \frac{12.58 \times 0.99}{24} = 2.99$$

$$\Rightarrow m_n = 3 \text{ mm}$$

$$\therefore a = \frac{m_n (Z_1 + Z_2)}{2 \cos \beta} = 175.7 \text{ mm}$$

⑦ 主要参数 (几何尺寸)

$$a = \frac{m_n (Z_1 + Z_2)}{2 \cos \beta} = \frac{3(24 + 92)}{2 \times \cos 8^\circ} = 175.7 \text{ mm}$$

$$\cancel{\cos \beta = \frac{m_n (Z_1 + Z_2)}{2a}}$$

$$\text{取 } a = 180 \text{ mm}$$

$$\cos \beta = \frac{m_n (Z_1 + Z_2)}{2a} = 0.96667, \quad \beta = 14^\circ 50' 6.4''$$

⑧ 几何尺寸

$$d_1 = \frac{m_n Z_1}{\cos \beta} = 74.483 \text{ mm}$$

$$d_2 = \frac{m_n Z_2}{\cos \beta} = 285.517 \text{ mm}$$

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课程名称：

$$b_2 = \psi_d \cdot d_1 = 1 \cdot d_1 = 74.483 \text{ mm}, \text{取 } b_2 = 75 \text{ mm}$$

$$b_1 = b_2 + (5 \sim 10) \text{ mm} = (80 \sim 85) \text{ mm} \text{ 取 } b_1 = 80 \text{ mm}$$

3. 弯曲校核

$$\sigma_H = 10^9 Z_E \sqrt{\frac{KT_1}{bd_1^2} \cdot \frac{u+1}{u}} \leq \sigma_{HP}$$

~~小齿轮：~~

$$\sigma_F = \frac{2000 KT_1}{bd_1 m_n} Y_{FS} Y_\varepsilon Y_\beta$$

$$\text{其中 } Y_\beta = 1 - \frac{\beta}{120^\circ} = 0.876$$

$$Y_\varepsilon = 0.25 + \frac{0.75}{\varepsilon_a} = 0.703$$

$$\text{其中 } \varepsilon_a = [1.88 - 3.2(\frac{1}{z_1} + \frac{1}{z_2})] \cos \beta$$

$$= 1.65482126$$

$$Y_{FS1} = 4.1 \quad Y_{FS2} = 3.95$$

$$\text{其中 } z_{v1} = \frac{z_1}{\cos^3 \beta} = 26.57$$

$$z_{v2} = \frac{z_2}{\cos^3 \beta} = 101.85$$

$$23.637$$

$$\sigma_{F1} = 24.25 \text{ MPa} < [\sigma_{F1}]$$

$$\sigma_{F2} = 21.658 \text{ MPa} < [\sigma_{F2}]$$

~~大齿轮：~~

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课程名称：

高速轴几何尺寸 $m_n = 3 \text{ mm}$

$$d_1 = 74.483 \text{ mm}$$

$$d_2 = 285.517 \text{ mm}$$

$$d_{a1} = 80.483 \text{ mm}$$

$$d_{a2} = 291.517 \text{ mm}$$

$$d_{f1} = 66.983 \text{ mm}$$

$$d_{f2} = 278.017 \text{ mm}$$

$$b_1 = ~~75~~ 80 \text{ mm}$$

$$b_2 = ~~80~~ 75 \text{ mm}$$

$$a = 180 \text{ mm}$$

$$\beta = 14^\circ 50' 6.4''$$

② 低速级齿轮

1. 寿命系数

$$小 : Y_{N3} = 1, Z_{N3} = 1$$

$$大 : Y_{N4} = 1, Z_{N4} = 1.08$$

2. 许用应力

$$小 : ~~[\sigma_{H1}] = 312.5 \text{ MPa}~~ [\sigma_{F1}] = 312.5 \text{ MPa}$$

$$[\sigma_{H1}] = 332.3 \text{ MPa}$$

$$大 : [\sigma_{F2}] = 250 \text{ MPa}$$

$$[\sigma_{H2}] = 332.3 \text{ MPa}$$

1. 寿命系数

$$小 齿轮 : 工作次数 N_3 = 4800 \text{ h} \cdot 60 \text{ min/h} \cdot n_{II} = 3.58 \times 10^8$$

$$Y_{N3} = 1$$

$$Z_{N3} = 1.015$$

$$大 齿轮 : 工作次数 N_4 = 4800 \text{ h} \cdot 60 \text{ min/h} \cdot n_{III} = 1.21 \times 10^8$$

$$Y_{N4} = 1$$

$$Z_{N4} = 1.08$$

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课程名称：

2. 许用应力

$$\text{小齿轮: } \sigma_{Flim3} = 200 \text{ MPa}, \quad \sigma_{FP1} = \frac{\sigma_{Flim3} Y_{St3}^{(2)}}{(1.6) S_{Fmin3}} = 250 \text{ MPa}$$

$$\sigma_{Hlim3} = 600 \text{ MPa}, \quad \sigma_{HP1} = \frac{\sigma_{Hlim3} Z_{N3}^{(1)} Z_{N2}^{(1)}}{(1.3) S_{Hmin3}} = 461.5 \text{ MPa}$$

$$\text{大齿轮 } \sigma_{Flim4} = 200 \text{ MPa}, \quad \sigma_{FP2} = \frac{\sigma_{Flim4} Y_{St4}^{(2)}}{(1.6) S_{Fmin4}} = 250 \text{ MPa}$$

$$\sigma_{Hlim4} = 400 \text{ MPa}, \quad \sigma_{HP2} = \frac{\sigma_{Hlim4} Z_{N4}^{(1)} Z_{N3}^{(1)}}{(1.3) S_{Hmin4}} = 332.3 \text{ MPa}$$

$$\Rightarrow \text{小齿轮 } [\sigma_{F1}] = 250 \text{ MPa}, \quad \text{大齿轮 } [\sigma_{F2}] = 250 \text{ MPa}$$

$$[\sigma_{H1}] = 332.3 \text{ MPa}, \quad [\sigma_{H2}] = 332.3 \text{ MPa}$$

3. 接触设计

$$\text{计算公式: } d_3 \geq 753 \sqrt[3]{\frac{KT_2}{\psi_d \sigma_H^2} \cdot \frac{u+1}{u}} \quad (Z_E = 189.8 \sqrt{\text{MPa}})$$

① 名义转矩

$$T_I = 172.28 \text{ N} \cdot \text{m}$$

$$\text{② } \psi_d = 1.0$$

$$\text{③ 载荷系数 } K = 1.66 \text{ (同高速)}$$

$$\text{④ } \beta = 10^\circ$$

$$\text{⑤ } u = i_{43} = 2.95$$

$$\Rightarrow d_3 \geq 113.98 \text{ mm}$$

⑥ 确定 m_n, z_3, z_4

$$\text{取 } z_3 = 40, \quad z_2 = i z_1 = 118$$

$$m_n = \frac{113.98}{40} = 2.8495 \Rightarrow \text{取 } m_n = 3 \text{ mm}$$

⑦ α, β 计算

$$a = \frac{m_n (z_3 + z_4)}{2 \cos \beta} = \frac{239.32}{2 \cos \beta} \Rightarrow \text{取 } a = 240 \text{ mm}$$

$$\cos \beta = \frac{m_n (z_3 + z_4)}{2 a} = 0.9875$$

$$\beta = 9^\circ 4' 7.4''$$

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课程名称：

⑧ 几何尺寸

$$d_3 = \frac{m_n z_3}{\cos \beta} = 121.519 \text{ mm}$$

$$d_4 = \frac{m_n z_4}{\cos \beta} = 358.48 \text{ mm}$$

$$b_4 = \psi_d \cdot d_1 = 121.519 \text{ mm} \rightarrow 122 \text{ mm}$$

$$b_3 = b_4 + (5-10) \text{ mm} \rightarrow 130 \text{ mm}$$

3. 弯曲应力

$$\sigma_F = \frac{2000 K T_3}{b d_3 m_n} Y_{FS} Y_\epsilon Y_\beta$$

$$Y_\beta = 1 - \frac{\beta}{120} = 0.924$$

$$Y_\epsilon = 0.25 + \frac{0.75}{\epsilon_a} = 0.678395$$

$$\epsilon_a = [1.88 - 3.2(\frac{1}{z_1} + \frac{1}{z_2})] \cos \beta$$

$$= 1.750720336$$

$$Y_{FS3} = 4.02 \quad Y_{FS4} = 3.95$$

$$\Rightarrow \sigma_{F3} = 32.4 \text{ MPa} \leq [\sigma_{F3}]$$

$$\sigma_{F4} = 30.3 \text{ MPa} \leq [\sigma_{F4}]$$

低速齿轮尺寸 $m_n = 3 \text{ mm}$ $a = 240 \text{ mm}$ $\beta = 9^\circ 4' 7.4''$

$$d_3 = 121.519 \text{ mm}$$

$$d_4 = 358.48 \text{ mm}$$

$$d_{a3} = 127.519 \text{ mm}$$

$$d_{a4} = 364.48 \text{ mm}$$

$$d_{f3} = 114.019 \text{ mm}$$

$$d_{f4} = 350.98 \text{ mm}$$

$$b_3 = 130 \text{ mm}$$

$$b_4 = 122 \text{ mm}$$