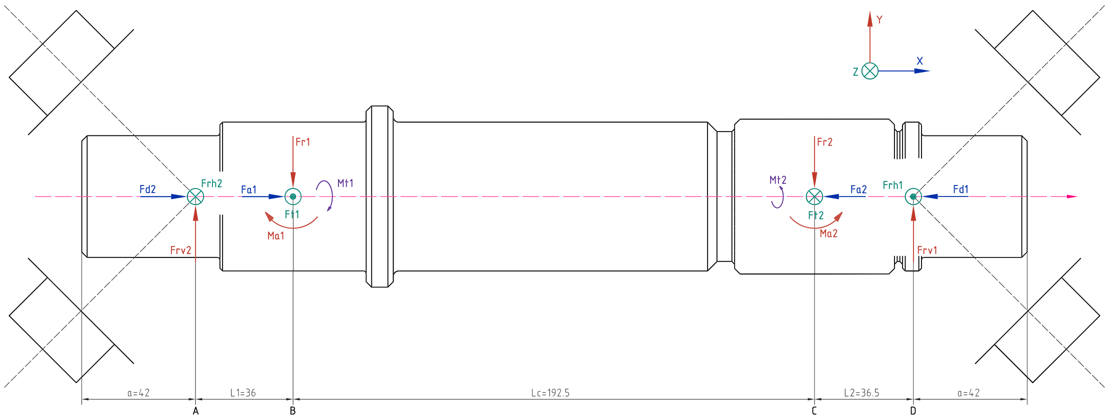


对于 cAxis 我们初选 7309B 轴承，查得轴承支点距背面的距离 $a = 42mm$，并且安装方式为正装，对于 H 面(XZ 面)有:

$$\begin{cases} \sum F_H = 0 \Rightarrow F_{rh2} - F_{t1} + F_{t2} - F_{rh1} = 0 \\ \sum M_{HA} = 0 \Rightarrow -F_{t1} * L1 + F_{t2} * (L1 + Lc) - F_{rh1} * (L1 + LC + L2) = 0 \end{cases}$$

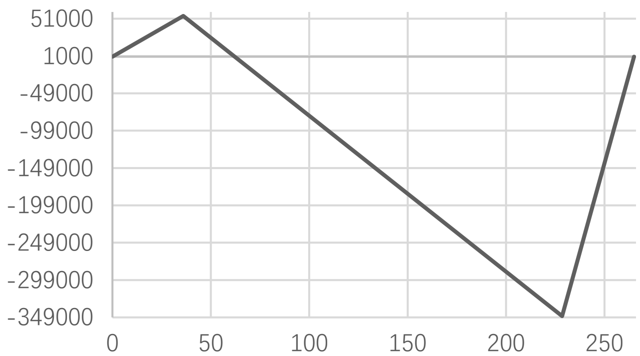
计算得 H 面的分支座反力:

$$F_{rh1} = 9514.732729779376N$$

$$F_{rh2} = 1518.4867406975986N$$

则 H 面轴的弯矩方程为:

$$\begin{cases} M(x) = F_{rh2} * x & (0 \le x \le L1) & (N * mm) \\ M(x) = F_{rh2} * x - F_{t1} * (x - L1) & (L1 \le x \le L1 + Lc) & (N * mm) \\ M(x) = -F_{rh1} * (L1 + Lc + L2 - x) & (L1 + Lc \le X \le L1 + Lc + L2) & (N * mm) \end{cases}$$



$$M_A = 0;\ M_B = 54665.5N * mm;\ M_C = -347287.7N * mm;\ M_D = 0;$$

对于 V 面有:

$$\begin{cases}\sum F_V = 0 \ \Rightarrow \ F_{rv2} - F_{r1} - F_{r2} + F_{rv1} = 0 \\ \sum M_{VA} = 0 \ \Rightarrow - F_{r1} * L1 - M_{a1} + M_{a2} - F_{r2} * (L1 + Lc) + F_{rv1} * (L1 + Lc + L2) = 0 \\ M_{a1} = F_{a1} * \dfrac{d_1}{2}; \qquad M_{a2} = F_{a2} * \dfrac{d_2}{2};\end{cases}$$

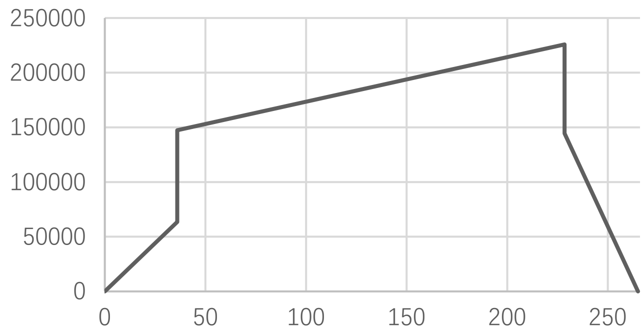
计算得 V 面的分支座反力:

$$F_{rv1} = 3955.4934131512223N$$

$$F_{rv2} = 1763.5630218096862N$$

则 V 面的弯矩方程为:

$$\begin{cases}M(x) = F_{rv2} * x & (0 \le x \le L1) & (N * mm) \\ M(x) = F_{rv2} * x - F_{r1} * (x - L1) + M_{a1} & (L1 \le x \le L1 + Lc) & (N * mm) \\ M(x) = F_{rv1} * (L1 + Lc + L2 - x) & (L1 + Lc \le x \le L1 + Lc + L2) & (N * mm)\end{cases}$$



$$M_A = 0; \ M_{BL} = 63488.3N * mm; \ M_{BR} = 147392.7N * mm;$$

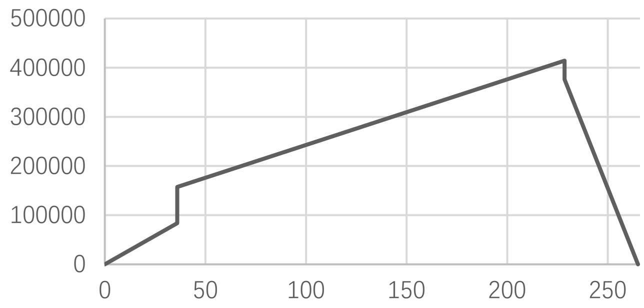
$$M_{CL} = 225820.8N * mm; \ M_{CR} = 144375.5N * mm; \ M_D = 0;$$

则轴承总支座反力为:

$$F_{r1} = \sqrt{F_{rv1}^2 + F_{rh1}^2} = 10304.177165626454N$$

$$F_{r2} = \sqrt{F_{rv2}^2 + F_{rh2}^2} = 2327.220770268461N$$

中间轴总弯矩图(矢量合成)为:



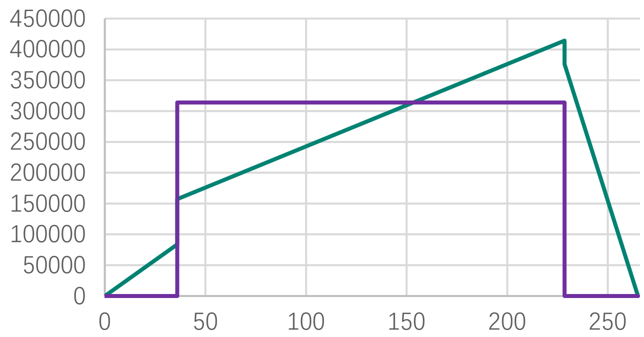
$$M_A = 0;\ \ M_{BL} = 83779.9N*mm;\ \ M_{BR} = 157203.5N*mm;$$

$$M_{CL} = 414250.8N*mm;\ \ M_{CR} = 376102.5N*mm;\ \ M_D = 0$$

对于中间轴的 BC 段，扭矩为:

$$T = M_{t2} = -M_{t1} = F_{t2} * \frac{d2}{2} = 313897.6448996824N*mm$$

中间轴的弯矩和扭矩图为:



根据弯扭图，中间轴(cAxis)危险截面为 C 截面(228.5mm 处，直径为 49mm)，轴截面因此抗弯截面系数为:

$$W_C = \frac{\pi d^3}{32} = 11374.275794573543mm^3$$

输出轴材料与热处理方式为 40Cr 调质后淬火，查得许用弯曲应力 $[\sigma_{-1}] = 70MPa$，轴所受弯矩所产生的弯曲应力为对称循环变应力，而扭矩所产生的扭转切应力为脉动循环变应力，故$\alpha = 0.6$，则轴的弯扭合成强度条件为:

$$\sigma_{ca} = \frac{\sqrt{M^2 + (\alpha T)^2}}{W} = \frac{\sqrt{(M_{CL})^2 + (\alpha M_{t2})^2}}{W_C} = 40.0073942995MPa < [\sigma_{-1}]$$

中间轴第三强度理论偏于安全.

对于输出轴轴承，设计期望寿命为 3 年 2 班制工作. 对于 7309B 轴承查表得

$F_d = eF_r(e = 0.423927$(线性插值))则:

$$\boldsymbol{F_{d1} = e * F_{r1} = 4091.7880006594523N}$$
$$\boldsymbol{F_{d2} = e * F_{r2} = 885.4157064994045N}$$

根据最大值法，轴承轴向力为:

$$\boldsymbol{F_{d2} - F_a = -1189.3229008337323N < F_{d1} = 4091N}$$
$$\boldsymbol{F_{a1} = F_{d1} = 4091.7880006594523N}$$
$$\boldsymbol{F_{d1} + F_a = 6166.52660799259N > F_{d2} = 885N}$$
$$\boldsymbol{F_{a2} = F_{d1} + F_a = 6166.52660799259N}$$

对于轴承 1，径向动载系数 X 与轴向动载系数 Y 为:

$$\boldsymbol{\frac{F_{a1}}{F_{r1}} = 0.4239 = e = 0.4239}$$
$$\boldsymbol{X_1 = 1;\quad Y_1 = 0;}$$

对于轴承 2，径向动载系数 X 与轴向动载系数 Y 为:

$$\boldsymbol{\frac{F_{a2}}{F_{r2}} = 2.95246 > e = 0.4239}$$
$$\boldsymbol{X_2 = 0.44;\quad Y_2 = 1.32024}\text{(线性插值)};$$

根据工况条件，轴承运行中冲击较小，因此$f_d = 1.1$，则两轴承动载荷 P 为:

$$\boldsymbol{P_1 = f_d * (X_1 * F_{r1} + Y_1 * F_{a1}) = 10617.32407688659N}$$
$$\boldsymbol{P_2 = f_d * (X_2 * F_{r2} + Y_2 * F_{a2}) = 9966.339975552453N}$$

因为$P_1 > P_2$，按 1 轴承的受力情况计算(对于球轴承$\varepsilon = 3$)(C 取 59500N):

$$\boldsymbol{L_h = \frac{10^6}{60n_m}\left(\frac{C}{P_m}\right)^{\varepsilon} = \frac{10^6}{60 * cAxis.n}\left(\frac{C}{P_2}\right)^{3} = 20263.8586h > [h] = 17520h}$$

中间轴轴承寿命符合设计预期.

中间轴与齿轮的连接使用 GB/T 1096-2003 键 B 16*10*50 (轴、齿轮、键的材

料均为 45) ([b, h, l] = [16, 10, 50])，轴径 d 为 55mm，工作方式为静连接，

受轻微冲击，故$[\sigma_{bs}] = 100\sim120\mathrm{MPa}$，校核该键连接:

$$\boldsymbol{\sigma_{bs} = \frac{4000 * T(N * m)}{h * work.l * d} = \frac{4000 * T * 10^{-3}(N * m)}{h * (l - b) * d} = 67.143881MPa < [\sigma_{bs}]}$$

齿轮与中间轴的键连接可靠.