HW05
第04章 轴承及轴设计
答案

南方科技大学

HW 05.1

1. 有一混合摩擦径向滑动轴承，轴颈直径$d = 60mm$，轴承宽度B $= 60mm$，轴瓦材料为ZCuAl10Fe3，试求：

(1). 当载荷$F_r = 36000N$，转速$n = 150\ r/min$时，校核轴承是否满足非液体润滑轴承的使用条件；

(2). 当载荷$F_r = 36000N$时，求轴的允许转速n；

(3). 当轴的转速$n = 960\ r/min$时，求轴的允许载荷F_r；

(4). 求轴的最大允许转速 n_{max}。

1. If there is a mixed friction journal bearing, where the shaft journal diameter $d = 60mm$, the width of the bearing B $= 60mm$, and the material of the bearing shell is ZCuAl10Fe3.

(1) If the load $F_r = 36000N$, and the shaft speed $n = 150\ r/min$, does the bearing meets the standard for non liquid lubricated bearings in this working condition?

(2) When the load $F_r = 36000N$, find the allowable speed of the shaft, n;

(3) If the speed $n = 960\ r/min$, what is the allowable load, F_r?

(4) What is the maximum allowable speed, n_{max}?

解　根据轴瓦材料 ZCuAl10Fe3，可查得　For the material ZCuAl10Fe3,

$$[p]=15\ \text{MPa},\quad [pv]=12\ \text{MPa}\cdot(\text{m/s}),\quad [v]=4\ \text{m/s}$$

(1) 当载荷 $F_r=36000$ N，转速 $n=150$ r/min 时，有

$$p=\frac{F_r}{dB}=\frac{36000}{60\times 60}\ \text{MPa}=10\ \text{MPa}<[p]$$

$$v=\frac{\pi dn}{60\times 1000}=\frac{3.14\times 60\times 150}{60\times 1000}\ (\text{m/s})=0.471\ \text{m/s}<[v]$$

$$[pv]=10\times 0.471\ \text{MPa}\cdot\text{m/s}=4.71\ \text{MPa}\cdot(\text{m/s})<[pv]$$

由此可知，该轴承满足使用要求。

Therefore, this bearing meets the standard for non liquid lubrication.

(2) 由 $pv=\frac{F_r}{Bd}\cdot\frac{\pi dn}{60\times1000}\leqslant[pv]$ 可得

$$n\leqslant\frac{60\times1000\times B\times[pv]}{\pi F_r}=\frac{60\times1000\times60\times12}{3.14\times36000}\ \text{r/min}=382.2\ \text{r/min}$$

故轴的允许转速为 382.2 r/min。 So the allowable speed is 382.2 *r/min*.

(3) 由 $pv=\frac{F_r}{Bd}\cdot\frac{\pi dn}{60\times1000}\leqslant[pv]$ 可得

$$F_r\leqslant\frac{60\times1000\times B\times[pv]}{\pi n}=\frac{60\times1000\times60\times12}{3.14\times960}\ \text{N}=14331.2\ \text{N}$$

所以轴的允许载荷 $F_r=14331.2$ N。 So the allowable load is 14331.2 *N*.

(4) 已知 $v=\frac{\pi dn}{60\times1000}$，因为 $v\leqslant[v]=4$ m/s，所以

$$n_{max}=\frac{60\times1000[v]}{\pi d}=\frac{60\times1000\times4}{3.14\times60}\ \text{r/min}=1273.9\ \text{r/min}$$

HW 05.2

2. 一轴上装有一对6313型深沟球轴承，轴承所受的负荷$R_1 = 5500\,N$、$A_1 = 3000\,N$、$R_2 = 6500\,N$、$A_2 = 0$，其转速$n = 1250\,r/min$，运转时有轻微冲击，预期寿命$L_h \geq 5000\,h$。试分析该轴承是否合用。

A pair of type-6313 deep groove ball bearing is assembled on a shaft, and the loads on the shaft are $R_1 = 5500\,N$、$A_1 = 3000\,N$、$R_2 = 6500\,N$、$A_2 = 0$. The speed of the shaft $n = 1250\,r/min$, and slight impact exists during the operation. The life expectancy for the shaft and bearing $L_h \geq 5000\,h$. Please analyze whether the bearings meets the standard.

查设计手册 6313 型轴承的 $C_r=72200$ N，$C_{0r}=56500$ N；轻微冲击，取 $f_p=1.2$；常温下工作，$f_t=1$。

首先，计算轴承的当量动负荷 P： The equivalent dynamic load:

$A_1/C_{0r}=3000/56500=0.0531$，查表 $e\approx0.26$；

$A_1/R_1=3000/5500=0.545>e$，查表 $X=0.56$，$Y=1.71$。

因轻微冲击，$f_p=1.2$，则 Since there exists slight impact, take $f_p = 1.2$.

$$P_1 = f_p(XR_1+YA_1) = 1.2(0.56\times5500+1.71\times3000)\ \text{N} = 9852\ \text{N}$$

$$P_2 = f_pR_2 = 1.2\times6500\ \text{N} = 7800\ \text{N}$$

因 $P_1>P_2$，则按轴承 1 计算其寿命。 Since $P_1>P_2$, take bearing 1's lifespan as the final lifespan.

其次，计算轴承寿命，判断其是否满足预期寿命的要求（球轴承 $\varepsilon=3$）：

$$L_{h1} = \frac{10^6}{60n}\left(\frac{C_rf_t}{P_1}\right)^{\varepsilon} = \frac{10^6}{60\times1250}\left(\frac{72200\times1}{9852}\right)^3\ \text{h} = 5251\ \text{h} > 5000\text{h}$$

$$L_{h2} > L_{h1}$$

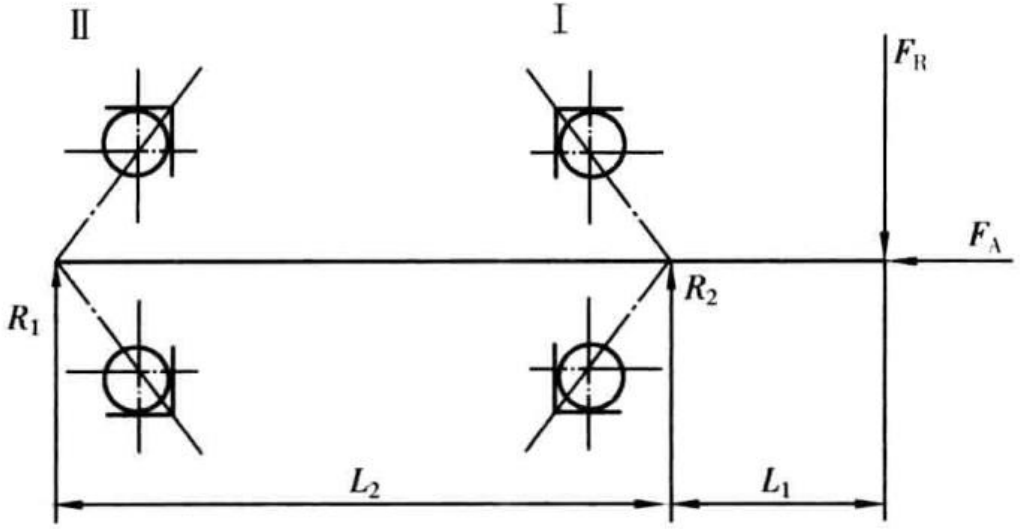
则两轴承寿命满足要求。

Therefore, this pair of bearing meet the working standard.

HW 05.3

如图所示，一根轴用两个角接触球轴承支承， $L_1 = 50mm$, $L_2 = 150mm$, 轴端作用轴向力$F_A = 800N$, 径向力$F_R = 1500N$。试分别求出两轴所承受的径向负荷R_1,R_2, 以及轴向负荷A_1, A_2. （轴承内部轴向力$S = 0.7R$）

As shown in the figure, a shaft is supported by two angular contact ball bearings, where $L_1 = 50mm$, $L_2 = 150mm$, the axial force $F_A = 800N$, radial force $F_R = 1500N$. Please find out the radial load R_1,R_2, and axial load A_1, A_2 for the 2 axis. (the axial force inside the bearings are $S = 0.7R$)



(1) 求 R：

The direction of R is indicated by the dashed line

$$R_2 = \frac{-F_R \cdot L_1}{L_2} = \frac{-1500 \times 50}{150}\ \text{N} = -500\ \text{N}(\text{方向如虚线所示})$$

$$R_1 = \frac{F_R(L_1 + L_2)}{L_2} = \frac{1500(50+150)}{150}\ \text{N} = 2000\ \text{N}$$

(2) 求 S：

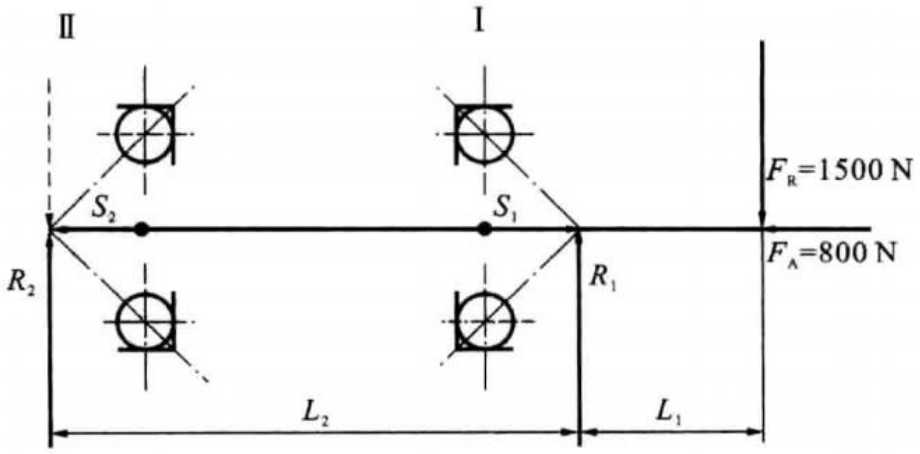
$$S_1 = 0.7R_1 = 0.7 \times 2000\ \text{N} = 1400\ \text{N}$$

$$S_2 = 0.7R_2 = 0.7 \times 500\ \text{N} = 350\ \text{N}$$

(3) 求 A：

轴承 Ⅰ $\begin{cases} A_1 = S_1 = 1400\ \text{N} \\ A_1 = S_2 + F_A = (350+800)\ \text{N} = 1150\ \text{N} \end{cases}$ 所以 $A_1 = 1400\ \text{N}$

轴承 Ⅱ $\begin{cases} A_2 = S_2 = 350\ \text{N} \\ A_2 = S_1 - F_A = (1400-800)\ \text{N} = 600\ \text{N} \end{cases}$ 所以 $A_2 = 600\ \text{N}$



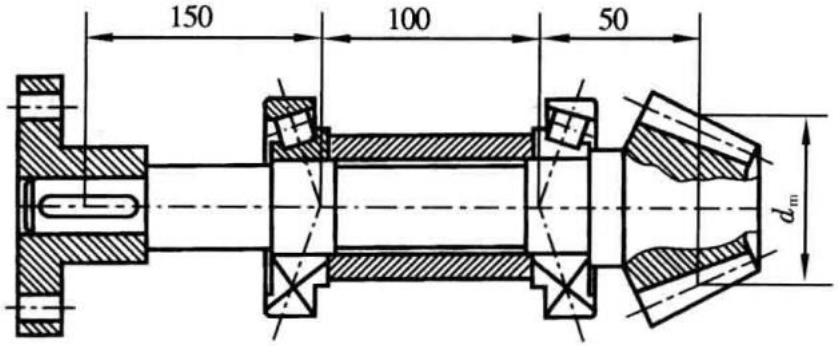
HW 05.4

如图所示的锥齿轮减速器主动轴，已知锥齿轮的平均分度圆直径$d_m = 56.25mm$, 所受圆周力$F_t = 1130N$, 径向力$F_r = 380N$, 轴向力$F_a = 146N$.

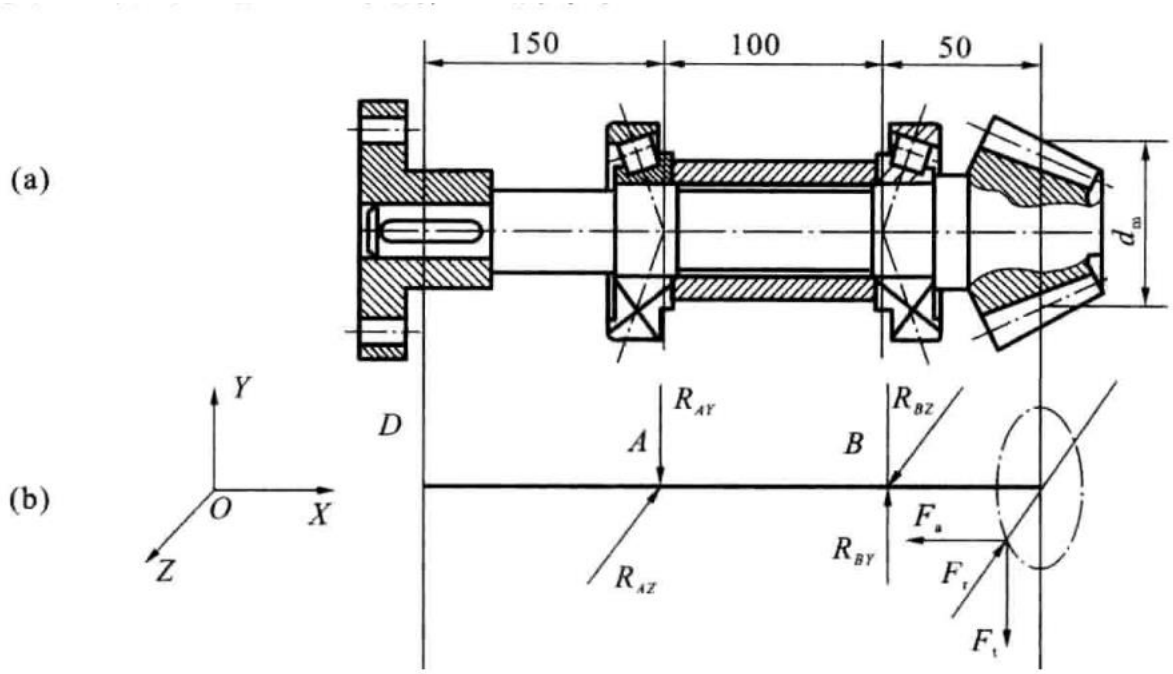
(1) 画出轴的受力简图;
(2) 计算支承反力;
(3) 画出轴的弯矩图、合成弯矩图及转矩图。

A driving shaft of a bevel gear reducer is as shown in the figure below. The pitch circle diameter for the bevel gear $d_m = 56.25mm$, the circumferential force $F_t = 1130N$, the radial force $F_r = 380N$, the axial force $F_a = 146N$.

(1) Please draw the simplified force diagram of the shaft.
(2) Calculate the bearing reaction.
(3) Draw the bending moment, the resultant bending moment, and the torque on this shaft.



(1) The force diagram is as shown in fig.(b) below.



(2) On the vertical plane, since $\sum M_A = 0$, 即 $-R_{BY} \times 100 + F_t \times 150 = 0$,

$$R_{BY} = \frac{F_t \times 150}{100} = \frac{1130 \times 150}{100}\ \text{N} = 1695\ \text{N}$$

Since $\sum Y = 0$

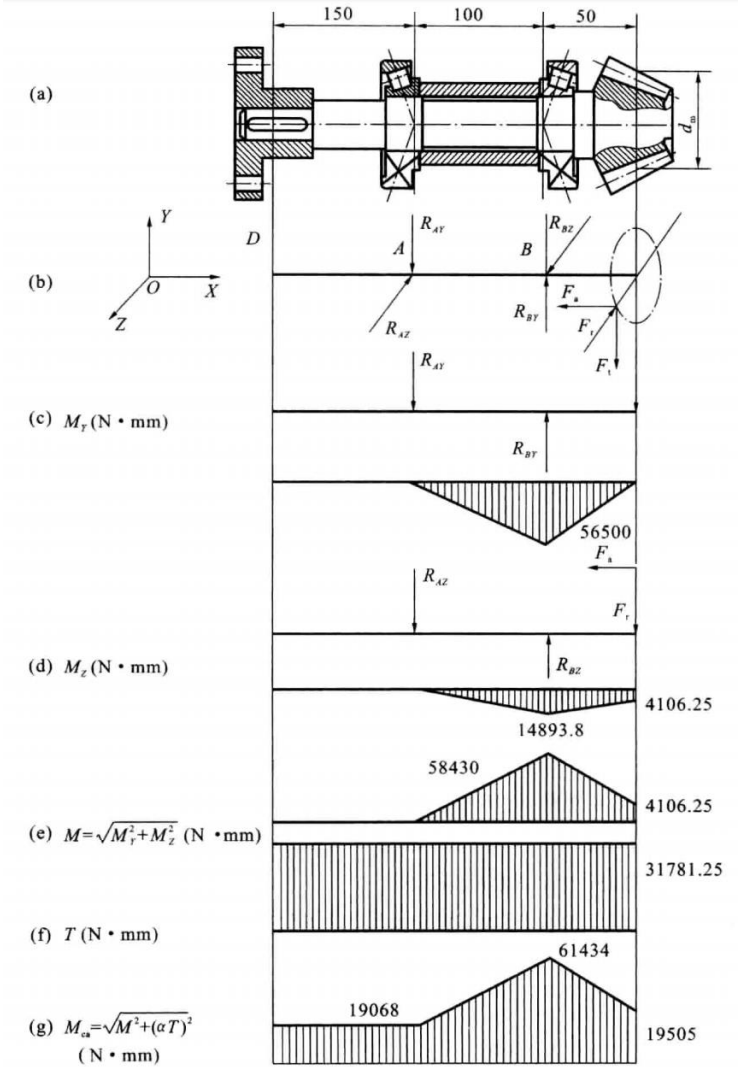
$$R_{AY} = R_{BY} - F_t = (1695 - 1130)\ \text{N} = 565\ \text{N}$$

On the horizontal plane, since $\sum M_A = 0$, 即 $R_{BZ} \times 100 + F_a d_m/2 - F_r \times 150 = 0$

$$R_{BZ} = \frac{F_r \times 150 - F_a d_m/2}{100} = \frac{380 \times 150 - 146 \times 56.25/2}{100}\ \text{N} = 528.938\ \text{N}$$

And since $\sum Z = 0$

$$R_{AZ} = R_{BZ} - F_r = (528.938 - 380)\ \text{N} = 148.938\ \text{N}$$



(3)

Bending moment on the vertical plane is shown in fig.(c).

①垂直面弯矩 M_Y 图如题 7-54 图解(c)所示。

B 点的弯矩 Bending moment at point B

$$M_{BY}=R_{AY}\times 100=565\times 100\ \text{N}\cdot\text{mm}=56500\ \text{N}\cdot\text{mm}$$

Bending moment on the horizontal plane is shown in fig.(d).

②水平面弯矩 M_Z 图如题 7-54 图解(d)所示。

B 点的弯矩 Bending moment at point B

$$M_{BZ}=R_{AZ}\times 100=148.938\times 100\ \text{N}\cdot\text{mm}=14893.8\ \text{N}\cdot\text{mm}$$

C 点的弯矩 Bending moment at point C

$$M_{CZ}=F_a d_m/2=146\times 56.25/2\ \text{N}\cdot\text{mm}=4106.25\ \text{N}\cdot\text{mm}$$

The resultant bending moment is shown in fig.(e).

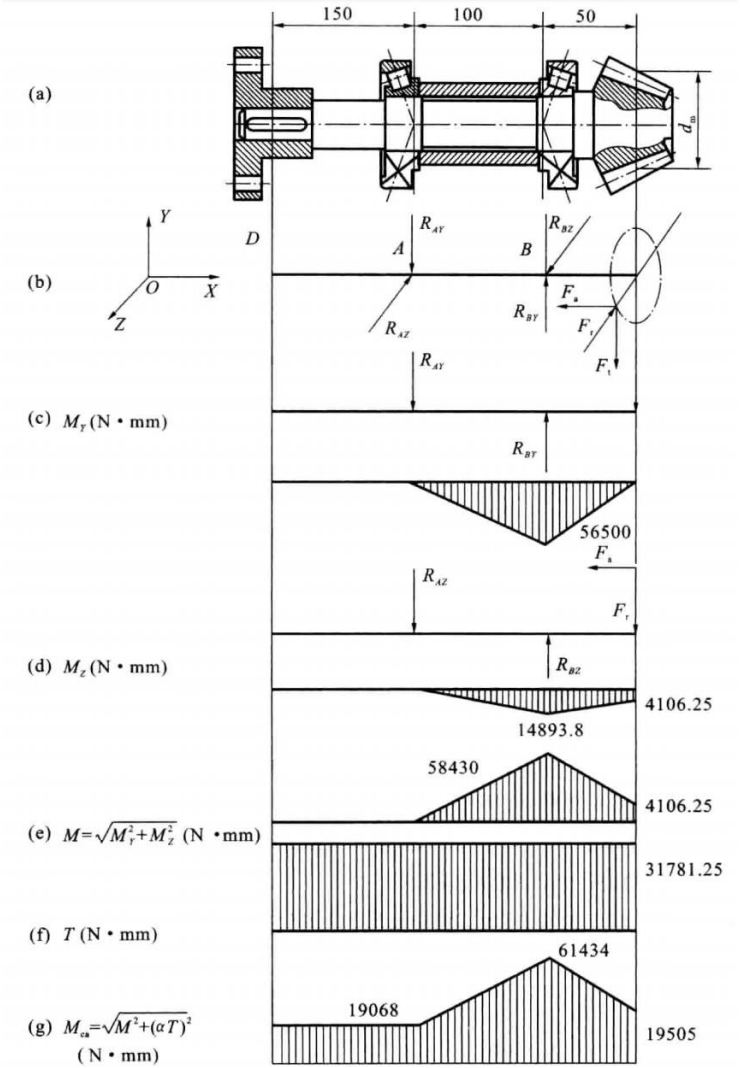
③合成弯矩 M 图如题 7-54 图解(e)所示。

B 点的弯矩 Bending moment at point B

$$M_B=\sqrt{M_{BY}^2+M_{BZ}^2}=\sqrt{56500^2+14893.8^2}\ \text{N}\cdot\text{mm}=58430\ \text{N}\cdot\text{mm}$$

C 点的弯矩 Bending moment at point C

$$M_C=\sqrt{M_{CY}^2+M_{CZ}^2}=\sqrt{0^2+4106.25^2}\ \text{N}\cdot\text{mm}=4106.25\ \text{N}\cdot\text{mm}$$



(3)

The torque on the shaft is shown in fig.(f).

④作转矩图如题 7-54 图解(f)所示。

$$T=F_t d_m/2=1130\times 56.25/2\ \text{N}\cdot\text{mm}=31781.25\ \text{N}\cdot\text{mm}$$

The equivalent bending moment is shown in fig.(g).

⑤作计算弯矩图如题 7-54 图解(g)所示。

This shaft works in one direction. Take $\alpha = 0.6$.

该轴单向工作,转矩产生的弯曲应力按脉动循环应力考虑,取 $\alpha=0.6$。

B 点的弯矩 Bending moment at point B

$$M_{caB}=\sqrt{M_B^2+(\alpha T_B)^2}=\sqrt{58430^2+(0.6\times 31781.25)^2}\ \text{N}\cdot\text{mm}$$
$$=61434\ \text{N}\cdot\text{mm}$$

C 点的弯矩 Bending moment at point C

$$M_{caC}=\sqrt{M_C^2+(\alpha T_C)^2}=\sqrt{4106.25^2+(0.6\times 31781.25)^2}\ \text{N}\cdot\text{mm}$$
$$=19505\ \text{N}\cdot\text{mm}$$

A 点的弯矩 Bending moment at point A

$$M_{caA}=\sqrt{M_A^2+(\alpha T_A)^2}=\alpha T=0.6\times 31781.25\ \text{N}\cdot\text{mm}=19068\ \text{N}\cdot\text{mm}$$

Deadline of this homework: Nov 21 @ **23:30**

Link to submission:
https://ancorasir.com/?page_id=3987

All homework MUST be hand-written.
No late submission is allowed!

Please refer to the above link for further details on how to make the submission and the detailed deadline for submission.

谢谢~

南方科技大学