Vehicle Engineering Comprehensive Exam

1. Review the principles of shaft bearing design, the possibility and conditions for installing rolling bearings for various applications; steps of rolling bearing selection for prescribed service life.

1.1. Represent the shaft locating bearing arrangement of the rotating shafts with the lines of action of the bearings. Describe the applicable bearing types with the appropriate ring support: shaft locating bearings, non-locating (floating) bearings.

1.2. Represent the cross located shaft bearing arrangement of the rotating shafts with the lines of action of the bearings. Describe the applicable types of bearings with the appropriate ring support: cross located support, radial support and only one axial direction retaining.

1.3. The radial direction bearing force is known of a single-row deep groove ball bearing used as a non-locating bearing. Determine the basic dynamic load rating C required for bearing selection, for a given shaft rpm and prescribed service life.

F_r= 6500N, n = 2960 1/min , L_h = 18000 hours

2. Review the most commonly used frictional and positive connection power transmission, their operating principle, and the steps of drive design (belt and chain drive). Describe the characteristics of gear drives, their application fields, and the basic geometric relationships.

2.1. Review the steps of the belt drive design. What is the ratio of the slack and the tight belt force of the flat belt drive, if the contact angle $\beta = 180^o$, and the friction coefficient $\mu = 0{,}3$?
How much is the peripheral force when ignoring the centrifugal force acting on the belt and the tension force of the shaft H = 200 N, and the tight belt force is 150 N?

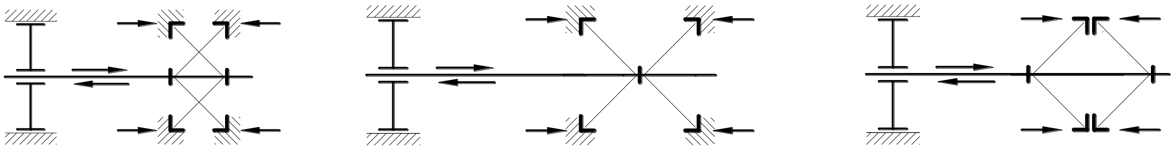
2.2. Review the steps of the chain drive design. Based on the take-up capacity of the sprocket, and the polygon effect of the chain drive, determine the number of teeth of the driver and driven sprocket for the different drive demands.

2.3. The reference center distance, the gear ratio, the module and number of teeth of an involute tooth profile spur gear drive are known. In order to achieve the prescribed working center distance, determine the working transfer pressure angle and represent it graphically as well, from which the Summa x addendum modification coefficient can be determined.

Task solutions

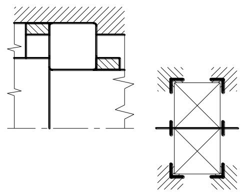
1.1. Represent the shaft locating bearing arrangement of the rotating shafts with the lines of action of the bearings. Describe the applicable bearing types with the appropriate ring support: shaft locating bearings, non-locating (floating) bearings.

Shaft locating bearing arrangements:



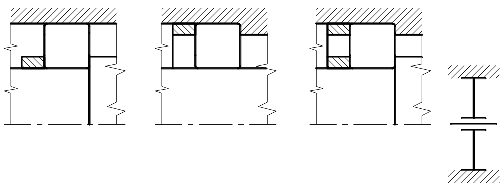
Shaft locating bearing:

- deep groove ball bearings
- self aligning ball and roller bearings
- double row angular contact ball bearing
- cylindrical roller-bearing without supporting discs



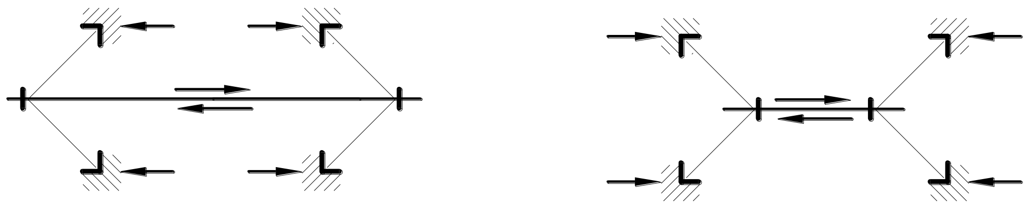
Non-locating (floating) bearings

- deep groove ball bearing
- self aligning ball and roller bearings
- cylindrical roller-bearing without supporting discs
- needle-roller bearing



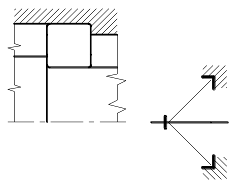
1.2. Represent the cross located shaft bearing arrangement of the rotating shafts with the lines of action of the bearings. Describe the applicable types of bearings with the appropriate ring support: cross located support, radial support and only one axial direction retaining.

Cross located shaft bearing arrangement:



Cross located support

- deep groove ball bearing
- self aligning ball and roller bearings
- single row angular contact ball bearings
- taper roller bearings

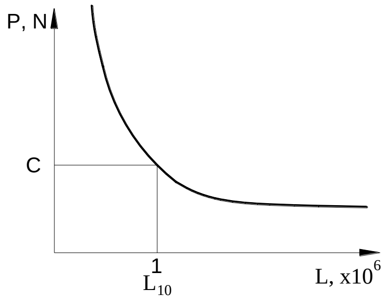


1.3. The direction bearing force is known of a single-row deep groove ball bearing used as a non-locating bearing. Determine the basic dynamic load rating C required for bearing selection, for a given shaft rpm and prescribed service life.

F_r= 6500N, n = 2960 1/min , L_h = 18000 hours

$P=F_r= 6500N$ basic dynamic load (since no axial force acts)

$$C=\sqrt[3]{L}P$$
$$L=60\left[\frac{\min}{h}\right]L_h[h]n\left[\frac{1}{\min}\right]\frac{1}{10^6}$$
$$L=60\frac{\min}{h}\cdot 18.000h\cdot 2960\frac{1}{\min}\cdot\frac{1}{10^6}=3200$$
$$C=\sqrt[3]{3200}\,6500\,N=95{,}8KN$$



2.1. Review the steps of the belt drive design. What is the ratio of the slack and the tight belt force of the flat belt drive, if the contact angle $\beta = 180^o$, and the friction coefficient $\mu = 0{,}3$?

How much is the peripheral force when ignoring the centrifugal force acting on the belt and the tension force of the shaft H = 200 N, and the tight belt force is 150 N?

$$H = 2T_o = T_1 + T_2 = 200\ N$$

$$\frac{T_1}{T_2} = \varepsilon = e^{\mu\beta} = 2{,}56$$

If, $T_1 = 150\ N, T_2 = 50\ N, than\ F_{ker} = 100\ N$

1. Determining the diameter of pulleys based on the optimal belt speed

$$v_{opt.}=18...22\frac{m}{s}$$

$$v=d_{p_1}\pi n_1 \Rightarrow d_{p_1}=\frac{v}{\pi n_1}\Rightarrow d_{p_1\ stand}$$

$$d_{p_2}=id_{p_1}\Rightarrow d_{p_2\ stand}$$

2. Choice of belt size according to
   - belt speed
   - transmittable power
3. Preliminary center distance

$$0.7\left(d_{p_1}+d_{p_2}\right)<a<2\left(d_{p_1}+d_{p_2}\right)$$

4. Calculating the belt length, choosing the standardized one.
5. Number of V-belts

$$P_1=P_0\frac{c_1c_3c_4}{c_2}[KW]$$

P_o – nominal power transmittable by one belt
P_1 – transmittable power by one belt

$$Z=\frac{P}{P_1}$$

$$2<Z\le 12$$

c_1- factor of contact angle
c_2 – load factor
c_3 – factor of belt length
c_4 – factor of the number of belts

6. Checking against fatigue

$$\upsilon=\frac{z_t v}{L_p}\left[\frac{1}{s}\right]<30\left[\frac{1}{s}\right]$$

7. Prescribing the belt tensioning force

$$H \approx (2...2.5) F_{per.}$$

2.2. Review the steps of the chain drive design. Based on the take-up capacity of the sprocket, and the polygon effect of the chain drive, determine the number of teeth of the driver and driven sprocket for the different drive demands.

1. Choosing the chain pitch (brand catalogue), based on:
   - chain speed
   - transmittable power
2. Number of teeth: z1, z2

$$Z_2 = iZ_1$$

3. Calculating the pitch diameters

$$d_1 = \frac{P}{\sin\frac{180°}{Z_1}} \quad d_2 = \frac{P}{\sin\frac{180°}{Z_2}}$$

4. Calculating the circumferential speed

$$v = d_1 \pi n_1$$

5. Peripheral force and checking for allowed tensile force

$$F_{per} = \frac{p}{v}$$

$$v \le 4\frac{m}{s} \qquad F_{\max} = F_{per}$$

$$v \ge 4\frac{m}{s} \qquad F_{\max} = F_{per} + c \qquad c = \frac{Gv^2}{g}$$

$$n = \frac{F_{allow}}{F_{\max}}$$

G: weight of the chain per meter

6. Preliminary center distance

$$a = (30...60)P$$

7. Number of chain link

   L: chain length calculation

$$s = \frac{L}{p} \Rightarrow \text{has to be whole number}$$

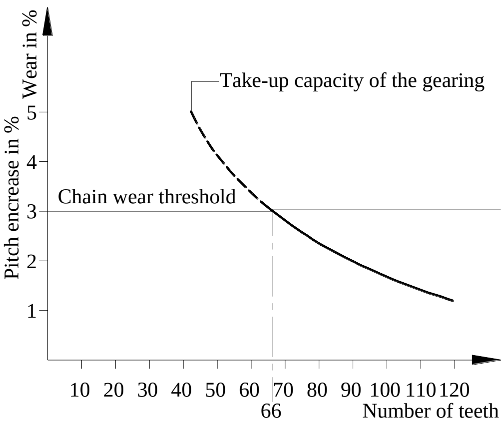
8. Number of chain strands

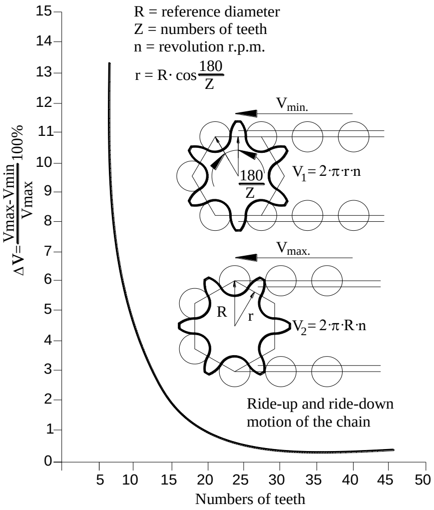
$$S = \frac{P_B}{P_{output}}$$

S	chain strands factor
$P_B = YP$	design power
P_{output}	band catalogue

9. Checking the chain pin for bearing stress

$$\frac{F_{\max}}{A} \le p_{allow}$$



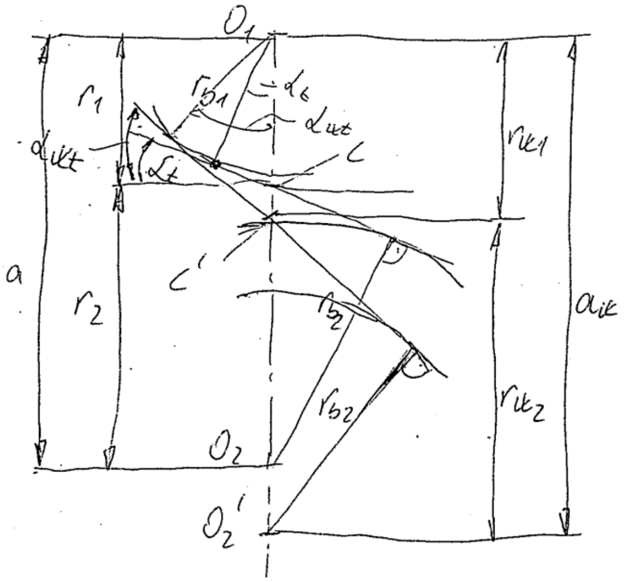


2.3. The reference center distance, the gear ratio, the module and number of teeth of an involute tooth profile spur gear drive are known. In order to achieve the prescribed working center distance, determine the working transfer pressure angle and represent it graphically as well, from which the $\sum x$ addendum modification coefficient can be determined.

$$\left(\sum x = \frac{z_1+z_2}{2}\frac{inv\alpha_{w_t}-inv\alpha_t}{tg\alpha_t}\right)$$

m = 3 mm, $z_1 = 20$, $z_2 = 40$, $\alpha_t = 20°$ $a_w = 91{,}25$ mm

$\alpha = \frac{d_1+d_2}{2} = \frac{z_1+z_2}{2} m$ = 90 mm, $r_1 = 30$ mm, $r_2 = 40$ mm



$$r_{b_1} = r_{w_1}\cos\alpha_{wt} = r_1\cos\alpha_t$$

$$r_{b_2} = r_{w_2}\cos\alpha_{wt} = r_2\cos\alpha_t$$

$$a_w = r_{w_1} + r_{w_2} = \left(r_1 + r_2\right)\frac{\cos\alpha_t}{\cos\alpha_{wt}} = a\frac{\cos\alpha}{\cos\alpha_{wt}}$$

$$r_{b_1} = r_1 cos\alpha_t = 28{,}19 \text{ mm}$$

$$r_{b_2} = r_2 cos\alpha_t = 37{,}59 \text{ mm}$$

$$cos\alpha_{w_t} = \frac{a}{a_w}cos\alpha = 0{,}9268$$

$$\alpha_{w_t} = 22{,}05°$$

$$inv\alpha_t = tg\alpha_t - \alpha_t = 0{,}0149$$

$$inv\alpha_{w_t} = tg\alpha_{w_t} - \alpha_{w_t} = 0{,}0202$$

$$\sum x = \frac{z_1+z_2}{2}\frac{inv\alpha_{w_t} - inv\alpha_t}{tg\alpha_t} = 0{,}437$$