Assignments
Complements of Machine Elements

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Contents

Introduction

The students should deliver 6 short reports in order to receive up to 30% in the final mark. Use the Table 1 to check the assignments that should be included in each report.

Table 1: Calendar to report delivery

Report	Assignment	Due date	Weight
R1	A01 + A02	Week 3	15%
R2	A03 + A04	Week 5	15%
R3	A05	Week 6	15%
R4	A06 + A07	Week 8	15%
R5	A08 + A09	Week 10	20%
R6	A10 + A11	Week 12	20%

The reports should be delivered in portable document format. The file should follow the following name convention: "NAME_RX.pdf", where NAME is the student name and RX is the report number.

Curved Beams

A01 – Crane hook

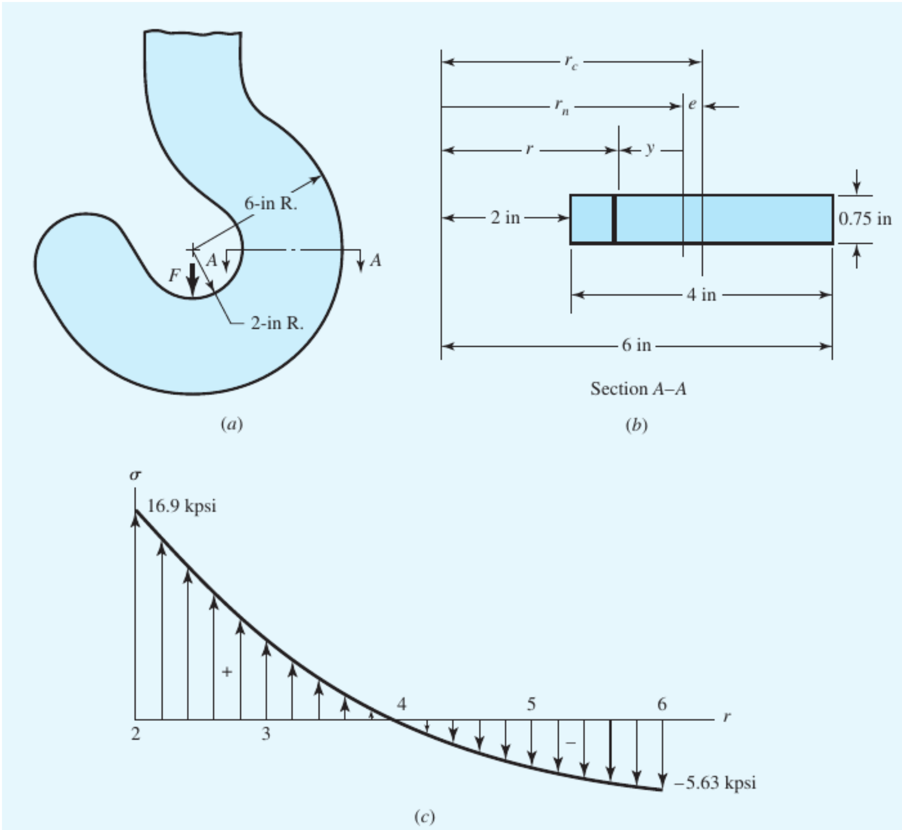

Figure 1: Crane hook: (a) plan view; (b) cross section and notation; (c) resulting stress [1].

The crane hook shown in Figure 1 across section A-A is rectangular with $b = 0.75\,\text{in}$, $h = 4\,\text{in}$ and the load is $F = 5000\,\text{lbf}$.

1. Plot the stress distribution across section A–A;
2. Compare the result with FEM software.

A02 – Ring

A link consisting of two semicircles and of two straight portions is submitted to the action of two equal opposite forces acting along the vertical axis of symmetry – see Figure 2 (a).

Determine the maximum bending moment, assuming that the cross-sectional dimensions of the link are small in comparison with the radius r.

Solve the previous problem, assuming that forces P are applied as shown in Figure 2 (b).

Using a software plot $\frac{M}{Pr}$ as a function of $0 \le \varphi \le \frac{\pi}{2}$ and $0 \le \frac{l}{r} \le 2$.

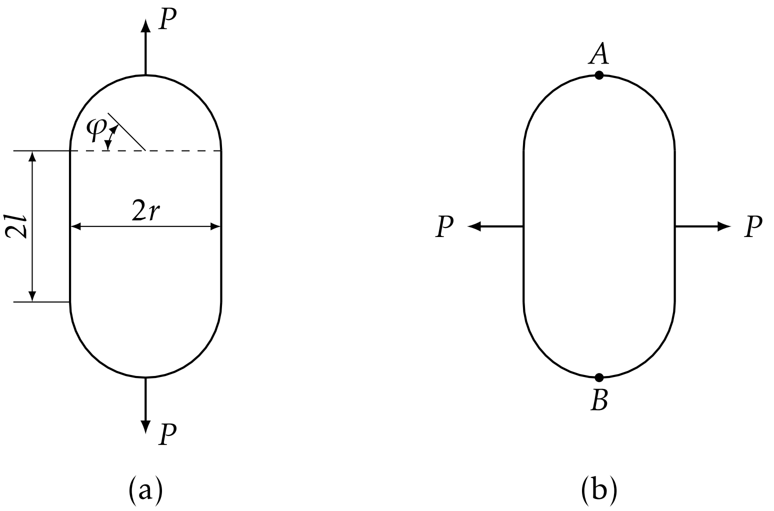

Figure 2: A link [2].

Thick cylinders

A03 – Interference fit

A 150 mm diameter steel shaft as to have a press fit with a 300 mm by 250 mm long hub of cast iron. The maximum tangential stress is to be 35 MPa. Consider $E = 206$ GPa for steel and $E = 100$ GPa for cast iron; $\nu = 0.3$ assumed for both steel and cast iron; $\mu = 0.12$ [3].

1. Determine the maximum diametral interference;
2. What axial force F_a will be required to press the hub on the shaft?
3. What torque may be transmitted with this fit?

Compare the results with a FEM code or KISSSoft and comment it.

Rotating cylinders

A04 – Flywheel

For a rotating disc of uniform thickness:

1. Choose material, radii and speed.
2. Plot the distribution of radial and hoop stress:
   - 2D as in lecture slides;
   - 3D with radial and hoop stress as a function of radius and ratio of inner and outer radii.

Fatigue design

A05 – Shaft analysis

Complete the KISSSoft tutorial 6 and repeat the calculations performed during the KISSSoft shaft design class. Compare the fatigue design safety factor of the shaft using the following methods:

- DIN 743:2012;
- Soderberg criteria.

Gears

A06 – Root stress: Lewis vs. ISO

Plot the form factor as function of the number of tooth according to the Lewis formula and ISO critical section. Use the Wallace equation (Lewis) and the ISO 6336 plot of the form factor for $\alpha = 20°$. Comment the results.

A07 – Hertz contact stress along path of contact

Consider a spur gear with $z_1 = 20$, $z_2 = 60$, $m = 2\,\mathrm{mm}$ and $\alpha = 20°$. Complete the following assignments:

1. Choose the load and plot the evolution of Hertz contact stress from T_1 up to T_2;
2. Determine the normal load that causes a maximum Hertz contact stress $\sigma_H = 1000\,\mathrm{MPa}$;
3. Choose another z_2 bigger than z_1 and repeat the plot of the Hertz contact stress and comment the results.

The software "GEARpie" allows to verify the results/plots and is available at GitHub.

A08 – Load carrying capacity according to ISO 6336

Consider a spur gear with $z_1 = 20$, $z_2 = 60$, $m = 2\,\mathrm{mm}$ and $\alpha = 20°$. The gear is made of 20MnCr5 steel.

First complete the KISSSoft tutorial 10 available on course contents. With KISSSoft determine:

- the safety factors for root bending (S_F) and contact stress (S_H) of the gear for $T_1 = 200\,\mathrm{Nm}$ and $n_1 = 1500\,\mathrm{rpm}$;
- maximum permissible torque.

List all the results and relevant factors used.

A09 – Efficiency

Calculate the gear loss factor of a gear with the following characteristics: $z_1 = 20$, $z_2 = 60$, $m = 2\,\text{mm}$ and $\alpha = 20°$ (no profile shift). Select a lubricant, the surface finishing and plot the results in the following way:

- efficiency vs. speed;
- efficiency vs. load;
- efficiency vs. operating temperature (viscosity).

Comment the influence of using a profile shift (to equalize the specific sliding) on the efficiency of the gear.

Rolling bearings

A10 – Load capacity

Consider an X-arrangement of a 30208 tapered roller bearing (left) and a 30206 tapered roller bearing (right) as presented in Figure 3.

The left bearing is submitted to a radial force $F_r = 4000\,\text{N}$ and an axial force $F_a = 5000\,\text{N}$. The right bearing is submitted to a radial force $F_r = 3000\,\text{N}$ [4].

Select a bearing manufacturer catalog to gather the necessary data and determine the expanded adjusted rating life L_{nm}, considering the following conditions:

1. $n = 1500\,\text{rpm}$;
2. $T_{lubricant} = 70\,°\text{C}$;
3. The lubricant is an ISO VG 100 oil;
4. The desired reliability is 95%;
5. Consider normal cleanliness conditions.

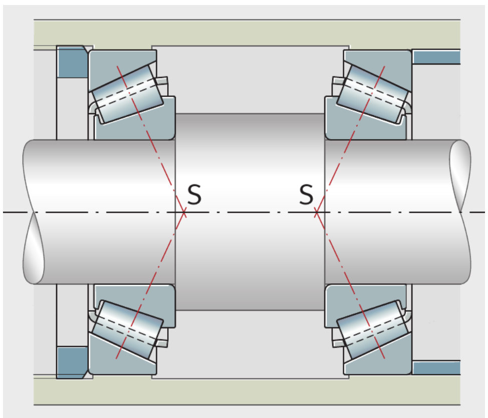

Figure 3: X-arrangement of two tapered roller bearings [5].

A11 – Efficiency

Consider the same data of A10 and determine the power loss of the rolling bearing arrangement (use SKF model).

Additionally present the following comparisons:

- power loss vs. speed
- power loss vs. load;
- power loss vs. operating temperature (viscosity).

References

[1] Budynas, Richard G.: *Shigley´s mechanical engineering design*. ISBN 9789339221638.

[2] Timoshenko, Stephen: *Strength of Materials. Part 1: Elementary Theory and Problems*. CBS, third edition, 1986, ISBN 81-239-1030-4.

[3] Hall, Allen S., Alfred R. Holowenko, and Herman G. Laughlin: *Schaum's Outline of Theory and Problems of MACHINE DESIGN*. McGraw-Hill, 1961.

[4] Branco, C. Moura, J. Martins Ferreira, J. Domingos da Costa, and A. Silva Ribeiro: *Projecto de Órgãos de Máquinas*. Fundação Calouste Gulbenkian, 2nd edition, 2008, ISBN 9789723112610.

[5] FAG: *Technical principles*. Schaeffler Technologies.