Assignments
Complements of Machine Elements

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Contents

Introduction

The students should deliver 8 posters in order to receive up to 30% in the final mark.

The completion of each assignment should be developed according to the schedule presented in Table 1. Please note that each assignment has a different weight in the final assignments mark.

Table 1: Proposed dates to complete the assignments

Assignment	A1	A2	A3	A4	A5	A6	A7	A8
Weight	10%	10%	10%	10%	15%	15%	15%	15%
Week	3	4	5	6	8	9	10	11

The posters should be delivered in portable document format. The file should follow the following name convention: "NAME_AX.pdf", where NAME is the student name and AX is the assignment number. The assignments should be submitted in the Moodle page of the course.

Grading

The grading is based on the following criteria:

1. Calculations and units consistency;
2. Text and equations clarity;
3. Figures and Tables quality;
4. Objectives accomplishment.

The grading scale for each criteria is from A (highest) to E (lowest).

The final grade of each poster is then obtained based on the system presented in Table 2.

Table 2: Grading system

19 a 20	All criteria A
17 a 18	At least one criteria with B and others with A
14 a 16	At least one criteria with C and others with A or B
10 a 13	At least one criteria with D and others with A, B or C
< 10	At least one criteria with E

Curved Beams

A1 – Crane hook

Find the geometry of a crane hook (books, catalogues, standards or real applications) [1]. Select the load and:

1. Plot the stress distribution across critical cross section;
2. Compare the result with FEM software.

Thick cylinders

A2 – Interference fit

Find a press fit of a shaft onto a bushing (books, catalogues, standards or real applications) [2]. Present all the geometry of the connection as well as the mechanical and tribological properties of the materials used.

Considering that the maximum tangential stress is to be less than 25% of the lowest yield strength of the materials of the connection:

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 press fit?

Compare the results with KISSSoft and comment it.

Rotating cylinders

A3 – 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

A4 – Shaft analysis

Find a shaft of a mechanical transmission (books, catalogues, standards or real applications) and determine the safety factor according to DIN 743 using KISSSoft. Compare the fatigue design safety factor of the shaft using the Soderberg criteria. Present the geometry of the shaft, the operating conditions and the mechanical properties of the material.

Gears

Find a spur gear (books, catalogues, standards or real applications): tooth number, module, face width and pressure angle. Present the operating conditions of the spur gear.

A5 – Root and Contact stress

Determine the root and contact stress. In the case of contact stress:

1. 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 $\sigma_H = 1000\,\text{MPa}$;
3. Calculate the profile shift to equalize the maximum specific sliding, repeat the plot of the Hertz contact stress and comment the results;
4. Change the value of z_2, repeat the plot of the Hertz contact stress and comment the results.

With the aid of KISSSoft determine:

- the safety factors for root bending (S_F) and contact stress (S_H) of the gear;
- maximum permissible torque;
- list in a table all the results and relevant factors used.

A6 – Efficiency

Do the following analysis for the gear selected:

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

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

Rolling bearings

Find an example (books, catalogues, standards or real applications) of an arrangement of two rolling bearings supporting a shaft (for example an X-arrangement of two tapered roller bearings) [3].

Select the operating conditions (loads, speed, lubricant and temperature) and choose a rolling bearing manufacturer. Consult the bearing manufacturer catalogue (SKF or FAG for example [4]) to gather the necessary data.

A7 – Load capacity

Determine the expanded adjusted rating life L_{nm}, considering the following conditions:

1. The desired reliability is 95%;
2. Consider normal cleanliness conditions.

A8 – Efficiency

Consider the same data of A7 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*. McGraw-Hill, 2014, ISBN 9789339221638.

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

[3] 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.

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