# Assignments
# Complements of Machine Elements

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## Contents

## Introduction

The students should deliver 2 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 + A03 + A04 | Week 6 | 40% |
| R2 | A05 + A06 + A07 + A08 + A09 + A10 | Week 12 | 60% |

The completion of each assignment should be developed according to the schedule presented in Table 2. The due date allow the students to have finished the assignment before discussion in the classes.

Table 2: Proposed dates to complete the assignments

| Assignment | A01 | A02 | A03 | A04 | A05 | A06 | A07 | A08 | A09 | A10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Week | 3 | 4 | 5 | 6 | 7 | 9 | 9 | 9 | 10 | 11 |

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.

## 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 report is then obtained based on the system presented in Table 3.

Table 3: 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

## A01 – 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

## A02 – 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 a FEM code or KISSSoft and comment it.

# Rotating cylinders

## A03 – 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

## A04 – 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.

## A05 – Root stress: Lewis vs. ISO

Determine the form factor of the spur gear according to the Lewis formula and the ISO critical section. Determine the root stress using both form factors and considering the contact ratio factor ($Y_\epsilon$). Compare and comment the results.

## A06 – Hertz contact stress along path of contact

Considering the spur gear defined previously:

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.

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

## A07 – Load carrying capacity according to ISO 6336

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 all the results and relevant factors used.

## A08 – Efficiency

Do the following analysis for the gear selected:

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

Comment 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 (FAG for example [4]) to gather the necessary data.

## A09 – 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.

## A10 – Efficiency

Consider the same data of A09 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.