Assignments
Complements of Machine Elements

Carlos M. C. G. Fernandes

Contents

Introduction

Students are required to submit 3 reports, which will contribute up to 30% of the final grade.

The submission of each report must adhere to the schedule outlined in Table 1. Note that each report carries a different weight in the overall assignments grade. Reports may include multiple assignments, and students are encouraged to complete each assignment and discuss their solutions with the course responsible (CR) during the weeks indicated in Table 1.

Table 1: Proposed dates for assignments and reports

Report	R1		R2			R3
Weight	20%		50%			30%
Assignment	R1.1	R1.2	R2.1	R2.2	R2.3	R3.1
Week to discuss with CR	2	3	5	7/8	9/10	12
Report due date	week 4 (18/10)		week 10 (06/12)			week 12 (20/12)

The reports should be delivered in portable document format. The file should follow the following name convention: "NAME_FAMILY-NAME_RX.pdf", where RX is the report number. The reports should be submitted in the Moodle page of the course.

Grading

The grading is based on the following criteria:

1. Calculations and units consistency[1];
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 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

[1] Recommended reading: Guilherme de Almeida, *Sistema Internacional de Unidades (SI) - Grandezas e Unidades Físicas: terminologia, símbolos e recomendações*, 3ª edição, Plátano Edições Técnicas, 2002.

R1. Stresses and strains

R1.1. Curved Beams: 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.

R1.2. Thick cylinders: 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.

R2. Design of Shafts, Gears and Rolling Element Bearings

Find a mechanical transmission (books, catalogues, standards or real applications) and present the expected operating conditions of the system.

R2.1. Fatigue design of shafts

Design the shafts according to DIN 743 using KISSSoft. Compare the fatigue design safety factor of the shafts using the Soderberg criteria. Present the geometry of the shafts, the operating conditions and the mechanical properties of the material.

R2.2. Gears

List the tooth number, module, face width and pressure angle of the gear of the mechanical transmission selected.

1. Determine the tooth root and the Hertz contact stress. In the case of the Hertz contact stress:
    a) Plot the evolution of Hertz contact stress from the base tangent points T_1 up to T_2;

b) Determine the normal load that causes a maximum Hertz contact stress $\sigma_H = 1000\,\text{MPa}$;

c) Calculate the profile shift to equalize the maximum specific sliding, repeat the plot of the Hertz contact stress and comment the results;

d) Change the value of z_2, repeat the plot of the Hertz contact stress and comment the results.

2. With the aid of KISSSoft, use ISO 6336 standard:

a) the safety factors for root bending (S_F) and contact stress (S_H) of the gear;

b) maximum permissible torque;

c) list in a table the results and comment all relevant factors used.

3. Do the following analysis for the gear selected:

a) efficiency vs. speed;

b) efficiency vs. load;

c) efficiency vs. operating temperature (viscosity);

d) influence of using the profile shift on the efficiency.

R2.3. Rolling element bearings

Describe the arrangement of the rolling element bearings supporting the shafts (for example an X-arrangement of two tapered roller bearings) [3].

Consult the bearing manufacturer catalogue (SKF or FAG for example [4]) to gather the necessary data.

1. Determine the expanded adjusted rating life L_{nm}, considering a suitable reliability and cleanliness conditions based on the selected application.

2. Determine the power loss of the rolling bearing arrangement (use SKF model) and present the following comparisons:

a) power loss vs. speed;

b) power loss vs. load;

c) power loss vs. operating temperature (viscosity).

R3. Tribology

R3.1. Hydrodynamic pad bearing

Use the lab experiment guide given on course contents, section Tribology.

1. Collect the experimental results for the finite length hydrodynamic pad bearing and present:

a) present experimental pressure field;

b) use finite difference method to solve the Reynolds equation for the bearing;

c) compare the results.

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.