U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

# Course Overview

## Complements of Machine Elements

Carlos Fernandes

2024/2025

Mestrado em Engenharia Mecânica

# Summary

# Objectives and Learning outcomes

## Objectives

This course seeks to reinforce the knowledge of the design of machine elements resulting from the introductory course “Machine Elements”, through treatment of new topics but also through deeper analysis of certain topics already discussed.

## Outcomes

The successful completion of this course leads to the competence to design a variety of machine elements.

# Program

1. Stress and strains
   - 1.1 curved beams;
   - 1.2 thick cylinders (Lamé equations); interference fits;
   - 1.3 rotating cylinders.
2. Shafting and associated parts
   - 2.1 flywheels;
   - 2.2 fatigue design according to DIN 743.
3. Welded joints
   - 3.1 introduction and practical cases;
   - 3.2 welds treated as lines.
4. Cylindrical Gears
   - 4.1 gearing overview;
   - 4.2 root stress; flank stress; the particularities of plastic gears;
   - 4.3 efficiency.

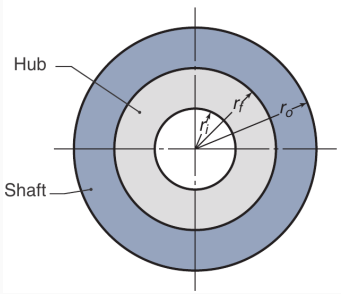
# Program (continuation)

5. Rolling Element Bearings
   - 5.1 rolling element bearing types; typical arrangements; clearance and stiffness;
   - 5.2 static load rating; fatigue life; Weibull distribution, dynamic load rating;
   - 5.3 efficiency: Coulomb, Palmgren and SKF models;
   - 5.4 solve machine elements problems with software (gears, rolling bearings, shafts).
6. Tribology
   - 6.1 technical surfaces; friction and wear (experiment with surface analysis);
   - 6.2 clutches and brakes;
   - 6.3 hydrodynamic bearings: numerical solution with the finite differences method;
   - 6.4 finite length hydrodynamic bearing: experiment vs numerical solution;
   - 6.5 lubrication and failures in rolling bearings and gears.

# 1. Stress and strains

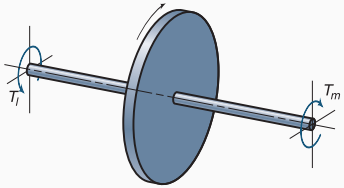
1.1. curved beams

Lecture:
27/09/2024




1.2. thick cylinders (Lamé equations); interference fits

Lecture:
30/09/2024



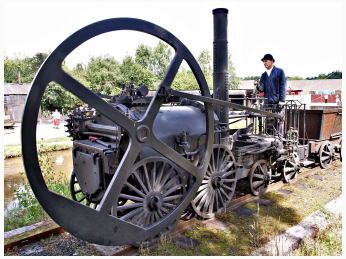

1.3. rotating cylinders

Lecture:
04/10/2024

Exercises

Recitation:
07/10/2024

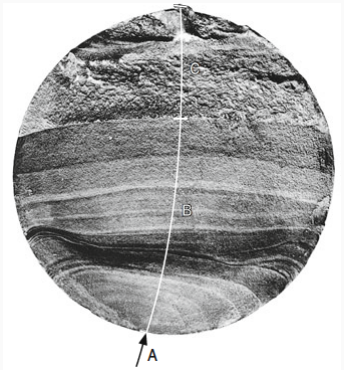
# 2. Shafting and associated parts



2.1 flywheels

Lecture:
09/10/2024

---




2.2. fatigue design according to DIN 743

Lecture:
14/10/2024

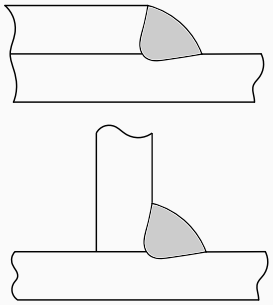
---

KISSsoft

KissSoft Software

Lab: 18/10/2024

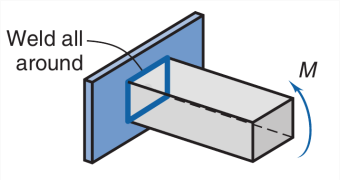
# 3. Welded joints



3.1. introduction and practical cases

Lecture: 21/10/2024

---



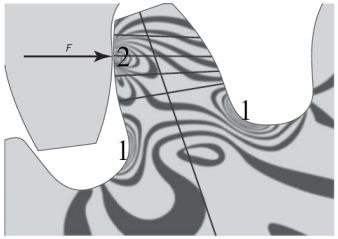

3.2. welds treated as lines

Lecture: 25/10/2024

# 4. Gears

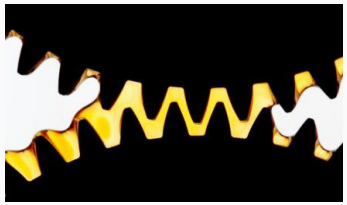
4.1. gearing overview

Lecture:
04/11/2024




4.2. root stress; flank stress; the particularities of plastic gears

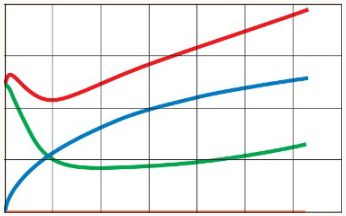
Lectures:
08/11/2024 and
11/11/2024



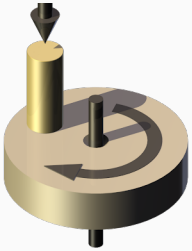
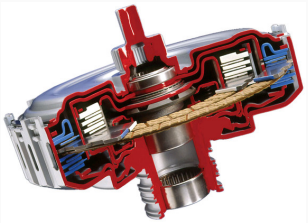
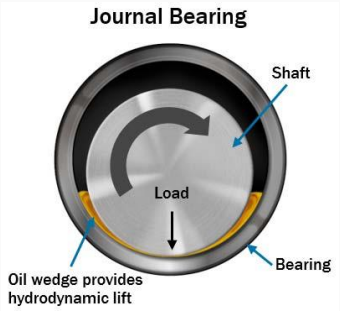
4.3. efficiency

Lecture:
15/11/2024

# 5. Rolling Element Bearings

| | | |
|---|---|---|
|  | 5.1. rolling element bearing types; typical arrangements; clearance and stiffness; | Lecture: 18/11/2024 |
|  | 5.2. static load rating; fatigue life; Weibull distribution, dynamic load rating; | Lecture: 22/11/2024 |
|  | 5.3. efficiency: Coulomb, Palmgren and SKF models; | Lecture: 25/11/2024 |
| KISSsoft | 5.4. solve machine elements problems with software (gears, rolling bearings, shafts) | Lab: 29/11/2024 |

# Tribology

| | | |
|---|---|---|
|  | 6.1. technical surfaces; friction and wear | Short Lecture + Lab: 02/12/2024 |
|  | 6.2. clutches and brakes; | Lecture: 06/12/2024 |
|  | 6.3. hydrodynamic bearings: numerical solution with the finite differences method; | Lecture: 09/12/2024 |
| | 6.4. finite length hydrodynamic bearing: experiment vs numerical solution; | Lab: 13/12/2024 |
| | 6.5. lubrication and failures in rolling bearings and gears; | Lecture: 16/12/2024 |

# Bibliography

“Mandatory”:


- Bernard J. Hamrock, *Fundamentals of Machine Elements*, ISBN: 0-07-111142-5;
- Georges Henriot, *Engrenages*, ISBN: 978-2-10-050857-0.


“Optional”:


- P. Timoshenko, *Resistência dos Materiais* (Curved beams, thick cylinders, rotating cylinders);
- Giulio Ballio, *Theory and Design of Steel Structures*, ISBN: 0-412-23660-5;
- P. J. Howard, *Theory of Machines*, Macdonald, 1966;
- Gwidon W. Stachowiak and Andrew W. Batchelor, *Engineering Tribology*, Elsevier, 2014, ISBN: 978-0-12-810031-8.

# Course Contents

Brief demonstration about:

## How to access the Course Contents

# Teaching methods and learning activities

1. Lectures:
    - Theoretical in nature
    - Proposal of assignments
    - Discussion of assignments

2. Recitations and Tutorials:
    - Exercises resolution
    - KISSSoft tutorials (2 sessions)

# Evaluation

**Distributed evaluation with final exam**

| Evaluation Components | |
|---|---|
| Designation | Weight (%) |
| Exam | 70,00 |
| Assignments | 30,00 |
| Total: | 100,00 |

| Amount of time allocated to each course units | |
|---|---|
| Designation | Time (hours) |
| Self study | 79.5 |
| Classes | 42.0 |
| Total: | 121.5 |

**Eligibility for exams:**
Attendance of classes; execution of suggested assignments using MATLAB or Python, FEM codes and KISSsoft.

# Examinations or Special Assignments

**Assignment:**

Deliver a report with:

- analytical/numerical resolution of the proposed assignments;
- make use of a programming tool (MATLAB, Python or other) to make relevant plots and parametric studies;
- compare the analytical results with numerical solutions. For example with Finite Element Analysis (Abaqus, Ansys, SolidWorks, PrePoMax);
- compare with KISSSoft - a commercial machine elements software. Usually has specific standards (DIN, ISO AGMA) implemented.

# Assignments

The Assignments are valued with **30% of the final mark**.

They are **optional** - the student which prefers only the final exam is ok.

The Assignments are proposed in the Course Contents and should be submitted on *Course's Moodle Website*.

# Assignment calendar

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

| 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.

# Calculation formula of final grade

| | |
|---|---|
| Final mark in the course: | **X** |
| Examination mark: | **Y** |
| Assignment: | **Z** |
| Final mark calculation: | **X=0,7Y+0,3Z** |

**Students may choose to have Z disregarded and the final mark is X=Y**

# Software

Mandatory for the course:

- **KISSSoft (Machine Elements)**
  `https://www.kisssoft.com`

**Useful to do the Assignments:**

- PrePoMax – Graphic User Interface for CalculiX (`http://lace.fs.uni-mb.si/wordpress/borovinsek/?page_id=41`)
- Abaqus
- SolidWorks
- GEARpie (`https://github.com/cfernandesFEUP`)

# KISSSoft

There are three ways to use **KISSSoft for FEUP students**:

1. At FEUP (computer rooms on building B)

2. Using a Remote Desktop Connection to apps.fe.up.pt server

3. Local installation on your personal computer (requires VPN connection to FEUP in order to validate the license)

# KISSSoft Installation

1. Map the license network drive into your PC:
    - Connect to VPN FEUP: configuration for Windows 10
    - Map the network drive
      `\\software.fe.up.pt\lickisssoft\` –
      see how to map a network drive
2. The installation file is inside the network drive in folder `KissSoft2024`
3. Install the software on your PC
4. When the installation asks for a license:
    - Select: “Yes, I have a license file”
    - Select the network drive previously configured in **2** and select “license2024_4602”.
5. Finish your installation and you are ready to start the Tutorials that are available on Course Contents.

# References


**[1]** Schmid, Steven R., Bernard J. Hamrock e Bo O. Jacobson: *Fundamentals of Machine Elements*.
**CRC Press, 2014, ISBN 9781482247503.**

**[2]** Budynas, Richard G.: *Shigley's mechanical engineering design*.
**McGraw-Hill, 2014, ISBN 9789339221638.**

**[3]** Juvinall, Robert C. e Kurt M. Marshek: *FUNDAMENTALS OF MACHINE COMPONENT DESIGN*.
**Wiley, 2017, ISBN 978-1-119-32153-8.**