U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Course Overview

Complements of Machine Elements

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2023/2024

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. Curved beams: stress and strain analyses.
2. Thick cylinders: Lamé equations.
3. Rotating cylinders: flywheels.
4. Fatigue design according to DIN 743.
5. Gears: load-carrying capacity (ISO 6336); efficiency.
6. Rolling Element Bearings: types; arrangements; load capacity (ISO 281); efficiency.
7. Clutches and brakes.
8. Welded joints.

Curved beams

Stress and strain analyses.

Figura 1: Lifting crane hook.

20/09/2023 - Straight vs. Curved beams
22/09/2023 - Curved beams (exercises)

Thick cylinders

Lamé equations and their applications.

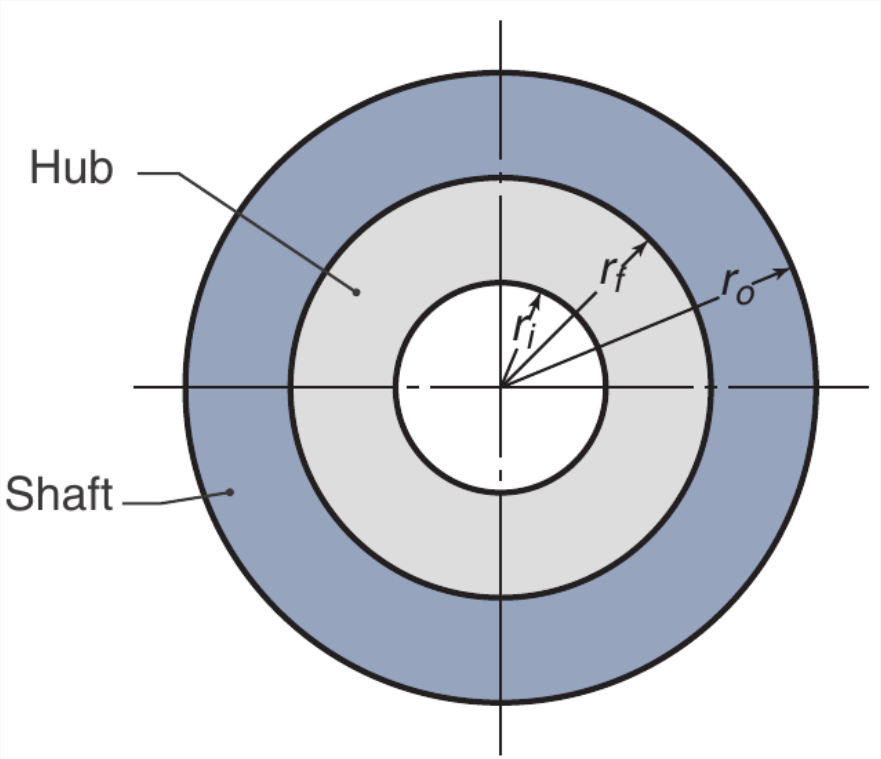


Figura 2: Cylinder assembled with an interference fit [1]

27/09/2023 - Thick cylinders
29/09/2023 - Thick cylinders (exercises)

Rotating cylinders

Flywheels (volante de inércia)

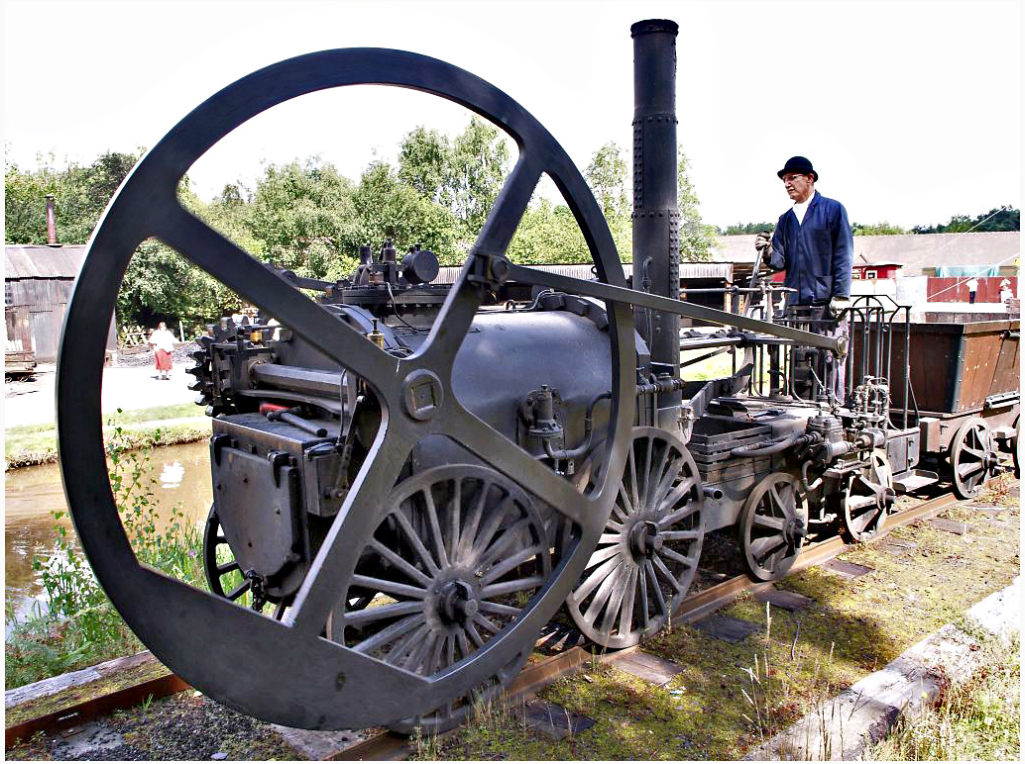


Figura 3: Flywheel (source: wikipedia).

04/10/2023 - Rotating cylinders
06/10/2023 - Rotating cylinders (exercises)

Fatigue design

Some specificities of German practice of fatigue design; DIN 743 approaches.

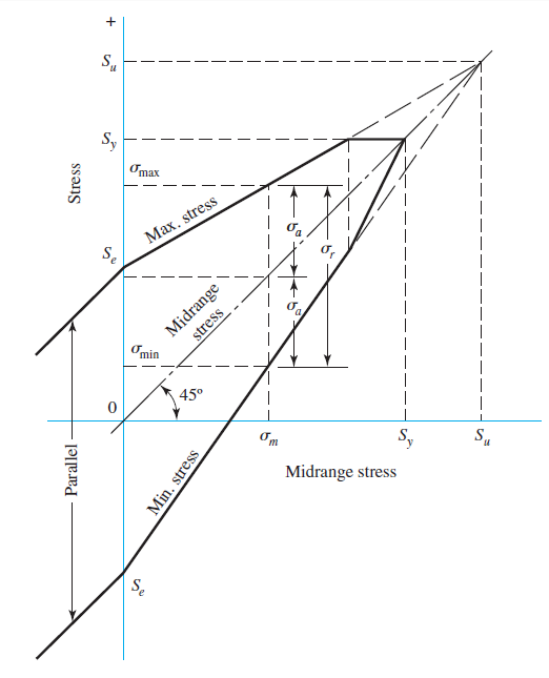


Figura 4: Smith diagram [2].

11/10/2023 - Bach, effort ratio and DIN 743
To define - KISSSoft tutorial (5) - shaft analysis

Gears

Load carrying capacity; ISO 6336; efficiency.

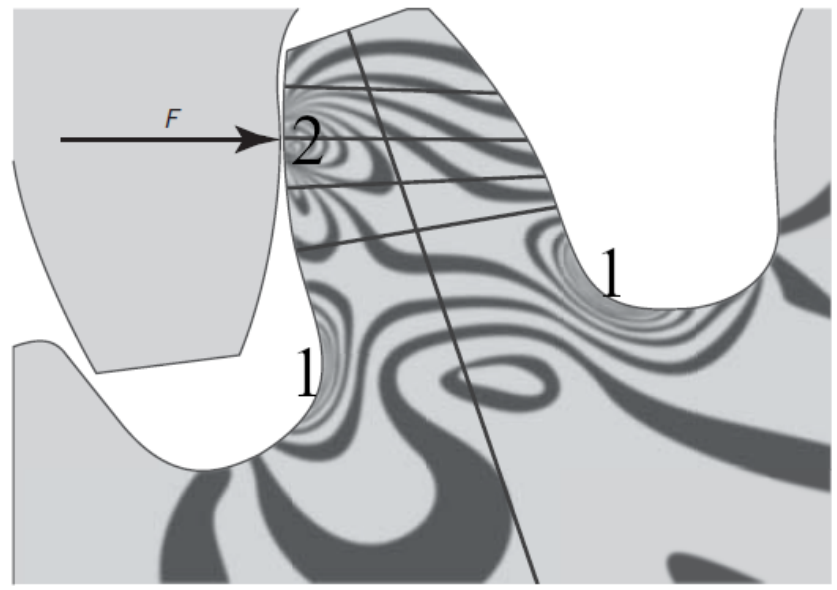


Figura 5: Stresses on gear tooth [3].

18/10/203 - Load carrying capacity: bending
20/10/2023 - Load carrying capacity: contact pressure
25/10/2023 - Efficiency (CoF, gear loss factor)
27/10/2023 - Failures

Rolling Element Bearings

Bearing types; assemblies; load capacity; ISO 281; efficiency

Figura 6: Some rolling bearings.

08/11/2023 - Types, assemblies + Load capacity (ISO 281)
10/11/2023 - Efficiency (Palmgren, Harris, SKF) + Failures
15/11/2023 - Load capacity + efficiency (exercises)
17/11/2023 - KISSSoft (gears, bearings and shafts)

Clutches and brakes

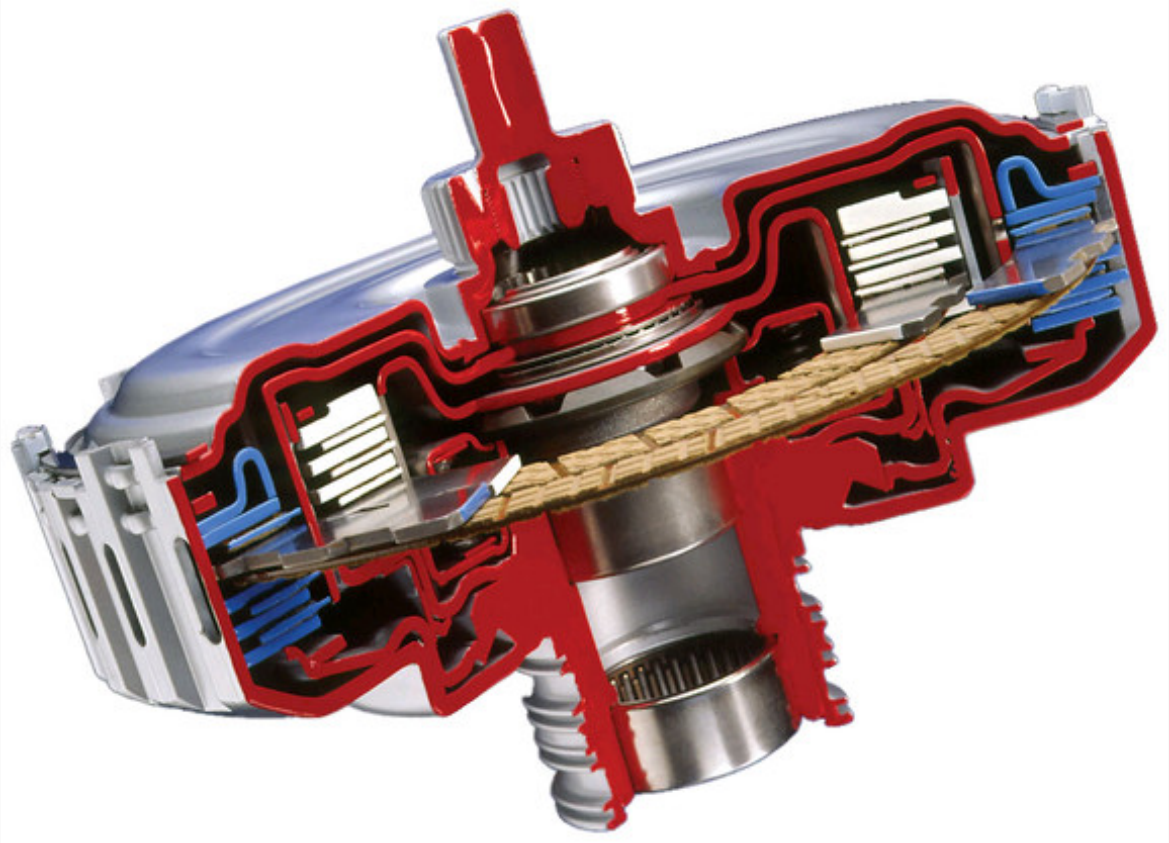


Figura 7: Multiple disc clutch (source: x-engineer.org).

22/11/2023 - Clutches and brakes
24/11/2023 - Clutches and brakes (exercises)

Welded joints

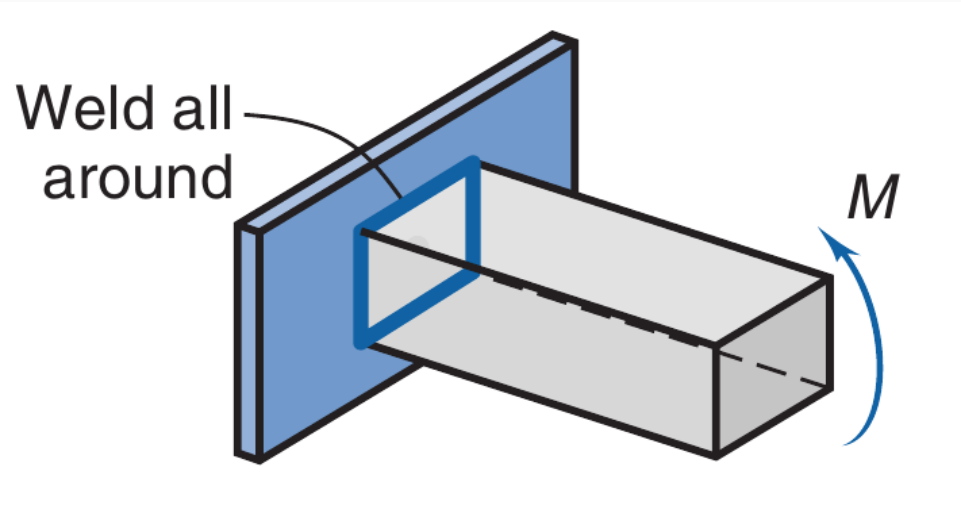
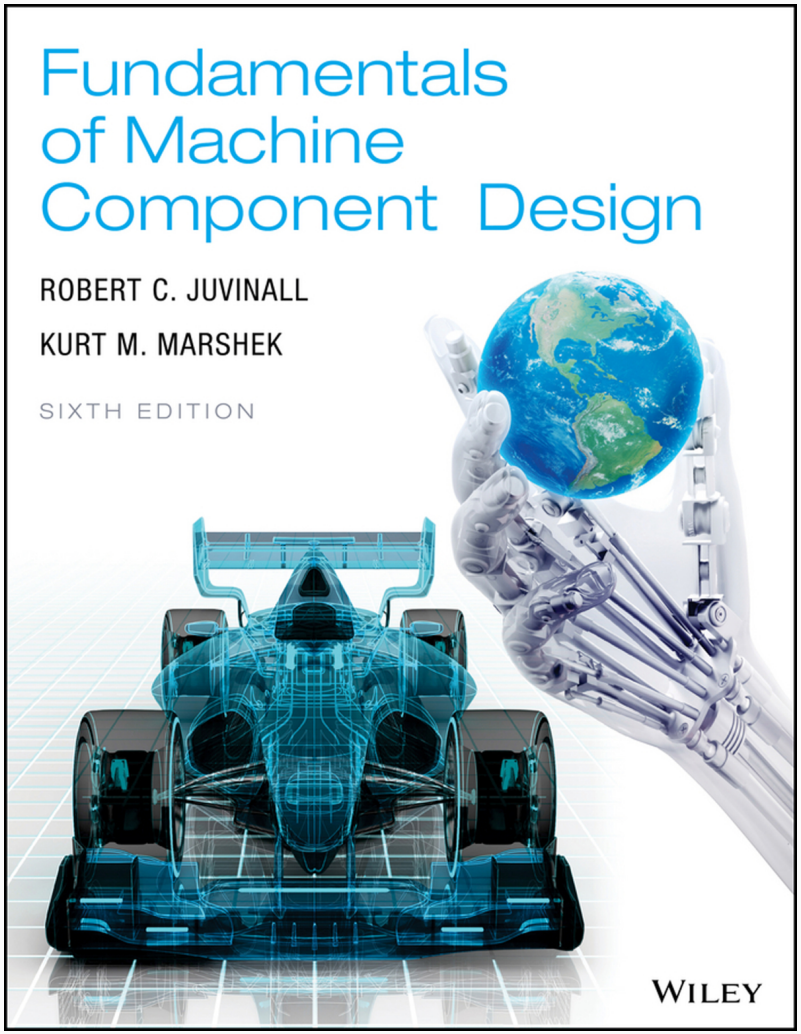


Figura 8: Welded joint under bending [1]

29/11/2023 - Introduction and REApE
06/12/2022 - Exercises using REApE cases
13/12/2022 - Welds treated as lines + Exercises

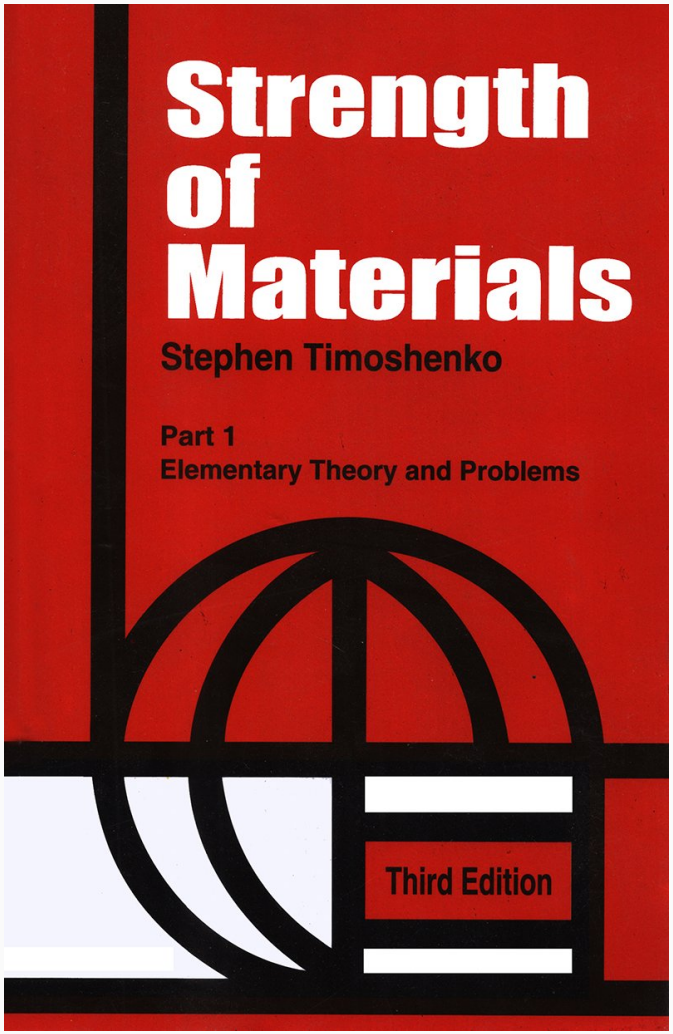
Bibliography

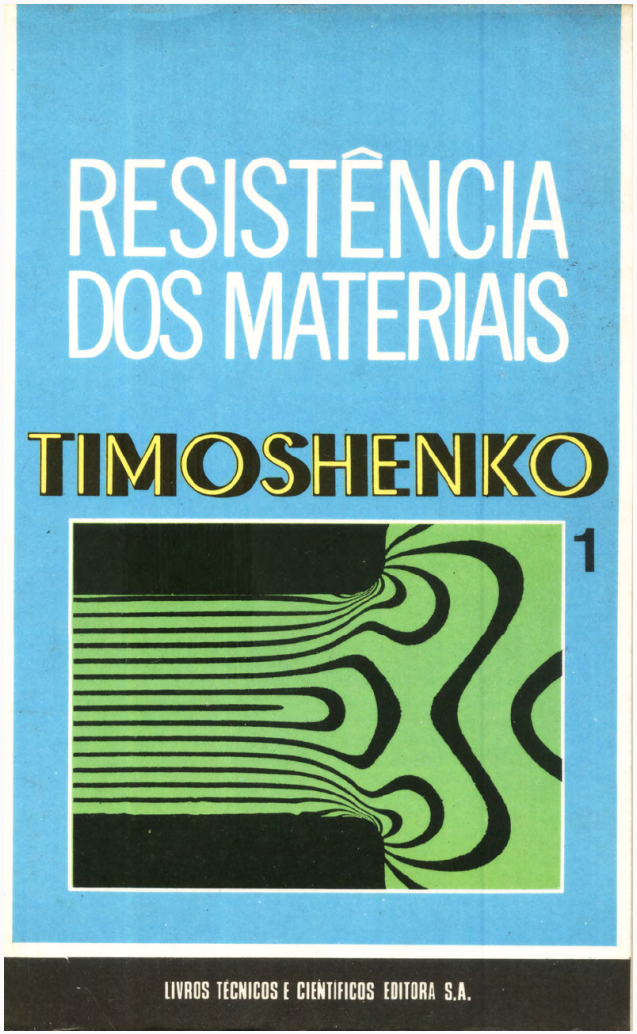
- Robert C. Juvinall, Kurt M. Marshek; Fundamentals of Machine Component Design, Wiley, 2017.



Bibliography

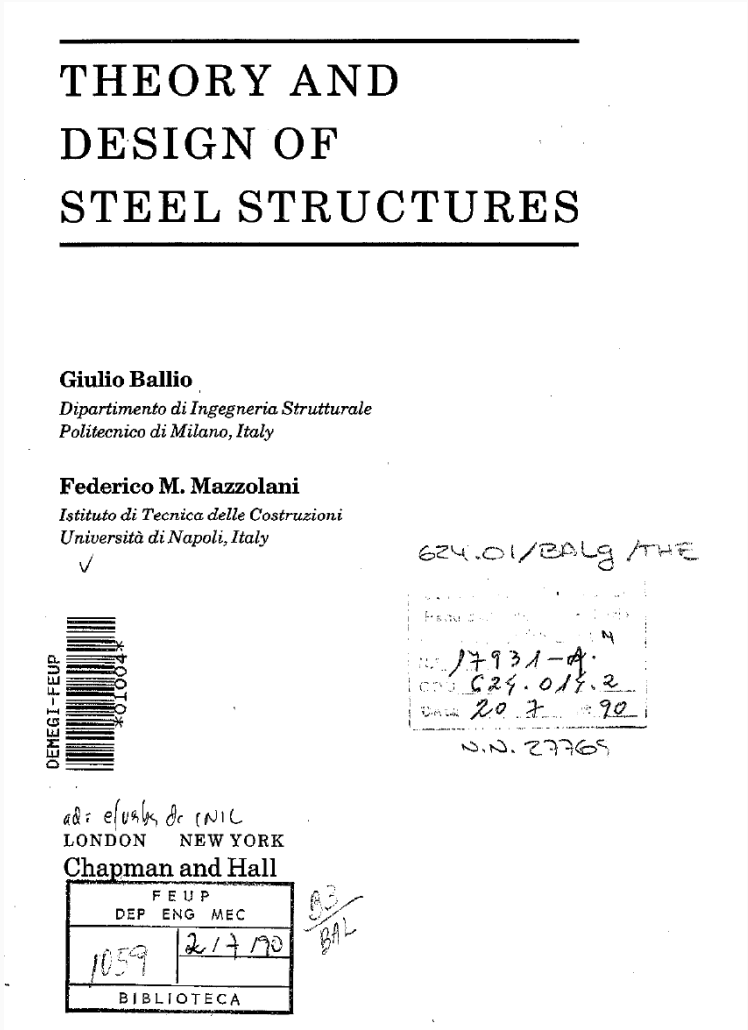
- Stephen P. Timoshenko; Resistência dos materiais (Curved beams, thick cylinders, rotating cylinders)





Bibliography

- Giulio Ballio; Theory and design of steel structures. ISBN: 0-412-23660-5 (Welded joints)



THEORY AND
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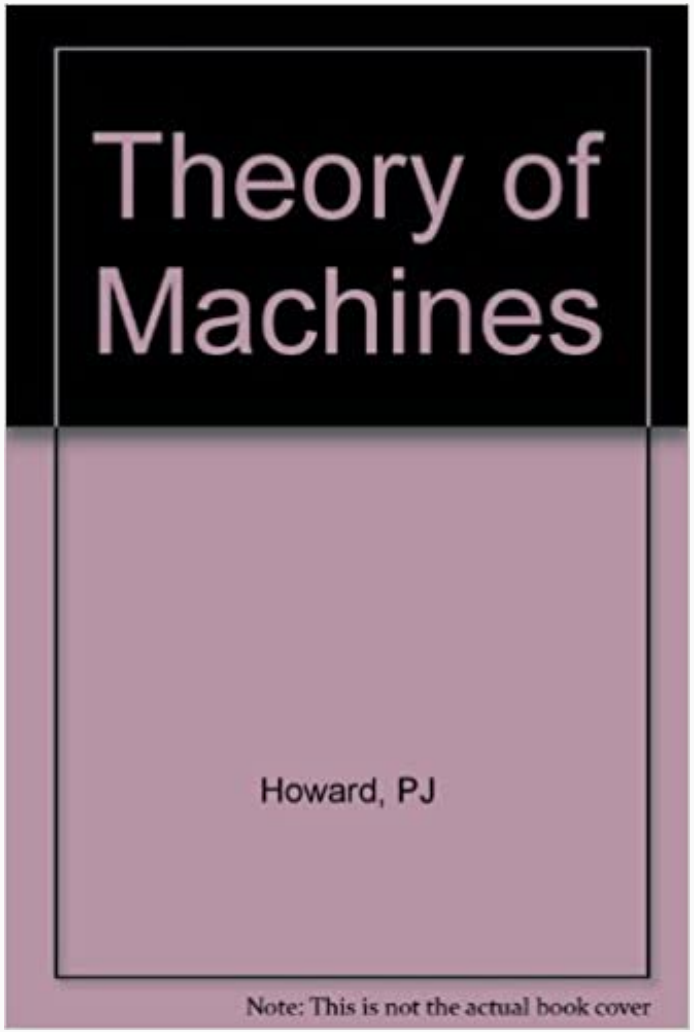
Chapman and Hall

Bibliography

- P. J. Howard; Theory of machines, Macdonald, 1966 (Friction in clutches and brakes)



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)

3. Webinars/seminars with industry specialists:
    - Rolling bearings (usually in Spanish) - Schaeffler;
    - Chains - Online at Iwis webinars
    - Belts - Online at Optibelt

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 poster with:

- analytical 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 Method (Abaqus, Ansys, SolidWorks, CalculiX, as you want);
- 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 Assignment are proposed in the Course Contents.

Assignment calendar

The students should deliver the 8 assignments 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.

Tabela 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.

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:

Open Source (free to use and modify):

- CalculiX (`http://www.calculix.de/`)
  - PrePoMax – Graphic User Interface for CalculiX (`http://lace.fs.uni-mb.si/wordpress/borovinsek/?page_id=41`)
- GEARpie (`https://github.com/cfernandesFEUP`)
- Gmsh (`https://gmsh.info/`)
- Python

Optional:

- Abaqus or SolidWorks (for example)

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
   `2fev2022\KissSoftInstall`
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 “license261_2021”.
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.

End

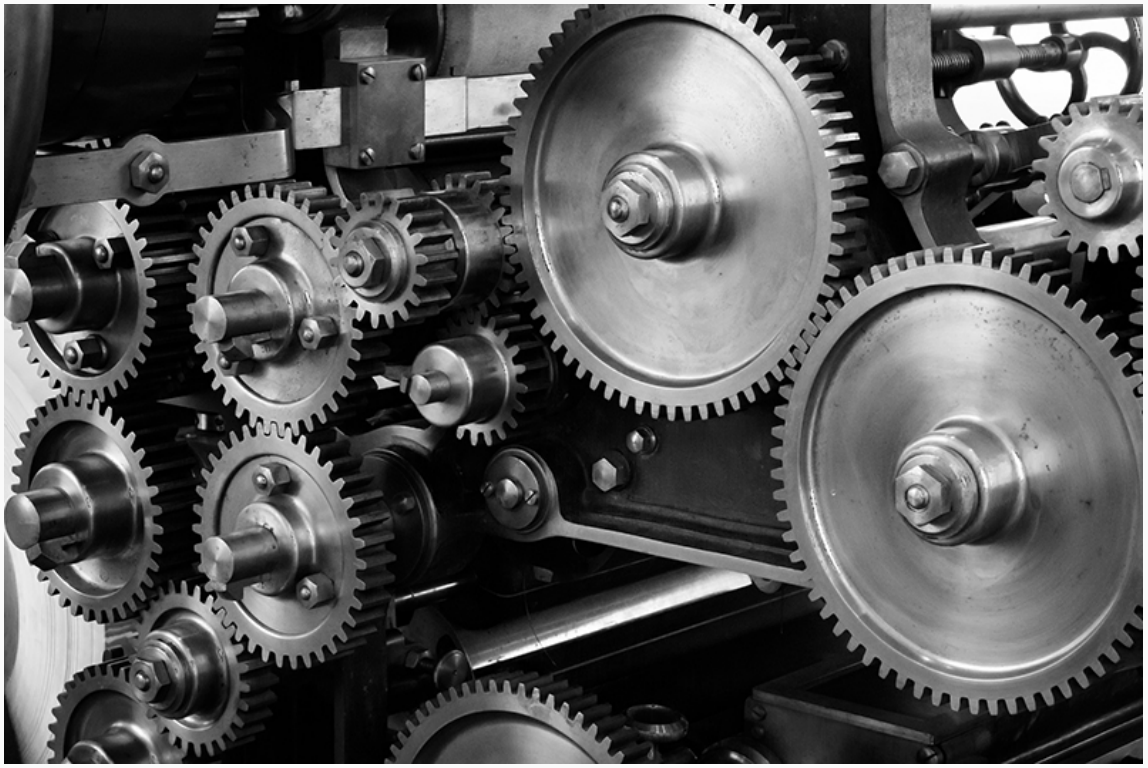


Figura 9: Machine (source: https://sjomaintenance.com.au)