U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

Course Overview

Complements of Machine Elements

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2021/2022

Mestrado em Engenharia Mecânica

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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. Welded joints
6. Flexible machine elements (not planed on this occurence)
7. Clutches and brakes.
8. Gears: load-carrying capacity (ISO 6336); efficiency; failures
9. Rolling Element Bearings: types; arrangements; load capacity (ISO 281); efficiency; failures

Curved beams

Stress and strain analyses.

Figura 1: Lifting crane hook.

08/03/2022 - Straight vs. Curved beams
14/03/2022 - Curved beams (exercises)

Thick cylinders

Lamé equations and their applications.

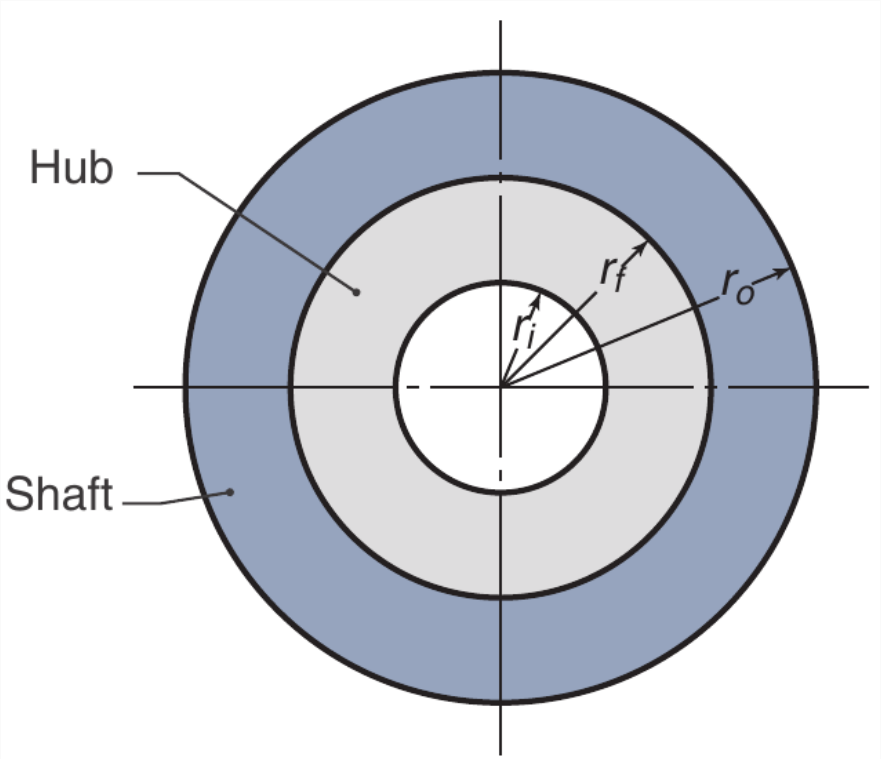


Figura 2: Cylinder assembled with an interference fit [1]

15/03/2022 - Thick cylinders
21/03/2022 - Thick cylinders (exercises)

Rotating cylinders

Flywheels (volante de inércia)

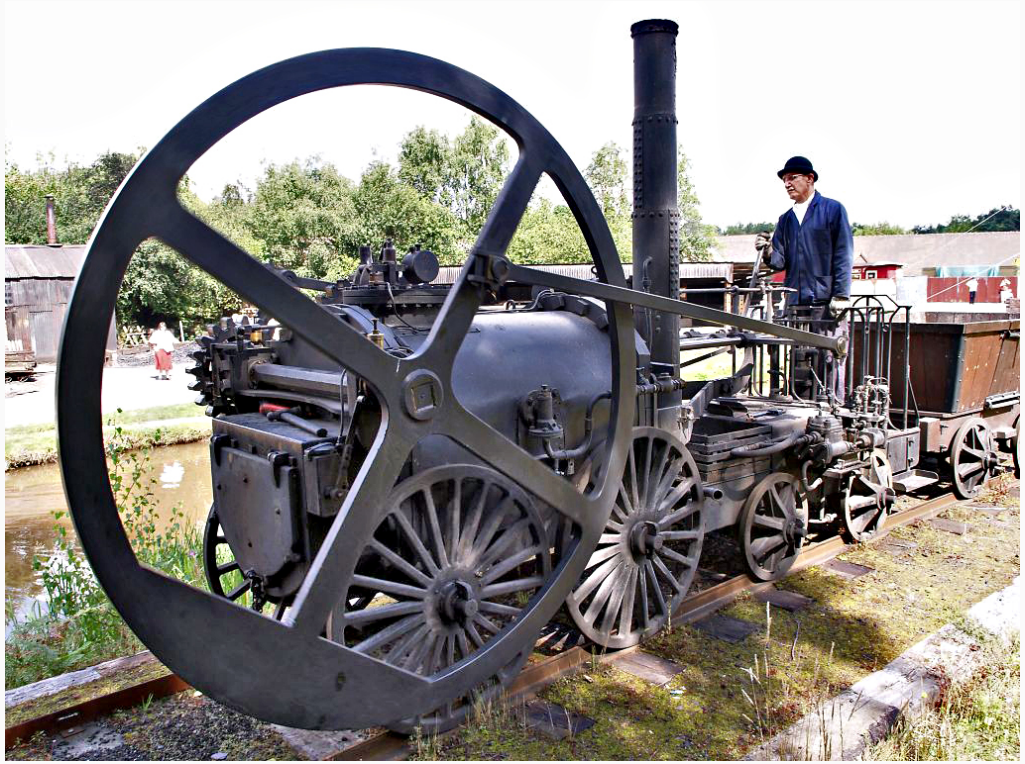


Figura 3: Flywheel (source: wikipedia).

22/03/2022 - Rotating cylinders
28/03/2022 - Rotating cylinders (exercises)

Fatigue design

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

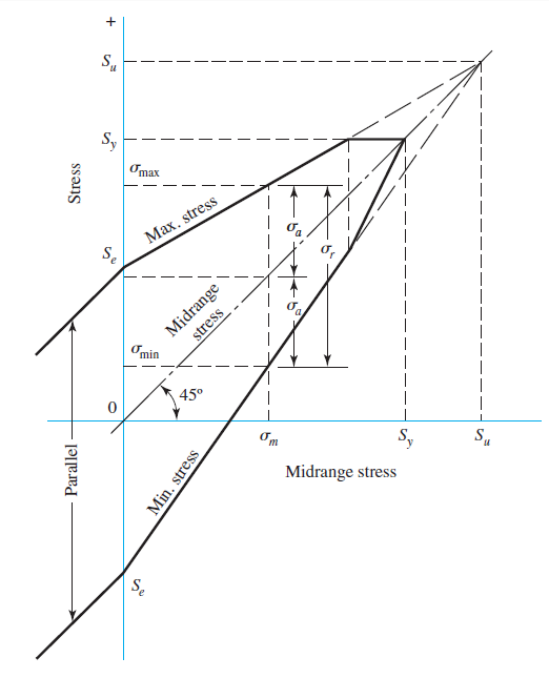


Figura 4: Smith diagram [2].

29/03/2022 - Bach, effort ratio and DIN 743
04/04/2022 - KISSSoft tutorial (5) - shaft analysis

Friction in clutches and brakes

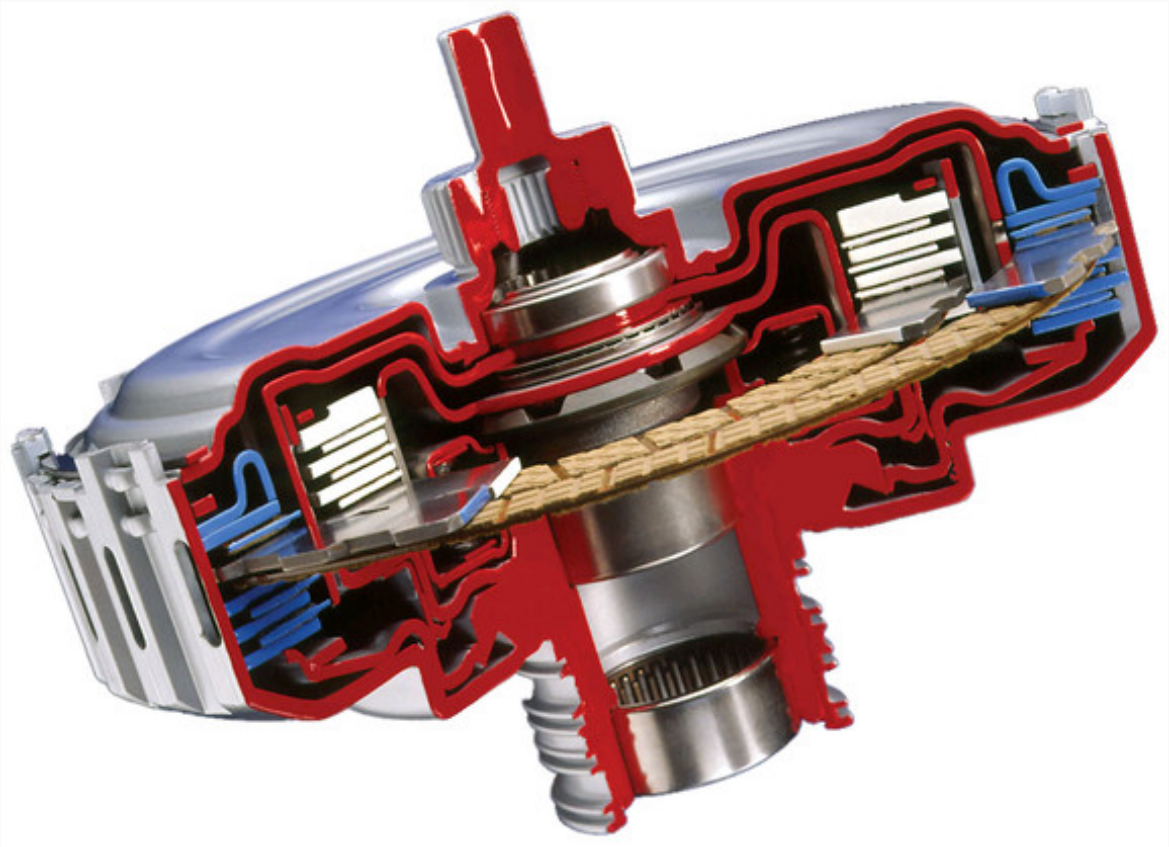


Figura 5: Multiple disc clutch (source: x-engineer.org).

Gears

Load carrying capacity; ISO 6336; efficiency.

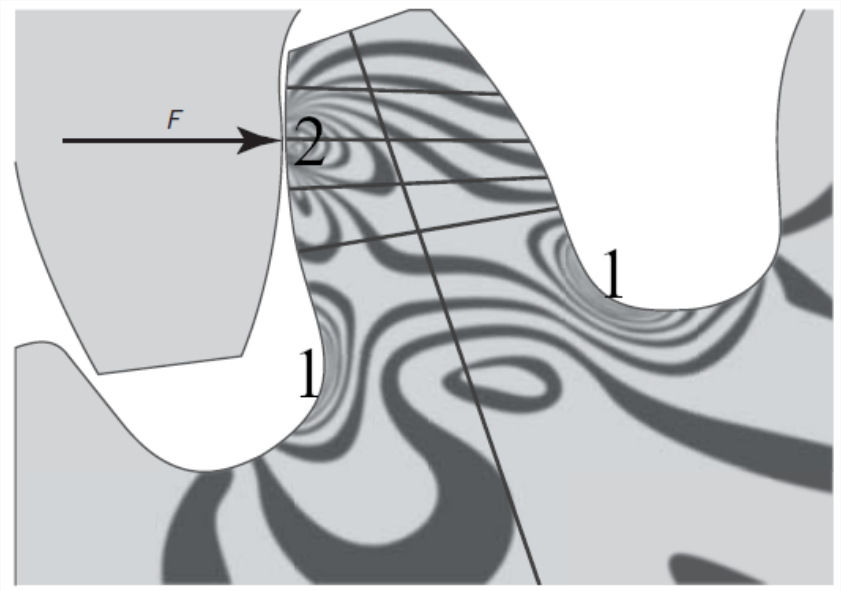


Figura 6: Stresses on gear tooth [3].

19/04/2022 - Load carrying capacity: bending
26/04/2022 - Load carrying capacity: contact pressure
09/05/2022 - ISO 6336 standard
10/05/2022 - Efficiency (CoF, gear loss factor) + Failures
16/05/2022 - Efficiency (exercises) + KISSSoft (gears)

Rolling Element Bearings

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

Figura 7: Some rolling bearings.

17/05/2022 - Types, assemblies + Load capacity (ISO 281)
23/05/2022 - Efficiency (Palmgren, Harris, SKF) + Failures
24/05/2022 - Load capacity + efficiency (exercises)
30/05/2022 - KISSSoft (gears, bearings and shafts)

Welded joints

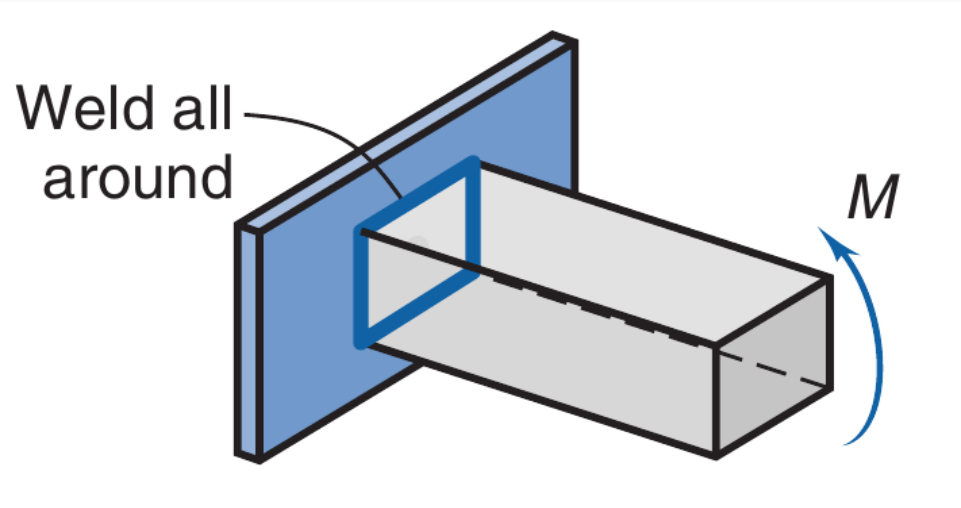
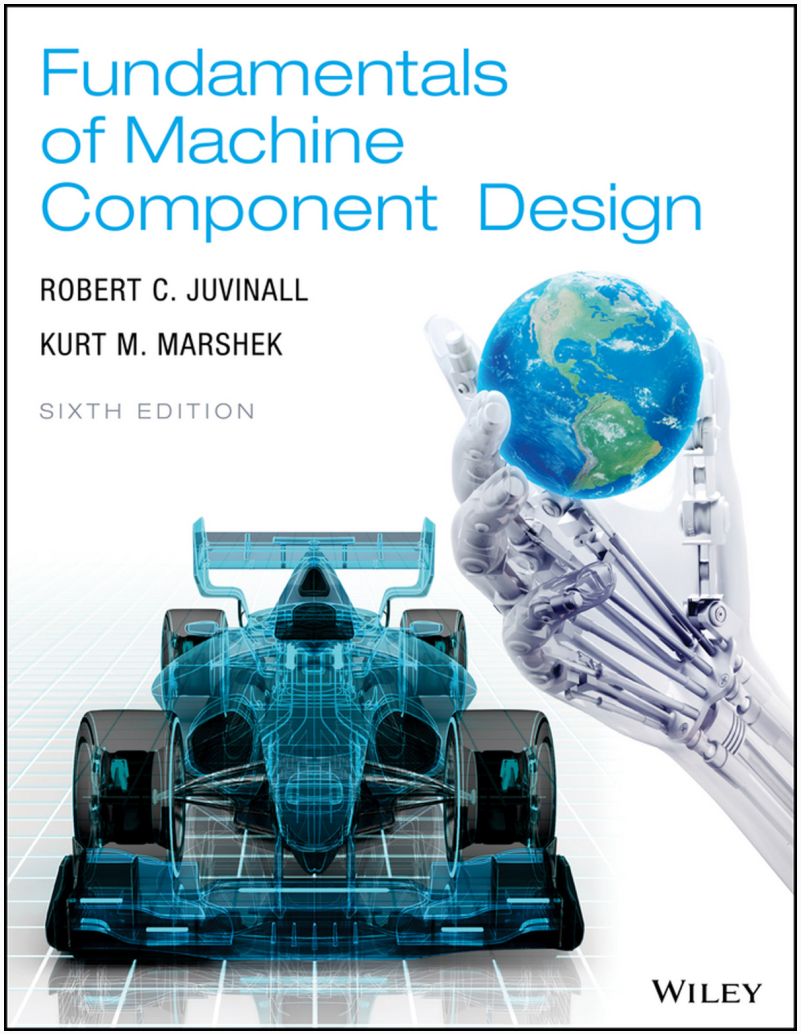


Figura 8: Welded joint under bending [1]

31/05/2022 - Introduction and REApE
06/06/2022 - Exercises using REApE cases
07/06/2022 - Welds treated as lines + Exercises

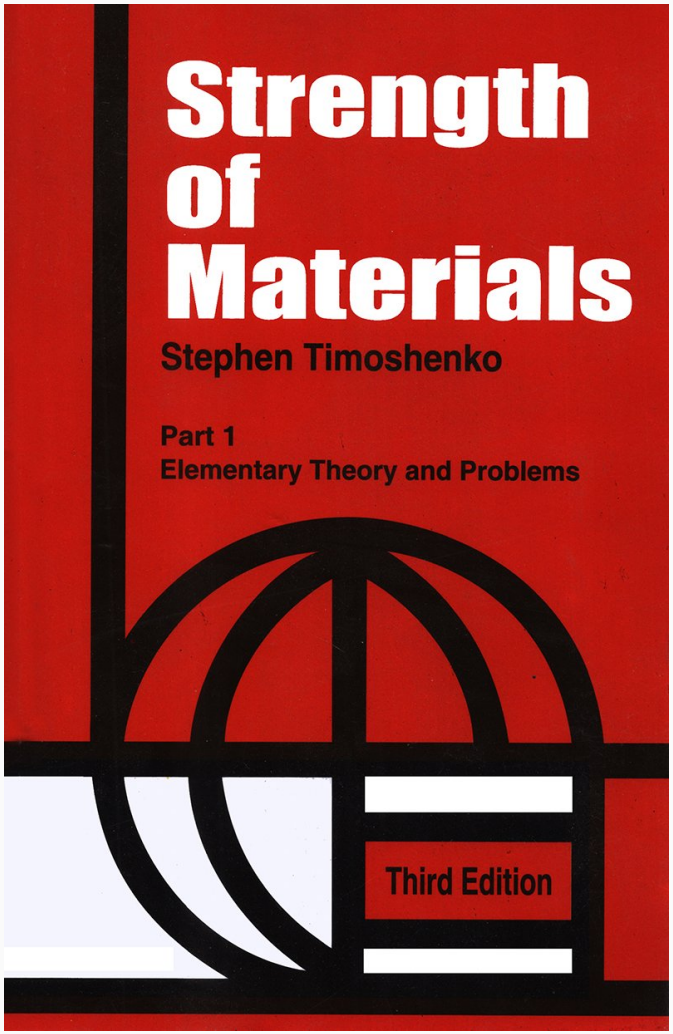
Bibliography

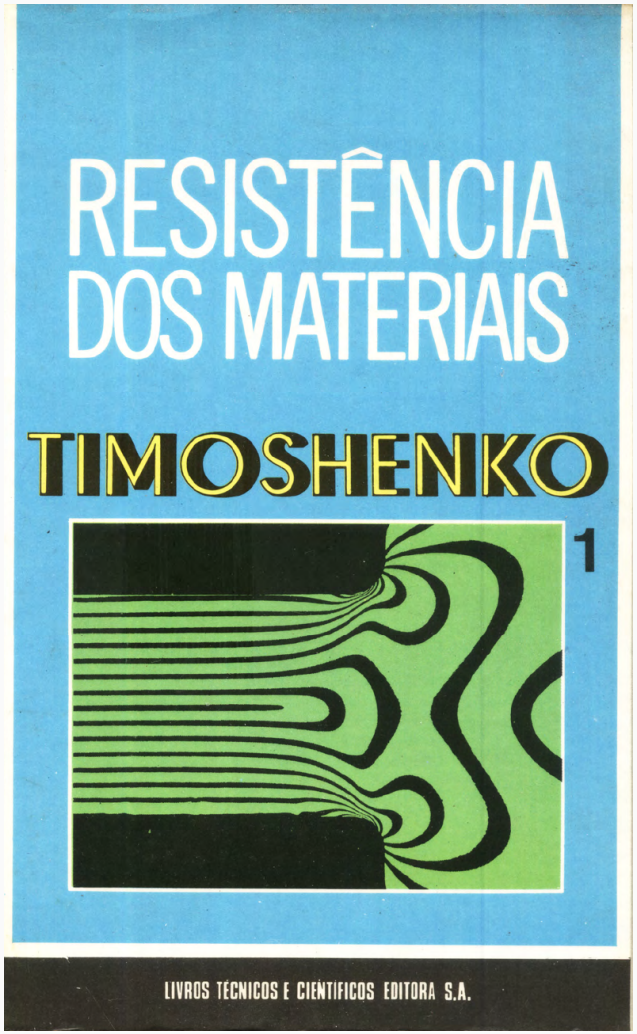
- Robert C. Juvinall, Kurt M. Marshek; Fundamentals of machine component, Wiley, 2017.



Bibliography

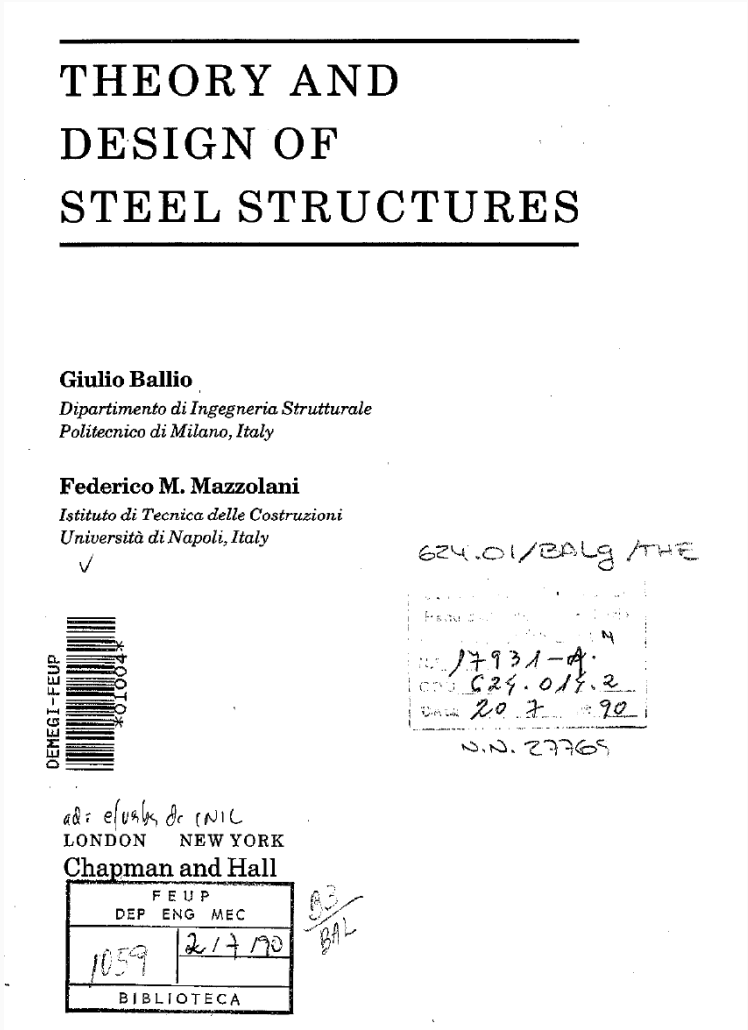
- Stephen P. Timoshenko; Resistência dos materiais (Curved beams, thick cylinders, rotating cylinders)





Bibliography

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



THEORY AND
DESIGN OF
STEEL STRUCTURES

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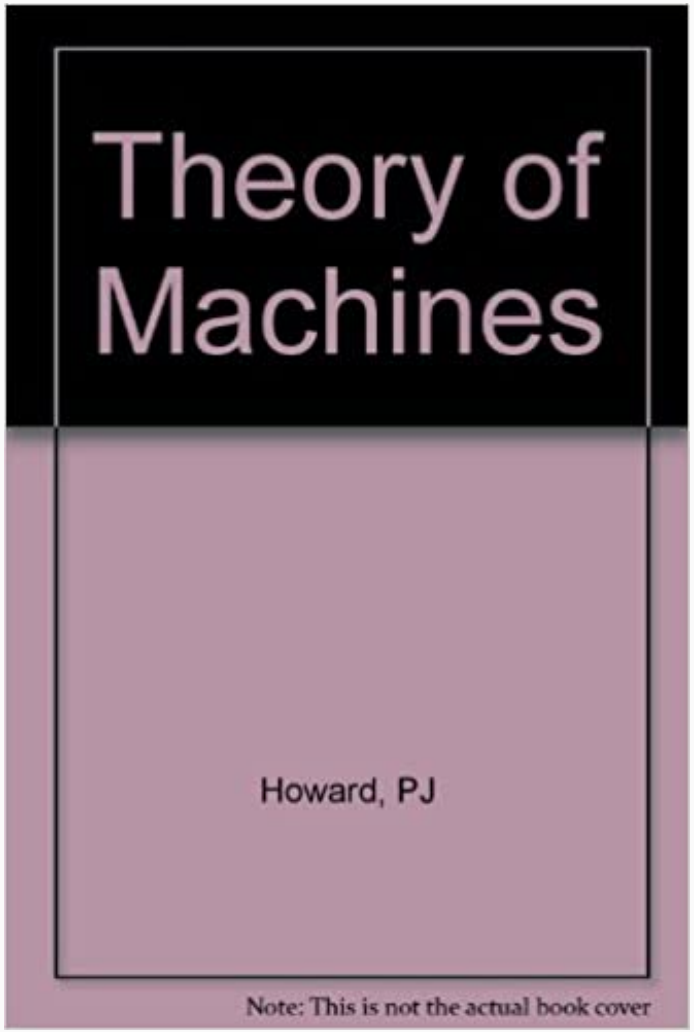
Chapman and Hall

Bibliography

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



Other bibliography

- Robert C. Juvinall, Kurt M. Marshek; Fundamentals of machine component design. ISBN: 0-0471-52989-3
- Stephen P. Timoshenko; Resistência dos materiais (Curved beams, thick cylinders, rotating cylinders)
- Giulio Ballio; Theory and design of steel structures. ISBN: 0-412-23660-5 (Welded joints)
- P. J. Howard; Theory of machines, Macdonald, 1966 (Friction in clutches and brakes)

The basic reading material for this course are course notes available on the contents page of the course. Supplemental material like papers, standards and industrial catalogues will be used.

Course Contents

Brief demonstration about:

How to access the Course Contents

Teaching methods and learning activities

1. Lectures:
    - Theoretical in nature (usually divided into two lectures)
    - Proposal of homeworks
    - Discussion of homeworks

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

3. Webinars/seminars with industry specialists:
    - Rolling bearings (usually in Spanish) - Schaeffler;
    - Belts - Optibelt - 28/04/2022 at 14pm

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
Clases	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 short reports with:

- analytical resolution of a proposed exercise;
- make use of a programming language (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 will be suggested every week.

A student should deliver **6 Short Reports about different topics to get 30%**.

Assignment calendar

Report	Assignment	Due date	Weight
R1	A01 + A02	Week 3	15%
R2	A03 + A04	Week 5	15%
R3	A05	Week 6	15%
R4	A06 + A07	Week 8	15%
R5	A08 + A09	Week 10	20%
R6	A10 + A11	Week 12	20%

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/`
  - Graphic User Interface for CalculiX – `http://lace.fs.uni-mb.si/wordpress/borovinsek/?page_id=41`
- Gear Calculation – `https://github.com/cfernandesFEUP`
- Gmsh – `https://gmsh.info/`

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 in inside the network drive
   `\\software.fe.up.pt\lickisssoft\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_2020”.
5. Finish your installation and you are ready to start the Tutorials that are available on Course Contents.

References

[1] Osgood, Carl e Fatigue Design: *Fundamentals of Machine Elements*.
2014, ISBN 9781482247503.

[2] Budynas, Richard G.: *Shigley ´s mechanical engineering design*.
ISBN 9789339221638.

[3] Juvinall, Robert C. e Kurt M. Marshek: *FUNDAMENTALS OF MACHINE COMPONENT DESIGN*.
Wiley, 2017.

End

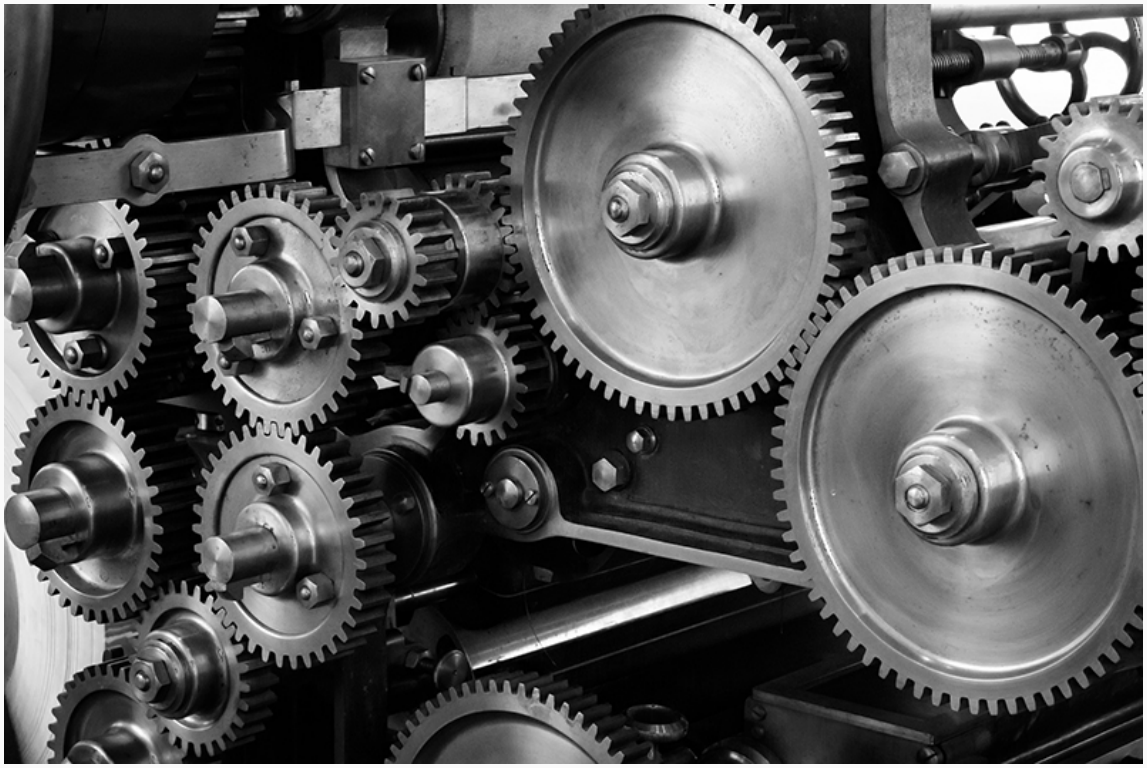


Figura 9: Machine (source: https://sjomaintenance.com.au)