Machine Design

MEC-E1060

Aalto-yliopisto
Insinööritieteiden
korkeakoulu

Kaur Jaakma

1.9.2023

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Responsible Teacher

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Aalto University
School of Engineering

Content

Course practical matters

Group work and first task

Practical Matters

Learning Outcomes

After the course the student recognizes basic elements, concepts and methods of machine design.

Student knows and can utilize computer aided tools in mechanical engineering tasks.

Terminology

CAD (Computer Aided Design)
- Creating 3D geometry

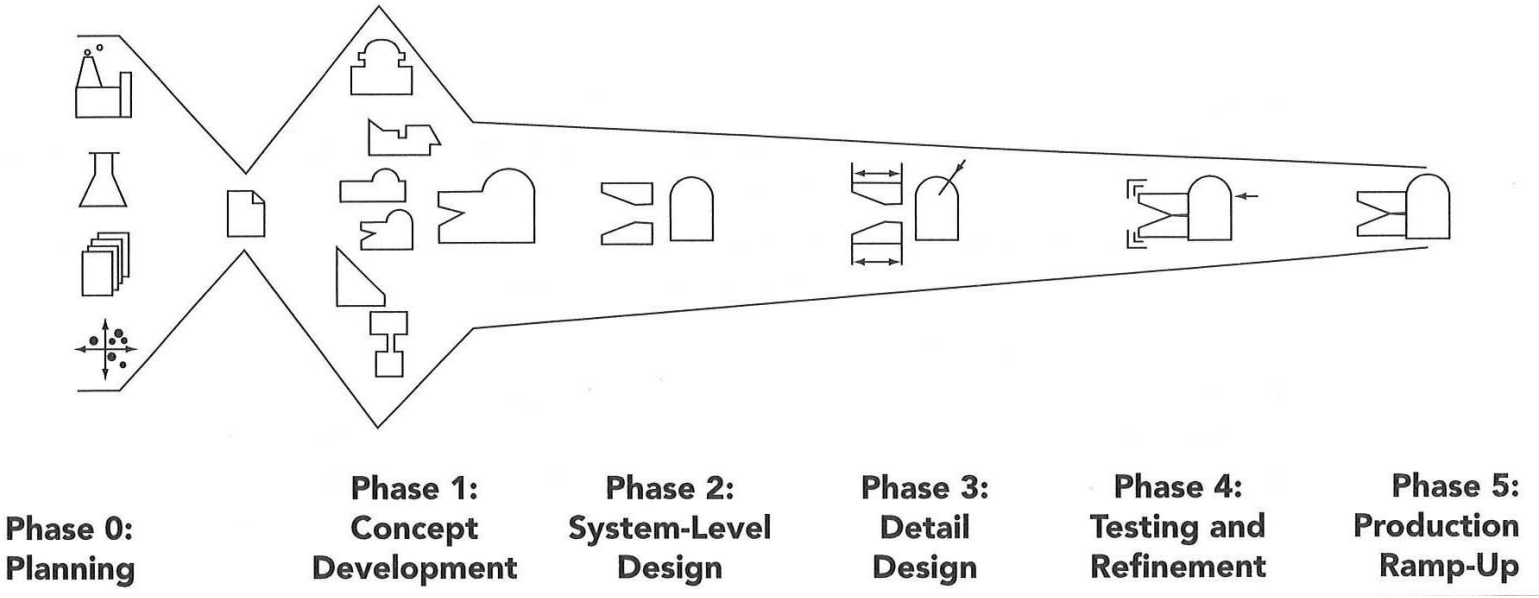
CAE (Computer Aided Engineering)
- Analyzing geometry

MBS (Multi-body Simulations)
- Analyzing moving bodies, i.e. mechanisms

FEA/FEM (Finite Element Analysis/Method)
- Used to calculate stresses, displacements, temperatures etc.

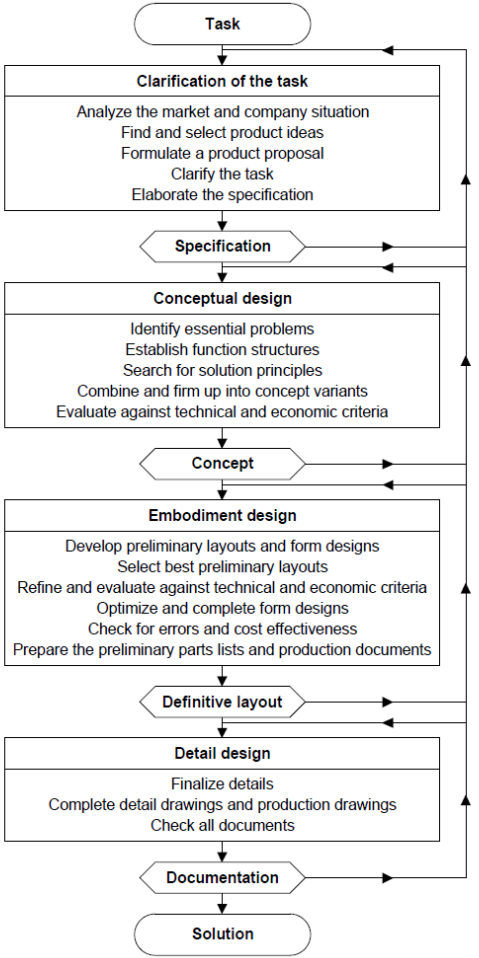
PDM/PLM (Product Data/Lifecycle Management)
- Storing and handling all data related to company products

Product Design Process



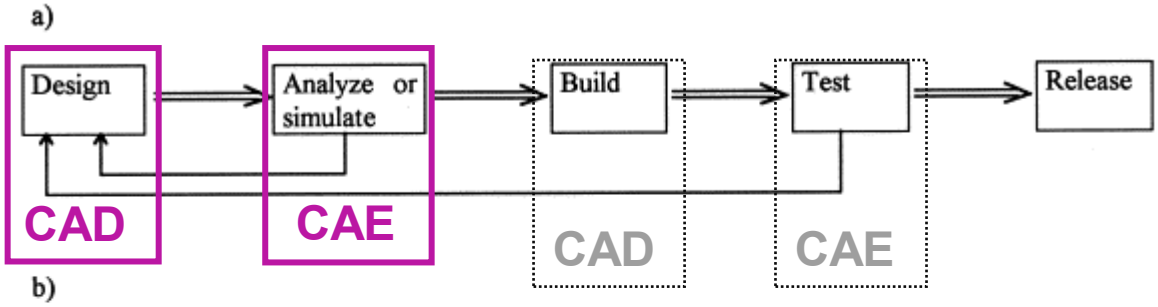
Ulrich & Eppinger. 1995. Product Design and Development.

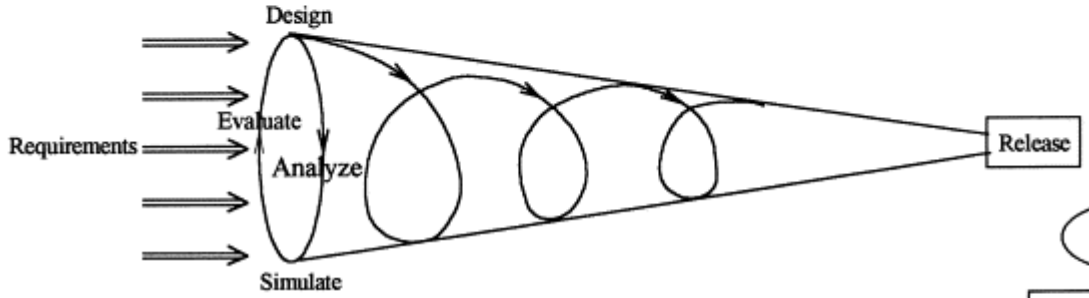
Systematic Approach to Engineering Design



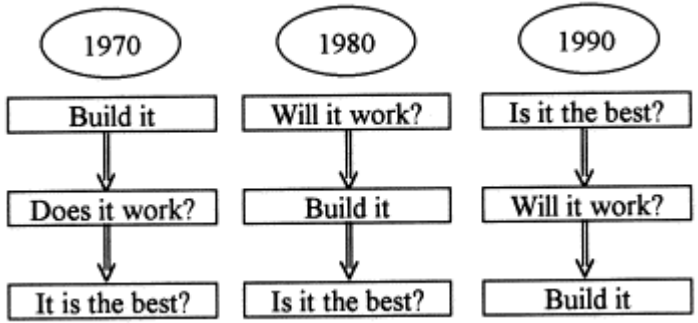
Pahl & Beitz. 1977 (1984 in English).
Systematic Approach to Engineering Design.

Simulation Based Design (SBD)





Source: Bossak, M. A. (1998). Simulation based design. *Journal of Materials Processing Technology*, *76*(1), 8–11. https://doi.org/10.1016/S0924-0136(97)00308-7



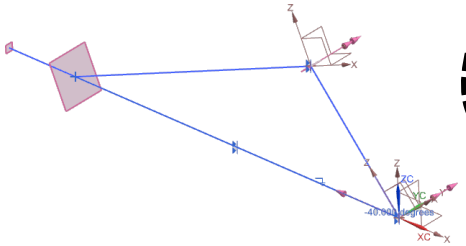
Iterative process

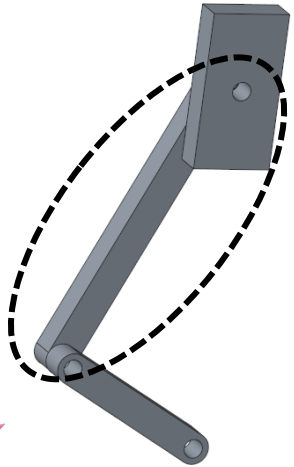
Simulation as an engineering tool

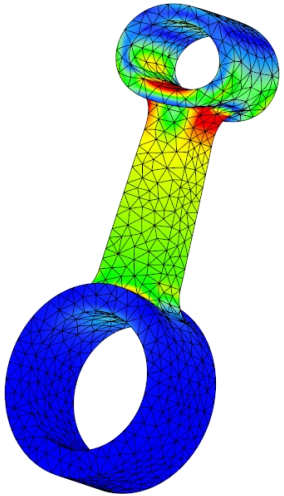
Course Themes

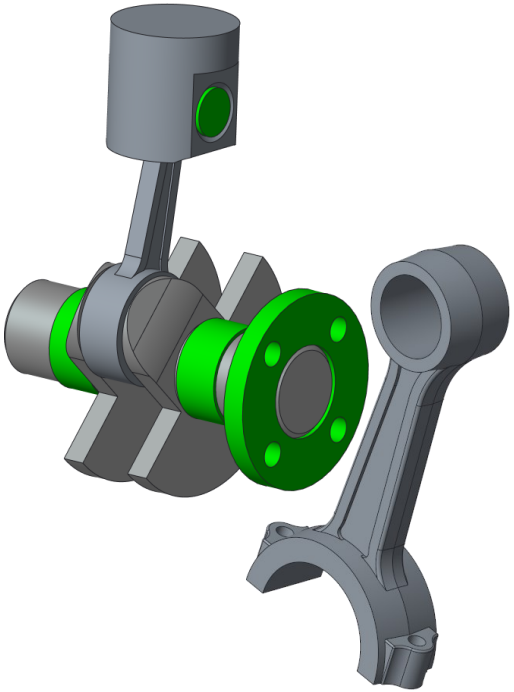
Requirements

- Yield stress under *250 MPa*
- *100 mm* > Dimensions > *250 mm*
- Temperature –20...500 °C
- Yield stress under *250 MPa*
- *100 mm* > Dimensions > *250 mm*
- Temperature –20...500 °C









Preliminary Design	Mechanism Analysis	Strength Analysis	Detailed Design
Week 1	2-3	4-5	6

Course Contains

Length 6 weeks
- Weeks 37-42
- One weekly visiting lecturer and two weekly exercise guidance slots

Group work
- In group of three, four deliverables
- Groups created in MyCourses

Several surveys
- Start and End
- Weekly status

Two personal quizzes in MyCourses
- MBS and FEM

Weekly Schedule

Time	Mon	Tue	Wed	Thur	Fri	Sat	Sun
8-10							
10-12	**Visiting Lecturer**						
12-14		**Exercise guidance sessions**		**Exercise guidance sessions**			
14-16							
16-18							

Lectures

Week	Monday 10-12 @ K213a	Visiting lecturer
36	PLM in Industry	Tuomas Ruippo, Kone Oyj
37	Multi-body Simulations (MBS)	Milla Vehviläinen, VTT Oy
38	Design Automation	Harri Taskinen?, Eviden Oy
39	FEM in Industry	Tuomo Kuusi, Entop Oy
40	Case from Industry	Niko Tapanainen, Bluefors Oy
41	Cases from research and education	Panu Kiviluoma, Aalto University

Exercise Guidance Sessions

Teaching assistants available for personal/group guidance

- Tue 12-16 and Thur 12-16
- Based on queue in MyCourses

Other times we try to follow the Zulip discussions and participate when needed

- Invitation link in MyCourses page
- Course related questions will be answered there

Workload

5 ECTS course → 5*26 h = 130 h

6 week course → 130 h / 6 weeks = 22 h / week

Distributed

- 4 h / week for preparation to weekly topic
- 2 h / week for lectures
- 16 h / week for group work
  - 8 h / week possible during exercise slots

Grading

The course final grade is based on the group work

Four deliverables

- Reports
- Models (if asked)

$$IF\ G_N > 0\ Then\ G_{final} = \frac{G_{Preliminary} + 2 * G_{MBS} + 2 * G_{FEM} + G_{Detailed}}{6}$$

University’s Grading System

Scale from 0-5

- 0 fail
- 1 passed
- 2 satisfactory
- 3 good
  - “has all the necessary elements, but no particular merits”
- 4 very good
- 5 excellent

Software Used Before N=106 (2022)

Software	Not at all	I know	Some experience	Use regularly
Catia	68	23	10	5
Creo	36	13	48	9
Fusion 360	58	13	19	3
Inventor	85	8	8	5
NX	72	20	11 This course!	3
Onshape	94	9	2	1
Solid Edge	42	9	38	17
SolidWorks	16	26	40	24
Vertex	99	6	1	0

Software Tools

CAD/CAE
Version 2027

Siemens Learning Advantage

Database for tutorials and videos related to software

- In this case NX

Students have access

- Registration with Aalto email required
- Instructions in MyCourses

Software Home Usage

NX can be downloaded from downloads.aalto.fi

- Includes an automatic installation script
- Requires VPN connection (vpn.aalto.fi)

Remote desktop to physical/virtual classroom computer

- vdi.aalto.fi
- *Classrooms K148*, *Maari C*, *A046/a (Windows 10)*
- *Virtual computers Win 3D*

Group Work

Group Work Task

In a group of three, choose an existing task/challenge

- Find and choose a mechanism with power source that can solve it
  - From living environment, industry, etc.
- Minimum of 3 moving bodies and ground/frame part
- One-degree-of-freedom planar linkage mechanism
  - So only one power source!
- This will be utilized during the whole course
  - MBS and FEM simulations will be performed to this mechanism, so it needs to have a power source (rotational/linear actuator etc.)

The aim of the group work is to learn together these tools and methods, not to build a perfect machine!

A Good Mechanism

Simple

- Three/four moving parts and a ground part
- One rotational or linear power source
- More complex can be interesting to analyze, but you must create much more complex simulations (takes a lot more time)

High forces

- Higher forces cause more stress to parts → interesting strength simulations and results
- Possibility to test different kind of part geometries

Course Themes

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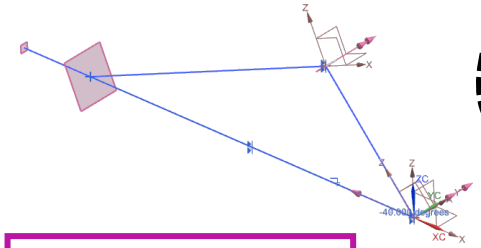

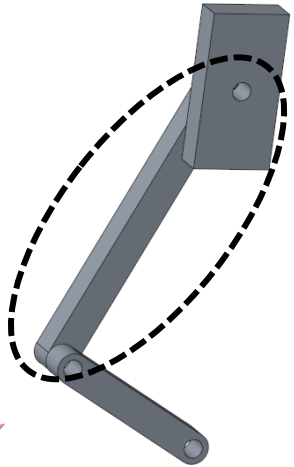

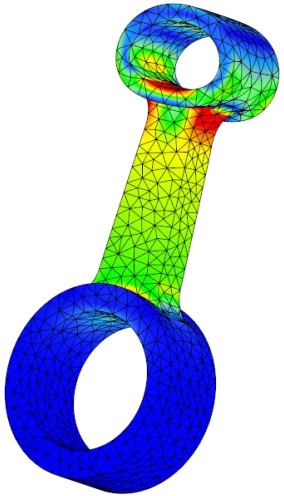

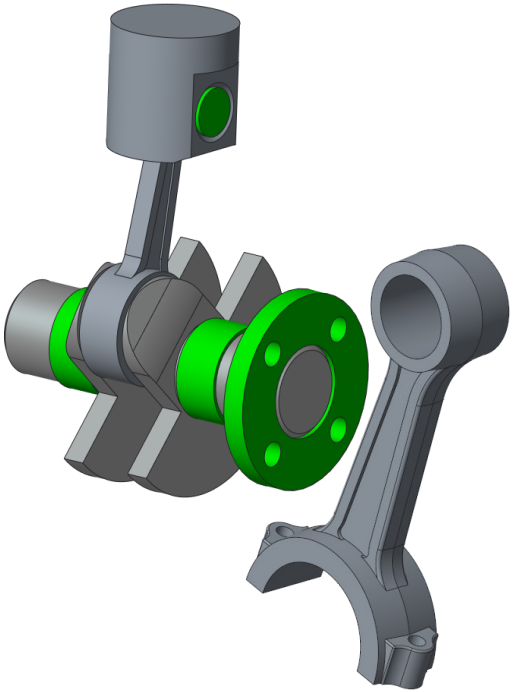

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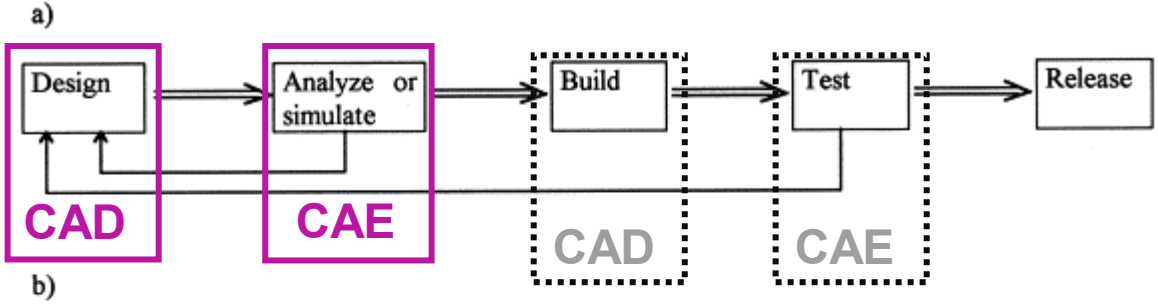
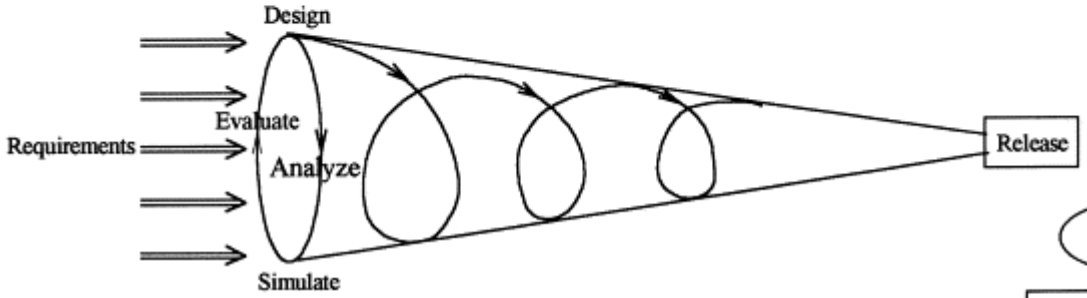
Simulation Based Design (SBD)





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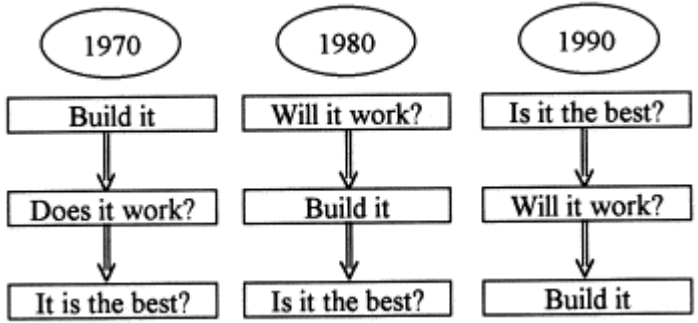
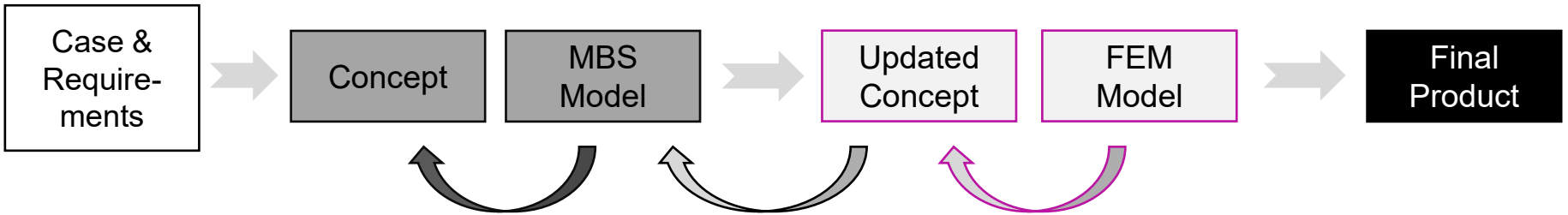


Iterative process

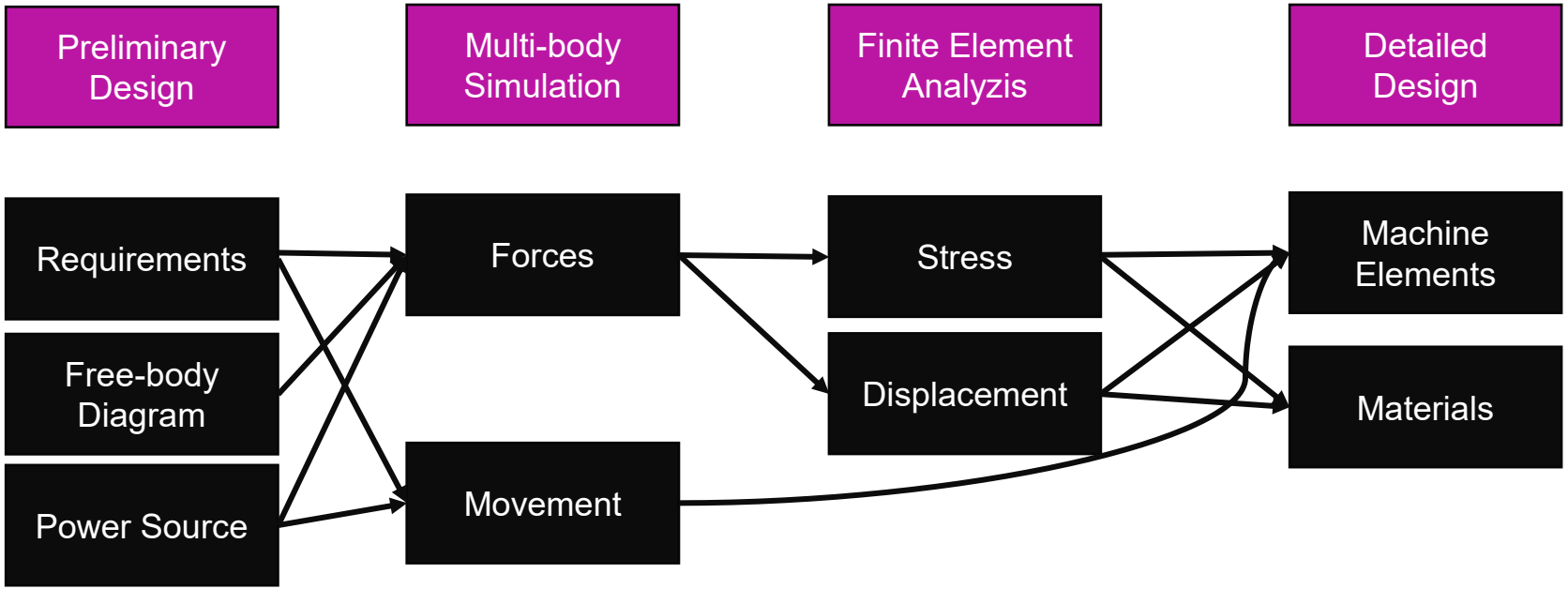
Simulation as an engineering tool

Simplified SBD Process in the Group Work

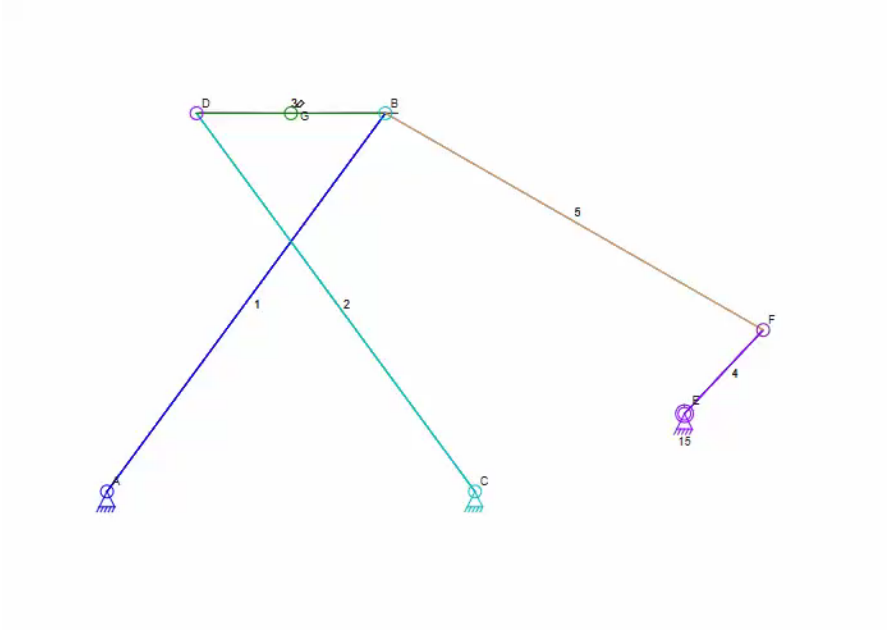


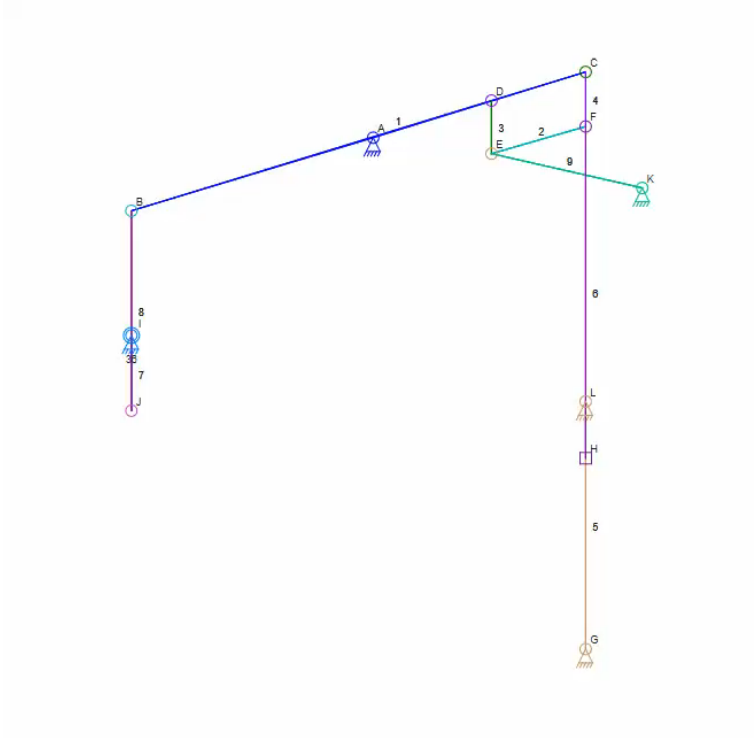
Skeleton models & Rough CAD models | Simplified CAD models | Detailed CAD models

Group Work Task



Planar one degree of freedom linkage mechanism examples





Group Work

Topic	Deliverables	DL
Preliminary Design	Analyzed case chosen, requirements list, and free-body diagram	10.9.
Mechanism Analysis	Multi-body simulation model of the concept MBS models, results, and plan how to validate	24.9.
Strength Analysis	Updated geometry of the concept FEM models, results, and plan how to validate	8.10.
Detailed Design	Selected machine components (bearings, motors etc.) Final assembly with updated geometry	15.10.

Preliminary Design Task

Description of the selected mechanism (one-degree-of-freedom)

- Operation principle, application environment, what makes it interesting
- Create a requirements list for that mechanism and draw a free-body diagram
- Pictures/sketches/operation principle about/of selected mechanisms

Define your group´s working rules

- How your group will be working, where, and with what tools etc.

Returned to MyCourses as a PDF-file

- By the end of week (10.9.2022)

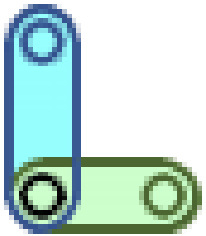
Linkage software

Free and simple planar mechanism design tool

- https://blog.rectorsquid.com/linkage-mechanism-designer-and-simulator/
- Download the zip-package (includes short tutorial)
- Kinematic solver, so no forces are calculated

Can be utilized as fast testing tool

- If the mechanism works, then you are in a good track



An example requirements list

You can choose the list type freely.

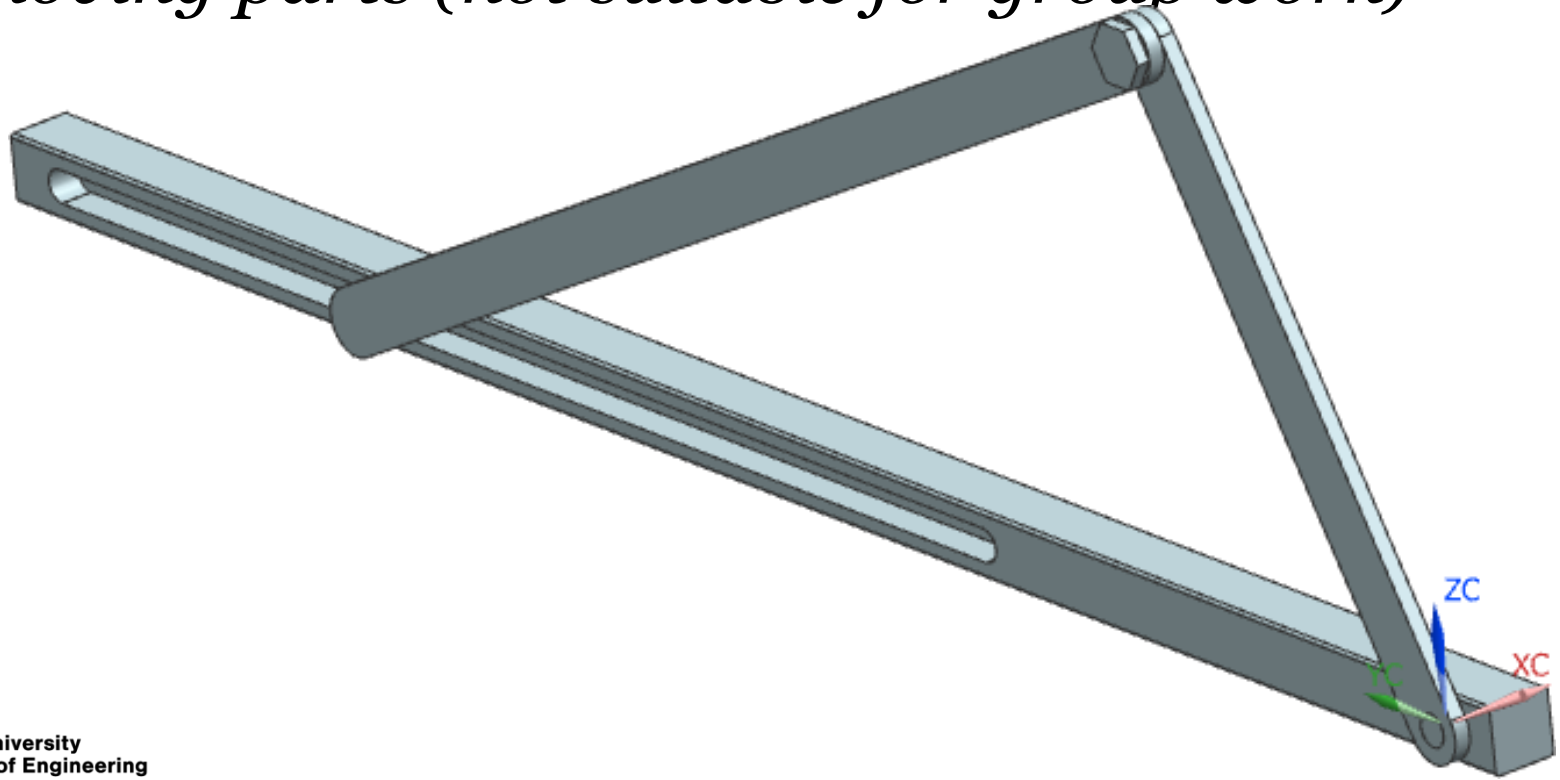
Just ensure that your requirements are measurable!

- You need to go back to them often

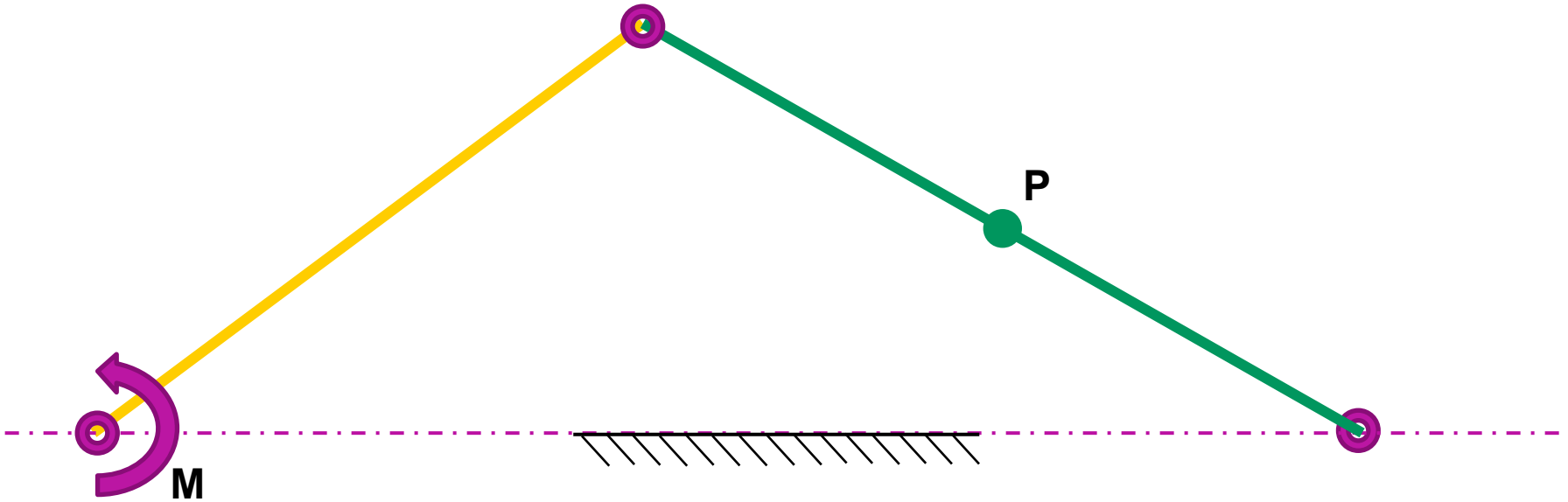
req	level	Measure	Other
Has to lift 10t	Demand	From MBS simulations	
Cycle time < 10 s	Demand	From MBS simulations	

A Mechanism

Two moving parts (not suitable for group work)

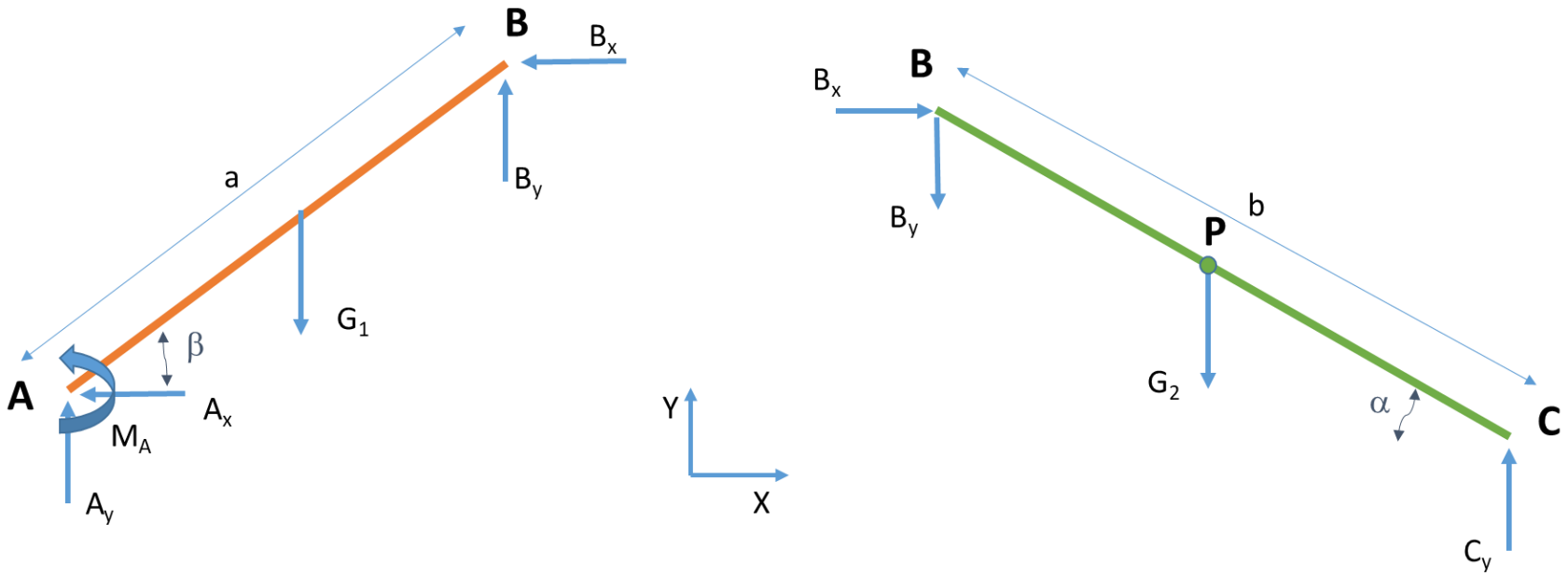


Free-body Diagram



Free-body Diagram

without friction



Structure of a Good Report

IMRAD (IMRaD)

Introduction

- What was done, why etc.
- Literature

Methods

- What tools were utilized, how the task was done etc.

Results

- What was obtained etc.

Discussion

- What was learned, what can be improved etc.
- Own justified grade estimate

References and Sources

During Week 1

Enroll to a group in MyCourses

- After the first visiting lecturer

Figure out a mechanism for your group

- Planar 1 DoF linkage mechanism, one source of motion
- Create requirements list for it
- Draw a free-body diagram of it

Present you initial idea to the course staff during exercise session on Thur 12-16!

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