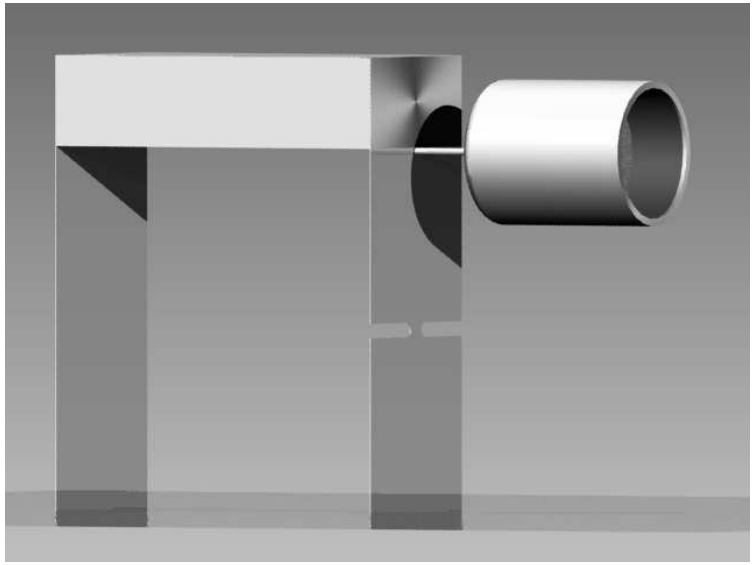
Flexible Multibody System Analysis for Control Purpose

DISC course 2009/2010

Lecturers: J.B. Jonker, R.G.K.M. Aarts, J. van Dijk
University of Twente / Faculty of Engineering Technology (CTW)
Mechanical Automation (Wa)
Horstring (building 21) W 218, W 234, W 232
Phone: (053) 489 2591, 2557, 2601
Email: J.B.Jonker@utwente.nl,
R.G.K.M.Aarts@utwente.nl,
J.vanDijk@utwente.nl

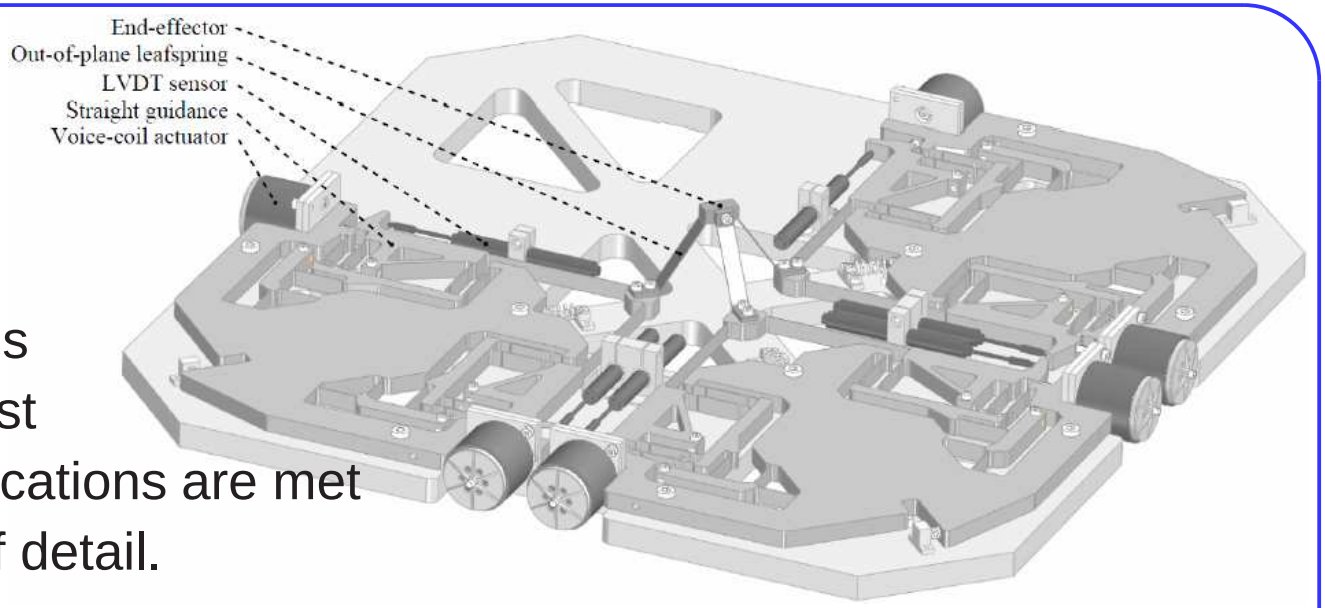
WWW: http://www.wa.ctw.utwente.nl/lectures/FMSA4CP/

Overview



- Introduction.
- Multibody system approach.
- Software package SPACAR.
- Mechatronic system design.
- Example system.
- Outlook on the analysis of example system with SPACAR.
- Course topics.

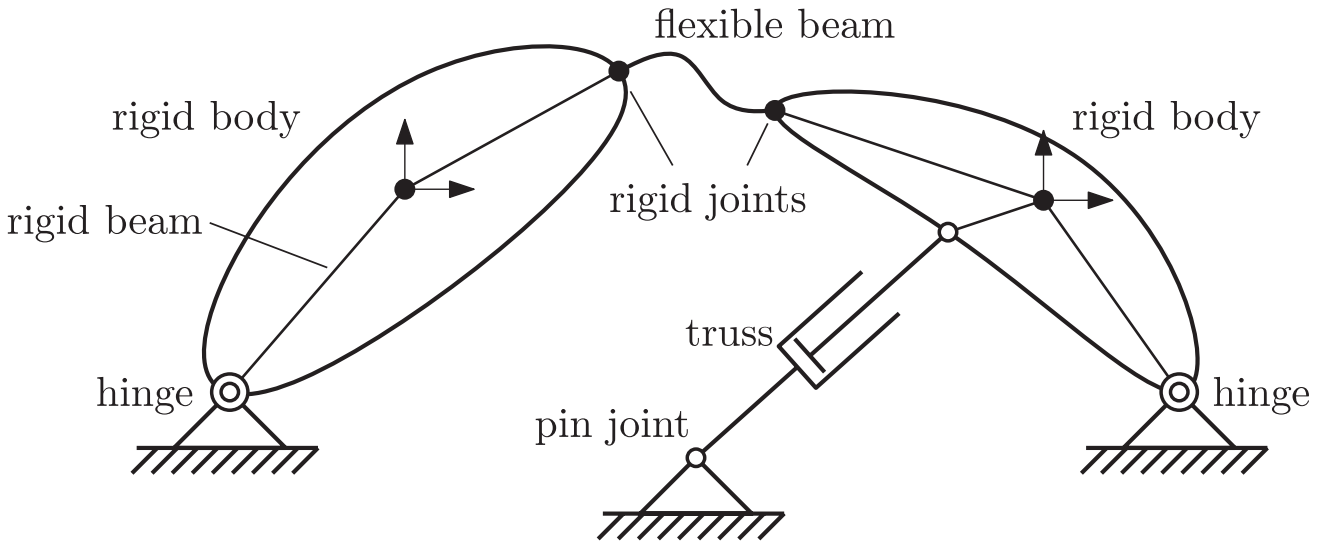
Introduction



- Modelling and analyses enable designers to test whether design specifications are met
  $\rightarrow$ with varying level of detail.
- In the early, conceptual stage: high level analysis when only a few design details are known.
- Simple prototype models with a few degrees of freedom:
  - Capture only the relevant systems dynamics
    $\rightarrow$ offer insight.
  - Quick to evaluate, quick to change
    $\rightarrow$ immediate feedback on design decisions.
  - Comprehensive exploration of design alternatives
    $\rightarrow$ well-considered selection of “best” design concept
    $\rightarrow$ to be analysed in more detail (e.g. with ANSYS).

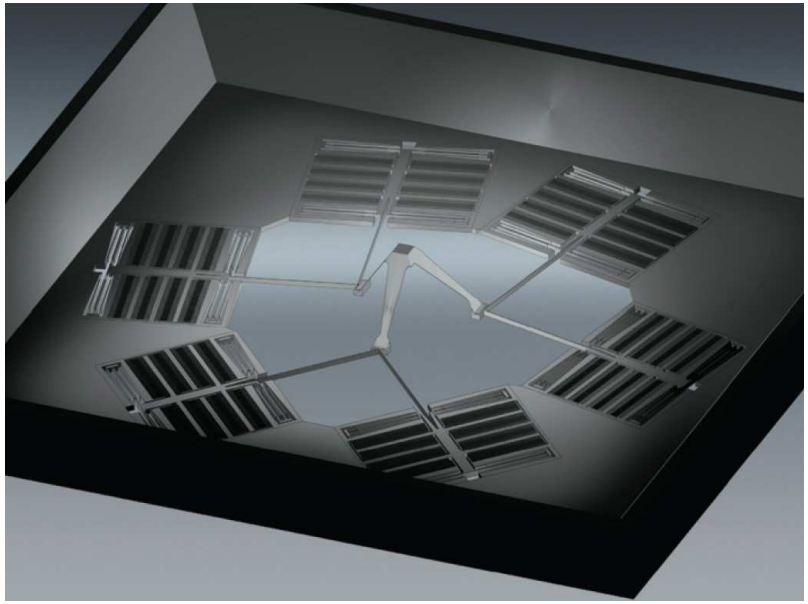
Multibody system approach

- Multibody systems: Collection of interconnected flexible and rigid bodies or links that move relative to each other, consistent with joints that limit the relative motion of the bodies.



- Equations of motion expressed in terms of system's degrees of freedom (DOF's) $\rightarrow$ Lagrange equations.
- Linearised equations of motion $\rightarrow$ State-space equations.

Software package SPACAR



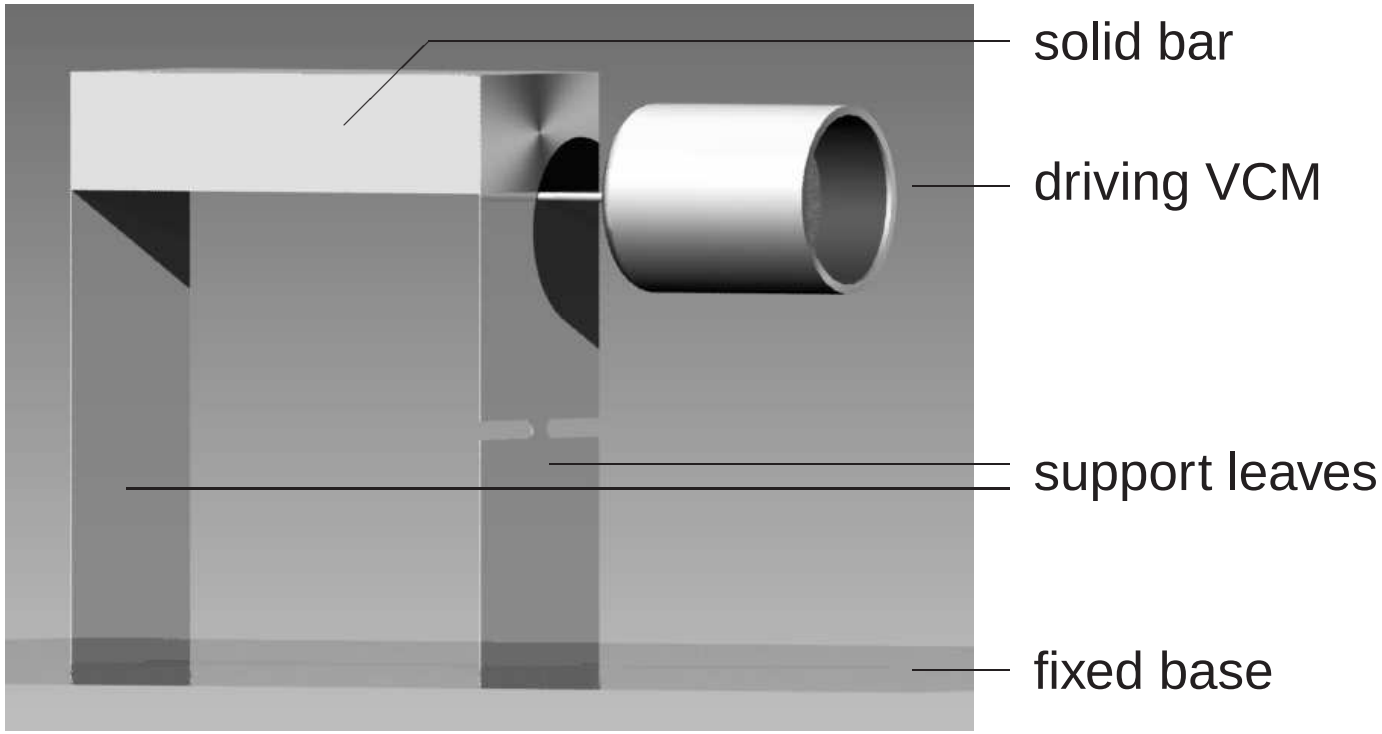
- Kinematic and dynamic analysis of
  - flexible multibody systems,
  - flexible structures.
- Based on the finite element method
- MATLAB and SIMULINK (win32) user interface for the analysis of (linear) systems including visualisation.
- GUI to facilitate the creation of models.

Mechatronic system design

- Conceptual design
  - Kinematic analysis.
- Dimensioning the concepts
  - Natural frequencies and mode shapes
  - Static stability (buckling)
  - State space input output formulations (SISO or MIMO)
  - Simulation of the dynamic behaviour.
- Computer aided prototyping.
- Final design (fine tuning, e.g. with ANSYS).

Example system

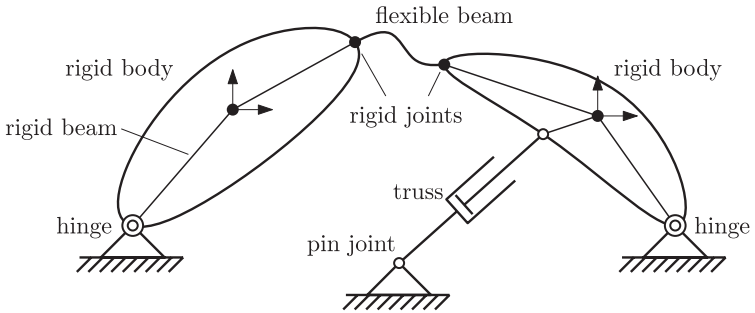
- One degree of freedom (1-DOF) VCM-driven support mechanism with elastic leaf springs. Both springs are fixed at the bottom (clamped support).



- This system will be analysed with an increasing degree of complexity using SPACAR.

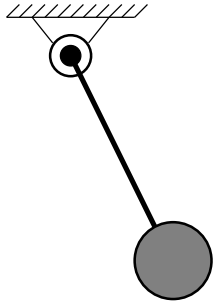
Outlook on the analysis of example system with SPACAR

- Introduction of the finite element concept with *nodal coordinates* and *element deformations*.

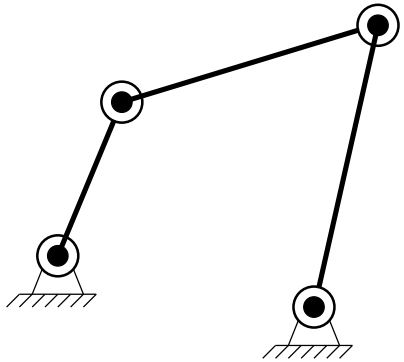


- Two-dimensional (planar) and three-dimensional (spatial) models with (a small number) truss and beam elements.
- Each element has nodal points: The coordinates of translational and rotational nodal points describe the element's position and orientation.
- For each element a fixed number of independent (discrete) deformation modes are defined as functions of the nodal coordinates. Deformation modes are always invariant for rigid body movements of the element.
- Systems are defined in SPACAR input files (e.g. using the GUI) and after the call to `spacar` the results are available in MATLAB variables and stored in output files.

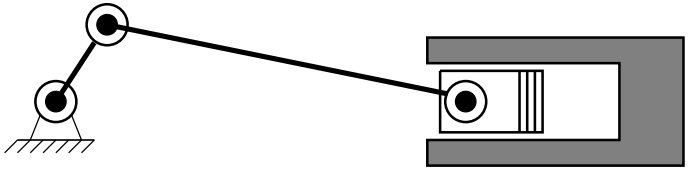
Mechanism: Primary function is to achieve a desired motion.



Single pendulum

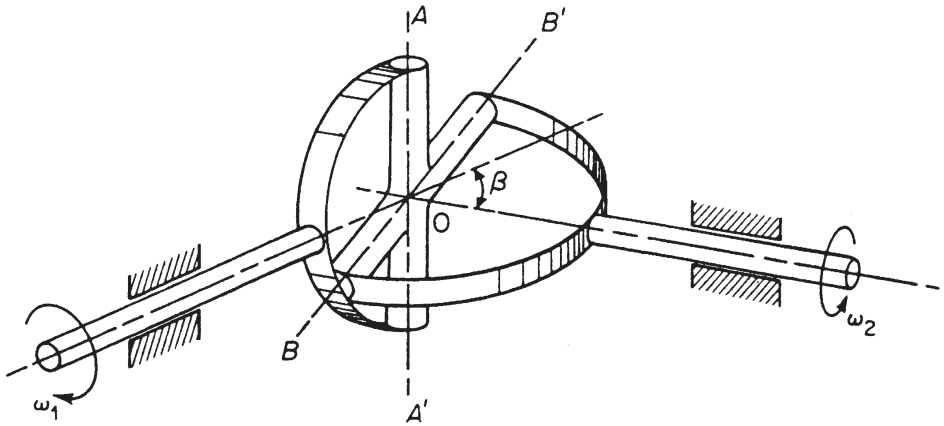


Four-bar mechanism



Slider-crank mechanism

Machine: Primary function is transmitting power or force.



Cardan-joint (machine component)

Course topics and schedule (1/2)

Week 1: Scope of flexible multibody kinematics and dynamics. Multibody versus finite element formulations.

Weeks 2, 3: Finite element representation of (planar) flexible multibody systems. Kinematical analysis: the concept of constraints, degrees of freedom and geometric transfer functions. Dynamic analysis: lumped mass formulation, consistent mass formulation.

$\rightarrow$ **Exercise 1.**

Week 4: Spatial flexible multibody systems. Description of spatial angular orientation: Euler angles, Quarternions.

Week 5: Linearized equations of motion. Simulations with the perturbation analysis.

$\rightarrow$ **Exercise 2.**

Course topics and schedule (2/2)

Week 6: Linearized equations for control system analysis. Linearized state-space equations. Derivation of transfer functions, pole zero cancellation.

Week 7: Modelling for mechatronic design (part 1): Exact constraint design considerations and higher order dynamics. SISO example of an active encoder head.

$\rightarrow$ **Exercise 3.**

Week 8: Modelling for mechatronic design (part 2): Control system synthesis. MIMO example of a 2-DOF tilting mirror.

$\rightarrow$ **Exercise 4.**

- The SPACAR software packages is introduced during the course.
- More detailed information and updates can be found on the course web page.