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“Requirements for FEM Programs in an Educational Environment”

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Applied Mechanics in the education program for Mechanical Engineers

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1st year: Statics; Strength and Stiffness I

2nd year: Dynamics I; Strength and Stiffness II

3rd year: Introduction of FEM; Dynamics II

4th year: FEM in Mechanical Engineering; Advanced Dynamics (50%); Theory of Elasticity; Theory of Plasticity; Plates and Shells; (± 25%)

1st year: Statics; Strength and Stiffness I

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- Statics: Resultant force and moment. Free-body diagram. Theory of equilibrium of forces and moments. Plane trusses, method of joints, method of sections. Beams, shear-force and bending-moment diagrams. Area and mass moments of inertia.
- S & S I: Definitions of stress, strain. Hooke's law. Axially loaded members. Deflection of beams by superposition, by solving the beam differential equation. Principal stresses, Mohr's circles. Torsion of circular shafts.

2nd year: Dynamics I; Strength and Stiffness II

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- Dynamics I: Kinematics and kinetics of particles, of systems of particles and of rigid bodies. Equations of motion. Conservation of energy and linear and angular momentum. Impact. Introduction linear vibrations of particles and rigid bodies.
- S & S II: Beams with combined loading, axial and lateral. Shear stresses in thin-walled members, shear center. Linear buckling of beams. Introduction theory of elasticity (index notation).

3rd year: Introduction of FEM; Dynamics II

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- FEM: Elements for pin-jointed bars, beams, two-dimensional solids, higher-order elements. Discretization of displacements fields, interpolation functions, DOFs. Weighted residual method, virtual work, minimal potential energy. How to mesh models, interpretation of results, Displacement and stress contour plots.
- Dynamics II: Eigenfrequencies and harmonic and time response of one, two and multi-DOF systems, continuous systems. Method of Rayleigh-Ritz. FEM for dynamical problems.

4th year:

FEM in Mechanical Engineering;

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- Advanced linear FEM calculations. The weak form of the equations of equilibrium or motion. Structural and thermal calculations, initial strains, reduced integration, incompressible materials (rubber).
- Assembly and solution of the FEM equations. Incorporation of bound. cond. Gausz-elimination, banded matrices, skyline method, wave front solution technique.
- Geometrical non-linear calculations. Linear buckling.
- Dynamical calculations. Eigenfrequency extraction methods. Numerical integration for transient problems. Acoustics and fluid-structure interaction in acoustics.

Some remarks on the use of FEM packages by students (beforehand)

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Not every FEM-code is directly suitable for use in education.

Special attention should be paid on easily accessible pre- and postprocessing.

Long input files filled by lots of blocks with numbers are not very attractive

Special student-proof manuals are useful.

First use of a FEM package during the education program

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Introduction of FEM; 3rd year course

Computer practical exercise with:

- MATLAB: a simple plane truss problem (calculation of element matrices; assemblage of the stiffness matrix; solving [K].{u}={F}
- ANSYS: bending and torsion of a frame (beams)
- ANSYS: 2dim. problem (plane solid elements)

ANSYS: 2dim. problem

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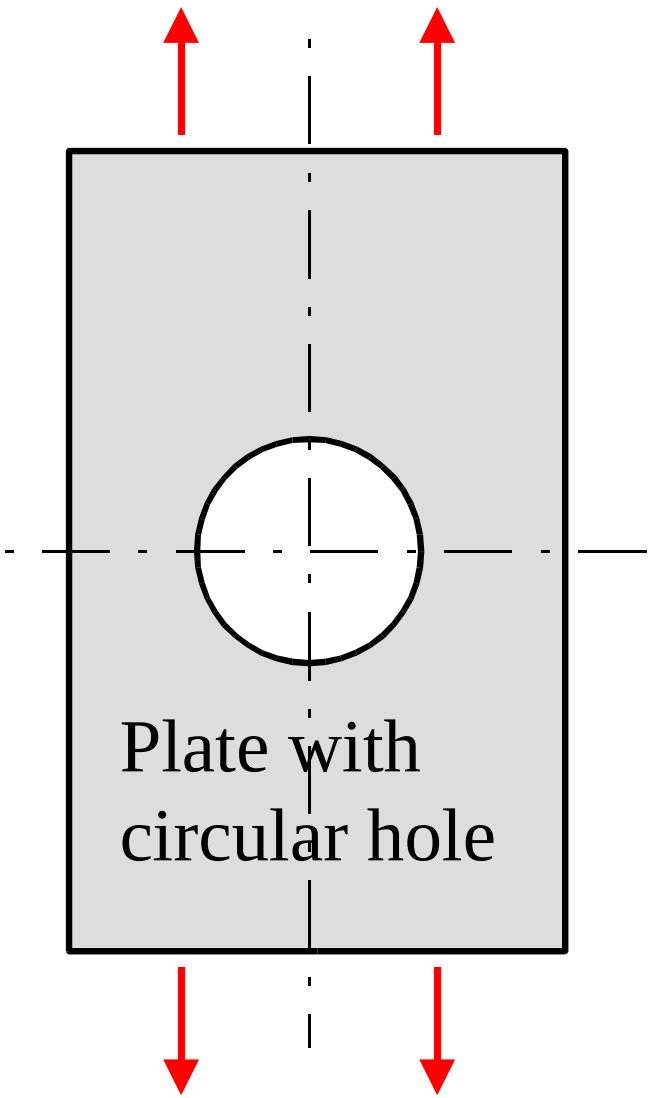

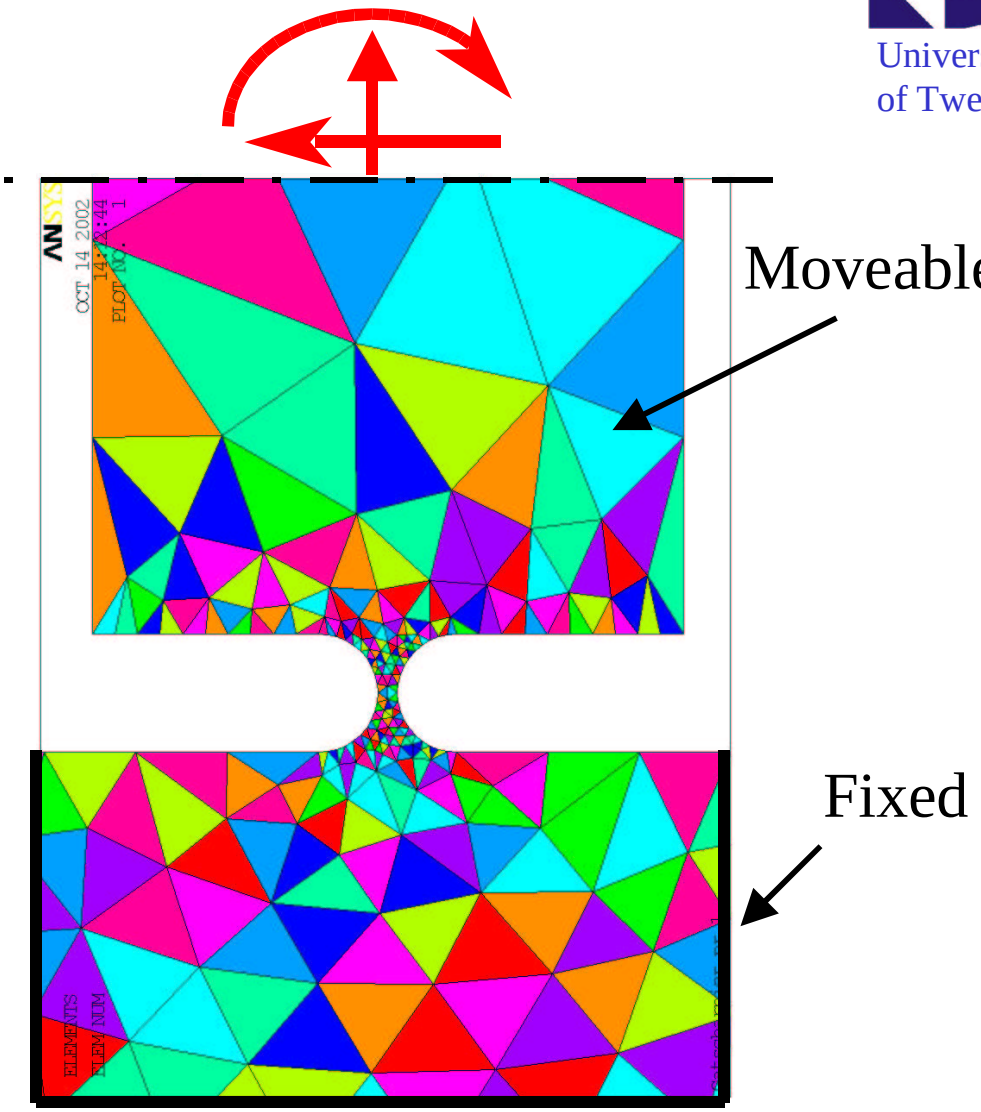

Elastic hinge

Further use of a FEM package (ANSYS) during the education program

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Dynamics II; 3rd year course, combined with mechatronical “Project F”

2dim. mechatronical structure with piezo exciter

Solid Works → IGIS file → ANSYS

Calculation of stress and displacement field

Calculation of eigenfrequencies

The results are used in a MATLAB – SIMULINK – DSPACE simulation and measurement

Mechatronical project F

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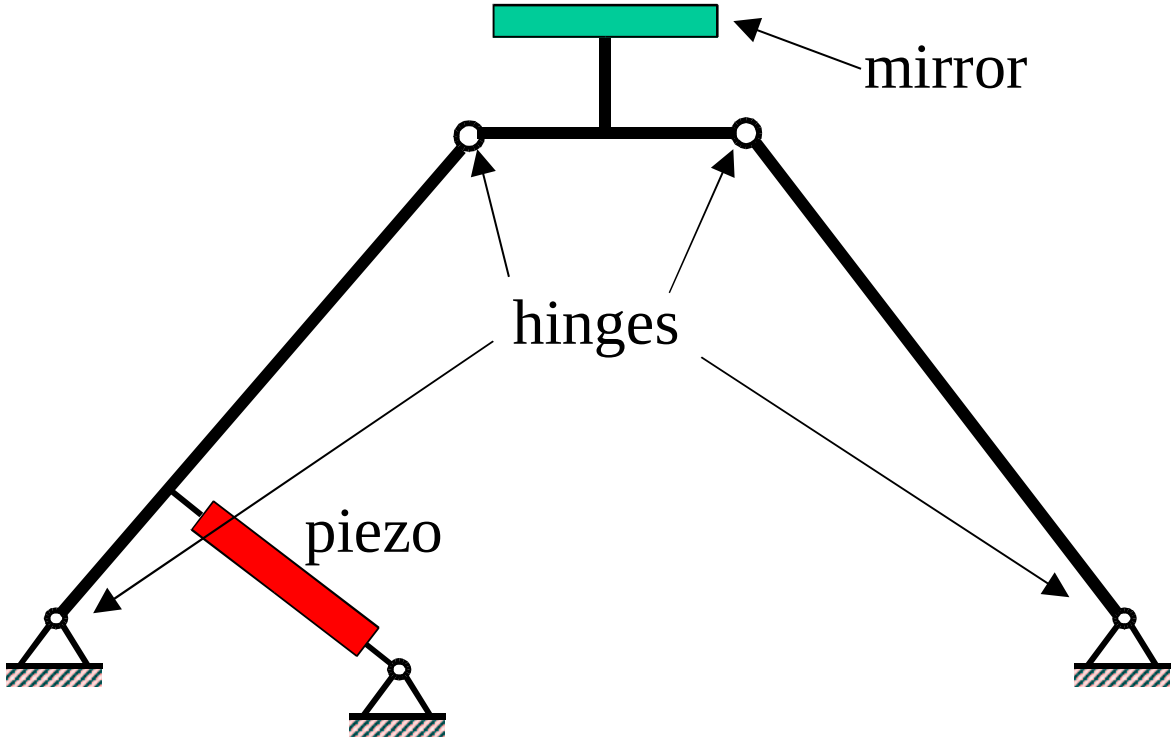
In principle a mechanism build up by beams, connected by elastic hinges, moved by a piezo exciter



ANSYS-plot

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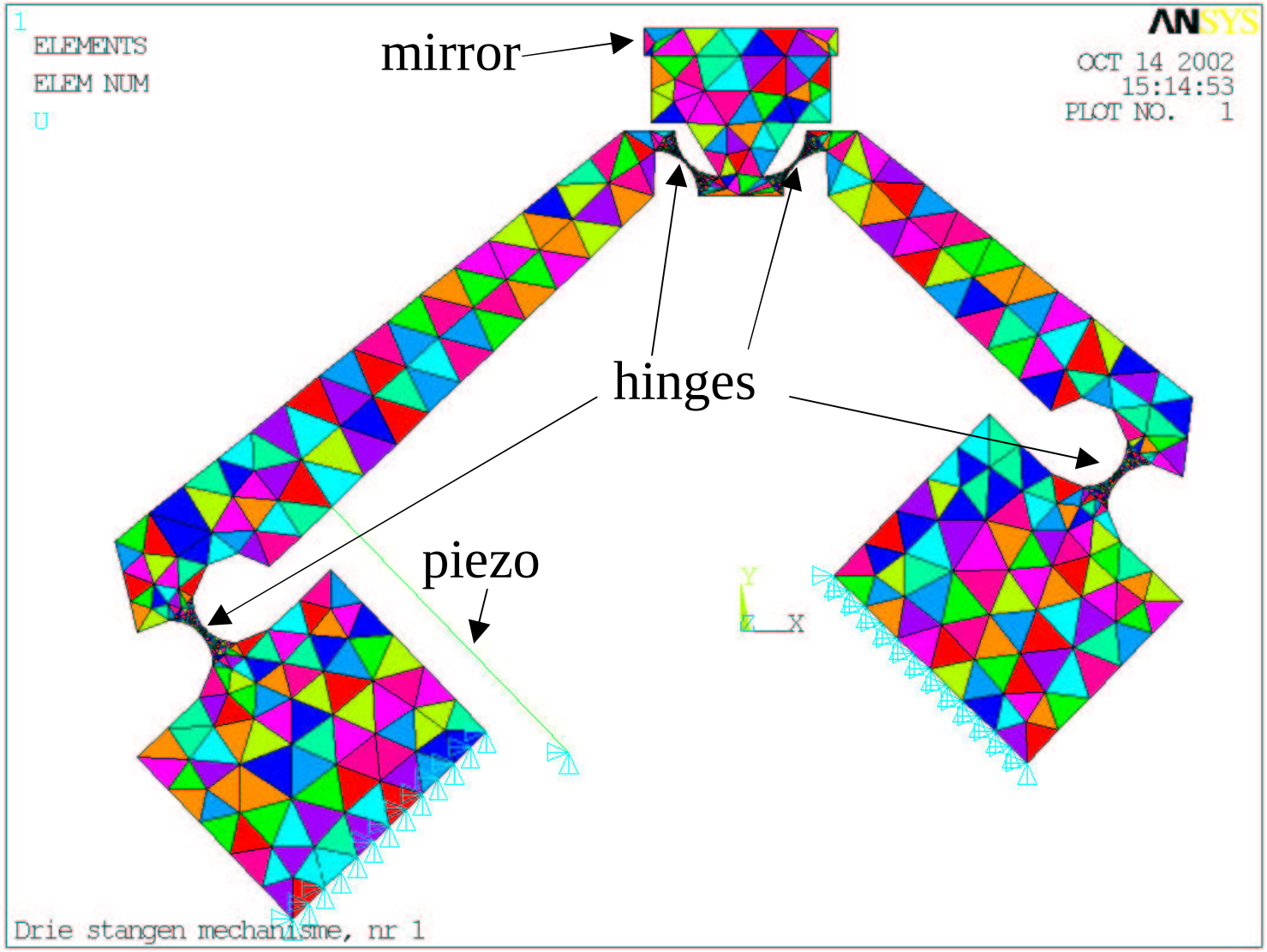

FEM in the 4th year

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FEM in Mechanical Engineering; practical exercise with ANSYS on a simple beam structure

- Dynamics; Eigenfrequencies; Guyan reduction; harmonic analysis; transient calculation
- Linear Buckling; Guyan reduction; geometrical non-linear calculation

In the future part of the MASTER education

Introduction ANSYS DEMO

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Importing and solving a problem in ANSYS is possible in several ways:

- By typing commands (keyboard)
- By input of a file with commands (script, macro)
- With the Graphical User Interface (GUI)
- Import of files from a CAD package (IGIS)
- Combinations of methods mentioned above

Commands in ANSYS

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Every action in the GUI (clicking the mouse on a item) is in the background interpreted as a command.

The commands are stored in a log file. After renaming and removing redundant commands with an editor this file can be used as input file for a new problem.

An input file can contain several programming like instructions, e.g. Do-loops, If … then … elseif … else sequences. Variables can be introduced. This is called: APDL (Ansys Parametric Design Language).

Structure of a command

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Keyword, parameter1, parameter2, ……

Examples:

```
N, 4, 3.4, 8.9      !Input of nodal point 4
E, 2, 5, 8          !Input of element with nodal pts.
EPLOT               !Plot the element mesh
NLIST               !List de nodal point coordinates
```

ANSYS Demo

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- ANSYS5.6ED is used (introduced ±3 years ago)
- Introduction of the GUI, the processors, the HELP,……
- How to build up a mesh….
- How to visualize the model and the mesh
- Finally as sample problem a project F mechanism is presented. It is build up by means of a command input file (a suitable IGIS file was not available).

Example

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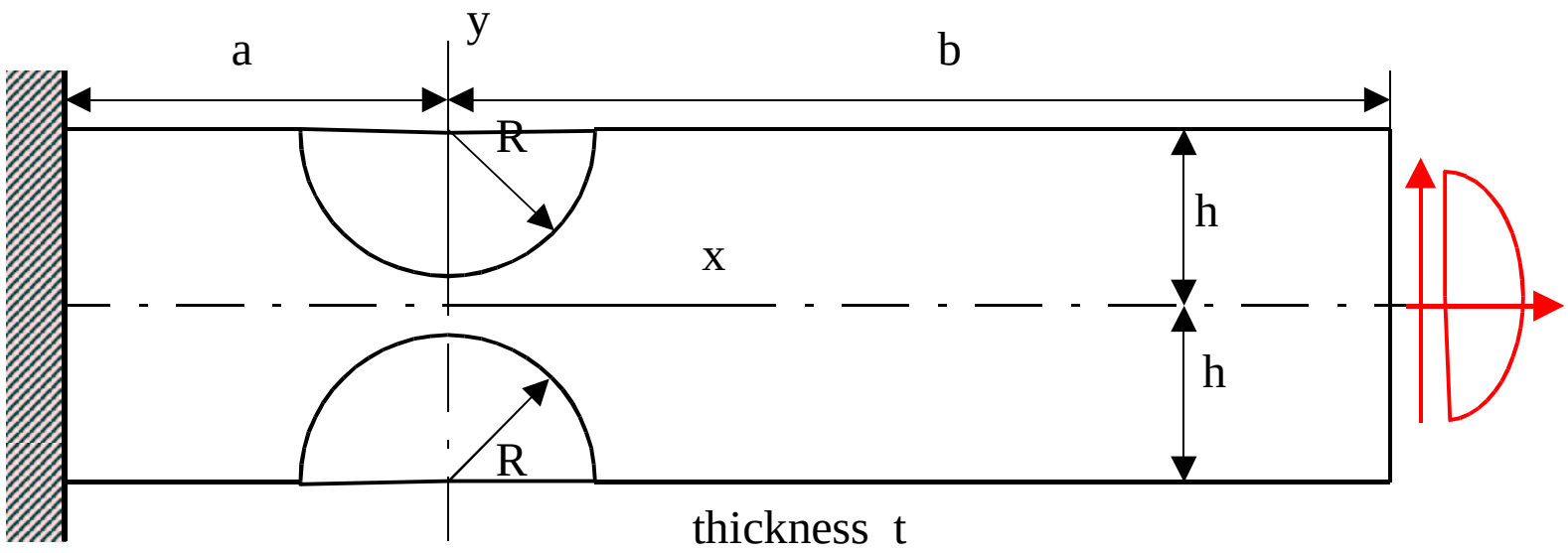

Dimensions:

R=0.05 ; a=0.15 ; b=0.4 ; h=0.06 ; t=0.01

Points of attention (conclusions???)

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Not every FEM-code is directly suitable for use in education.

Special attention should be paid on easily accessible pre- and postprocessing.

The “Help”-function is an important tool in completing a successful FEM-calculation.

Special student-proof manuals are useful.

Nowadays students hardly are familiar with programming languages like Fortran, C++. They have used (maybe/hopefully?) Matlab, Maple, MathCad.