# Using Multibody Dynamics for Simulation of Adaptive Systems

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# Overview

- Adaptive Systems
- Institute of mechanics of the OvGU Magdeburg
- Problem magnetically circular table (MCT)
- SIMPACK to the design of adaptive systems exemplified by MCT
- Results
- Abstract and further steps

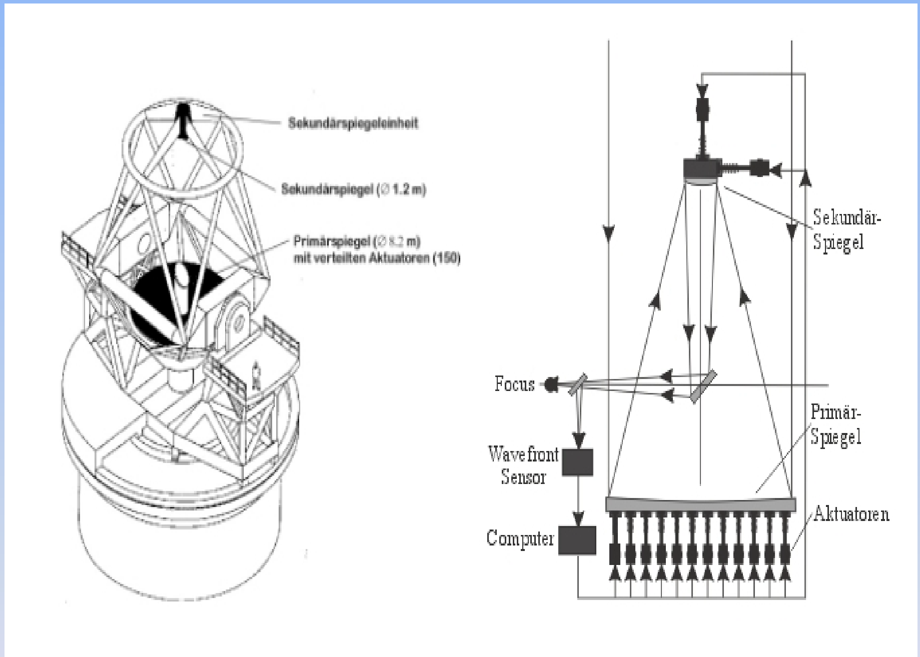
# Adaptive systems in nature

**adaptive** - to adapt, to act on environmental influences

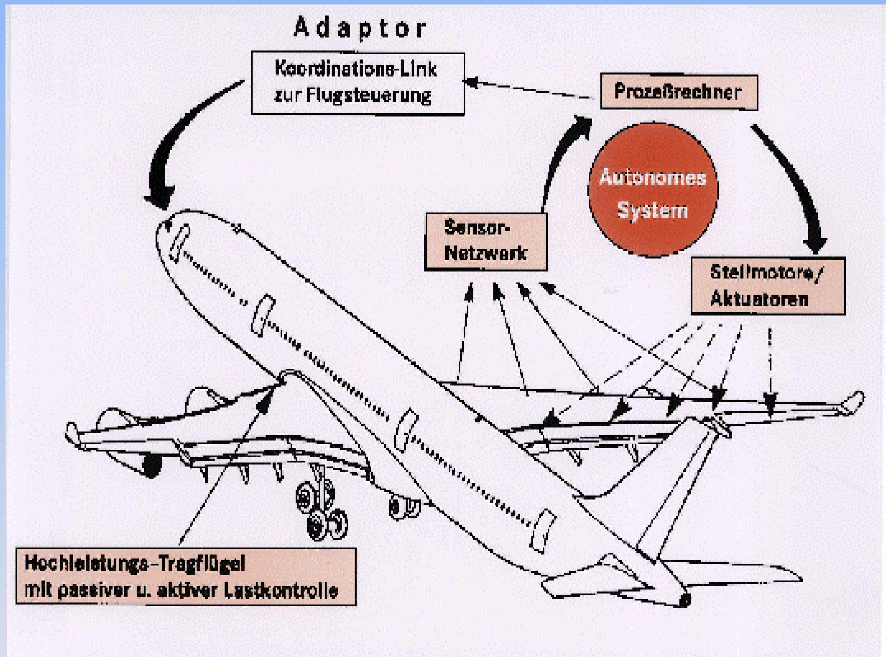
Albatros

Mimose

# Adaptive systems in the engineering




Active optic for a VL Telescope (source: ESO)



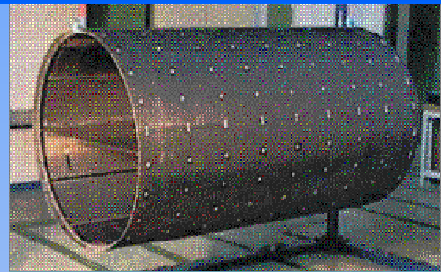

Adaptive wing for an aircraft (source: DLR)

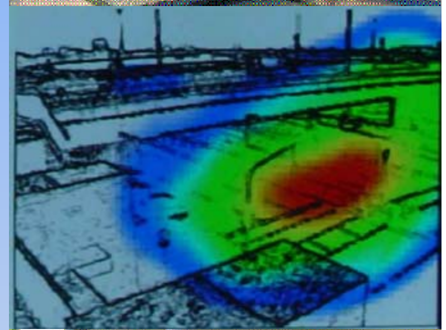
## Using Multibody Dynamics for Simulation of Adaptive Systems

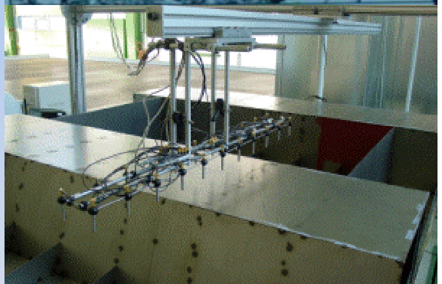
### <u>One of the main research at the institute of mechanics of the Otto-von-Guericke-University is:</u>

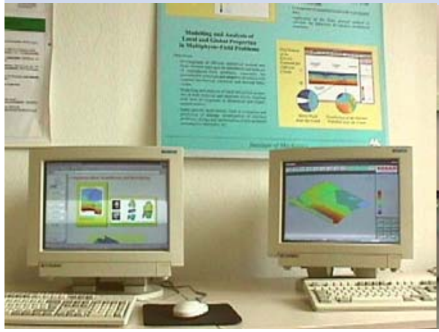
Modelling, simulation, complete optimisation, production and experimental verification of adaptive systems. Using of adaptive solutions for industrial applications (automotive industry, medical engineering, robotics, domestic appliances, ...).

Main research: DFG Innovationskolleg ADAMES
BMBF-Leitprojekt ADAPTRONIK
industrial applications,....



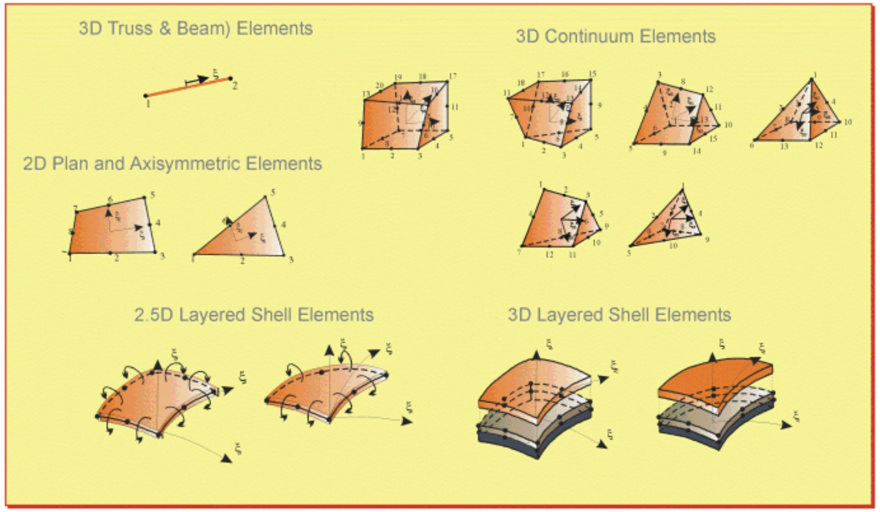







# Simulation of adaptive Structures with FEA

## Element Library of COSAR Software



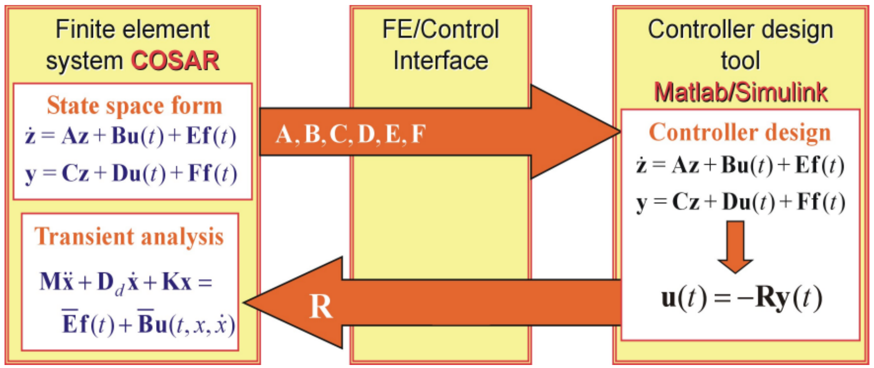

## Model reduction

$$\mathbf{M}\ddot{\mathbf{x}} + \mathbf{D}_d\dot{\mathbf{x}} + \mathbf{K}\mathbf{x} = \overline{\mathbf{E}}\mathbf{f}(t) + \overline{\mathbf{B}}\mathbf{u}(t, x, \dot{x})$$

$$(\mathbf{K} - \lambda_i \mathbf{M})\boldsymbol{\varphi}_i = \mathbf{0} \qquad \mathbf{x} = \boldsymbol{\Phi}\mathbf{q}$$

$$\ddot{\mathbf{q}} + \boldsymbol{\Delta}\dot{\mathbf{q}} + \boldsymbol{\Lambda}\mathbf{q} = \boldsymbol{\Phi}^T\overline{\mathbf{E}}\mathbf{f}(t) + \boldsymbol{\Phi}^T\overline{\mathbf{B}}\mathbf{u}(t, x, \dot{x})$$

## Coupling of COSAR with Matlab/Simulink




## State space form

$$\mathbf{z} = \begin{bmatrix} \mathbf{q} \\ \dot{\mathbf{q}} \end{bmatrix}$$

$$\dot{\mathbf{z}} = \begin{bmatrix} \mathbf{0} & \mathbf{I} \\ -\boldsymbol{\Lambda} & -\boldsymbol{\Delta} \end{bmatrix}\mathbf{z} + \begin{bmatrix} \mathbf{0} \\ \boldsymbol{\Phi}^T\overline{\mathbf{B}} \end{bmatrix}\mathbf{u}(t) + \begin{bmatrix} \mathbf{0} \\ \boldsymbol{\Phi}^T\overline{\mathbf{E}} \end{bmatrix}\mathbf{f}(t) = \mathbf{A}\mathbf{z} + \mathbf{B}\mathbf{u}(t) + \mathbf{E}\mathbf{f}(t)$$

$$\mathbf{y} = \overline{\mathbf{C}}\,\overline{\boldsymbol{\Phi}}\,\mathbf{z} = \mathbf{C}\mathbf{z}$$

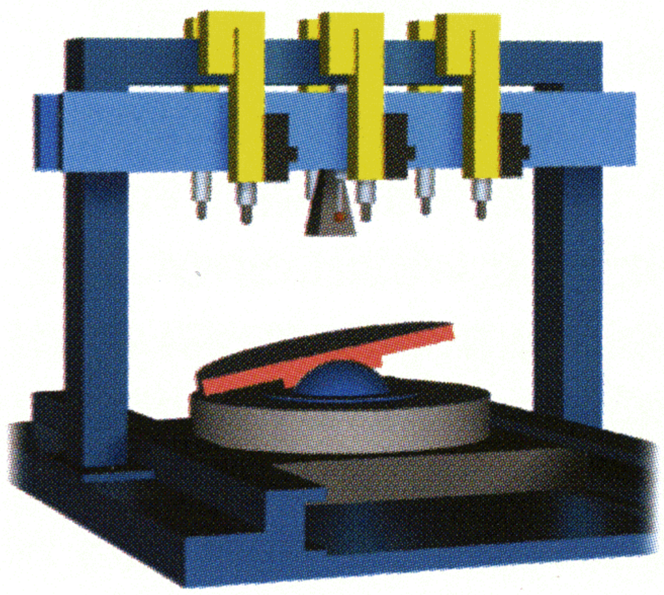
On the basis of a new magnetically circular table - MCT (made by w.i.t. Magdeburg/Barleben company) should be demonstrate partly finished work with SIMPACK.

Advantages by using the interconnection of COSAR and SIMPACK for the solution of adaptive problems:

- Decrease the degrees of freedom
- Parameter analysis with SIMPACK
- Including of user routines in SIMPACK
- Special element library in COSAR
- Interconnection of COSAR and Matlab/SIMULINK
- Coupling of mechanic and piezoelectric problems
- Optimisation algorithms for the sensor and actuator placement in COSAR

## Problem magnetically circular table (MCT)

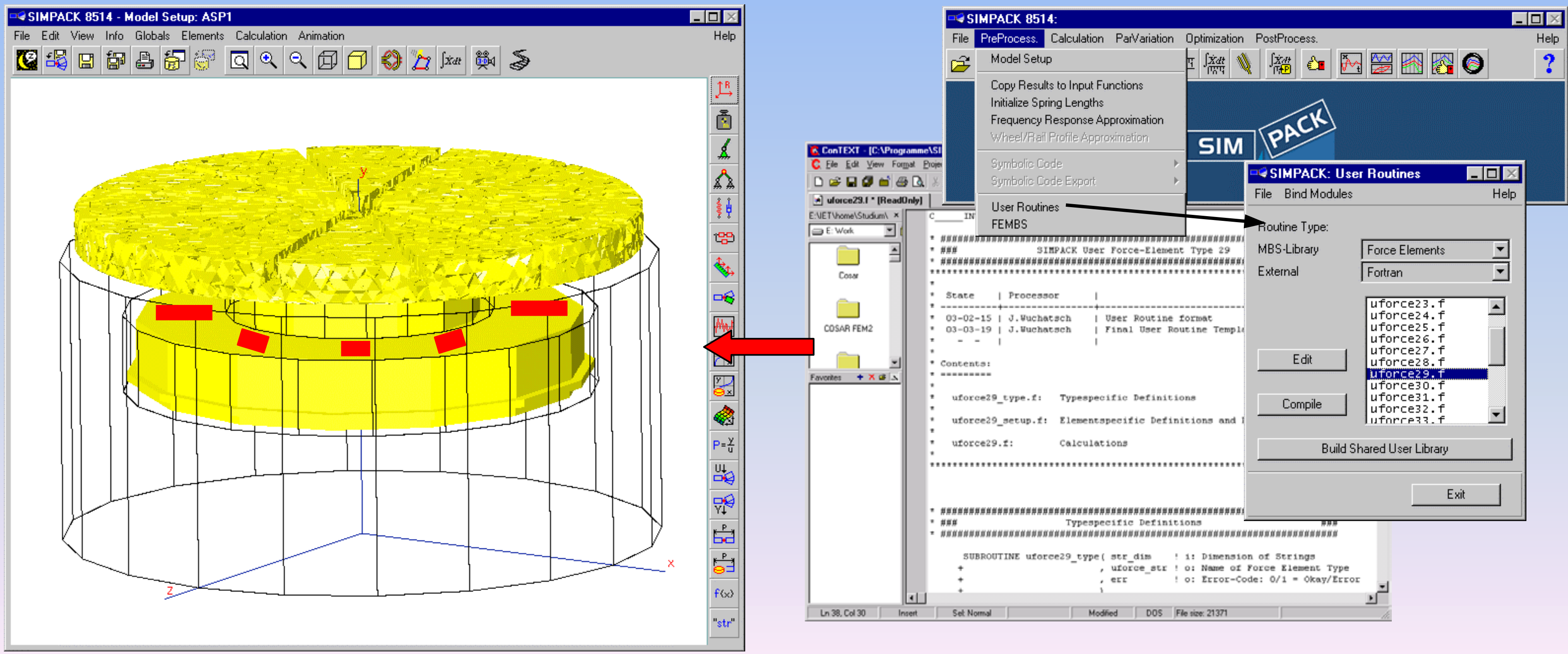
**Development and verification of some basic adaptive strategies to increase the machining accuracy of machine tools with magnetically guidance considering as example a magnetically circular table (machining accuracy +/- 2,5µm).**



circular table of Wiemers innovative Technik GmbH Magdeburg/Barleben company

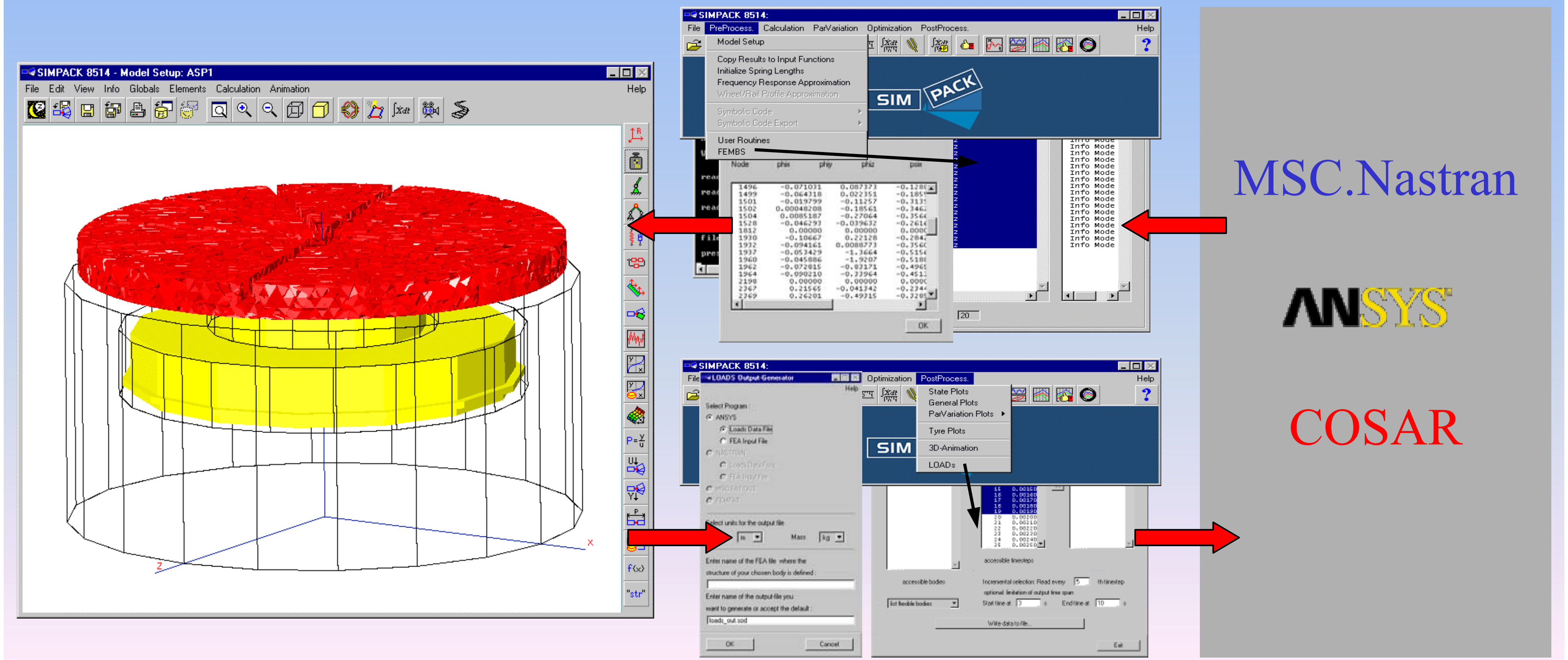
# SIMPACK to design of adaptive systems exemplified by MCT

**Build up a ridged body systems of the MCT and the implementation of the magnetically guidance by new generated force elements with SIMPACK user routines and verification of the results**



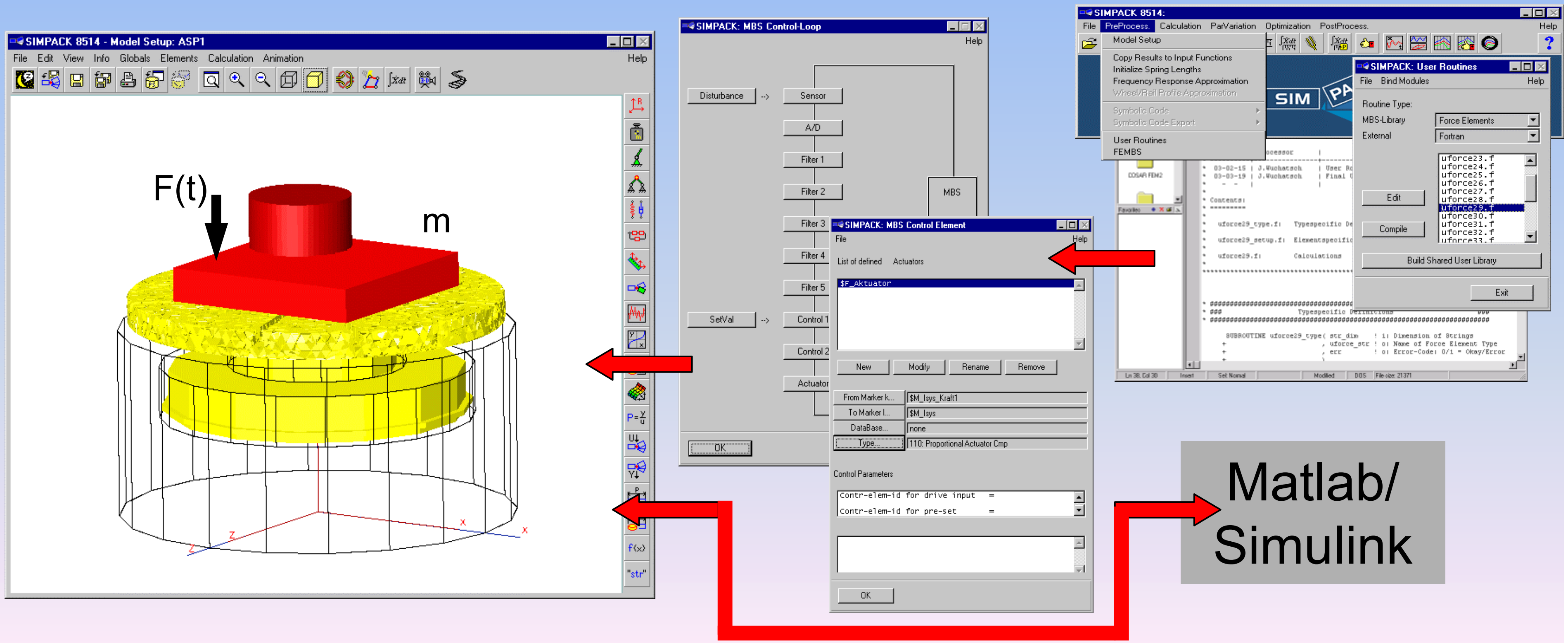
# SIMPACK to design of adaptive systems exemplified by MCT

**Implementation of elastic components in the multibody system by using of the FEMBS interface for data from ANSYS and NASTRAN.**
**Import data by a new interface from COSAR.**
**Verification of results and/or export data with SIMPACK LOADS in FEA.**



# SIMPACK to design of adaptive systems exemplified by MCT

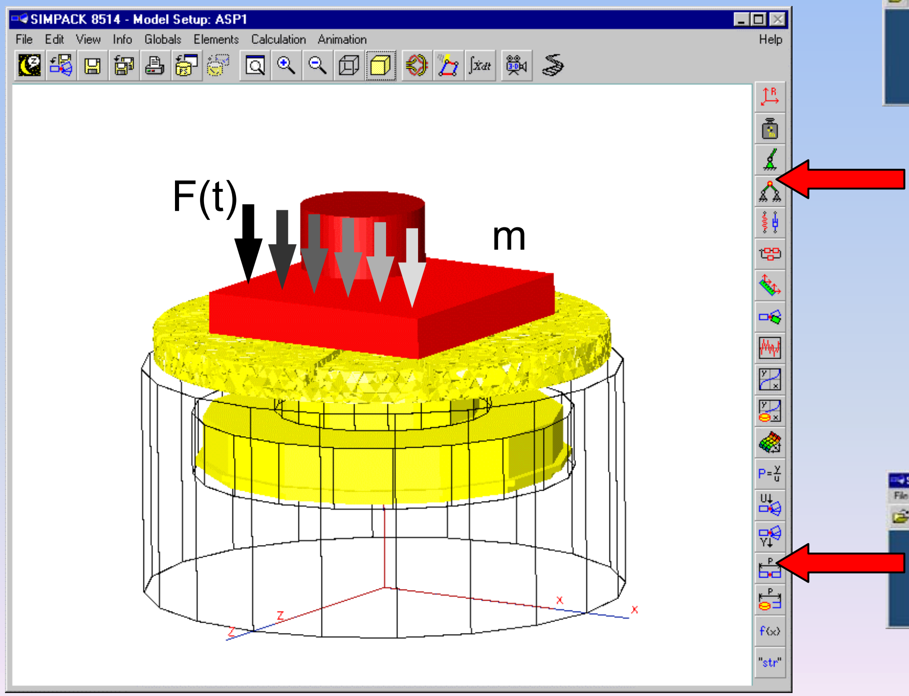
Implement the real magnetically guidance of the MCT with SIMPACK-Control.
Developement and implementation of new control algorithms by using Matlab/Simulink and SIMPACK user routines

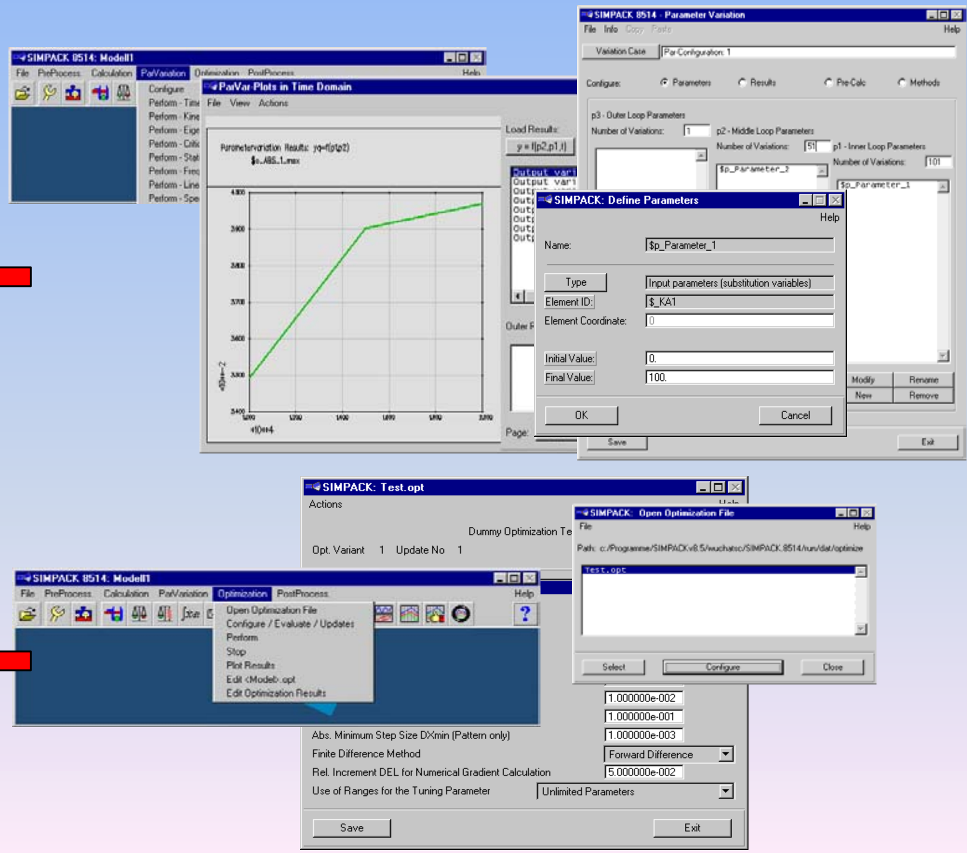


## Using Multibody Dynamics for Simulation of Adaptive Systems

# SIMPACK to design of adaptive systems exemplified by MCT

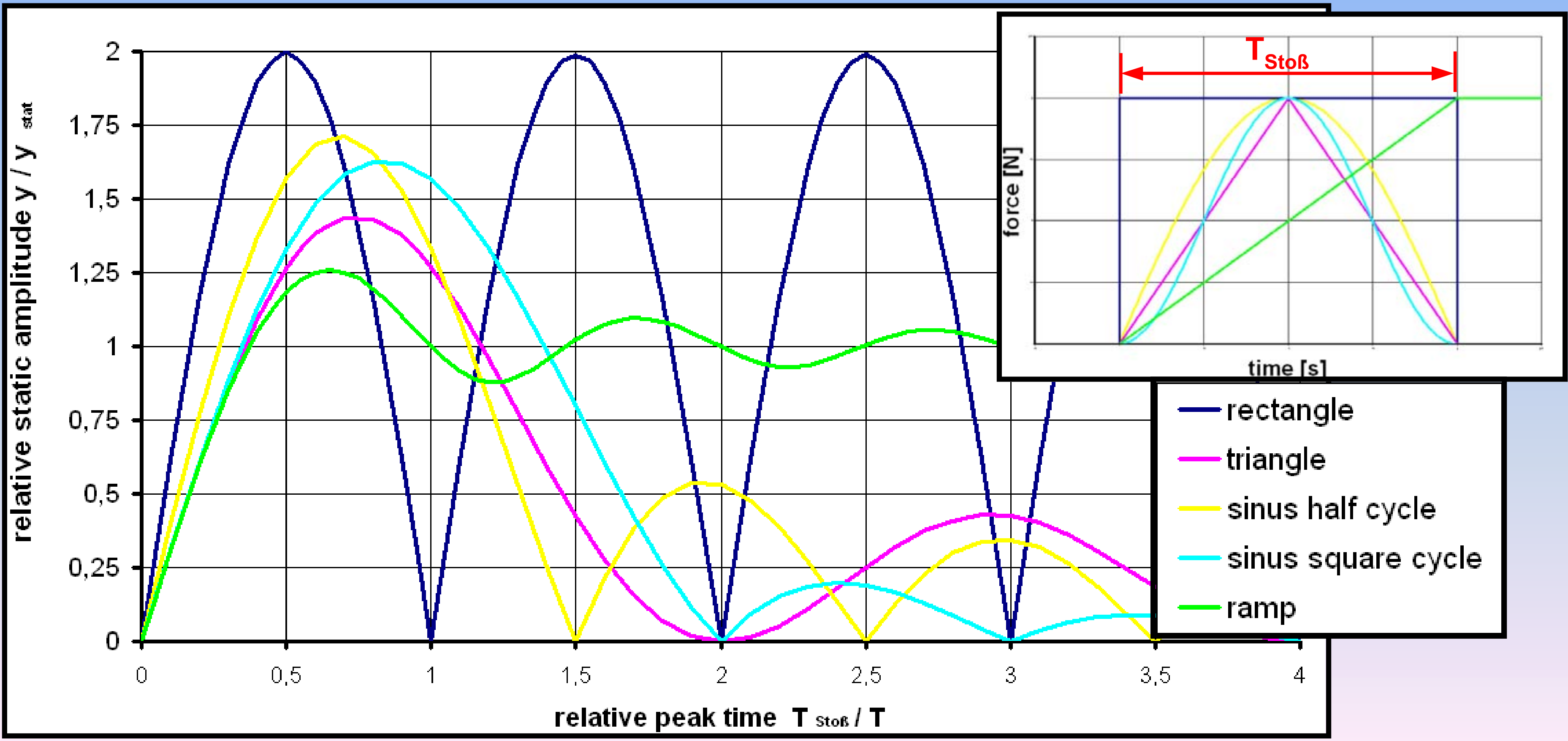
**Analysis and optimisation the influence of a some single parameter to the behaviour of the multi body system with SIMPACK-ParVariation and SIMPACK-Optimization.**



# Results

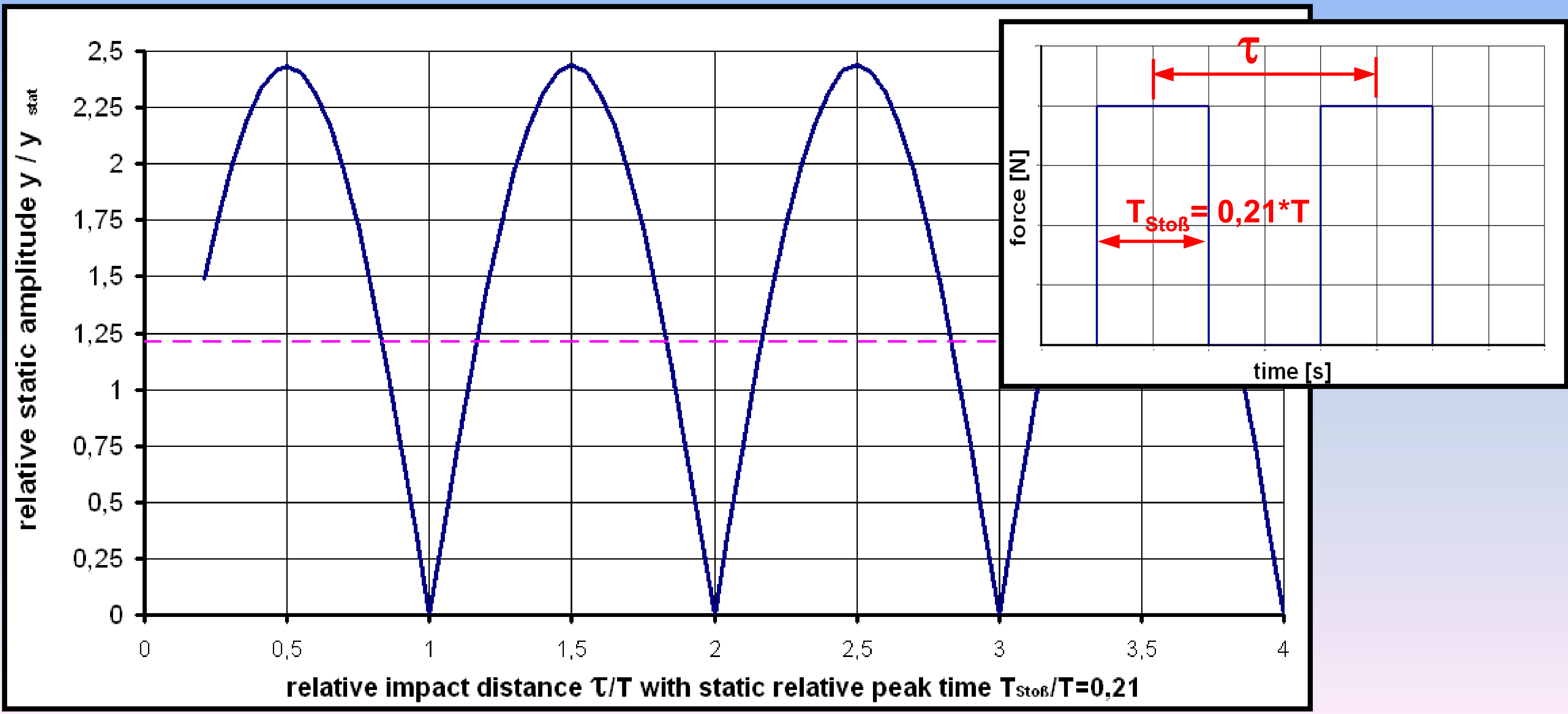
**Influence of a centrical, normal impact of the unregulated, undamped, linearised System by variation of impact mode.**



Using Multibody Dynamics for Simulation of Adaptive Systems

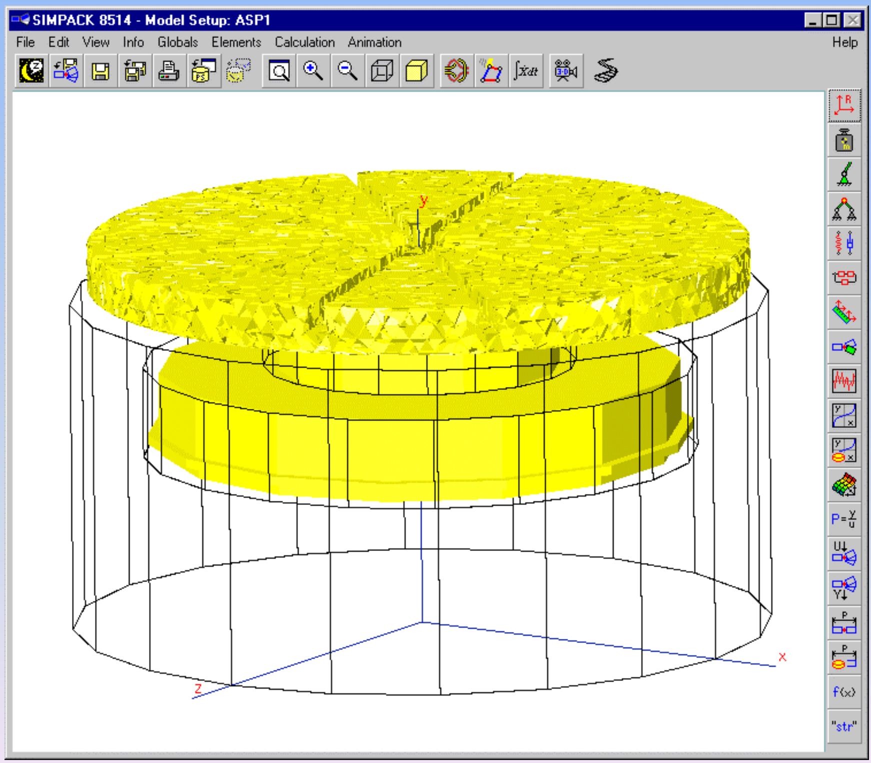
# Results

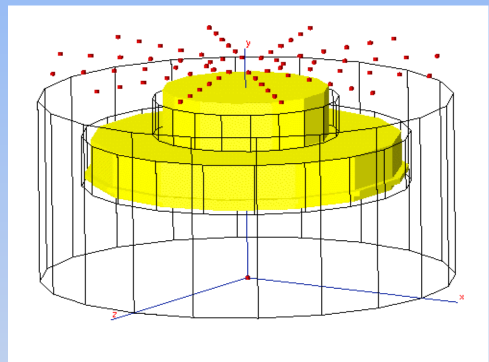
**Influence of a pair of centrical, normal impacts of the unregulated, undamped, linearised System by variation of impacts distance**

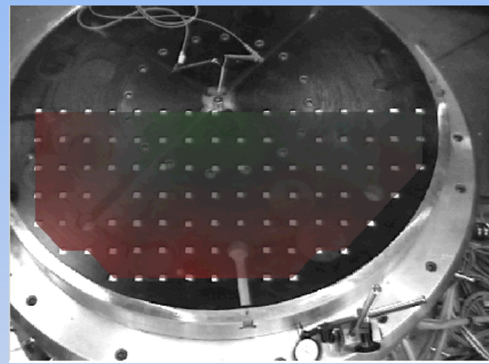


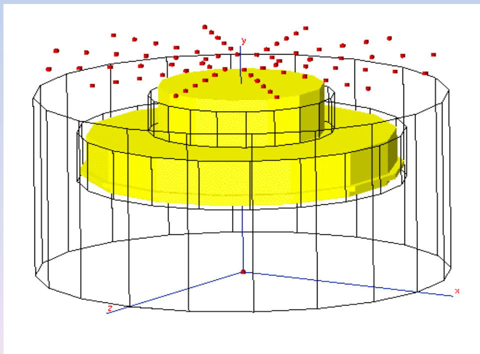
# Results

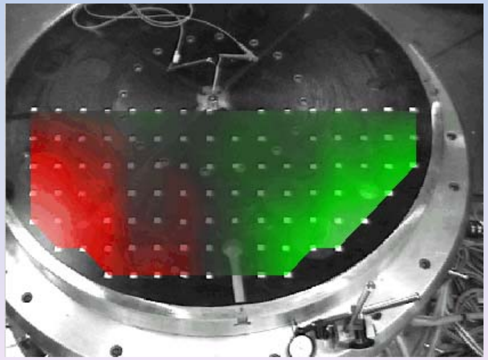
**Some modal modes of the MRT with elastic plate in comparison of experimental data.**



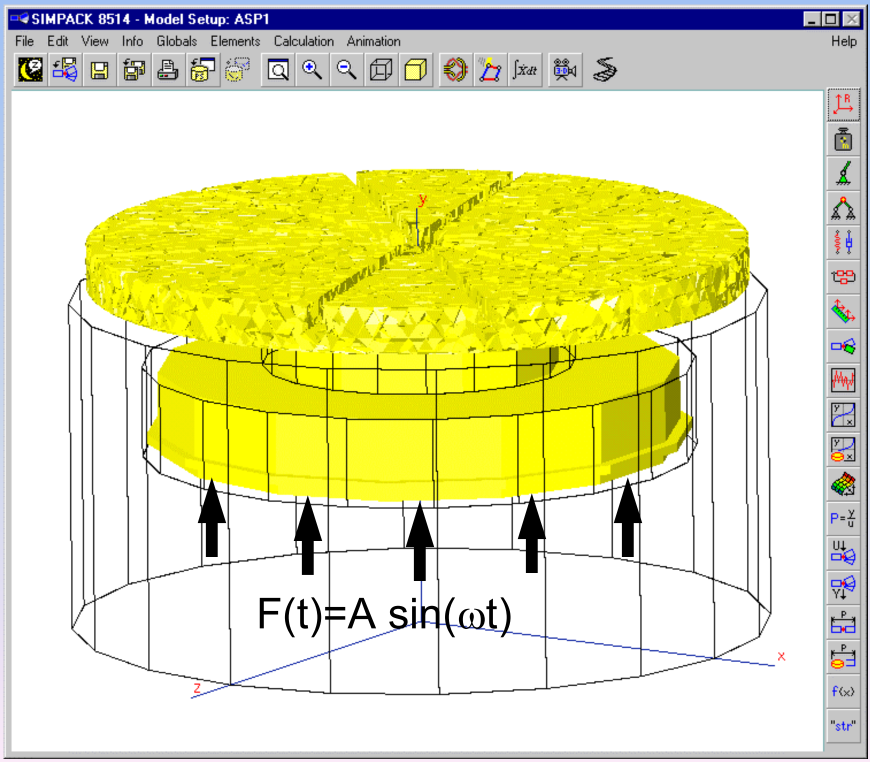


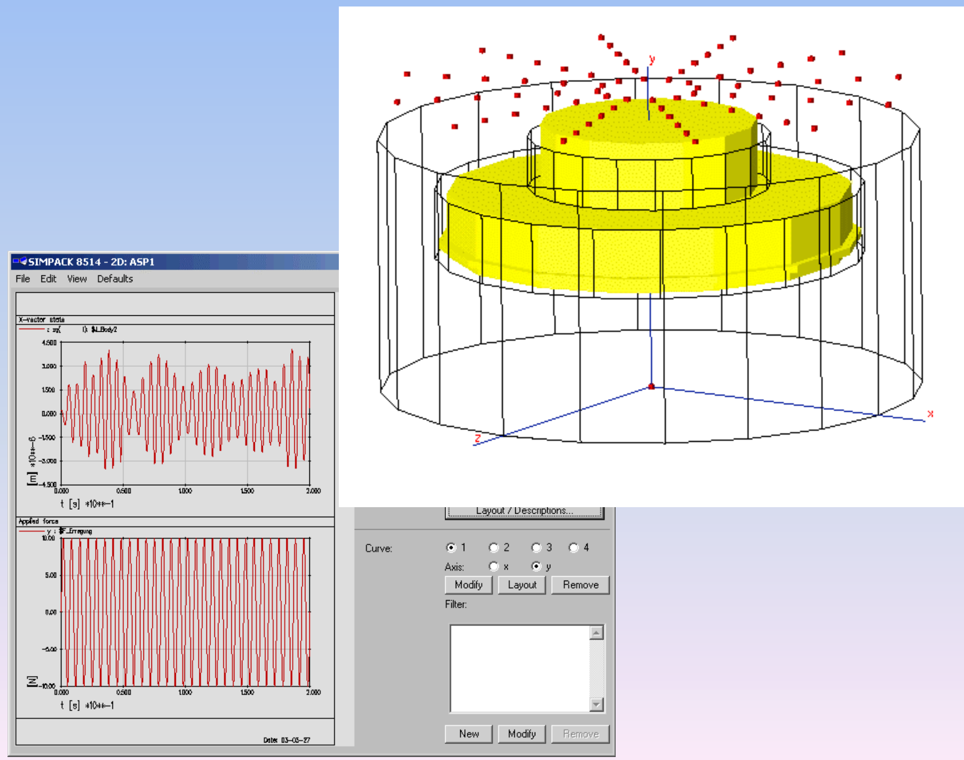




# Results

- System reaction by acting at the points of magnetically guidance
- Sinus excitation below the first elastic eigenfrequency of the plate
- Result: amplitude of the elastic plate is near 10µm

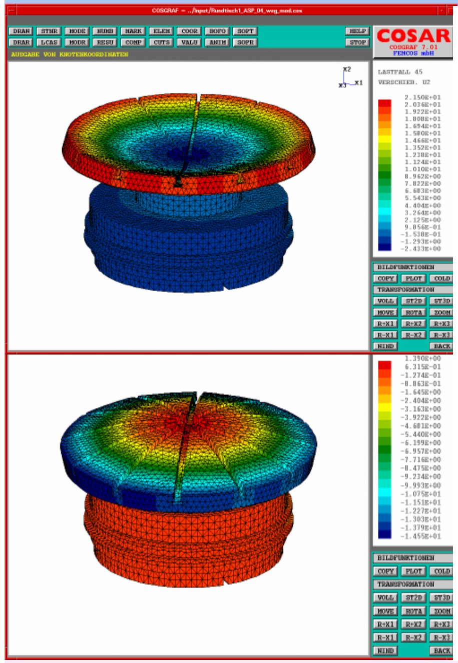


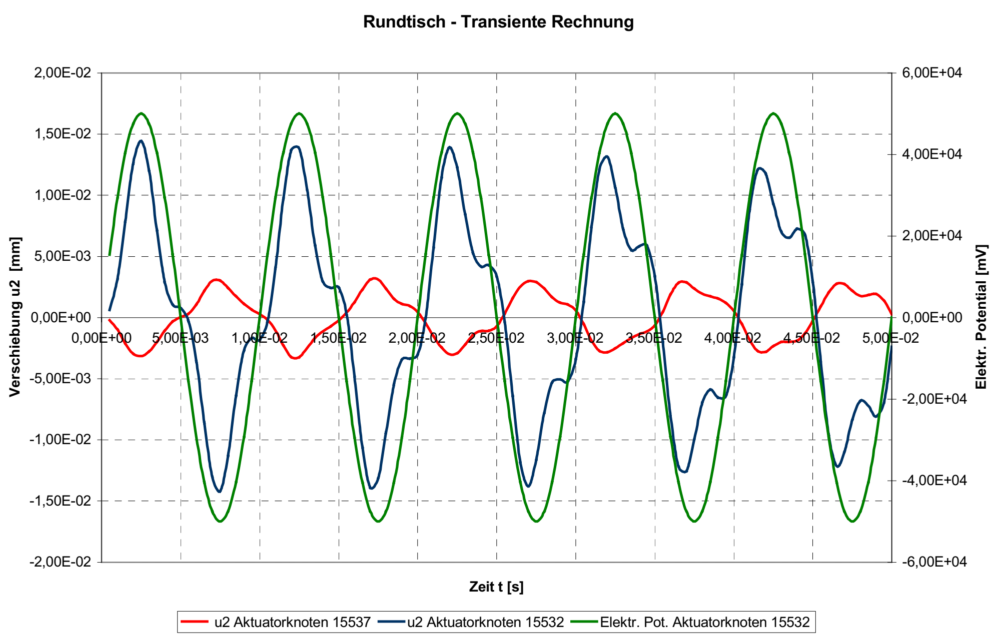



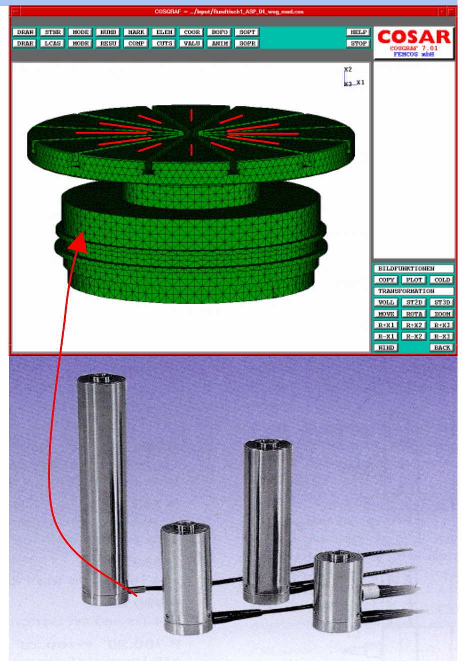


# Results

- fitting norm stack actuator in the elastic plate
- Sinus excitation below the first elastic eigenfrequency of the plate
- Result: amplitude of the elastic plate is near 15µm





## Abstract and further steps

- Build up a ridged body systems of the MCT with elastic components and the real control loops of the magnetically guidance
- Consideration of dynamic excitation by guidance and tool of MCT
- Consideration of elastically deformation by workpieces
- Consideration of elastically deformation by tool support
- Verification of the multibody results
- Development and implementation of a new control algorithm with respect of machining accuracy +/- 2,5µm
- Realisation of new control loops at the MCT