Complementary Use to Main-Stream Analysis

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Outline

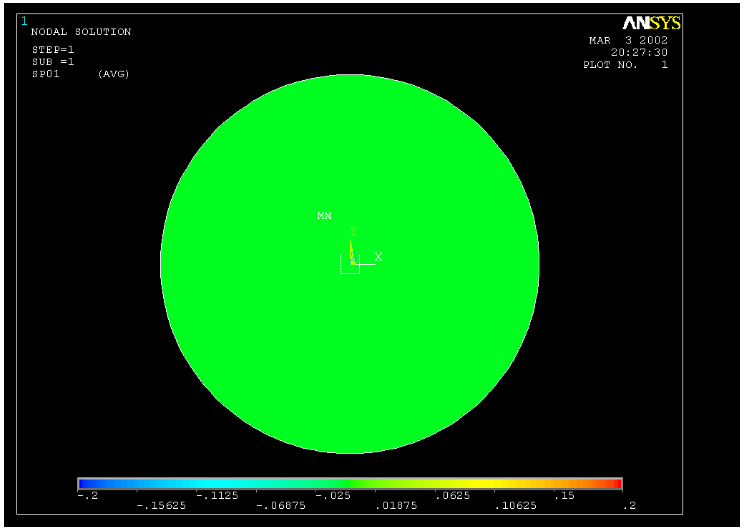
- Standard FEM-Programs
- Apply control concepts on an Ansys model
- CAPA
- Mathcad – simple heat solver behind mathcad
- Mathcad – parametrized more complex geometries

Diffpack – to fill in the gaps in functionality

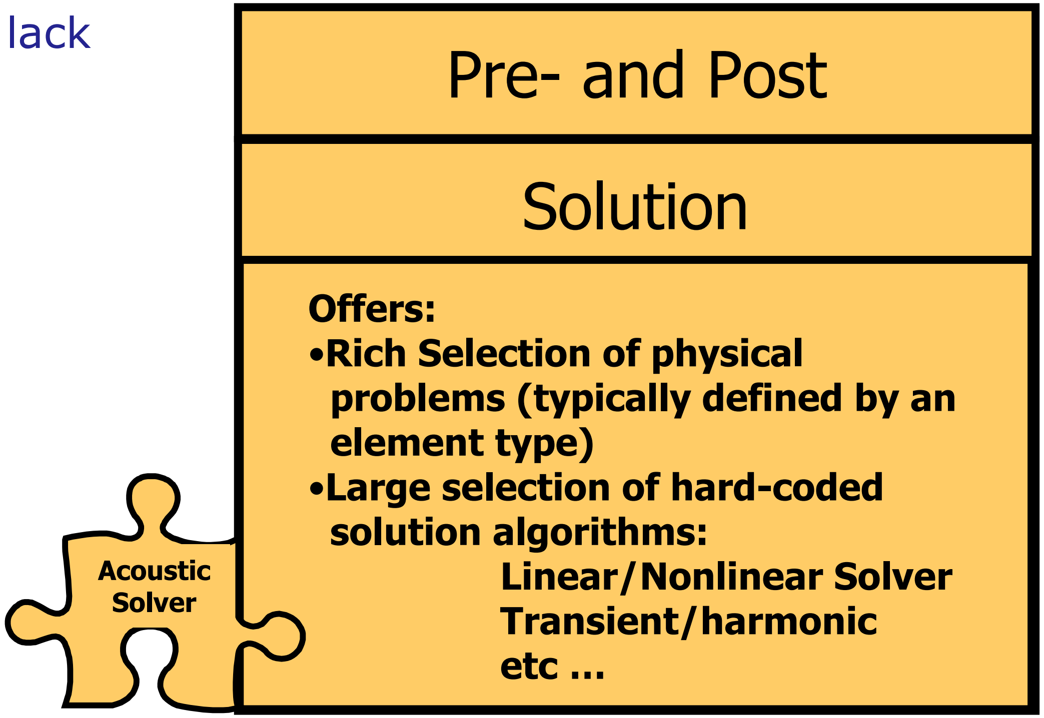
of standard FEM-Programs

Your standard FEM-Program may lack in model features, i.e.

- Acoustics



Standard FEM-Program

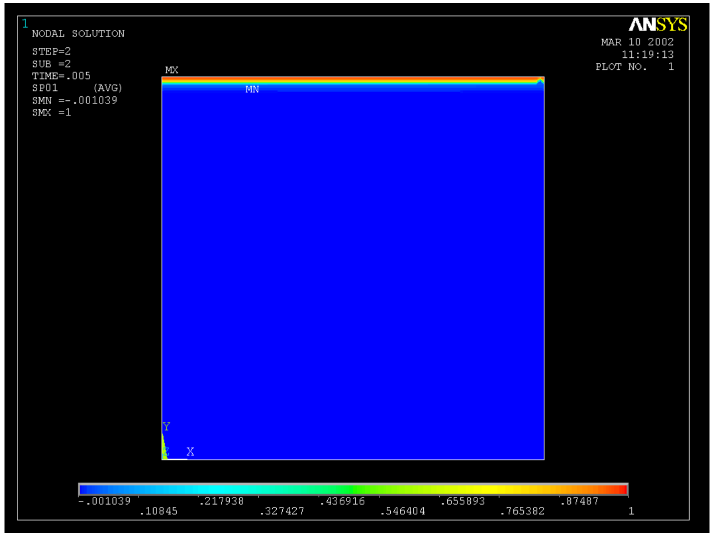


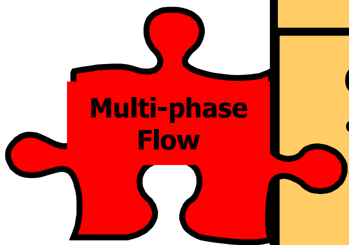
Diffpack – to fill in the gaps in functionality

of standard FEM-Programs

Your standard FEM-Program may lack in model features, i.e.

- Multi-phase flow





Standard FEM-Program

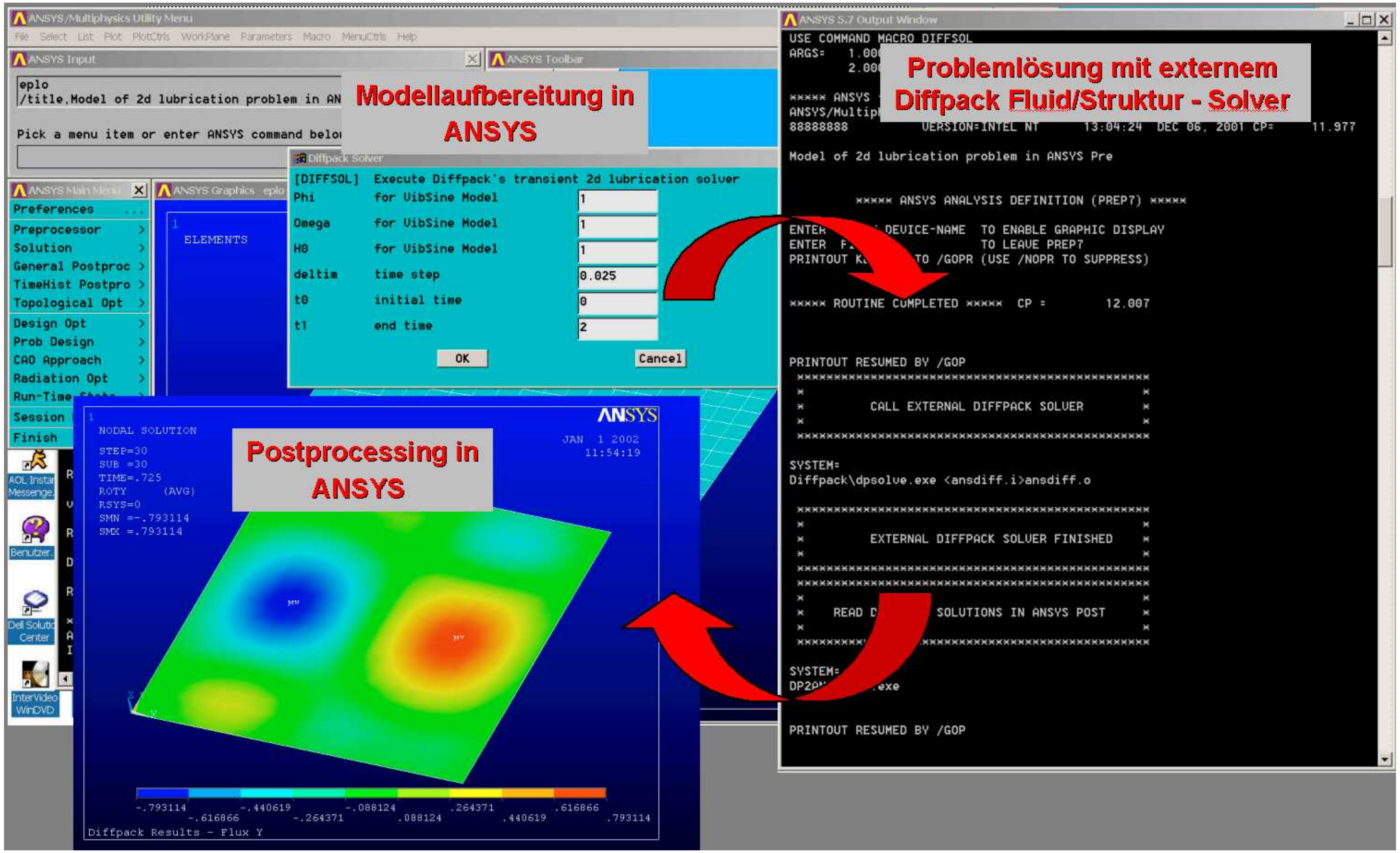
Pre- and Post

Solution

Offers:

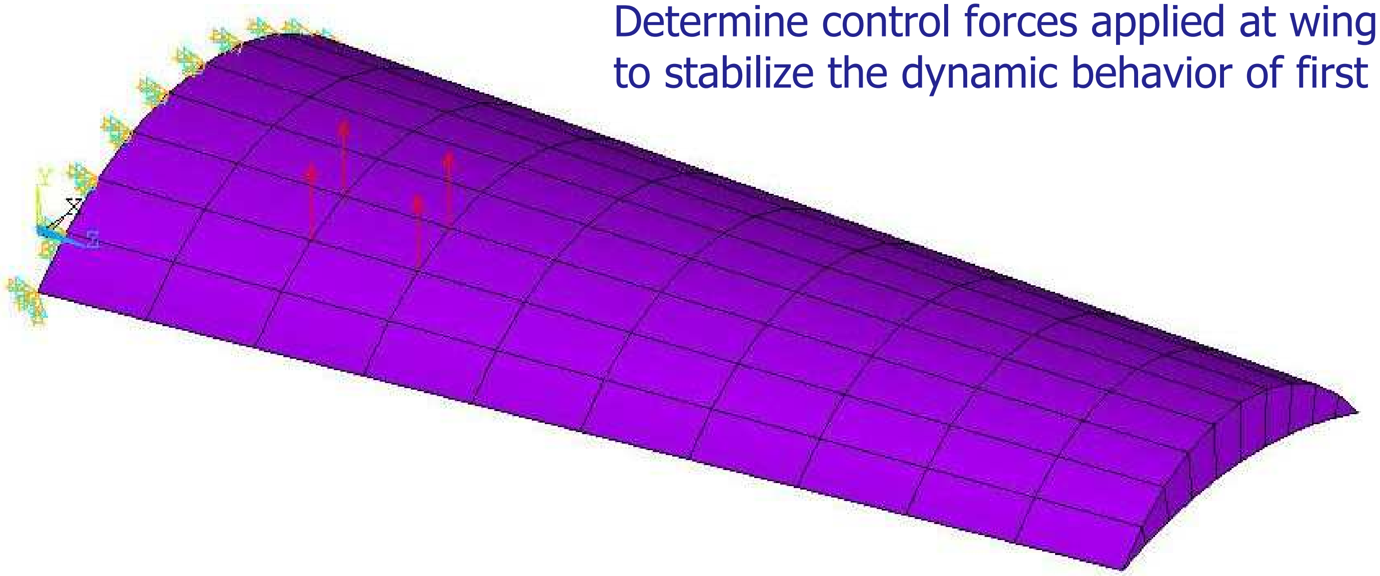
- **Rich Selection of physical problems(typically defined by an element type)**
- **Large selection of hard-coded solution algorithms:**
  - **Linear/Nonlinear Solver**
  - **Transient/harmonic**
  - **etc …**

Diffpack® - ANSYS Integration - Workflow



Diffpack® - ANSYS Integration – Wing tip control

- Employ concepts of control theory



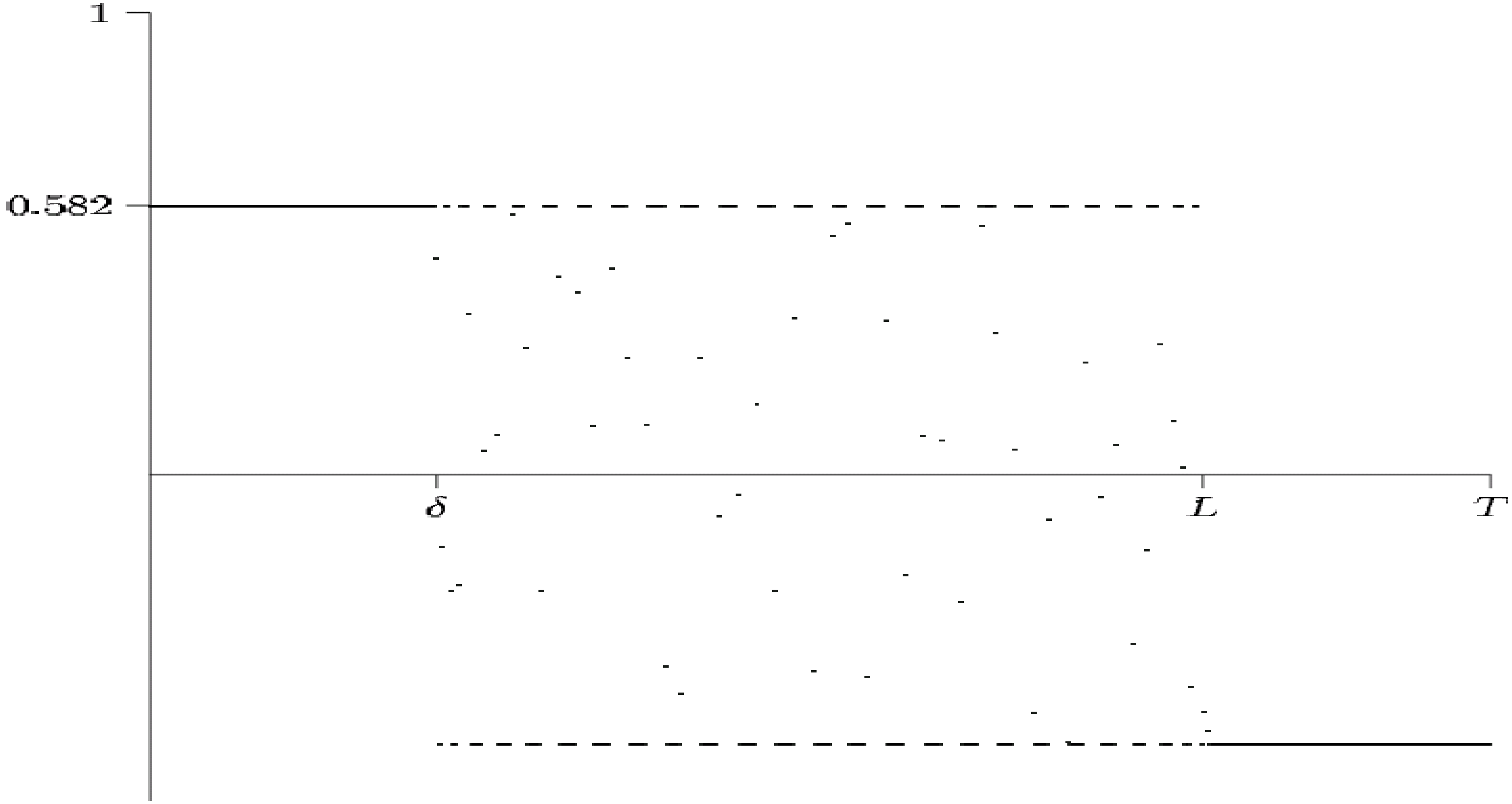
Determine control forces applied at wing tip
to stabilize the dynamic behavior of first mode.

Why control on PDE level?

- FE-matrices represent the model in discretized form (finite dimensional model)
- Simply apply control concepts from finite dimensional may steer to wrong solution!
- Finite dimensional systems may controlled in arbitrary short time (by infinite costs)
- This is not true for continuous systems
  $\rightarrow$ waves with finite traveling velocity

Why control on PDE level?

- Counter example



Control problems

- Stabilization

$$J = \int_0^T \left\| F(\tau) \right\| + \left\| u(\tau) - u_D \right\| \mathrm{d}\tau$$

- Final State

$$J = \frac{1}{2} \int_0^T \left\| F(\tau) \right\| \mathrm{d}\tau + \frac{k}{2} \left\| u(T) - u_D \right\| + \frac{k}{2} \left\| \dot{u}(T) - \dot{u}_D \right\|$$

Stabilization - Optimality system

- Direct system (forward running PDE)

$$\mathcal{M}\ddot{u} + \mathcal{A}u = f, \quad x \in \Omega,$$

$$u\big|_{\partial\Omega} = 0,$$

$$\mathcal{B}u\big|_{\partial\Omega_{con}} = F,$$

$$u(0,x) = u_{0,}$$

$$\dot{u}(0,x) = u_{1.}$$

Stabilization - Optimality system

- adjoint system (backward running PDE)

$$\mathcal{M}\ddot{\varphi} + \mathcal{A}\varphi = u, \quad x \in \Omega,$$

$$\varphi\big|_{\partial\Omega} = 0,$$

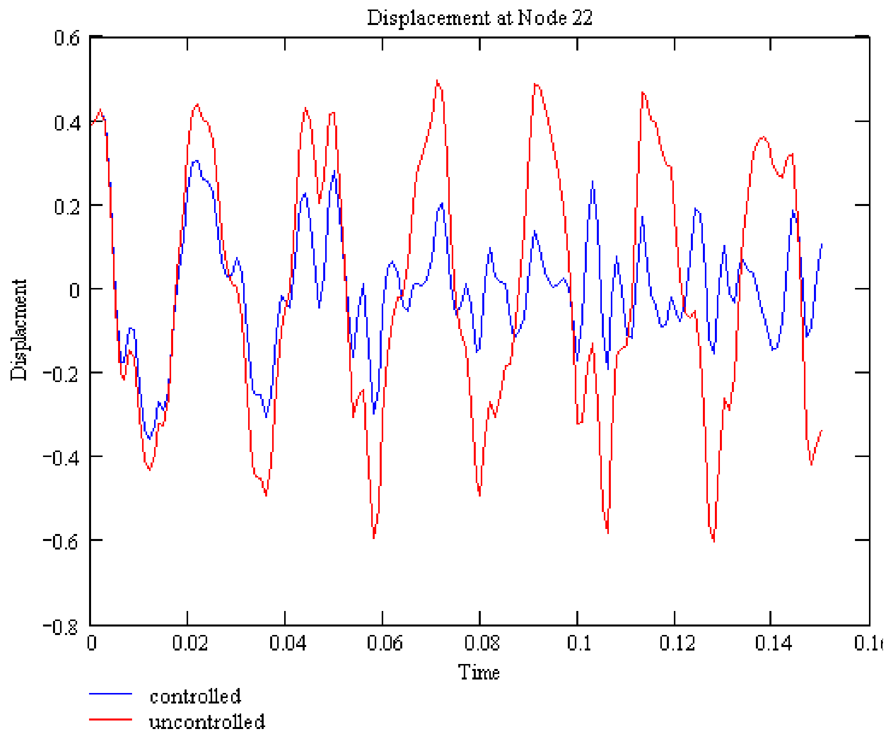
$$\mathcal{B}\varphi\big|_{\partial\Omega_{con}} = 0,$$

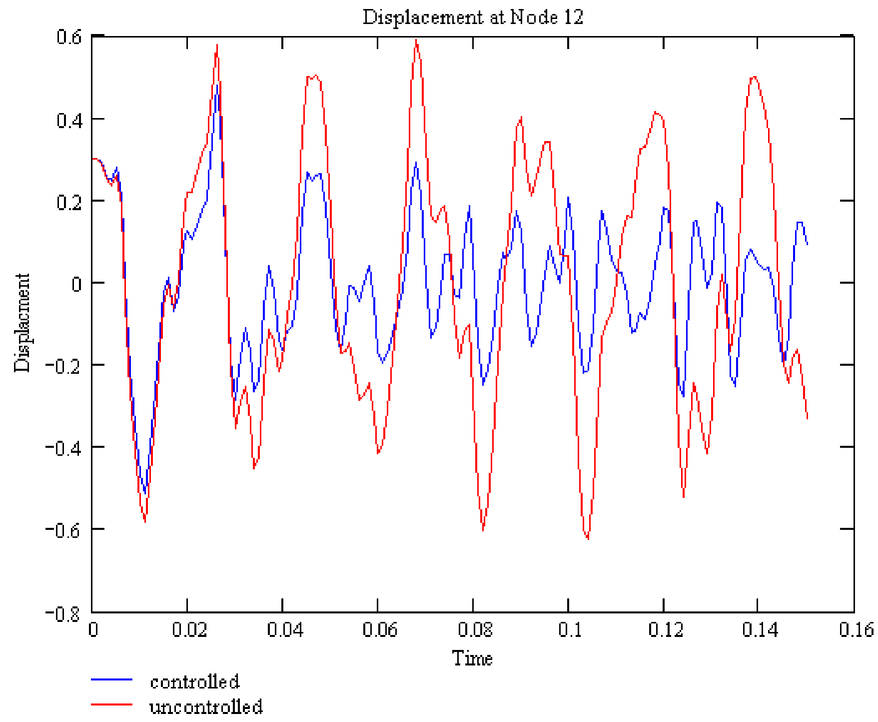
$$\varphi(T, x) = 0,$$

$$\dot{\varphi}(T, x) = 0.$$

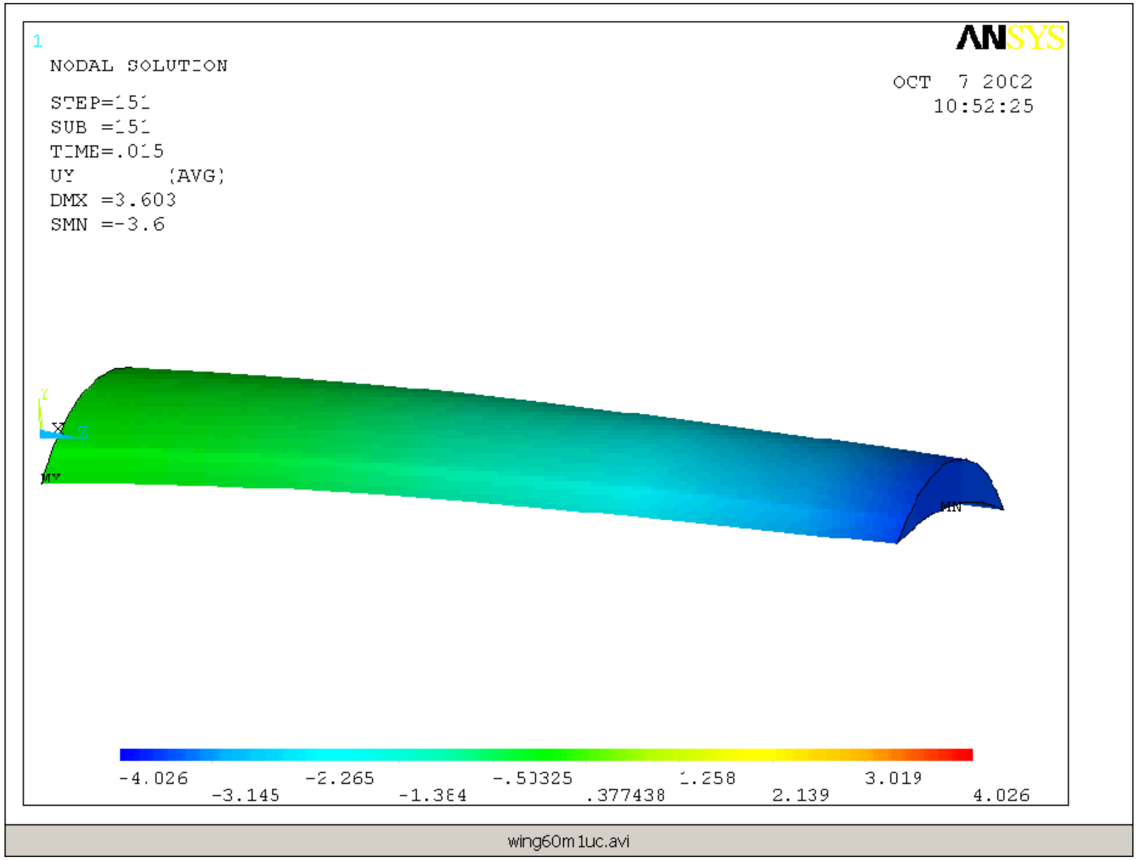
- coupling $\quad u = -\varphi, \; x \in \partial\Omega_{con}$

Wing tip control - Results

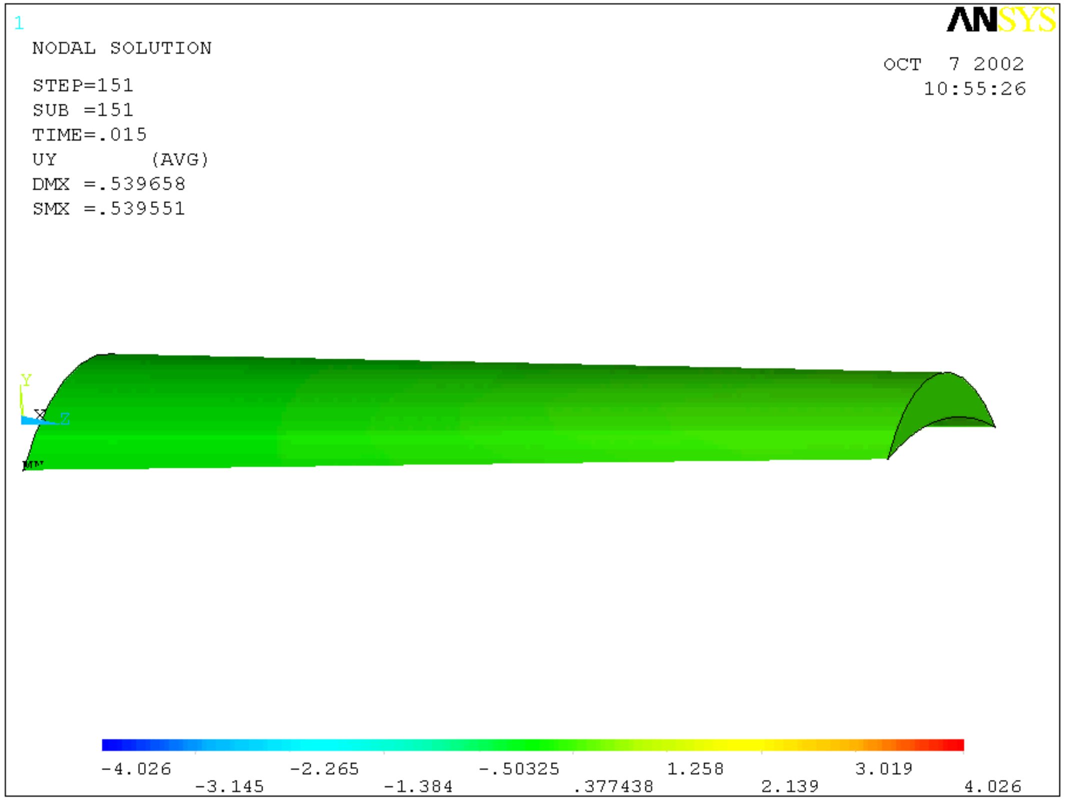




Wing tip control - Results - uncontrolled, tip load



Wing tip control - Results - controlled, tip load



Sound in Flowing Media

- Wave Equation (Pierce)

$$\nabla \cdot (\rho \nabla \psi) - \rho D_t \left(\frac{1}{c^2} D_t \psi \right) = 0$$

  - generalized velocity potential y
  - Convective derivative operator
  - Flow not influenced by sound

$$D_t = \frac{\partial}{\partial t} + v \cdot \nabla$$

- FEM Formulation

$$\mathbf{K}\{\Psi\} + \mathbf{C}\{\dot{\Psi}\} + \mathbf{M}\{\ddot{\Psi}\} = \{F\}$$

  - Unsymmetric matrices
  - Damping matrix required even in undamped case
  - Infinite elements and fluid-structure interaction

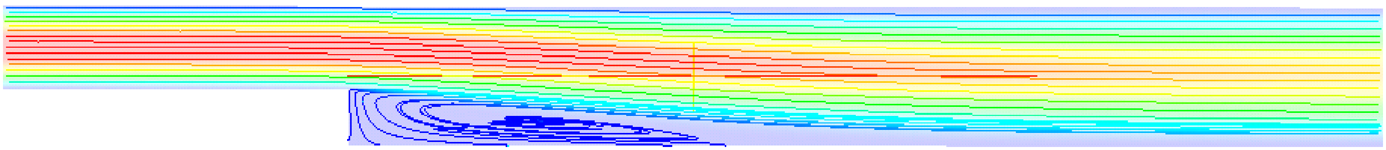
Coupling CAPA and Diffpack

- General approach: use CAPA for acoustics and Diffpack for the flow simulation
- Feasibility study: use simple flow solver NSPenalty1 based on

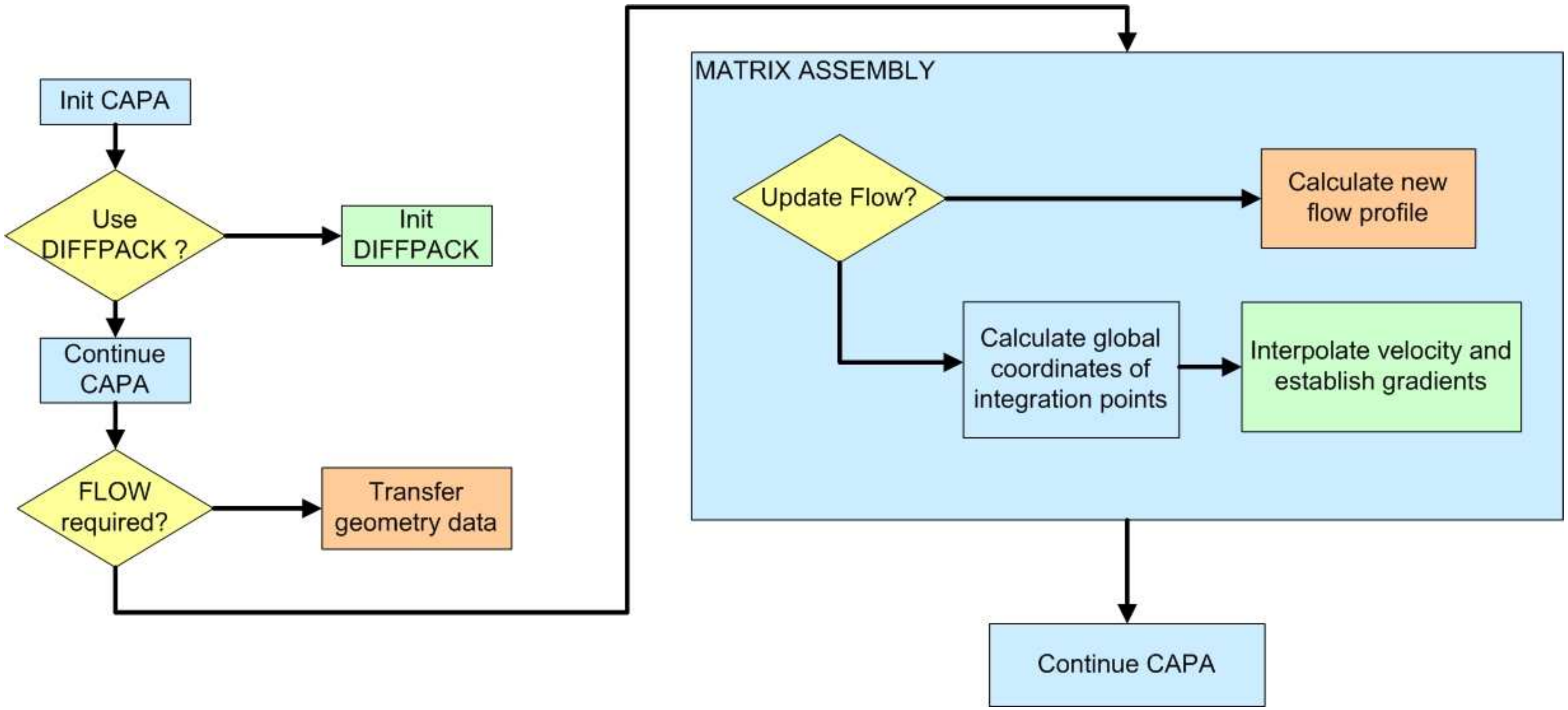
$$\rho(\dot{v} + v \cdot \nabla v) = -\nabla(-\lambda \nabla \cdot v) + \mu \Delta v$$

$$p = -\lambda \nabla \cdot v, \qquad \lambda \to \infty$$

- Meshing with ANSYS, use cdb-file and ANSYS-CAPA interface
- Datafilter toolbox to convert
  - mesh from cdb file to Diffpack grid
  - boundary conditions from ANSYS to Diffpack
- Validation runs

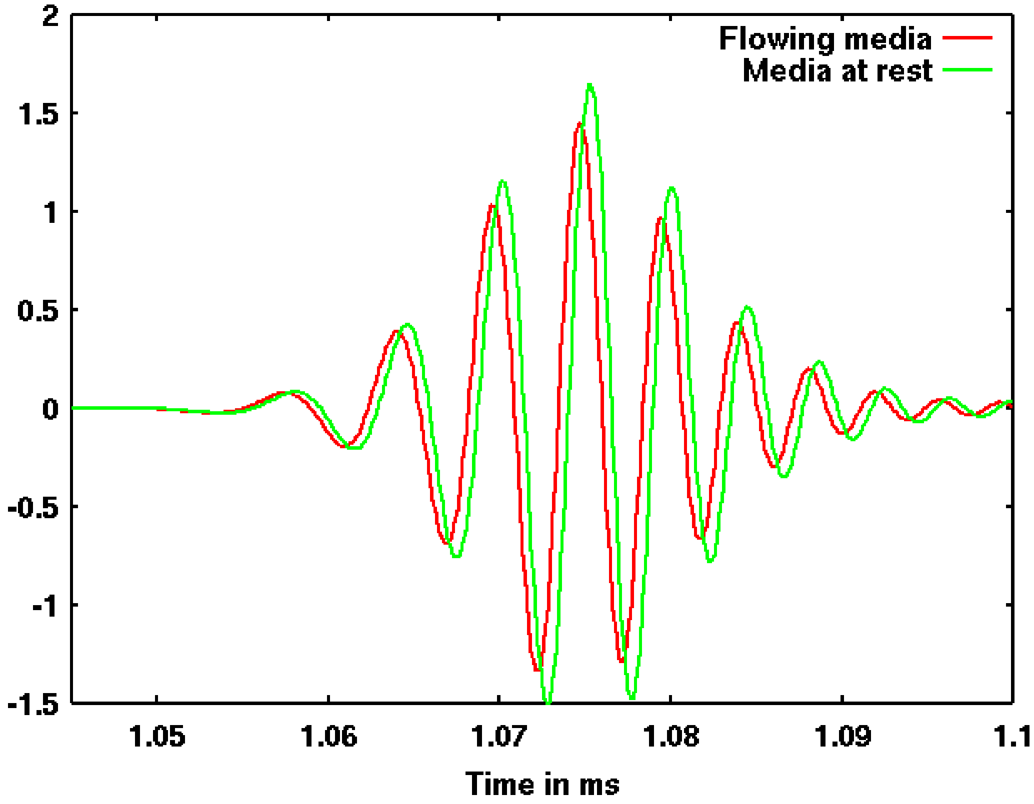


Coupling CAPA and Diffpack (cont.)



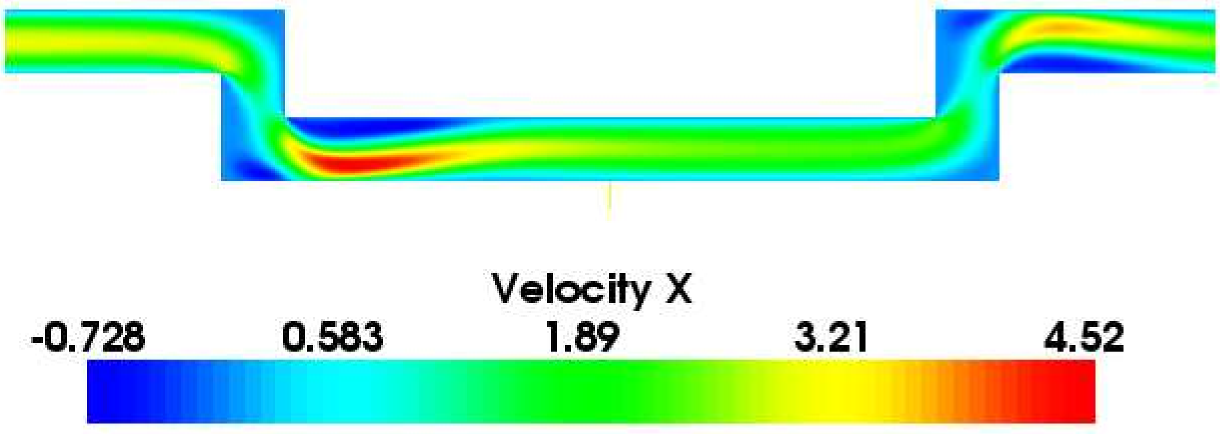
Application: Flowmeter

- Signal at receivers



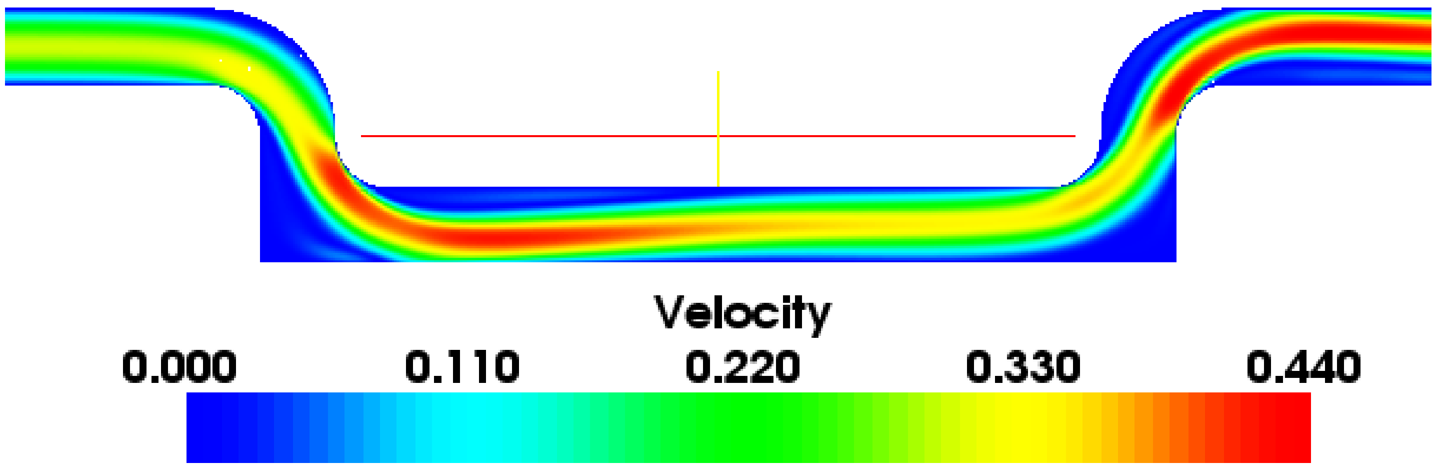
Results for Glyzerol

- Penalty 10000, velocity = 3



Results for Air

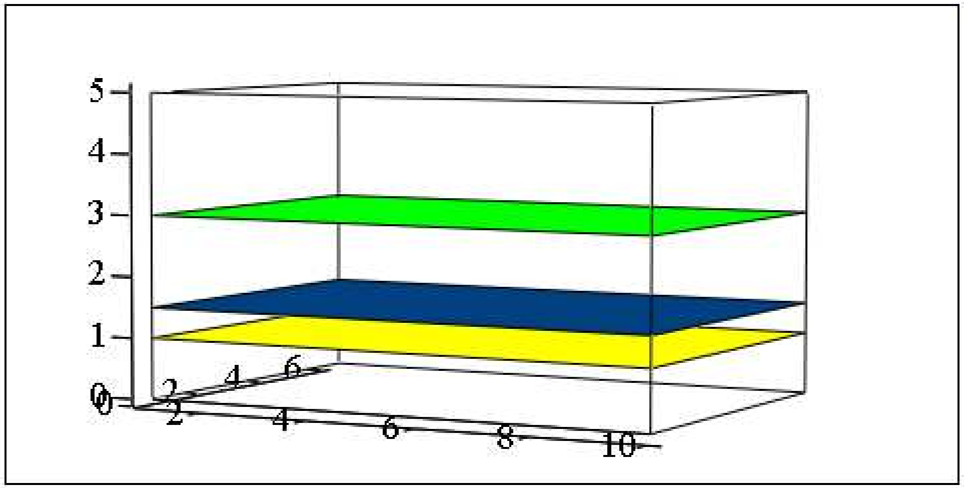
- Penalty 50, velocity = 0.3



Mathcad - Diffpack

Diffpack® & Mathcad

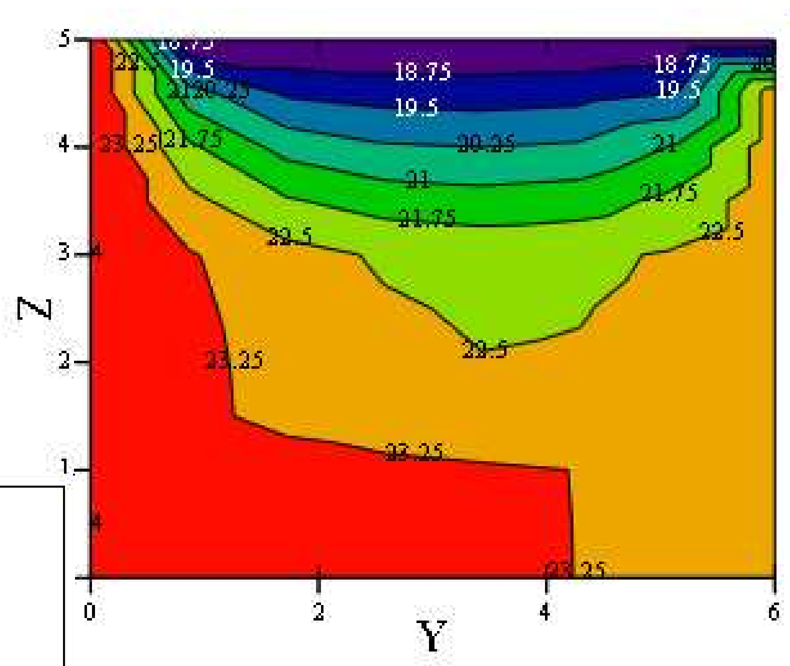
- Diffpack Heat equation solver packed in Mathcad Userefi dll
- new function in Mathcad available: DpHeating
- Mathcad:
  - specify a 3D cube with different layers
  - Apply different heat transfer coeffs in each layer
  - Define boundary conditions

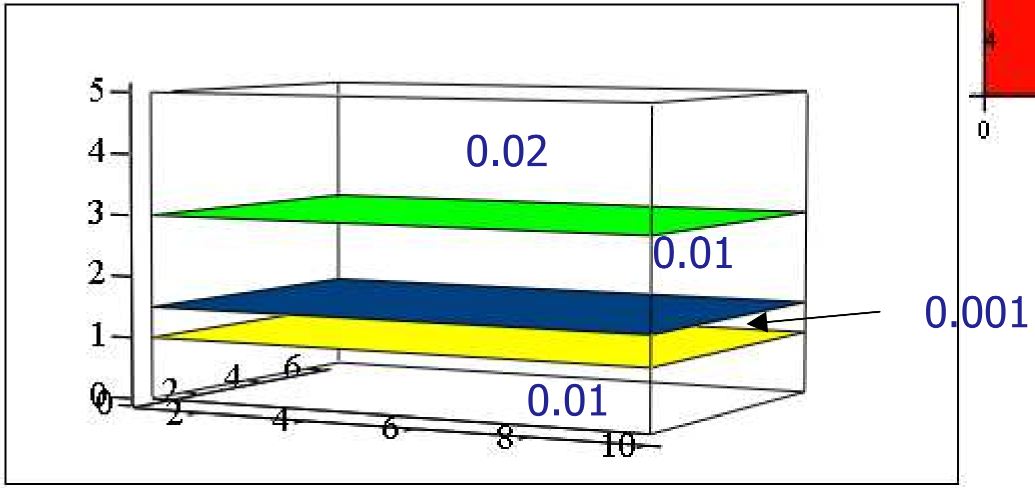


Box,Layerr

Diffpack® & Mathcad

- Boundary condtions:
  - T= 18 at Z-top
  - T= 24 at Y-bottom
  - T= 23 at Y-top
  - Neumann condition at X-bottom, X-top, Z-bottom





Box,Layerr