



Complementary Use to Main-Stream Analysis

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Outline

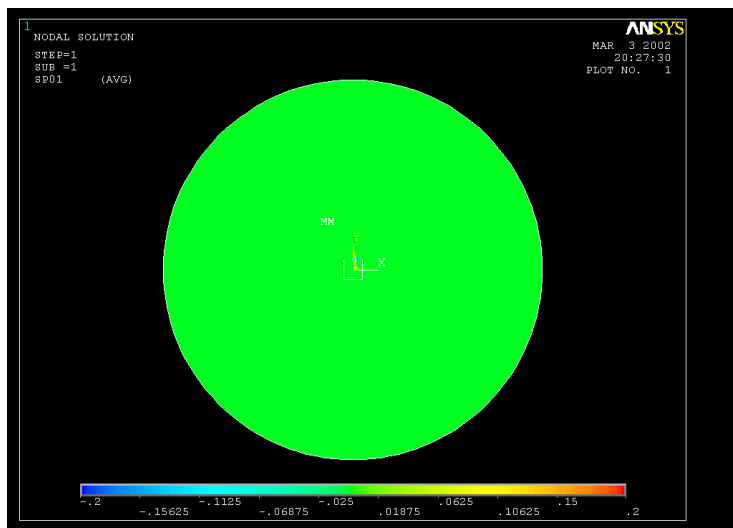
- Standard FEM-Programs
- Apply control concepts on an Ansys model
- CAPA
- Mathcad – simple heat solver behind mathcad
- Mathcad – parametrized more complex geometries

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

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 ...

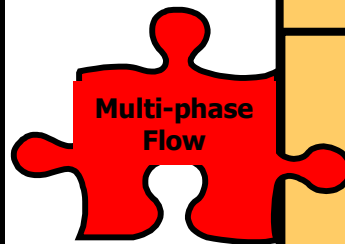
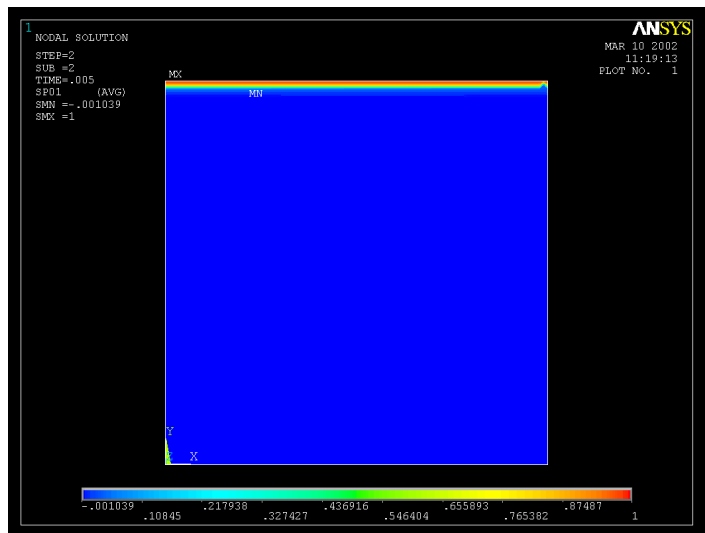


Diffpack – to fill in the gaps in functionality

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

Modellaufbereitung in ANSYS

Problemlösung mit externem Diffpack Fluid/Struktur - Solver

Postprocessing in ANSYS

ANSYS 5.7 Output Window

```

USE COMMAND MACRO DIFFSOL
ARGS= 1,00
      2,00
***** ANSYS
ANSYS/Multiphysics
88888888      VERSION=INTEL NT      13:04:24 DEC 06, 2001 CP=      11.977

Model of 2d lubrication problem in ANSYS Pre

***** ANSYS ANALYSIS DEFINITION (PREP7) *****
ENTER /DEVICE-NAME TO ENABLE GRAPHIC DISPLAY
ENTER /FACET TO LEAVE PREP7
PRINTOUT K... TO /GOPR (USE /NOPR TO SUPPRESS)

***** ROUTINE COMPLETED ***** CP =      12.007

PRINTOUT RESUMED BY /GOP
*****
*          CALL EXTERNAL DIFFPACK SOLVER          *
*****
SYSTEM=
Diffpack\dpsolve.exe <ansdiff.i>ansdiff.o
*****
*          EXTERNAL DIFFPACK SOLVER FINISHED      *
*****
*          READ DATA SOLUTIONS IN ANSYS POST      *
*****
SYSTEM=
DP20...
*****
PRINTOUT RESUMED BY /GOP
    
```

ANSYS Graphics - epla

NODAL SOLUTION

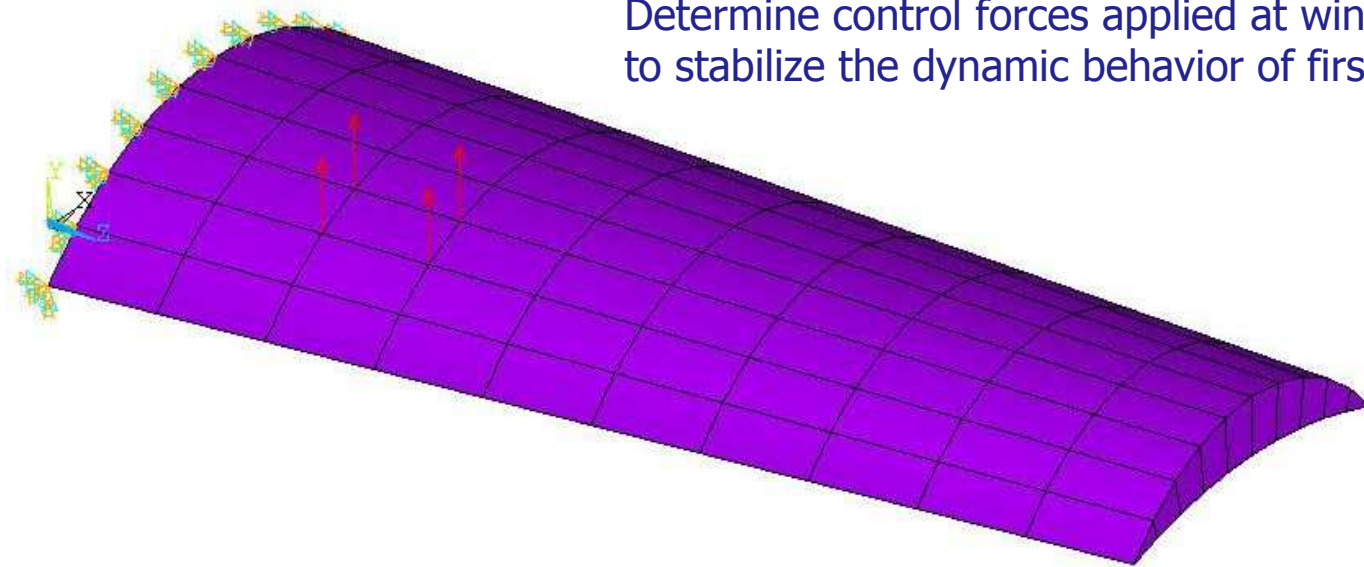
STEP=30
SUB =30
TIME=-.725
ROTY (AVG)
RSYS=0
SMN =-.793114
SMX =.793114

Diffpack Results - Flux Y

Color scale: -.793114, -.616866, -.440619, -.264371, -.088124, .088124, .264371, .440619, .616866, .793114

Diffpack® - ANSYS Integration – Wing tip control

- Employ concepts of control theory



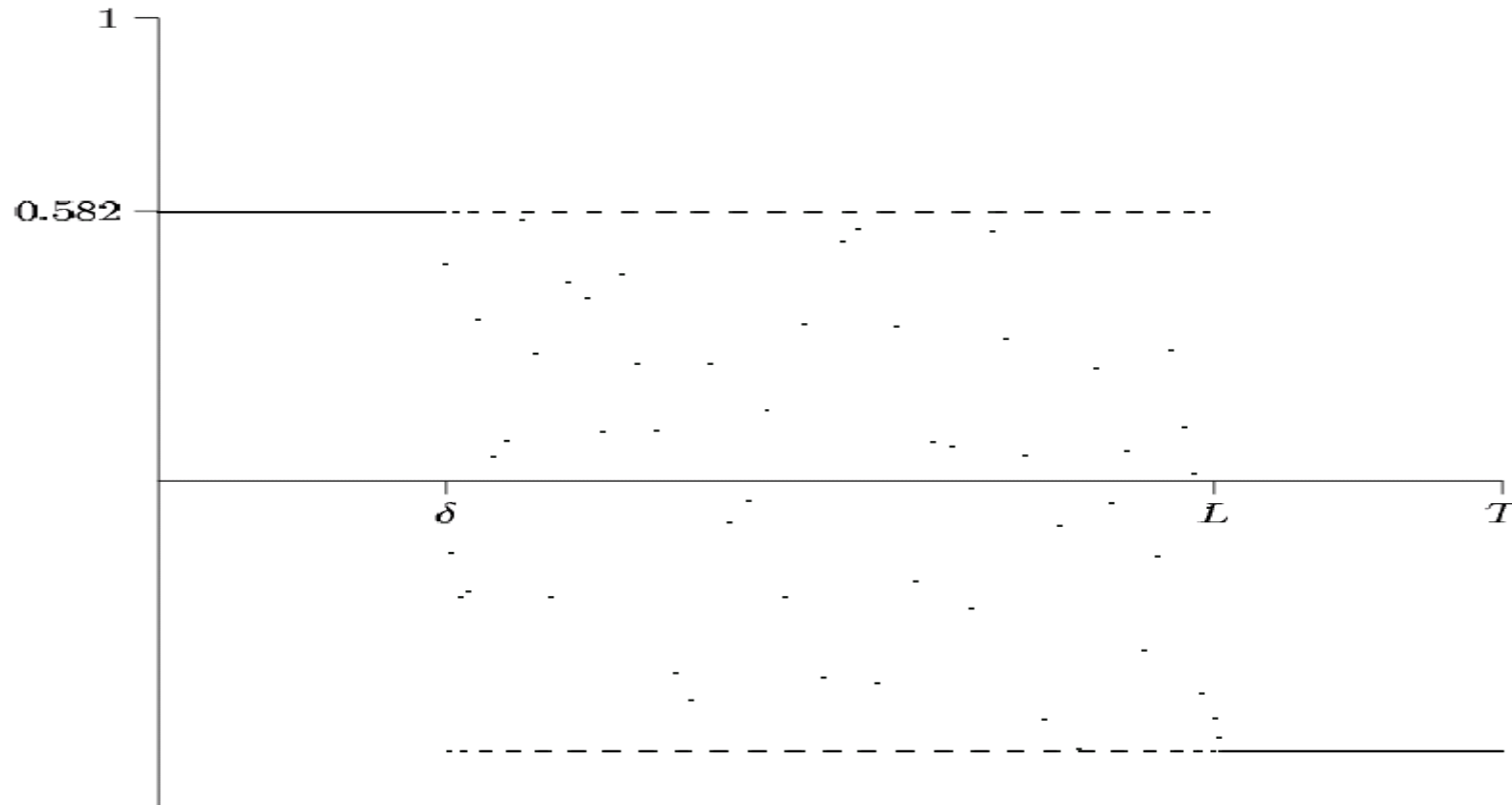
Determine control forces applied at wing tip to stabilize the dynamic behavior of first mode.

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
→ waves with finite traveling velocity

Why control on PDE level?

- Counter example



Control problems

- Stabilization

$$J = \int_0^T \|F(\tau)\| + \|u(\tau) - u_D\| \, d\tau$$

- Final State

$$J = \frac{1}{2} \int_0^T \|F(\tau)\| \, d\tau + \frac{k}{2} \|u(T) - u_D\| + \frac{k}{2} \|u(T) - u_D\|$$

Stabilization - Optimality system

- Direct system (forward running PDE)

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

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

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

$$u(0, x) = u_0,$$

$$u(1, x) = u_1.$$

Stabilization - Optimality system

- adjoint system (backward running PDE)

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

$$\phi|_{\partial\Omega} = 0,$$

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

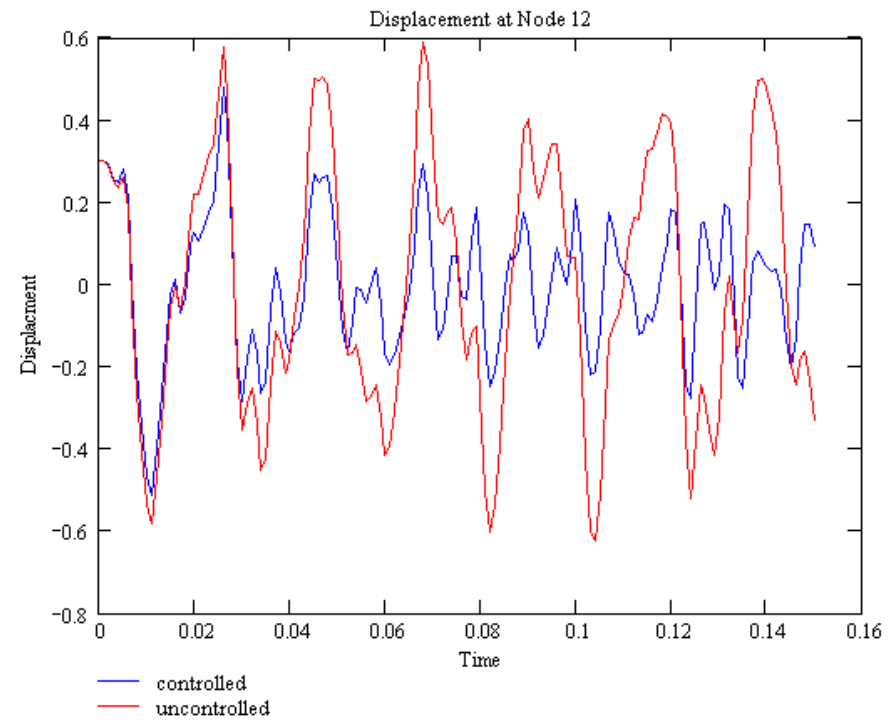
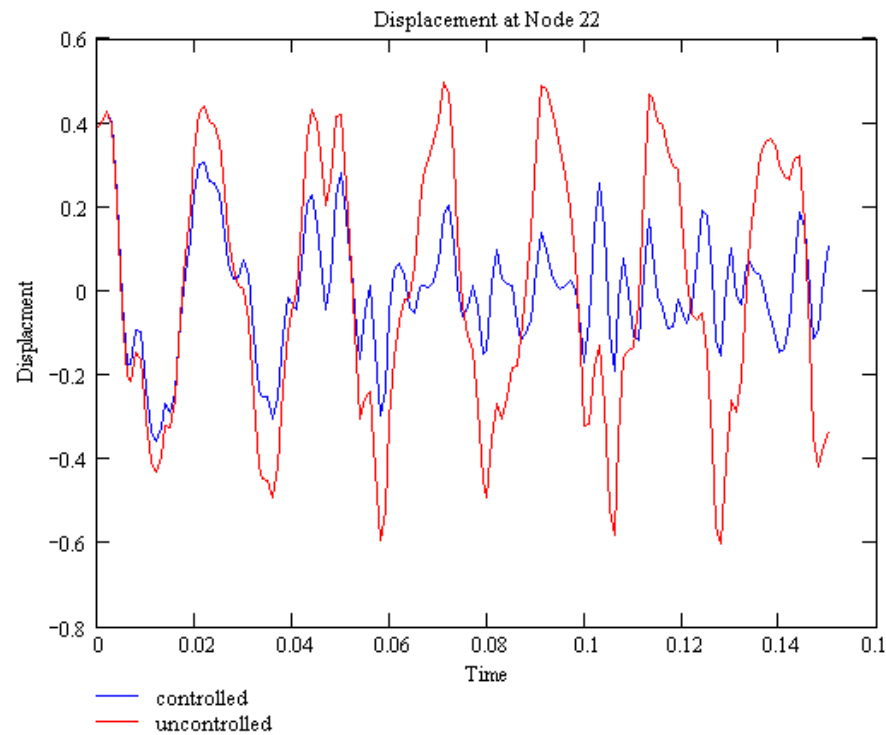
$$\phi(T, x) = 0,$$

$$\phi(T, x) = 0.$$

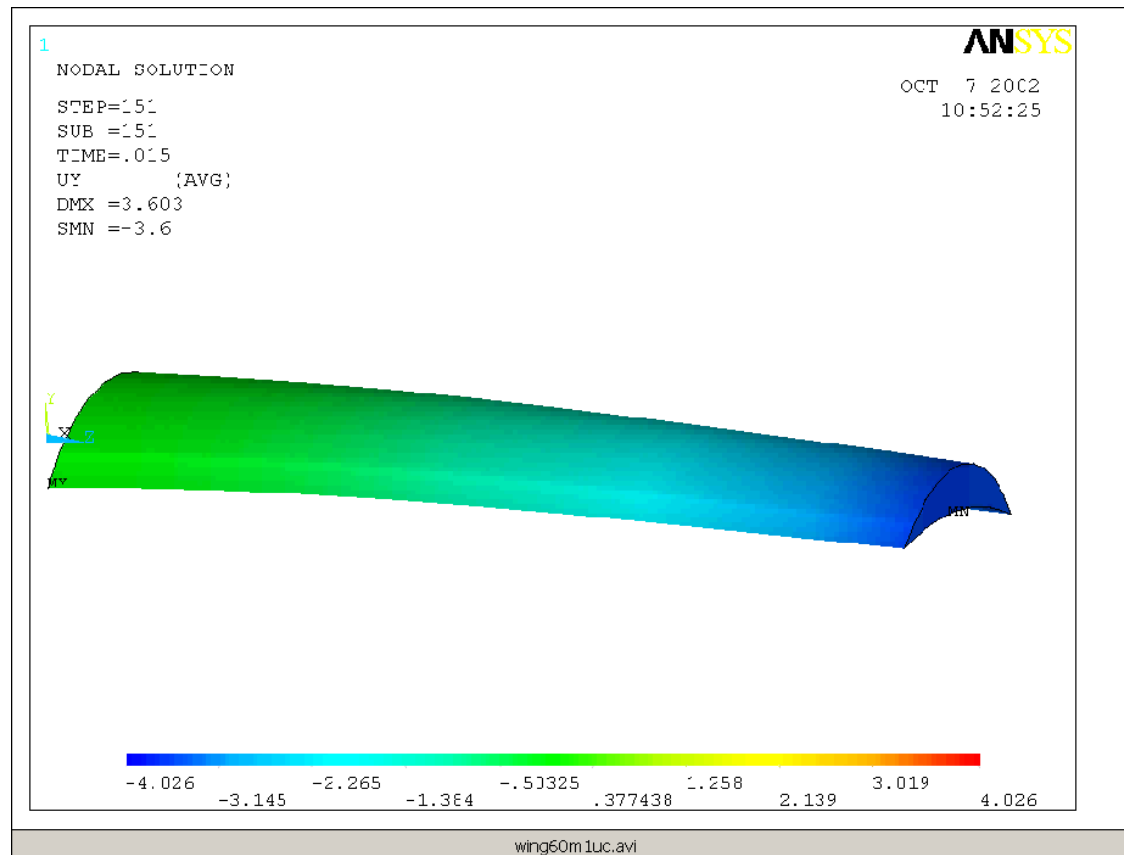
- coupling

$$u = -\phi, \quad x \in \partial\Omega_{con}$$

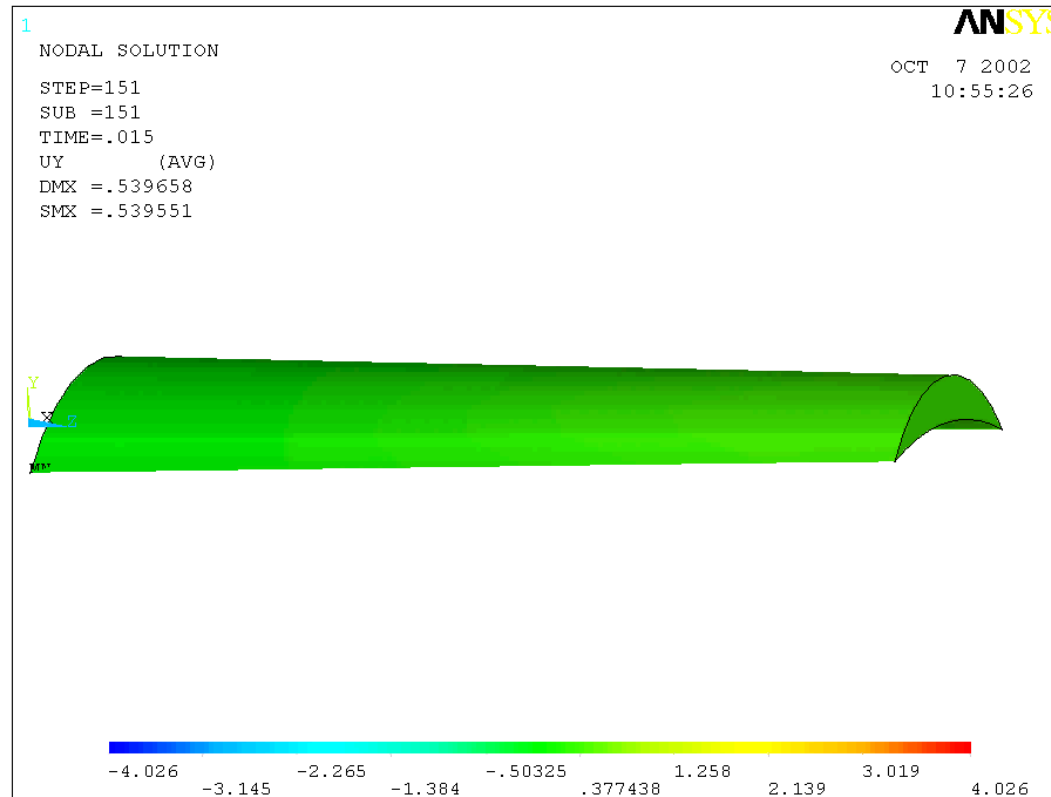
Wing tip control - Results



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 ψ
- 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

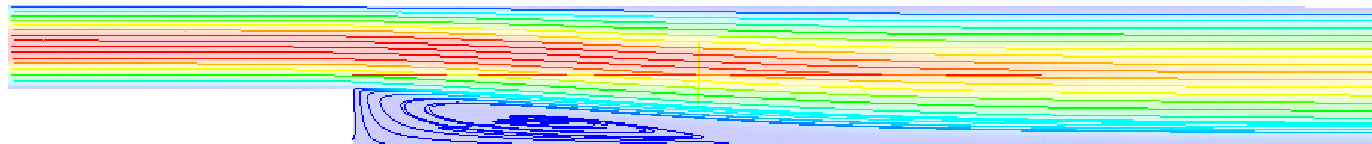
Coupling CAPA and Diffpack

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

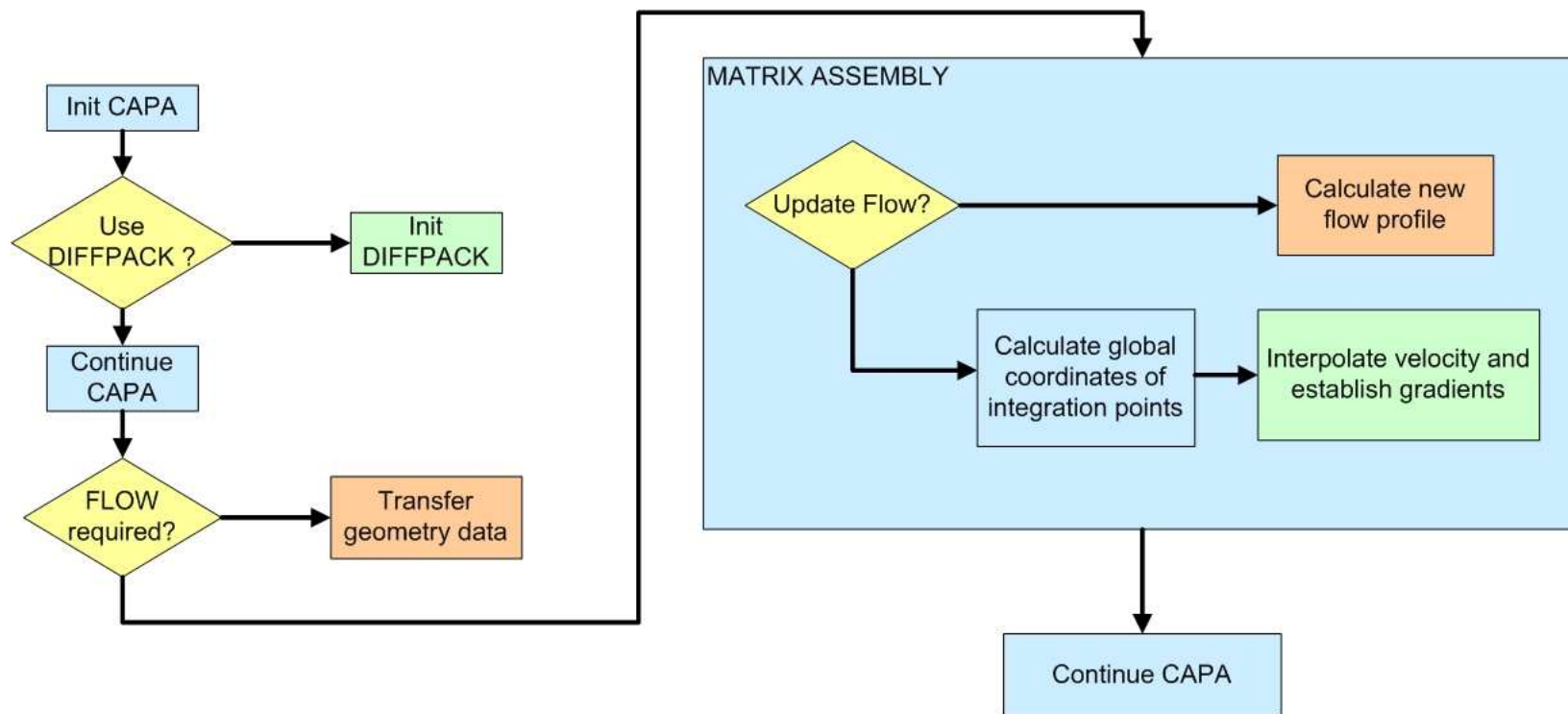
$$\rho(\mathbf{v} + \mathbf{v} \cdot \nabla \mathbf{v}) = -\nabla(-\lambda \nabla \cdot \mathbf{v}) + \mu \Delta \mathbf{v}$$

$$p = -\lambda \nabla \cdot \mathbf{v}, \quad \lambda \rightarrow \infty$$

- 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

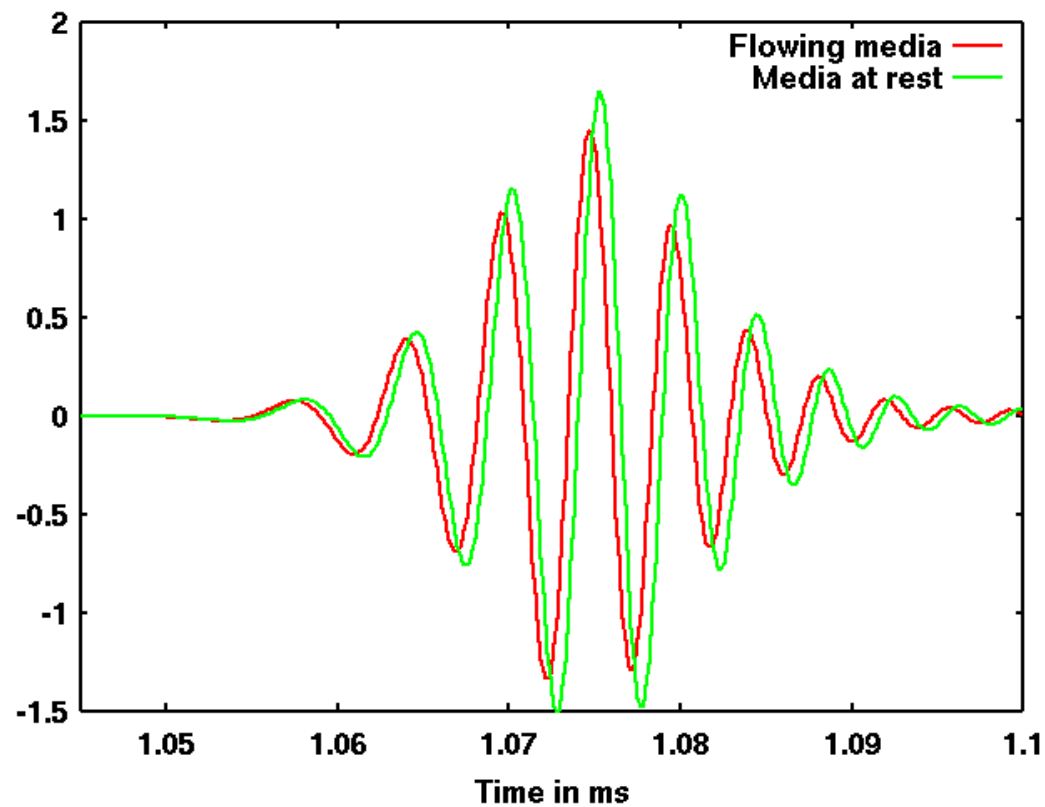


Coupling CAPA and Diffpack (cont.)



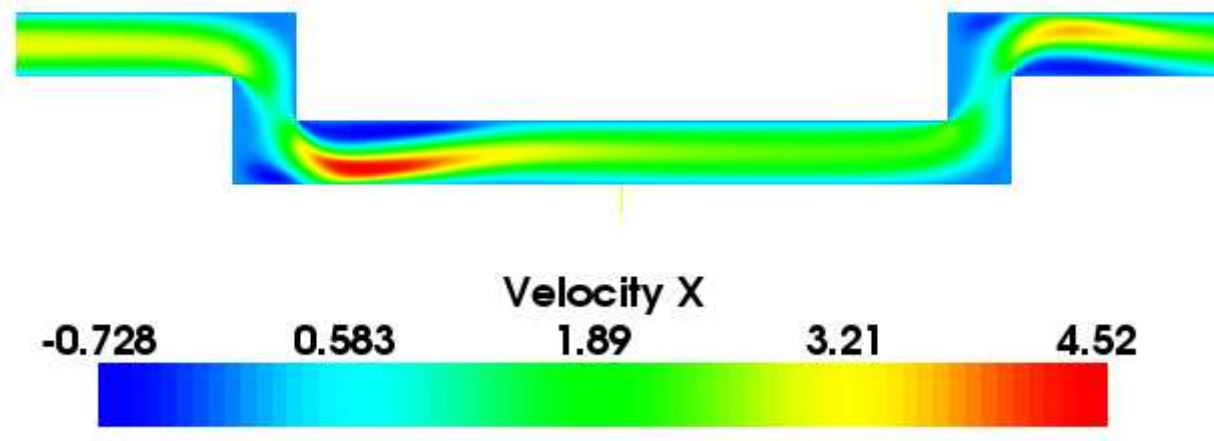
Application: Flowmeter

- Signal at receivers



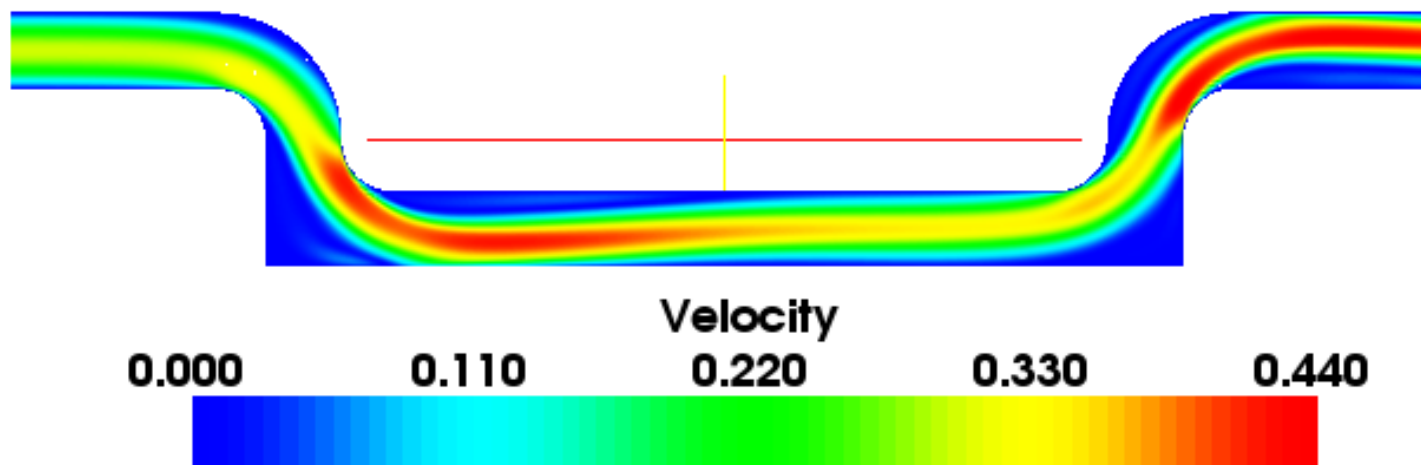
Results for Glyzerol

- Penalty 10000, velocity = 3



Results for Air

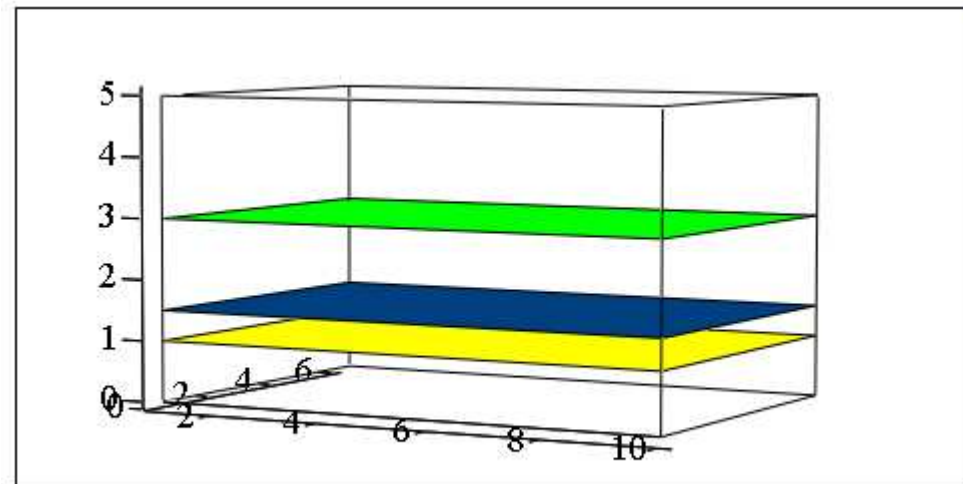
- Penalty 50, velocity = 0.3



Mathcad - Diffpack

Diffpack® & Mathcad

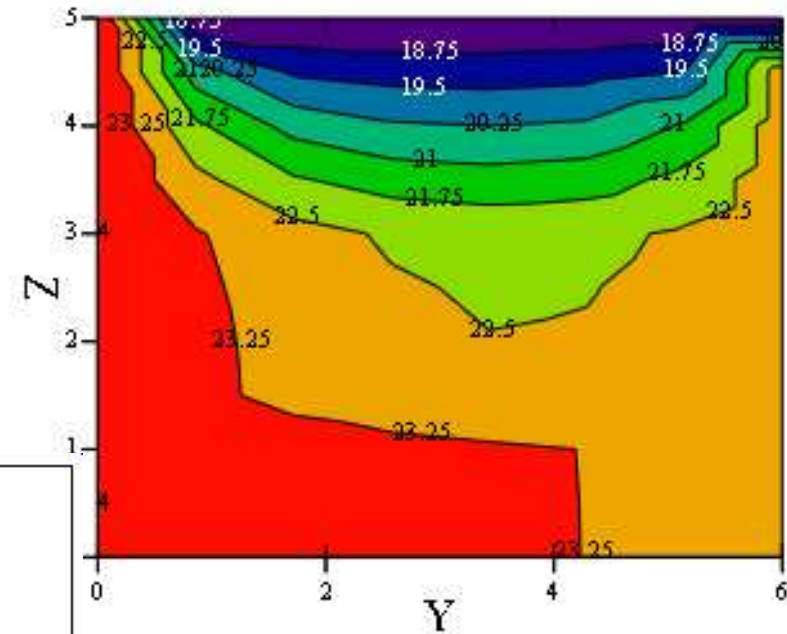
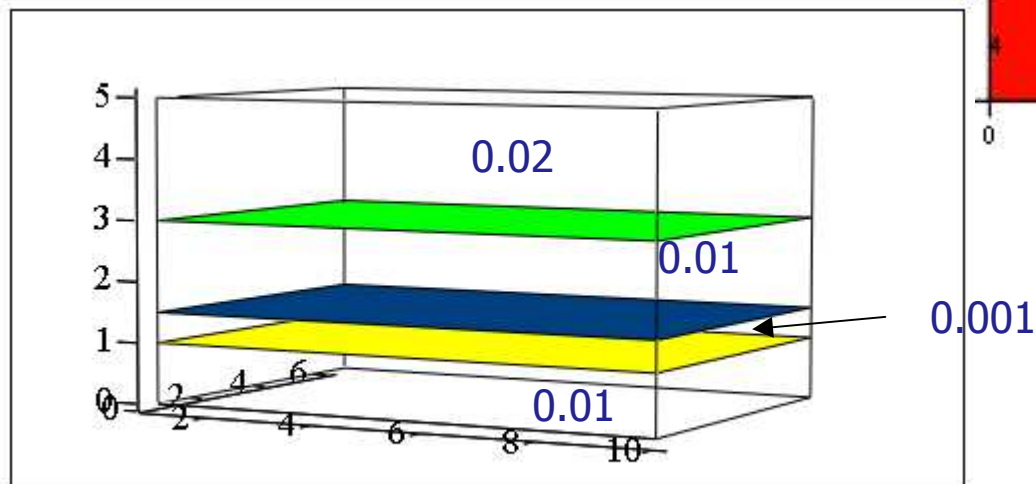
- Diffpack Heat equation solver packed in Mathcad Userrefi dll
- new function in Mathcad available: DpHeating
- Mathcad:
 - specify a 3D cube with different layers
 - Apply different heat transfer coeffs in each layer
 - Define boundary conditions



Box,Layer

Diffpack® & Mathcad

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



Box, Layer