Nečas Center for Mathematical Modeling

Inaugural seminar

- WELCOME
- MISSIONS
  - ☞ To provide basic information on NCMM and its goals
  - ☞ To look at our research from more general perspective
  - ☞ To have a small ceremony

Vision 1

Nečas Center for Mathematical Modeling

Within five years to form a *coherent* group of researchers specializing in analysis related to models of continuum physics, that will be able to interact with similar teams or individuals working in applied areas at home and abroad. The role of the center will be at least two-fold: first, it will act as an advisory center that will address questions with regard to which approach should be taken to a given problem, and second, as an acceptor of new stimulations to further development.

More on the use of the word ***coherency*** will follow

Vision 2

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To achieve new and significant results in theoretical, numerical and computational analysis of continuum physics models.

Balance laws - sufficiently robust framework to capture behavior of many materials

- ☞ Gases and conventional liquids
- ☞ Biological fluids (blood, sinovial fluids) and materials (bones)
- ☞ Soft tissue (arterial walls, cartilage)
- ☞ Geomaterials (magma, soil, asphalt, glacier)
- ☞ Shape memory materials
- ☞ Materials exposed to permanent or cyclic large defformation

To enlarge current state of knowledge.

New scientific results in the following areas:

- ☞ Nonlinear theoretical, numerical and computer analysis of problems of continuum mechanics
- ☞ Heat-conductive and deforming processes in compressible fluids, incompressible substances of fluid type, and in linearly elastic matter
- ☞ Interaction of the substances
- ☞ Biochemical processes in substances
- ☞ Passages between models, dimensional analysis

Vision 3

An unified focus on understanding the governing equations from the point of view of modeling, mathematical analysis, numerical approximations, and computational simulations.

Significant role should be played by PhD and M.S. students.

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- unsteady and steady compressible fluid flows
  - ➡analysis (Feireisl, Petzeltová, Straškraba)
  - ➡numerical methods (Feistauer, Felcman, Dolejší)
- mathematical analysis in calculus of variations (Malý, Roubíček)
- function spaces, functional analysis, operator theory (Krbec, Malý, Pick)
- non-Newtonian incompressible fluid flows
  - ➡ analysis (Kaplický, Málek, Nečasová, Pražák, Pokorný)
  - ➡computational simulations (Hron)
- fluid-structure interaction
  - ➡analysis (Feireisl, Nečasová)
  - ➡numerical methods and computer simulations (Feistauer, Hron)
- incompressible Navier-Stokes equations
  - ➡analysis (Pokorný, Neustupa, Nečasová)
  - ➡numerical methods (Knobloch)
  - ➡computational simulations (Hron, Feistauer)
- porous media flows and free surface problems (Beneš, Mikyška)
- multiphase and multicomponent fluid flows
  - ➡analysis (Feireisl, Málek)
  - ➡numerical methods and computer codes (Beneš)
- optimization (analysis, numerics, computaer simulations)
  - ➡shape (Haslinger)
  - ➡flow (Roubíček, Haslinger)
- bifurcation (Janovský)
- integro-differential equations (Janovský, Bárta)
- regularity theory (Kaplický, Malý)

Mathematical Modeling Group
Faculty of Nuclear Sciences and Physical Engineering
Czech Technical University Prague

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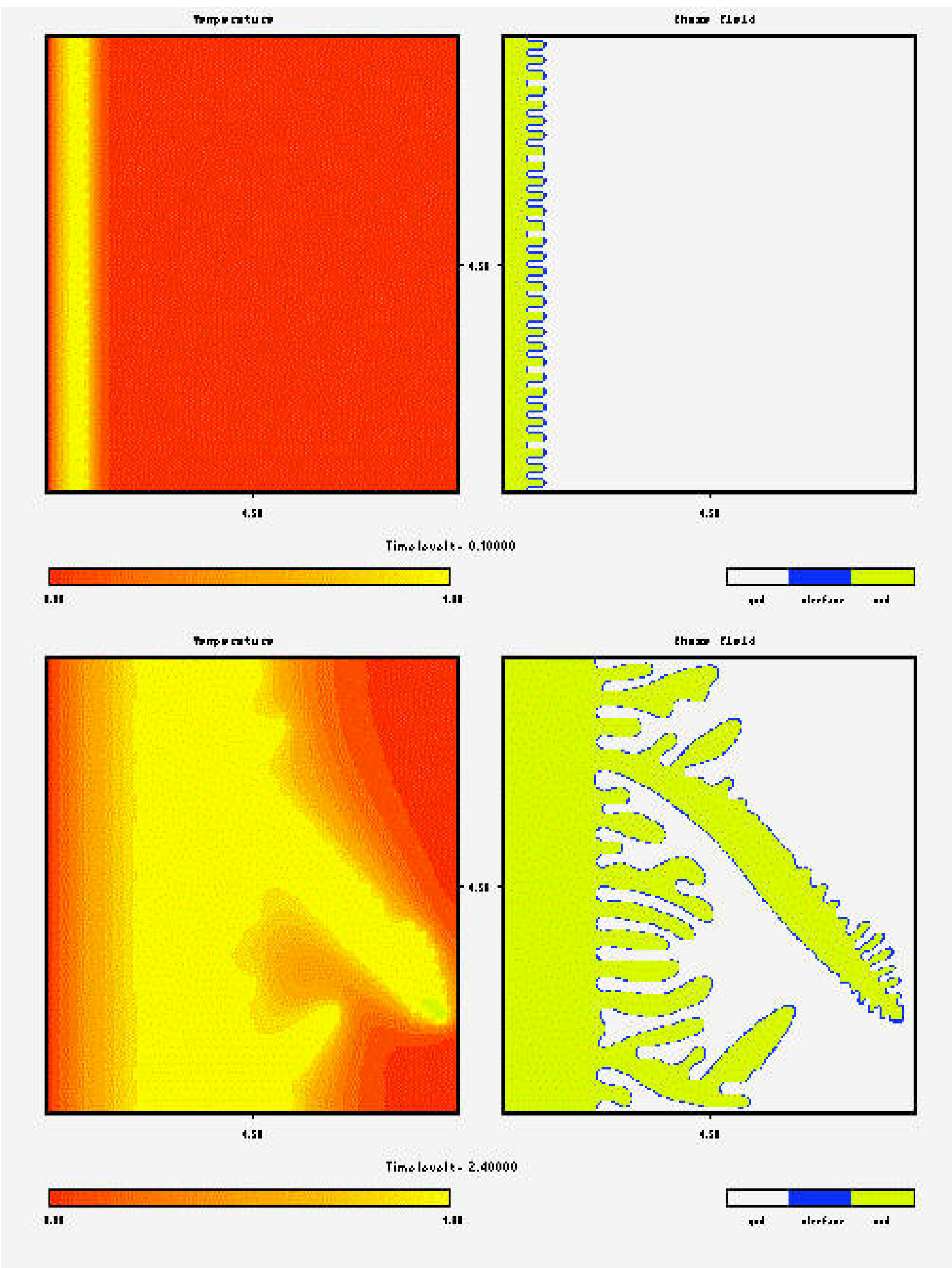
Example – microstructure in metals



- Computer models of microstructure (dendrites) formation help in understanding material properties.
- Application: manufacturing turbine blades, jet engines, semiconductors, etc.

Research Team 3, M. Beneš

Compressible Navier-Stokes equations

$$\frac{\partial \mathbf{w}}{\partial t} + \sum_{s=1}^{2} \frac{\partial}{\partial x_s} \mathbf{f}_s(\mathbf{w}) = \sum_{s=1}^{2} \frac{\partial}{\partial x_s} \mathbf{R}_s(\mathbf{w}, \nabla \mathbf{w}) \text{ in } \Omega \times (0, T) \quad (1)$$

$$\mathbf{w} = (\rho, \rho v_1, \rho v_2, e)^T,$$

$$\mathbf{f}_s(\mathbf{w}) = (\rho v_s, \rho v_s v_1 + p\delta_{s1}, \rho v_s v_2 + p\delta_{s2}, (e+p)\, v_s)^T, \ \ s = 1, 2,$$

$$\mathbf{R}_s(\mathbf{w}, \nabla \mathbf{w}) = \left(0, \tau^V_{1s}, \tau^V_{2s}, \sum_{r=1}^{2} \tau^V_{rs} v_r + \frac{\gamma}{Re\ Pr} \frac{\partial \theta}{\partial x_s}\right)^T, \ \ s = 1, 2,$$

$$\tau^V_{rs} = \frac{1}{Re}\left[\left(\frac{\partial v_s}{\partial x_r} + \frac{\partial v_r}{\partial x_s}\right) - \frac{2}{3} \mathrm{div}\mathbf{v}\delta_{rs}\right], \ \ r, s = 1, 2,$$

constitutive relations:

$$p = \theta\rho(\gamma - 1), \qquad p = (\gamma - 1)\left(e - \rho|\mathbf{v}|^2/2\right)$$

- benchmark of unsteady flow of inviscid fluid
- given IC, inflow/outflow BC from IC
- grid with 2914 triangles, P_2 approximation, 2nd order in time

Research Team 1,
M. Feistauer, V. Dolejší

School of Mathematics
Faculty of Mathematics and Physics
Charles University in Prague

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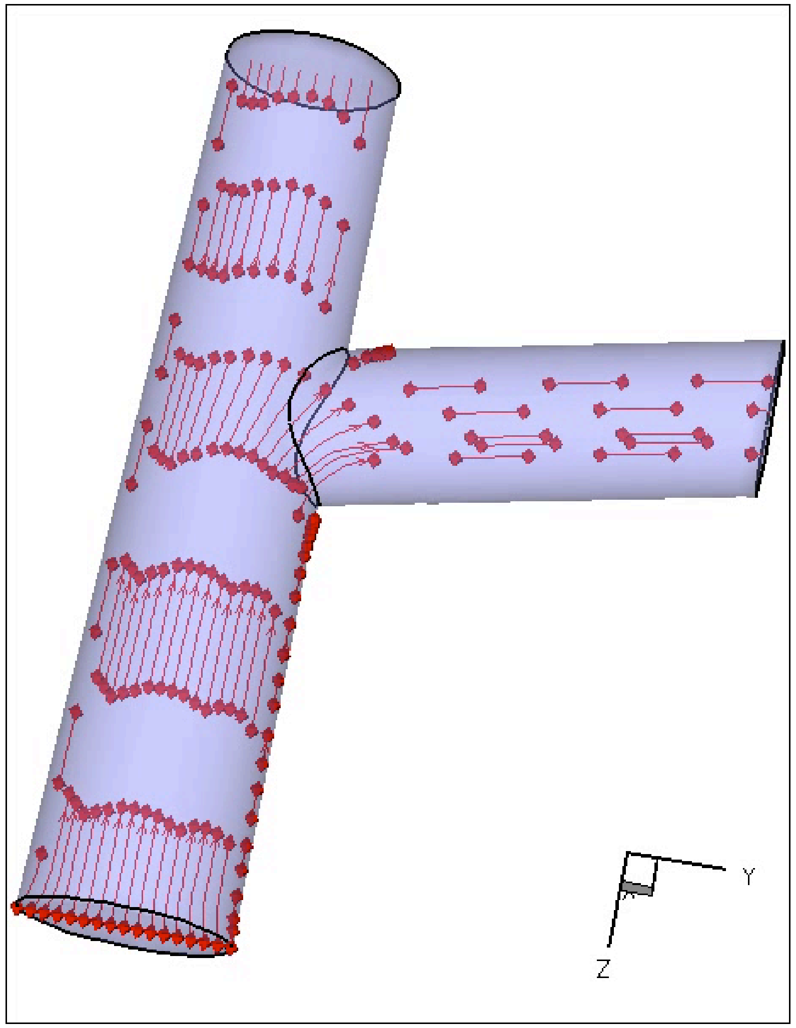
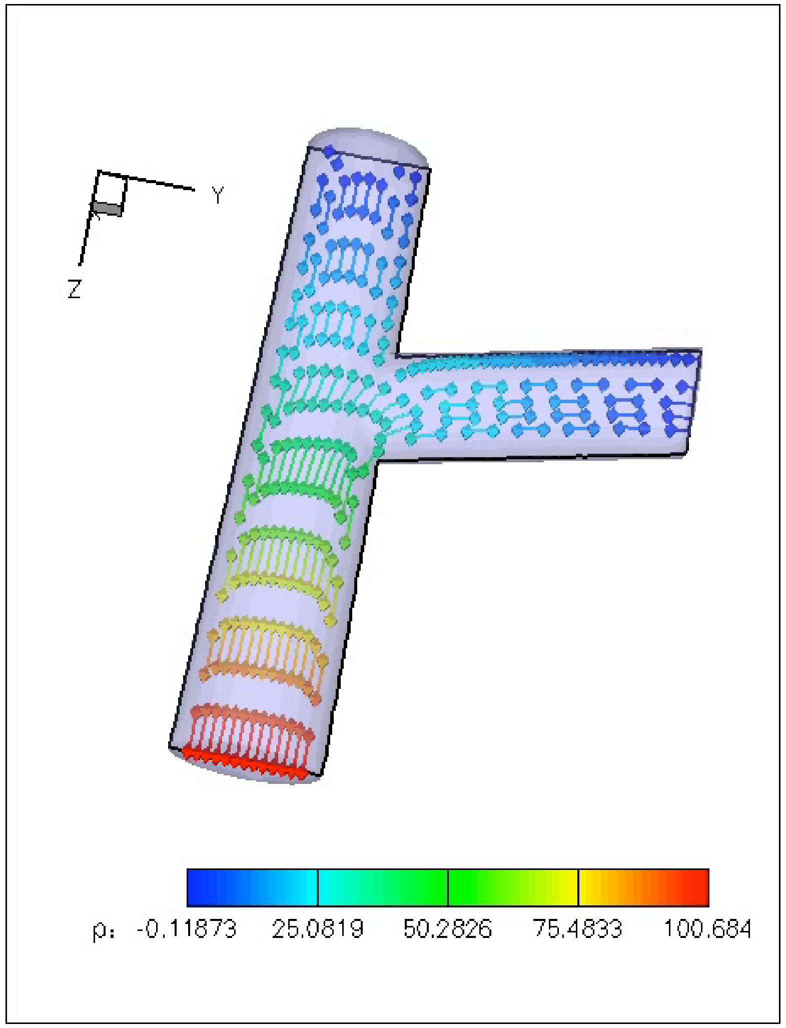
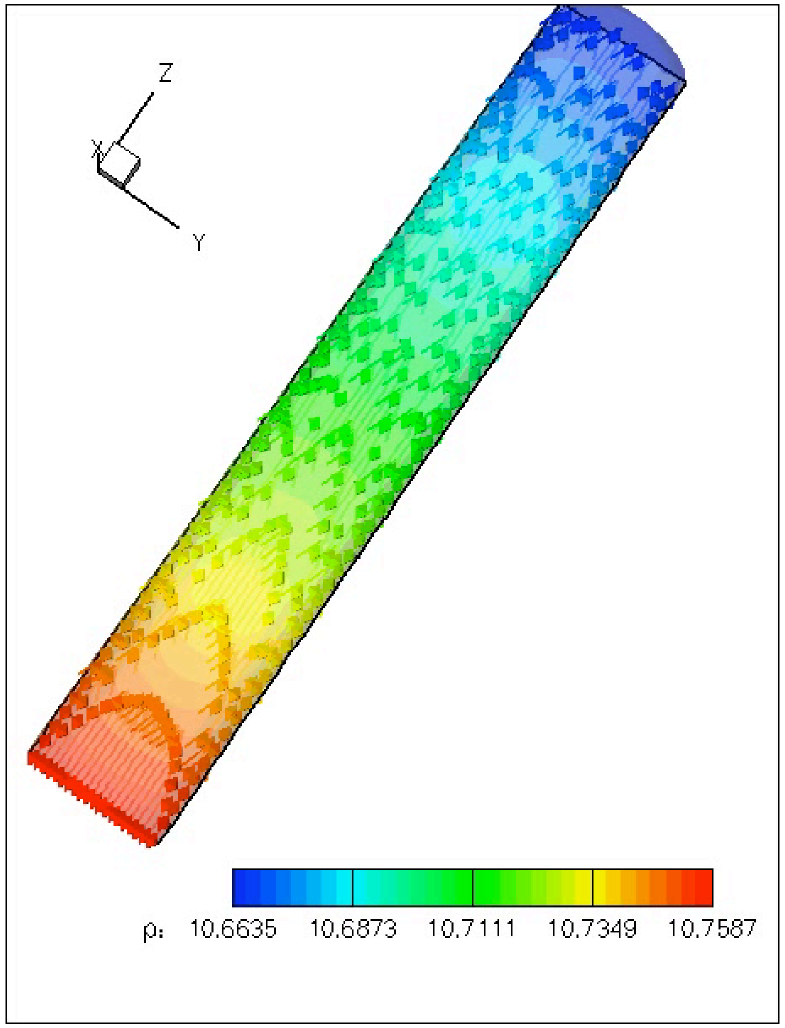
3D incompressible flow problems







Research Team I, M. Mádlík

Incompressible fluid - elastic structure interaction

Research Team I, J. Hron

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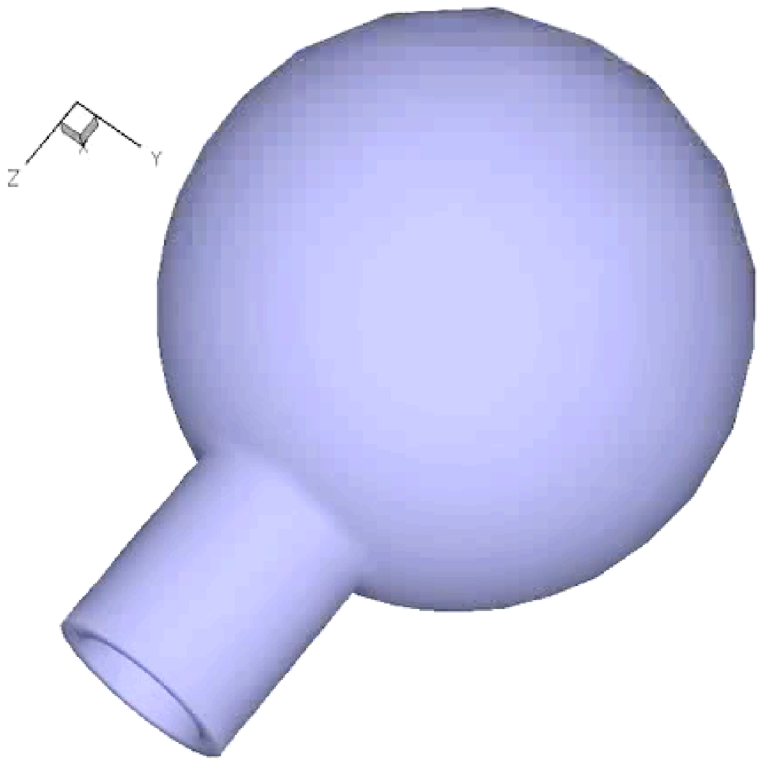
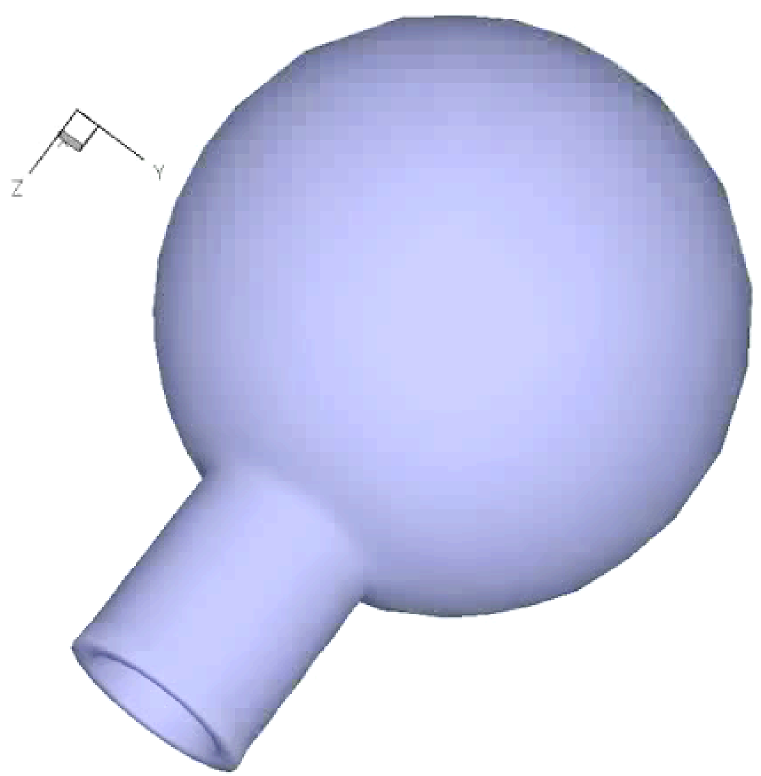
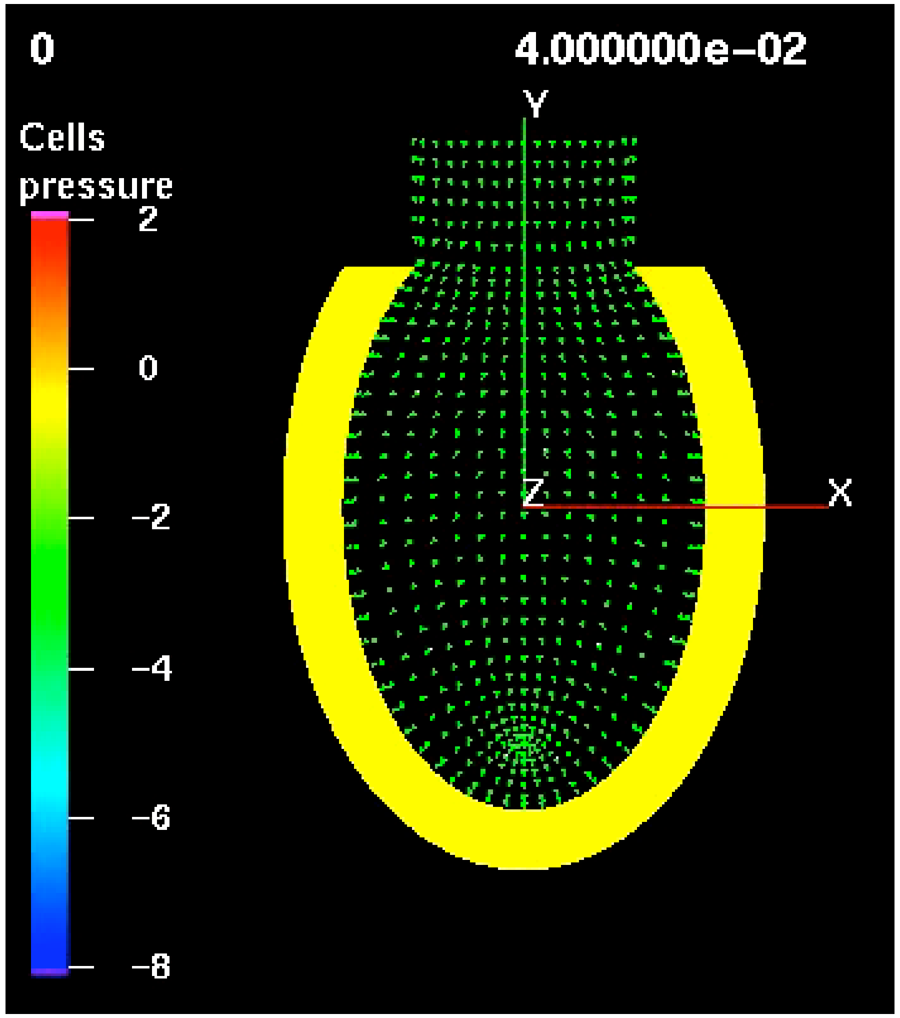
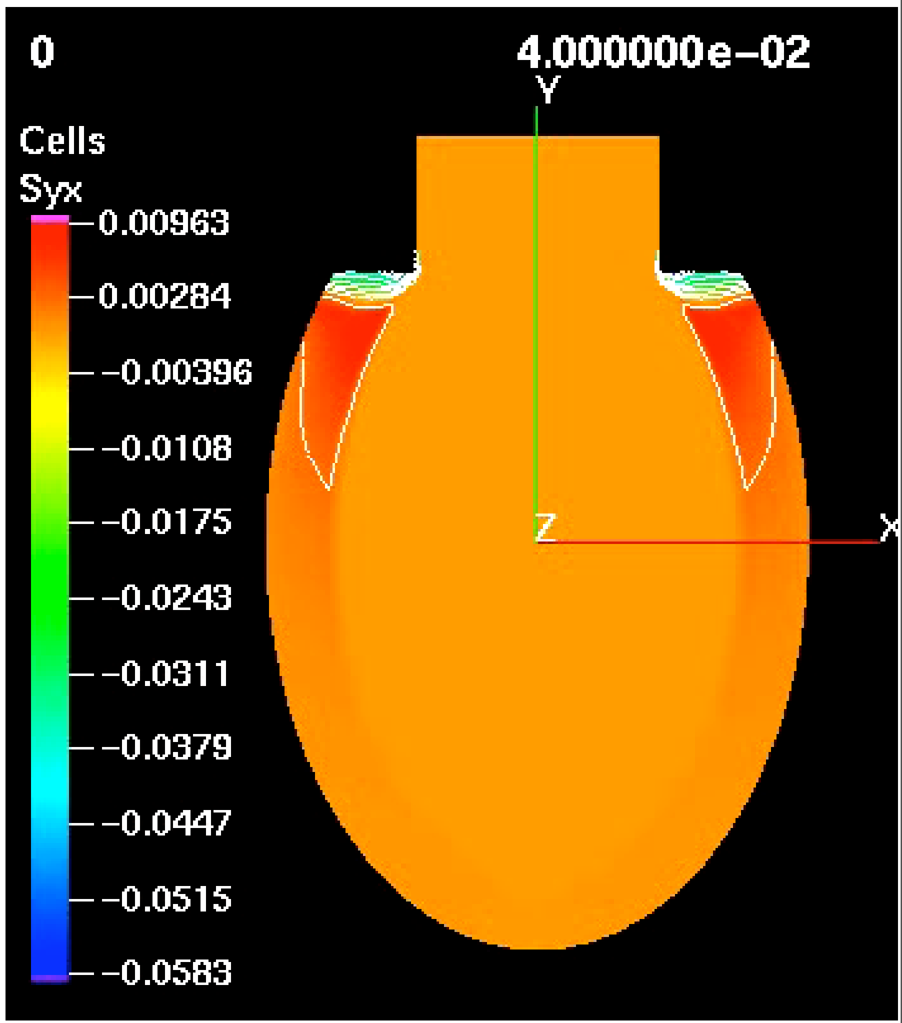




Fluid-structure interaction, inflation of an elastic cavity





Research Team I, J. Hron, M. Mádlík

Vision 4

To carry on the tradition established by Jindřich Nečas.

Founder of the Czech applied analysis school

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K. R. Rajagopal

University Distinguished Professor
Forsyth Chair and Professor Department of Mechanical Engineering
Professor Civil Engineering
Senior Research Engineer
Professor of Biomedical Engineering
Professor of Mathematics
Senior Research Scientist, Texas Transportation Institute

Texas A&M University
College Station

Honors:

- Distinguished Scholar Award, University of Auckland Foundation, 2006
- Archie Higdon Award, American Society of Engineering Education, 2005
- Eringen Medal, Society of Engineering Science, 2004
- Bush Excellence Award for Faculty in International Research 2004
- Cullimore Lecture, New Jersey Institute of Technology, 2004
- Invited main lecture, Stokes' Death Centenary Meeting, Royal Irish Academy, Dublin, 2003
- Award for Excellence in Fluid Mechanics, University Grants Comission For Center of Excellence in Fluid Mechanics, India
- Distinguished Honorary Professor, Indian Institute of Technology

Editor: More than 38 journals

Publications: More than 330 original publications, 6 books and monographs

K. R. Rajagopal

University Distinguished Profesor
Forsyth Chair and Professor Department of Mechanical Engineering
Professor Civil Engineering
Senior Research Engineer
Professor of Biomedical Engineering
Professor of Mathematics

Collaborations with Czech scientists:

- 1992 course on “Mechanics of non-Newtonian fluids” as part of the International school on “Mathematical theory of fluid mechanics”
- 1995 course on “Mixture theory” as part of the International school on “Mathematical theory of fluid mechanics”
- 2005 an intensive weekend course on “Finite elasticity” as a part of the PhD students project “Nonlinear models of continuum mechanics”
- 1996-2000 project contact MŠMT and NSF
- numerous publications together with J. Nečas, J. Kratochvíl, T. Roubíček, J. Málek
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