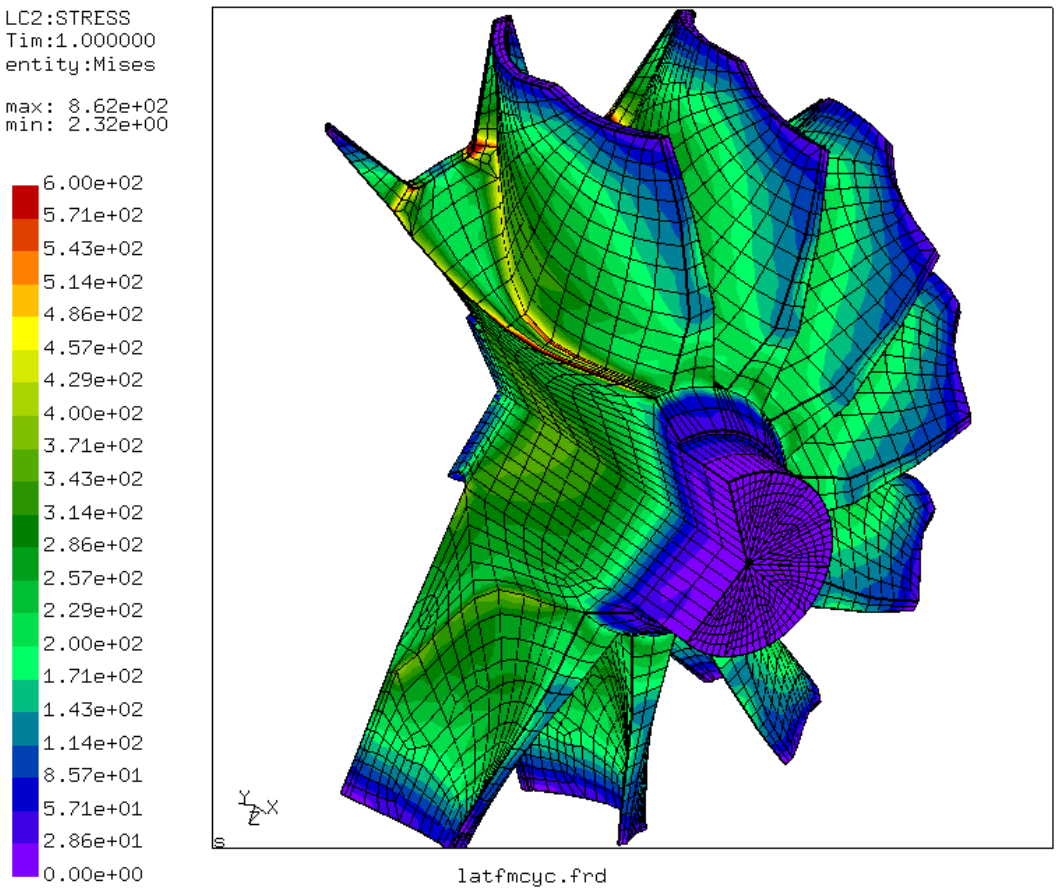
CalculiX

A free software finite element program for three-dimensional thermomechanical calculations

Authors: Guido Dhondt and Klaus Wittig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Static Analysis

- Element types
  - Quadratic bricks, tets, wedges
  - Linear bricks, tets wedges
  - Springs, dashpots
  - 2d-elements: plane stress/strain, axisymmetric elements and shells
  - 1d-elements: beams and trusses

Static Analysis

- Materials
  - Linear elastic (isotropic, orthotropic, anisotropic)
  - Hyperelastic
  - Isotropic Plasticity
  - Isotropic Creep
  - Single crystal plasticity and creep
  - Tension-only and compression-only materials
  - Material dependence of all properties

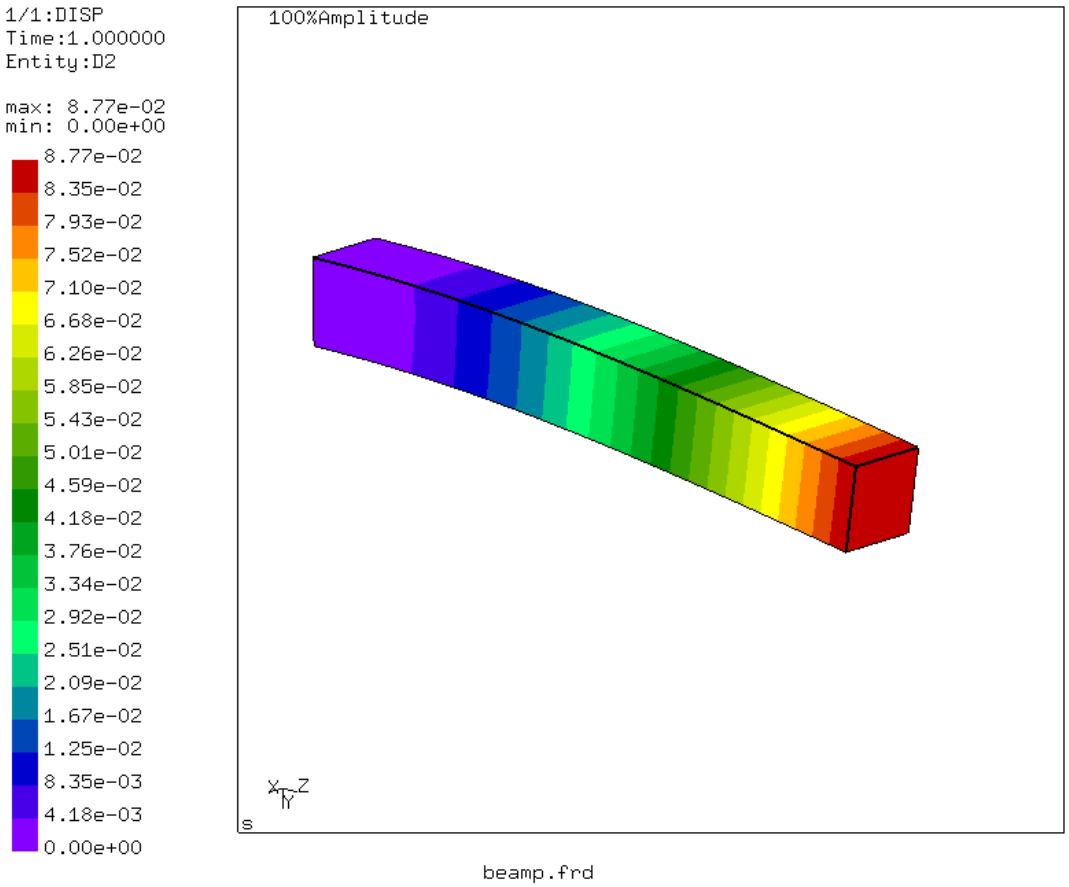
Static Analysis

- Boundary conditions
  - Single point constraints
  - Multiple point constraints
  - Nonlinear equations
  - Rigid body motion

Static Analysis

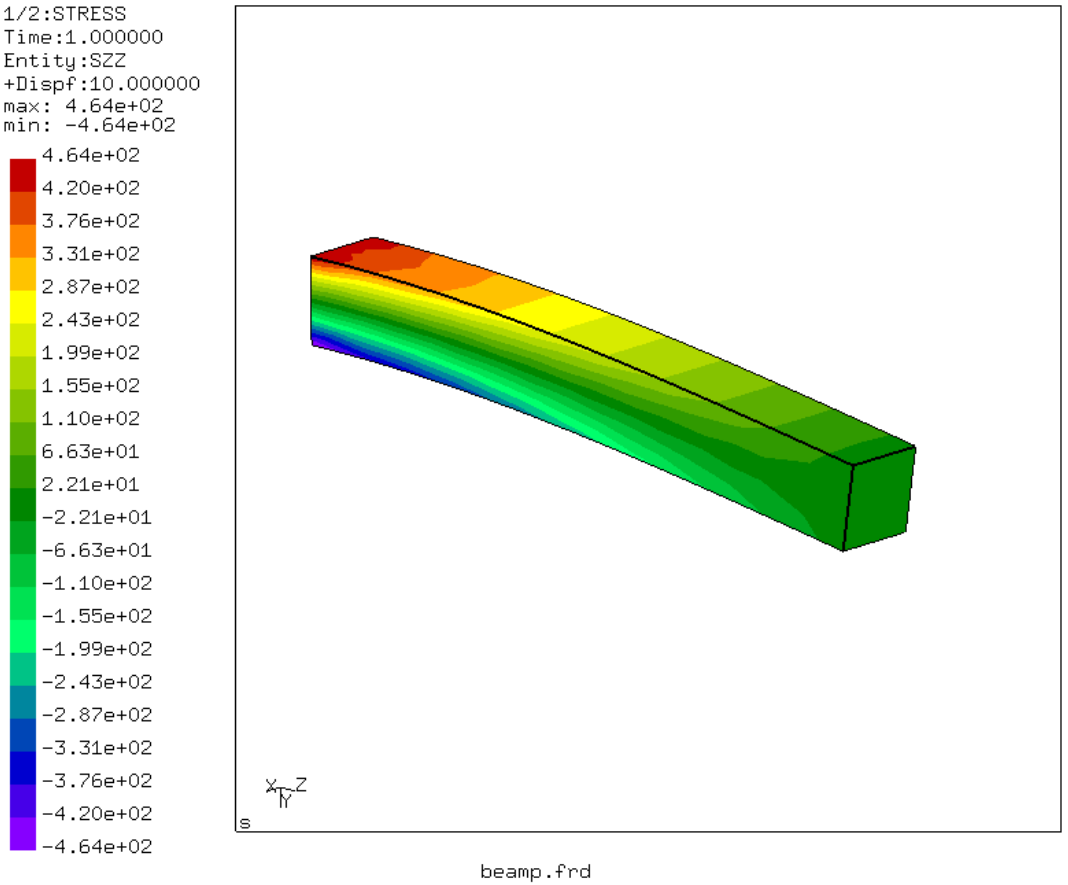
- Loading
  - Point loads
  - Distributed surface load
  - Centrifugal loading
  - Gravity loading
  - Distributing coupling

Static Analysis



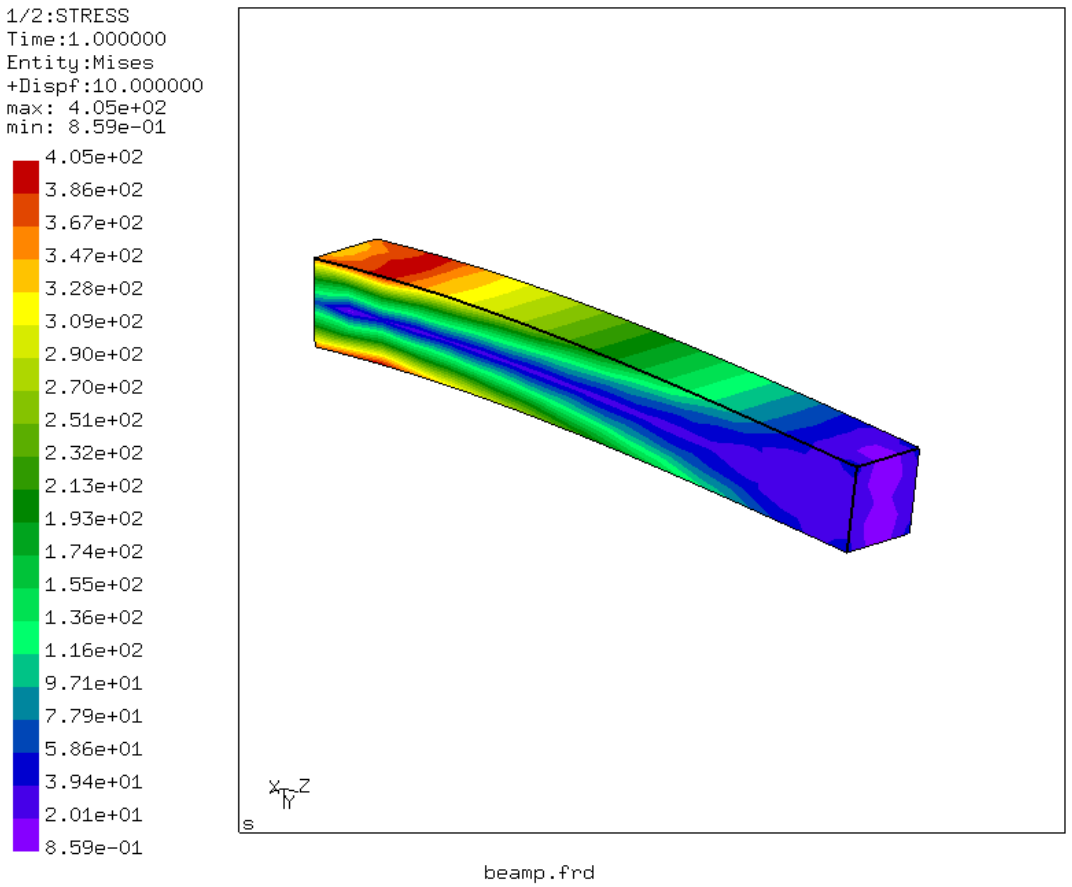
Displacements in a cantilever beam

Static Analysis



Axial stress in a cantilever beam

Static Analysis

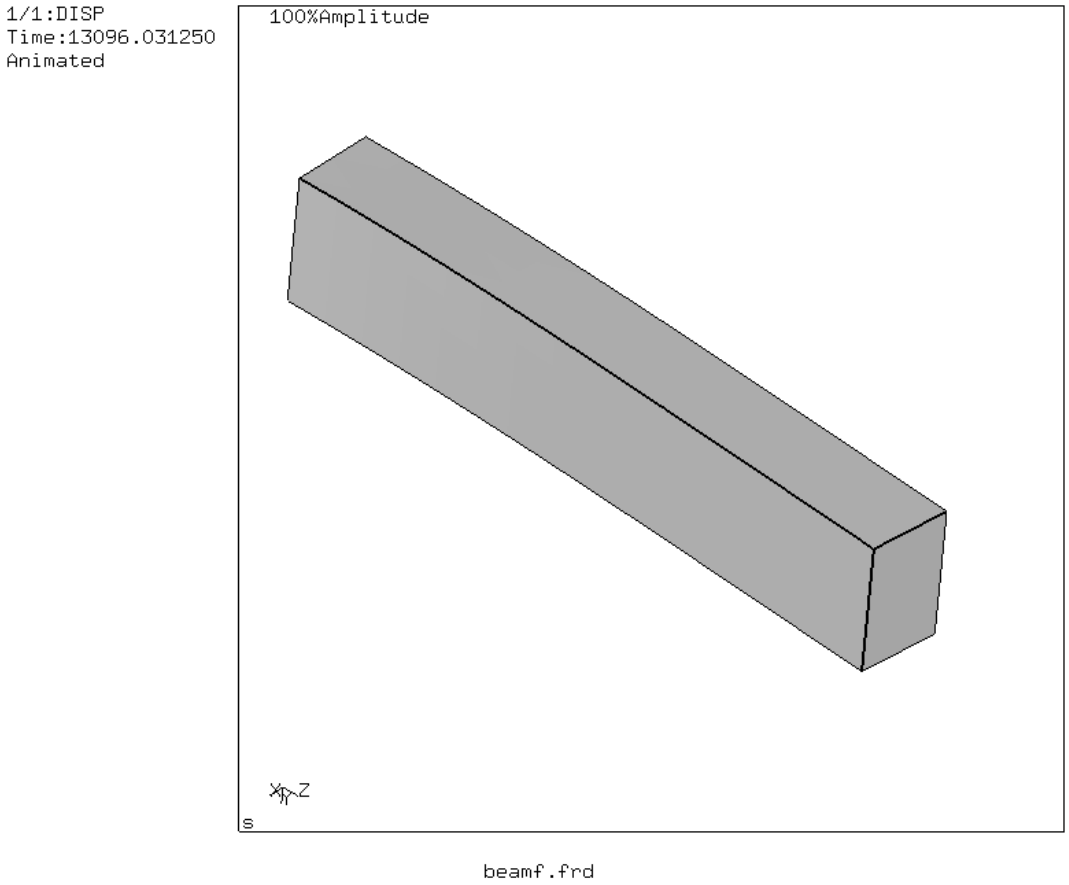


Von Mises stress in a cantilever beam

Frequency Analysis

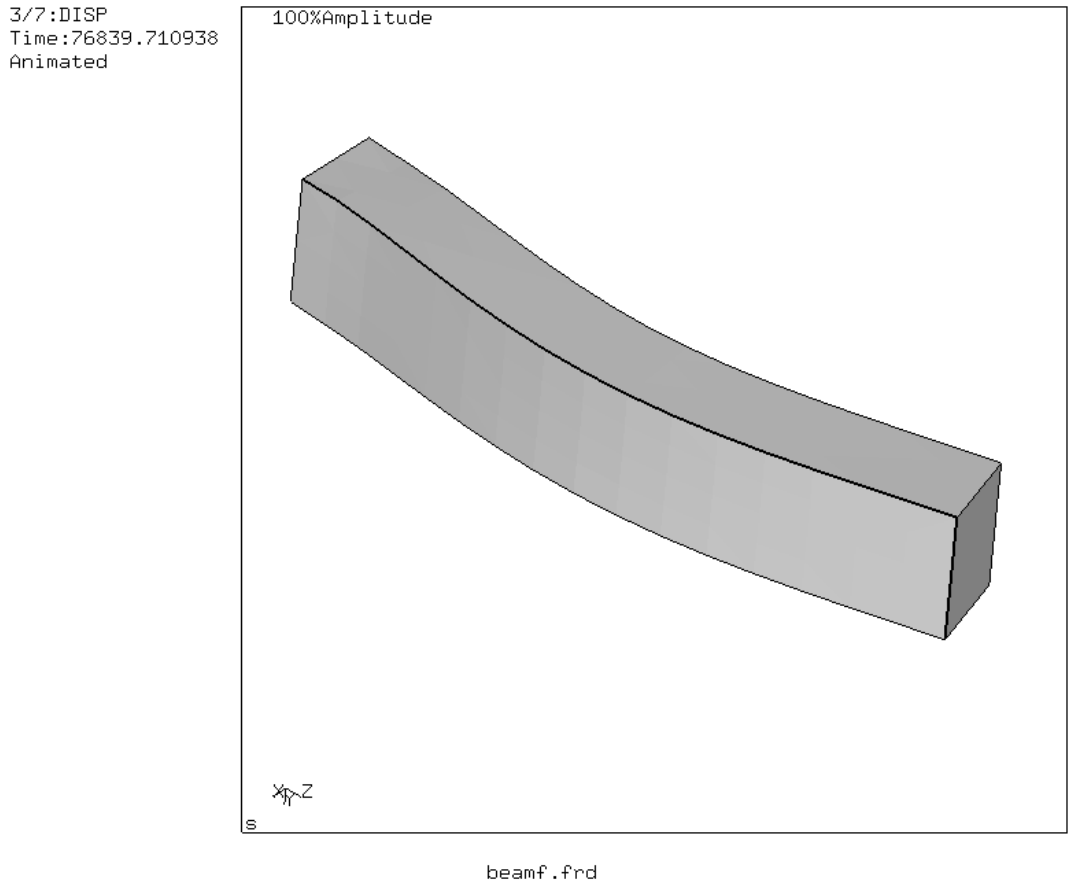
- Eigenmodes (animation in CalculiX GraphiX)
- Eigenfrequencies
- Storage of stiffness and mass matrix for further use
- Modal dynamic analysis (time domain)
- Steady state dynamics analysis (frequency domain)
- Participation factors

Frequency Analysis



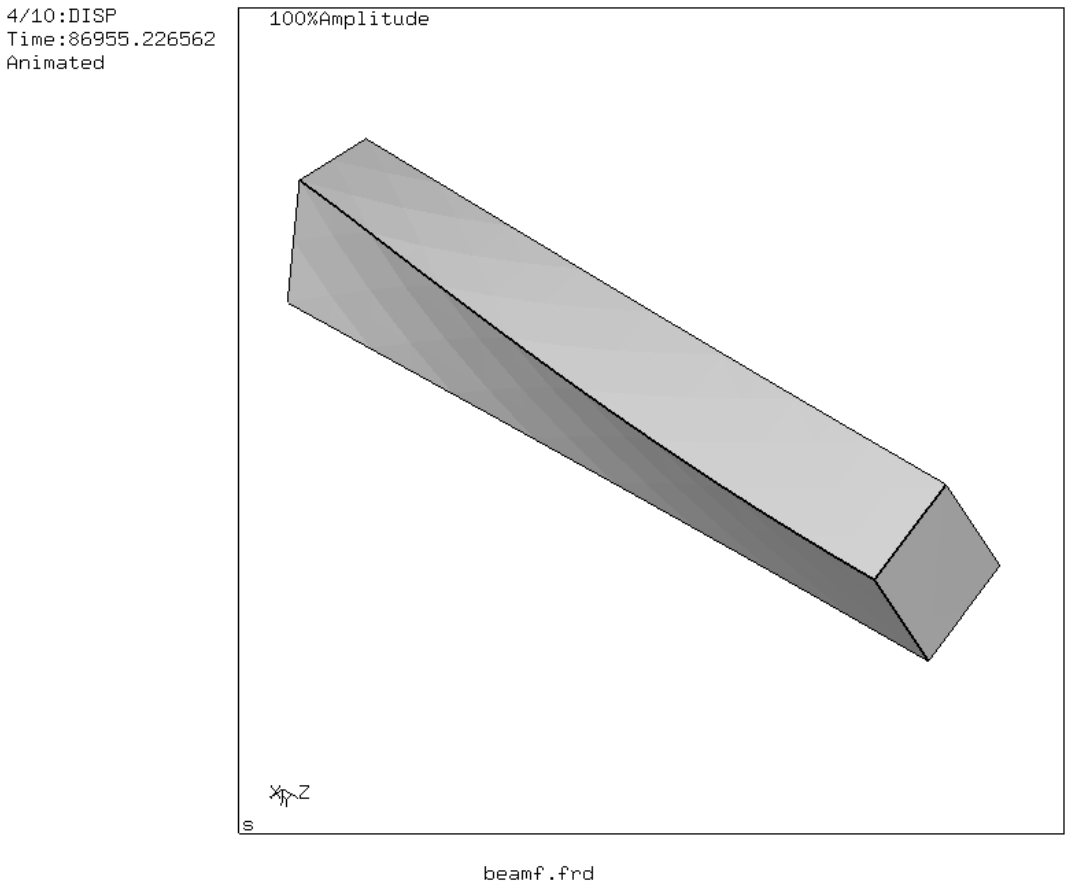
First bending mode in a cantilever beam

Frequency Analysis



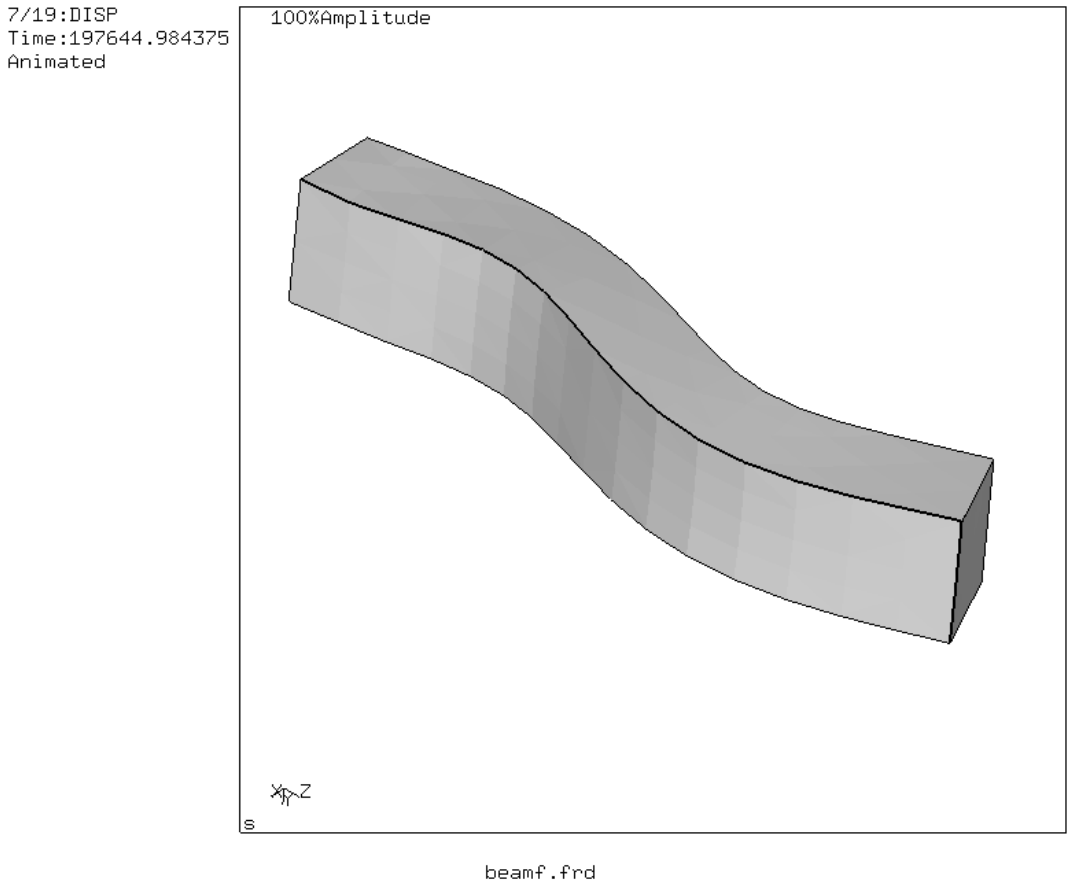
Second bending mode in a cantilever beam

Frequency Analysis



First torsional mode in a cantilever beam

Frequency Analysis

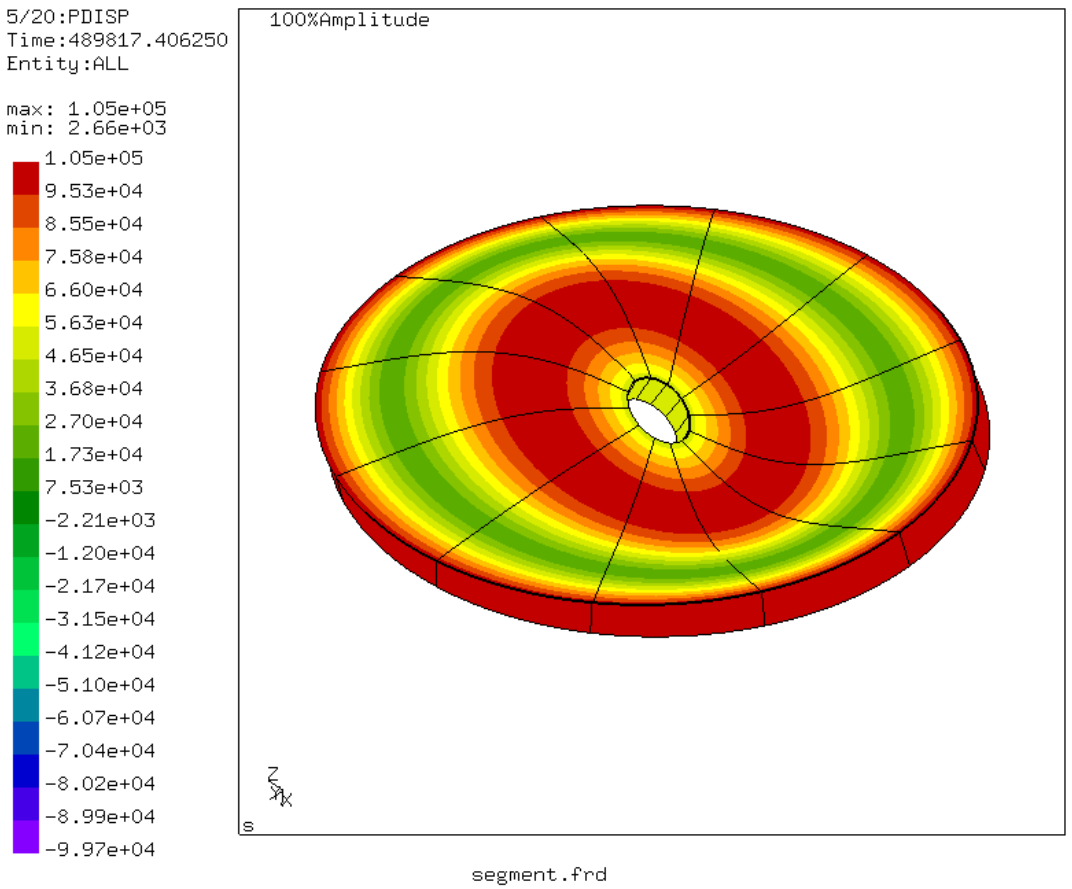


Third bending mode in a cantilever beam

Cyclic Symmetry

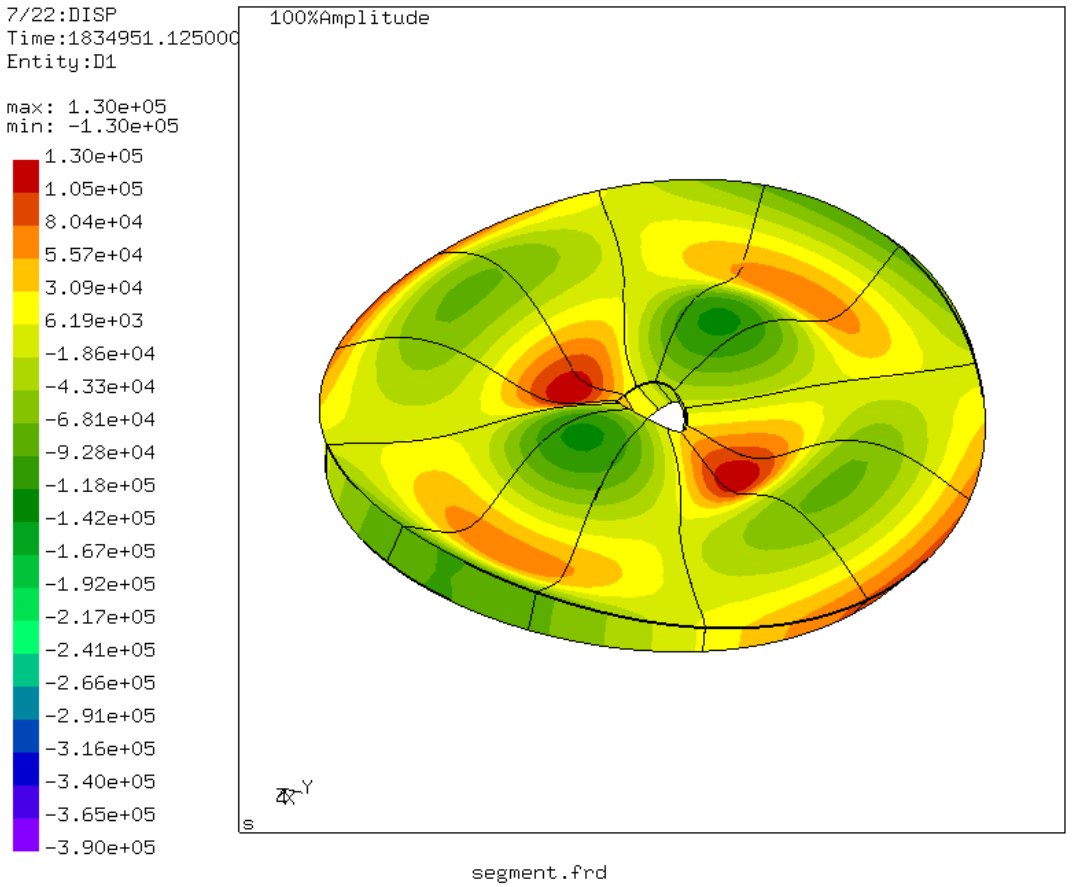
- Propagating modes
- Forward and backward modes
- Calculation of amplitude and phase
- Selection of appropriate nodal diameters

Cyclic Symmetry



Displacement amplitude of a mode with nodal diameter 1

Cyclic Symmetry

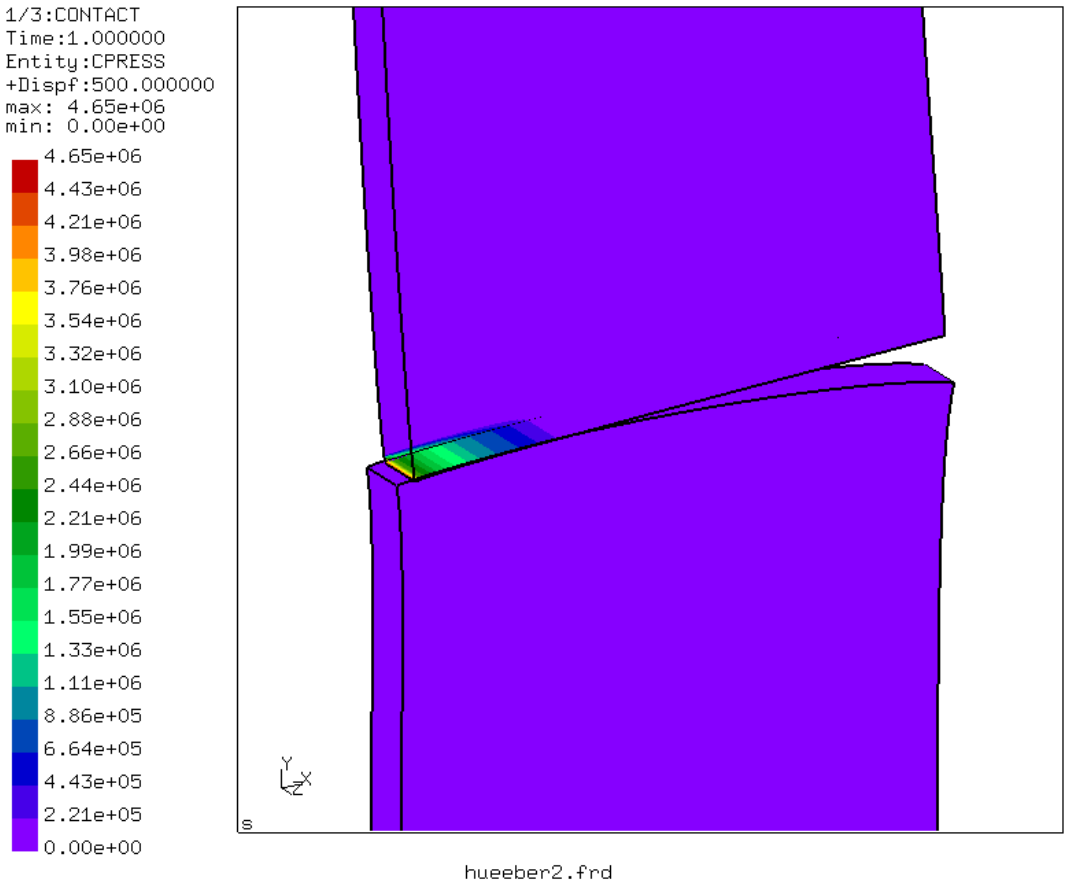


Displacement in x of a mode with nodal diameter 2

Contact

- Penalty contact
  - Node-to-face
  - face-to-face
- Mortar contact
- Contact stresses and relative displacements
- Several pressure-overclosure relationships
- Contact forces

Contact

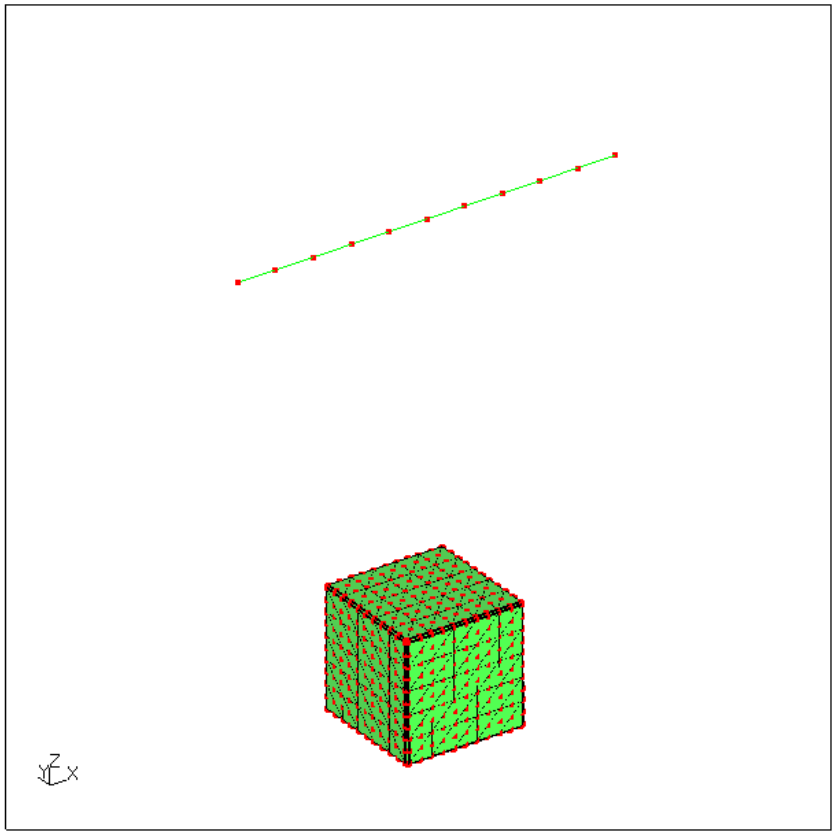


Contact pressure in between two bodies

Thermal analysis

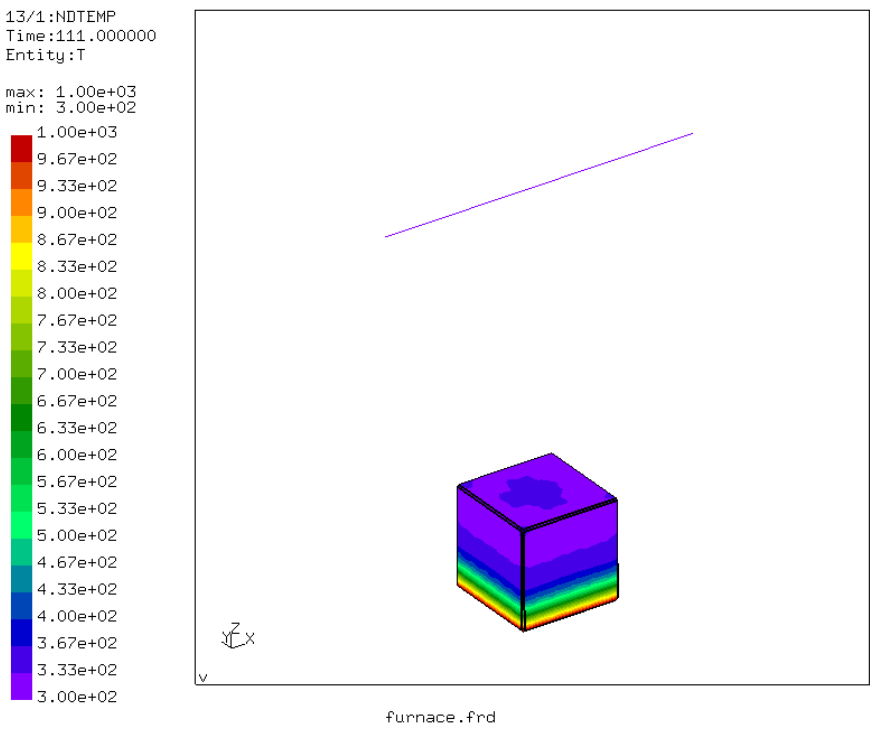
- Conduction, convection and radiation
- Convection with fluid networks
- Cavity radiation
- Gap conductance
- Can be coupled with structural calculations: thermo-mechanical analyses
- Can be coupled with fluid networks: aero-thermal analyses

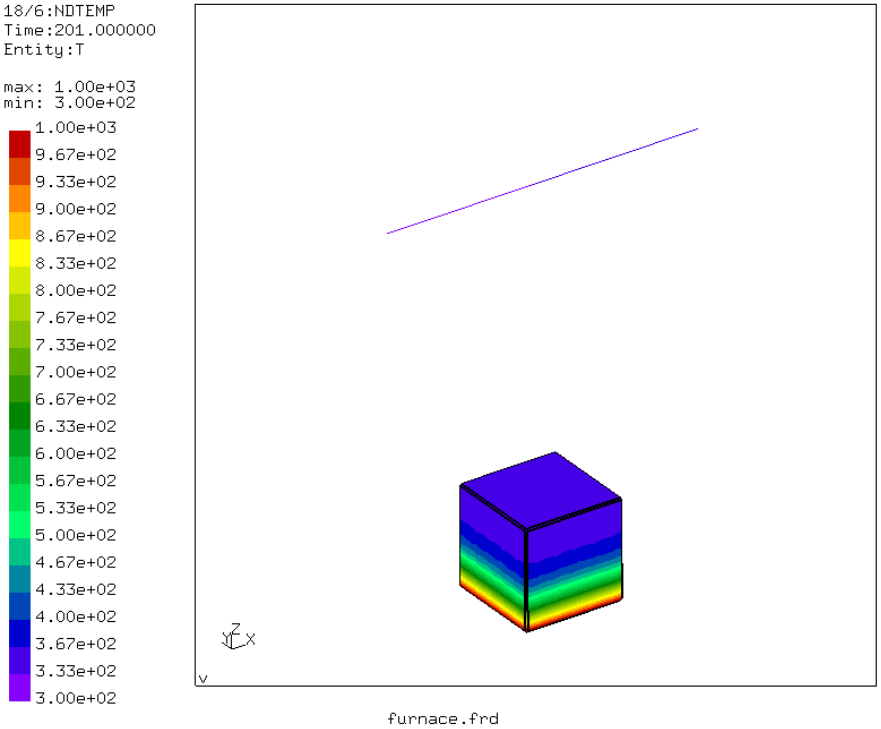
Thermal analysis



Mesh of furnace (radiation and convection with a thermal network)

Thermal analysis



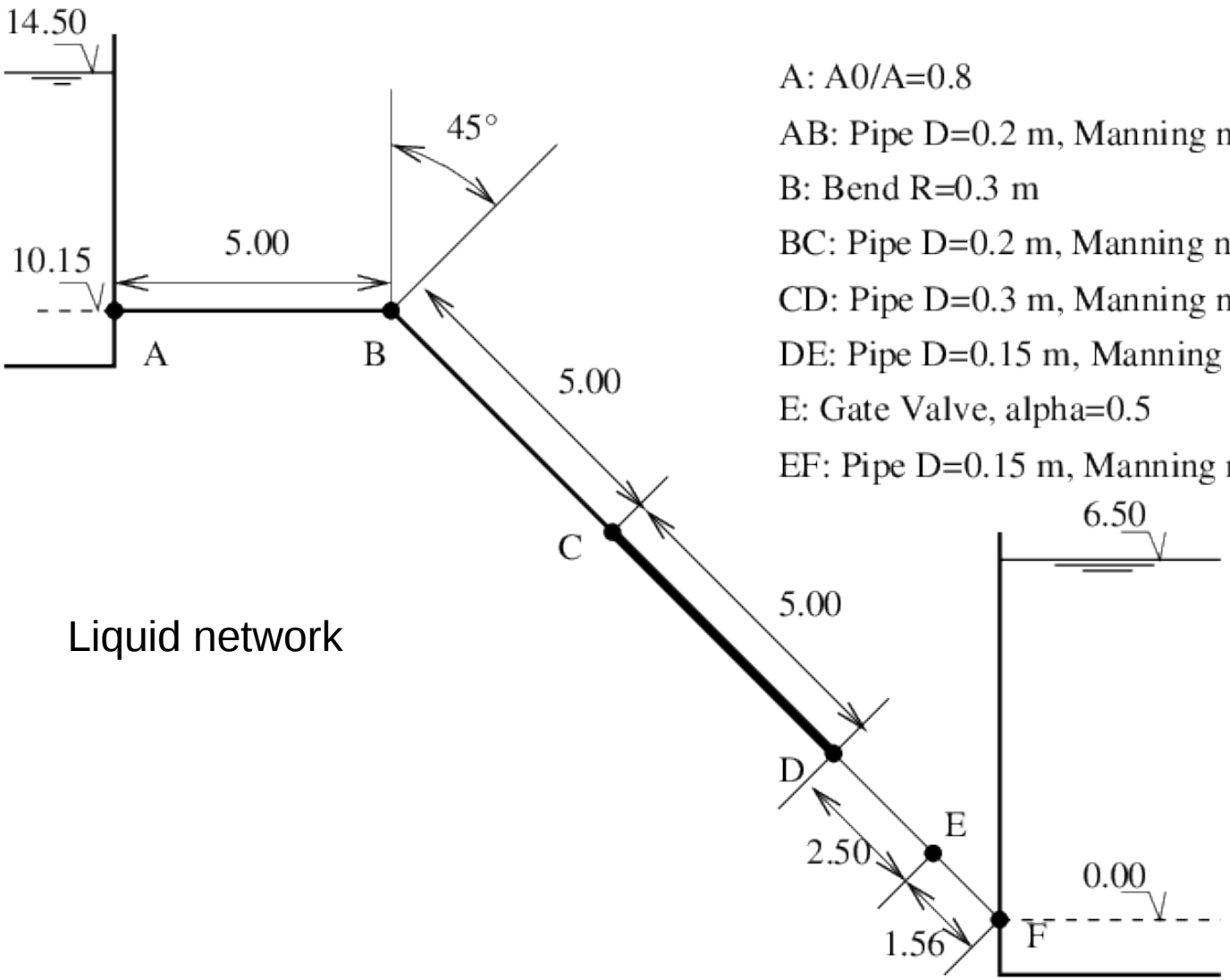


Transient temperature calculation of a furnace
(bottom plate at 1000 °C)

Fluid networks

- Compressible (gas) and incompressible (water) networks
- Unknowns: temperature, pressure and mass flow (incompressible), total temperature, total pressure and mass flow (compressible)
- Many network elements available:
  - Pipe, valve, contraction… (incompressible)
  - Gas pipe, orifice, seals, vortex, labyrinth….

Fluid networks



A: A0/A=0.8

AB: Pipe D=0.2 m, Manning n=0.015

B: Bend R=0.3 m

BC: Pipe D=0.2 m, Manning n=0.015

CD: Pipe D=0.3 m, Manning n=0.015

DE: Pipe D=0.15 m, Manning n=0.015

E: Gate Valve, alpha=0.5

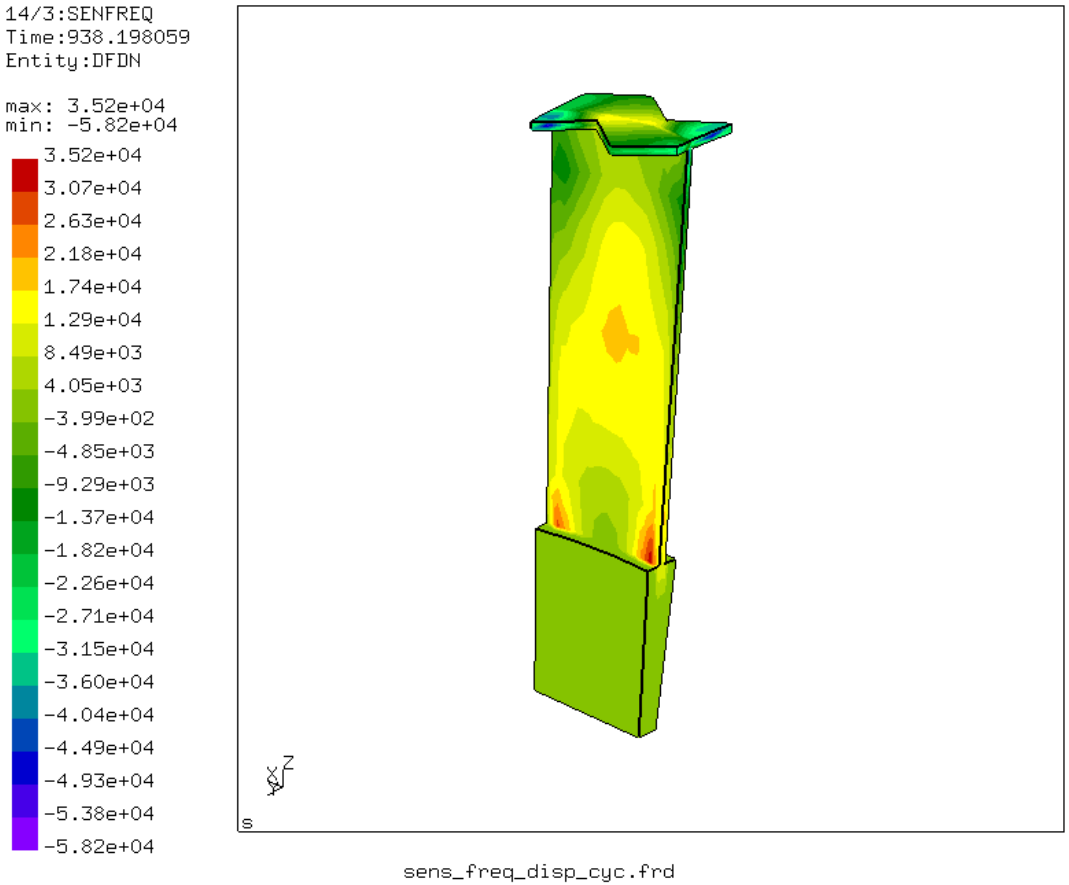
EF: Pipe D=0.15 m, Manning n=0.015

Liquid network

Sensitivity Analysis

- Several objective functions (mass, internal energy, von Mises stress, displacements, thickness, frequencies, Green functions)
- Several design variables (displacements, material orientations)
- Adjoint implementation (takes marginally longer than a usual static or frequency calculation)
- Can be used for optimization and stochastics

Sensitivity Analysis

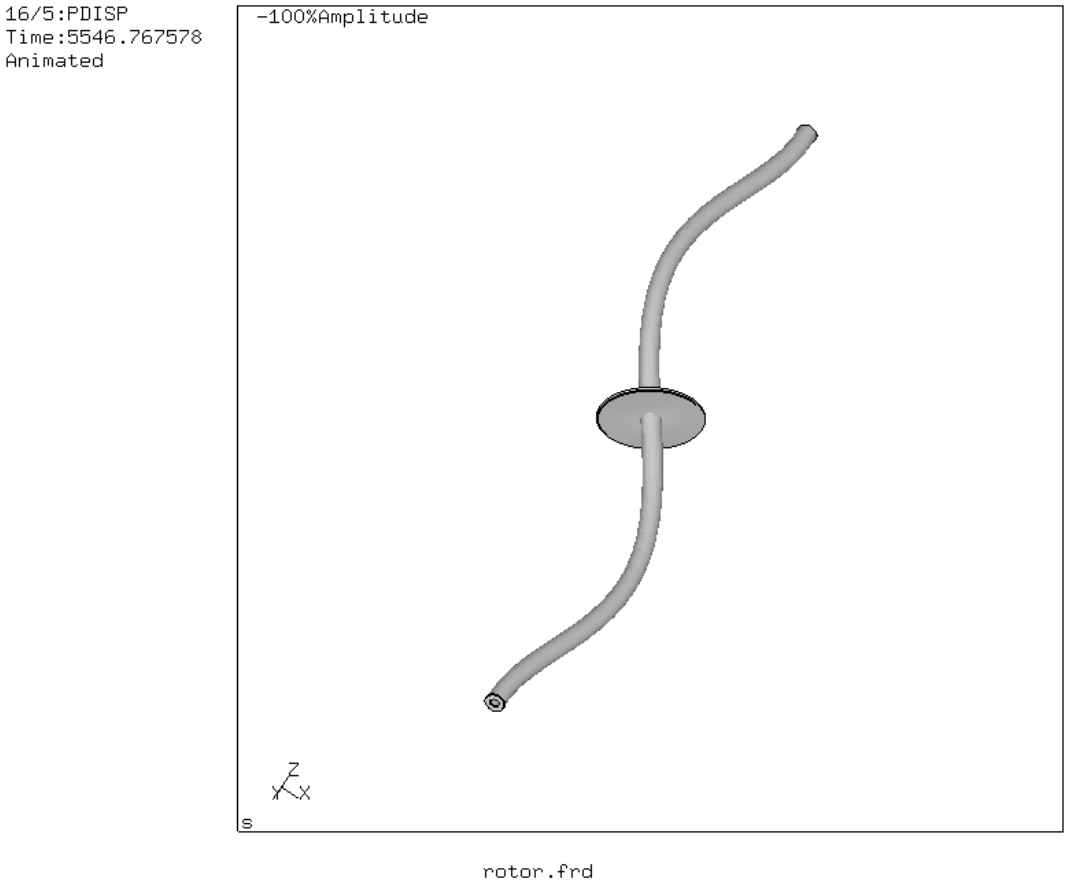


Sensitivity of the first torsional mode for a nodal diameter 1

Rotor Dynamics

- Calculation of eigenmodes taking Coriolis into account
- Solution is calculated as a linear combination of the eigenmodes without coriolis
- Eigenvalues are real, eigenmodes are complex (propagating waves)

Rotor Dynamics

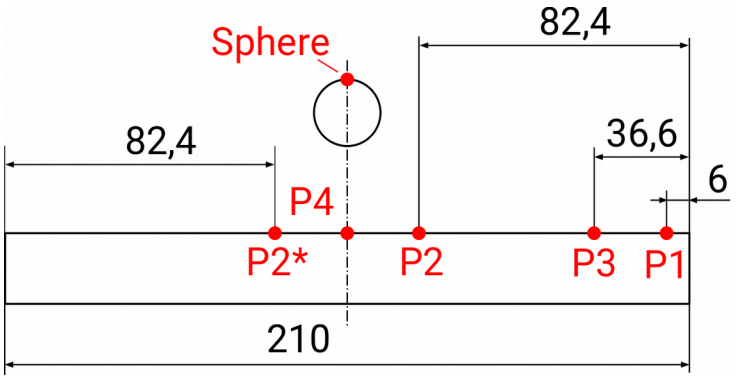


Rotating bending mode in a Laval rotor

Implicit Dynamics

- Integration of equation of motion
- Alpha-Method
- Dynamic contact available
- Some forms of damping allowed
- Extension to explicit dynamics is worked on

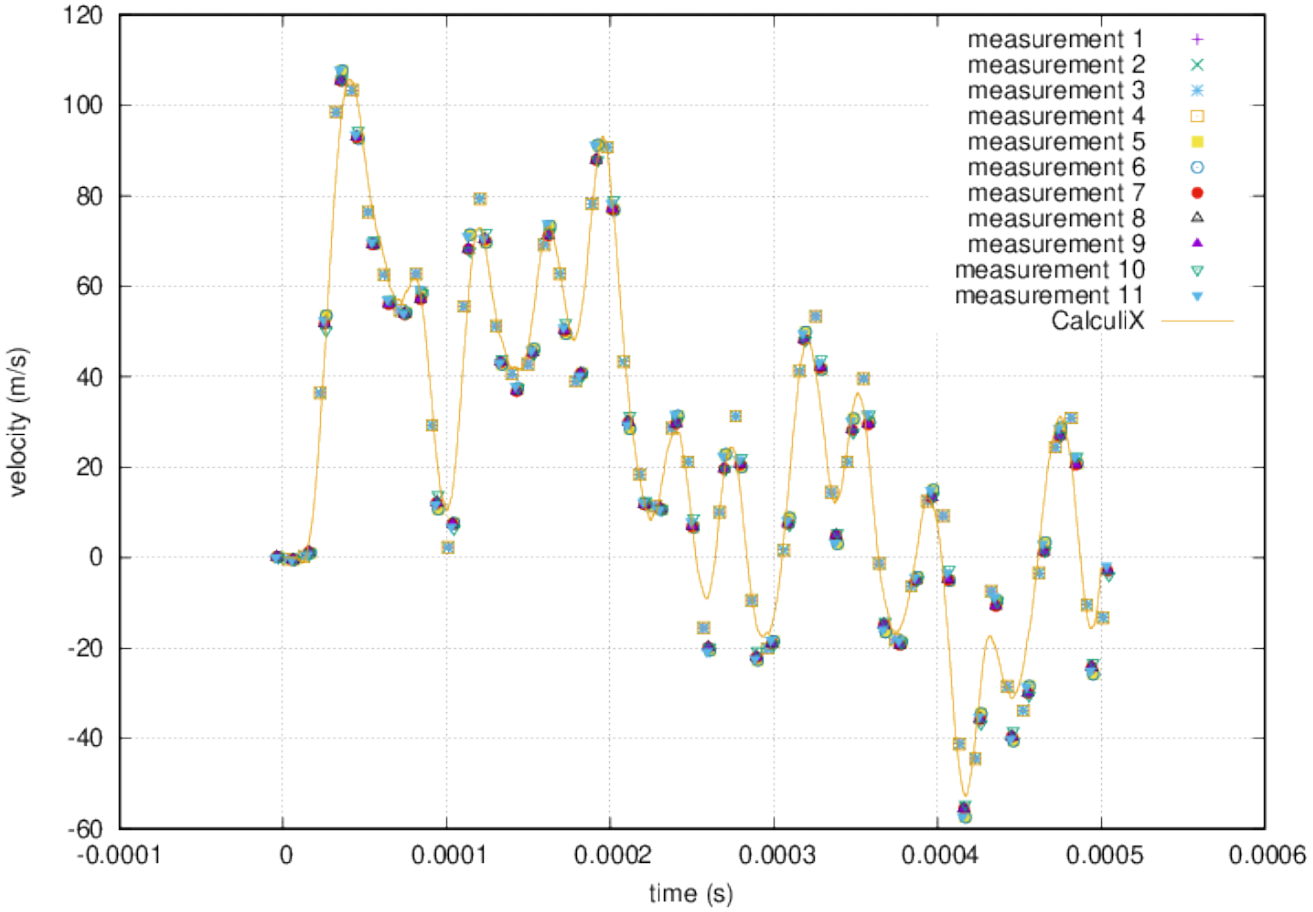
Implicit Dynamics



Measurement Point	Node number in mesh
Sphere	494
P1	6106
P2	4392
P3	6170

Impact of ball on beam

Implicit Dynamics

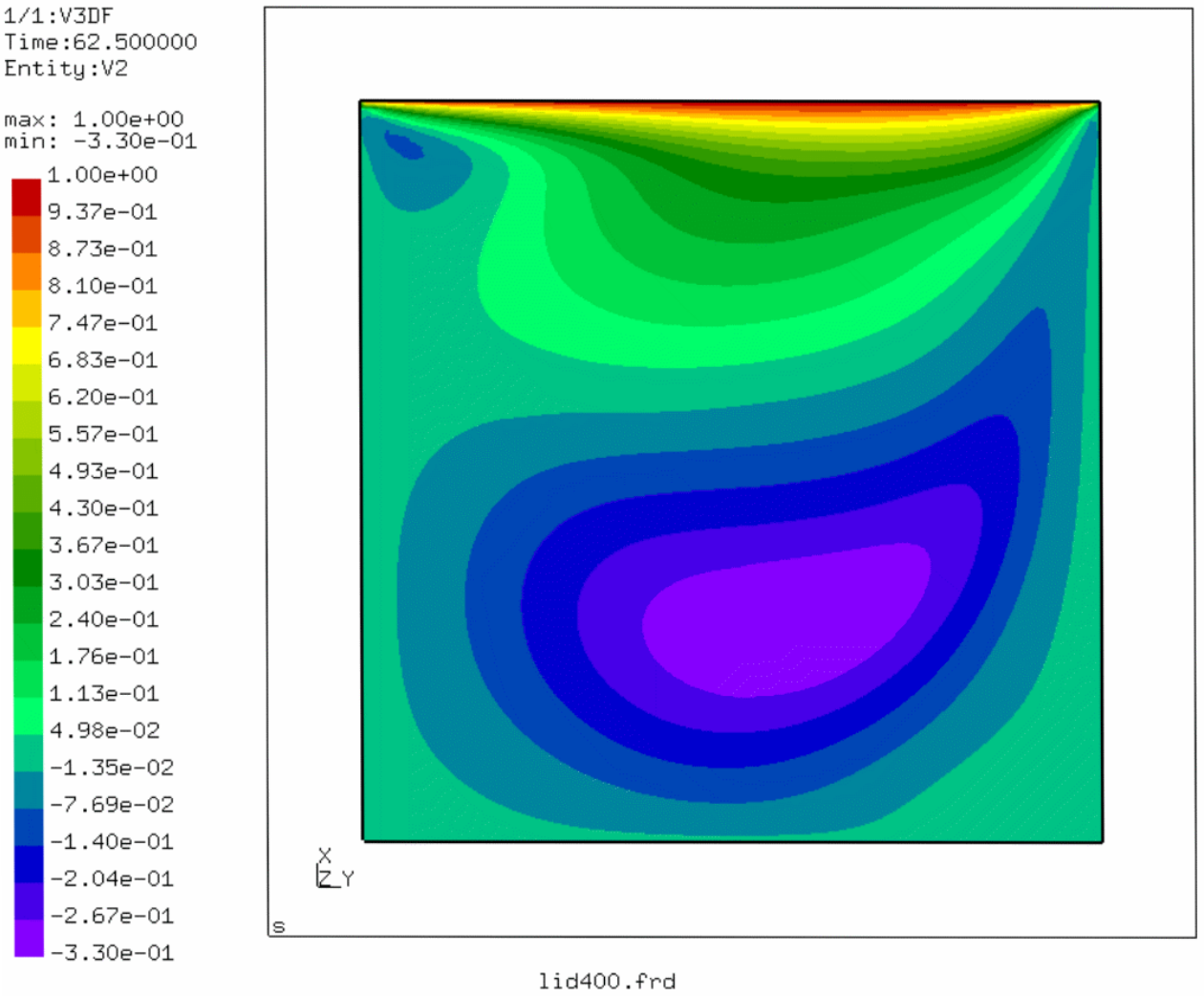


Comparison of numerical values for vertical displacement in P2 with experimental evidence

Fluid Dynamics

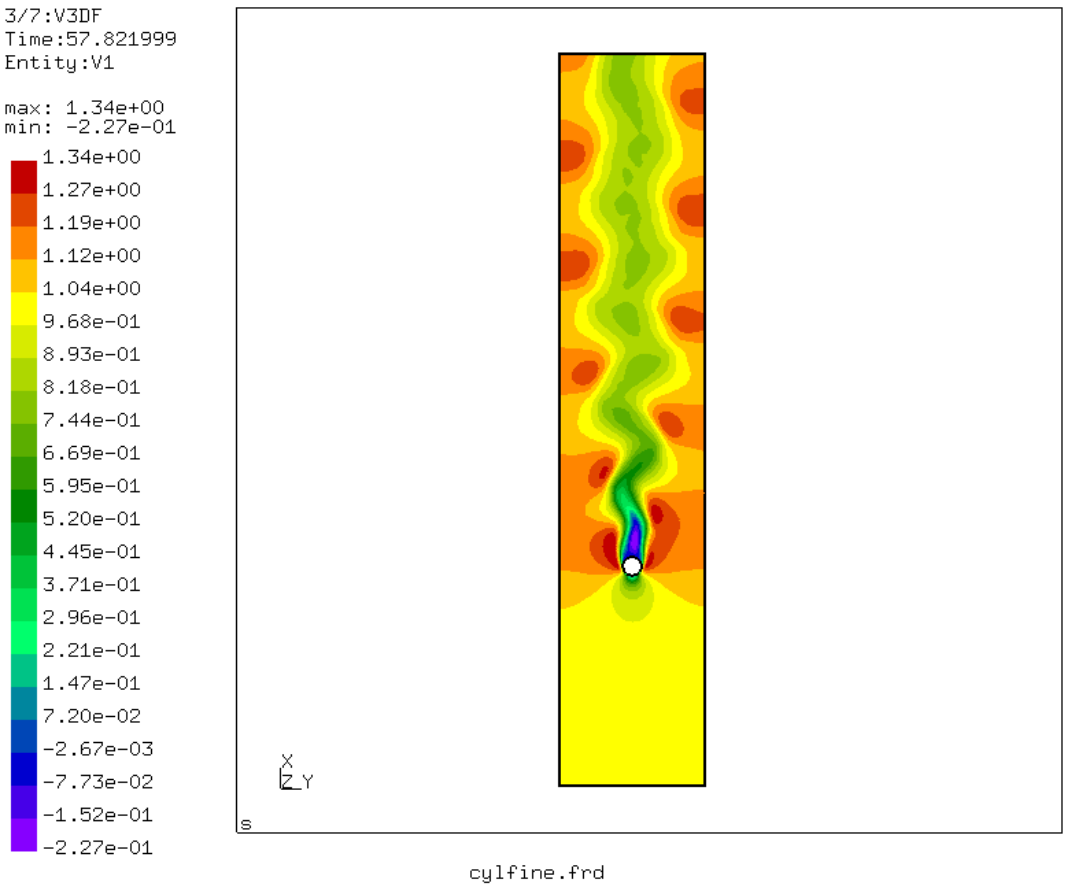
- Finite volume method
- Compressible and incompressible flow
- Unstructured meshes
- Velocity, pressure and temperature as independent variables
- Highly parallelized
- Turbulence models in preparation

Fluid Dynamics



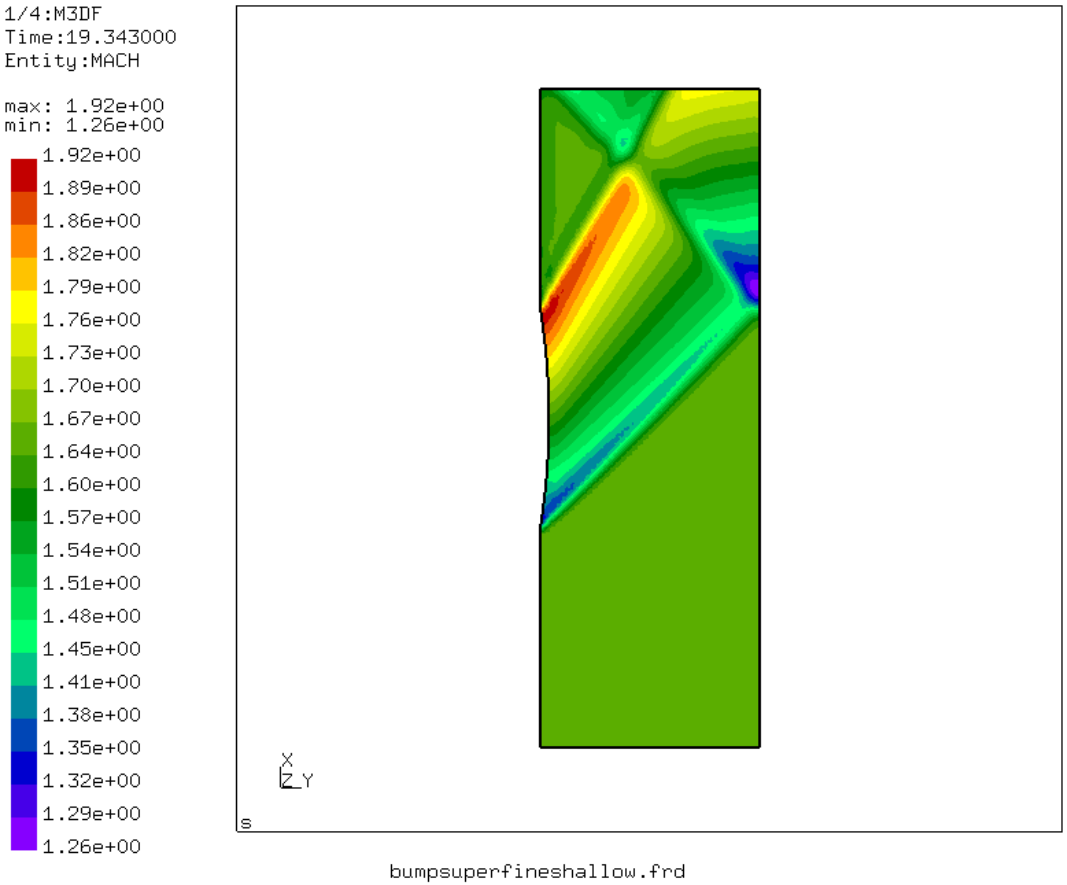
Lid-driven cavity (incompressible flow)

Fluid Dynamics



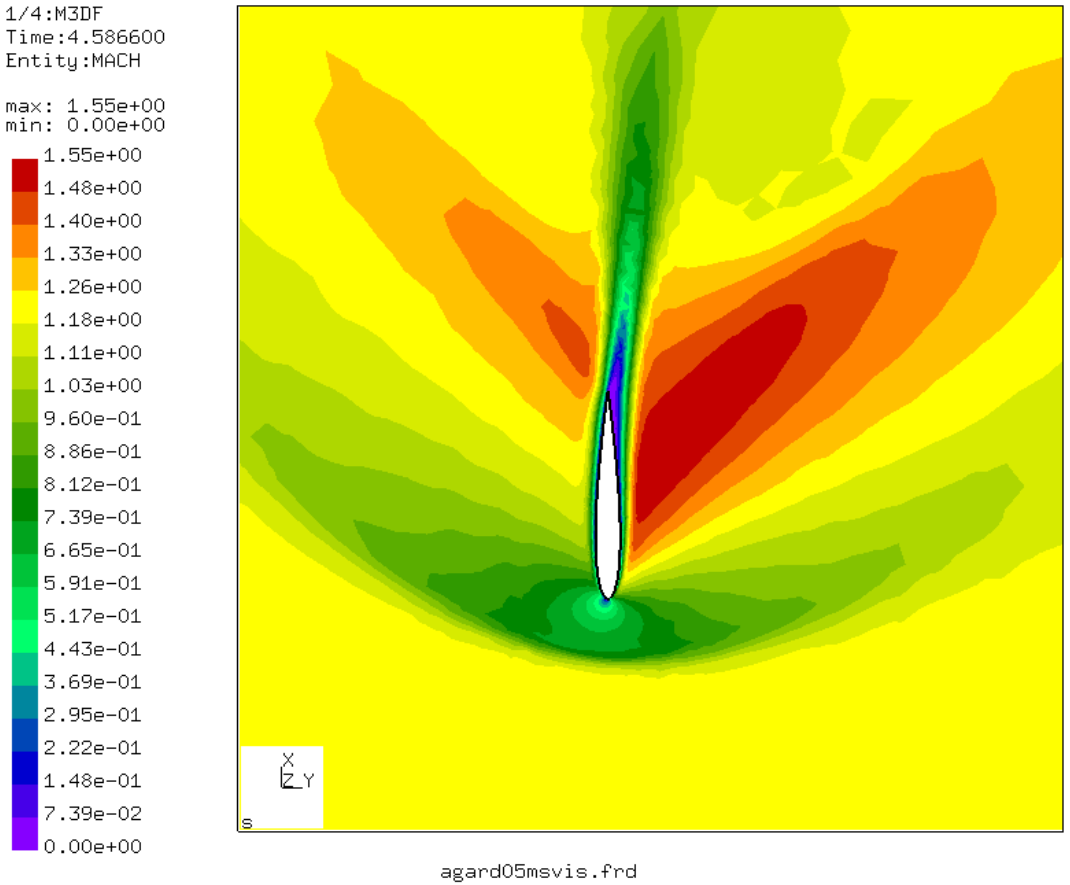
Von Karman vortex street (incompressible flow)

Fluid Dynamics



Hypersonic inviscid compressible flow

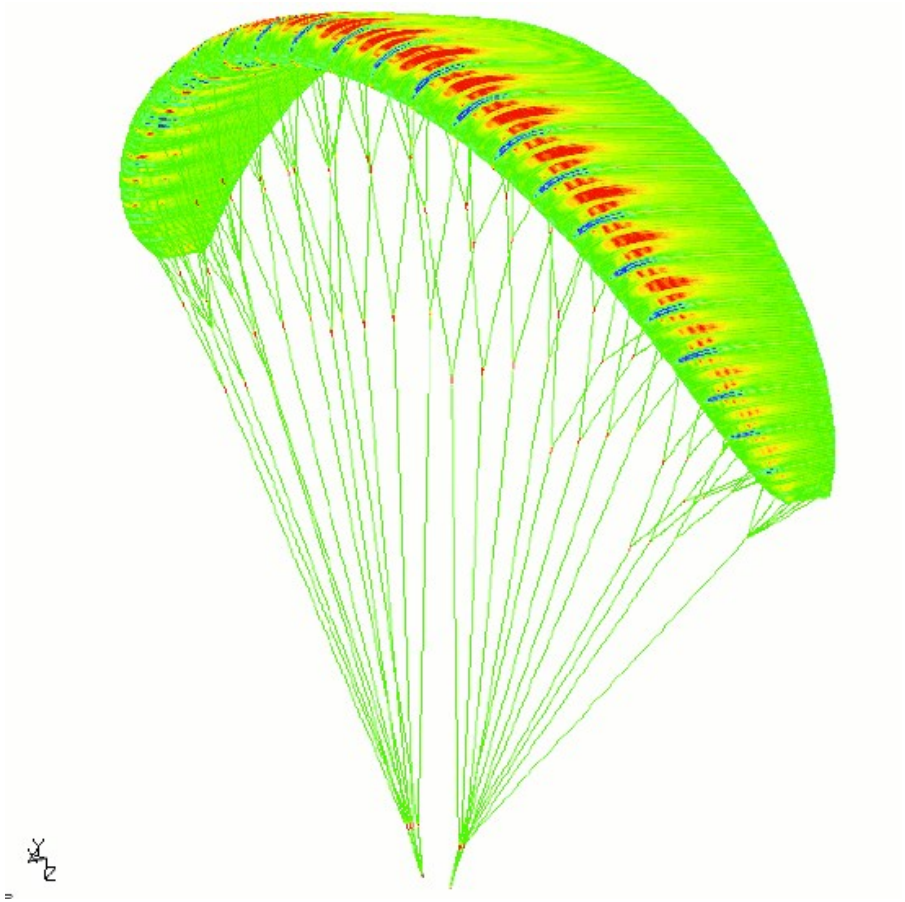
Fluid Dynamics



Hypersonic viscous flow about a NACA profile

Fields of operation

- Fracture mechanics analyses (automatic crack propagaton)
- Production-related part-by-part analyses
- Optimization using vortex morphing
- Statistical analyses



Thank you for your attention!