



The northernmost University of Technology in Scandinavia
World-class research and education



Numerical Calculations of Rotordynamical Coefficients and Forces on a Hydropower Turbine Runner Using OpenFOAM

Second OpenFOAM Workshop
Zagreb 2007-06-08

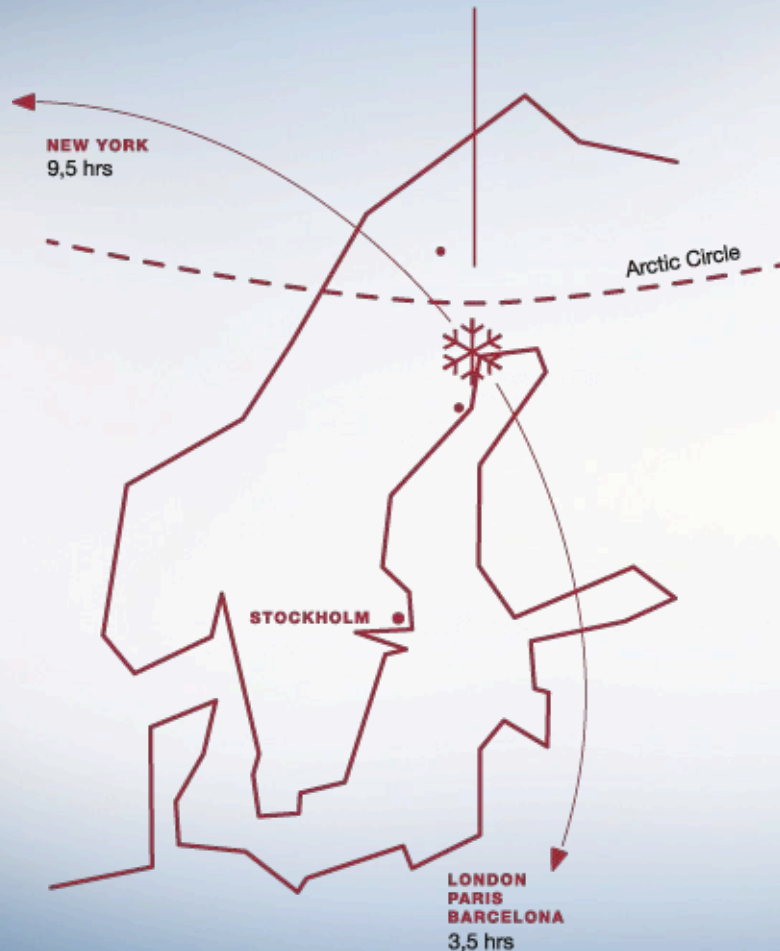
Martin Karlsson

LULEÅ
UNIVERSITY
OF TECHNOLOGY



The northernmost University of Technology in Scandinavia
World-class research and education

Luleå University of Technology



Personnel: 1,600
Students: 13,600
Turnover: EUR 140
million



Outline

- Rotordynamics
- Fluid-rotor Interactions of Hydropower Turbines
- OpenFOAM Implementation of Fluid-rotor Interactions
- Future Rotordynamical Applications of OpenFOAM in Turbomachinery

Rotordynamics

- Torsional, Axial and Lateral Vibrations

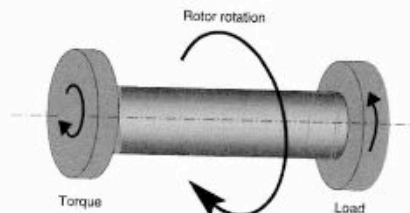


Figure 1.1.1 Main required performance of the rotor: Torque to load through rotational speed.

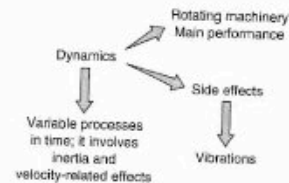


Figure 1.1.2 Energy flow in rotating machine during its operation; vibrations result as side effects of the main dynamic process.

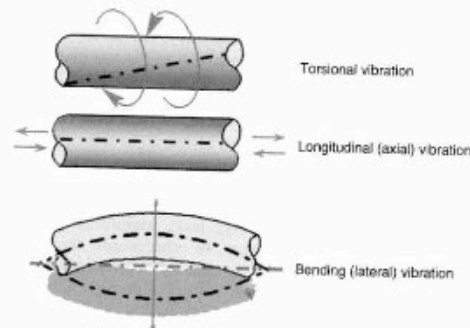
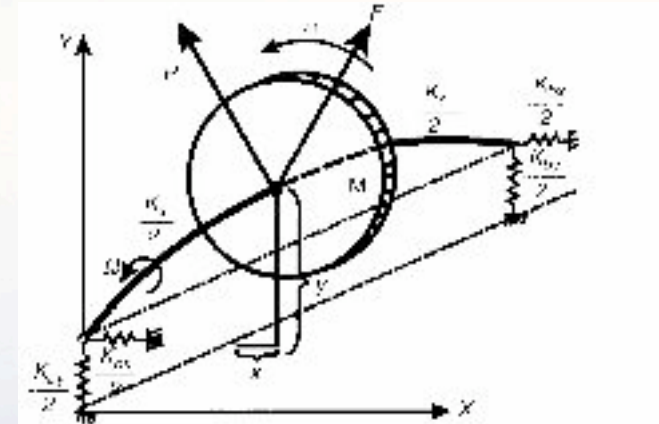
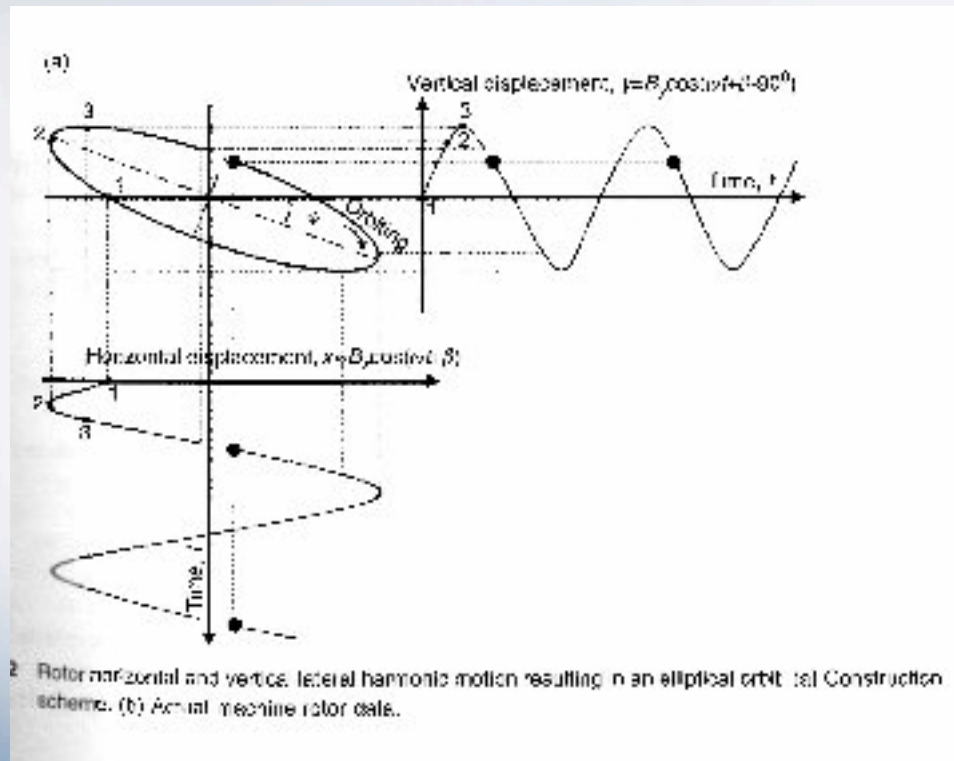


Figure 1.1.3 Rotor vibration modes as side effects of dynamic process of energy transfer from the source to work.

Rotordynamics

- Orbital lateral motion, sign of whirling frequency





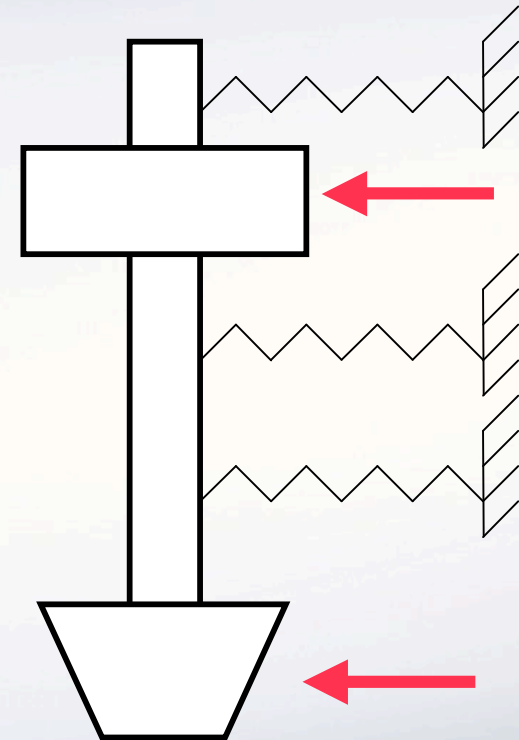
Rotordynamics

- Gyroscopic effect => natural frequencies changes with rotational speed
- Bearings and seals affect stiffness, damping and stability of the rotating system
- Electro-mechanical forces in generators/motors influences the mechanical system
- Turbines and process machines => fluid-rotor interactions

$$\bar{M}\ddot{\vec{x}} + (\bar{C} + \omega\bar{G})\dot{\vec{x}} + \bar{K}\vec{x} = \vec{F}(t)$$

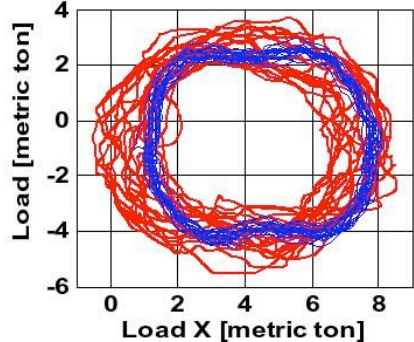
Fluid-rotor interactions of Hydropower Turbine Runners

- Excitations due to blade passage, guide vane wakes and drafttube vortex swirl
- Fluid-rotor forces proportional to rotor acceleration, velocity and displacement (e.g. added mass, damping and stiffness)
- Transient interactions due to change of load, start-up and stops

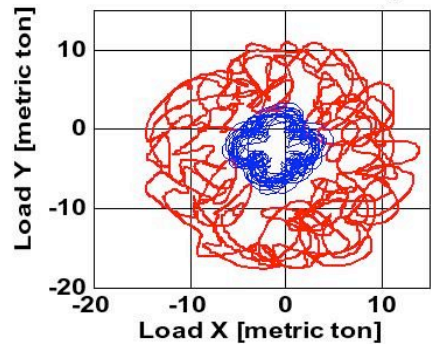


Fluid-rotor interactions of Hydropower Turbine Runners

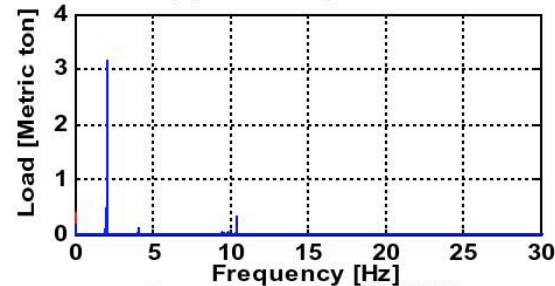
Upper Generator Bearing Load



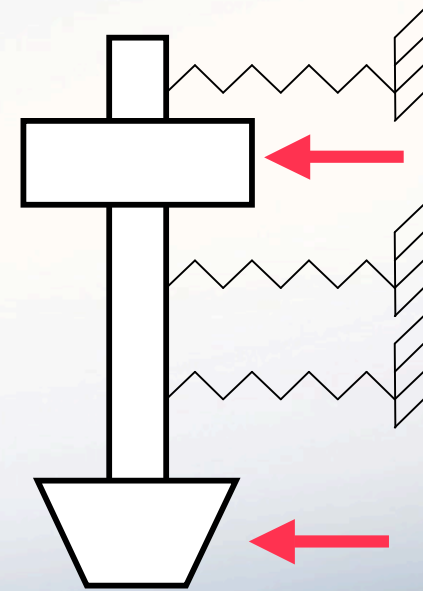
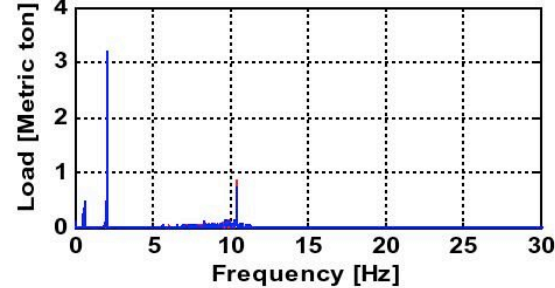
Lower Generator Bearing Load



Upper bearing Load X-Y



Lower Bearing Load X-Y





OpenFOAM Implementation of Fluid-rotor Interactions

- Pre- and post-processing tools (using python) for calculation of rotordynamical forces, moments and coefficients
- URANS solver based on simpleFoam in order to analyse
 - Periodic forces on turbine runner
 - Forces due to prescribed rotational speed
 - Forces due to prescribed rotor whirling (moving mesh)

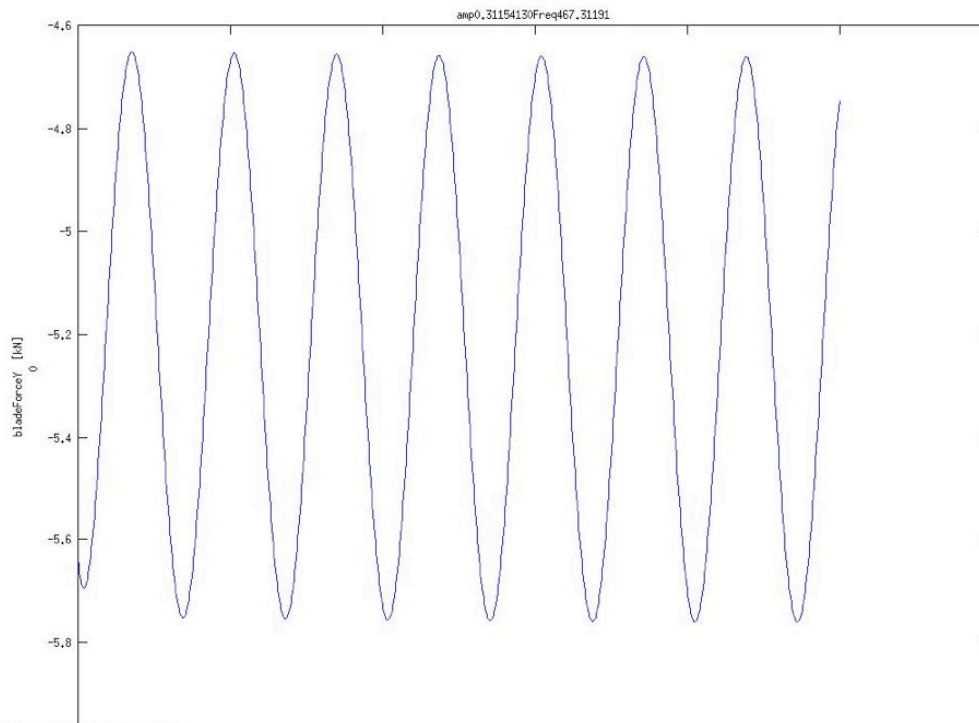


Pre- and post-processing tools

http://www.mt.lth.se/~karmar/simulationMonitor/h010402nohprOF5Acc0.0OscA0.3115413OscF467.31191oscPhase-467.31191Omega-62.3082542964v14Fri/html/index.html

rted Latest Headlines Apple Amazon eBay Yahoo! News OpenFOAM SMD07 Linux rotorDynamics

rotorView::Forces::bladeForceY

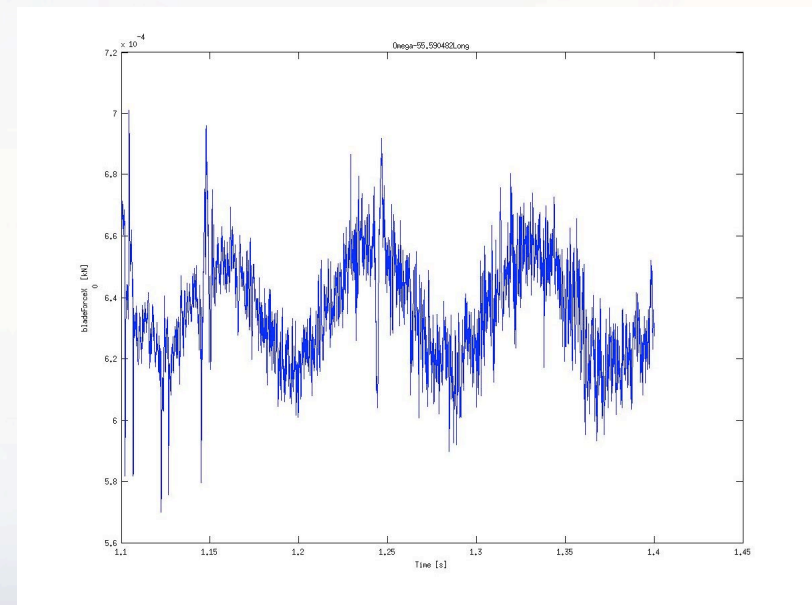
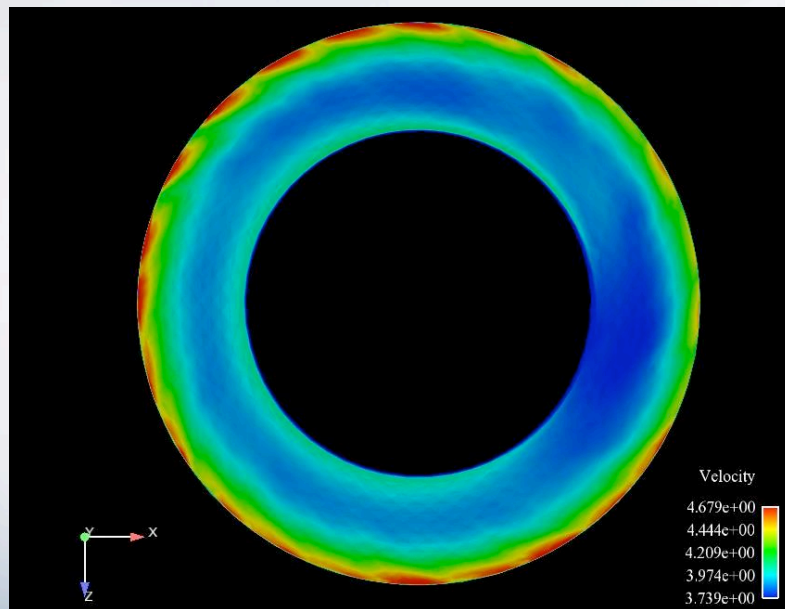


rotorView for OpenFOAM by Martin Karlsson

- Summary of simulation**
conDict,rotProp.transPropturbProtranPropbounPropfVolfvSch
- OpenFOAM Log**
residuals, courant number, CPU-usage, wall-time etc
- Forces**
blade, hub, cone, shaft
- Moments**
blades, hub, cone, shaft
- Displacements**
blades, hub, cone, shaft
- Calculated angle**
blades, hub, cone, shaft
- Calculated power**
blades, hub, cone, shaft
- Visualisation**
geometry, mesh, pressure, velocity
- External Information**
cluster.LoadGungnercluster.LoadSwegridOpenFOAMe



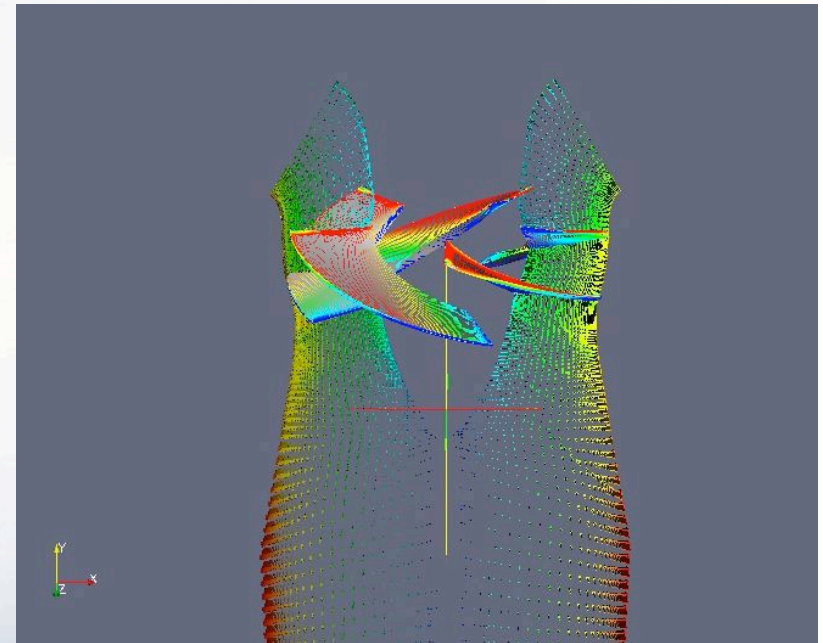
Periodic forces on a hydropower runner





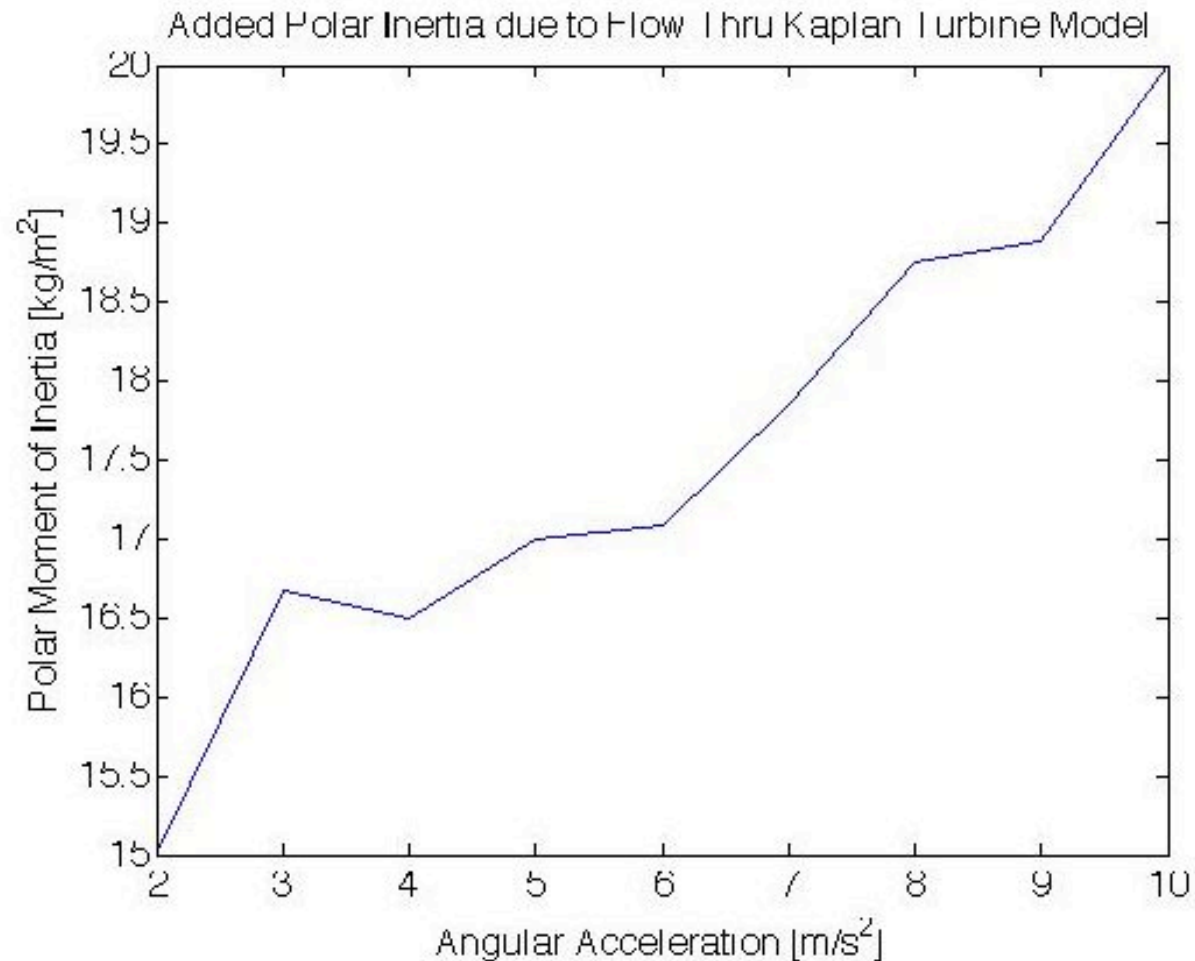
Problems to obtain unsteady results

- Outlet boundary conditions
 - Draft tube
- Turbulence model
- Discretization of equations
- Others?





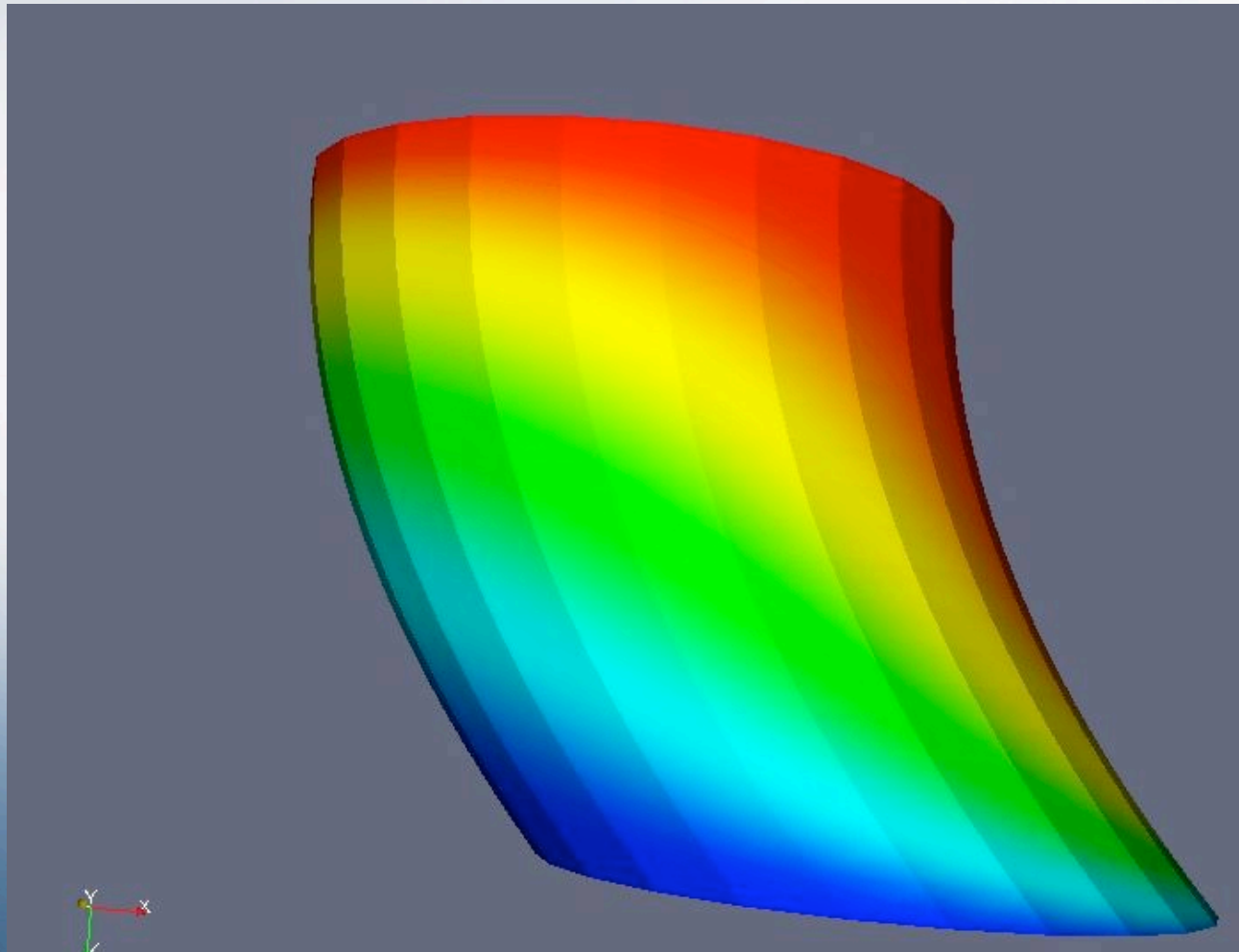
Prescribed rotational speed to obtain added polar inertia





The northernmost University of Technology in Scandinavia
World-class research and education


Prescribed rotor whirling to obtain rotordynamical coefficients





Future Rotordynamical Applications of OpenFOAM in Turbomachinery

- Fluid film bearings- and seals
- Electro-mechanical interactions
- Process machines (multi-phase flow)
- Coupled simulations for transient analysis



What can we do together?

Martin Karlsson

Division of Computer Aided Design

Phone: +46 705 641 911

E-mail: karmar@ltu.se

**Great ideas
grow better
below zero!**

LULEÅ
UNIVERSITY
OF TECHNOLOGY

