SIM&TEC
Simulación y Tecnología
Simulation and Technology

On the modeling of industrial processes

Eduardo N. Dvorkin

Industry

Processes	Products
• Set-ups • Tooling design	• Mechanical properties • Geometrical tolerances • Integrity requirements

Technological windows

The Methodology

Physical Problem

↓

Mathematical Model
(PDE + BC + IC)

↓

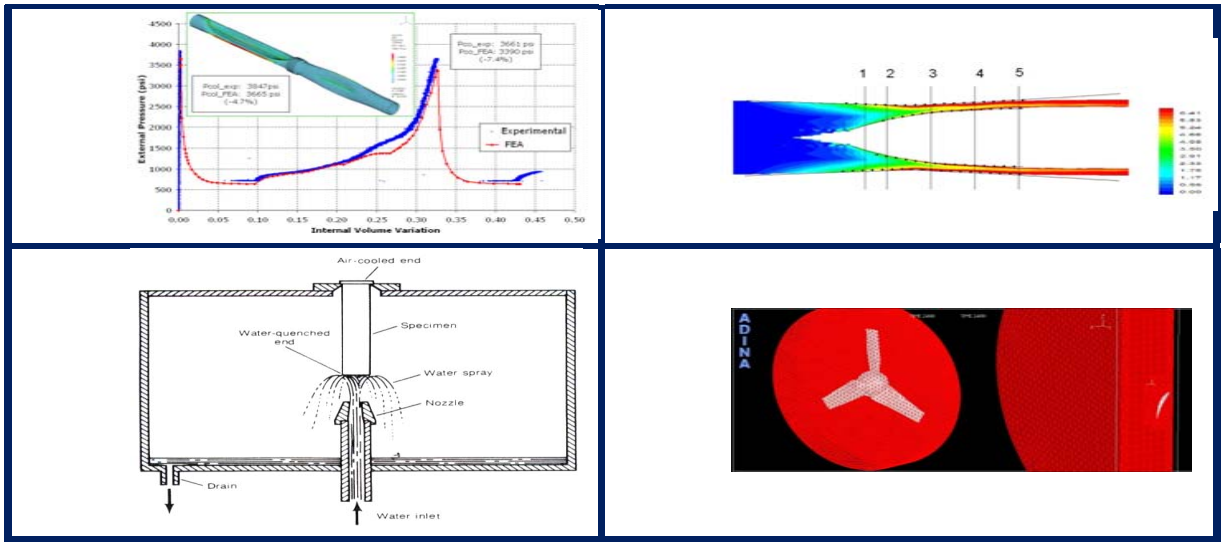
Numerical Model

↓

Results verification
and validation

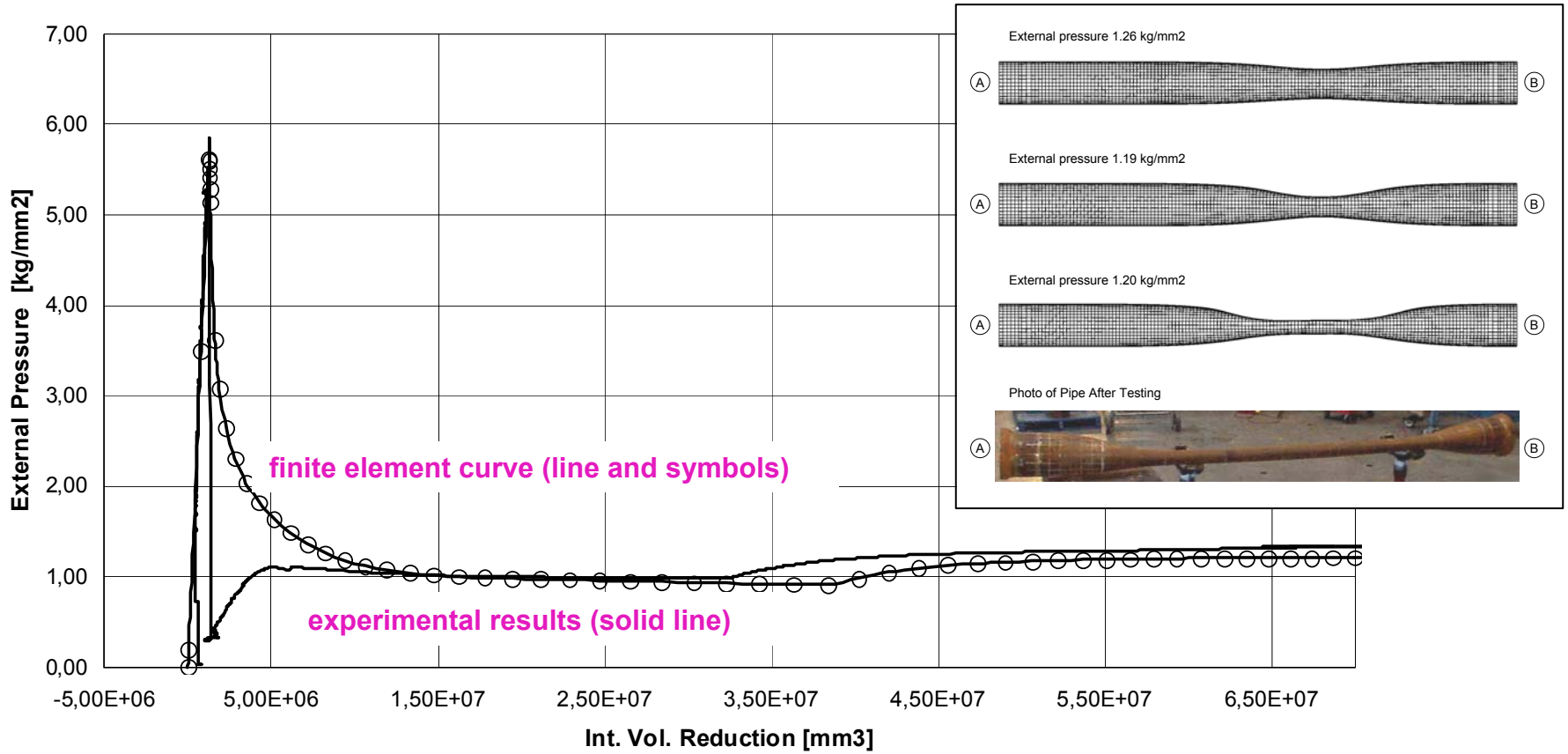
Engineering Applications

1. Structural analysis
2. Metal forming
3. Heat transfer and metallurgical processes
4. Computational fluid mechanics



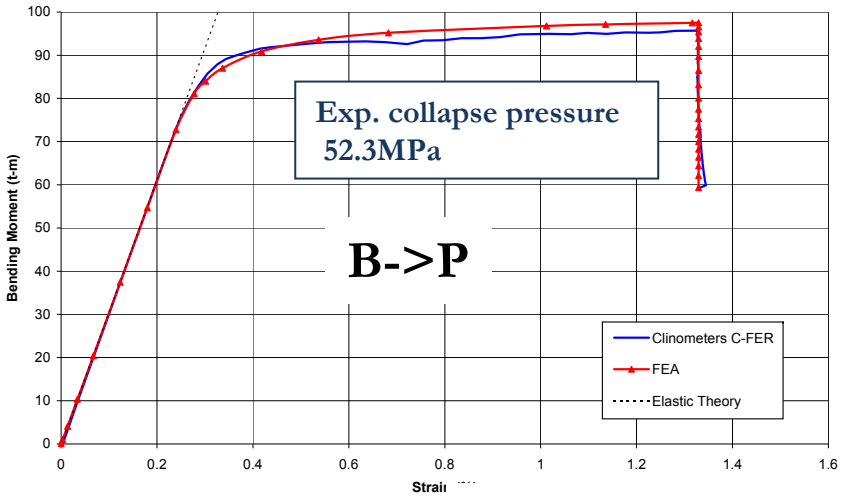
Structural Analysis

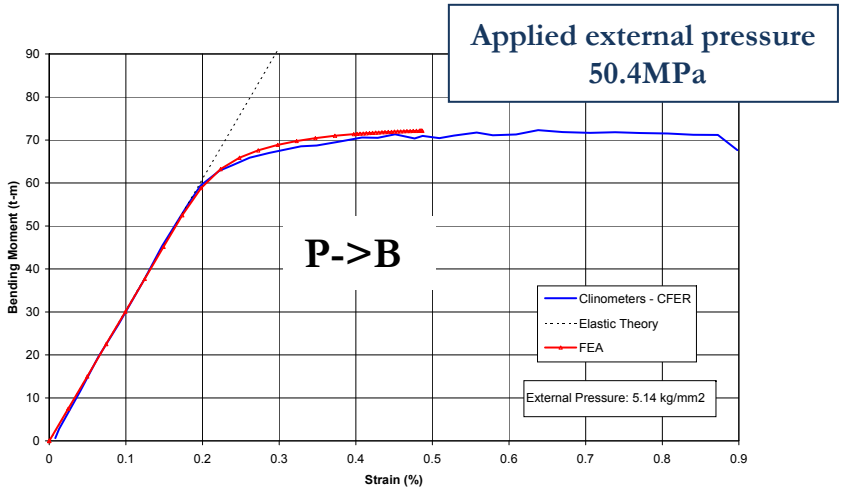
Collapse and post-collapse of pipelines (external pressure only)



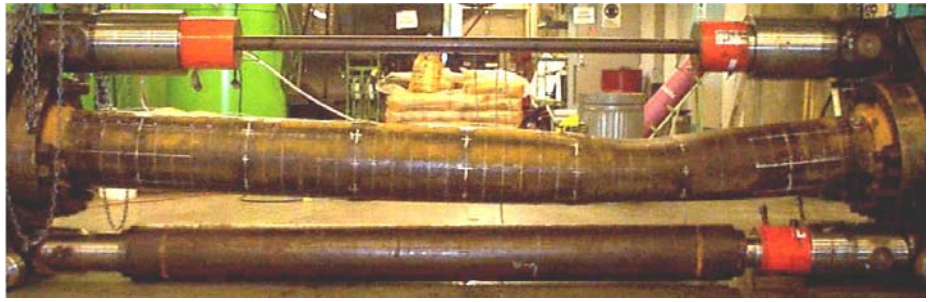
Structural Analysis

Collapse and post-collapse of pipelines (pressure-bend tests)



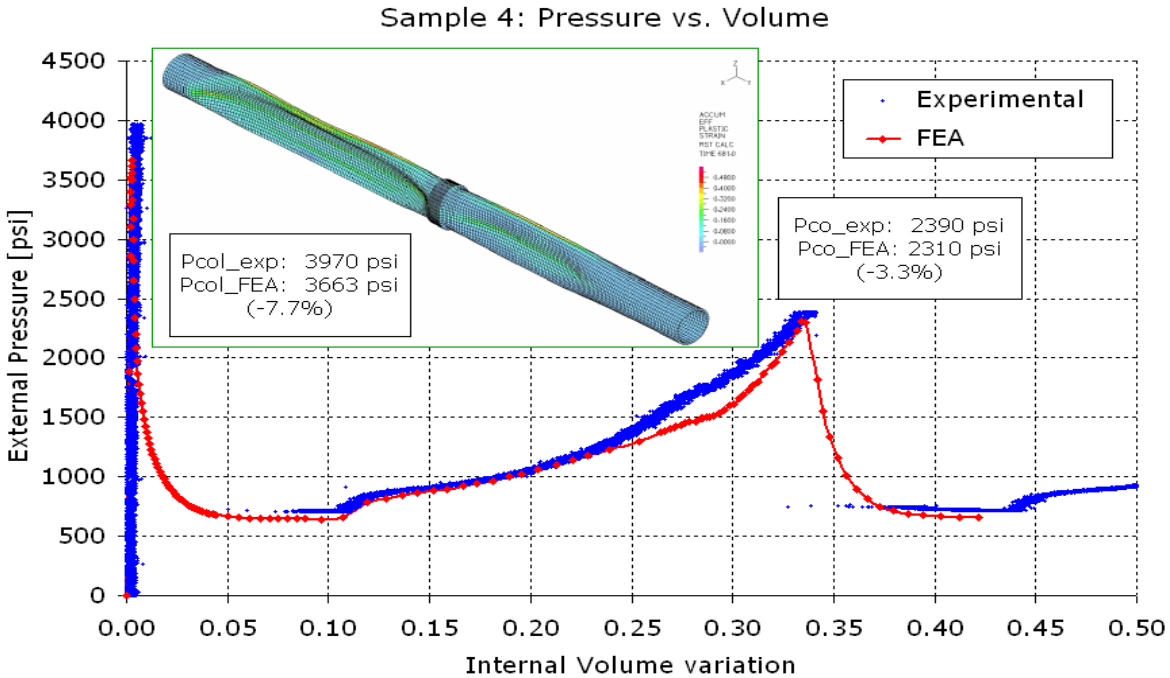


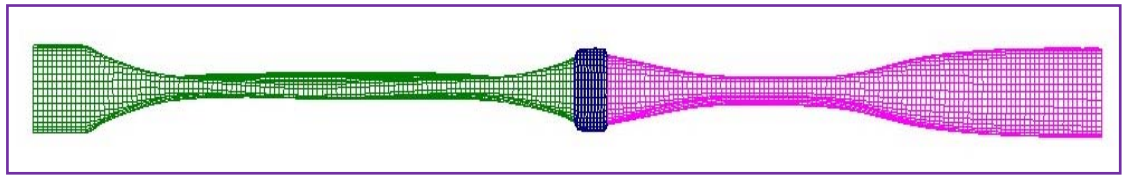
Bending moment vs. Average bending strain



Structural Analysis

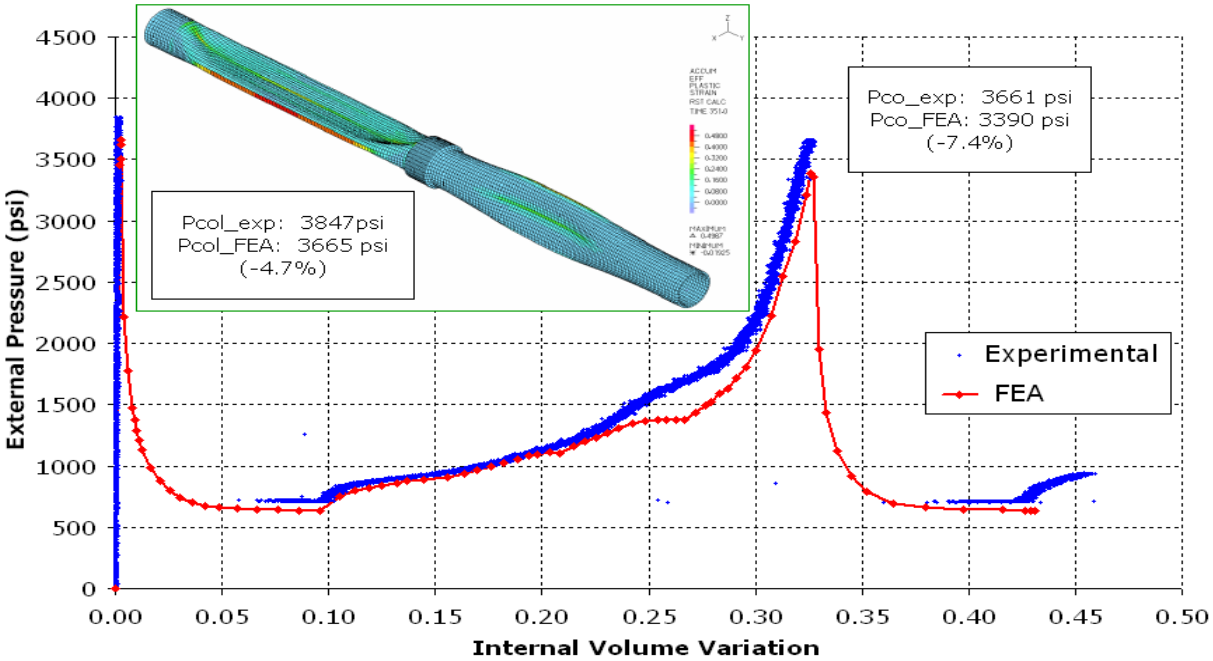
Collapse and post-collapse of pipelines

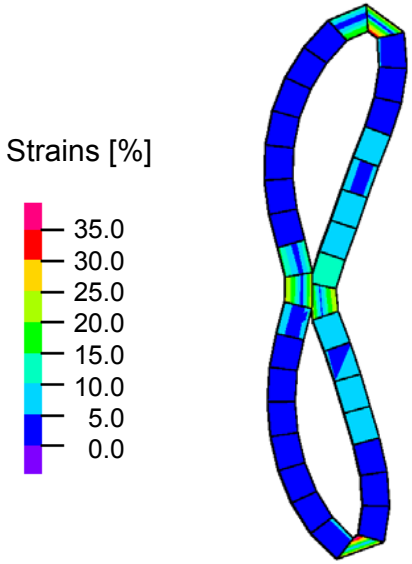


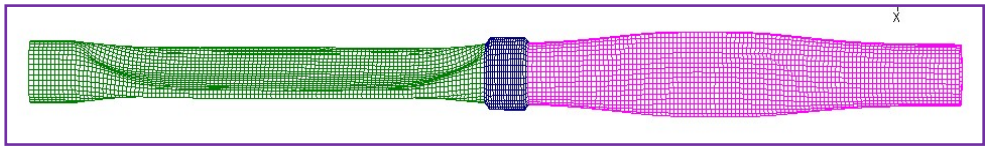


Structural Analysis

Collapse and post-collapse of pipelines

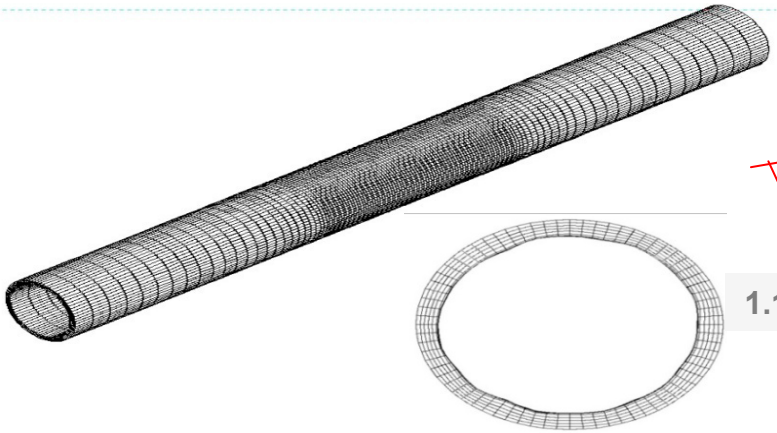


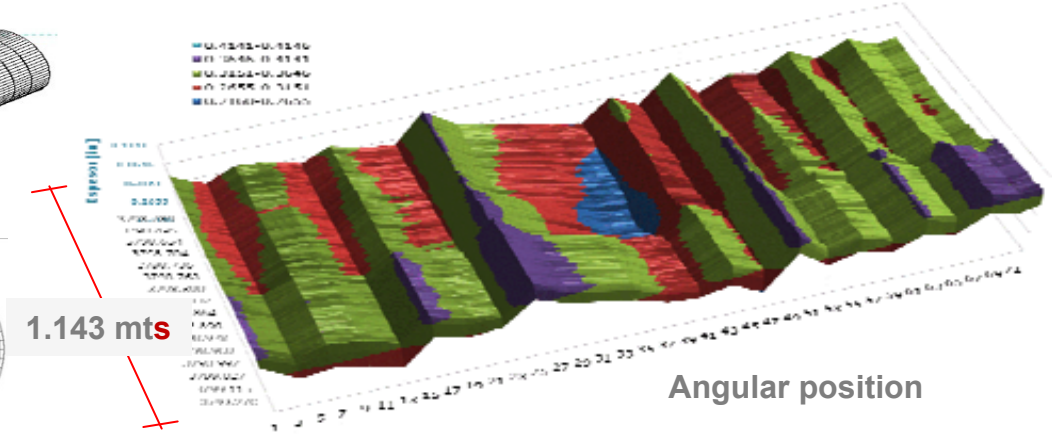


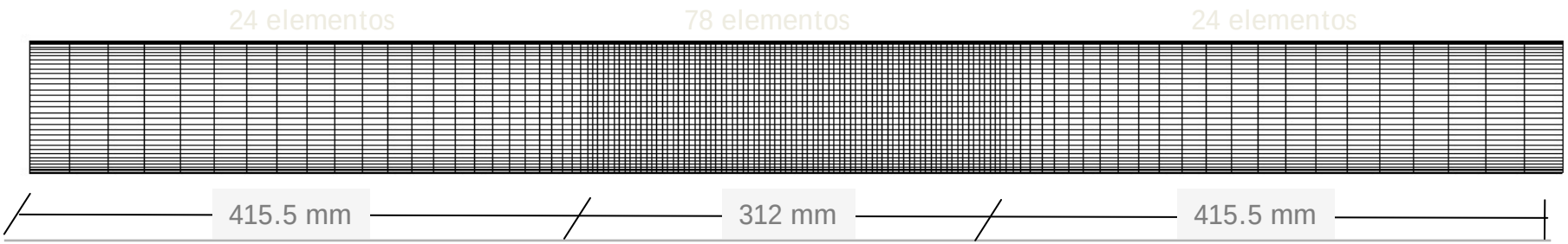


Structural Analysis

Collapse of corroded pipes (Repsol-Bolivia)

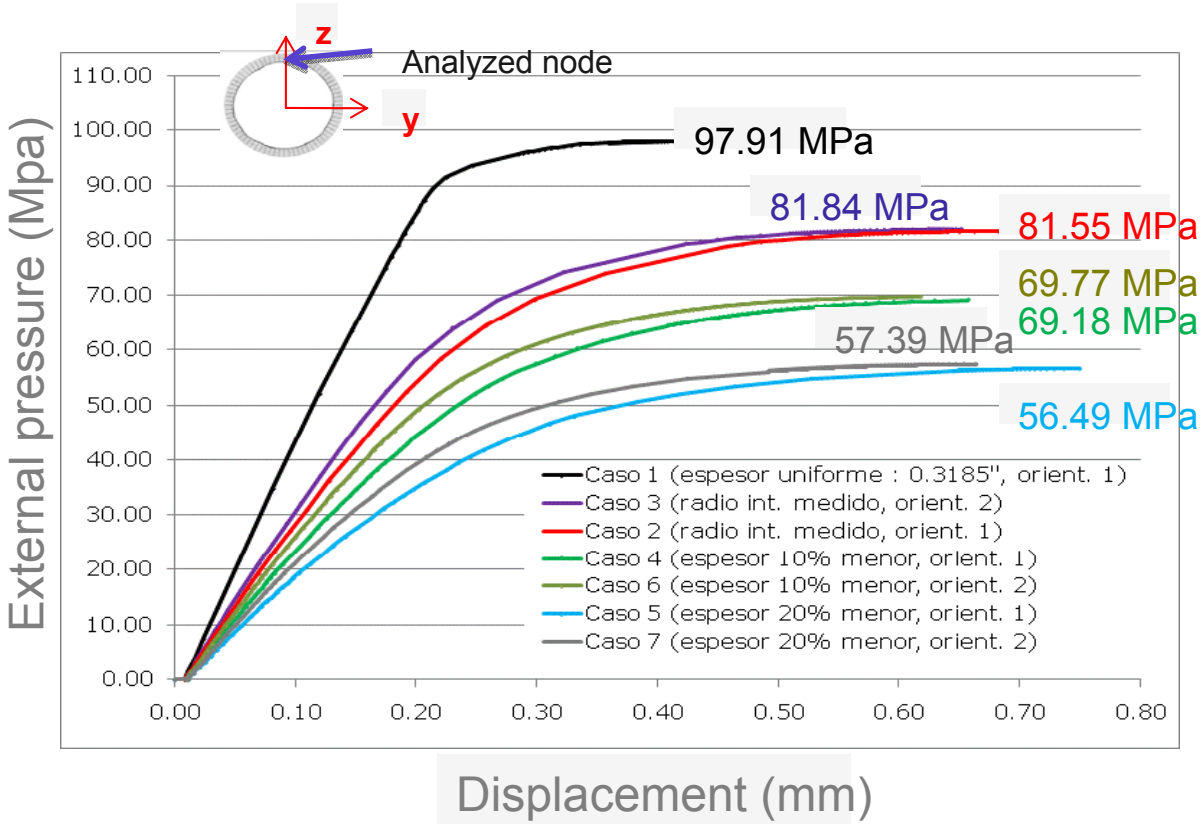






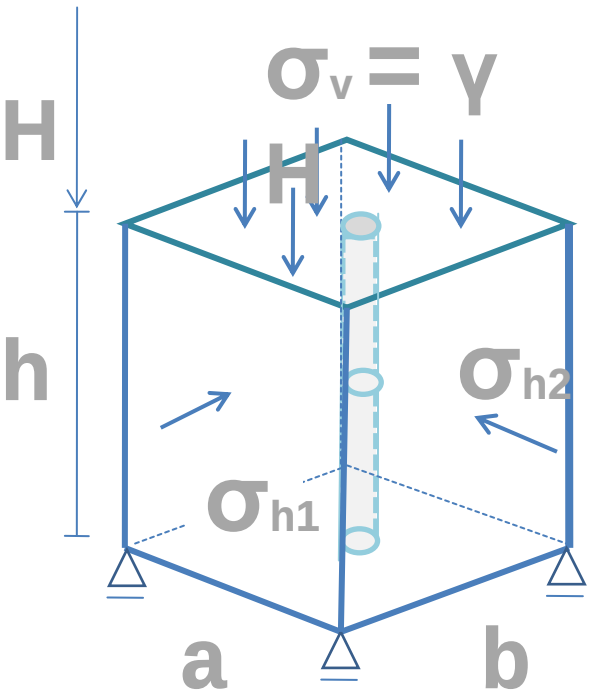
Structural Analysis

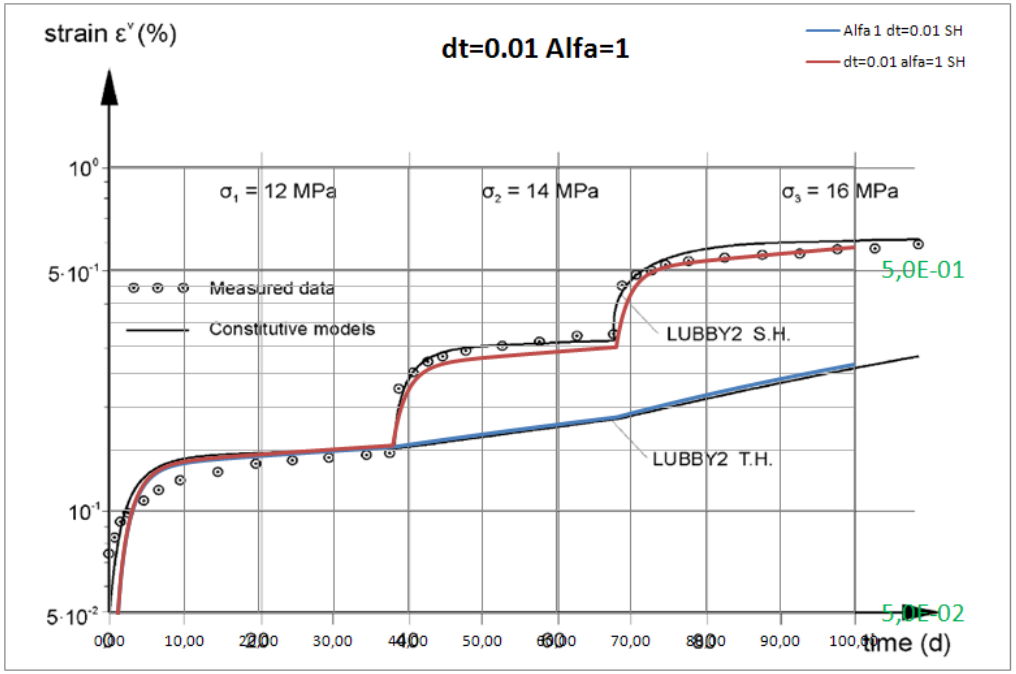
Collapse of corroded pipes (Repsol-Bolivia)



Structural Analysis

Salt domes





[1] Lux, K. H., & Heusermann, S. (1983). Creep tests on rock salt with changing load as a basis for the verification of theoretical material laws. Toronto: Proceedings of 6th Symposium on Salt,vol. I, 1983. p. 417–35.

Structural Analysis Creep parameters

MATERIAL PARAMETERS 1

Young Modulus=31000 MPa
Poisson's Modulus=0.25

m =-3.27 E-01 MPa^{-1}
k1=-2.54 E-01 MPa^{-1}
k2=-2.67 E-01 MPa^{-1}
Etam*=1.21E+08 Mpa d
Gk*=1.88E+05 MPa
Etak*=4.98E+05 Mpa d

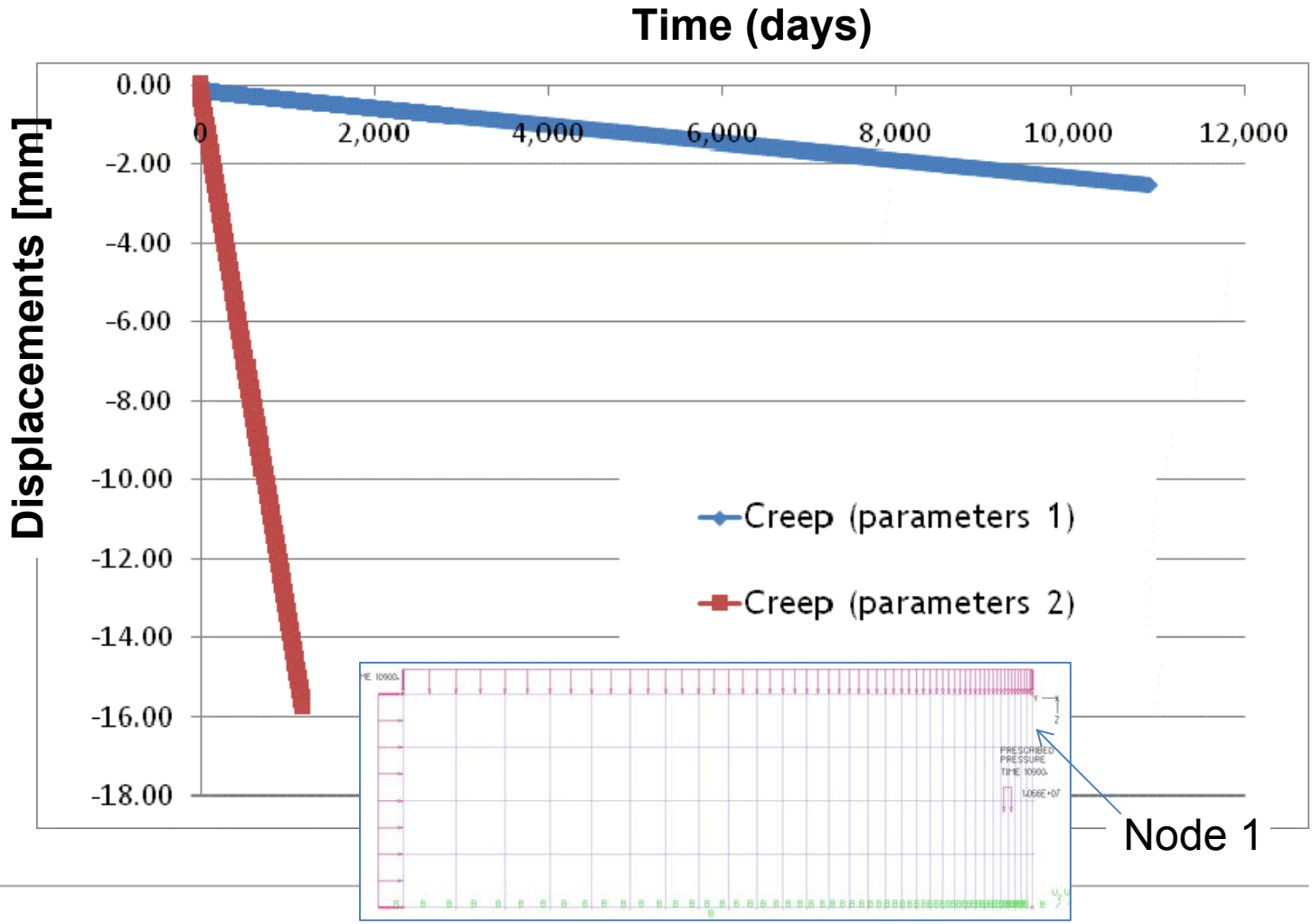
Creep Hardening: Strain Hardening

MATERIAL PARAMETERS 2

Young Modulus=31000 MPa
Poisson's Modulus=0.25

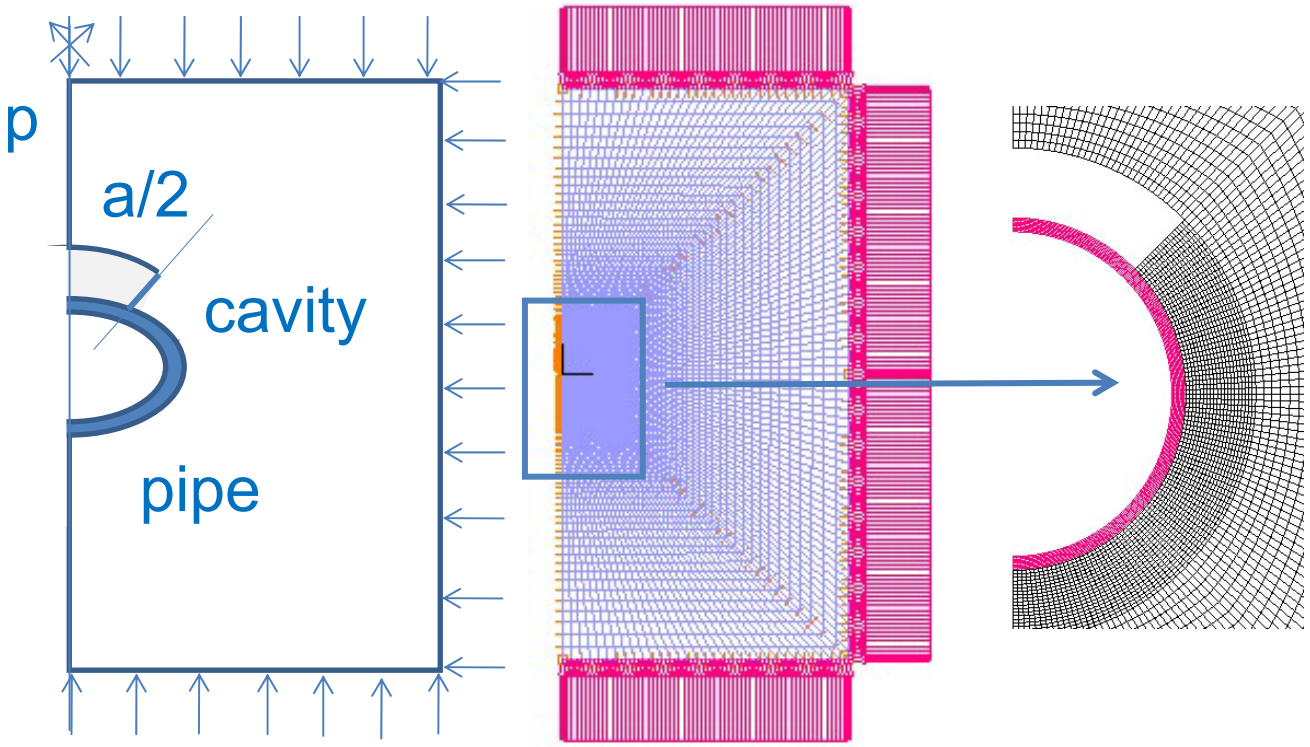
m =-2.54 E-01 MPa^{-1}
K1=-1.22 E-01 MPa^{-1}
k2=-1.61 E-01 MPa^{-1}
Etam*=1.21E+06 Mpa d
Gk*=8.0E+03 MPa
Etak*=1.67E+04 MPa d

Creep Hardening: Strain Hardening



Structural Analysis

Design of casings through salt domes

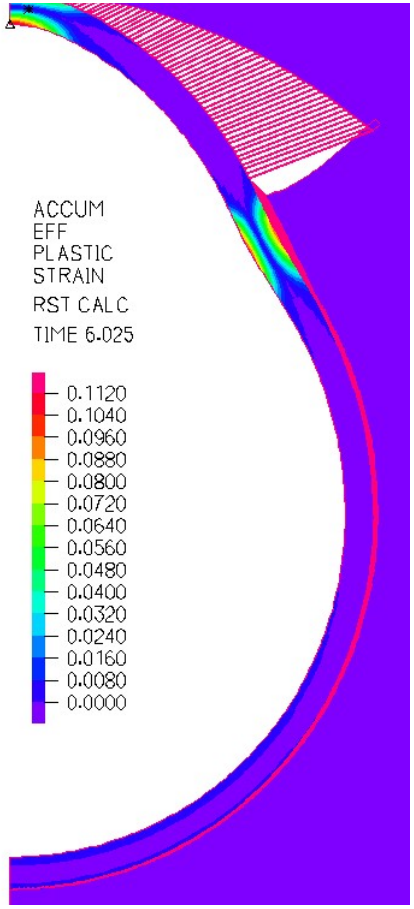


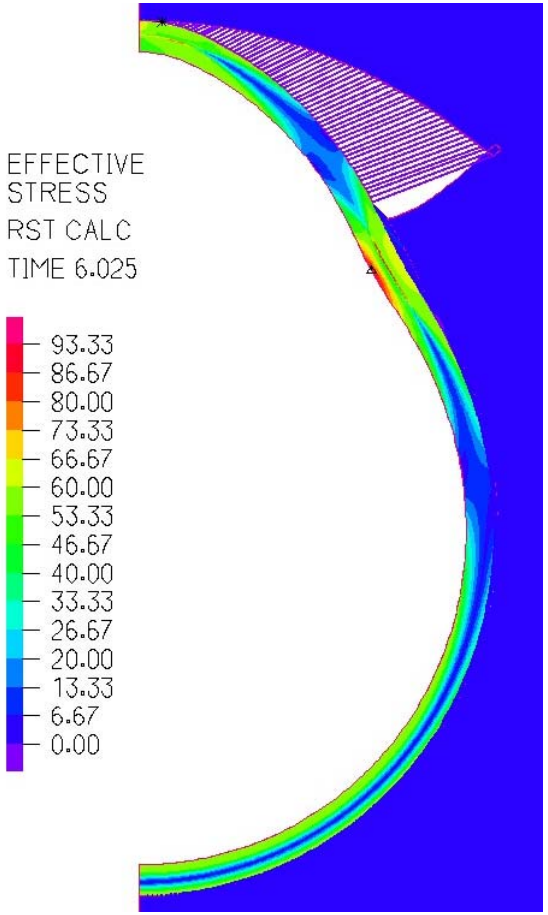
F.E. mesh

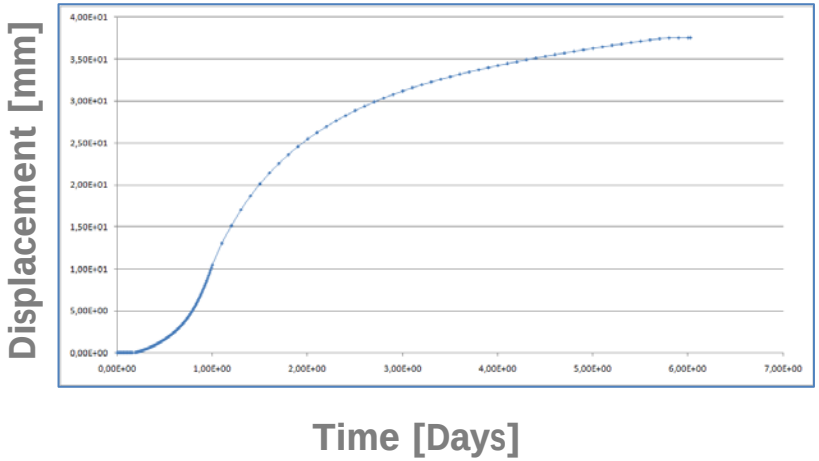
Casing detail

Structural Analysis

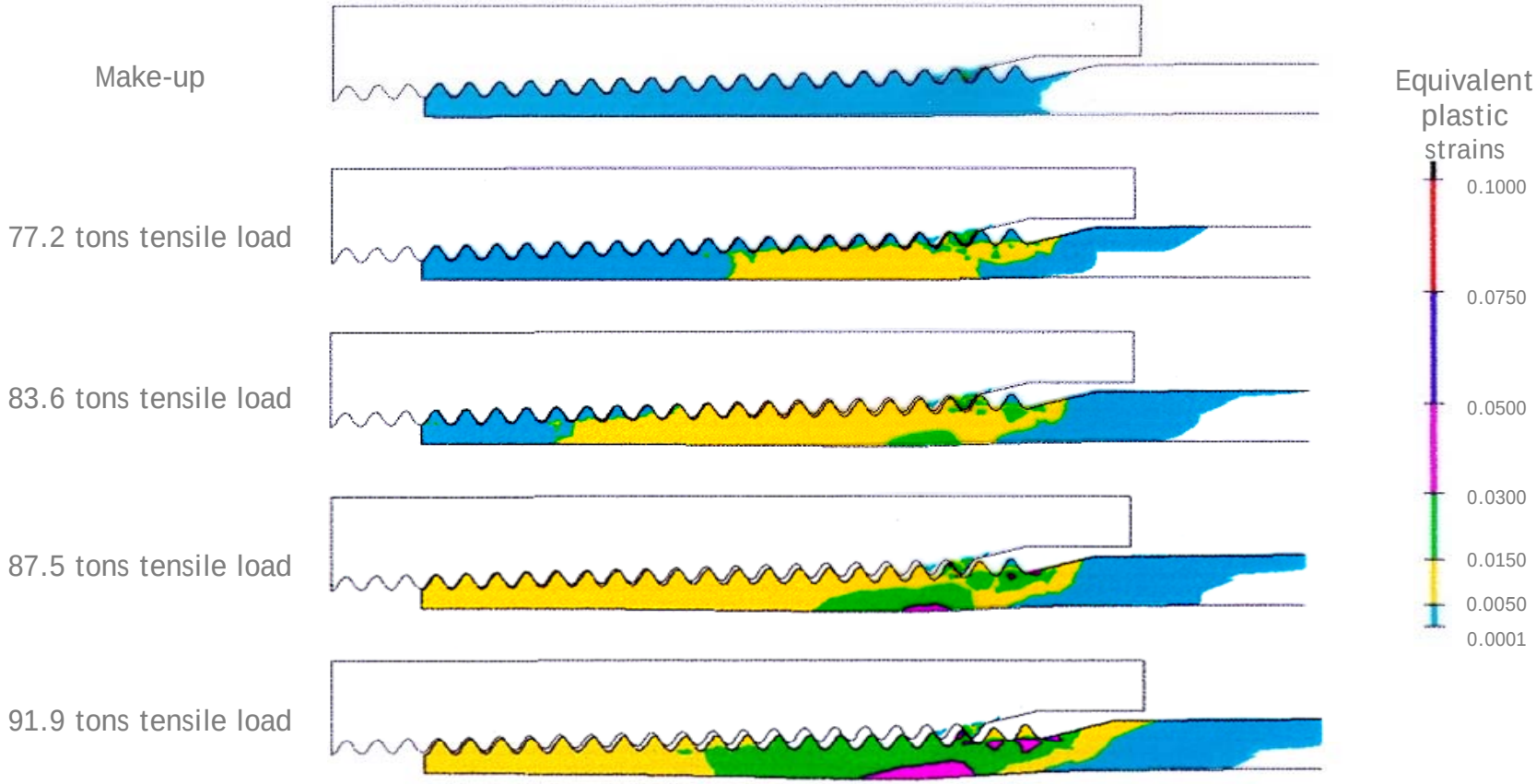
Design of casings through salt domes





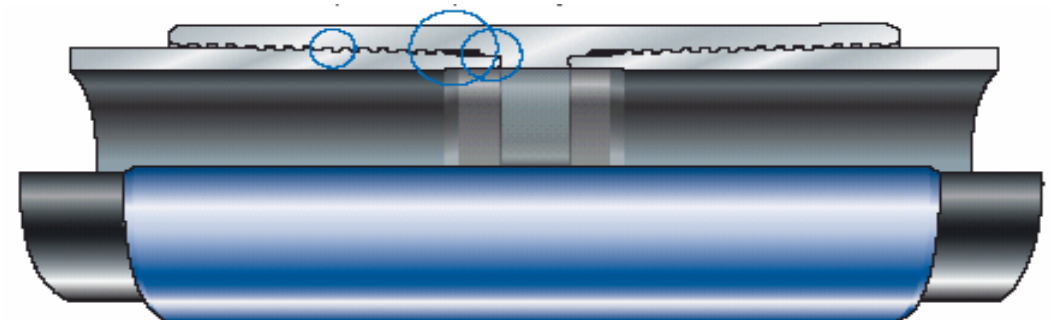


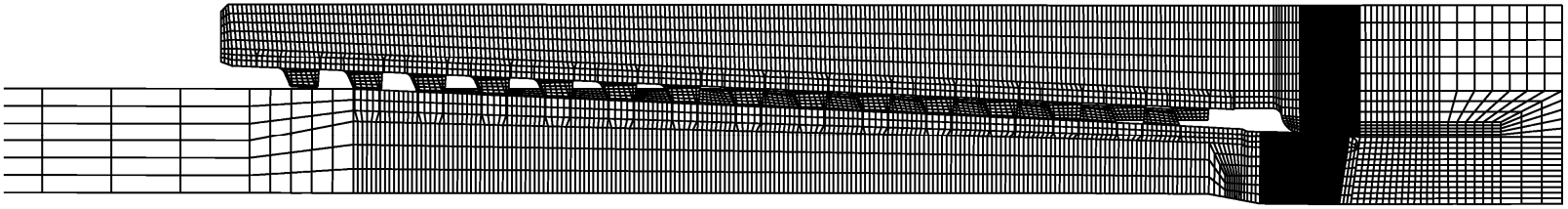
Structural Analysis



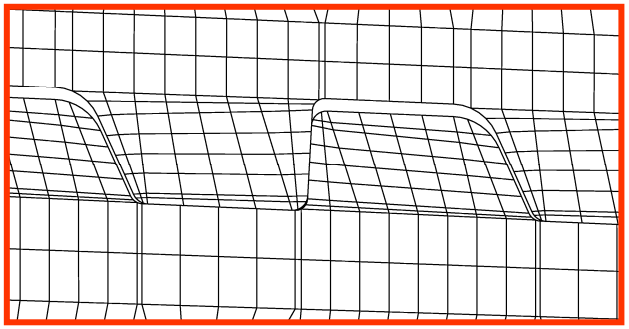
Jump-out of an API 8R connection

Structural Analysis

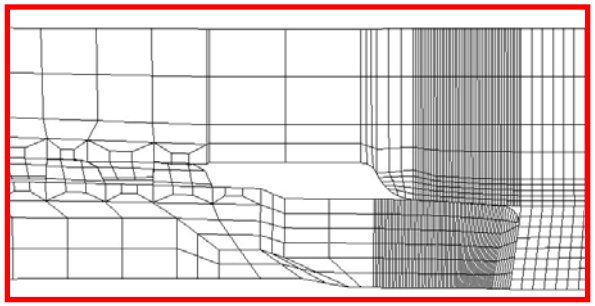




Detail of the threads

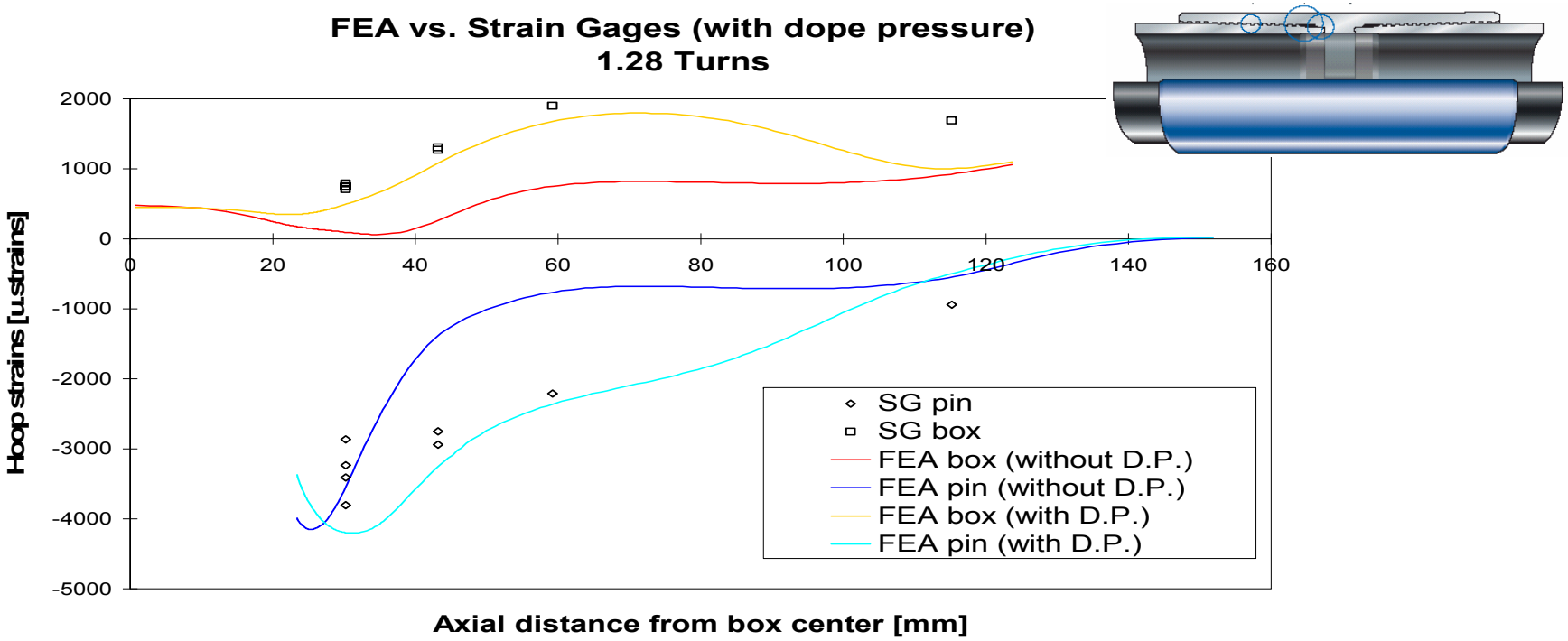


Detail of the seal area



Structural Analysis

OCTG Premium Connections

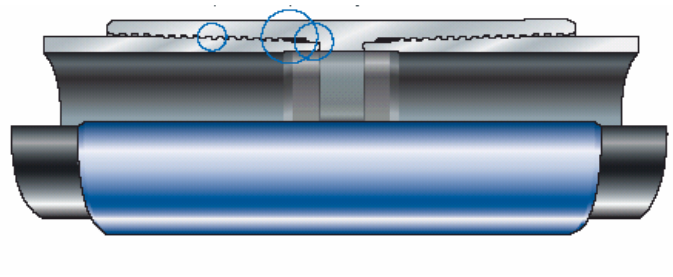


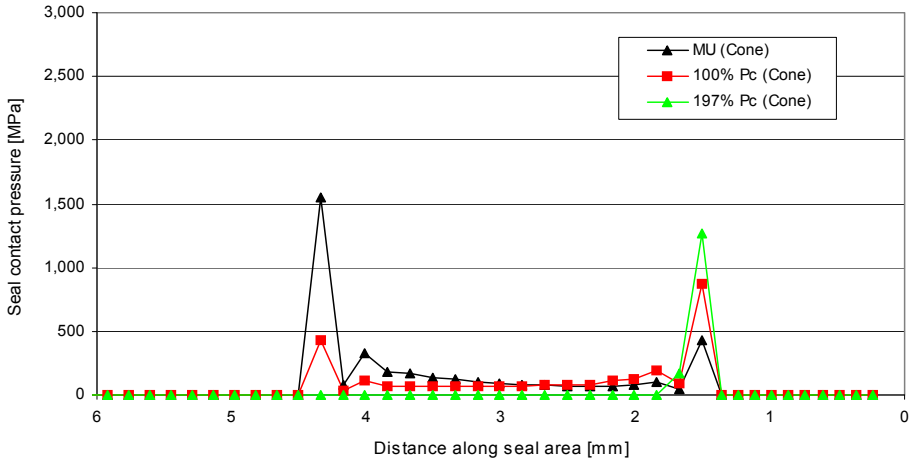
When the dope pressure distribution determined in the full-scale test was included in the finite element model, the numerical results showed a very good agreement with the experimental ones.

Structural Analysis

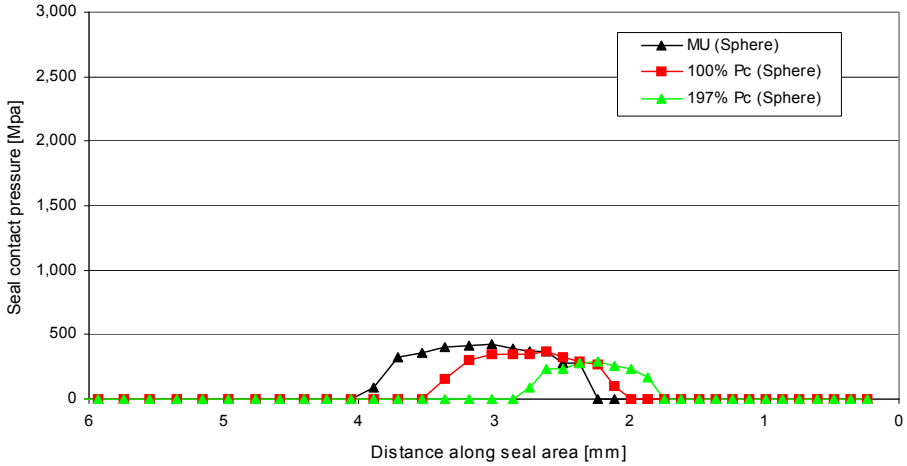
OCTG Premium Connections

Cone-cone seal



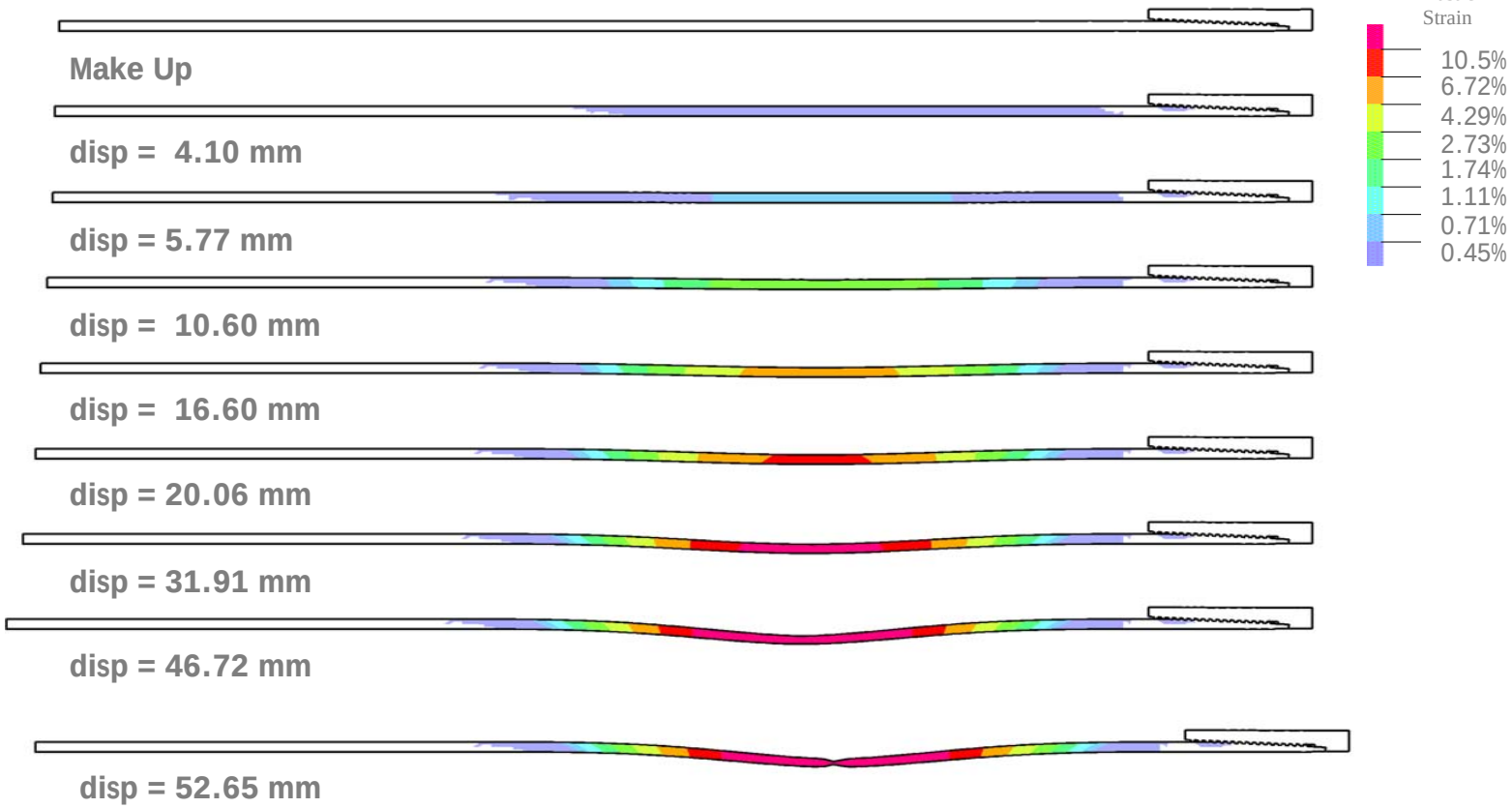


Sphere-cone seal



Structural Analysis

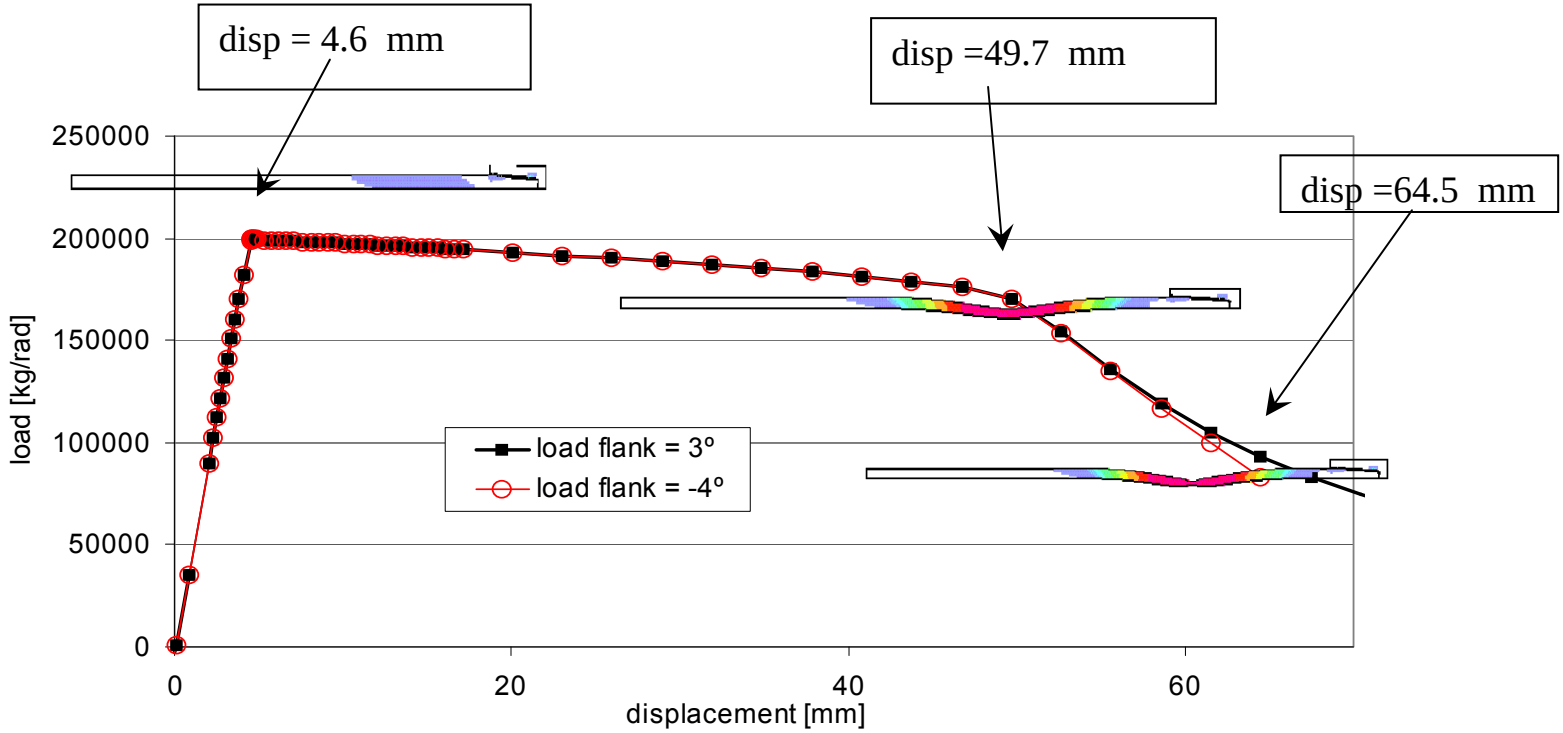
OCTG Premium Connections



Structural Analysis

OCTG Premium Connections

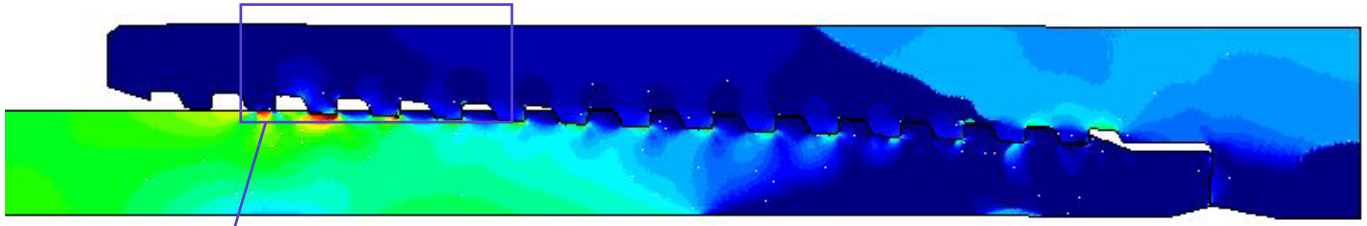
Curve load vs. displacement



Structural Analysis

OCTG Premium Connections

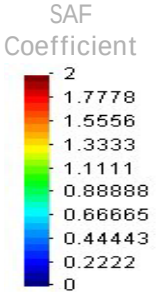
Fatigue analysis: Stress concentration factor

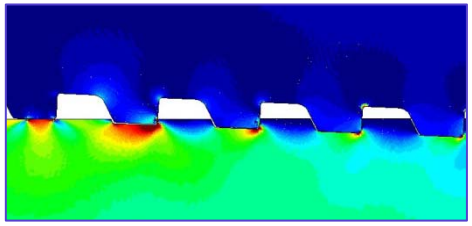


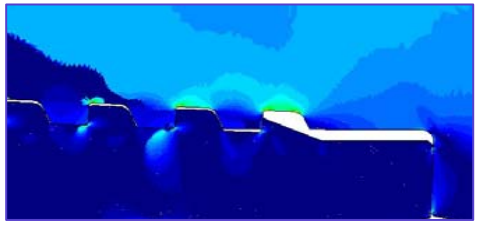
SAF = max [DPS / || DTS ||]
(for the whole cycle)

Where :
- DPS: Change in the maximum first principal stress
- || DTS ||: Absolute value of change in the average stress applied to the pipe wall

Min. Load = 130 Mpa
Max. Load = 220 Mpa

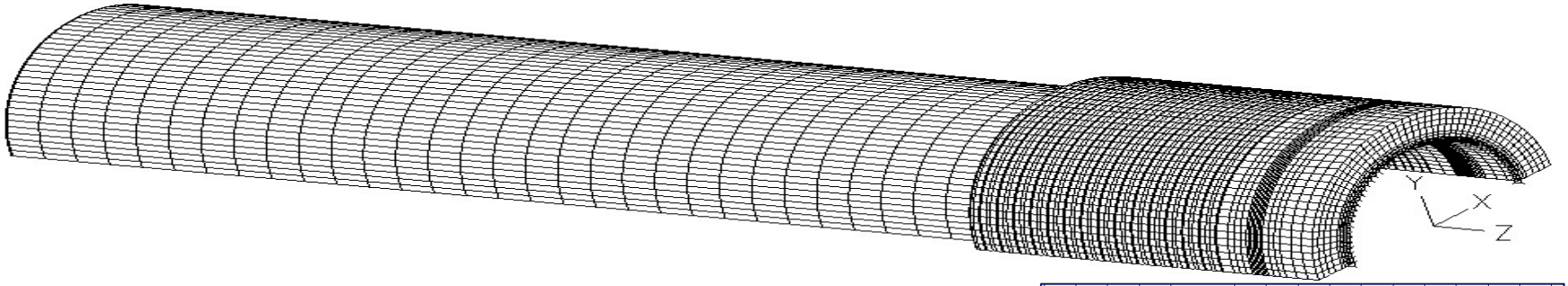


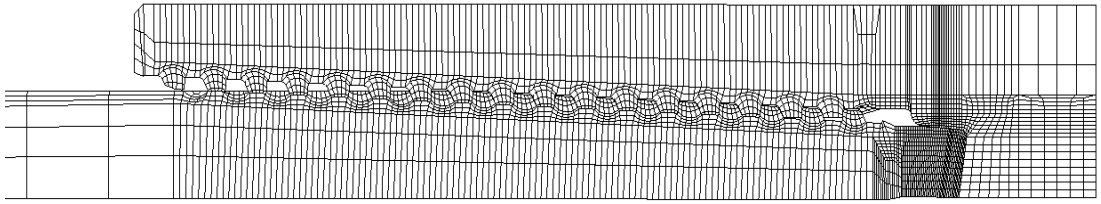


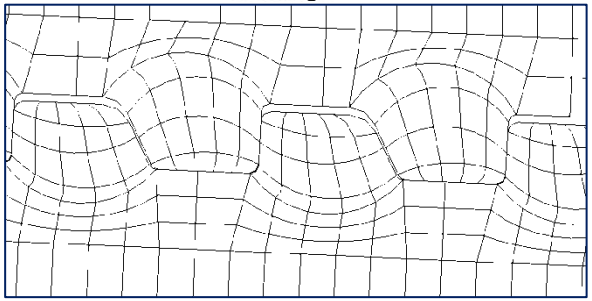


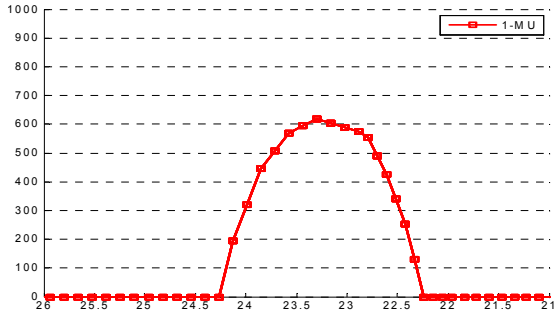
Structural Analysis

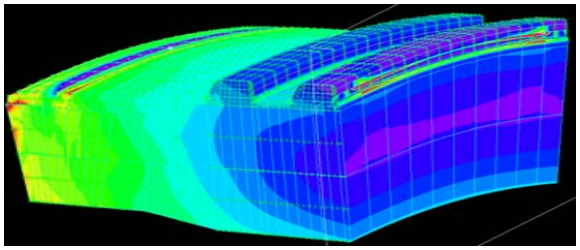
OCTG Premium Connections





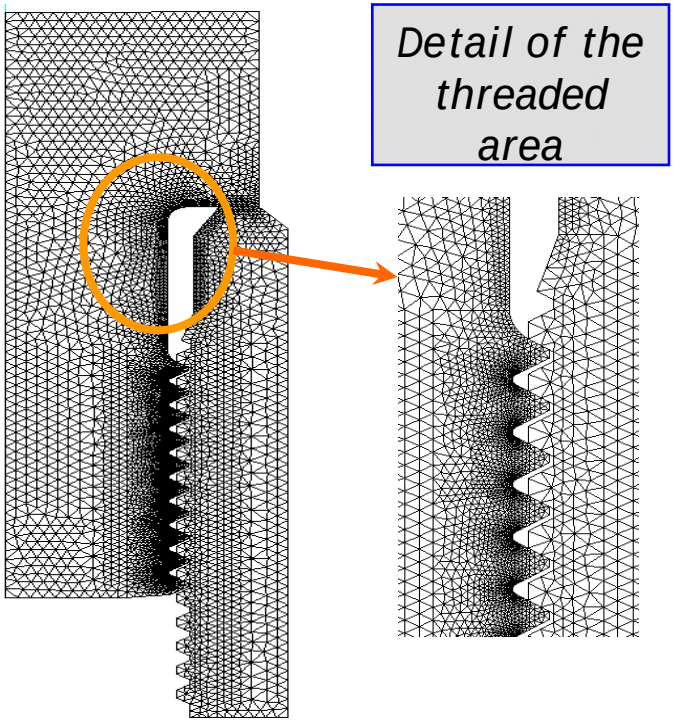


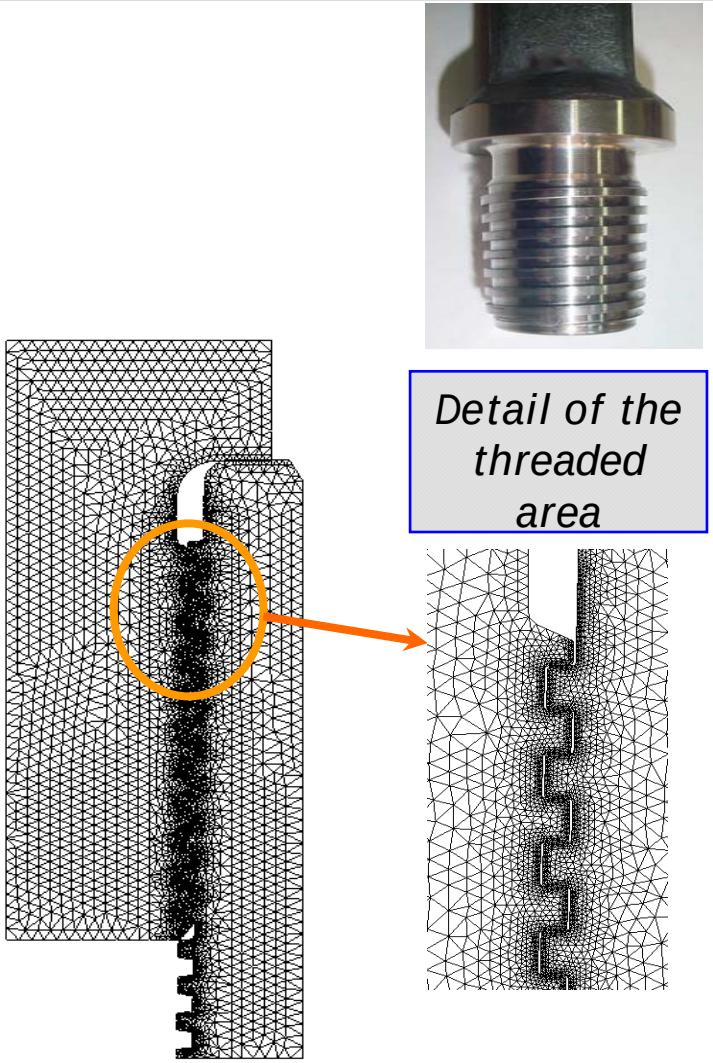




Structural Analysis

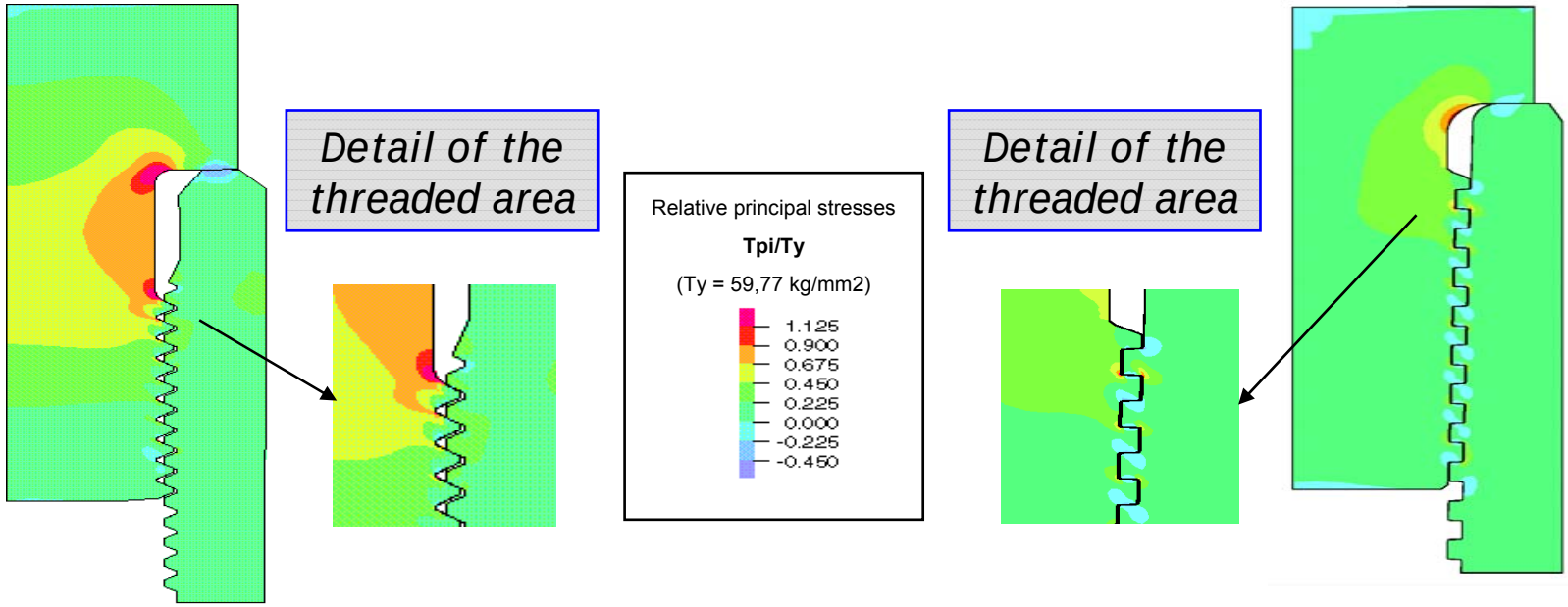
Sucker Rod Premium Connection





Structural Analysis

Sucker Rod Premium Connection



API Design

Principal stress I

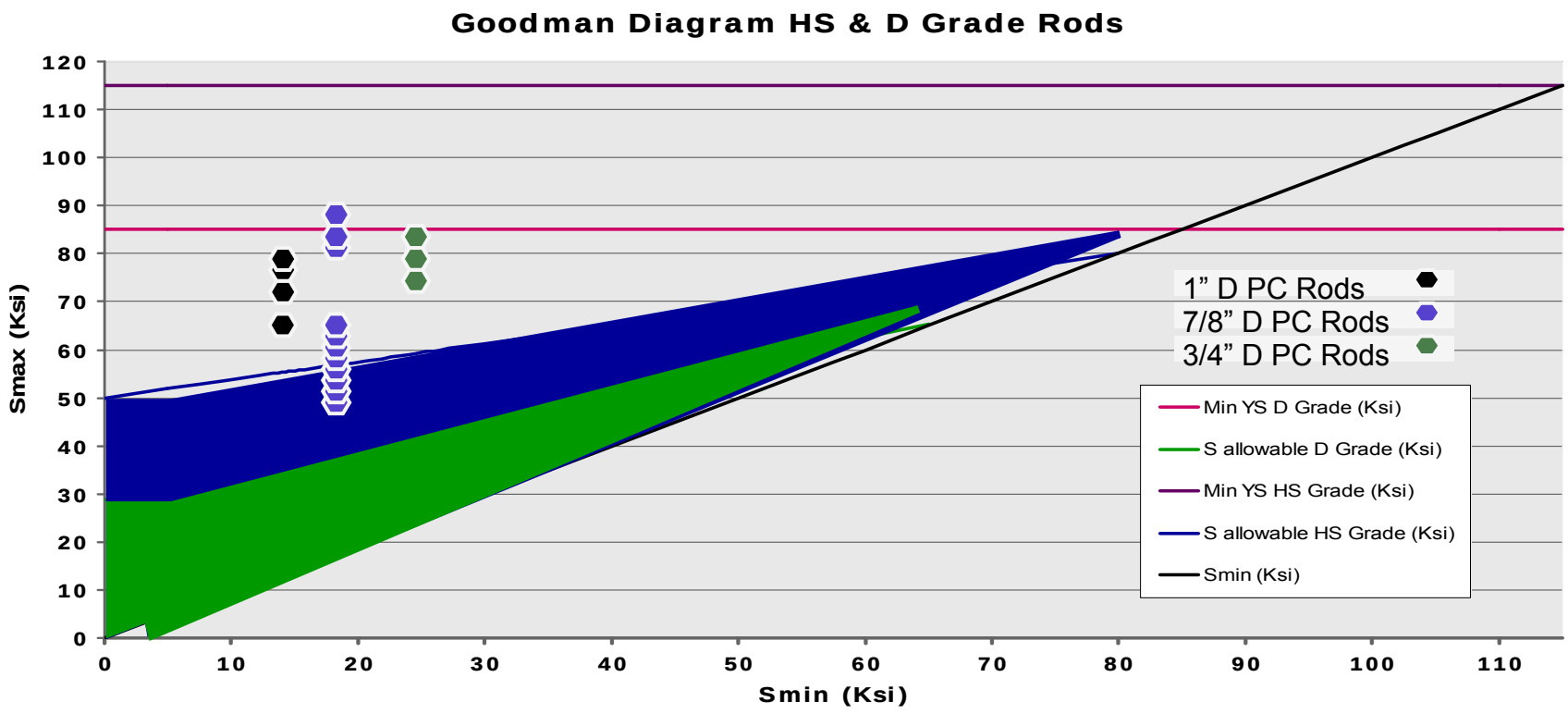
New Design

Principal Stress I

Structural Analysis

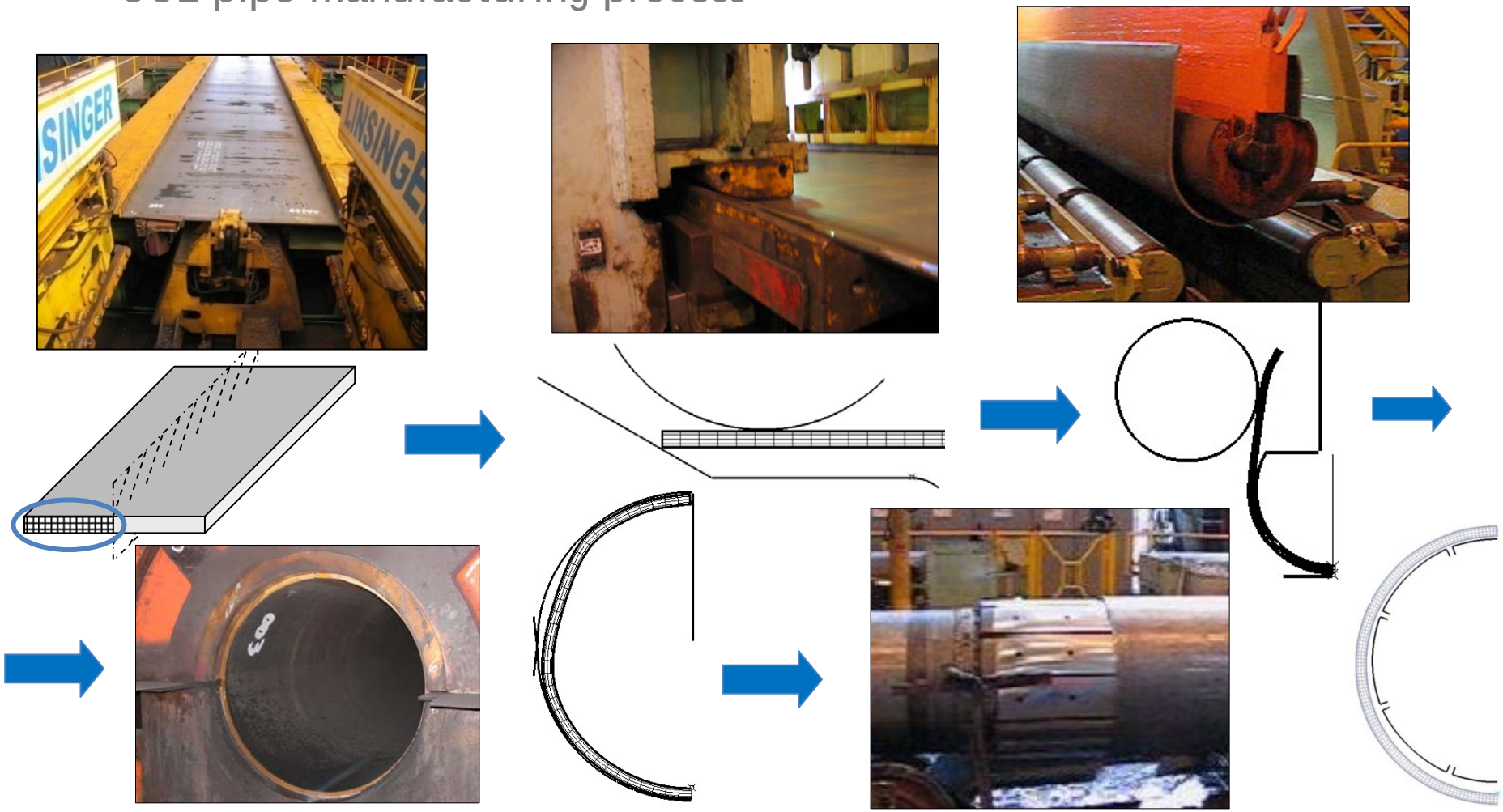
Sucker Rod Premium Connection

Fatigue Tests Results



Structural Analysis

UOE pipe manufacturing process

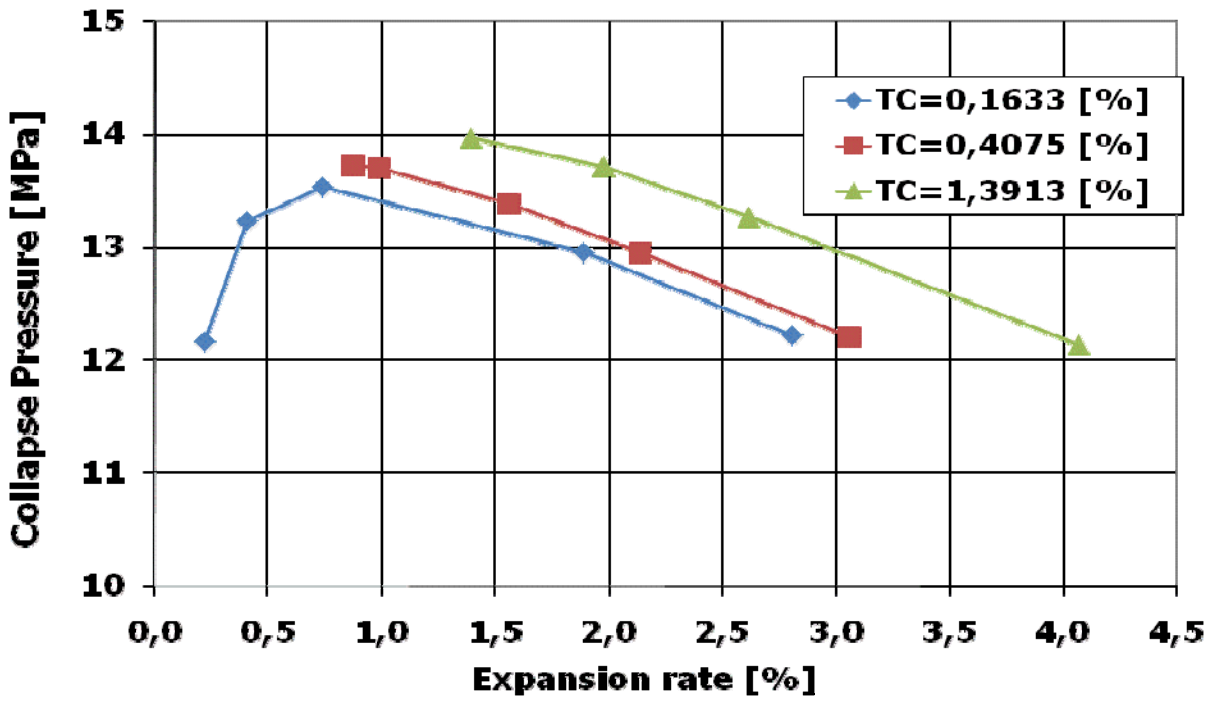


Structural Analysis

UOE: Process control and Properties assurance

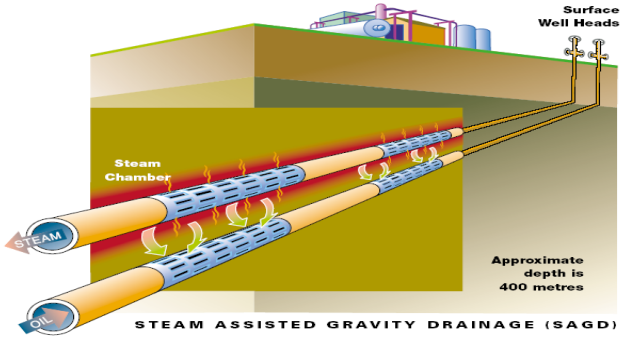
16” OD x 0.5” WT X60

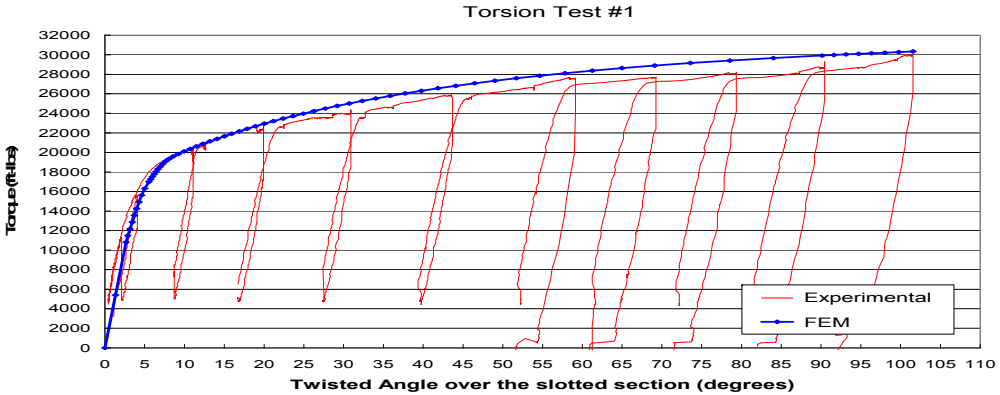
D/t=32

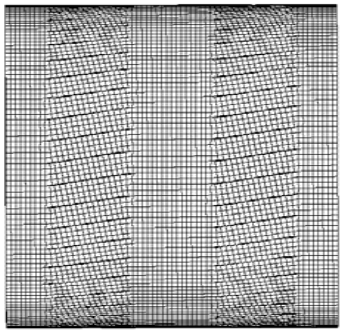


Structural Analysis

Steam Assisted Gravity Drainage (SAGD)

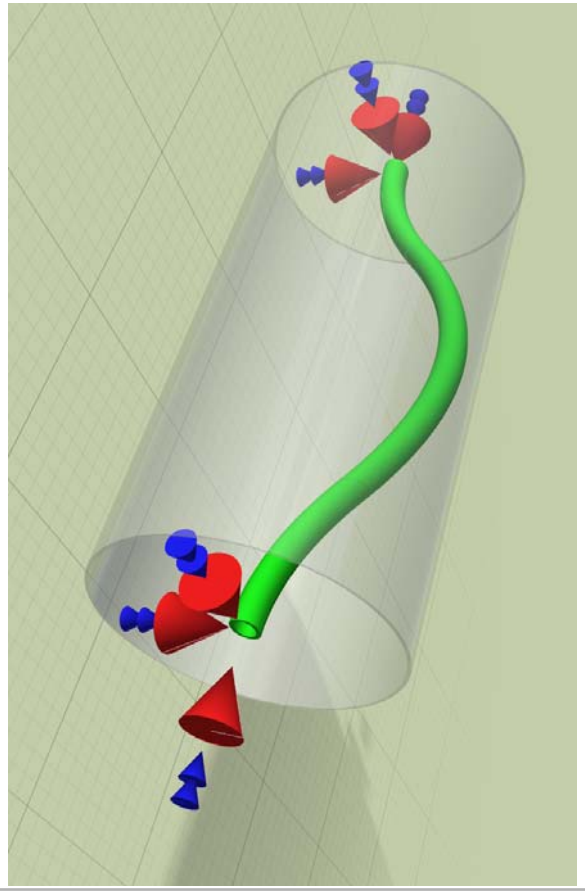


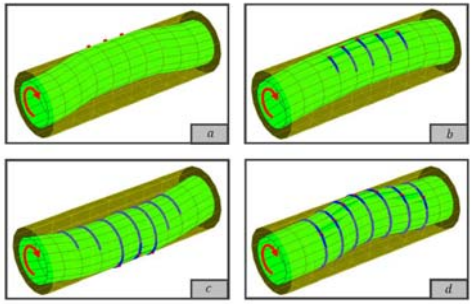




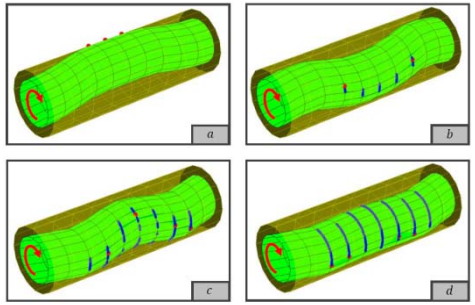
Structural Analysis

DrillFem





μ (pipes/well)=0.0



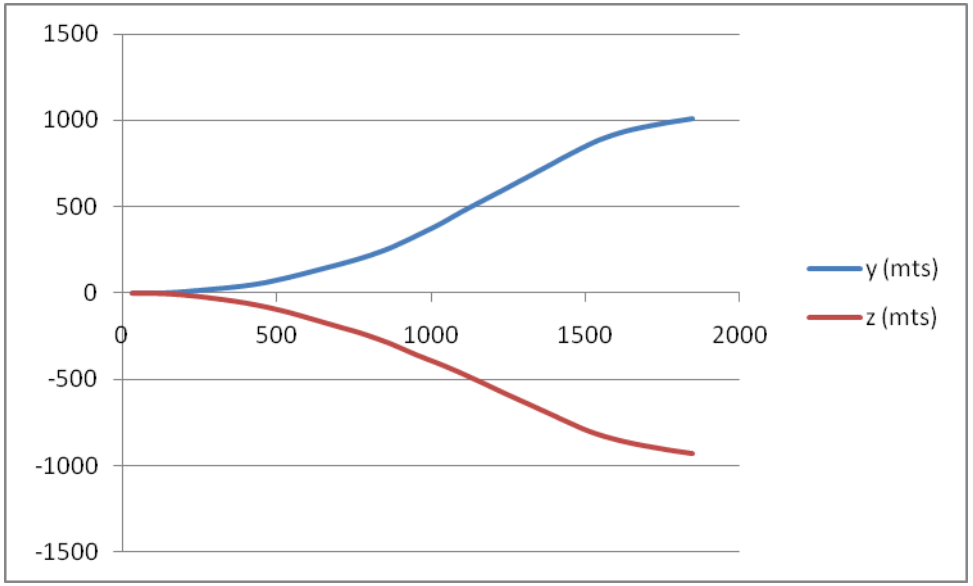
μ (pipes/well)=0.1

Comparison at the central cross section

Structural Analysis

DrillFem

Deviated Well - Data



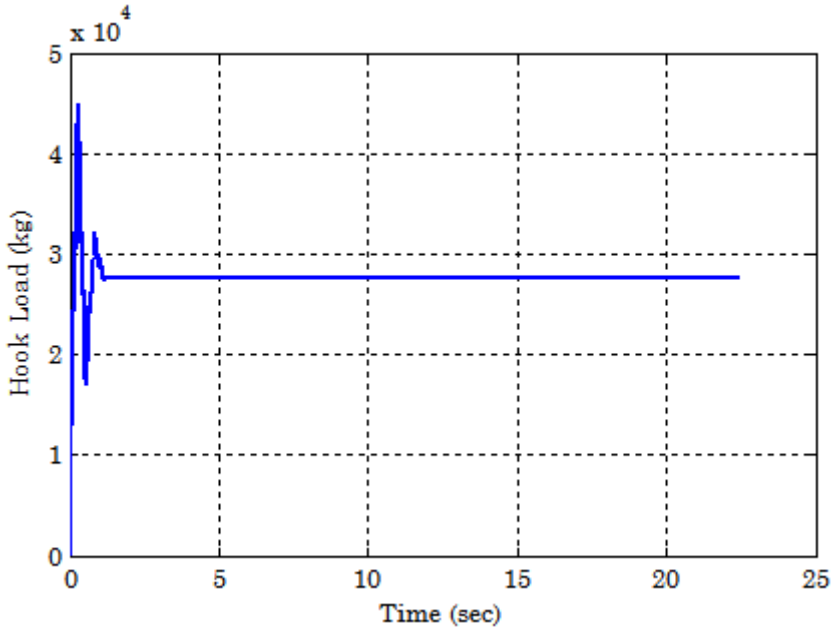
ID well = 250.825 mm

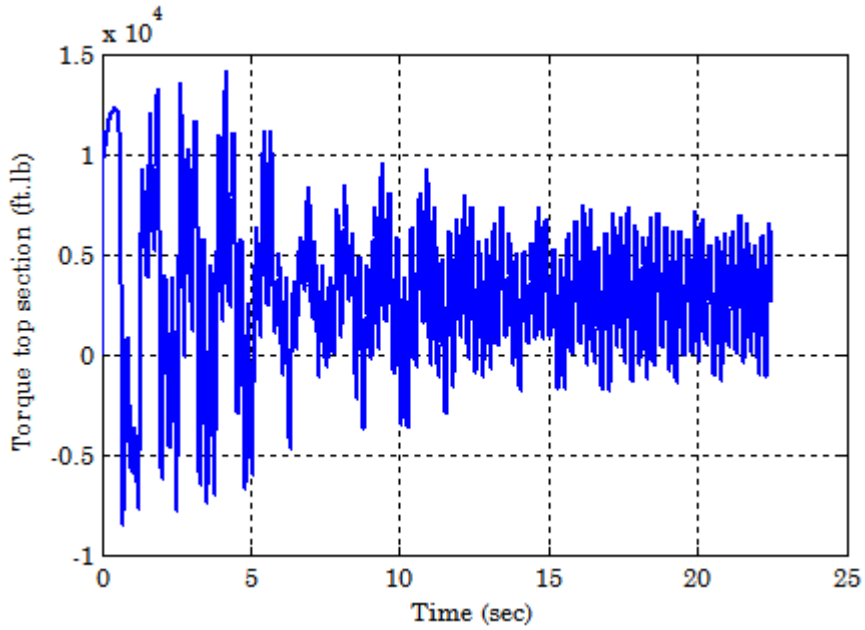
Pipes MD= 720mts

Structural Analysis

DrillFem

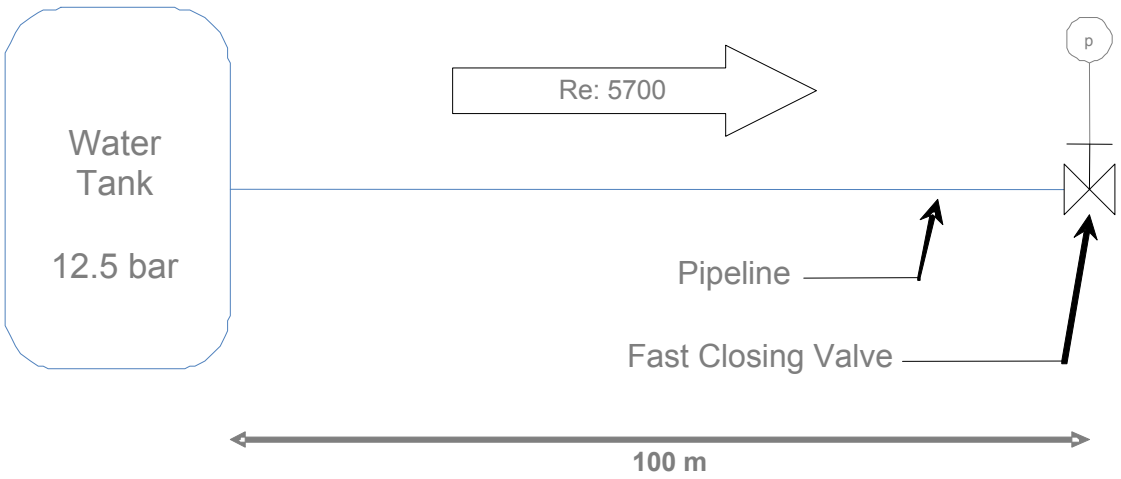
Deviated Well - μ=0.3





Structural Analysis

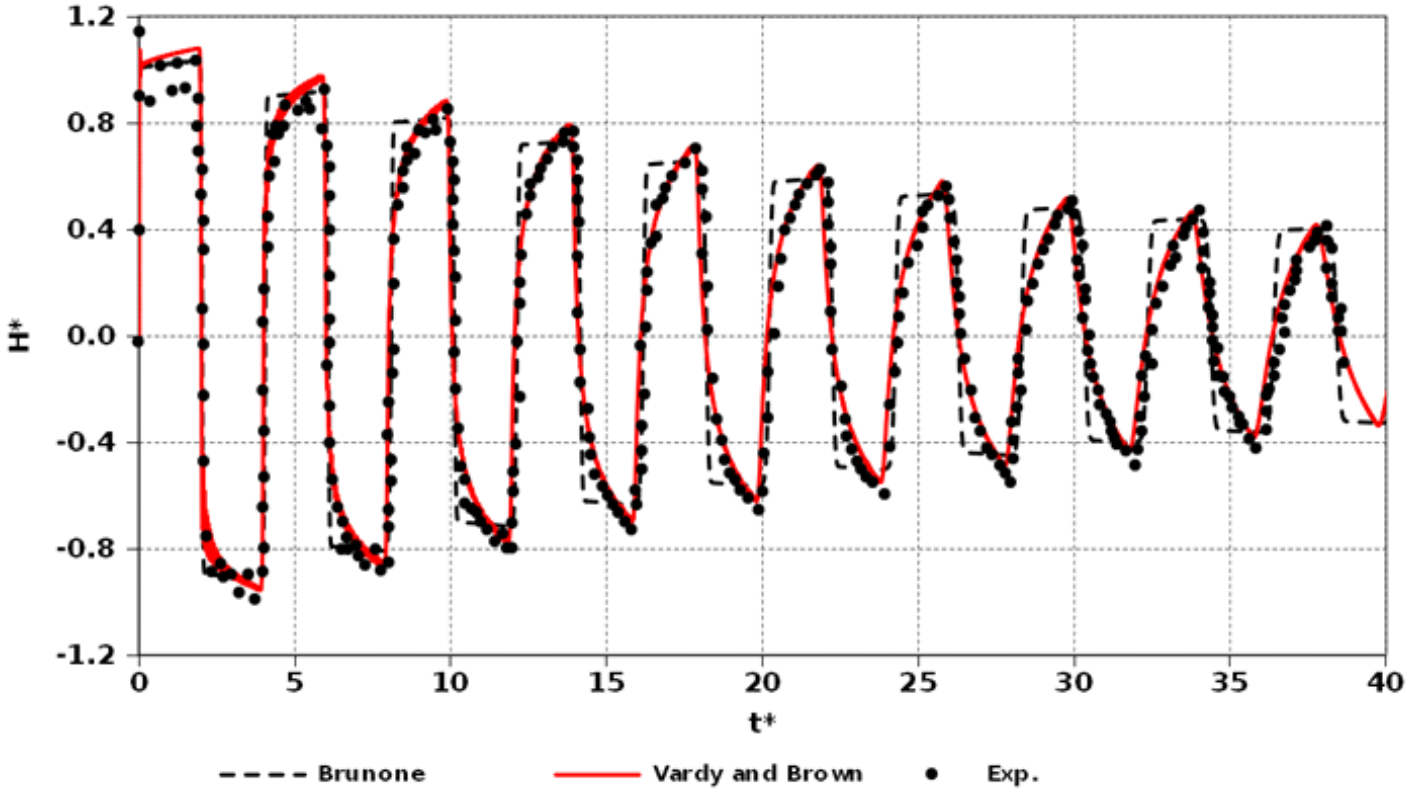
Waterhammer



Waterhammer experiment. The valve is closed at t=0; the pipe dimensions are L=100m; ID=0.016m and OD=0.018m. Fluid: water (blue)

Structural Analysis

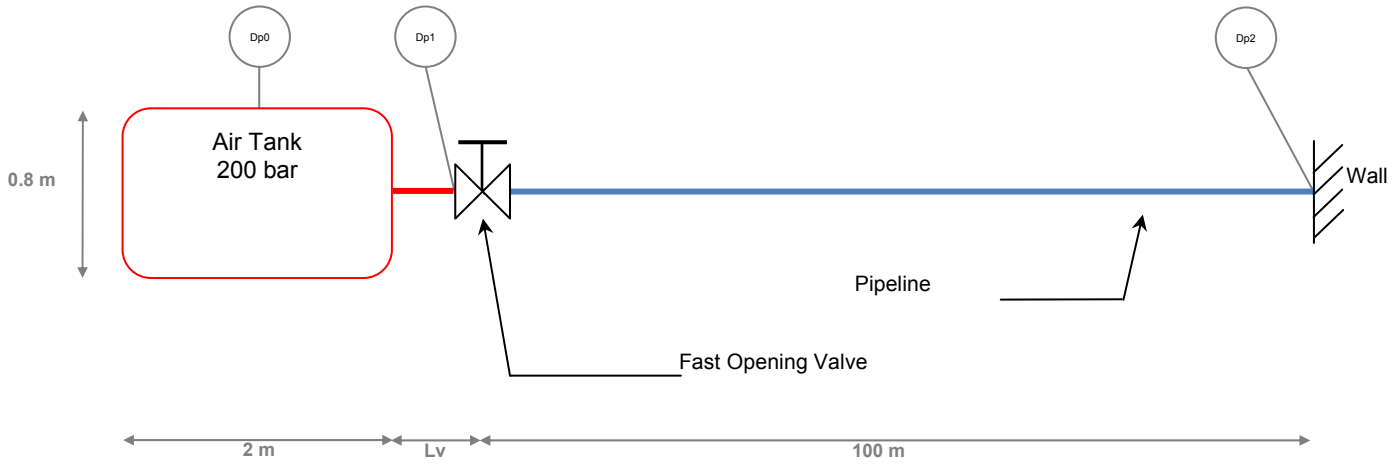
Waterhammer



Normalized pressure at the valve. Comparison of calculated and experimental results

Structural Analysis

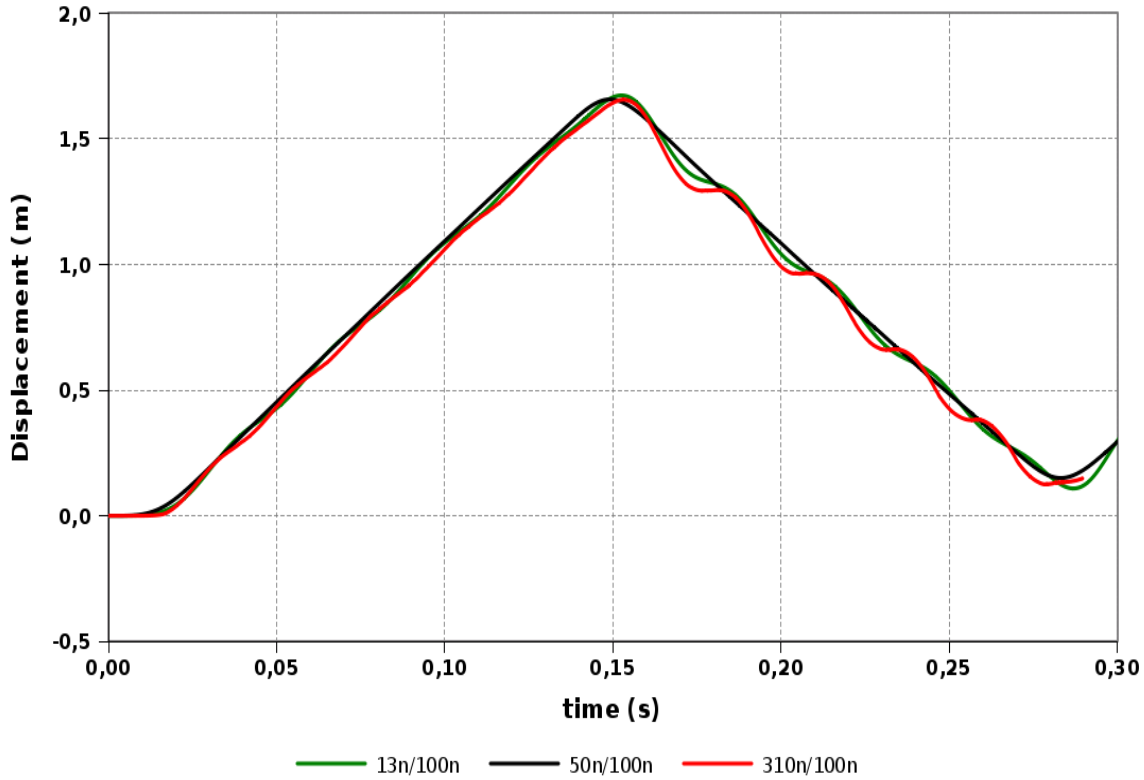
Waterhammer



Non-miscible fluids test. The valve is opened at t=0.02; the water pipeline dimensions are L=100m; ID=0.0893m and OD=0.01143m. Fluid: air (red), water (blue)

Structural Analysis

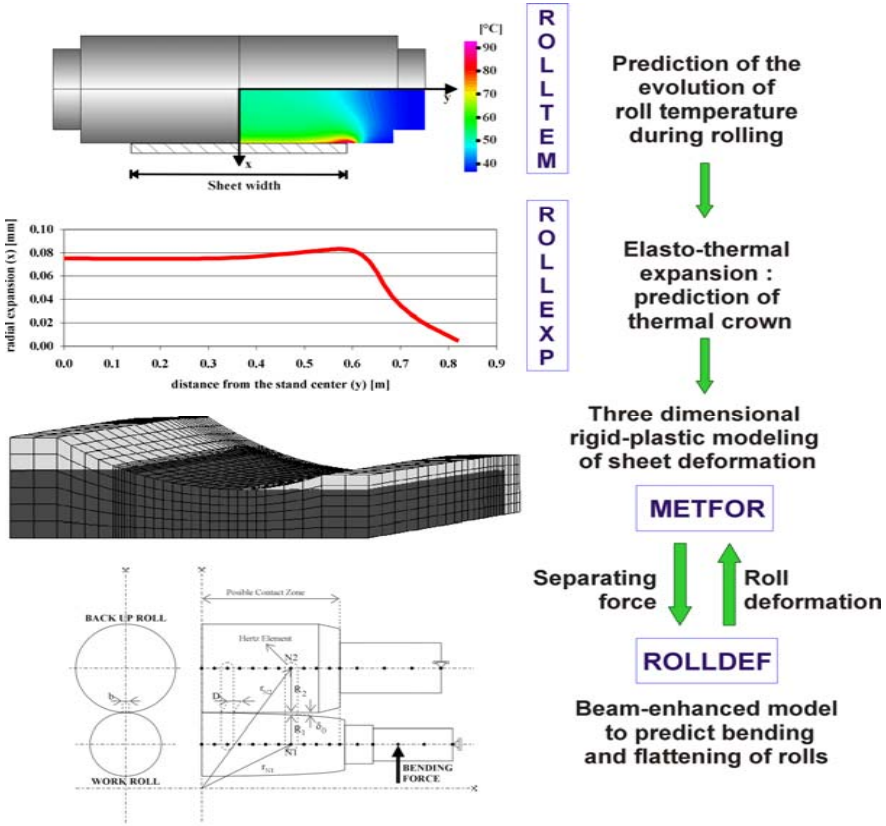
Waterhammer

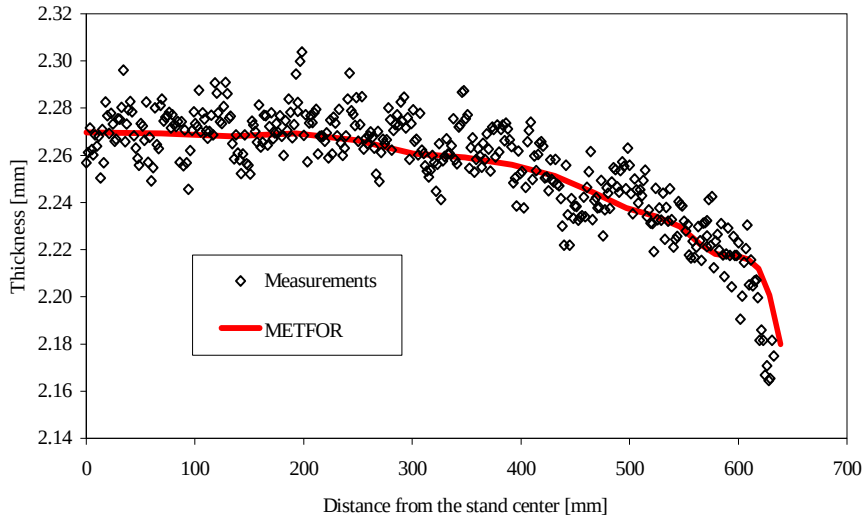


Air mesh refinement results for the interface position

Metal Forming

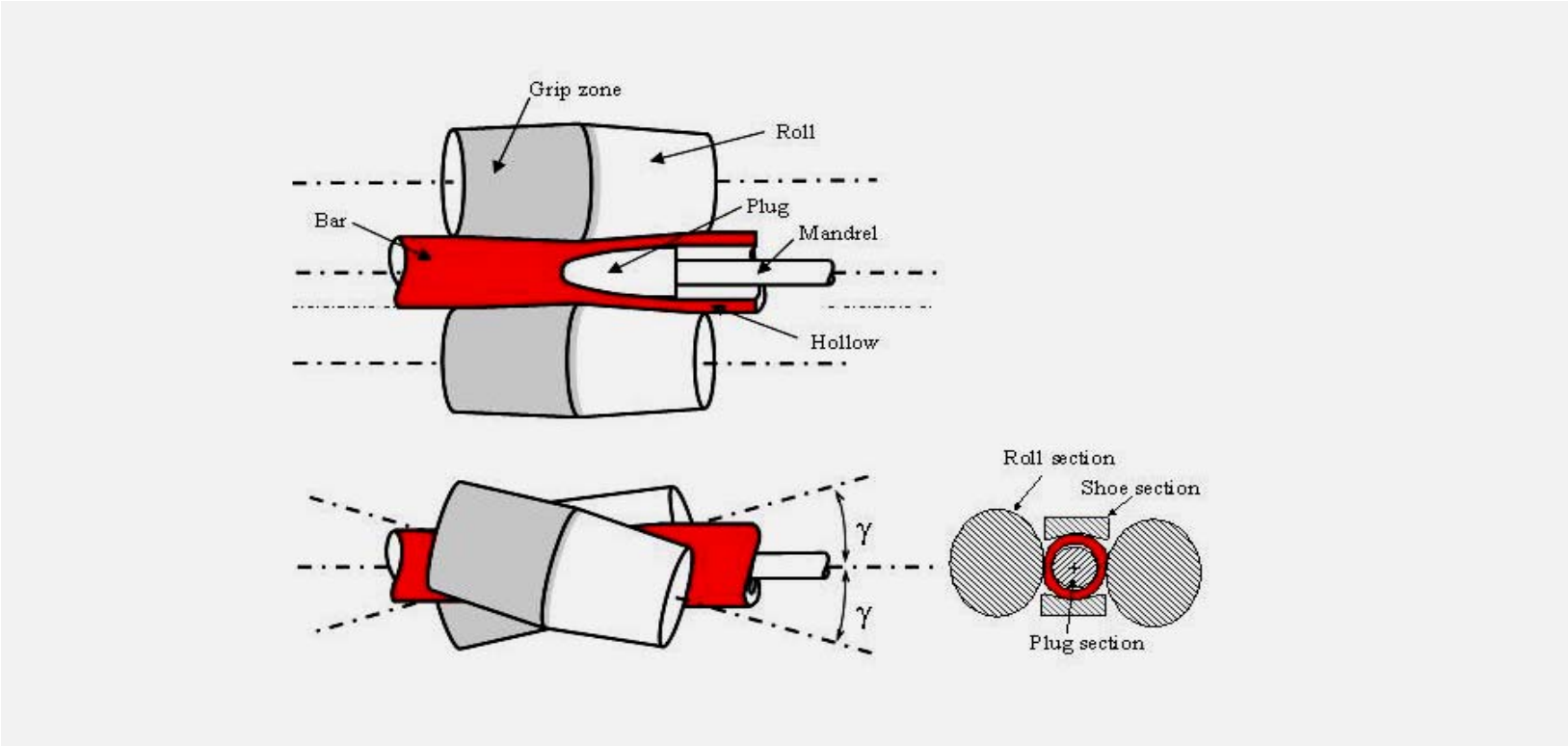
Rolling Processes





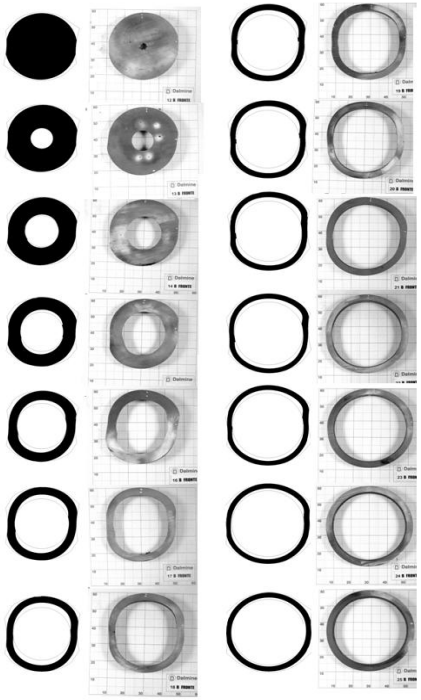
Metal Forming

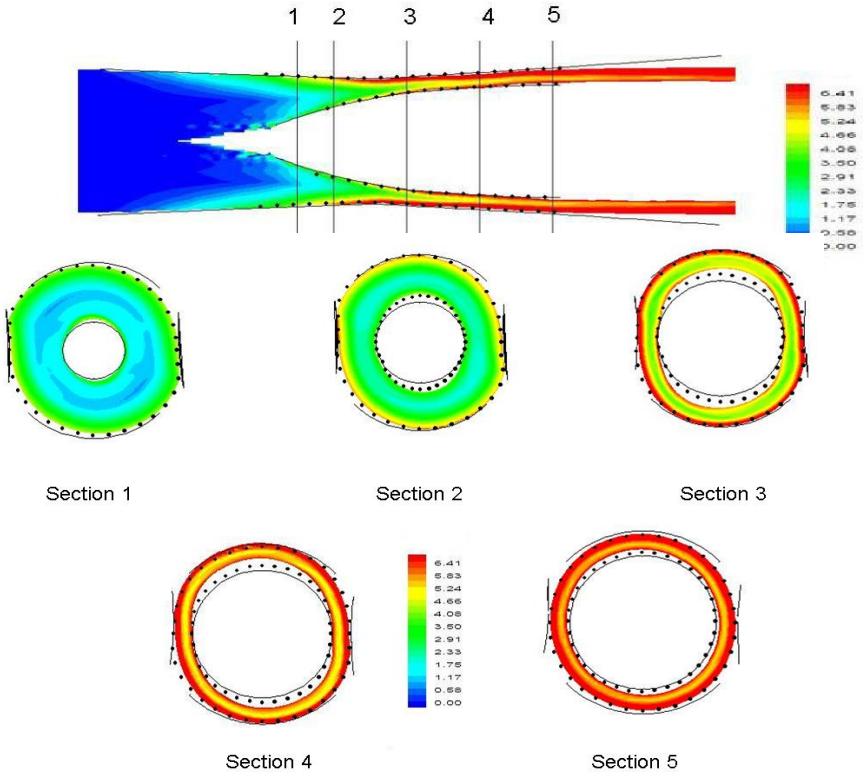
The Mannesmann piercing process



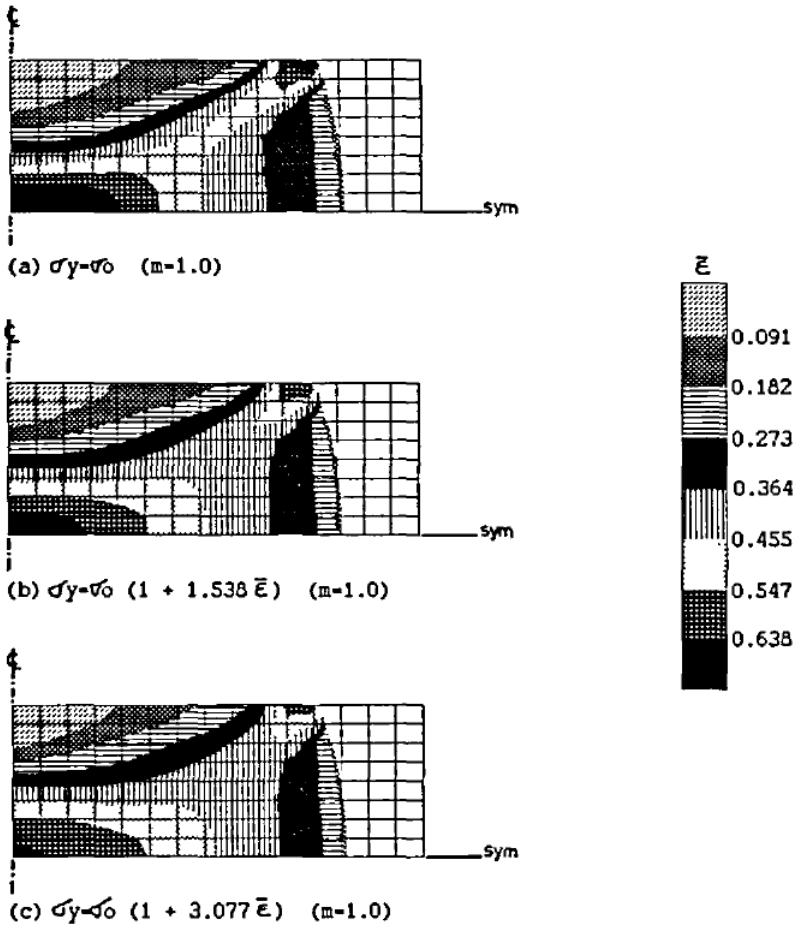
Metal Forming

The Mannesmann piercing process

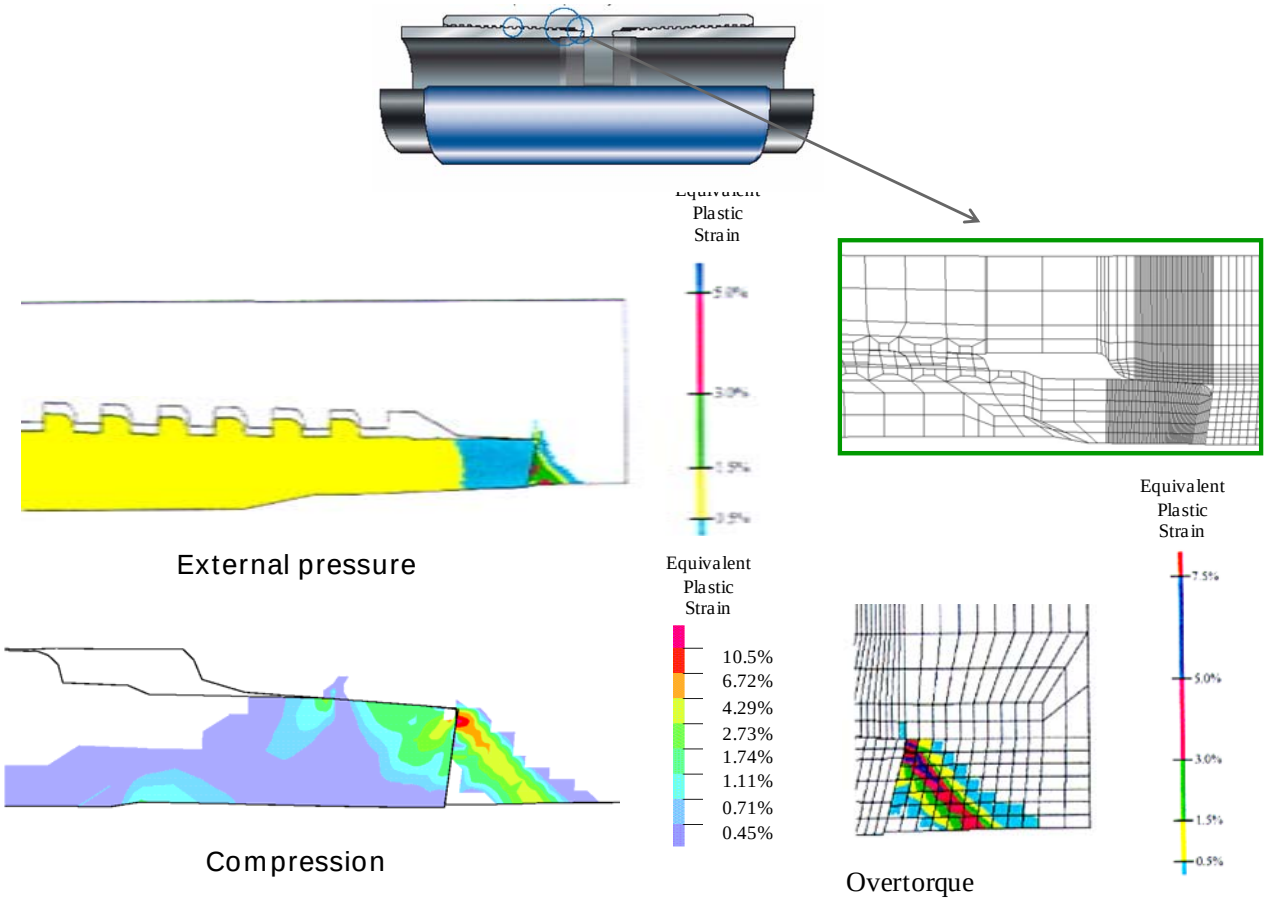




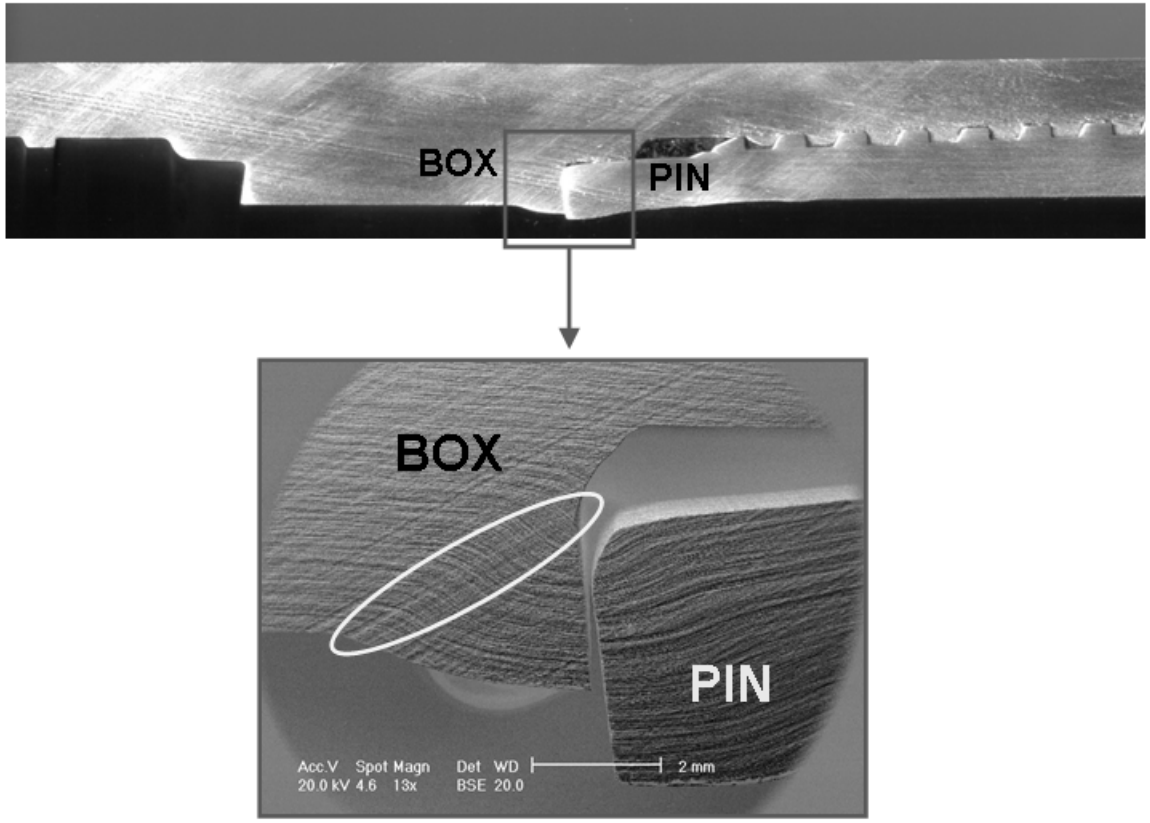
Localization



Localization

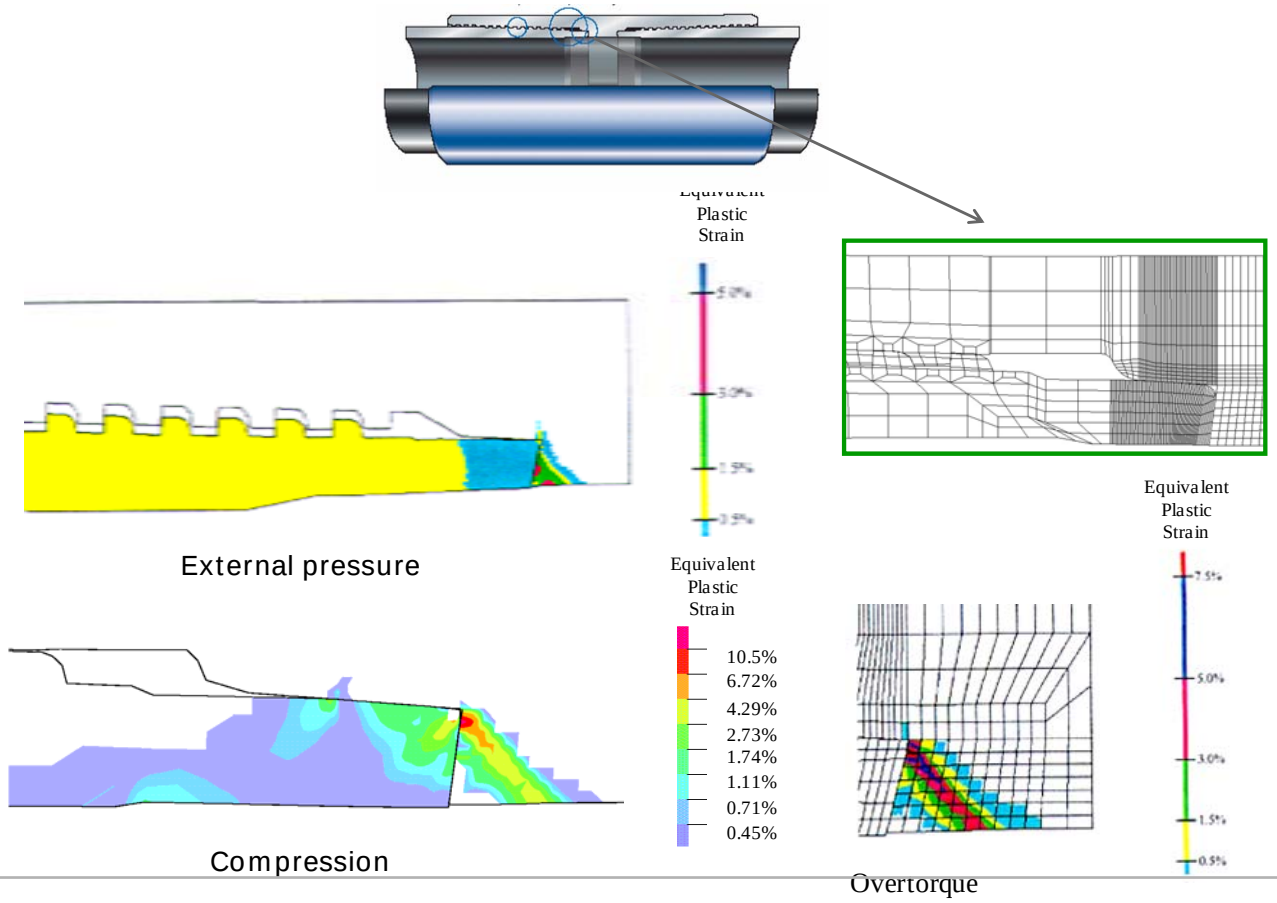


Localization



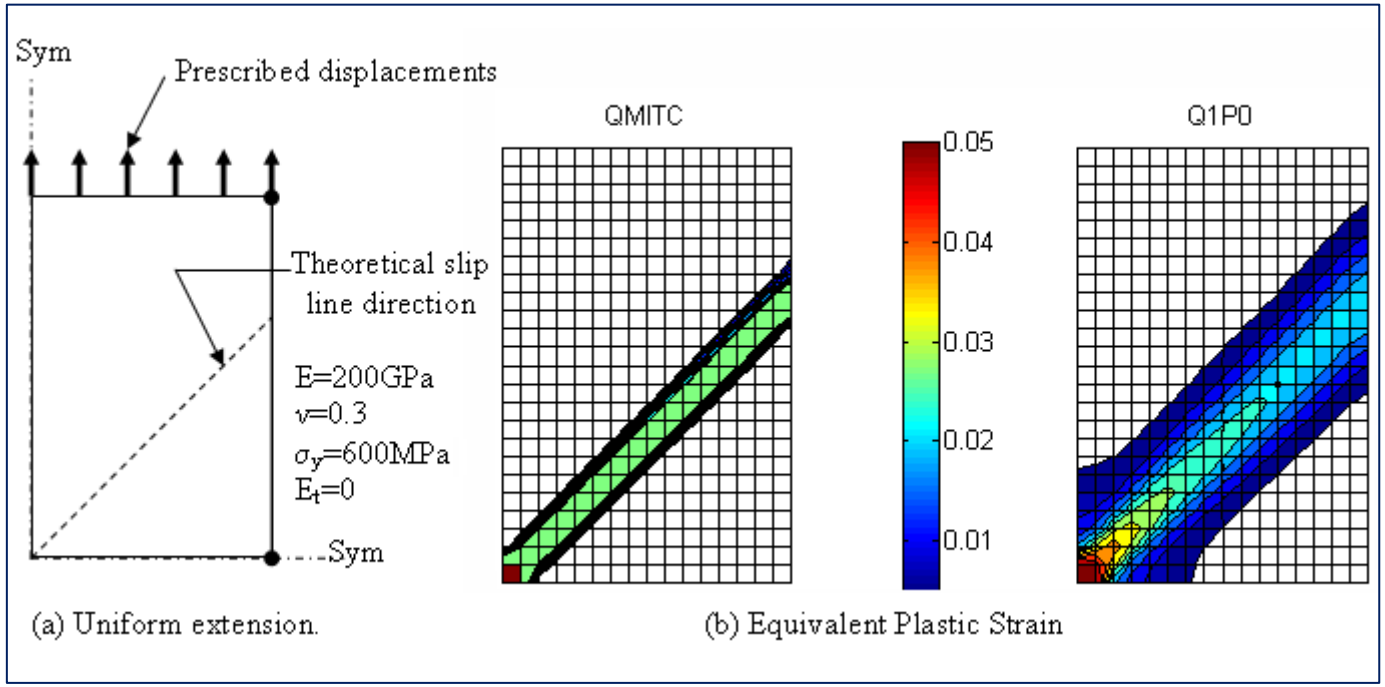
Localization

Finite element modeling and mesh dependency



Localization

Finite element modeling and mesh dependency



Localization

Finite element modeling and mesh dependency

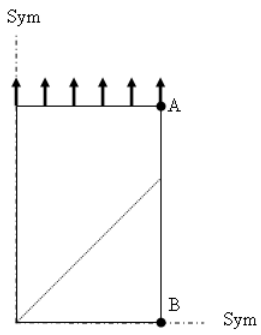
The width of the localized zone is forced to be in the elements size scale

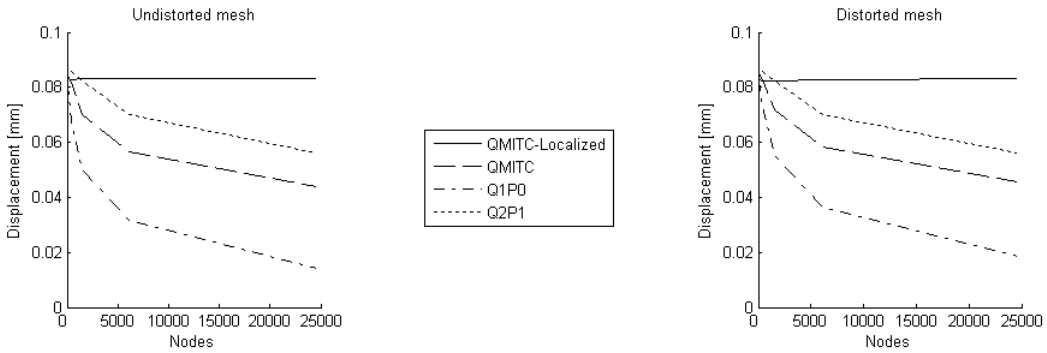
Mesh dependent results

Special techniques need to be developed to solve this problem

Localization

Finite element modeling and mesh dependency

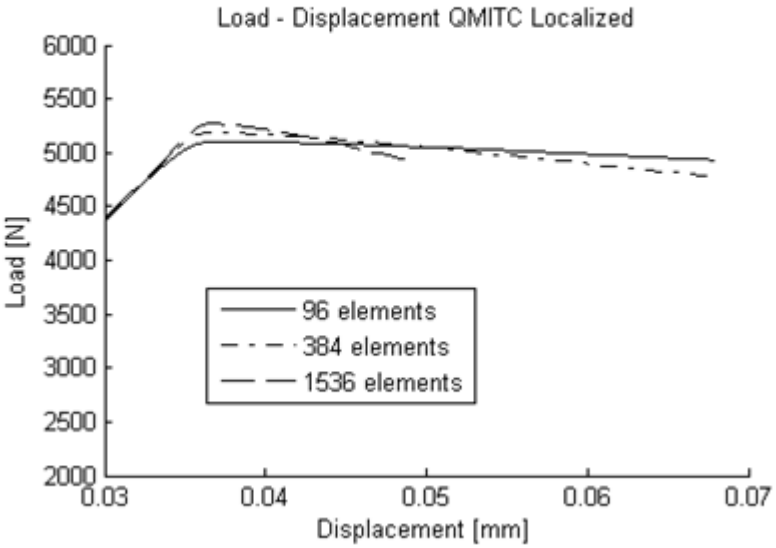


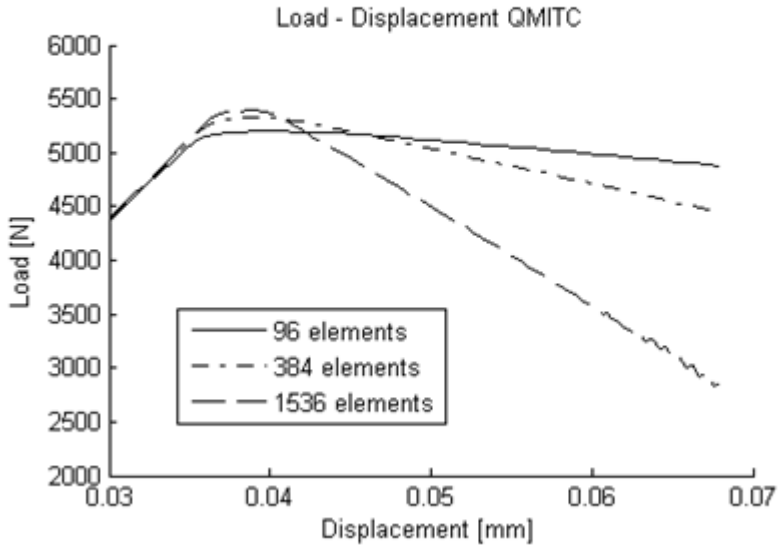


Localization

Finite element modeling and mesh dependency

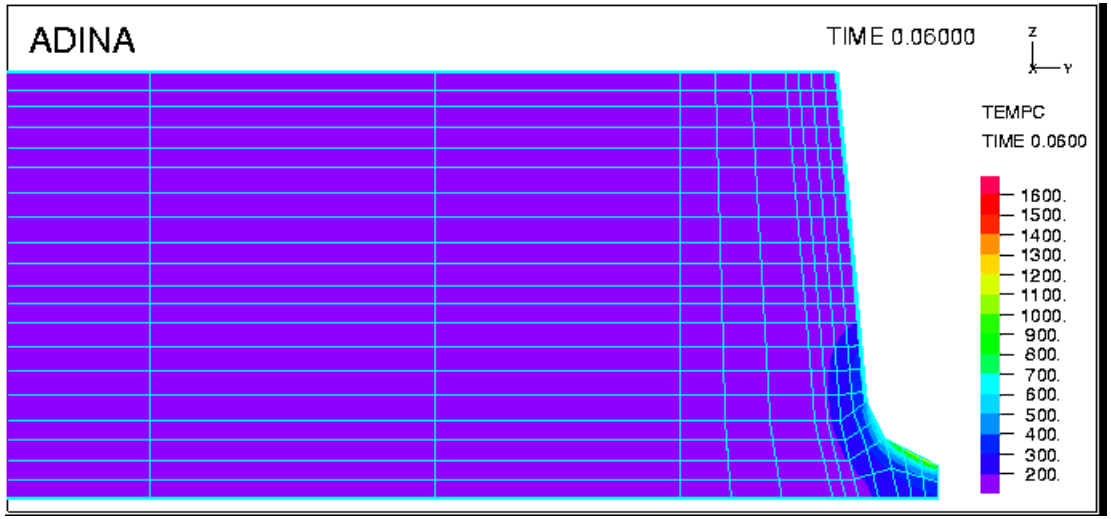
Plasticity + Damage

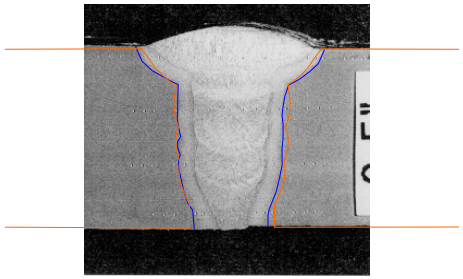




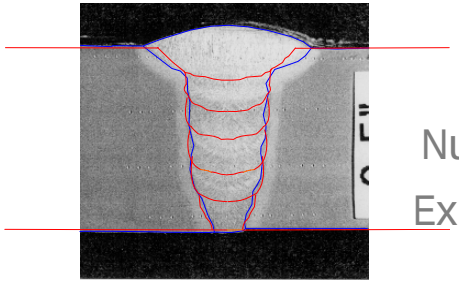
Heat transfer

Welding





HAZ



Liquid pool zone

Numerical values

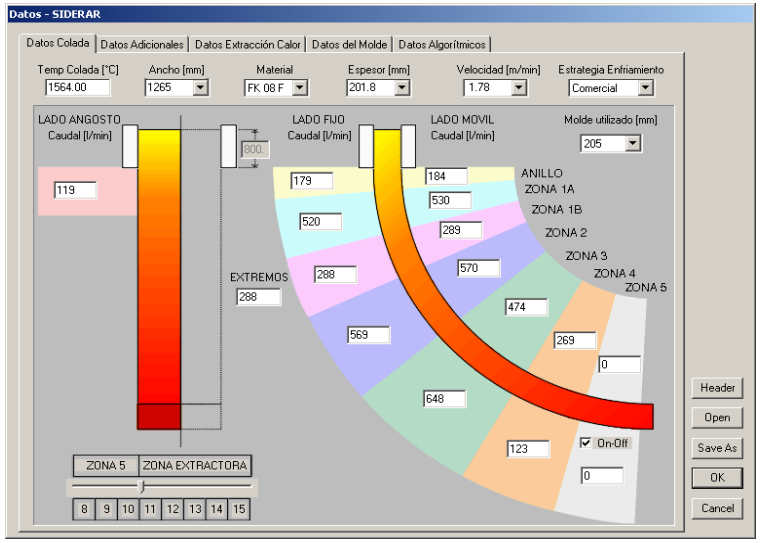
Experimental values

Heat transfer

CCAST System: Thermal model of the continuous casting process

We perform **Inverse Analysis** to determine the heat transfer coefficients

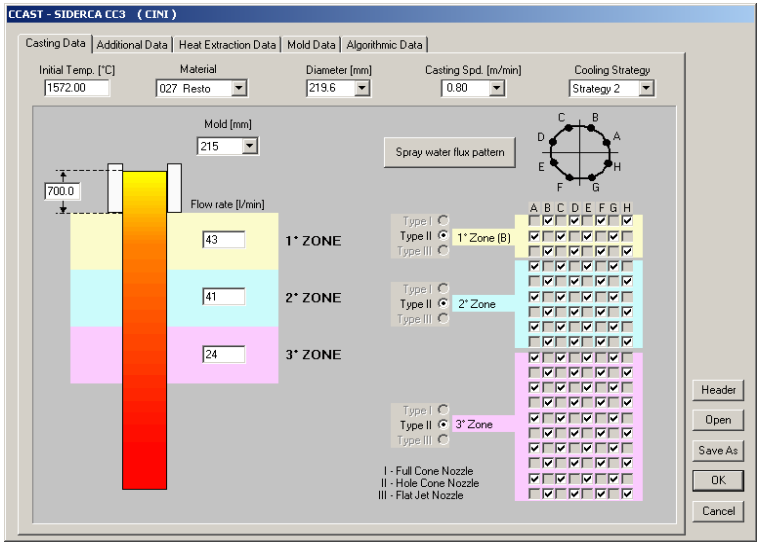
Slab continuous casting process



CCAST – SIDERAR v3.0

CCAST – SIDOR v1.0

Round continuous casting process

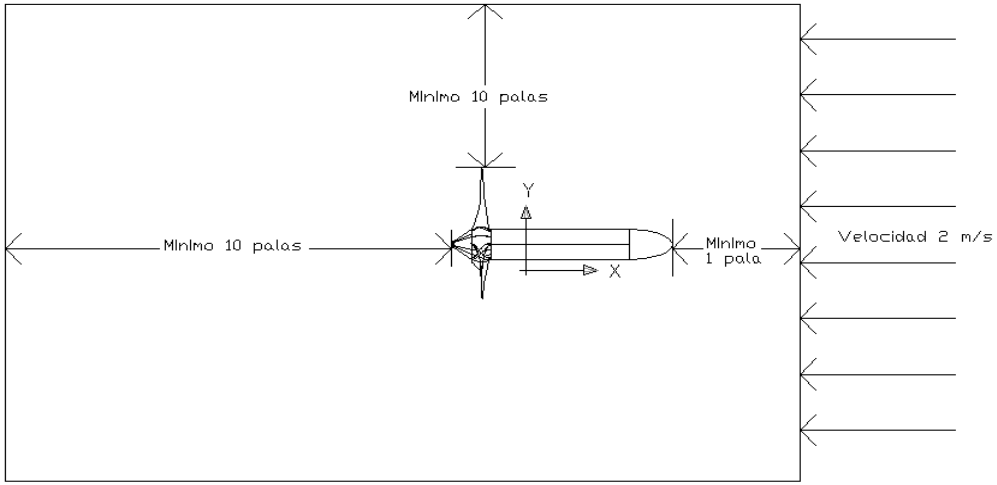


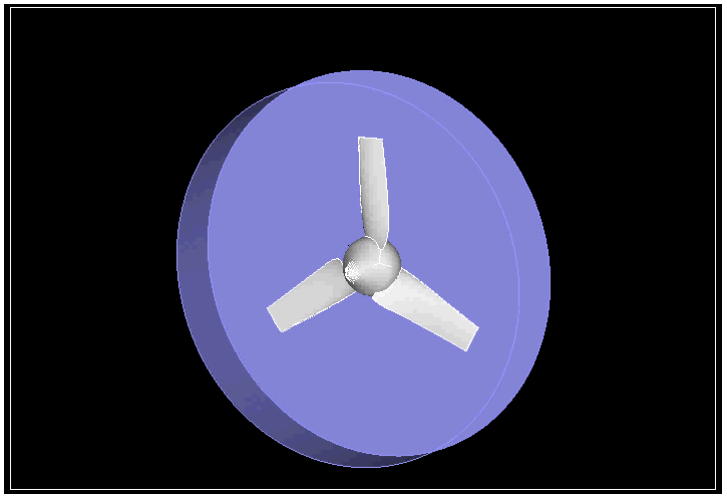
CCAST – SIDERCA v1.1

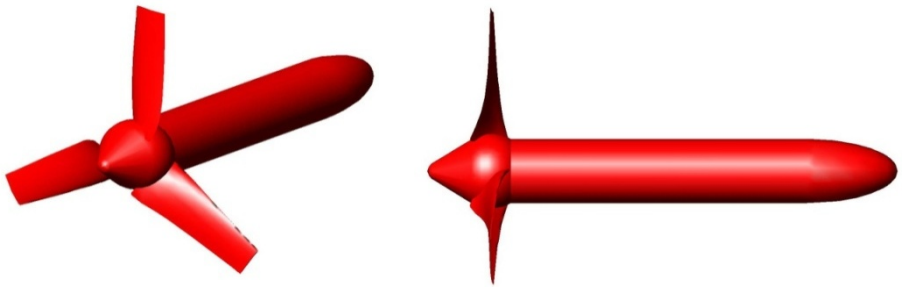
CCAST – DALMINE v1.0

CFD

Free Flow Kinetic Hydropower Turbine

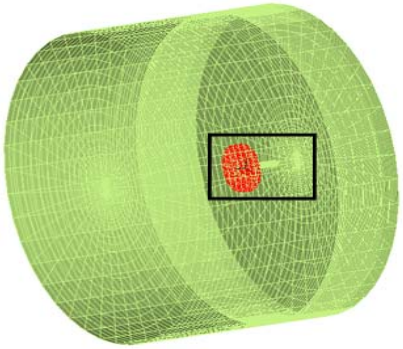


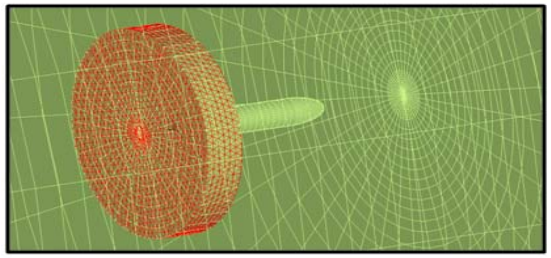


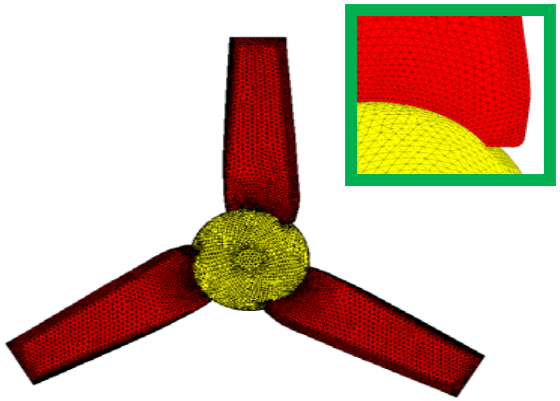


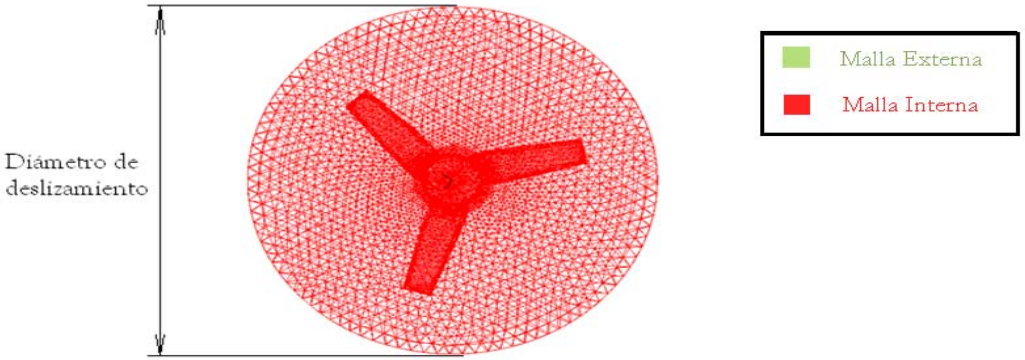
CFD

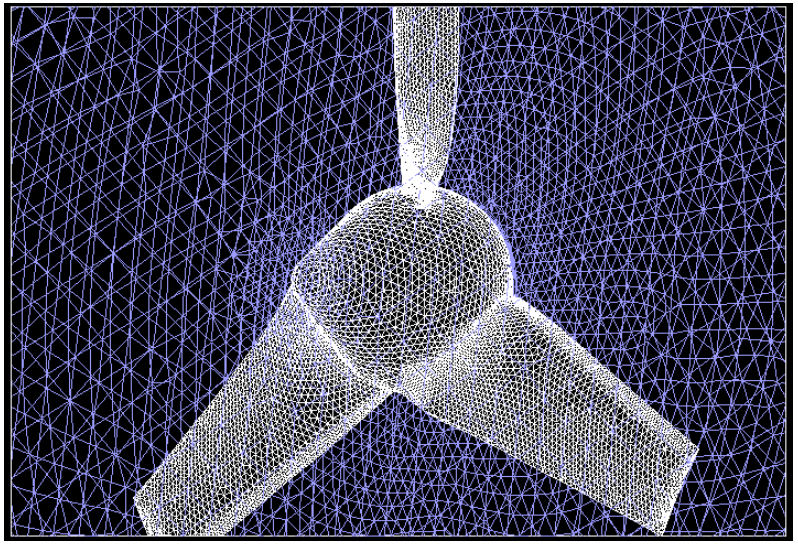
Free Flow Kinetic Hydropower Turbine





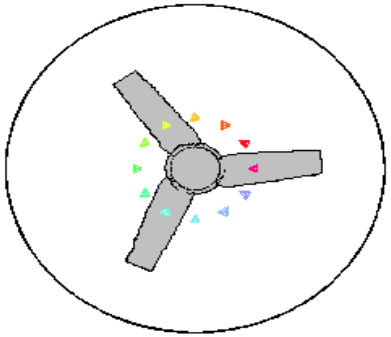




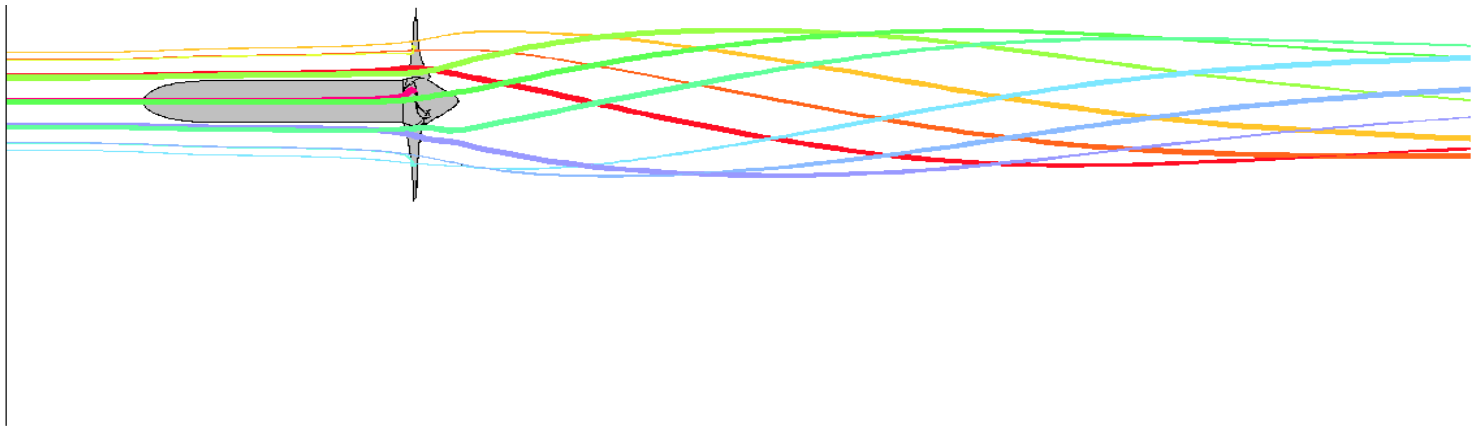


CFD

Free Flow Kinetic Hydropower Turbine

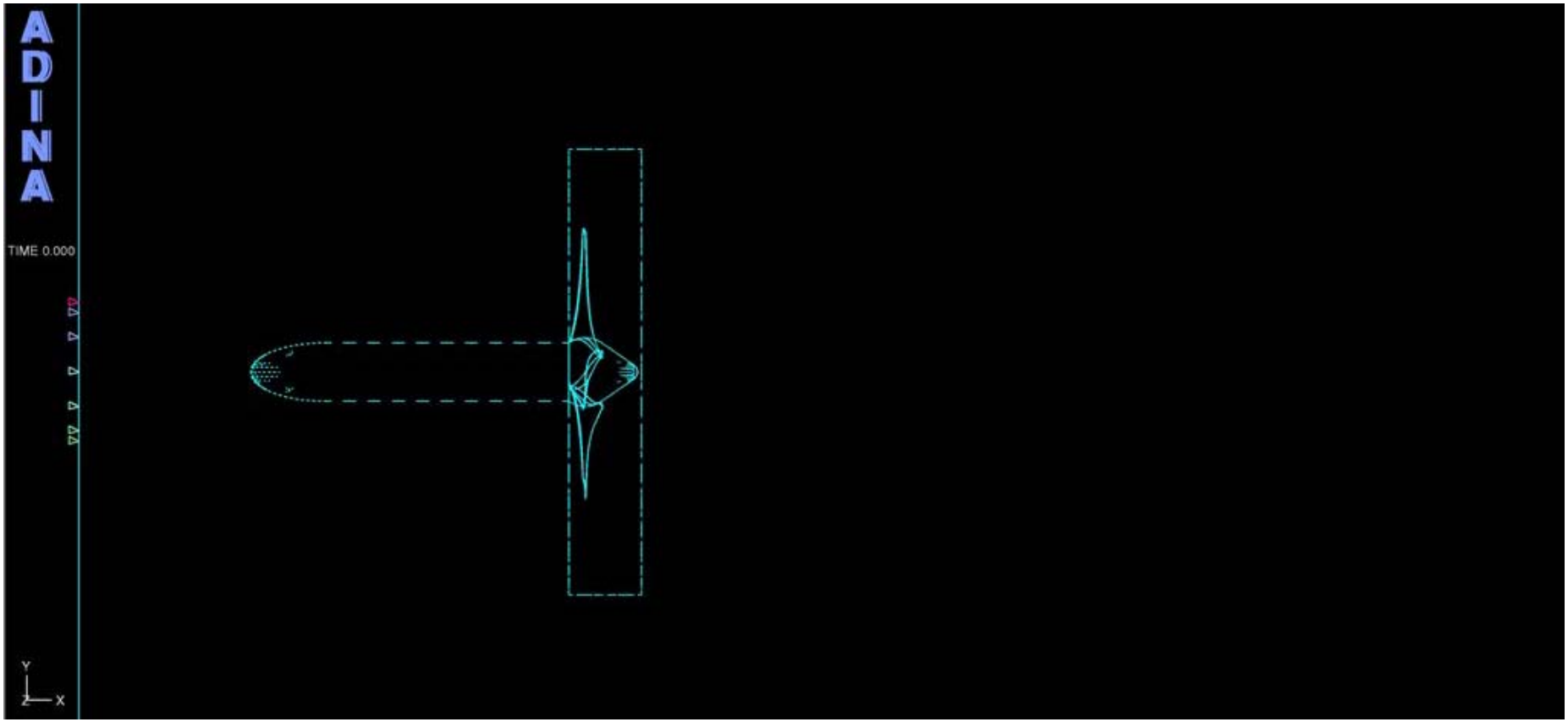


Flow lines



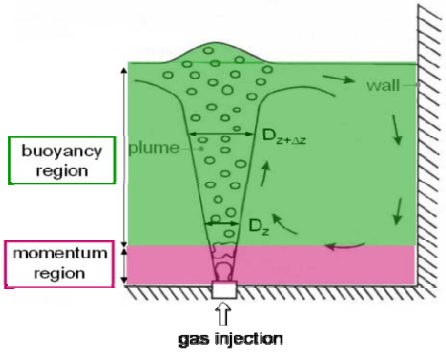
CFD

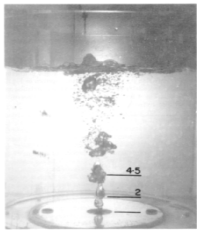
Free Flow Kinetic Hydropower Turbine



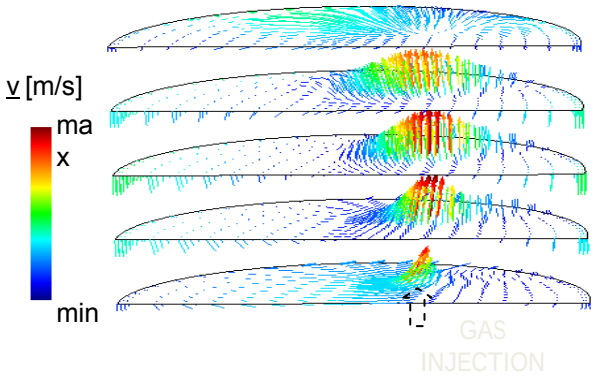
CFD

Dispersed two phase flow: liquid and gas

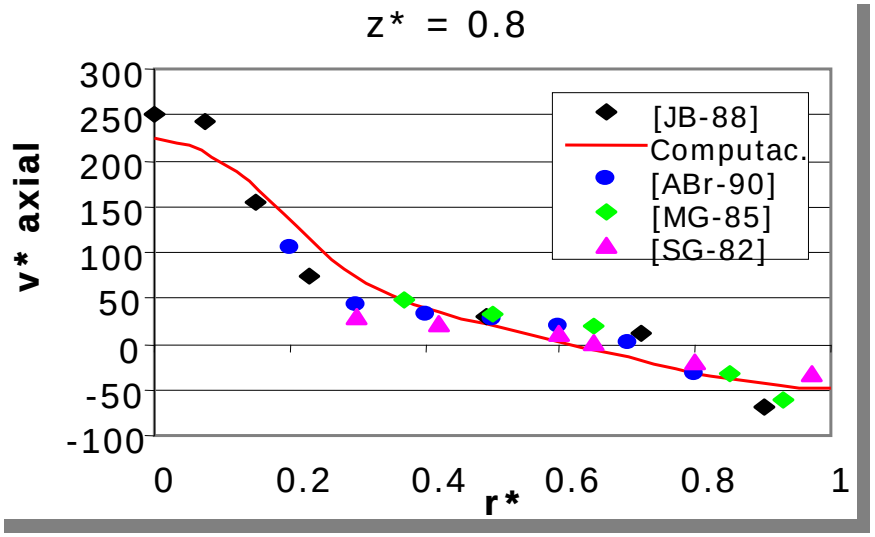


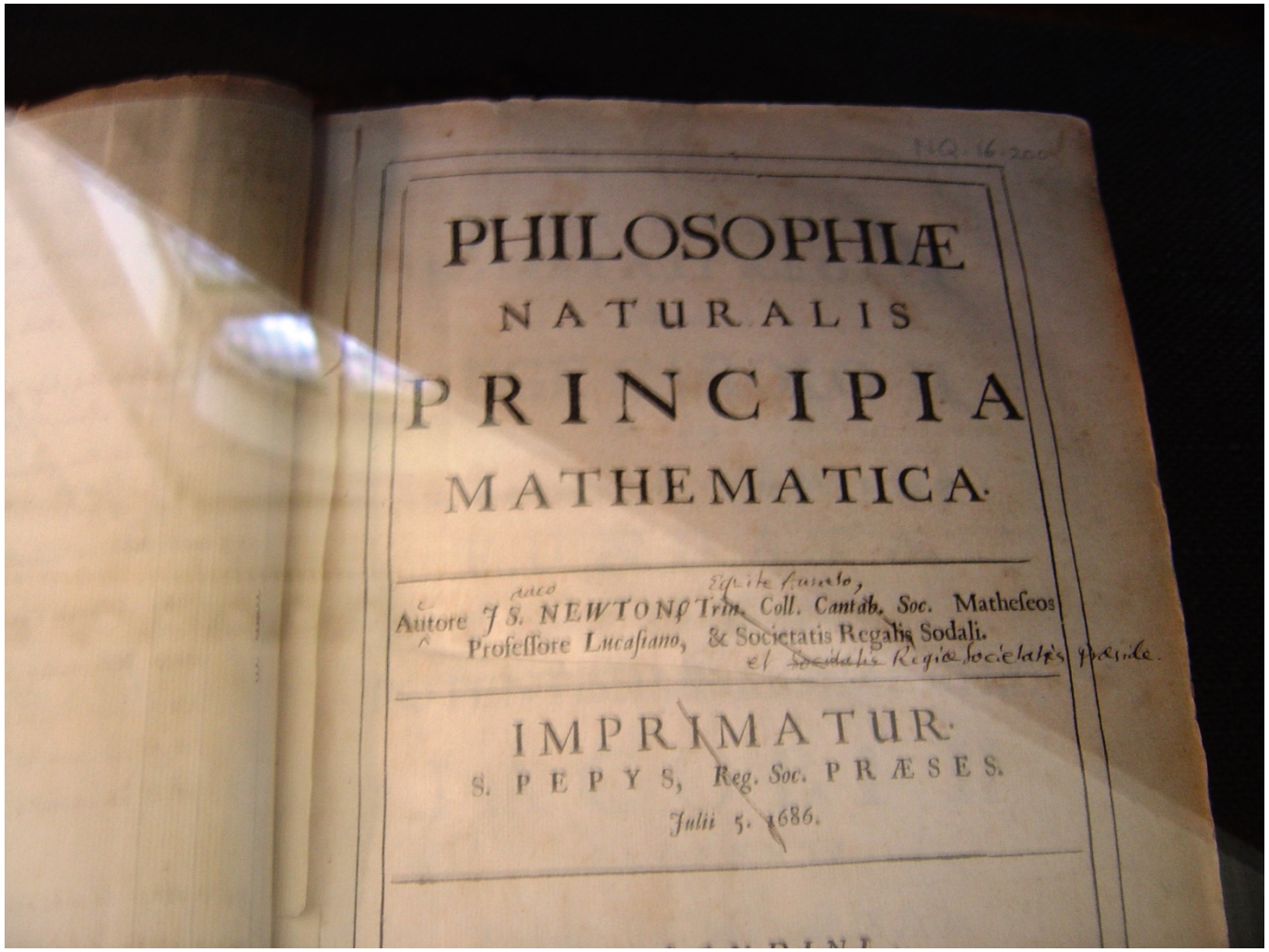


Photograph of the biphasic plume [ABC-88]



Velocity distribution
Coanda effect





PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA.

Autore JS. NEWTONO Trin. Coll. Cantab. Soc. Matheseos
Professore Lucasiano, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, Reg. Soc. PRÆSES.
Julii 5. 1686.