Mechanical design considerations for SPL b=1 cavities

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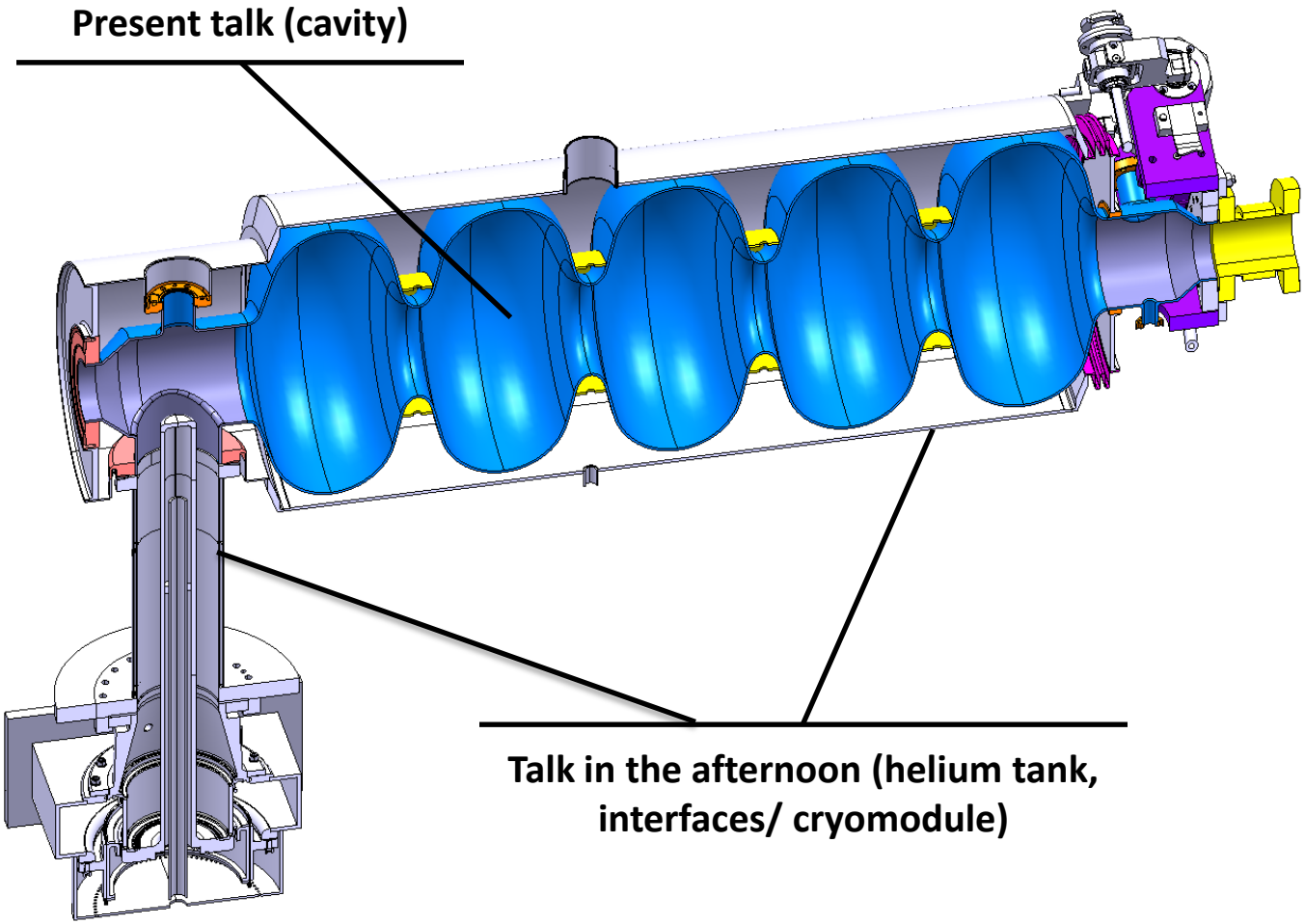
+ discussions and contributions from CEA and CNRS colleagues

Introduction

- SPL beta = 1 cavity + helium tank + tuner + main coupler + bellow to next cavity



β=1 Cavity mechanical considerations

- Ideal shape / dimensions
- From ideal to real
- Mechanical behaviour for real dimensions
  - Static (or quasi-static)
  - Natural vibration modes
  - Bucking
- Status for cavity manufacturing
- Conclusions

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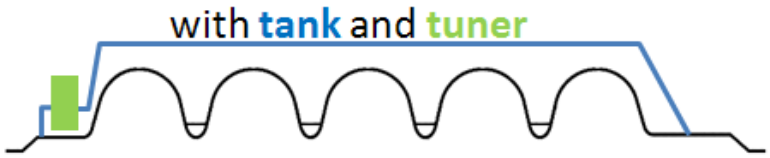
CEA, Saclay

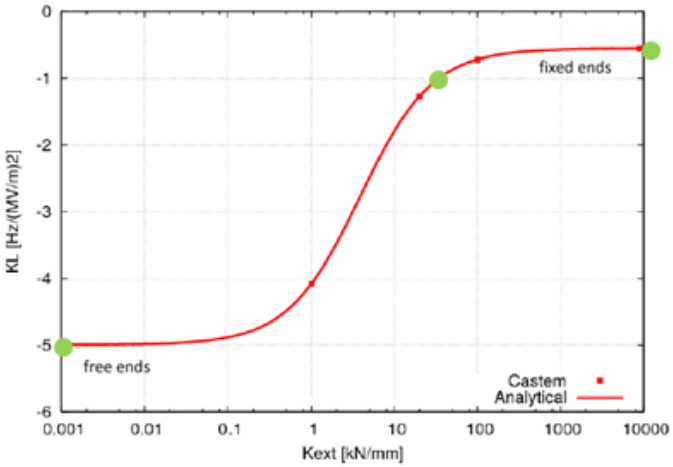
Ideal shape / dimensions

Irfu cea saclay

Mechanical parameters of the cavity

	SPL	HIPPI
Nominal wall thickness [mm]	3	4
Cavity stiffness Kcav [kN/mm]	3.84	2.25
Tuning sensitivity $\Delta f/\Delta z$ [kHz/mm]	164	295
K_L with fixed ends [Hz/(MV/m)²]	-0.55	-2.7
K_L with free ends [Hz/(MV/m)²]	-5	-20.3
Pressure sensitivity K_P [Hz/mbar] (fixed ends)	1.2	





The cavity will be equipped with a Saclay 4 tuner. The stiffness of the HIPPI - Saclay 4 tuner has been measured : K_{ext} 35 kN/mm

The SPL cavity equipped with this tuner would present a detuning coefficient
$|K_L| = 1$ Hz/(MV/m)² ≈ $|K_L|$ estimated for Tesla

From ideal to real

- Manufacturing technology chosen:
  - Half cells to be EB welded
  - Choice for Spinning based on:
    - Half cells dimension
    - Number of cavities to be manufactured
- Process main steps (based on DESY)

Task
Spinnnig of half-cells
Machining for iris and stiffening rings welding preparation
RF measurement of half-cell frequency
Ultrasonic cleaning; Etching (20 µm)
3 µm chemical cleaning if storage time > 8h after previous step
EB welding of the iris from inside
EB welding of stiffening rings

DESY 1.3 GHz dumb-bell

From ideal to real

- Process main steps

Task
Frequency measurement of dumb-bell
Machining of both equator ends / evaluation of frequency
Ultrasonic cleaning; Etching 20 µm
Anodization of dumb-bell and inspection
Grinding if needed + 20 µm etching, rinsed, dried, anodized again
3 µm chemical cleaning
EB welding from outside of all equators (intermediate 3µm etching)
EP 150 microns
UHV annealing at 800°C
Field flatness measurement
flash BCP 10 microns or final EP 30 microns
alcohol rinsing, drying in class 10
UHV baking at 120°
HPR at 100 bars (6 times), drying in class 10

From ideal to real

- First manufacturing tests results
  - Spinning test of half cell bulk Niobium
    - Starting thickness 3 mm & 4 mm
    - Loss in thickness ≈ 0.6 mm



- Optimised start thickness:
  - For cells Nb sheets 3.6 mm
  - For extremities 3.2 mm

From ideal to real

- Spinning test of half cell bulk Copper
  - Dimensions control on-going

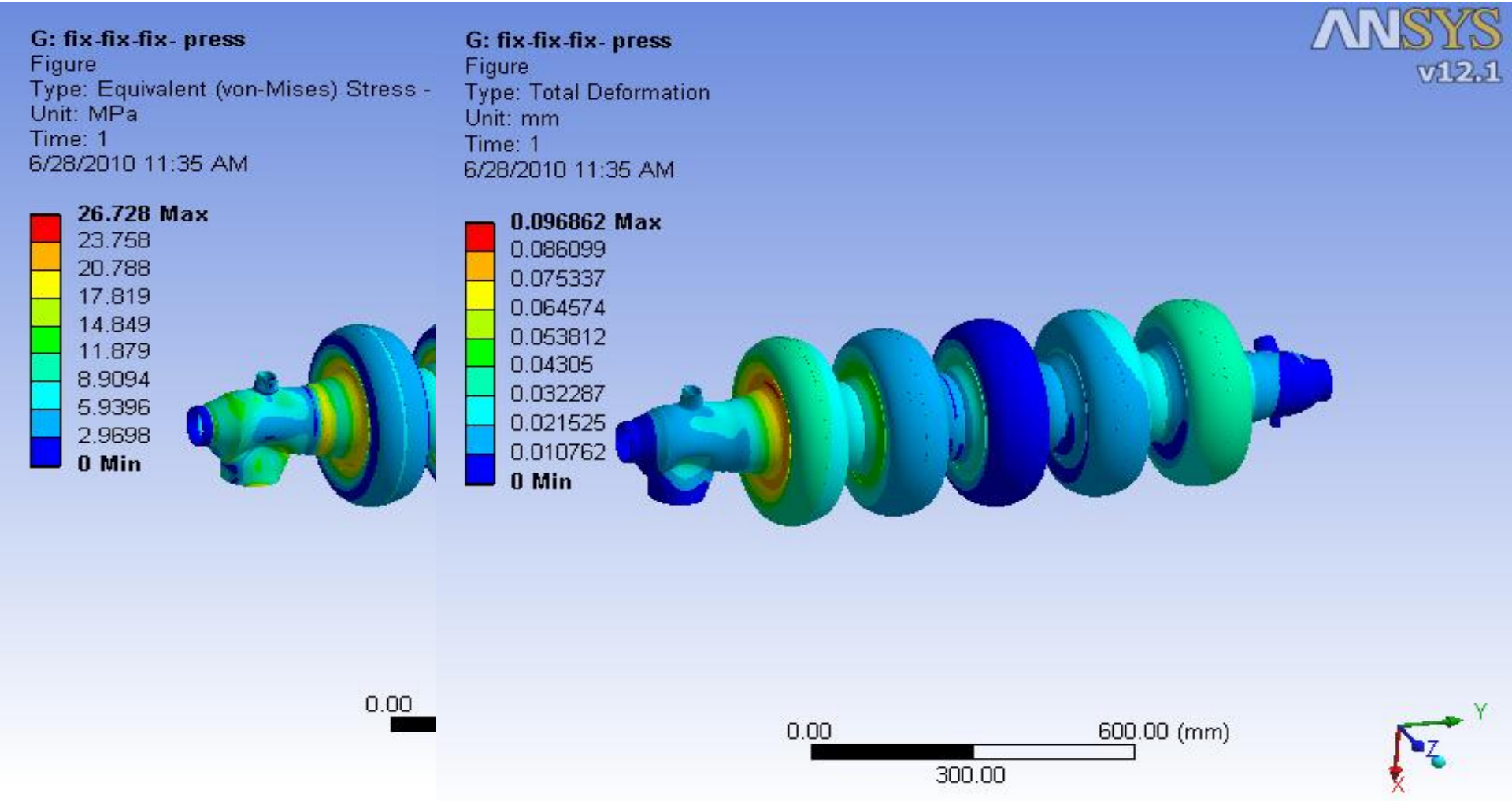
Mechanical behaviour for real dimensions

- Mechanical calculations performed with non uniform thickness (representative for manufacturing tests results)

- Static (quasi-static)
  - Maximum pressure (external)
    - At 300 K : 1.5 bars
    - At 2K: 2 bars
  - Sensibility to pressure fluctuations
  - Lorentz detuning
  - Deformation for tuning
  - Handling configurations

Mechanical behaviour for real dimensions

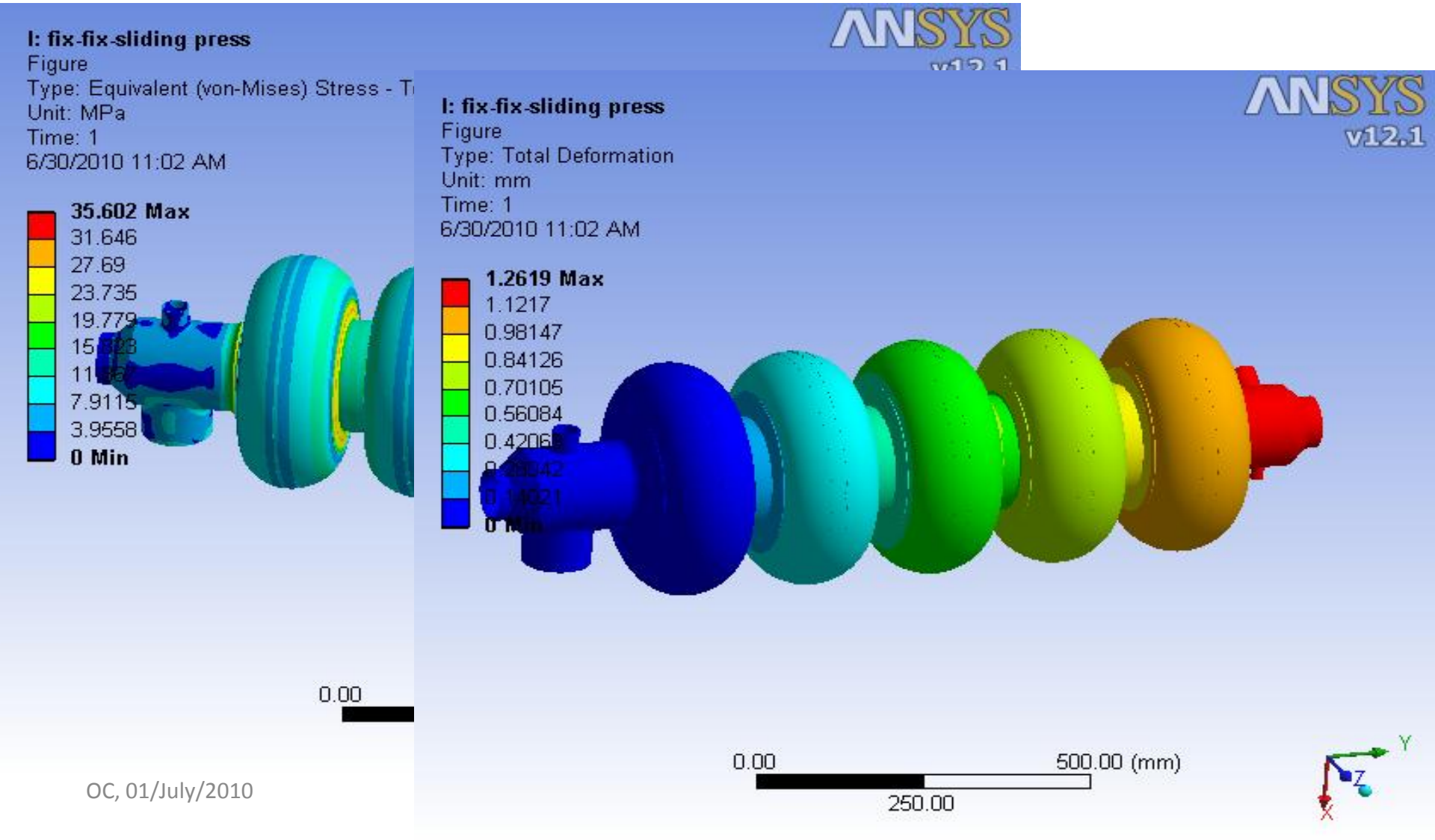
- External pressure of 2 bars – fix-fix boundary condition



- Sensibility to pressure fluctuations => one order of magnitude lower that the frequency bandwidth

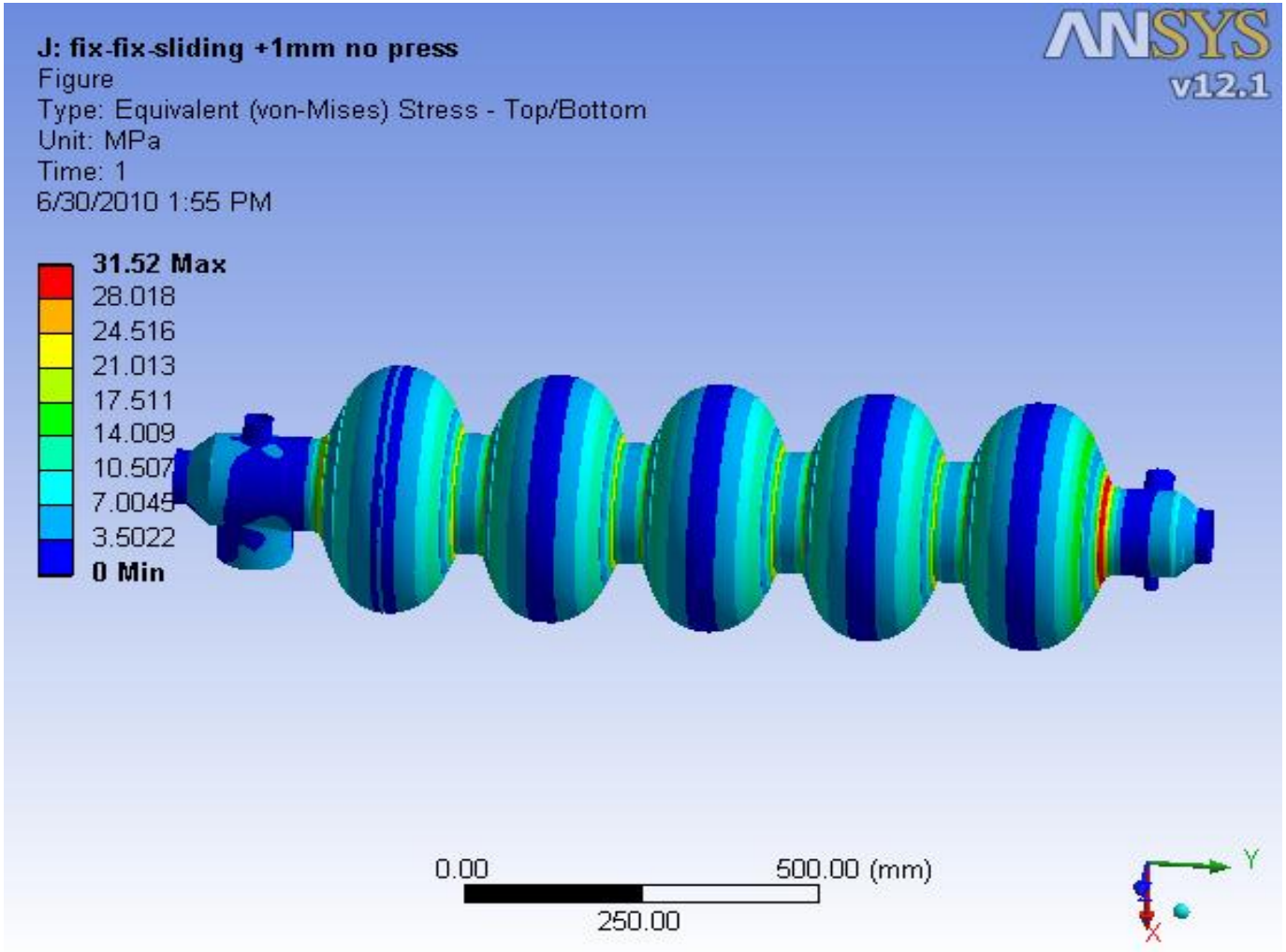
Mechanical behaviour for real dimensions

- External pressure of 2 bars – fix-sliding boundary condition



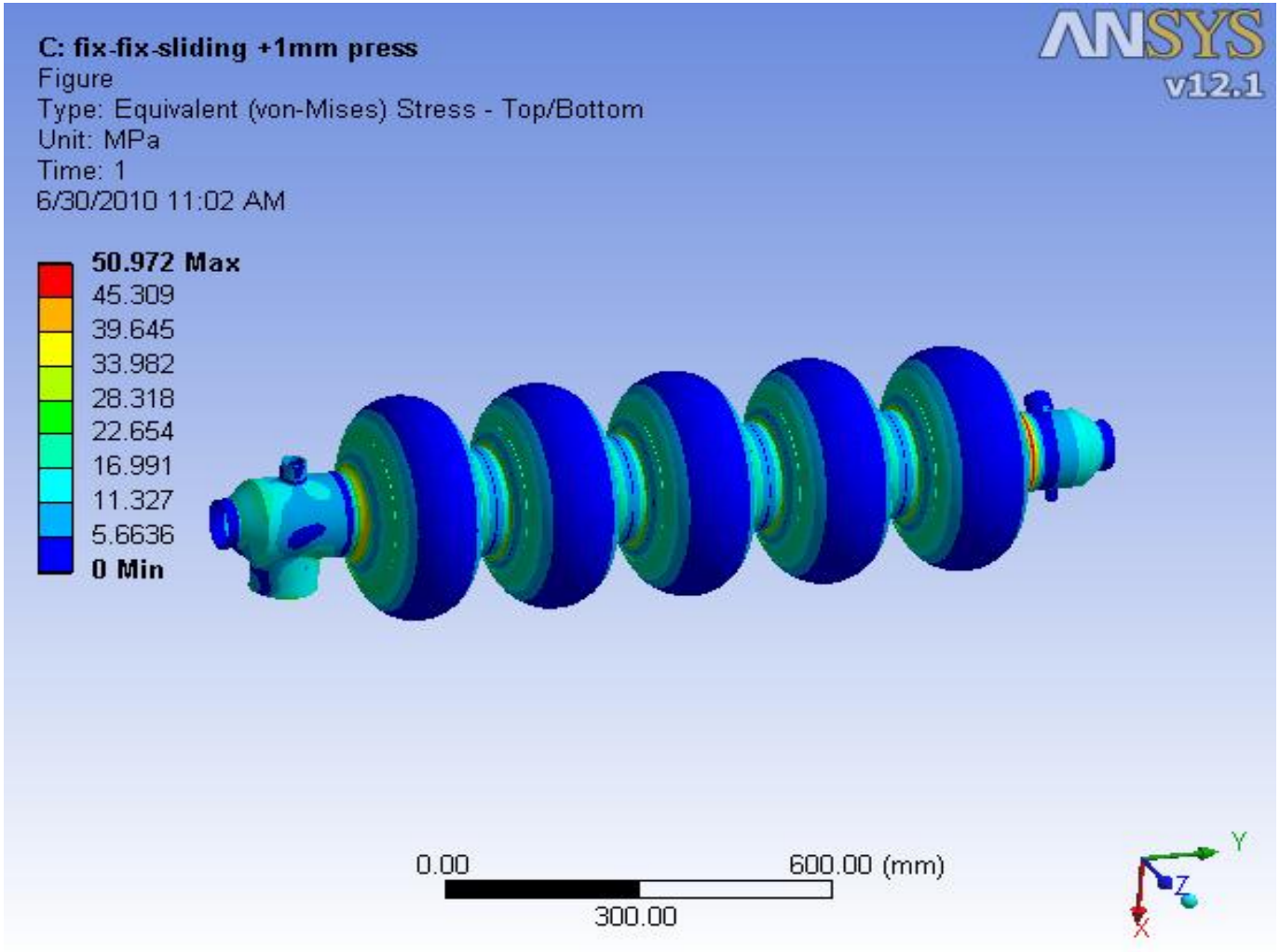
Mechanical behaviour for real dimensions

- Deformation for tuning of 1mm longitudinal



Mechanical behaviour for real dimensions

- External pressure (external) of 2 bars + 1mm deformation for tuning



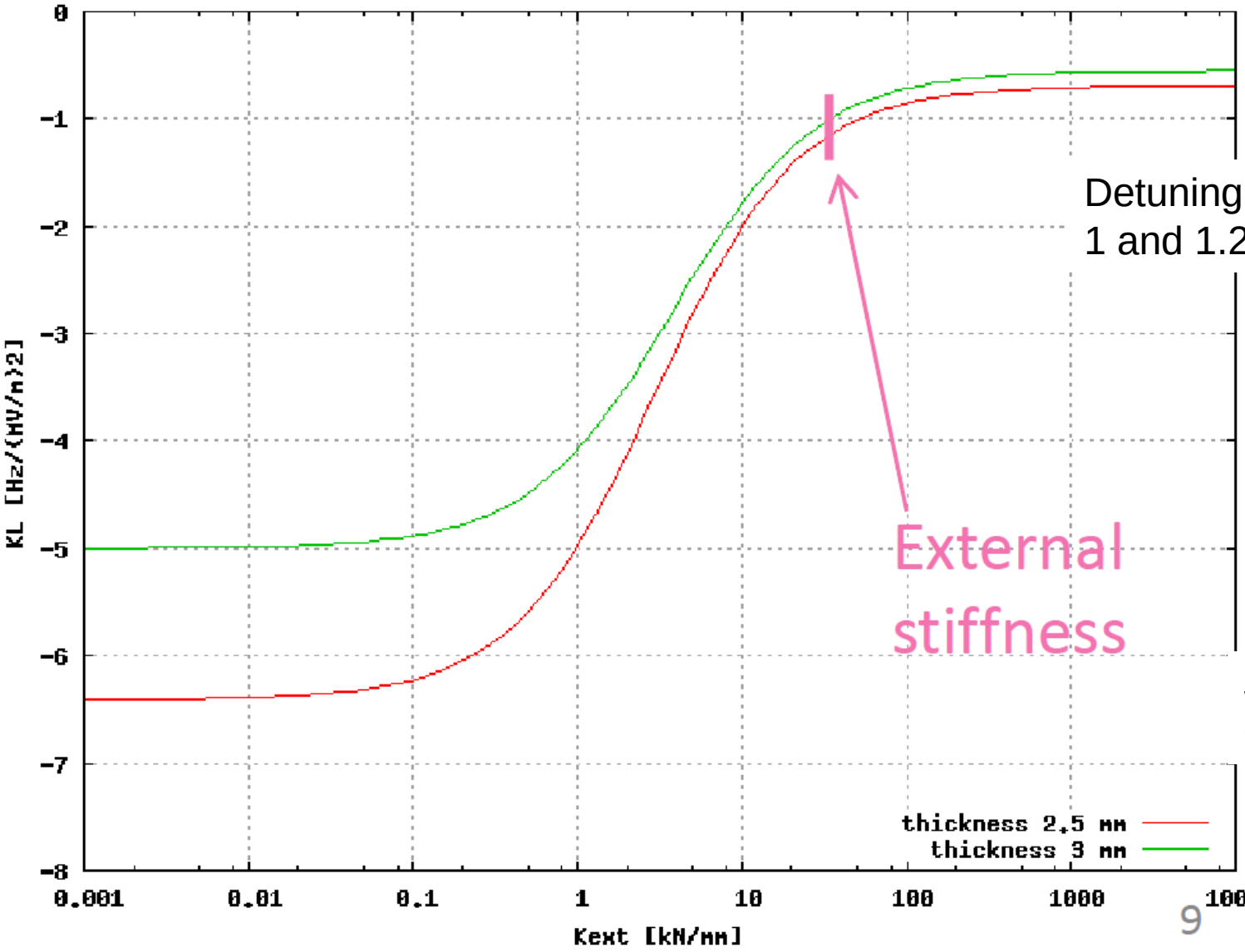
Mechanical behaviour for real dimensions

- Maximum stress (MPa) for niobium for different static load cases

	Calculated stress					Allowable stress	
	2 bars; free extrem	2 bars; fixed extrem	2 bars + 1mm (traction)	2 bars – 1mm (compress)	0 bars + 1mm	At 300K	At 2K
Non uniform based on manufacturing results	**~35 MPa**	**~25 MPa**	**~50 MPa**	**~35 MPa**	**~30 MPa**	**50 Mpa**	**400 Mpa**

Mechanical behaviour for real dimensions

- Lorentz detuning



Detuning between
1 and 1.2 Hz/(MV/m^2)

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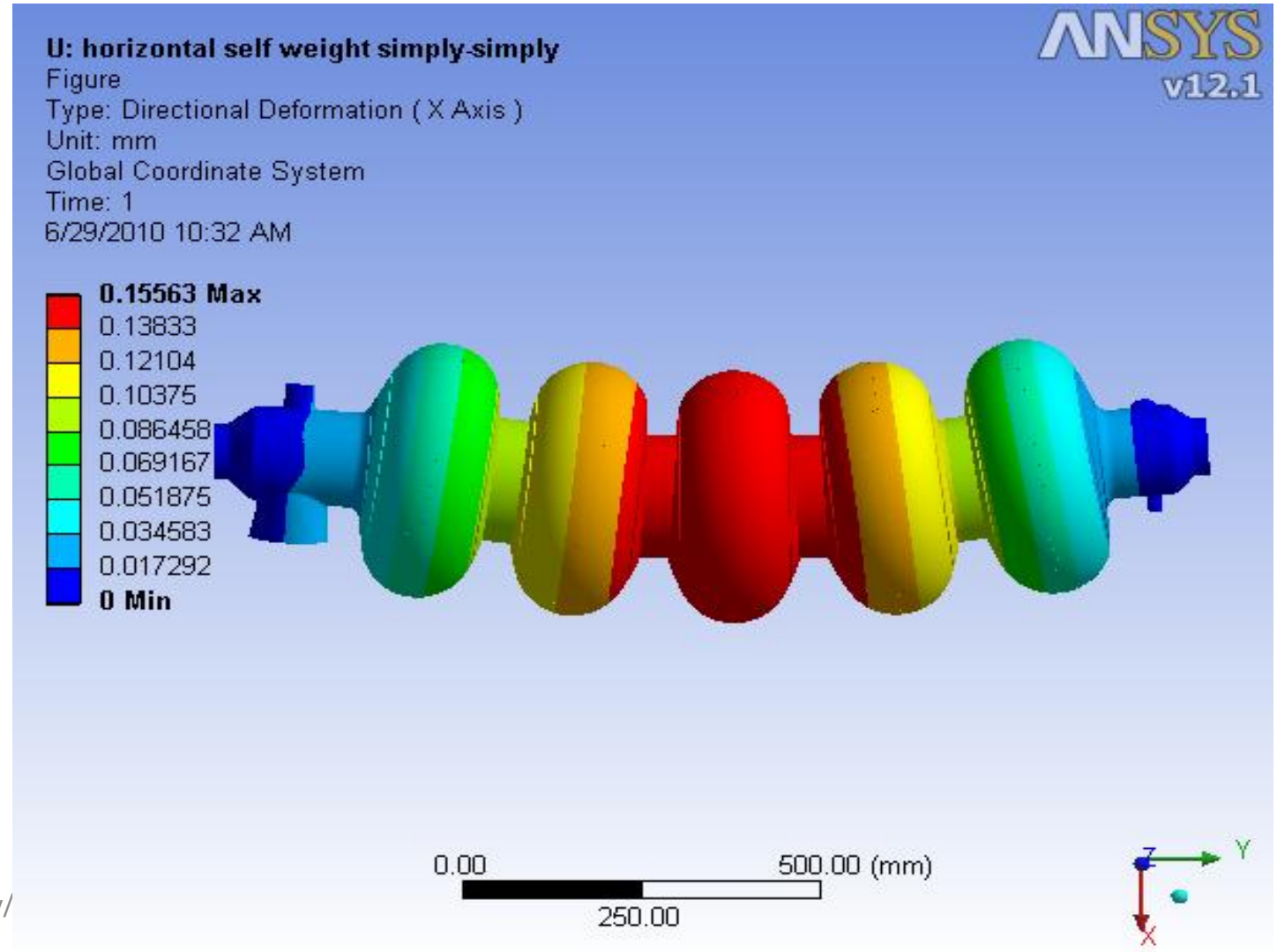
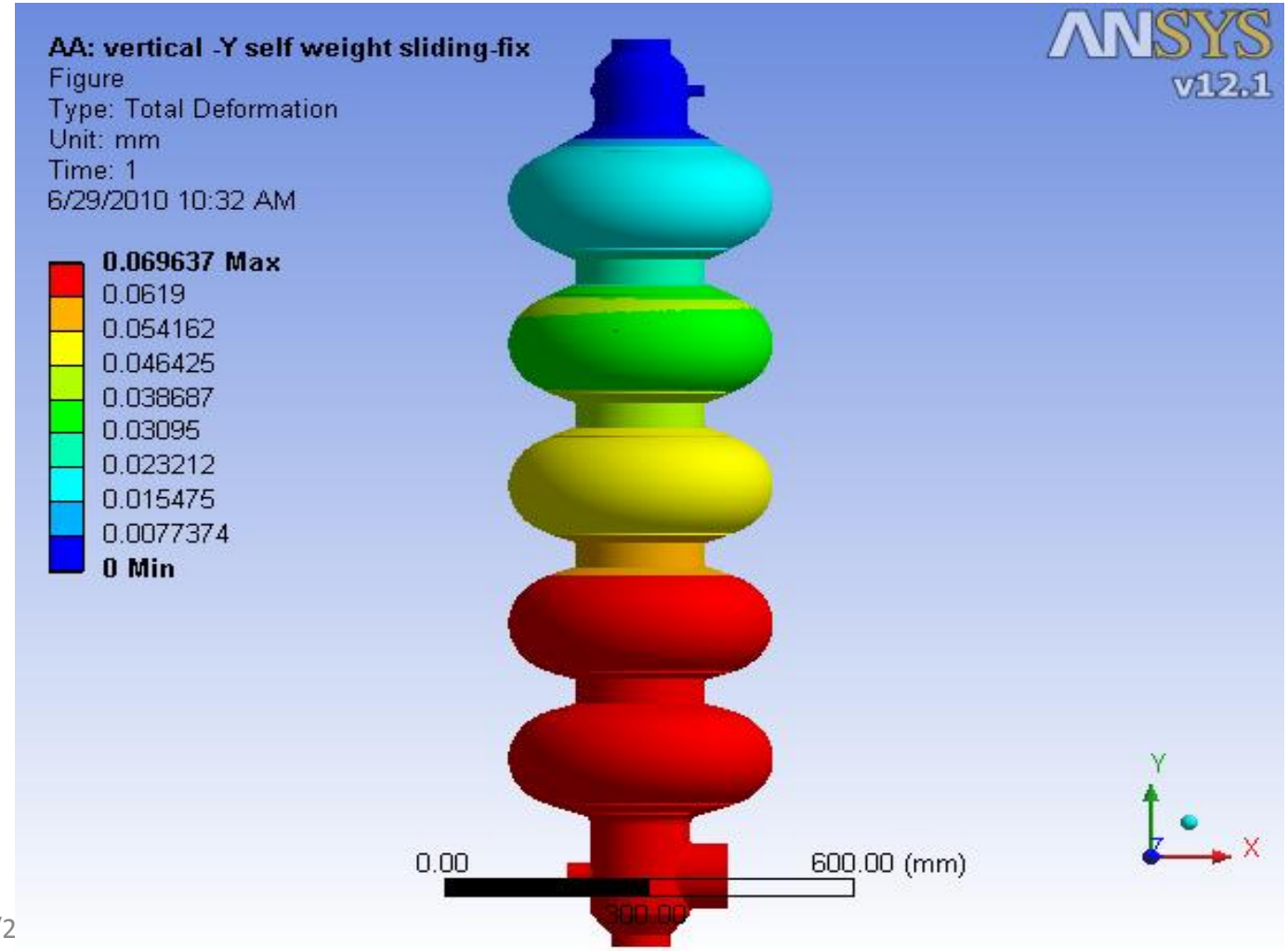
Mechanical behaviour for real dimensions

- Cavity under own weight – horizontal simply supported: 0.15 mm maximum deflection



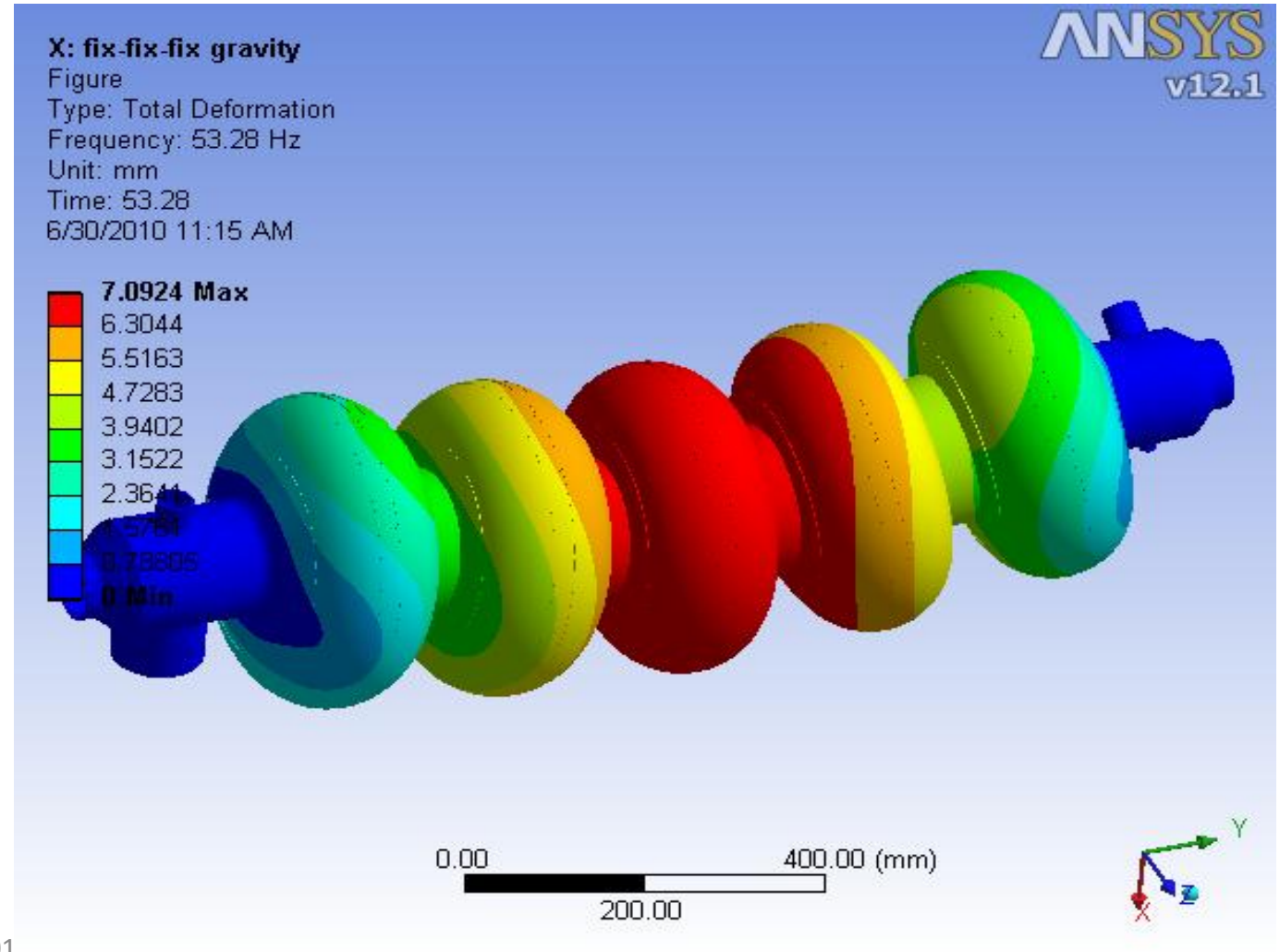
Mechanical behaviour for real dimensions

- Cavity under own weight – vertical fixed at one end: maximum deformation 0.07 mm



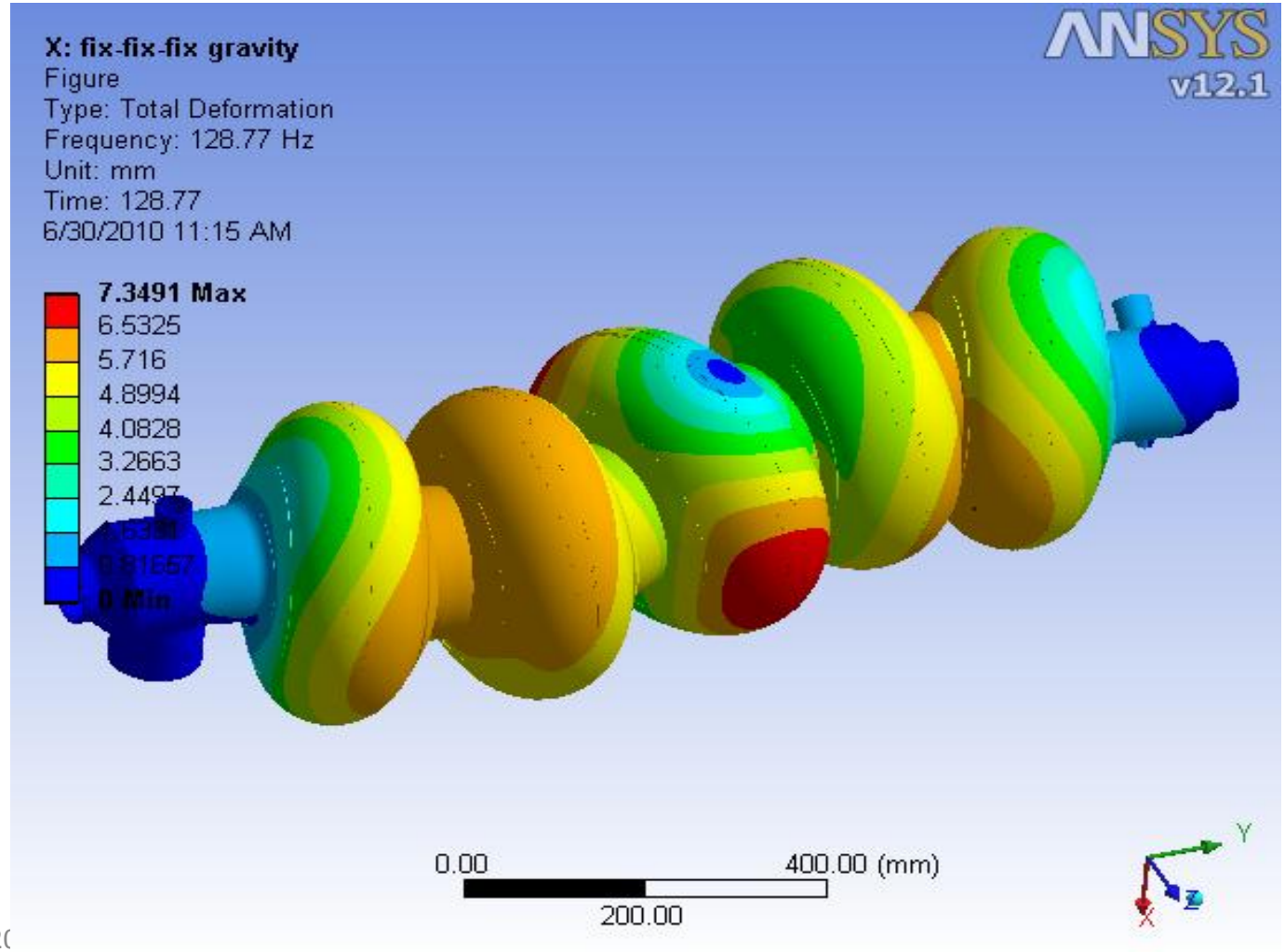
Mechanical behaviour for real dimensions

- Dynamic (natural frequencies):
  - 1st mode at ~50 Hz (transverse)



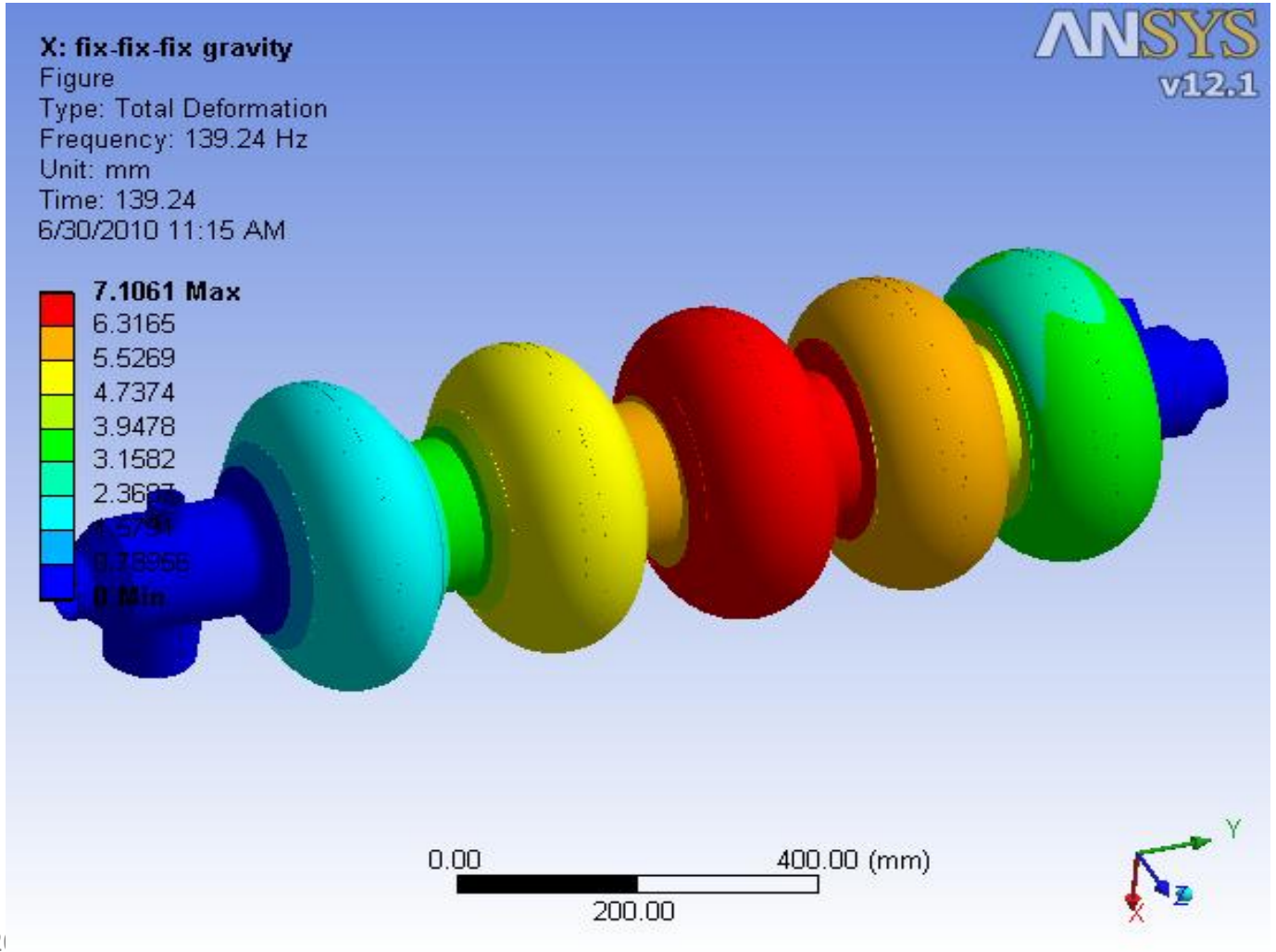
Mechanical behaviour for real dimensions

- Dynamic (natural frequencies):
  - 2nd mode at ~130 Hz (transverse)



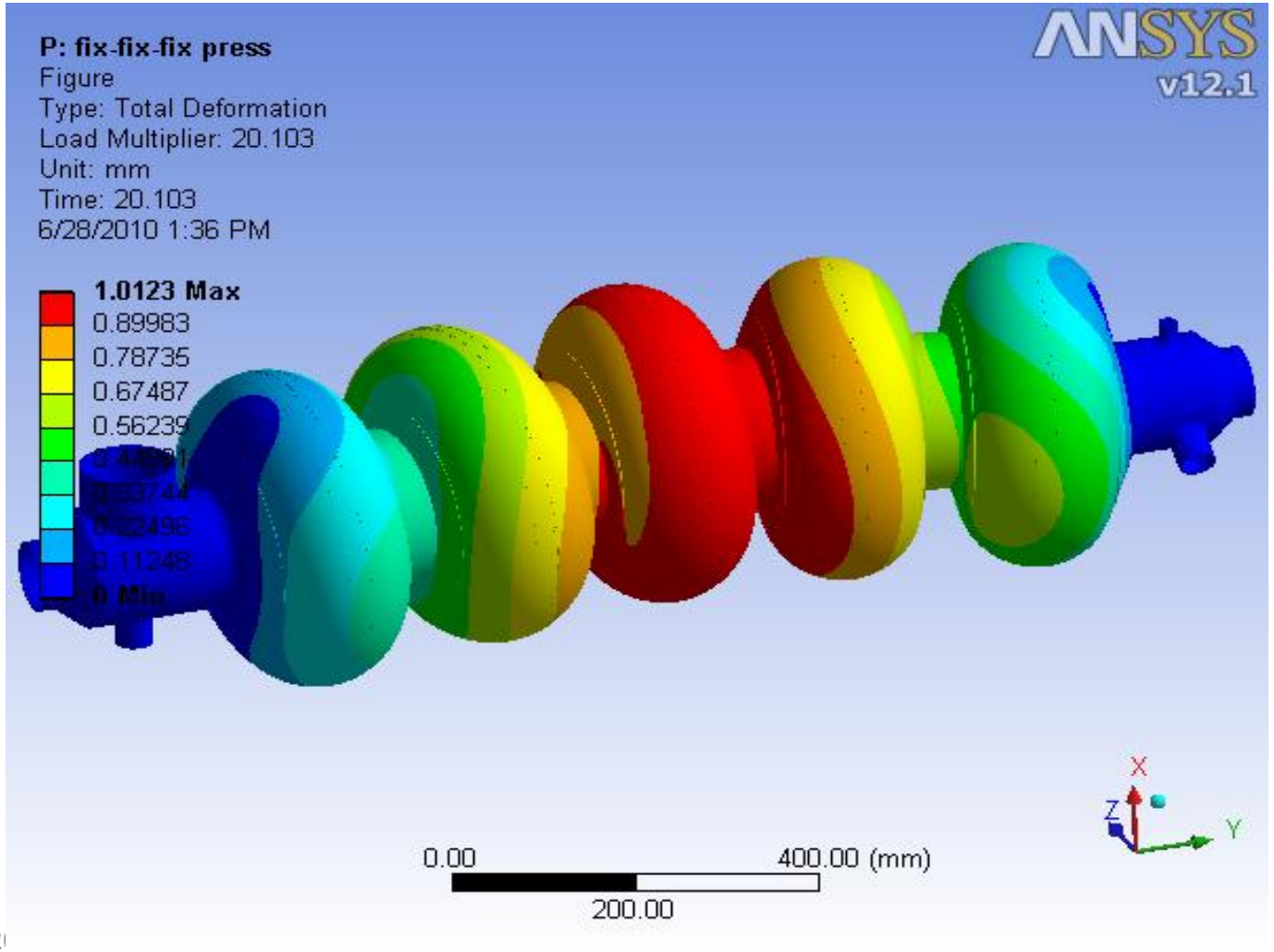
Mechanical behaviour for real dimensions

- Dynamic (natural frequencies):
  - 3nd mode at ~140 Hz (longitudinal)



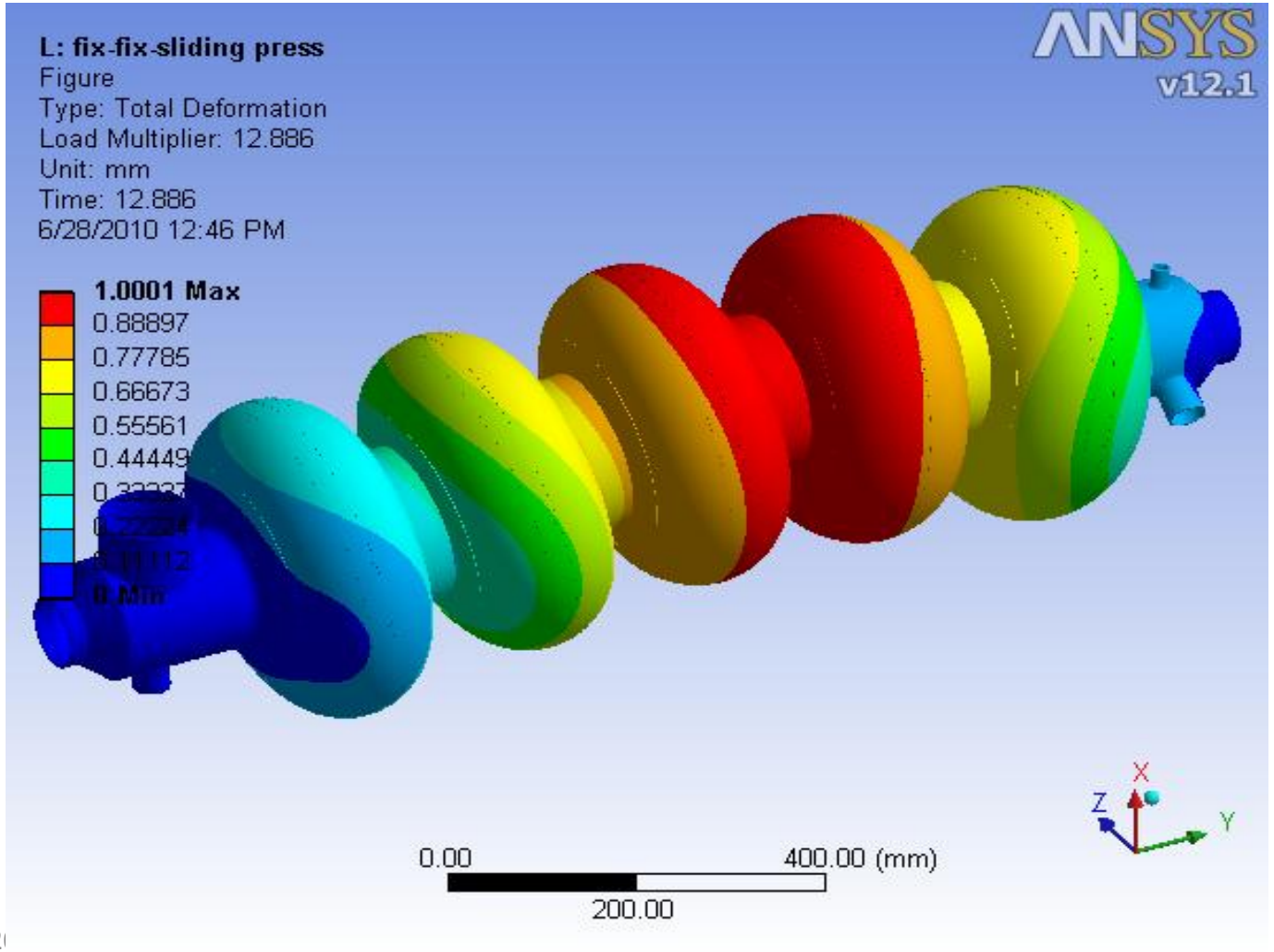
Mechanical behaviour for real dimensions

- Bucking under external pressure for fix-fix boundary conditions: security factor 20



Mechanical behaviour for real dimensions

- Bucking under external pressure for fix-sliding boundary conditions: security factor 12



Status for cavities manufacturing (at CERN)

- 2 (3 TBC) copper cavities to be manufactured by end 2010
- Niobium RRR=300 (cavity) and RRR=40 (stiffening rings)
  - Specification defined
  - Invitation to tender sent to 7 companies worldwide for procurement equivalent of 4 cavities + 25% spares
- 4 Nb cavities to be manufactured by end of 2011
  - *Rmq*: HOM coupler design still to be defined
- 4 additional Nb cavities to be manufactured by end of 2013

Conclusions

- Conclusions
  - Mechanical shape / dimensions fixed
  - Manufacturing technology chosen, manufacturing tolerances still TBC
  - First manufacturing results => dimensions for Nb sheets and info on final cavity non uniform thickness
  - Mechanical calculations:
    - Below allowable maximum stress for static calculations
    - Low frequency of transversal vibration modes (first at ~ 50 Hz)
    - Safety factor large enough to avoid buckling under external pressure
  - Invitation to tender sent for Niobium procurement equivalent to 4 cavities + 25%
- More details on Indico cavity WG meetings

  http://indico.cern.ch/categoryDisplay.py?categId=2722