



Vibration and Powertrain LAB. INTERMECH

<http://www.vibrazioni.unimore.it>



Francesco Pellicano

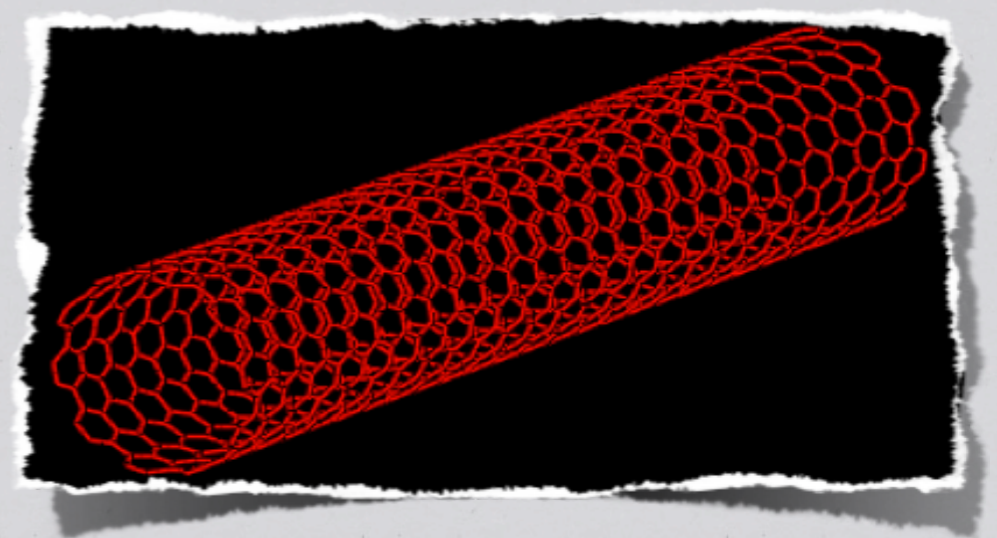
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Università di Modena e Reggio Emilia, Via P. Vivarelli 10/1, 41125 Modena

Scientific research

- ▶ Structural dynamics/vibration
 - Numerical modeling
 - Experimental testing
 - Fluid structure interaction
 - Carbon Nanotubes
 - Lubrication



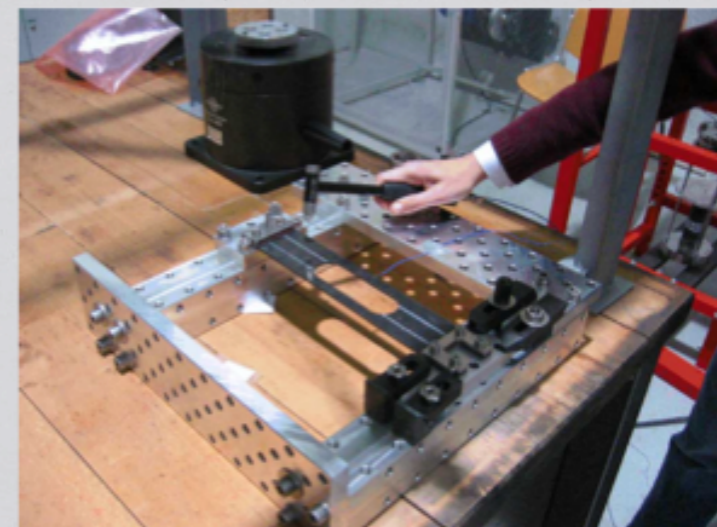
Industrial research

▶ Mechanical transmissions

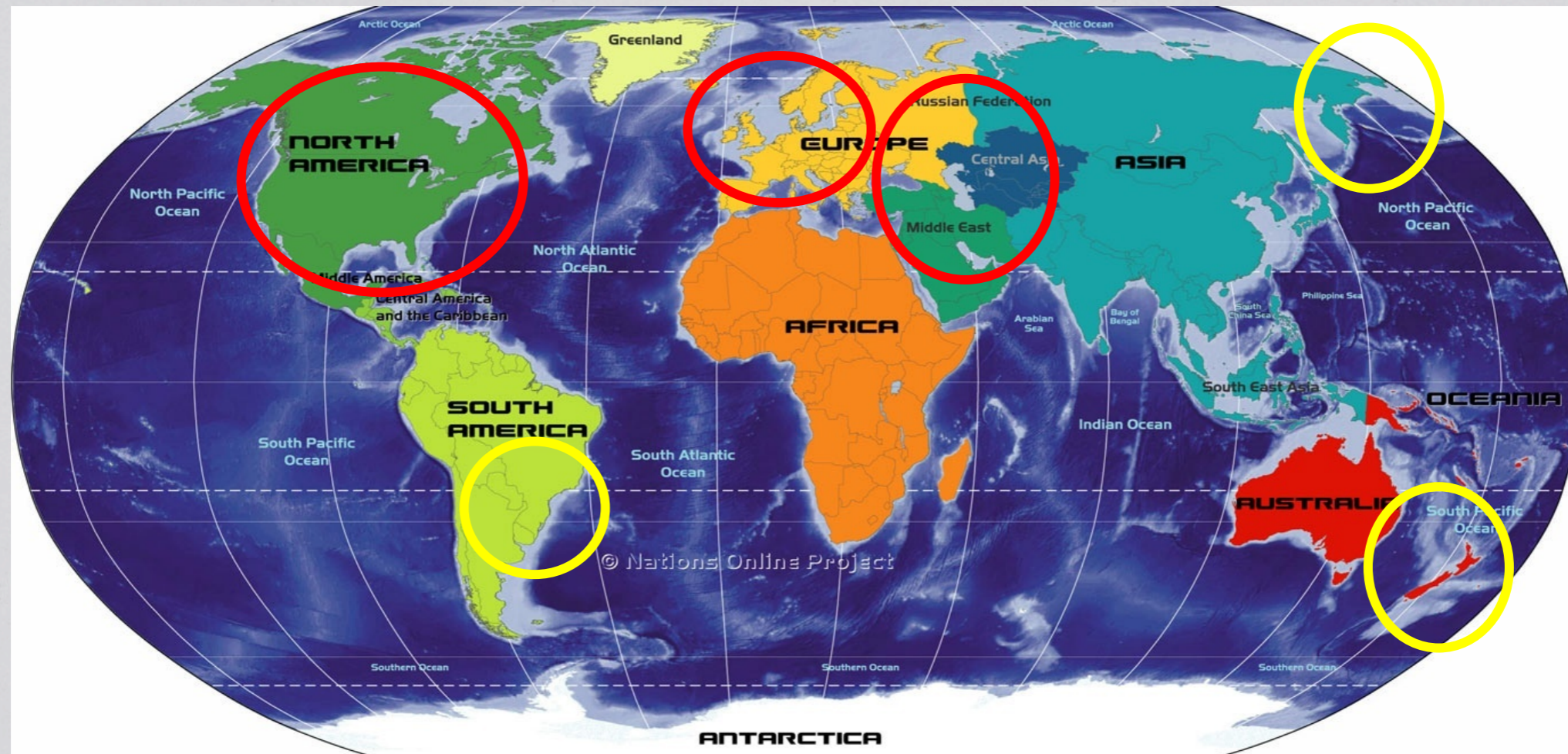
- NVH
- Deformation, stress and durability
- Optimization
- Wear/fatigue/lubrication

▶ Service

- Measurement
- Experimental modal analysis
- Mechanical tests (endurance, dwell...)



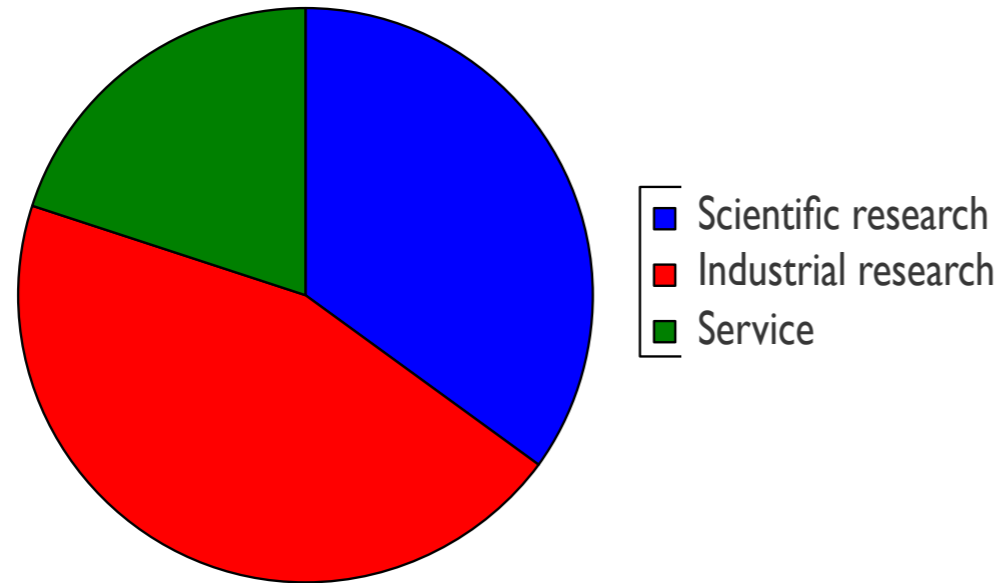
International cooperations



- America (**US, Canada, Brasil**)
- Europa (**UK, France,...**)
- East-Europe/Asia (**Ukraine, Russia, ...**)
- Middle East (**Iran**)
- Oceania (**New Zeland**)

- Gear Lab, OHIO State Univ. (US)
- Loughborough University (UK)
- INSA Lyon
- KPI Univ. (Kharkov)
- Semenov Institute (Moscow)
- Kerman University (Iran)
- Waitako University (Hamilton)

Founding



Lab investments

- **People**
 - **High education**
- **Equipments**
- **Software**
- **International cooperations**

ABOUT 400k€ INVESTMENT IN 5 YEARS

ADDITIONAL 200k€ FROM INDIRECT PRIVATE SUPPORTERS

PUBLIC FOUNDING:

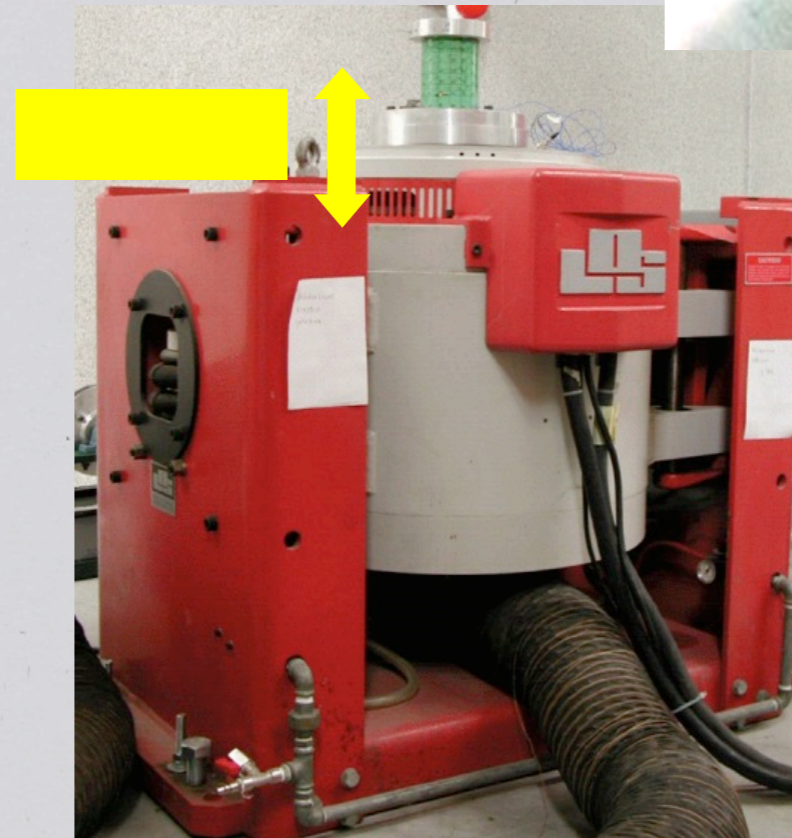
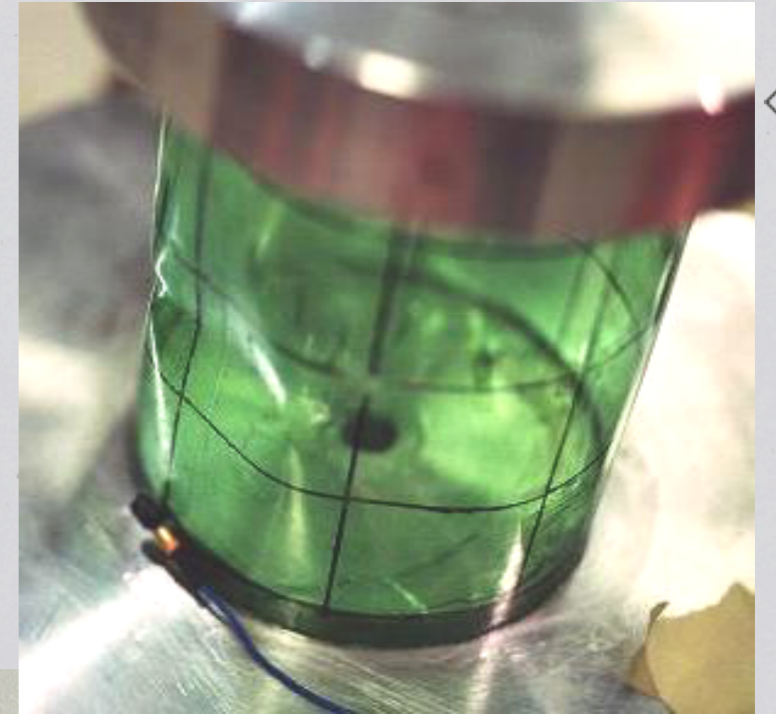
- ASI, MIUR, UNIVERSITY up to 2005
- Emilia Romagna Region (SIMECH/INTERMECH More) 2007-2011

PRIVATE FOUNDING:

- Industrial contracts
- Services
- Bank Foundations (by means of SIMECH/University)

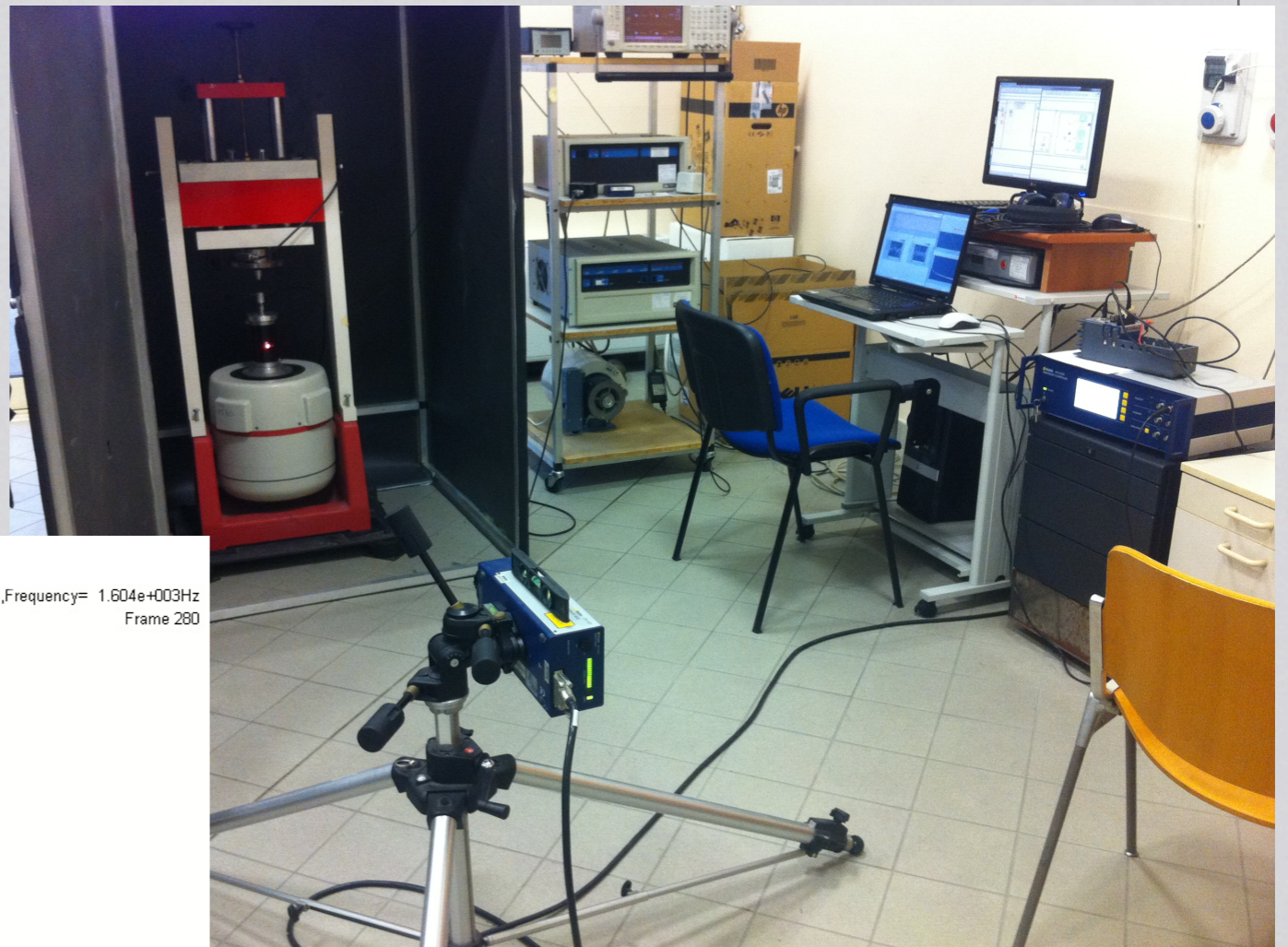
Dynamics of thin walled structures

- Development of new theories for thin walled structures: SPACE APPLICATIONS
- Nonlinear Dynamics, Stability, Fluid-Structure interaction
- Dynamic tests on shaking table
- Modal analysis (numerical and experimental)

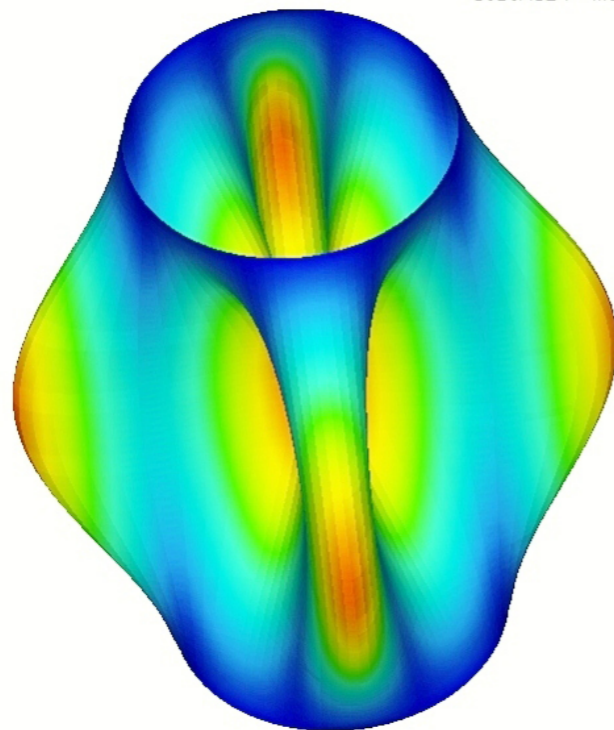


Dynamics of thin walled structures

- Modeling and testing on prestressed circular cylindrical shells
- Non linear dynamics



Contour Plot
Displacement(Mag)
Analysis system
2.374E+01
2.111E+01
1.847E+01
1.583E+01
1.319E+01
1.055E+01
7.915E+00
5.277E+00
2.638E+00
0.000E+00
No result
Max = 2.374E+01
Node 1147336
Min = 0.000E+00
Node 1136851

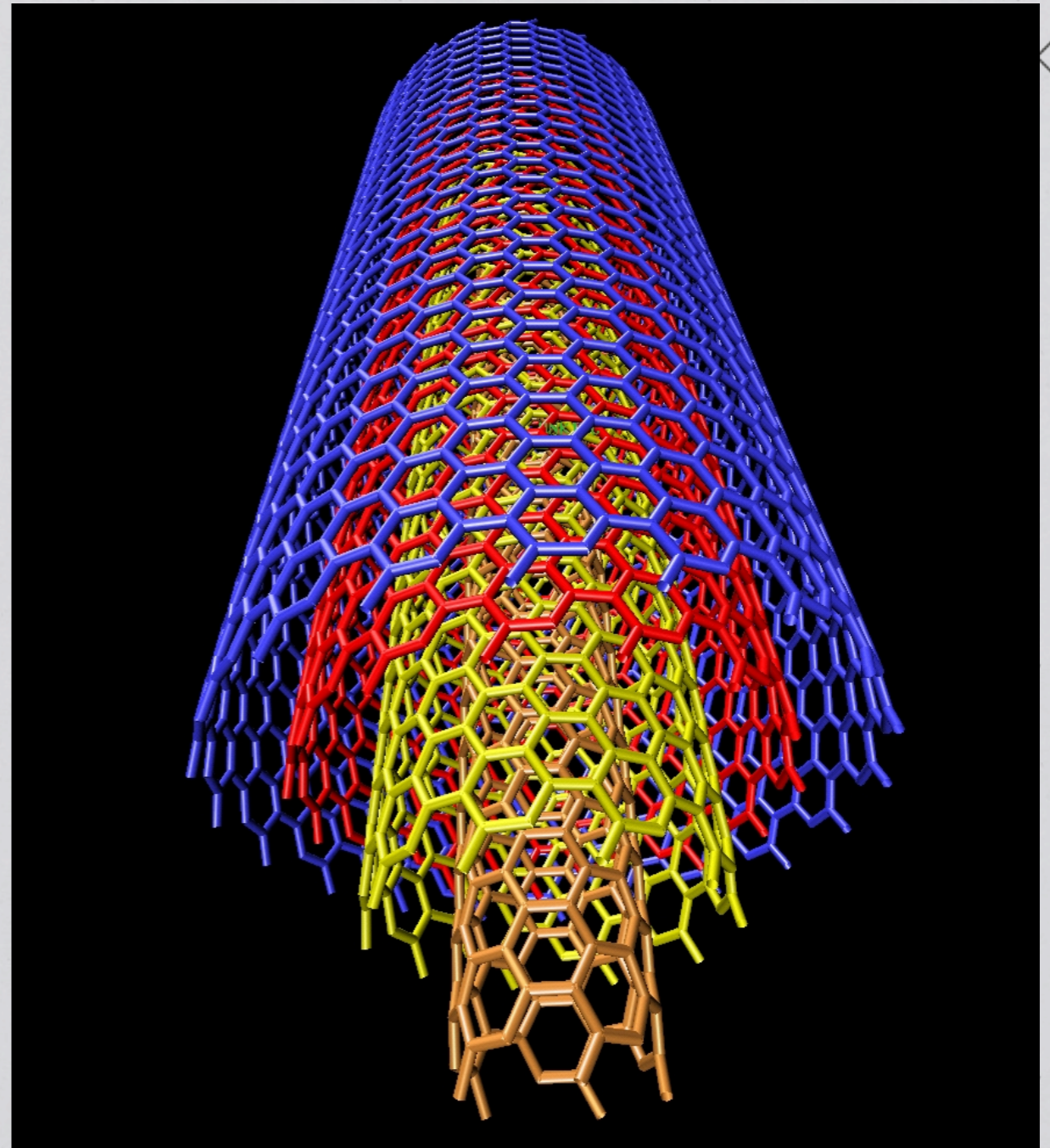


SUBCASE 1 = MODALE : Mode#9, Frequency= 1.604e+003Hz
Frame 280

Dynamics of Carbon Nanotubes

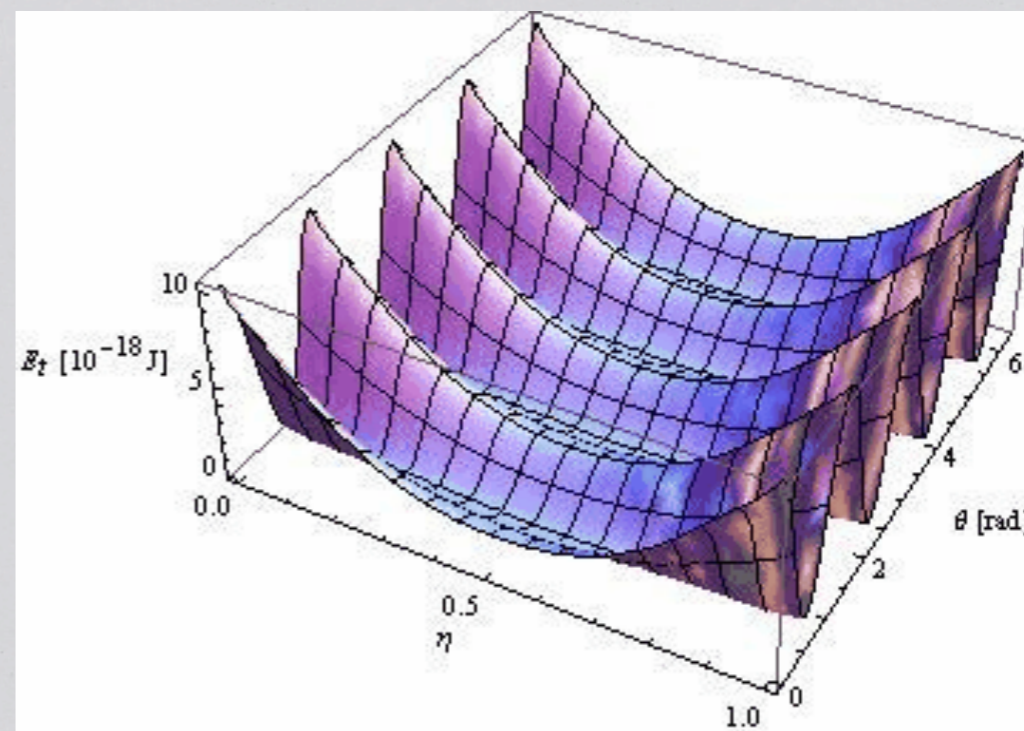
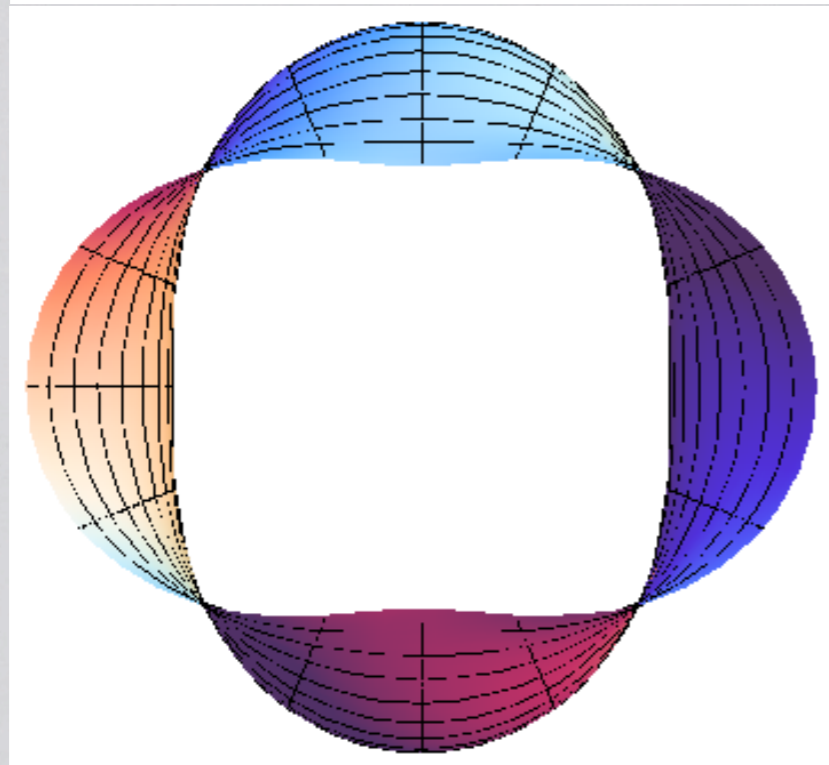
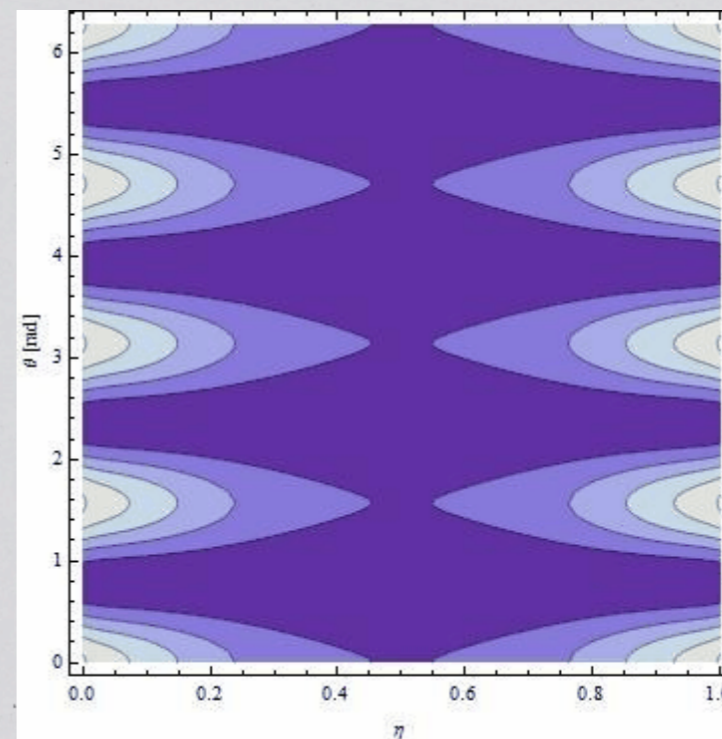
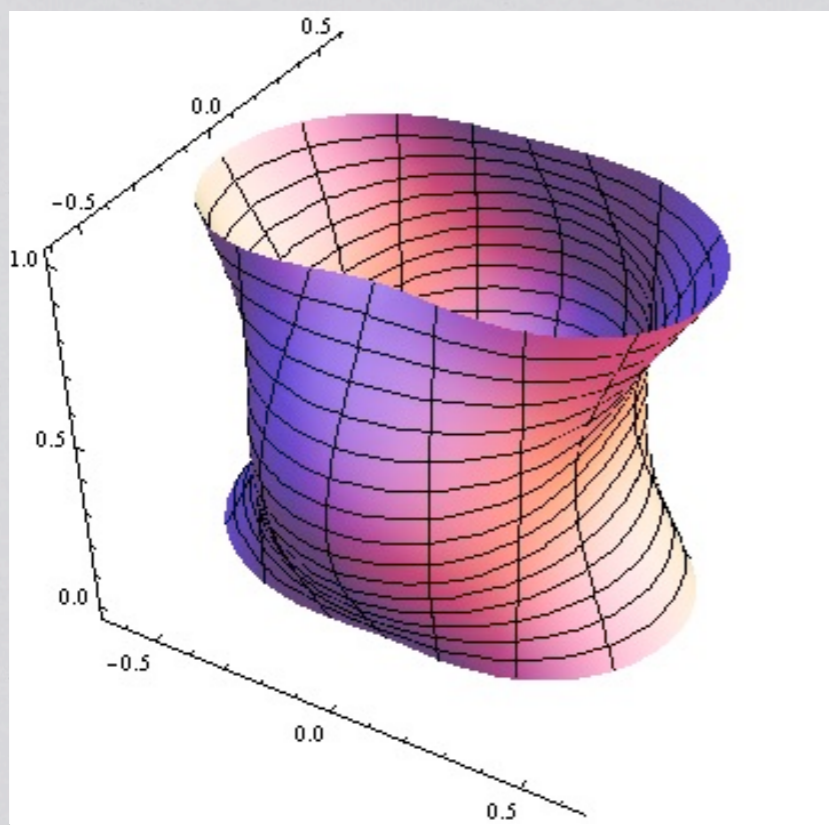
- Introduced in 1991, S.Ijima, NEC Corporation
- Single-walled and multi-walled
- Usage as semiconductors
- Thermal dissipation issue

- Vibrations as continuum shell
- Comparison with molecular dynamic models
- Young's modulus $E=1-2$ Tpa
- Tensile strength $R_t=100$ Gpa



Multi-Walled Carbon Nanotube

Dynamics of Carbon Nanotubes

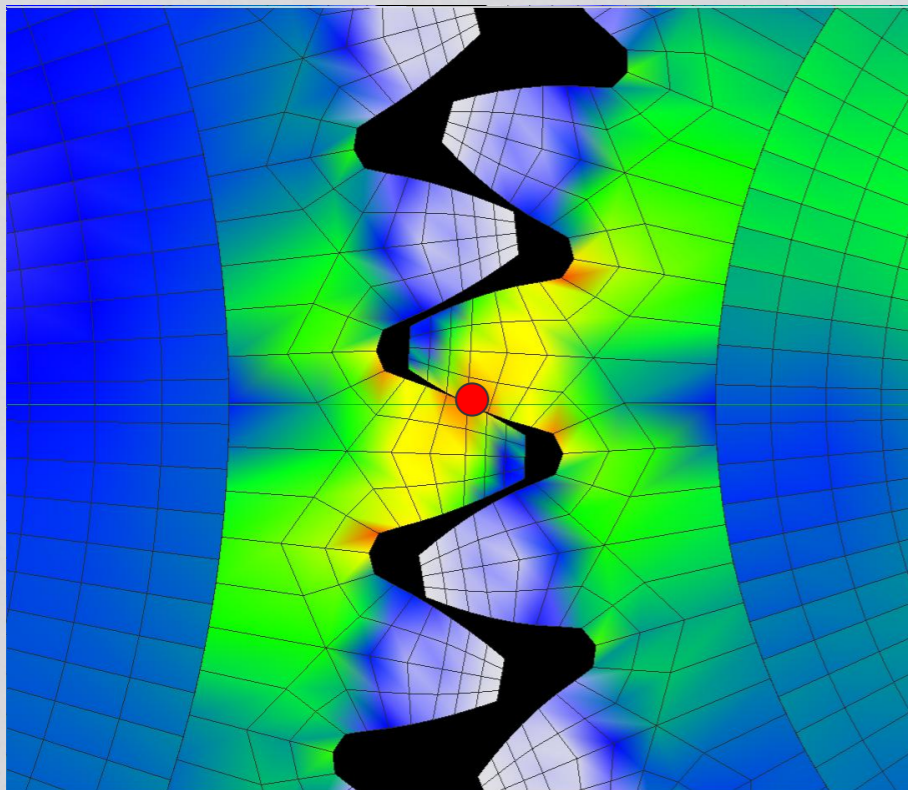


Vibration mode $(m,n)=(2,2)$

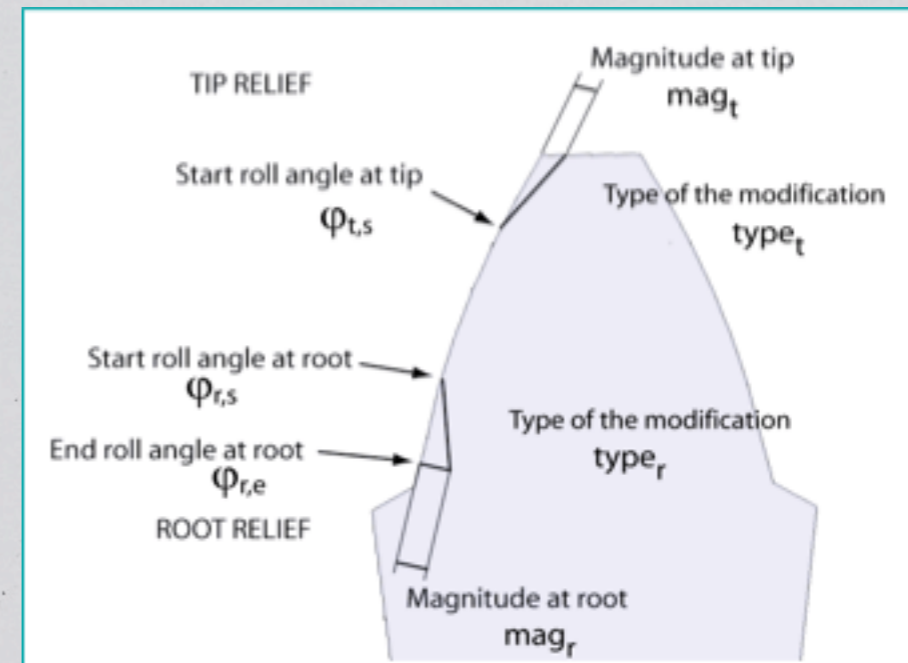
Total energy $E_t(\eta, \theta, t)$

Gear profile optimization

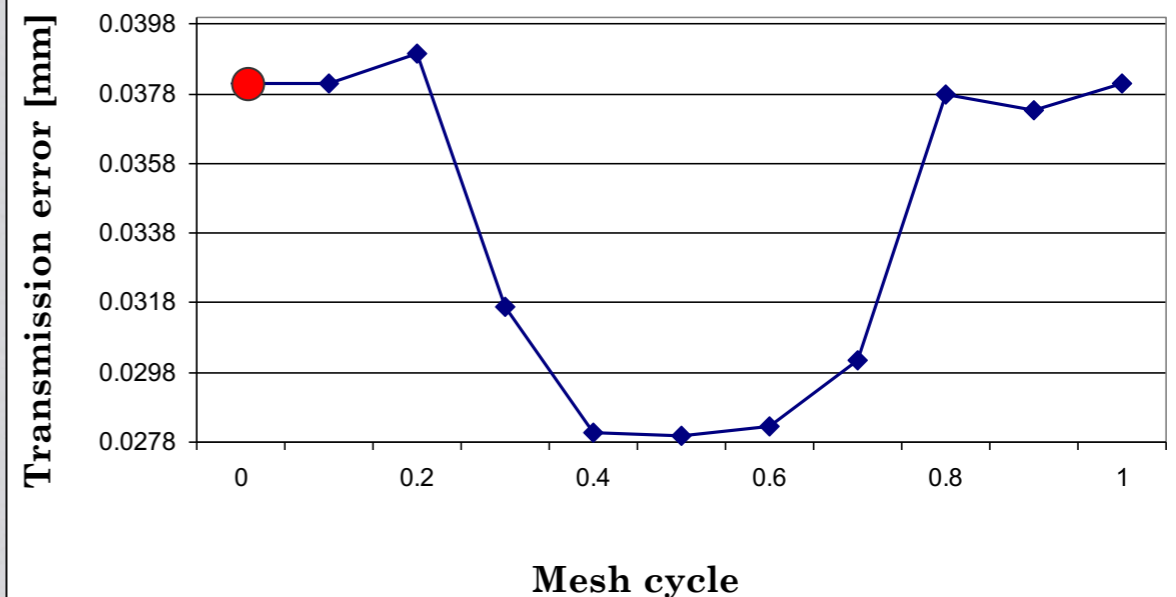
- Profile errors
- Profile Reliefs
- Elastic deflection



The static transmission error is a periodic dynamic excitation for the gear pairs



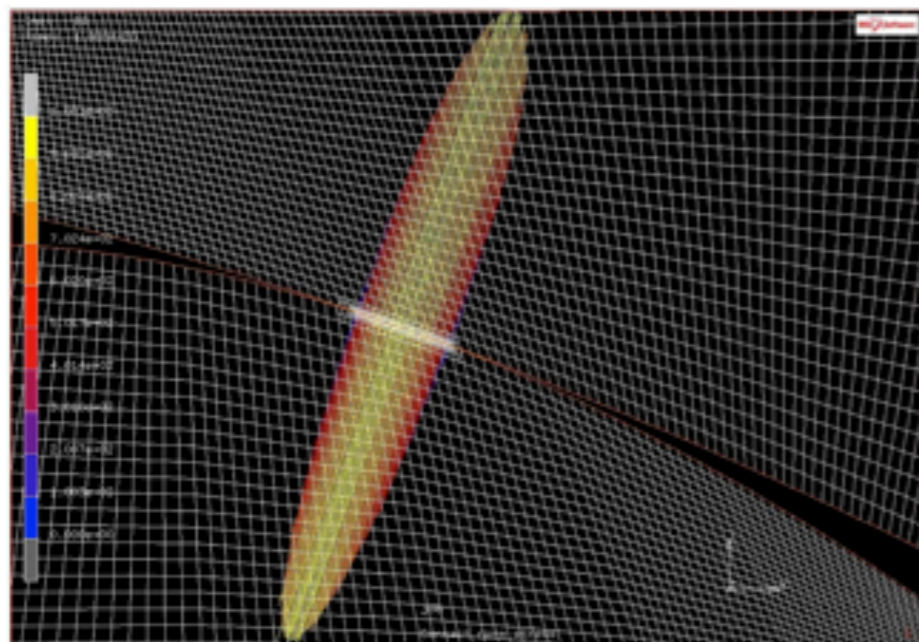
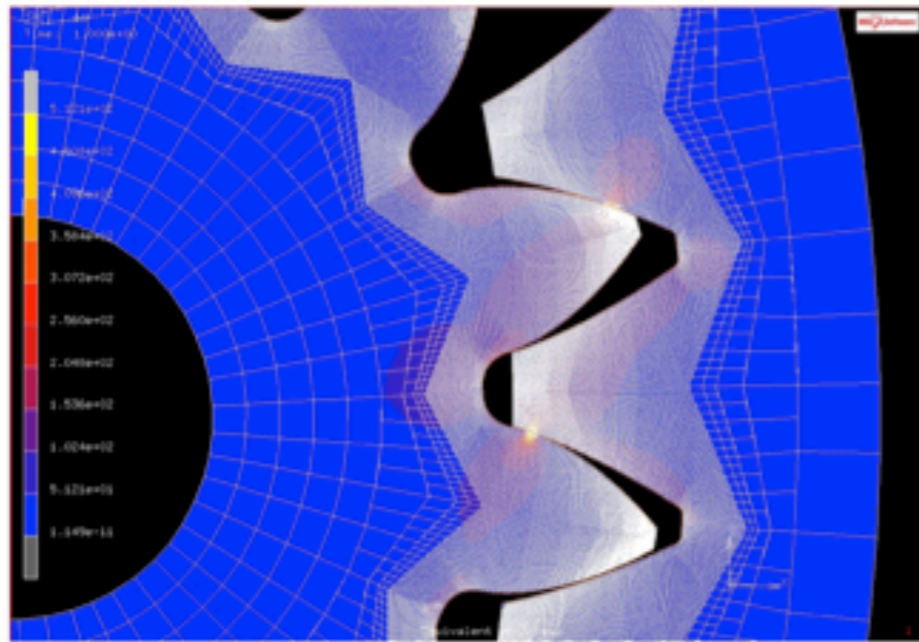
STATIC TRANSMISSION ERROR



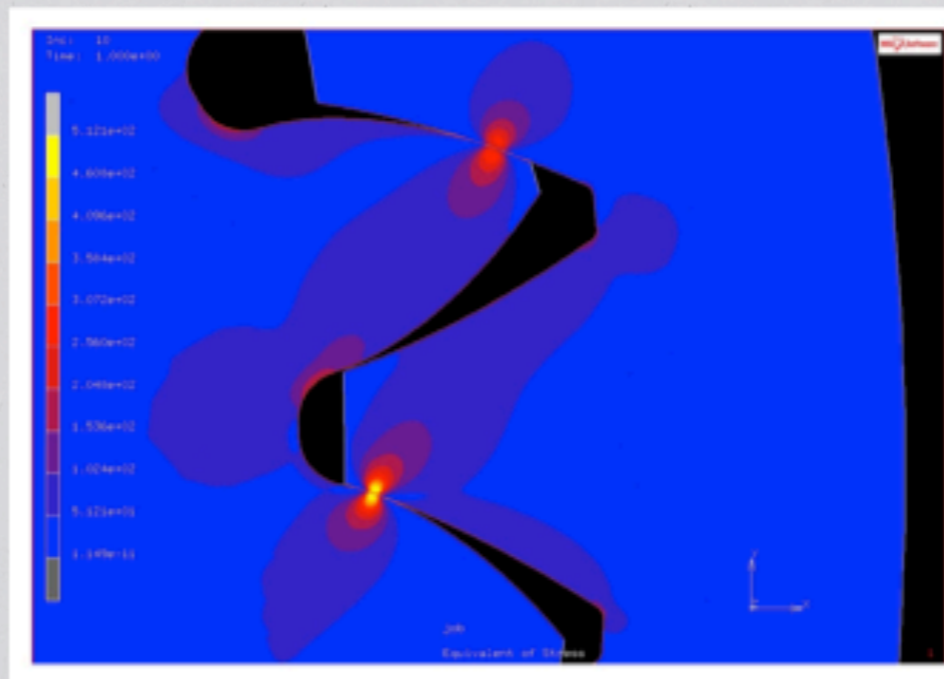
Loaded Tooth Contact Analysis

- Technical Software development (Helicalpair)
- 2D-3D FEM static analyses
- Reliefs and misalignments

Internal 2D helical pair



7-4 refined grid in internal gear pair

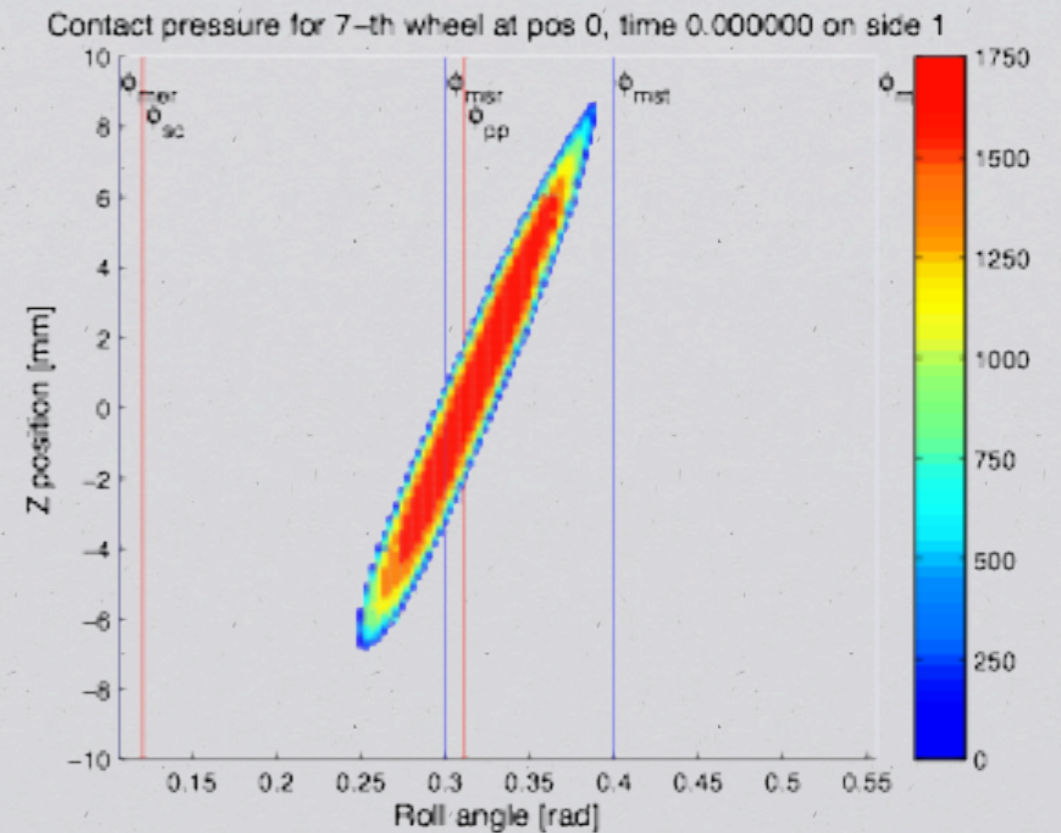
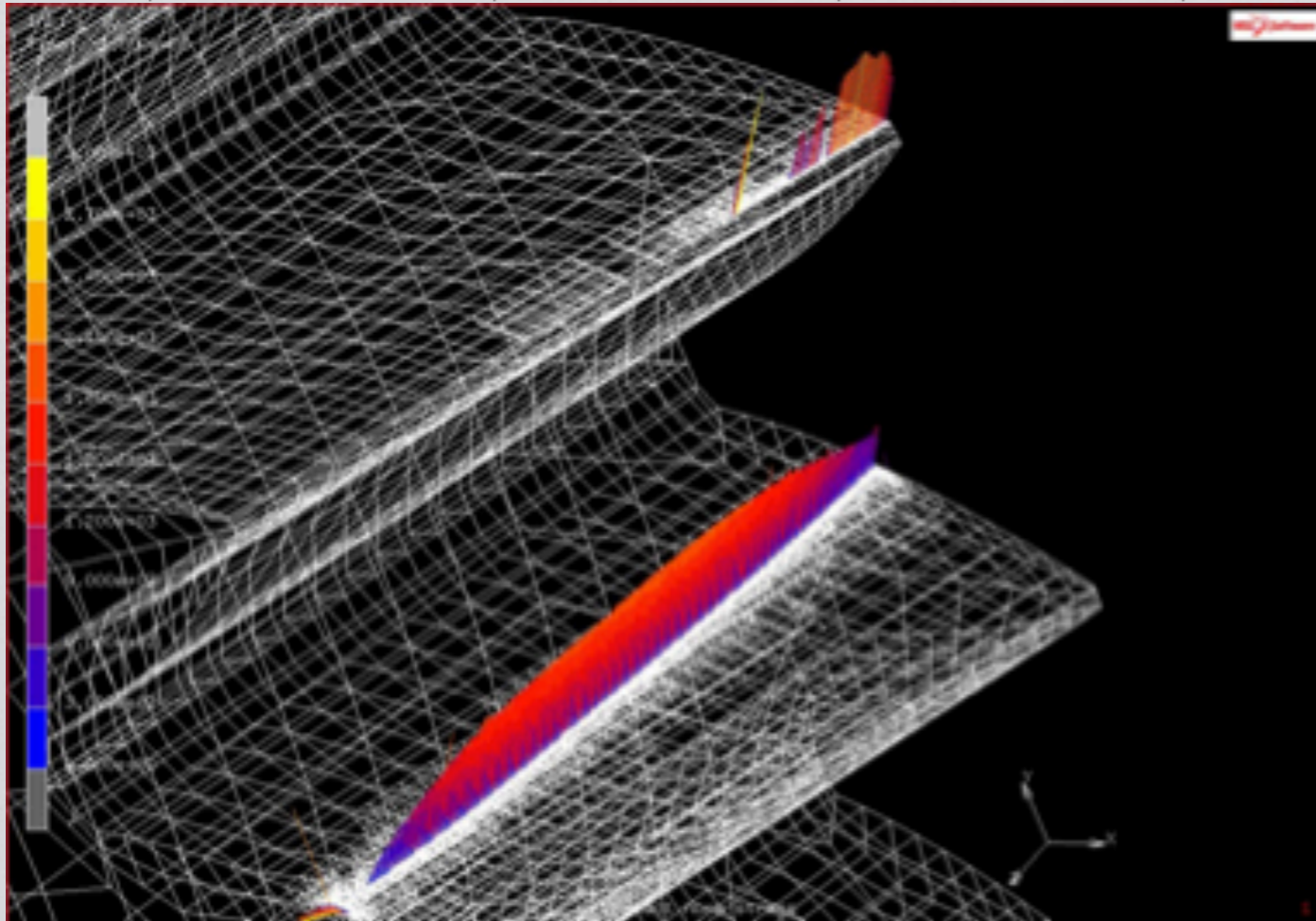


Von Mises equivalent stresses

Contact pressure

HPGA Software

- 3D contact pressure
- Effect of crowning or profile reliefs
- Estimating the contact pattern

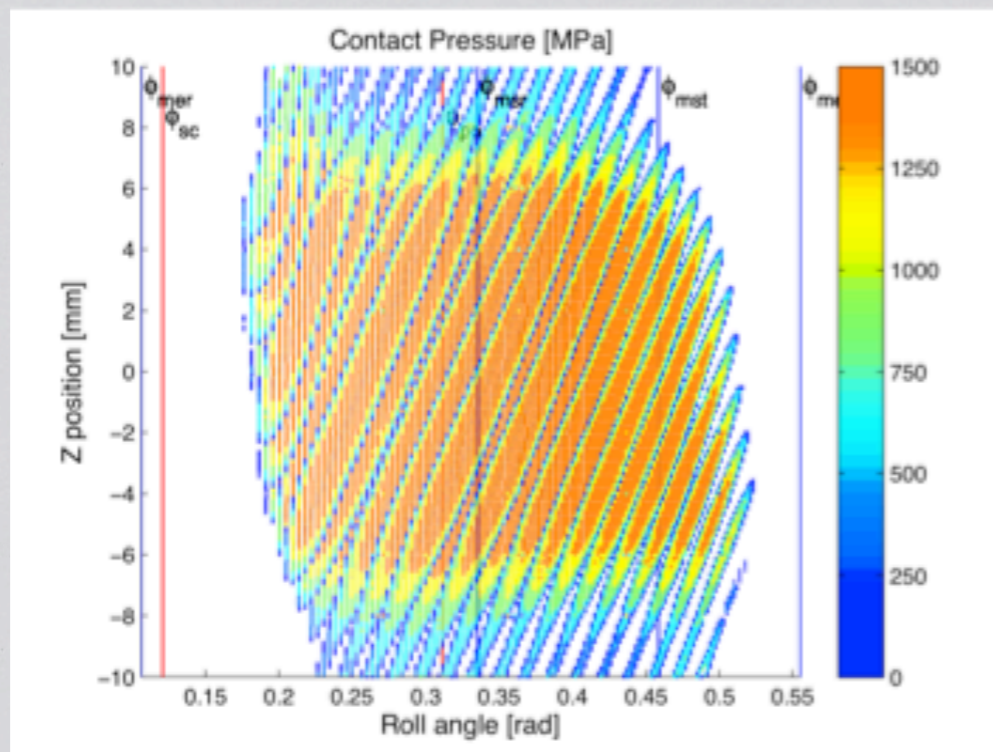


Contact pressure at pitch point for an external helical pair with crowning
(FEM original output and extraction)

HPGA Software

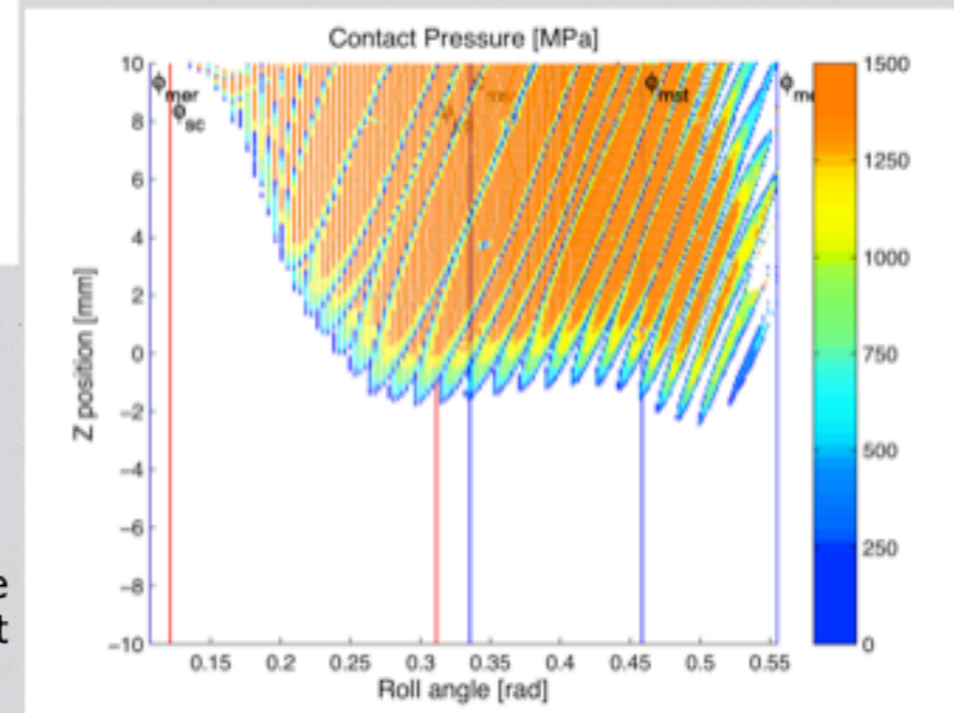
- Effect of misalignments
- Tooth strength evaluation
- Static transmission error

Effect of misalignments

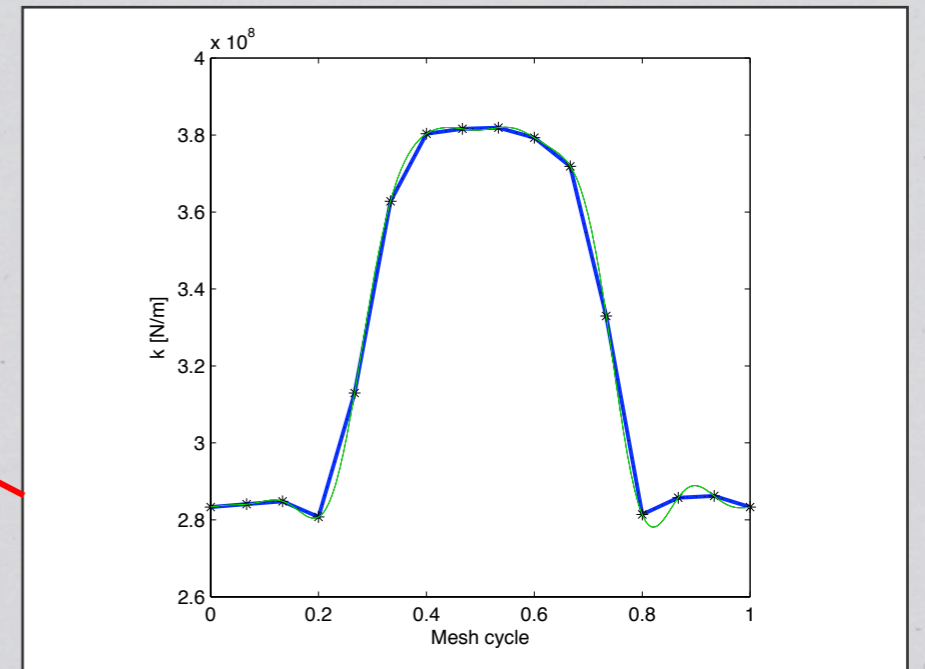
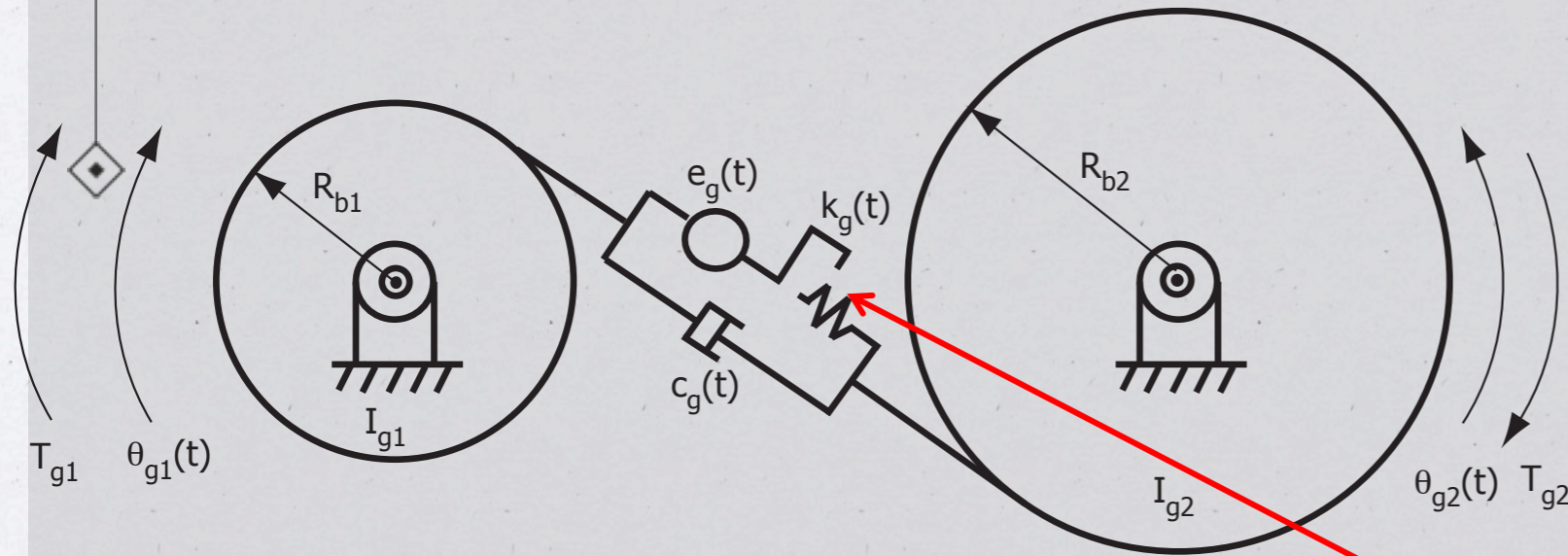


Contact pressure under severe (unphysical) misalignment

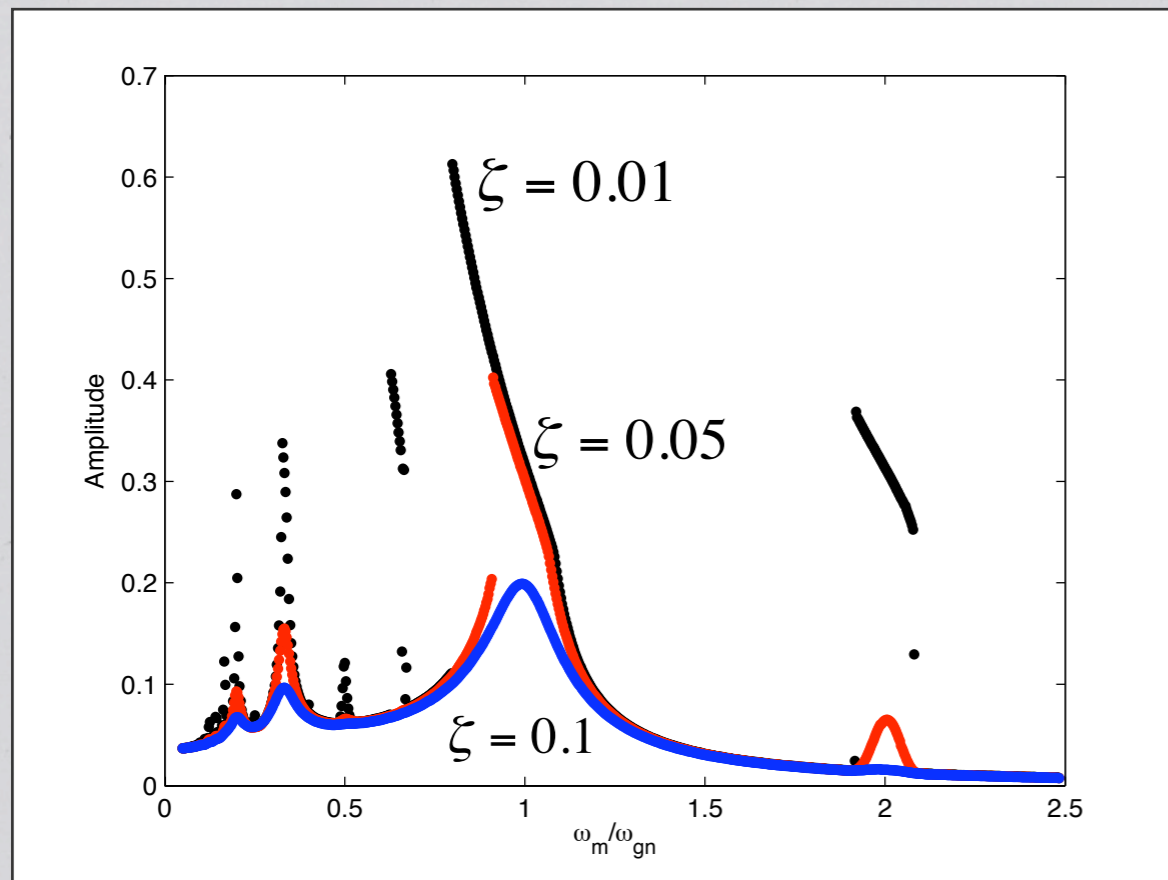
Contact pressure with crowning



Gear dynamics

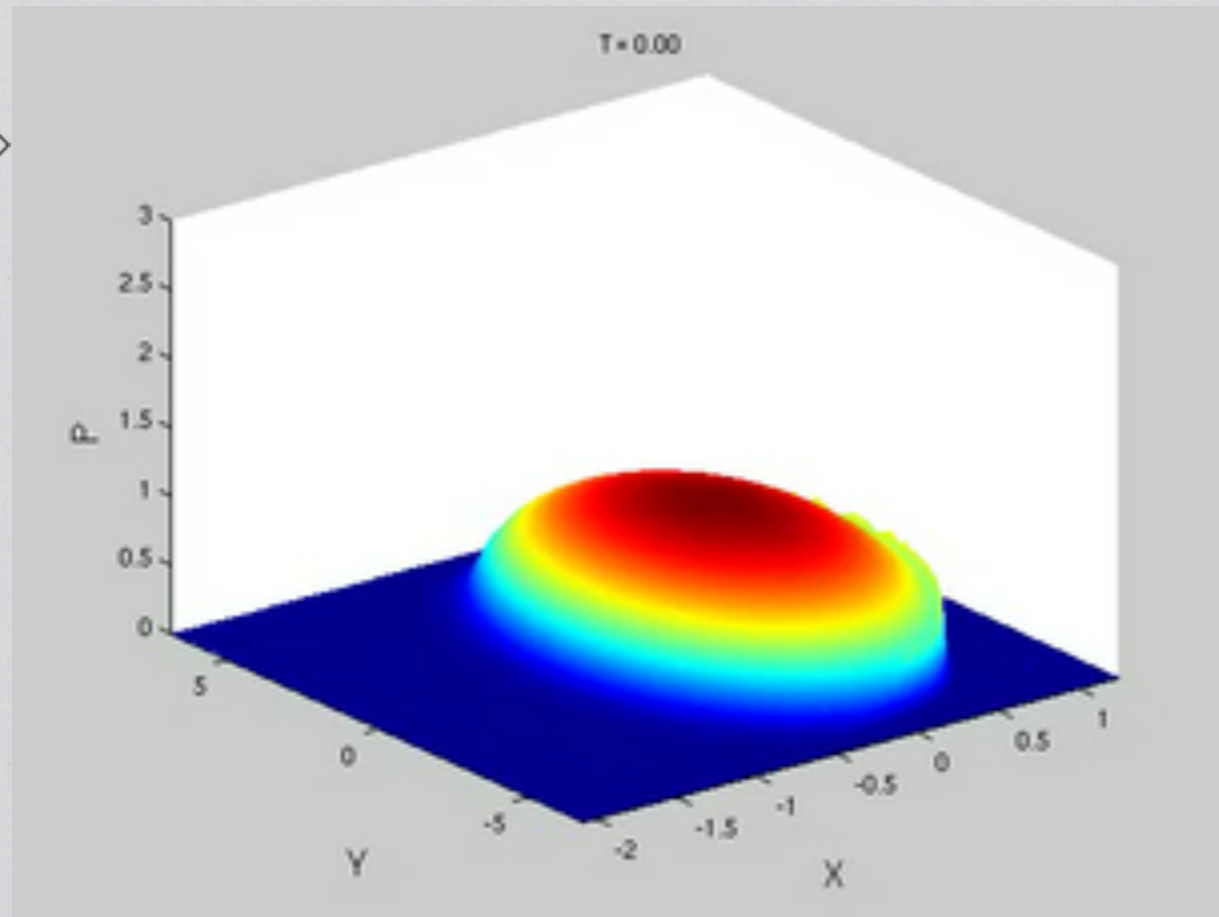


Time-varying Stiffness



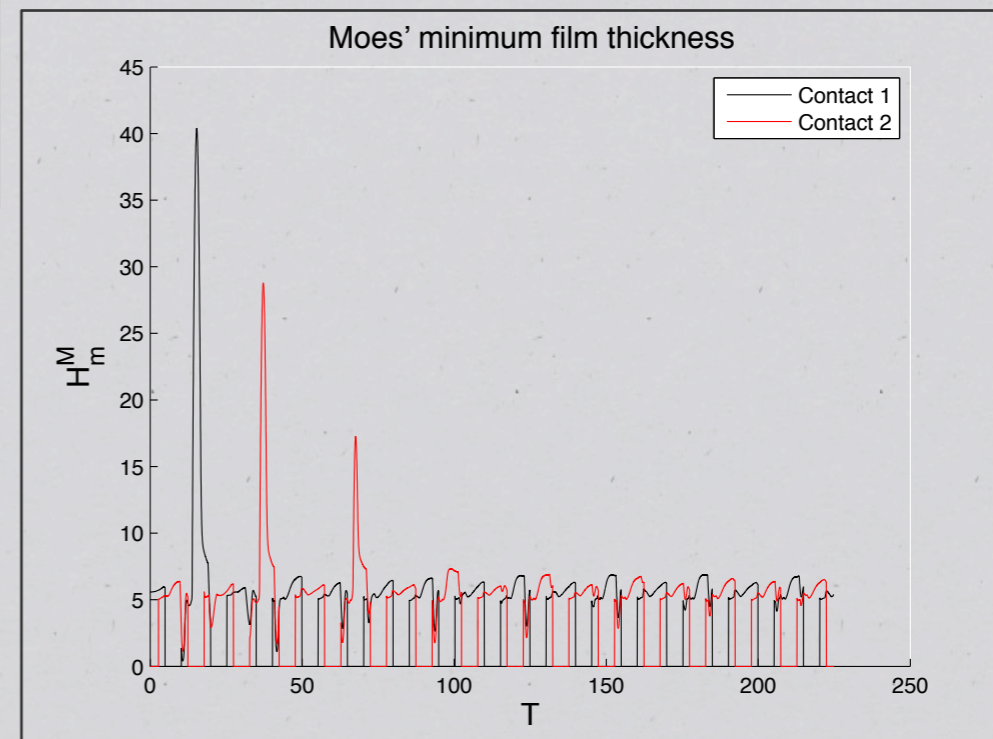
- Linear – non-linear behavior depending on damping
- Problem: characterization of the viscous damping ζ

EHL lubrication in gears



Pressure – 15000 RPM

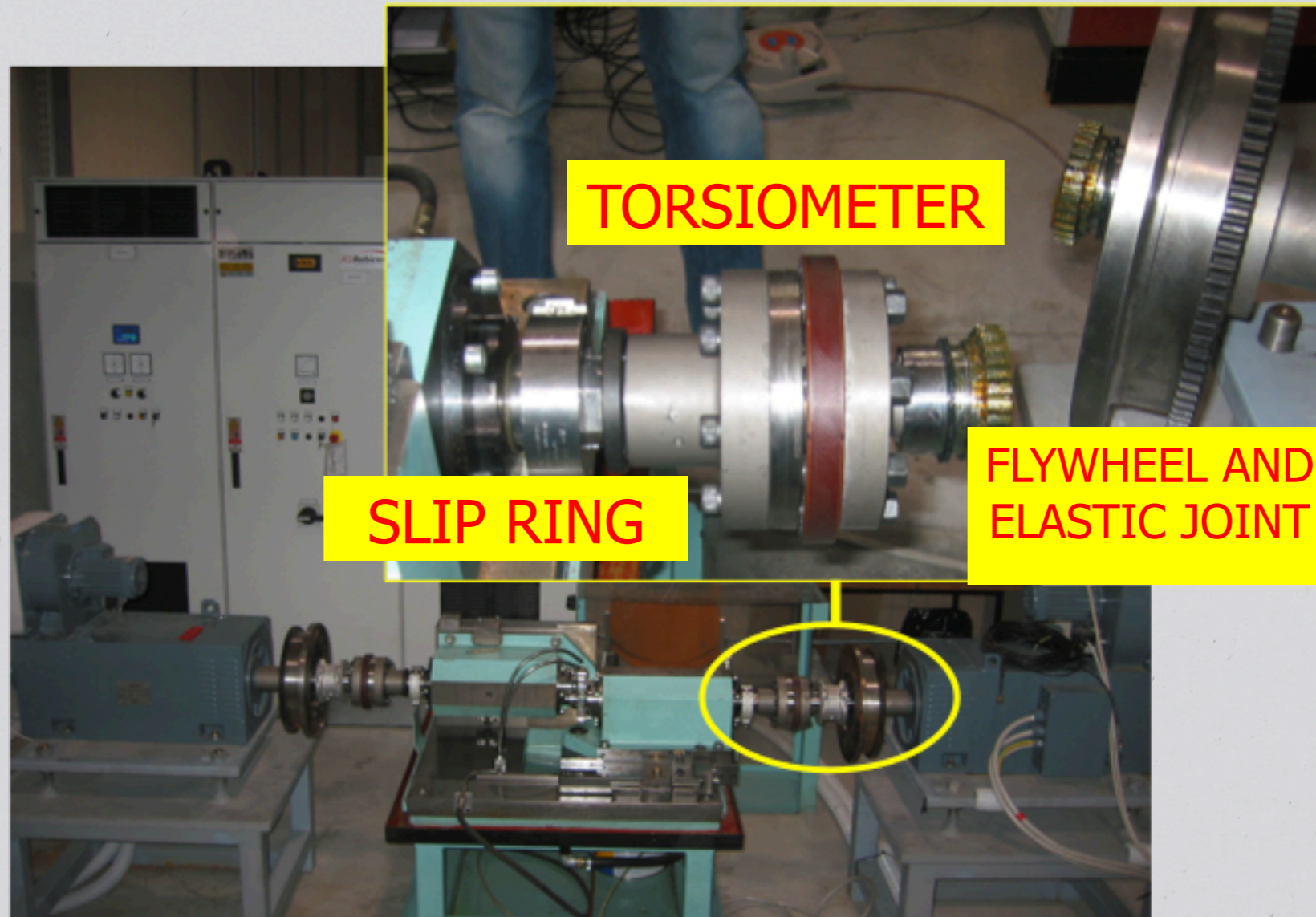
- Modeling the fluid film lubrication in gear pairs
- Effect of the dynamic loading conditions
- Viscous dissipation due to the squeeze effect in the film



Minimum film thickness – 15000 RPM

Experimental gear vibrations

- A gear pair coupled with electric engine/brake
- Measuring angular vibrations in the shafts
- Effect of profile reliefs is to be investigated

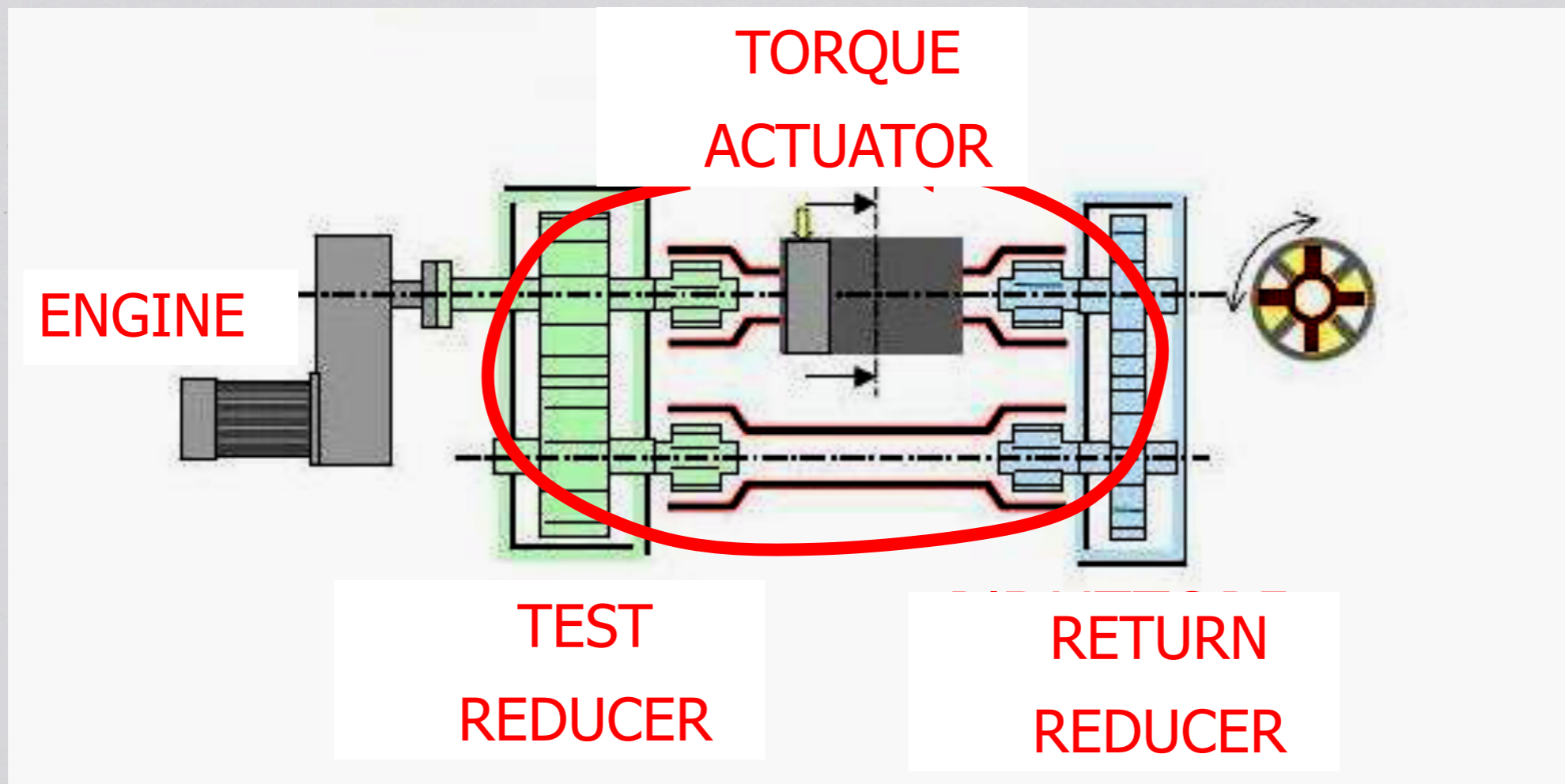


Gear reducer fatigue test



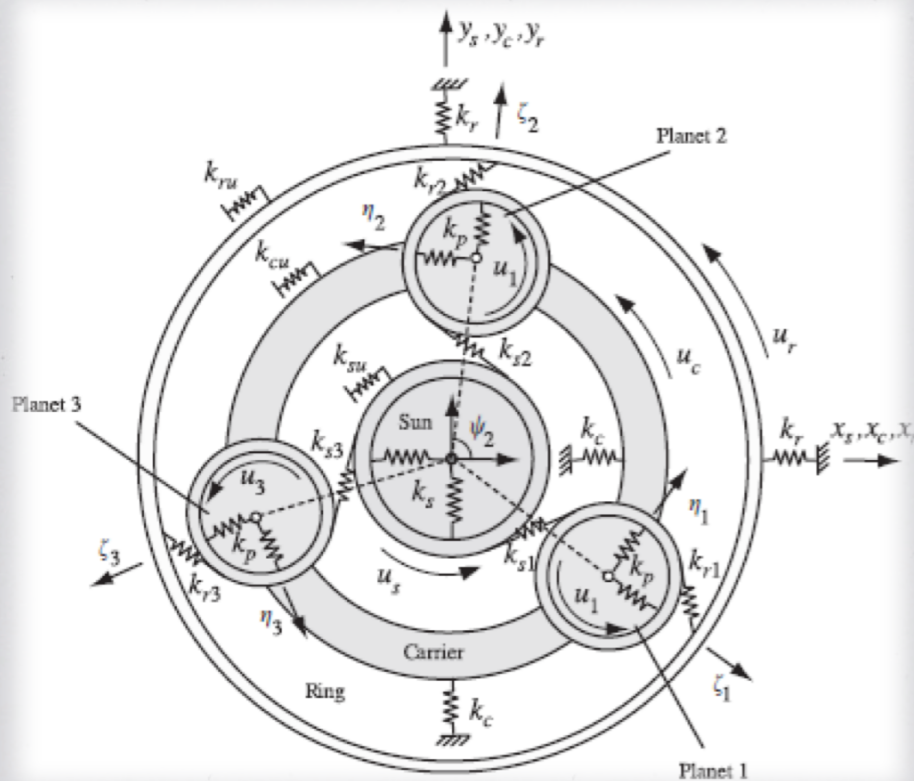
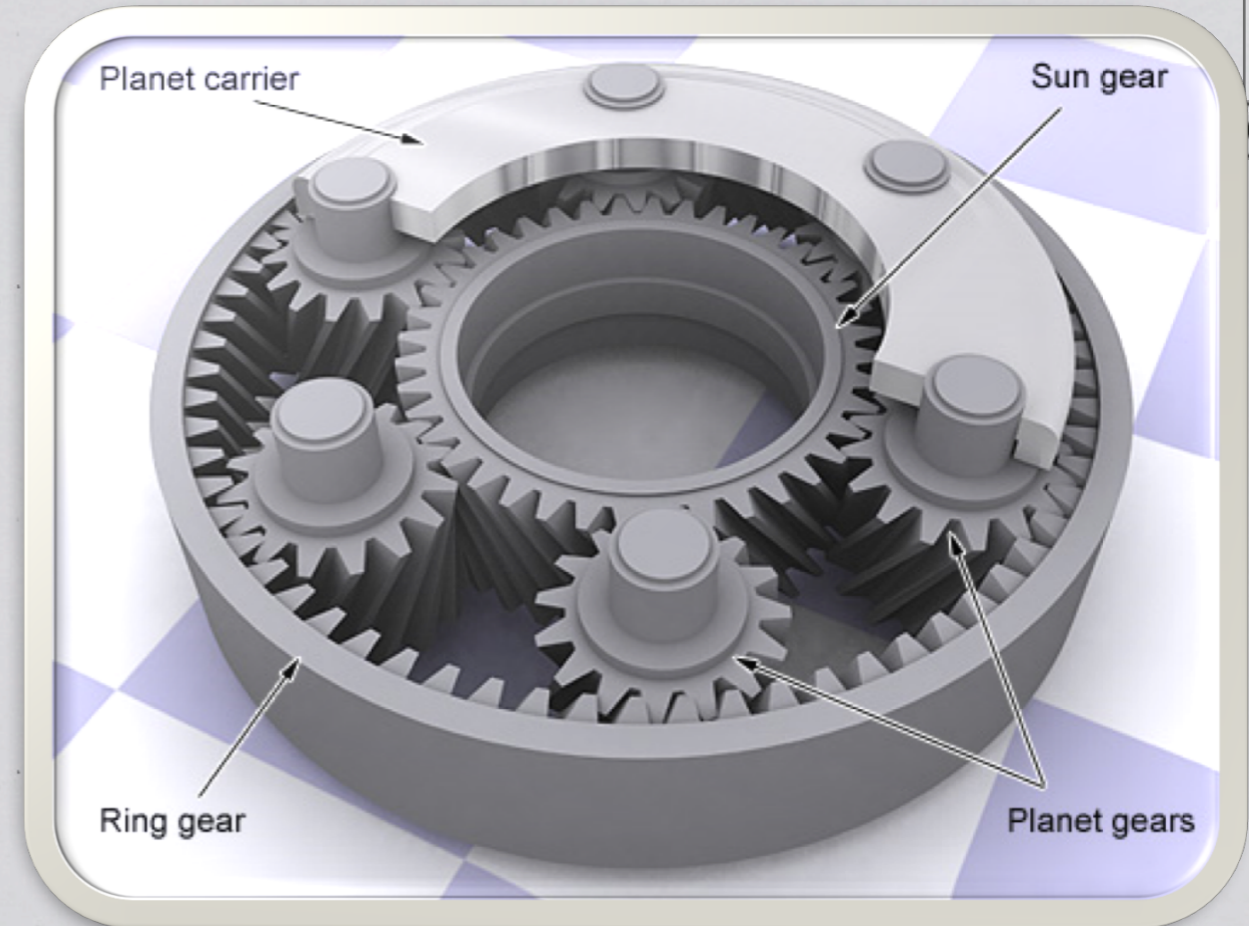
Recirculating power test rig

- Two gear reducers in back-to-back configuration
- A 30 kW engine is enough for a 150 kW test
- Pitting failure check



Planetary gear modeling

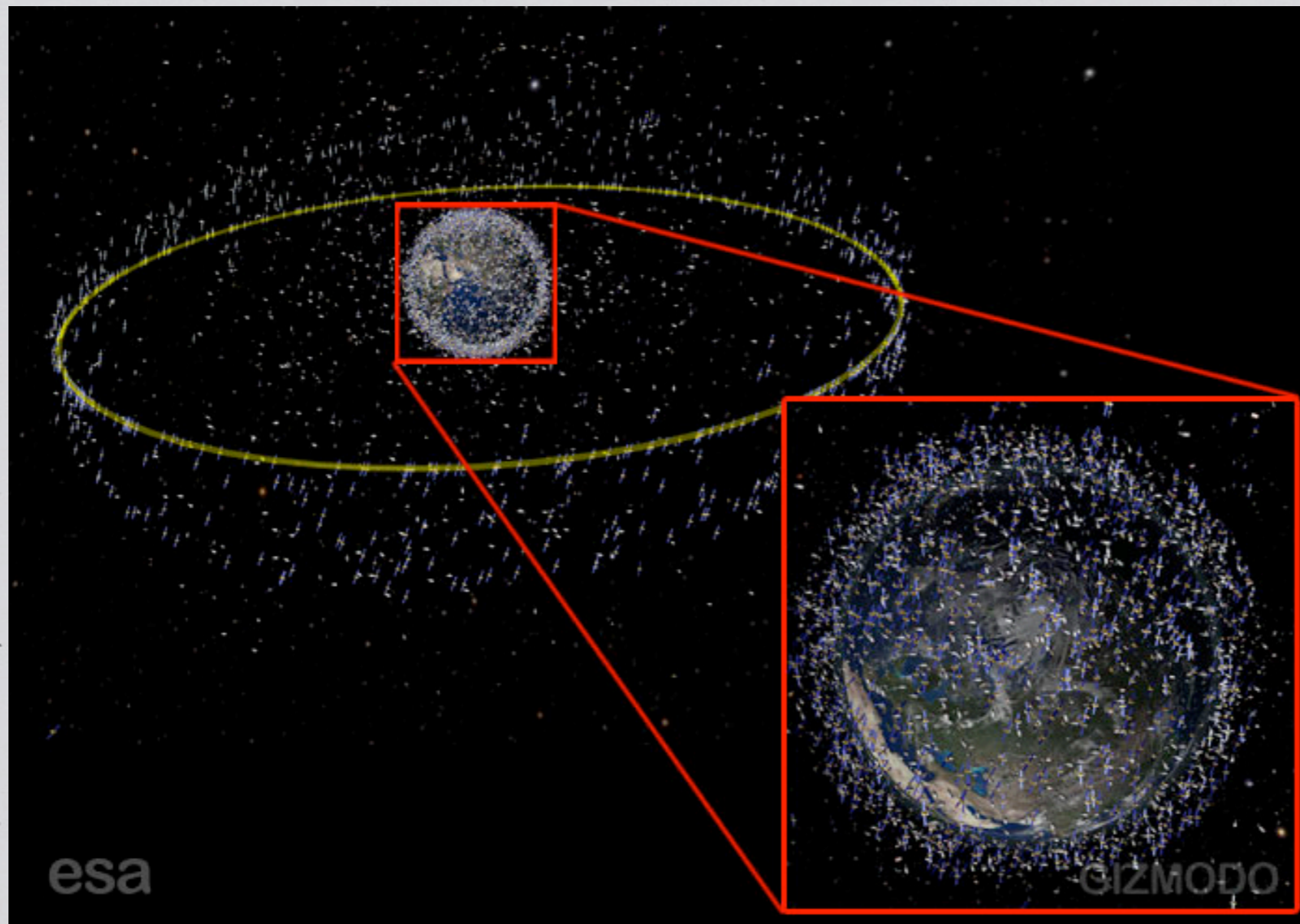
Three main components:
sun, planets,
and ring.



$$M\ddot{x} + C\dot{x} + K(x,t)x = F(t)$$

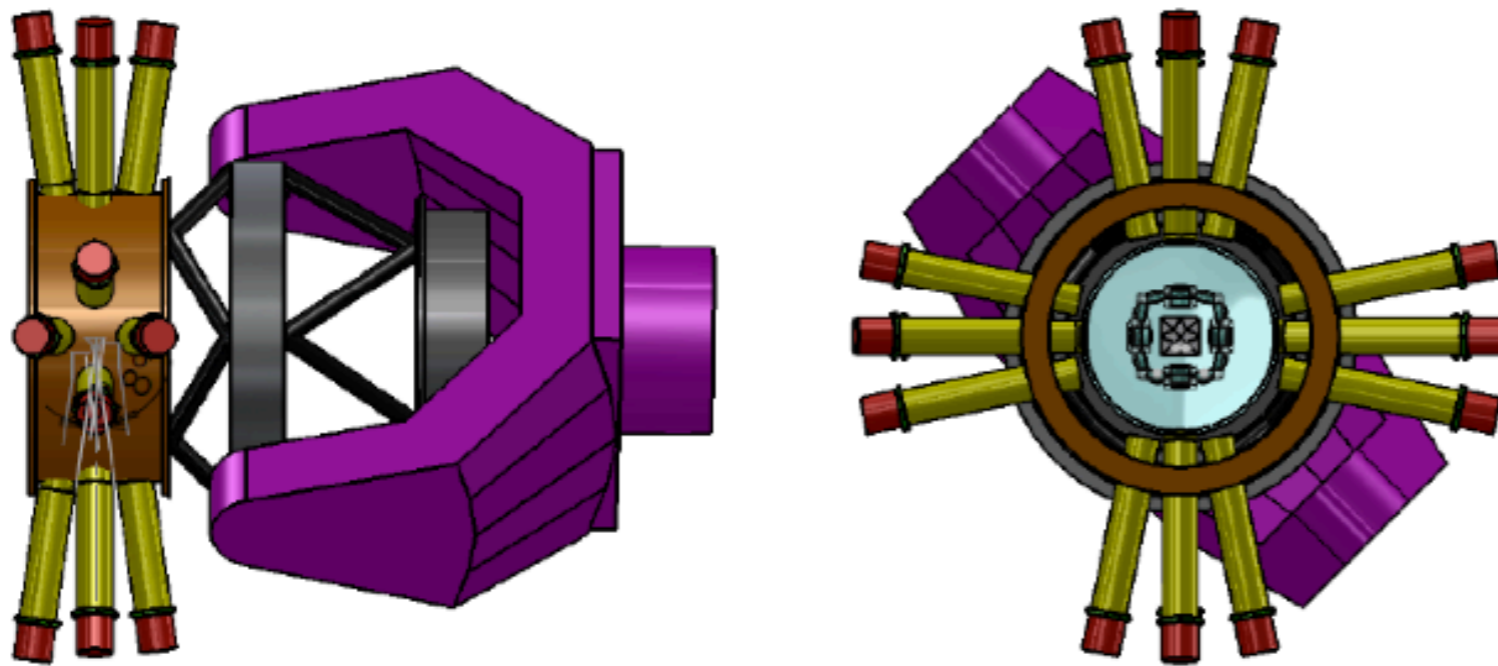
Fast-pointing telescope design

- Optical telescope for space debris identification
- Finding and tracking objects in LEO, MEO, GEO orbits



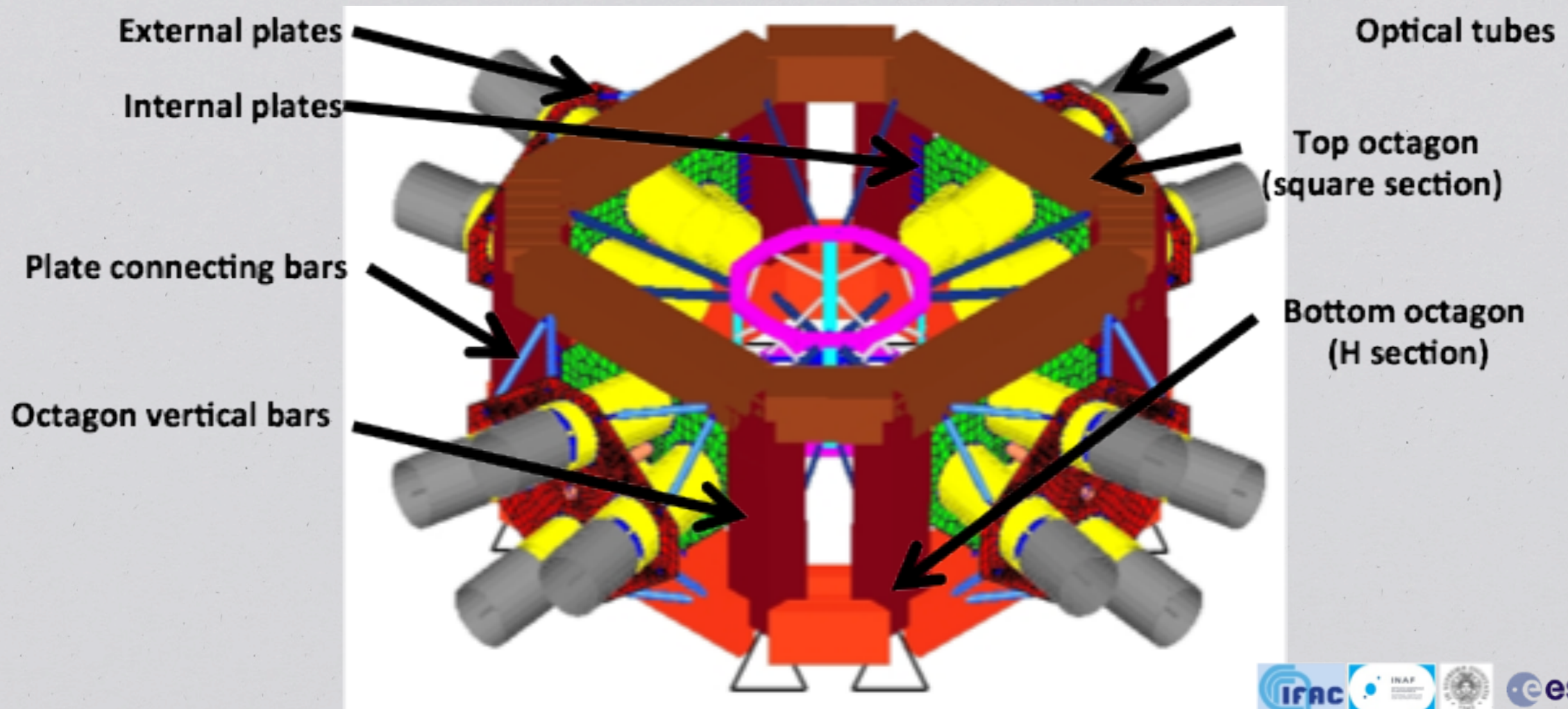
Fast-pointing telescope design

- “Fly eye” technology, in order to increase optical resolution in fast telescopes
- Can find & track debris 20cm wide at 100km
- Much cheaper than radar (costs as much as R^2 instead of R^4)
- Demanding for mechanical performance

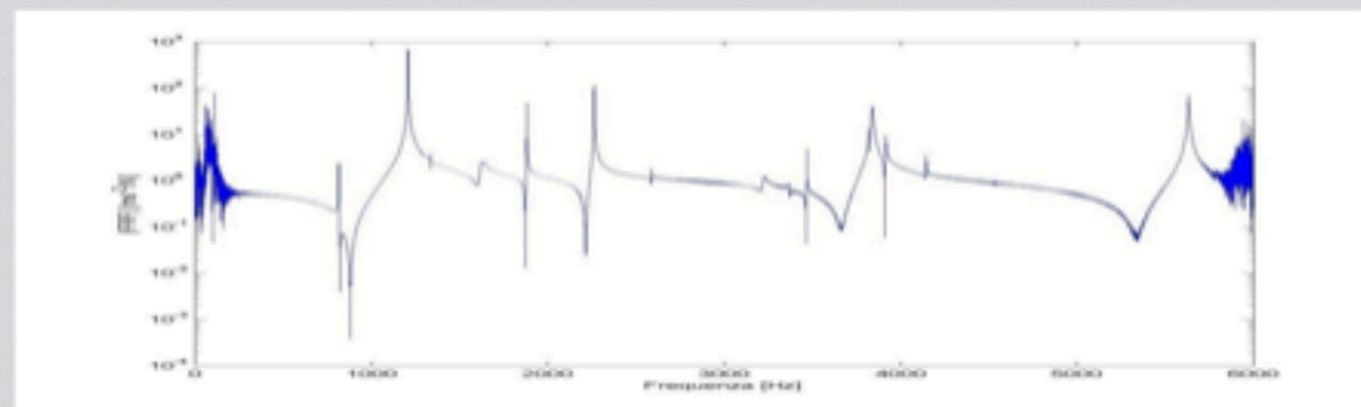
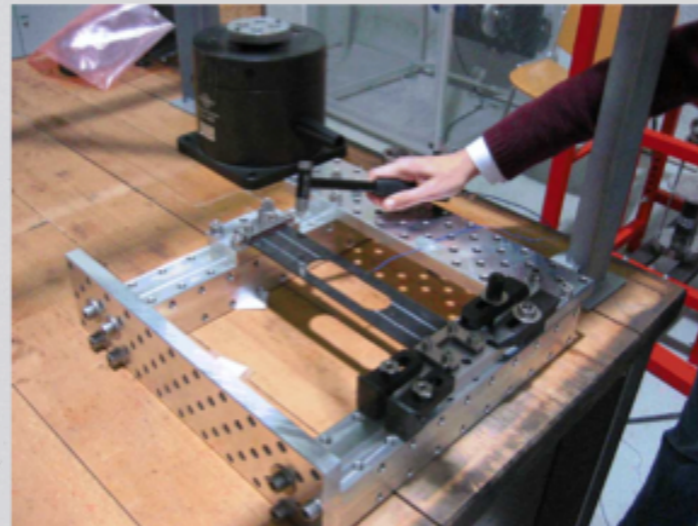
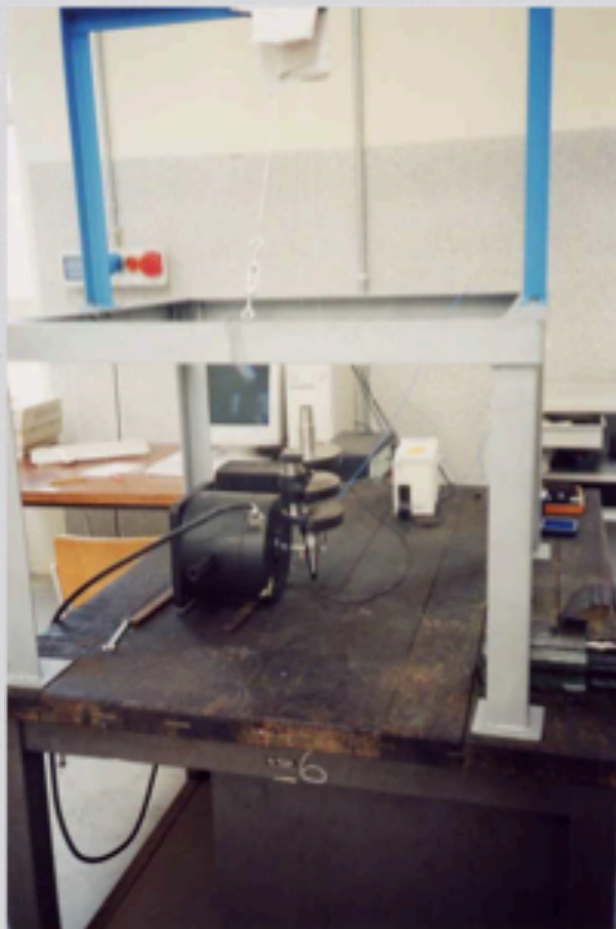


Secondary mirror design

- Complicated mechanical structure
- High natural frequencies and low deformations required
- Effect of pre-stressing the “spider” support



Service: Vibrations/Testing



Experimental Modal Analysis on crankshafts and aerospace structures

Start-up of the Lab.

PULSAR DYNAMICS

VIBRATION ENGINEERING CONSULTANTS



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Thank you for your attention