Politecnico di Torino
DIMEAS Dip. Ing.
Meccanica e Aerospaziale

Imperial College London
Vibration University Technology Centre

Joints Workshop

Vibration and Turbomachinery

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Theoretical research

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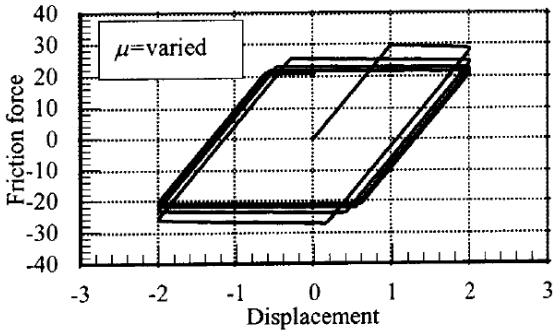
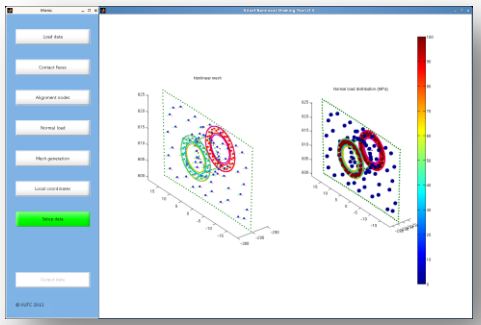
- **Development of nonlinear tools**
  - Friction contact elements
  - Bifurcation and instability
  - Graphical user interfaces
- **Application to aircraft engine**
  - Methodology
  - Response behaviour
- **Validation**
  - Against experimental data





Experimental research

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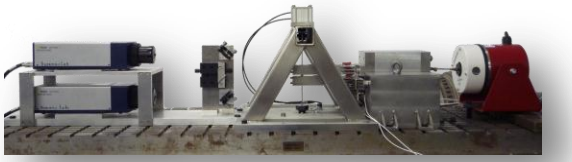
- **Basic research**
  - Friction contact behaviour
- **Nonlinear structural damping**
  - Engine components
    - Blade root
    - Under platform damper
    - Flange
  - Rotating and stationary systems
- **Measurement techniques for nonlinear behaviour**
  - Large amplitude excitation
  - Data processing



An example of our current work: Nonlinear flange joint analysis

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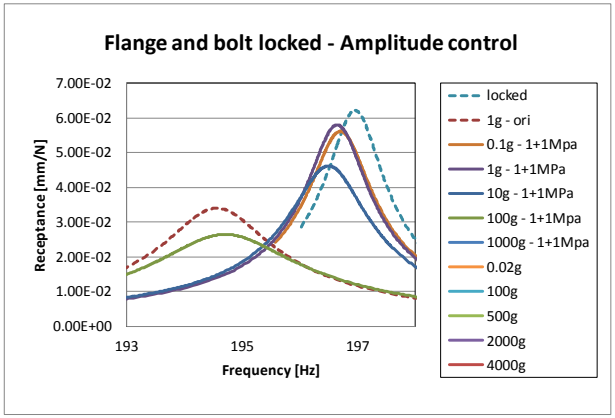

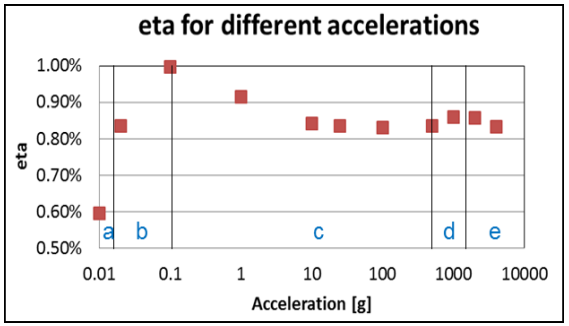

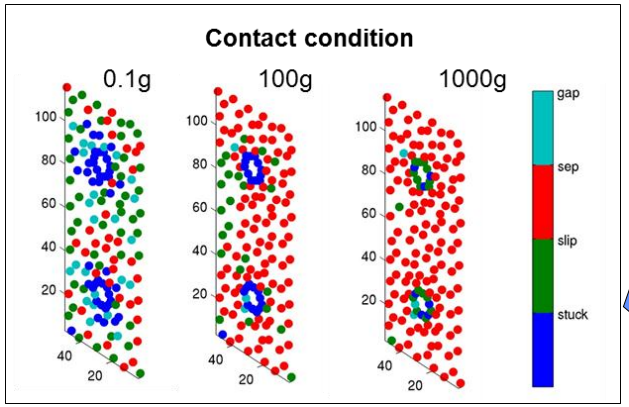

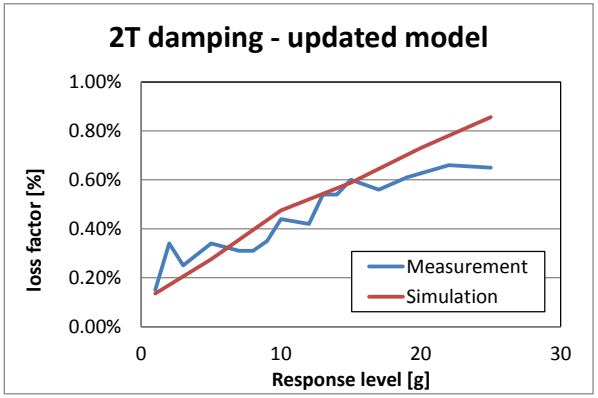

Main problem areas

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- **Overall dynamic response of structure**
  - Effect of joint on stiffness and damping
- **Need for robust prediction methods**
  - Macro level
  - Variability of joints
  - Contact conditions unknown
- **Designing joints that are insensitive**
  - Manufacturing tolerances
  - Wear
- **Industrial environment**
  - Damper design has matured and is routinely used
  - Focus is shifting to
    - new joint types
    - large models

What needs to be done

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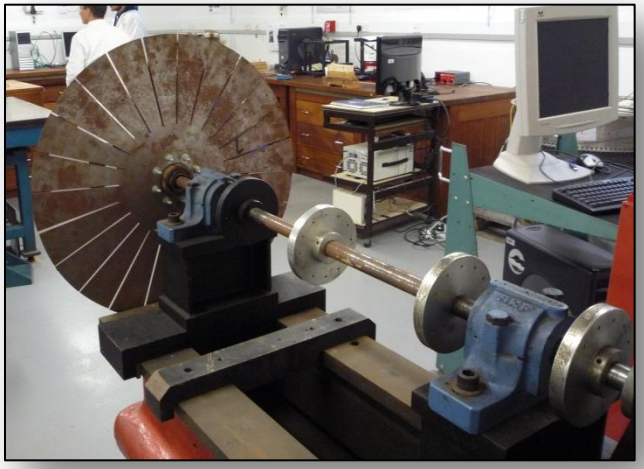
- Robust tools for joint analysis
  - Fast and reliable
  - Large scale modelling
    - Too much detail may get in the way
  - Change over time
- Criteria for effective joint design
  - Don’t deal with it, use it
- Nonlinear friction joint validation
  - Which parameters?
  - Level of validation
    - Global or local response
- Novel test methods
  - Operational level testing
  - Data processing



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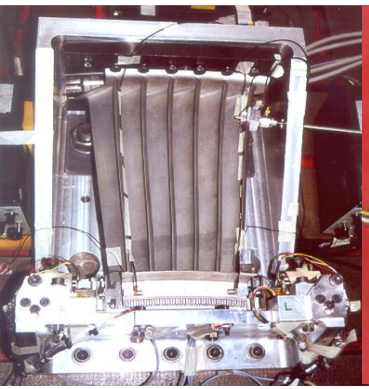
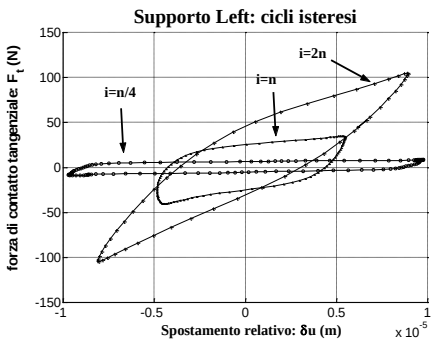
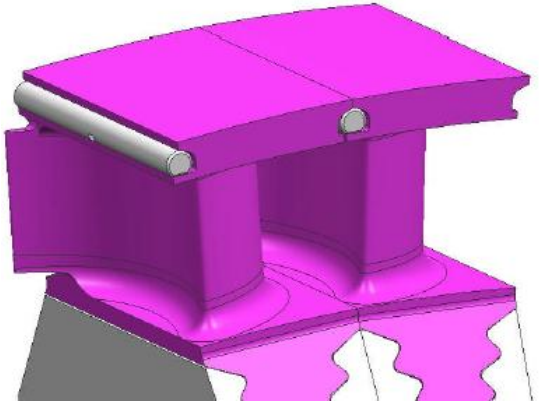
Overview of requests from companies / european projects (funding)

Contact mechanics
and tribology
Sliding wear tests in vibration

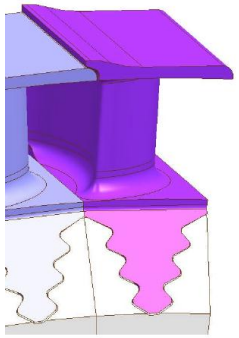




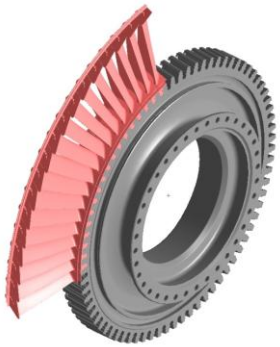
Damper mechanics and wear



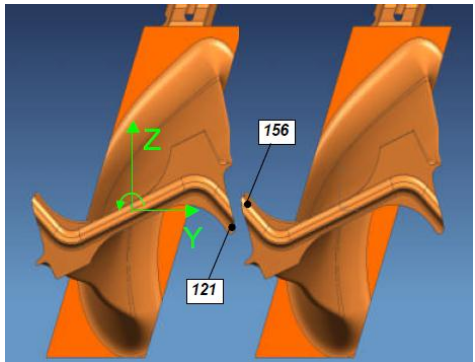
Contact modelling on
rotating components



Turbine and gear dynamics
(flutter, mistuning)



Damping and wear
assessment on blades



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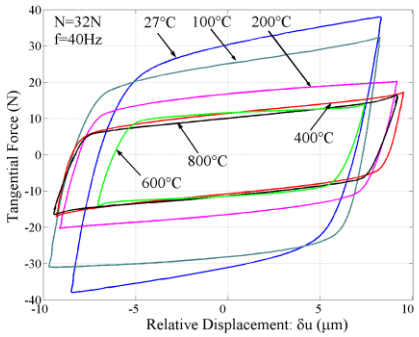
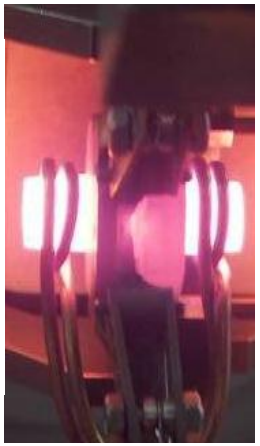
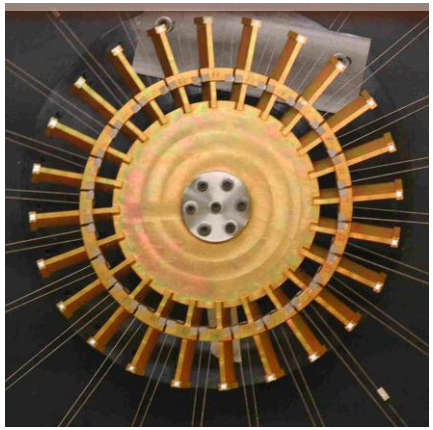
Overview of capabilities

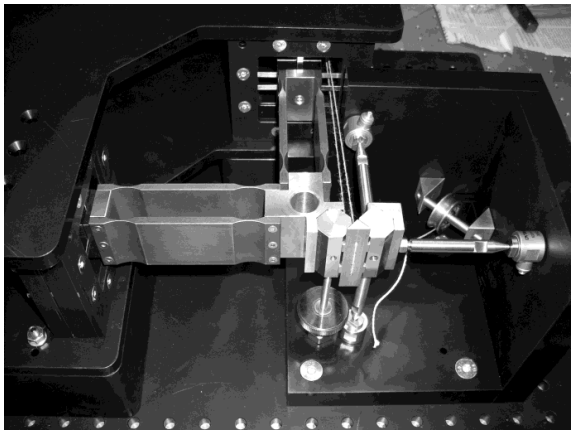
Contact mechanics and tribology



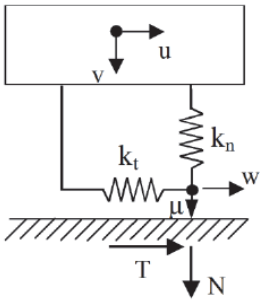


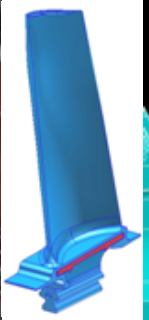
Damper mechanics on dedicated test rigs and on rotors



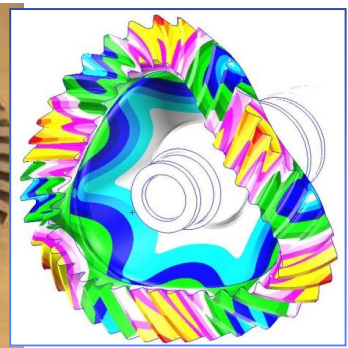


Contact modelling on rotating components





Turbine and gear dynamics & damping



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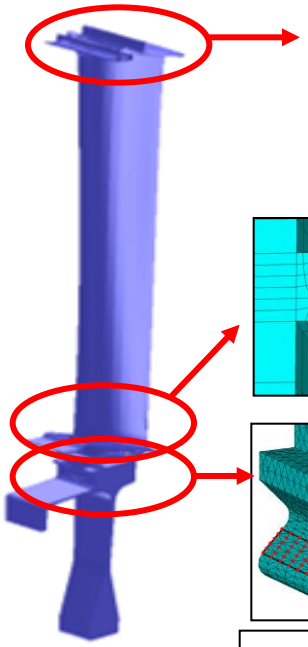
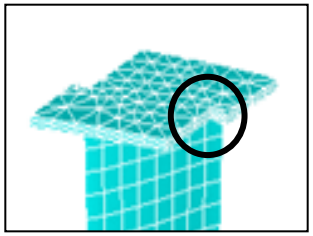
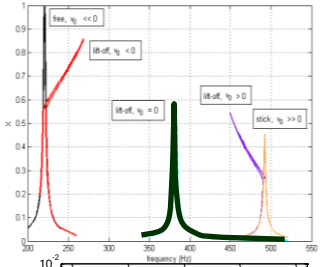
Friction Damping @ LAQ AERMEC

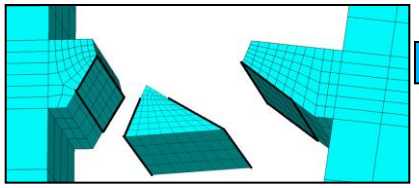
Poli.Contact: Non-linear Simulation Code



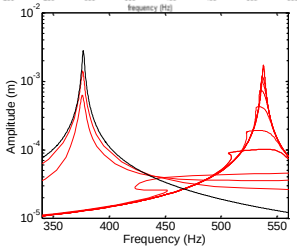


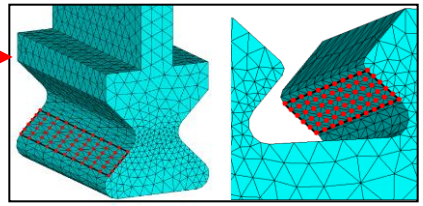
Poli.Shroud



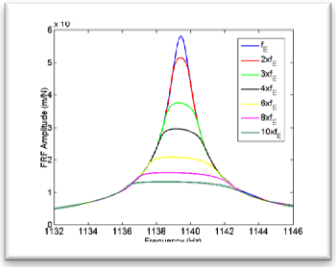


Poli.Damper

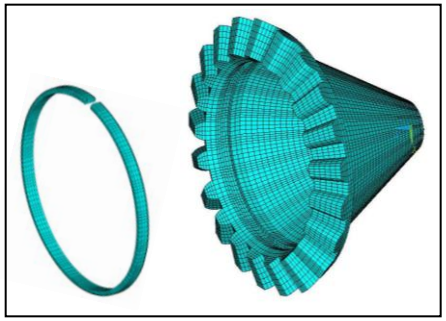




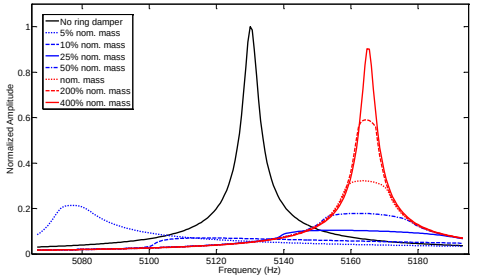
Poli.Root



Schwingshackl

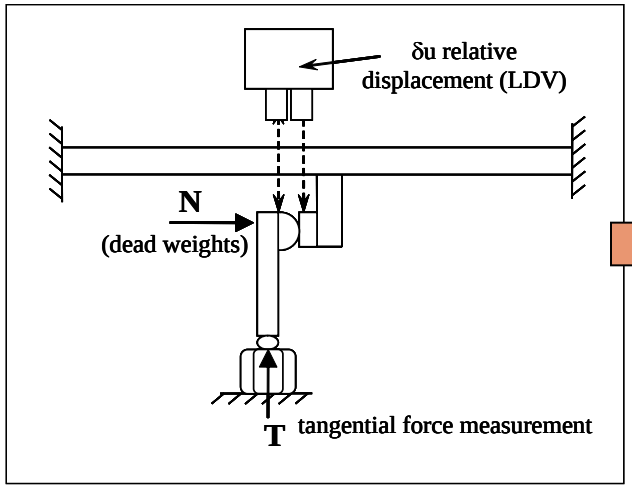


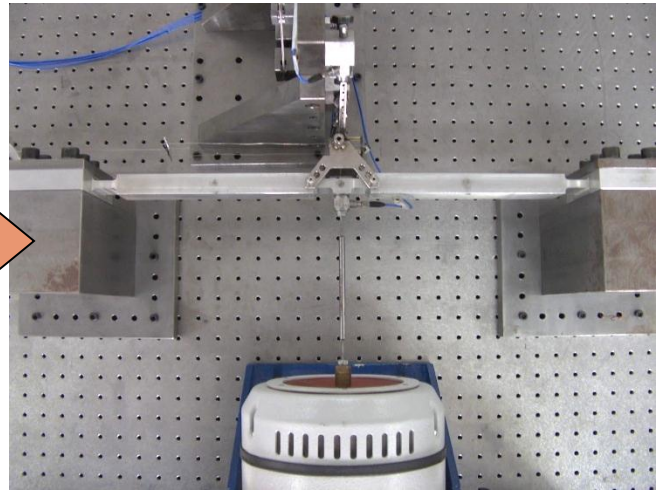
Poli.Gear

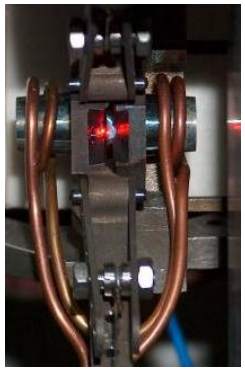


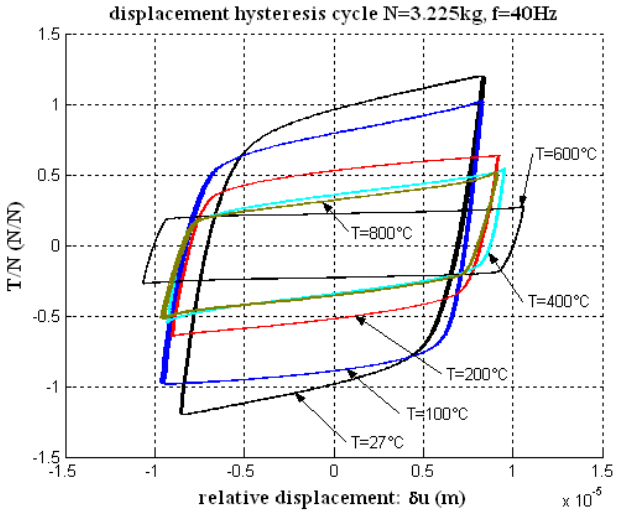
Friction Damping @ LAQ AERMEC

Validation of Contact Models: High Temperature Test Rig No. 1









Working range:

- Temperature : 20 – 1000 ° C
- Displacement: 0,1 μm - 100μm
- Normal loading: 1kg a 10kg
- Excitation frequency: 1 - 100Hz

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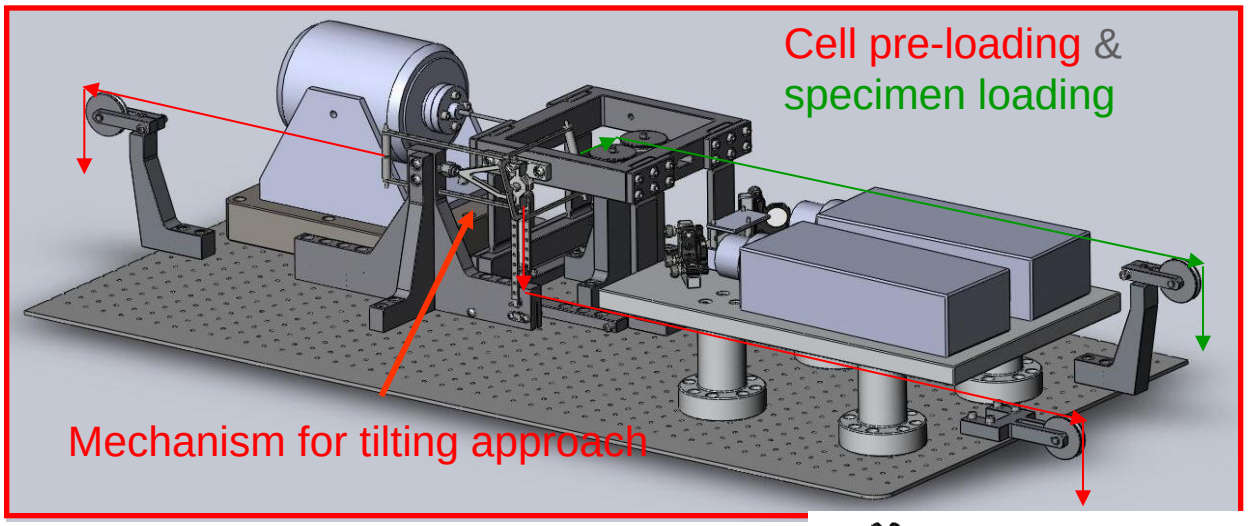
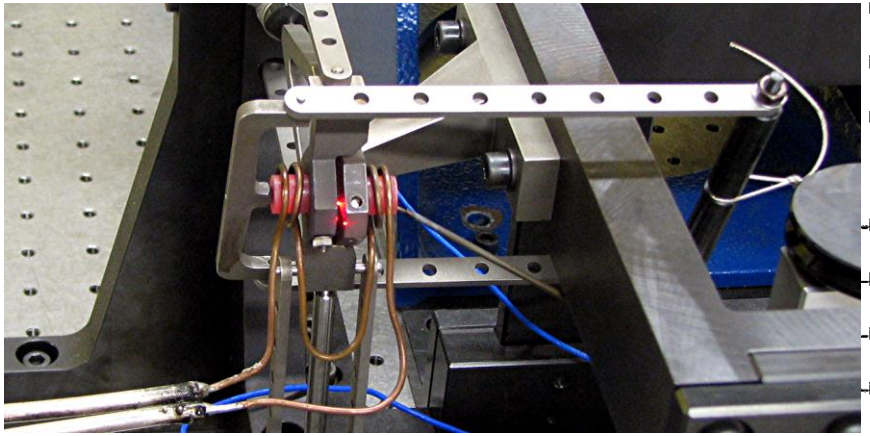
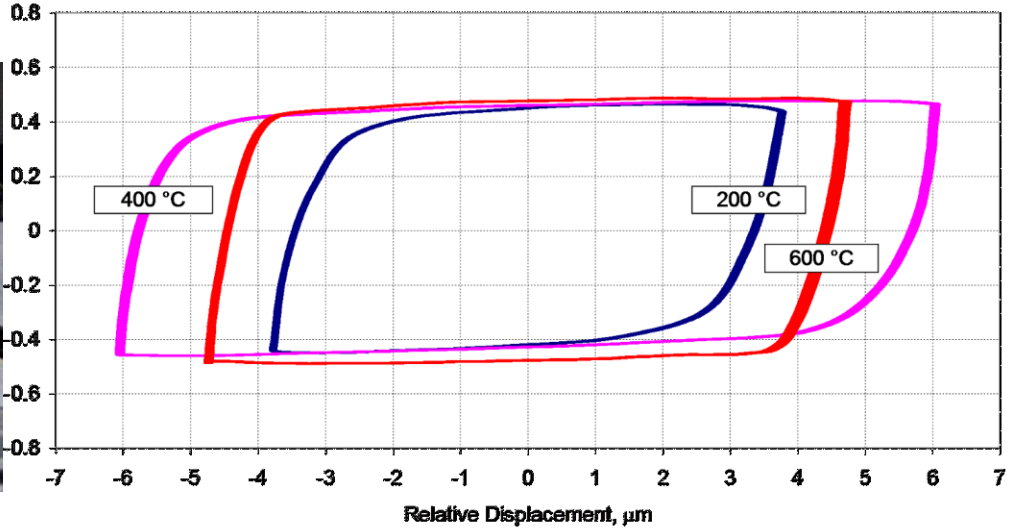
Friction Damping @ LAQ AERMEC

Validation of Contact Models: High Temperature Test Rig No. 2



- Test Frequency: 2÷200 Hz;
- Relative motion range 2÷100 µm
- Temperature up to 1000° C
- Overall force measurement error : ~ 0,7%
- Overall displacement measurement error: < 1%
- Feedback control of the test conditions (temp. & displ.)





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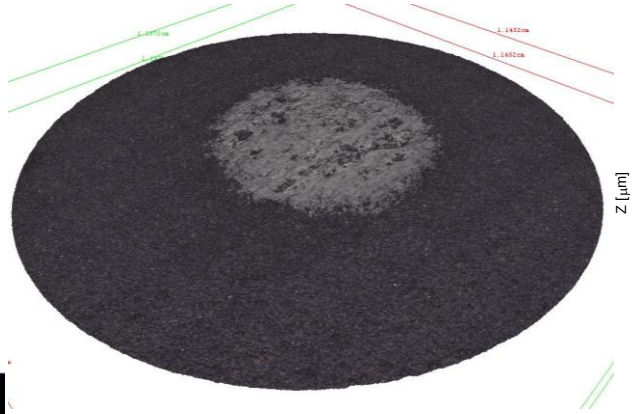
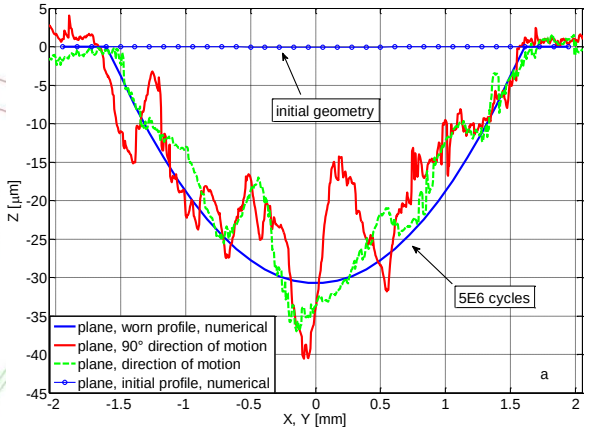
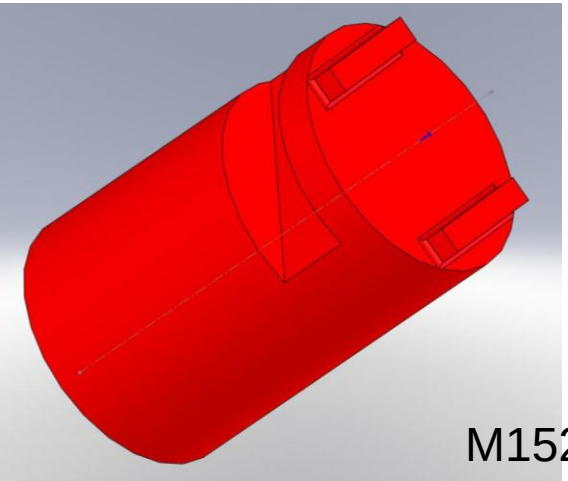
Friction Damping @ LAQ AERMEC

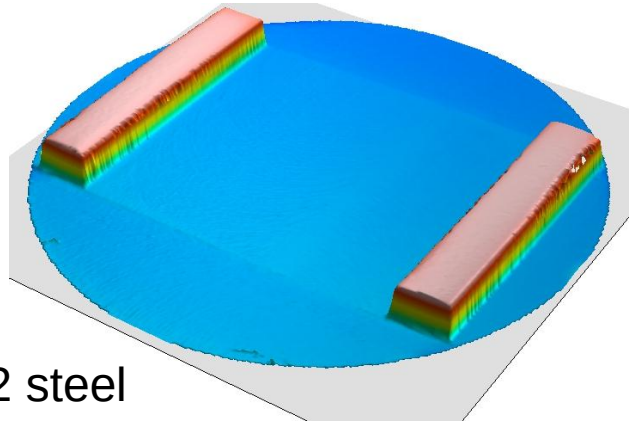
Validation of Contact Models: Wear Measurements

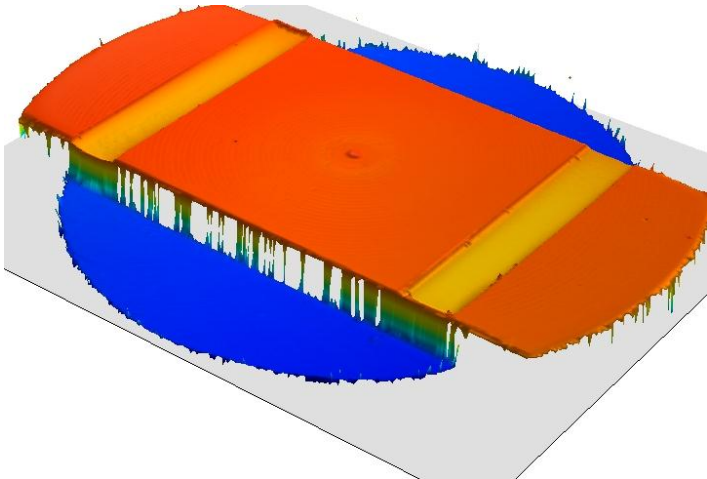
Inconel 718 - T800 coated











M152 steel

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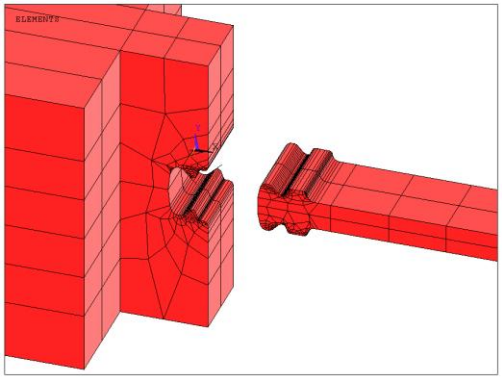
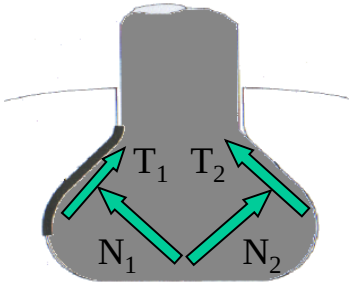
Friction Damping @ LAQ AERMEC

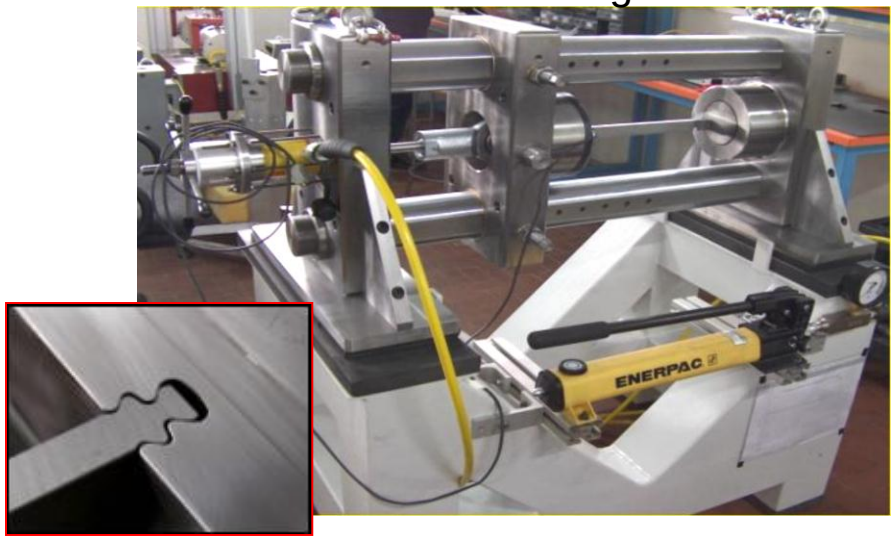
Validation of Contact models (blade/root joints)

Numerical Contact Model

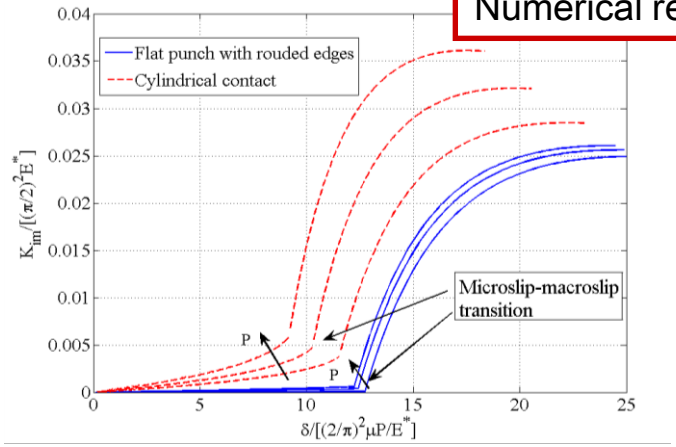




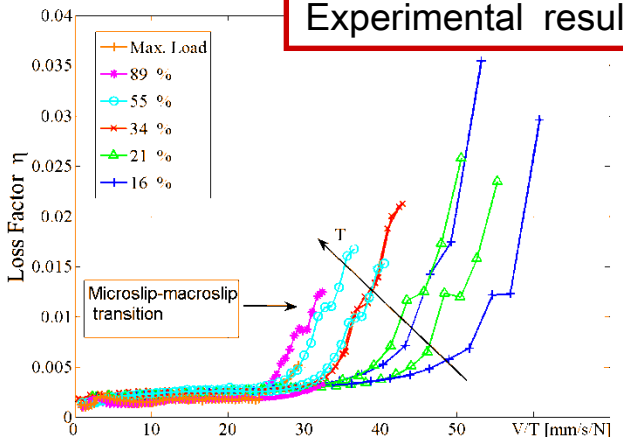
The Test Rig



Numerical results



Experimental results



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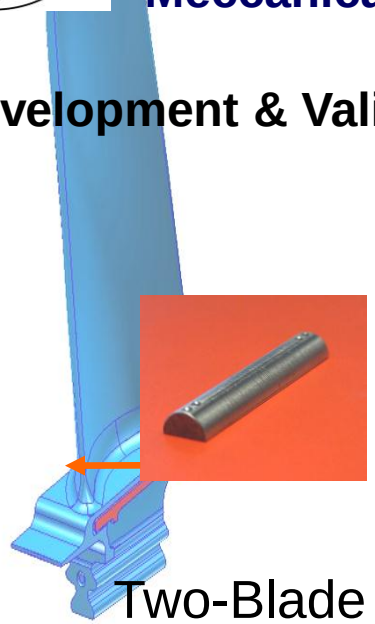
Friction Damping @ LAQ AERMEC

Development & Validation of Damper Models

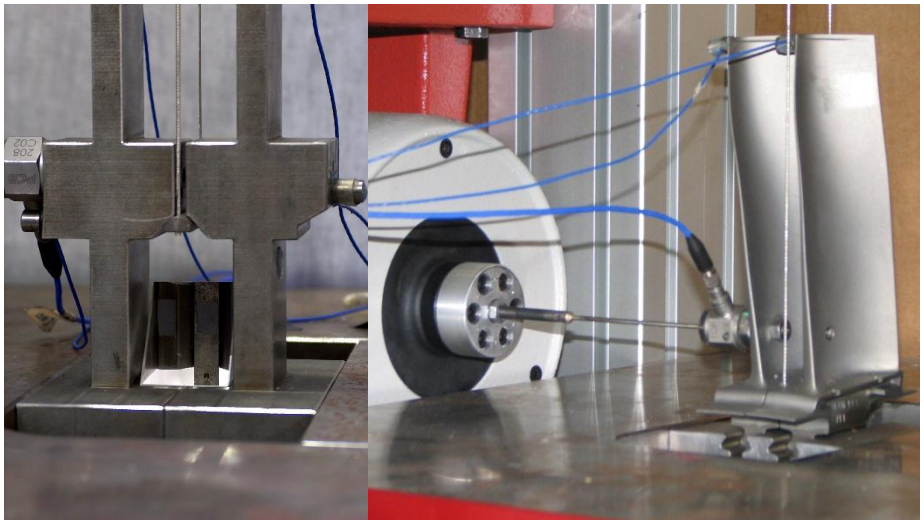


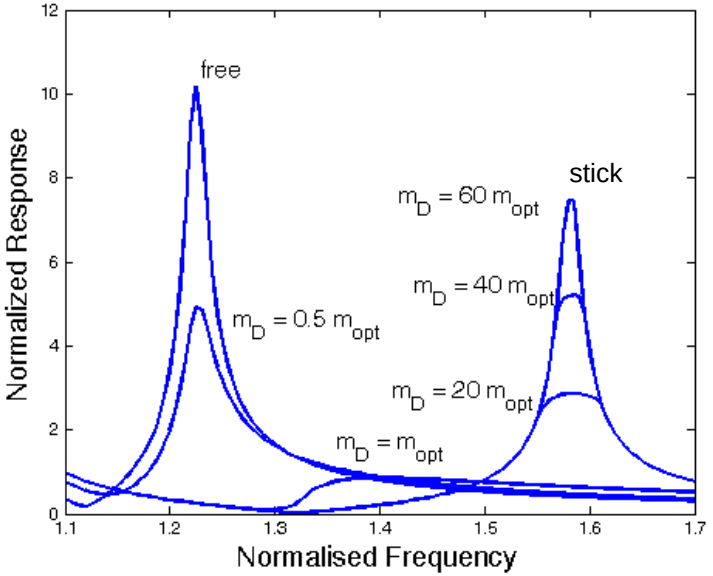
The underplatform damper is a free body pressed against the blade platforms by centrifugal force.

Damper models are necessary to simulate the complex damper kinematics.

1
Through damper response

Two-Blade Test Rig





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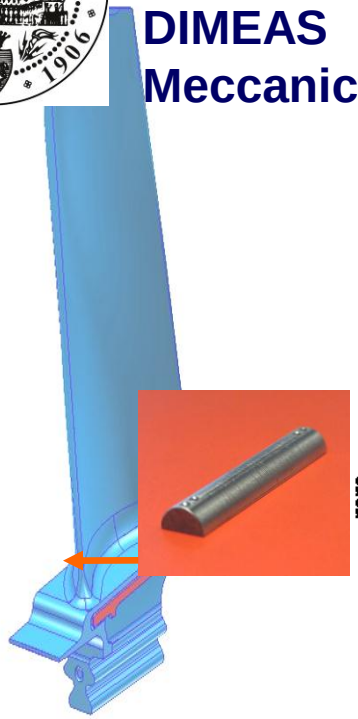
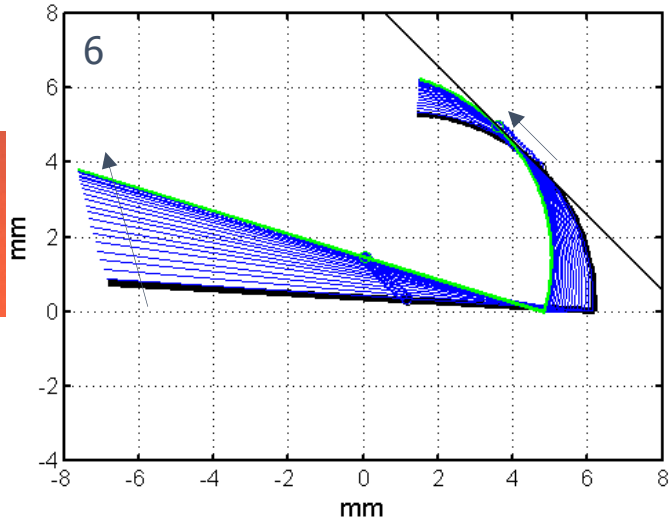
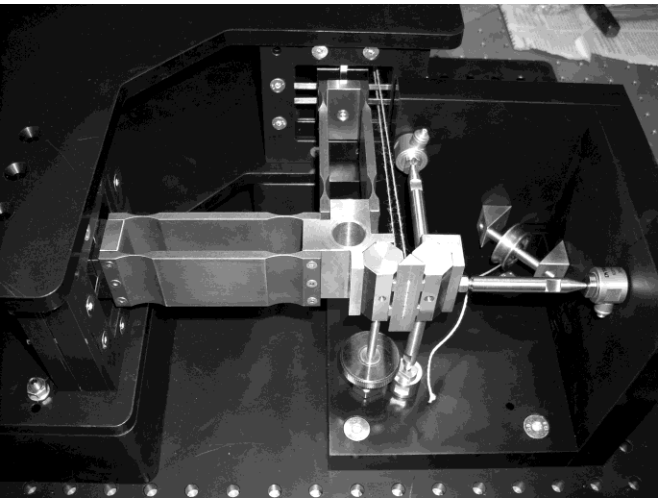
Friction Damping @ LAQ AERMEC

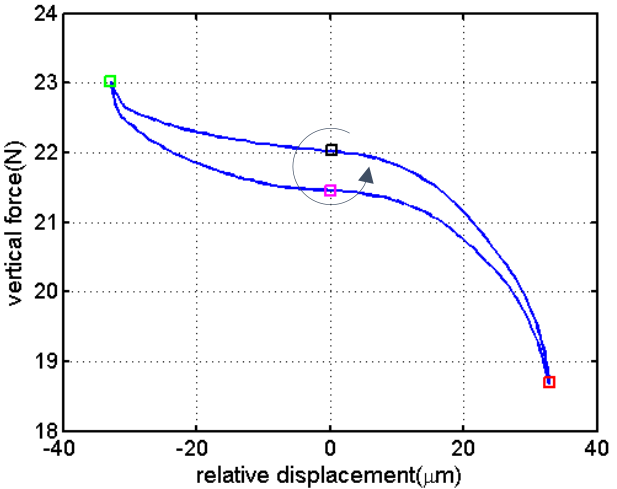
Development & Validation of Damper Models

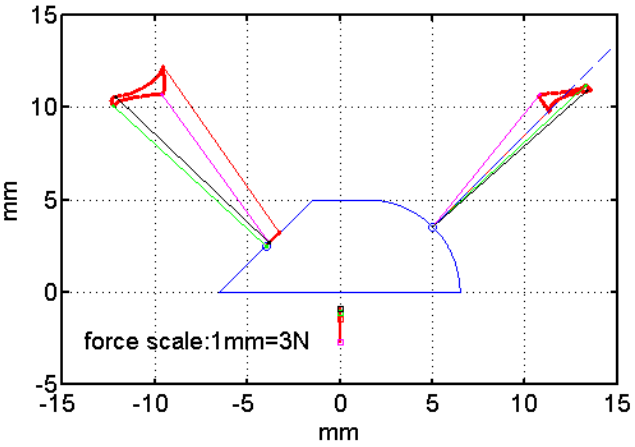




2
Through hysteresis cycle damper force and kinematics measurements







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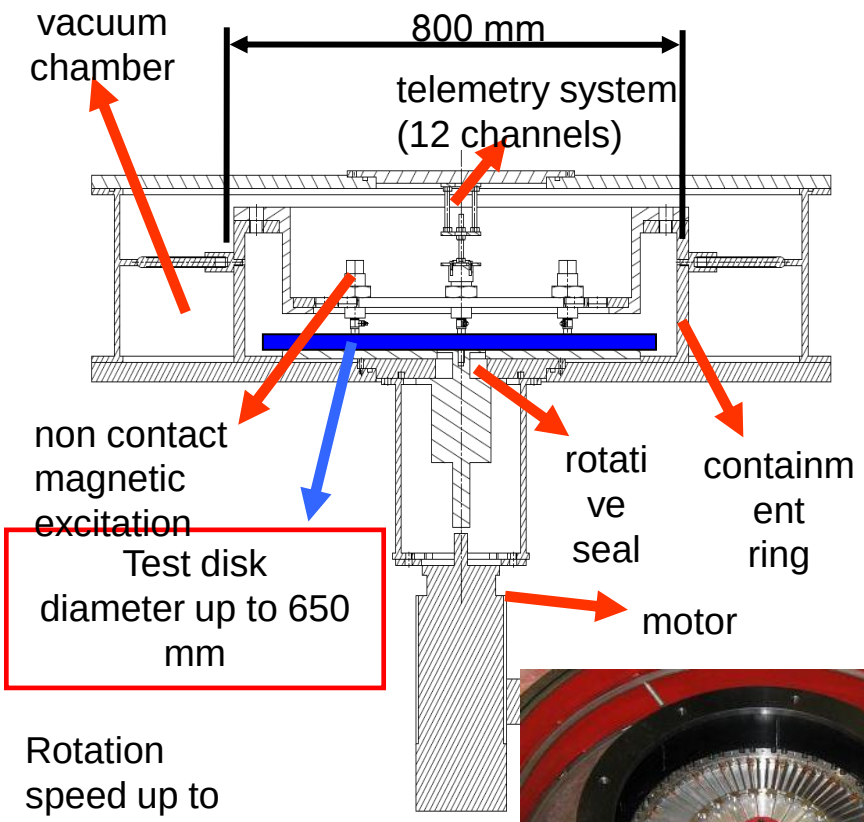
Meccanica e Aerospaziale

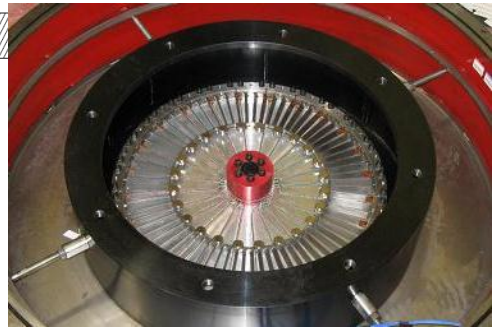
Friction Damping @ LAQ AERMEC

Full scale tests & mistuning

Rotating Rig

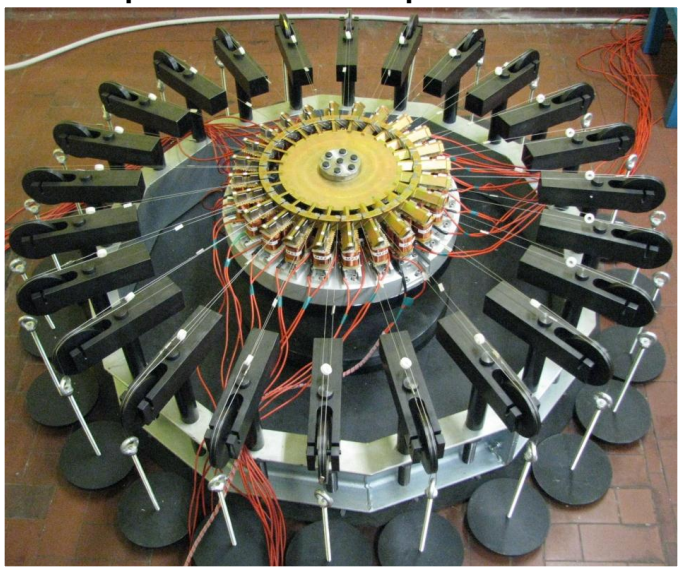


Rotation speed up to 4000 rpm



Static Rig

underplatform dampers & shrouds



non-contact rotating excitation by **electromagnets**

Some other considerations

- **How to determine which problems to tackle**
  - Experience and discussions within the institution
  - Good understanding of the needs from industry
  - Conferences and this workshop
- **Who will use your research?**
  - Strong industrial focus
  - Rolls-Royce, AVIOGroup, GE-NP, ANSALDO?
- **Where is the funding coming from?**
  - Industrial partner directly
  - Government/Industry partnership
  - European Projects