Joints - Rolls-Royce Perspective

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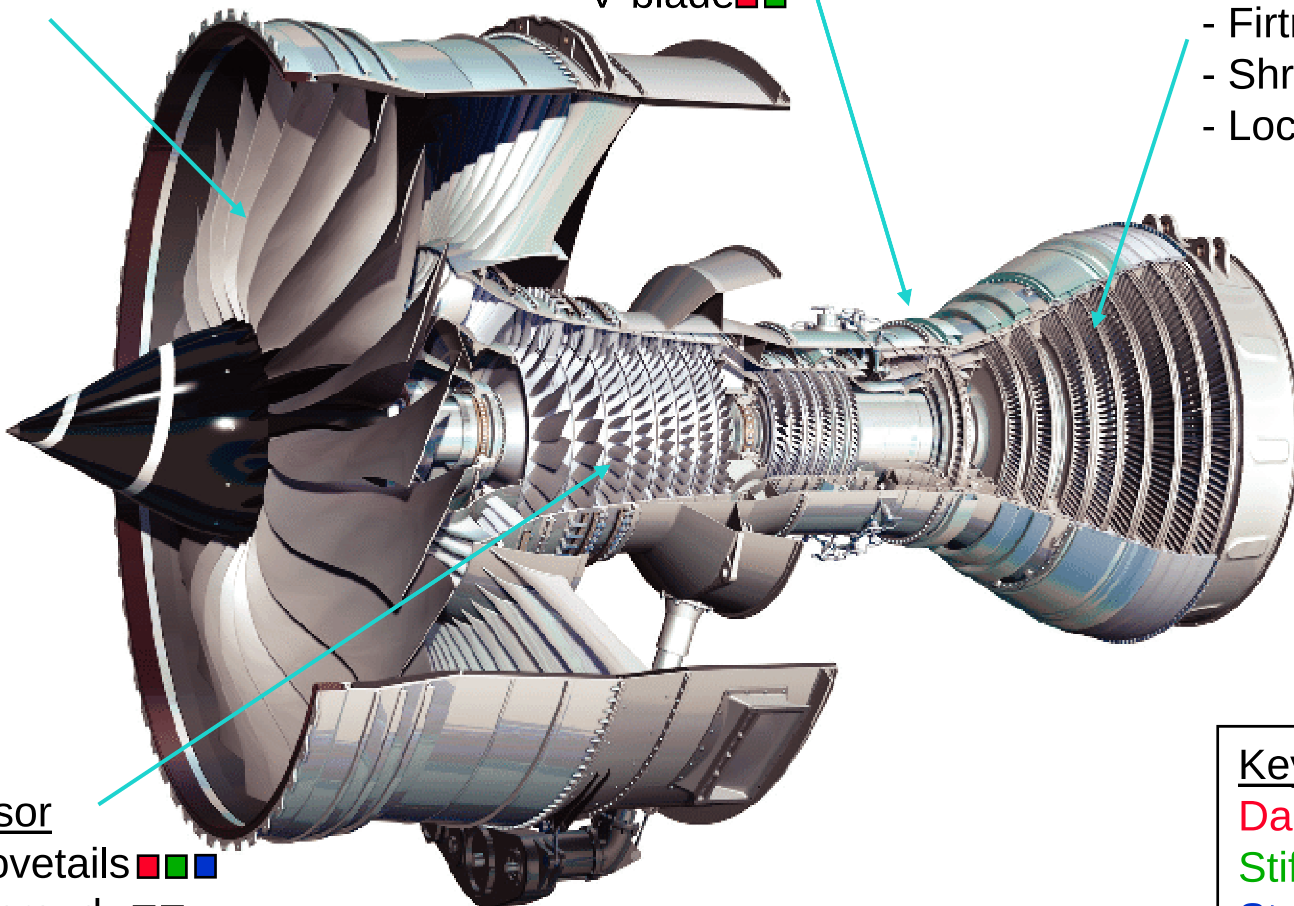
Joints Workshop April 2009.

Joints in Gas Turbine

Fan
- dovetail
- snubbers

Engine Structure
- Flanges / spigots
- Splines
- V-blade

Turbine Blades
- Dampers / seals
- Firtree
- Shroud
- Lockplate / cover plates

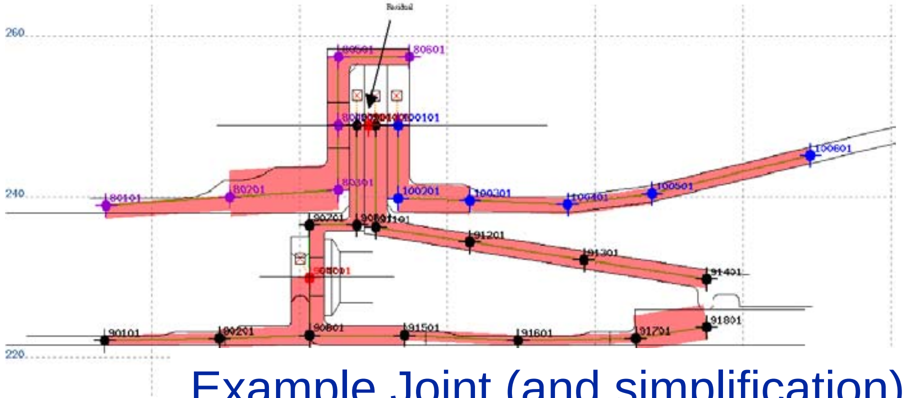


Compressor
- Rotor dovetails
- Stator shrouds

Key
Damping
Stiffness / frequency
Stress

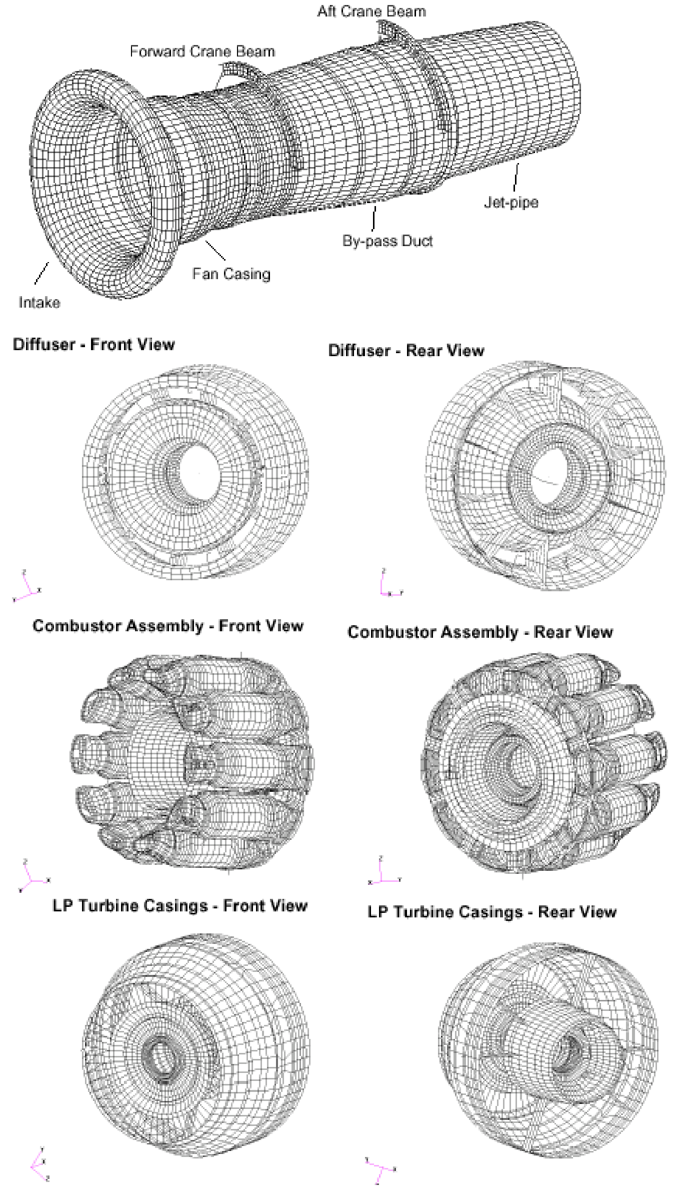
Whole Engine Issues

- **Whole engine uses a simplified model.**
  - Need simplified respresentation of joints.
- **Static loads (thrust / external loads / manoeuvres)**
  - Are stiffness effects adequate for tip clearances and load distribution etc?
- **Dynamic Loads**
  - **Engine/Wing Dynamics (0-10 Hz)**
    - Frequency, damping, loads
  - **Engine Rotordynamics (30-500 Hz)**
    - Frequency, damping, loads
  - **Extreme events (eg Fan Blade Off)**



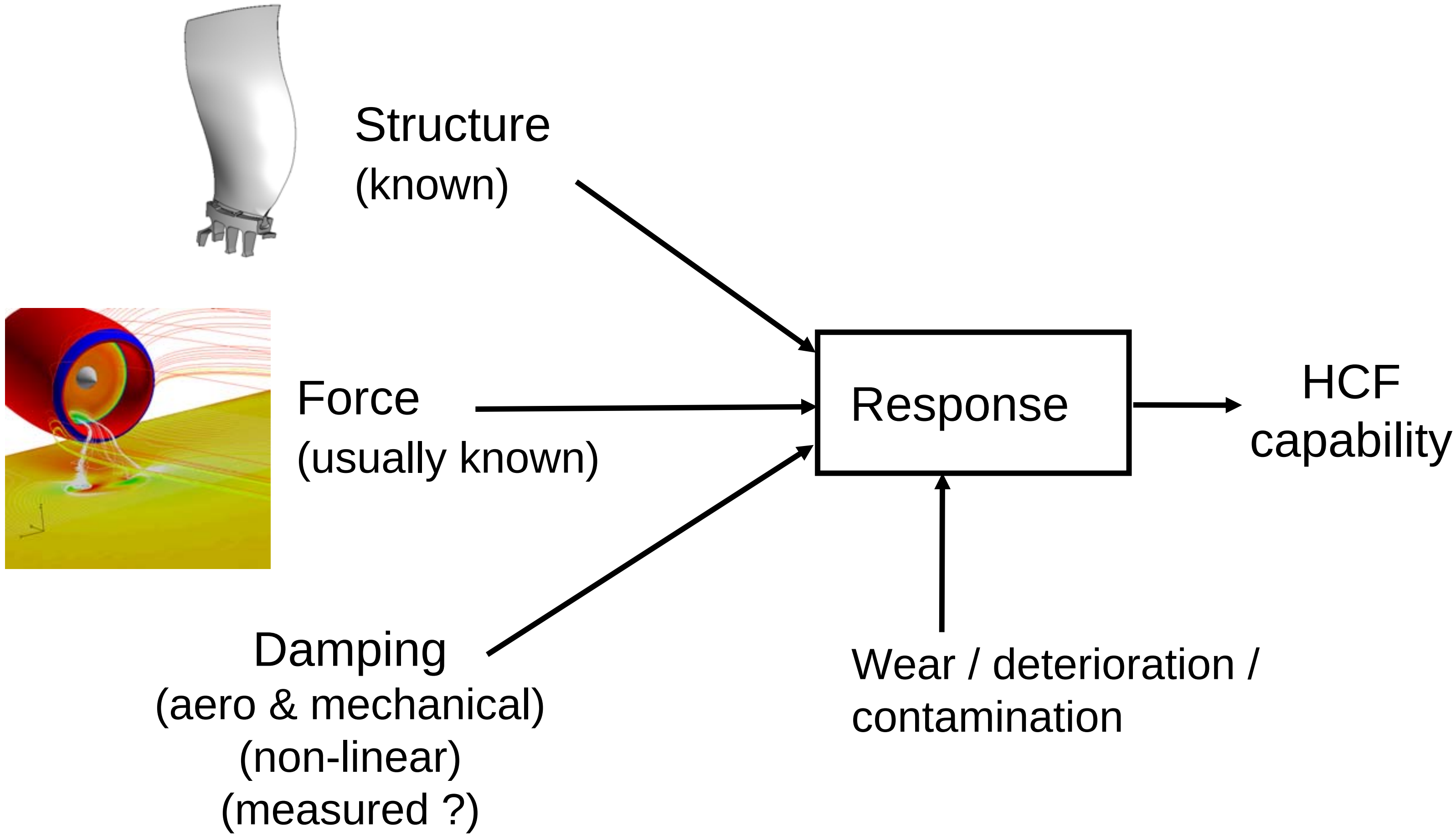
Example Joint (and simplification)

Simplified Engine Model



Damping

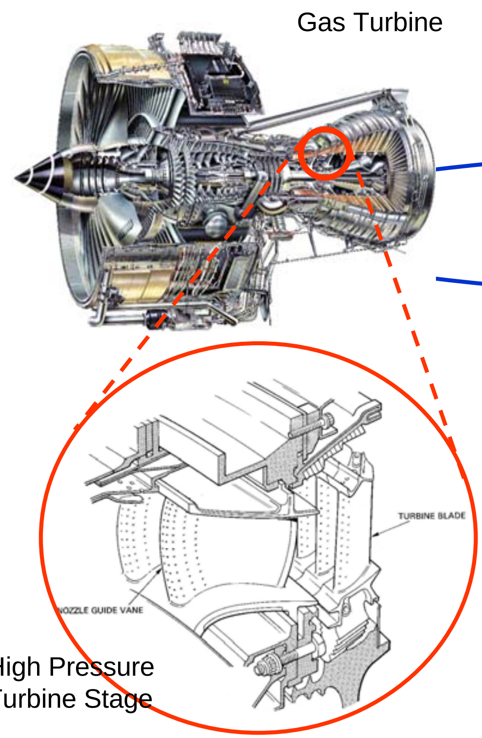
- **Drive towards prediction of vibration amplitude for design and certification.**

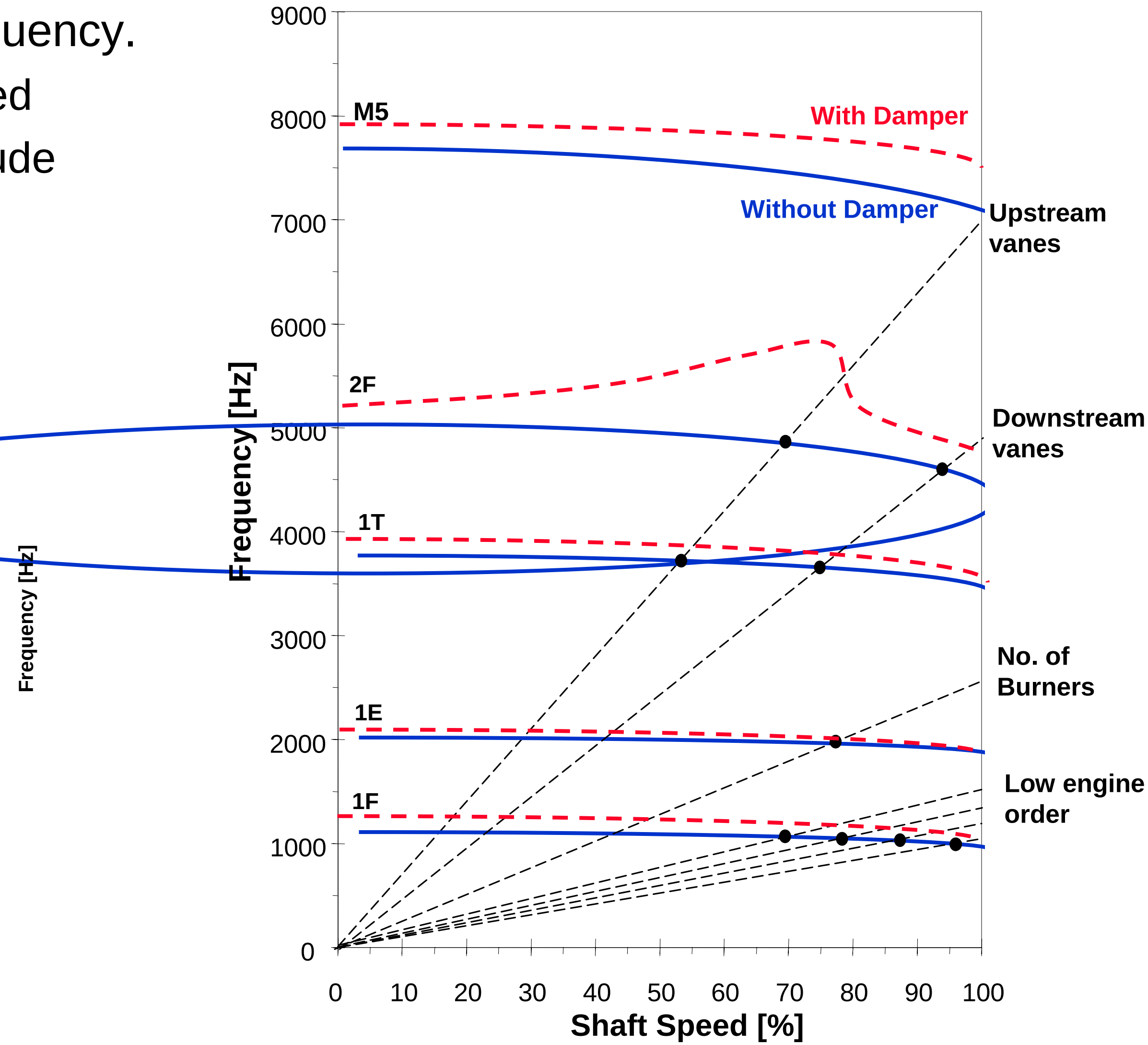


Effect of Non-linear Contact on Frequency

- Dampers can have a significant influence on resonant frequency.
  - Affect on resonant speed
  - Change in force amplitude

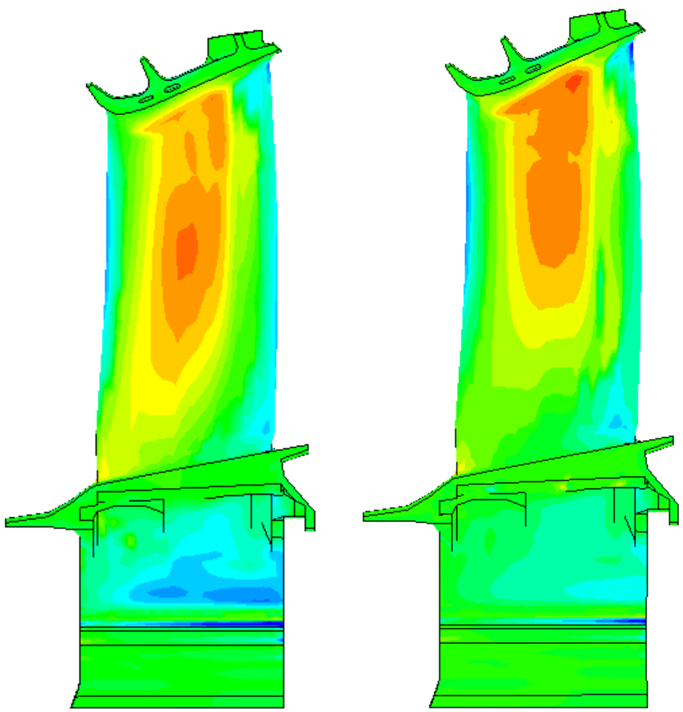
Campbell Diagram of HP Turbine





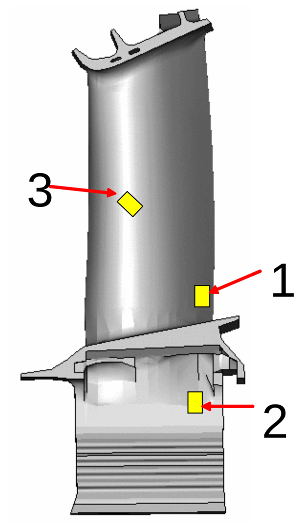
Effect of Joint on Modeshape => Stress

Contours of WP Stress
At 2F resonance



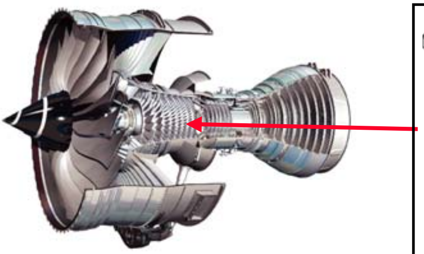
No damper **With damper**

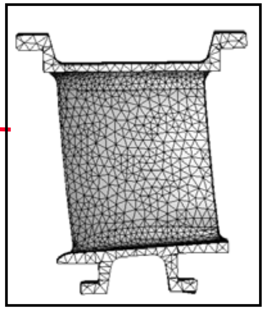
Typical position of strain gauges In engine tests.

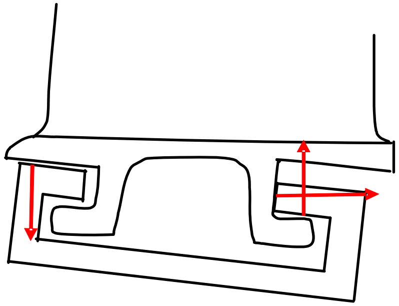


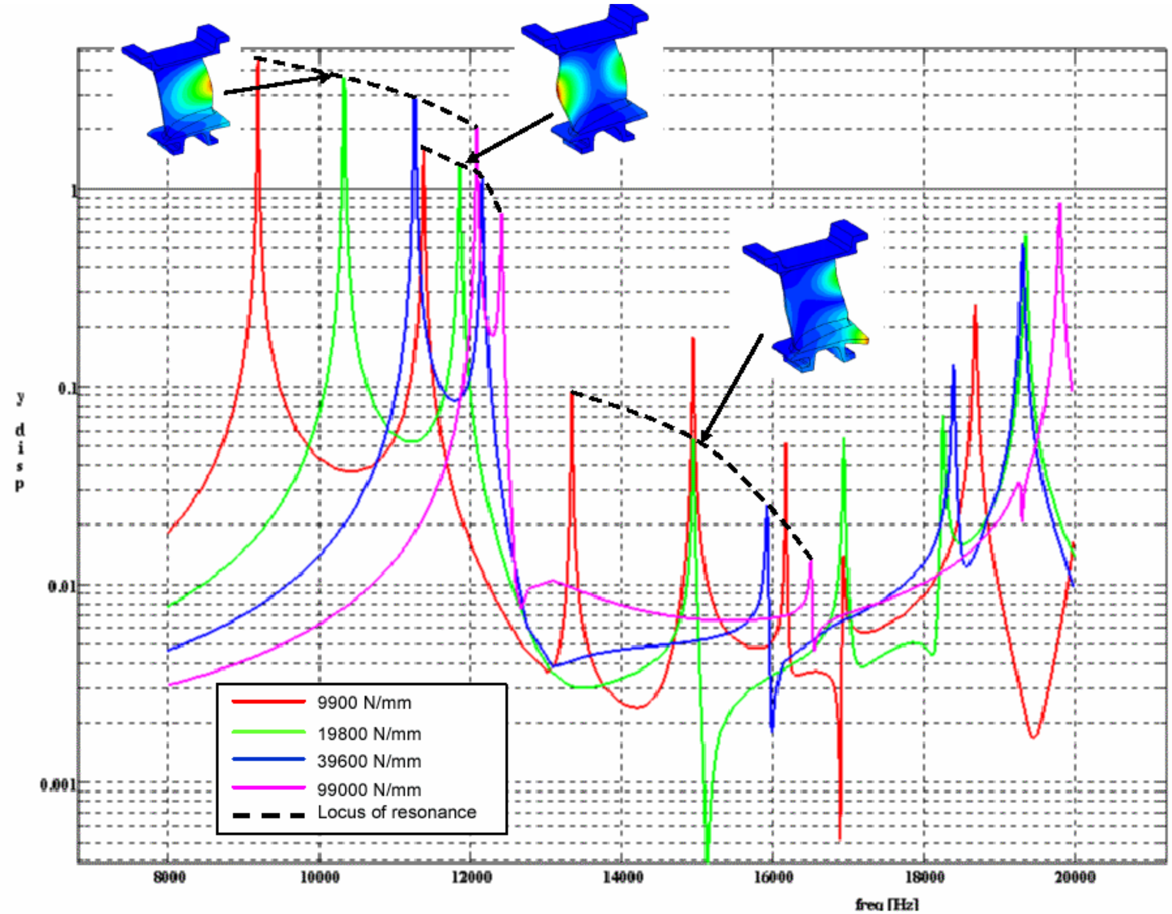
	Gauge Position	Gauge Sensitivity [Mpa/mm]	
		1T Mode	**2F Mode**
Undamped	1	579	**779**
	2	156	**394**
	3	**731**	354
Damped	1	348	**876**
	2	62	**277**
	3	**705**	265

Effect of Shroud Contact on Stator Response





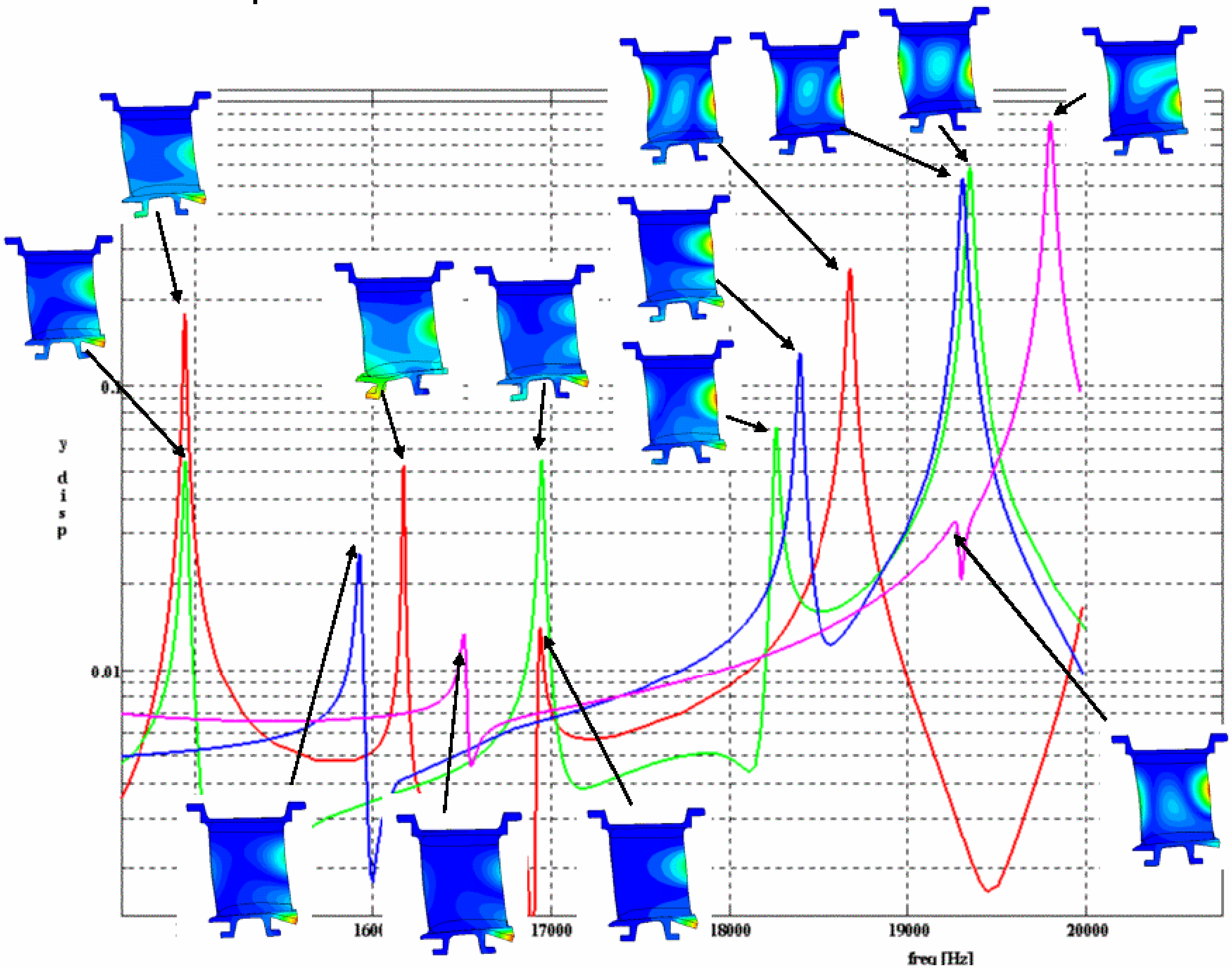




- Uncertainty about inner shroud restraint => variability in effective stiffness
- Change of stiffness leads to change in amplitude and frequency.
- Difficulty interpreting measured results

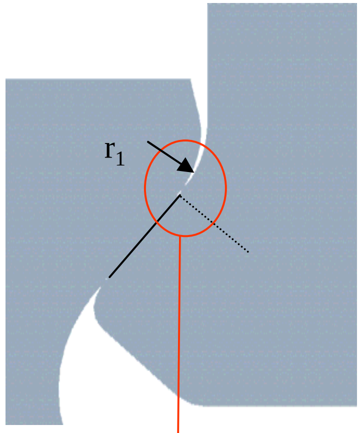
Effect of Shroud Contact on Stator Modes

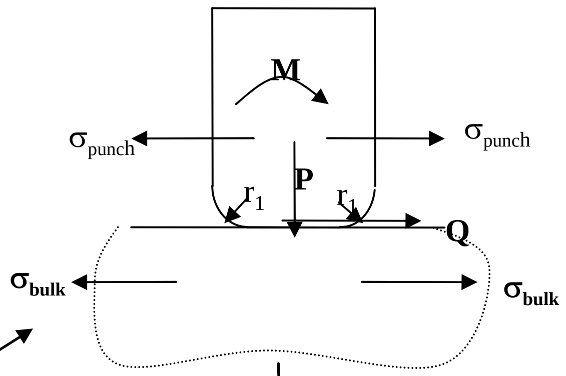
- It gets more complicated ...

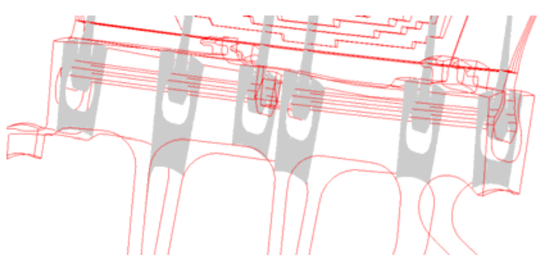


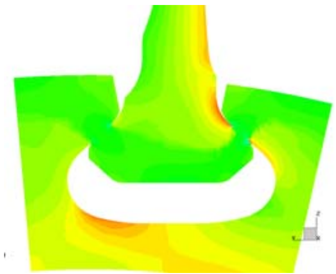
Structural Integrity Assessment of Fan Dovetail Joints

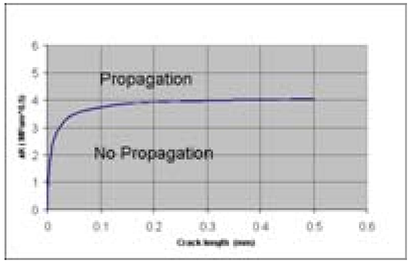
- Assessment capabilities enhanced significantly in recent years
  - Steady and vibration stress predictions
    - based on load extraction from 'coarse' FE model and analytical half-space model.
    - Converged stresses using detailed FE sub-sub modelling.
  - Robustness determined using short crack modelling techniques.
  - Integrity of root managed via use of surface coatings and treatments.
  - More careful design possible.





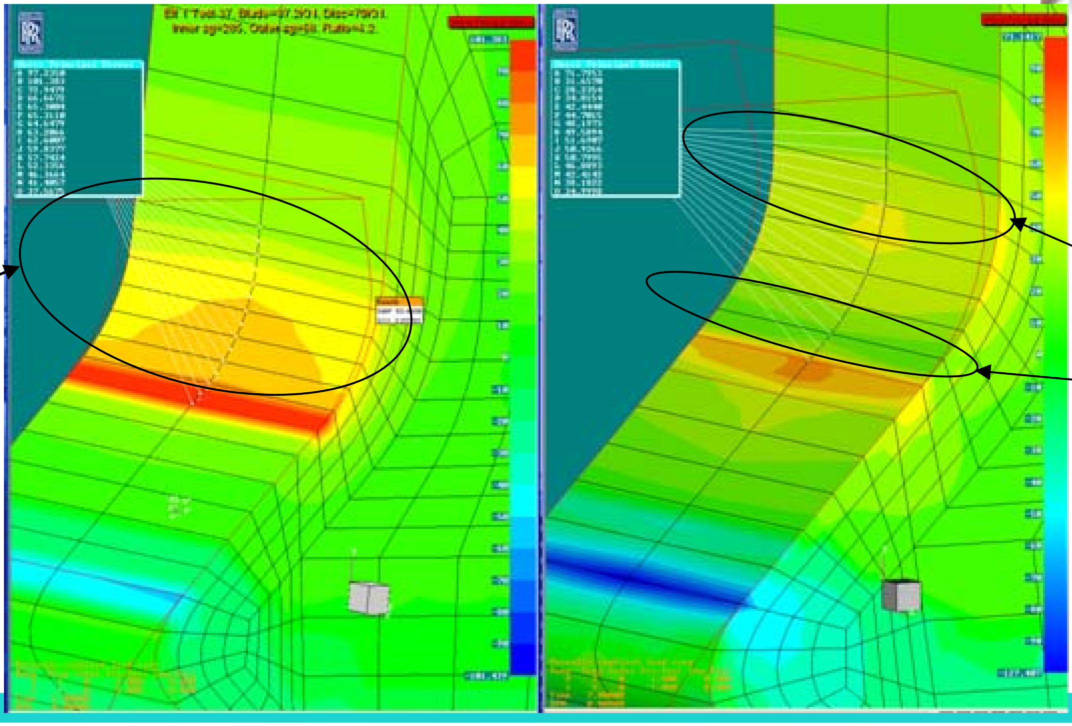






Outstanding Issues?

- Varying (patchy) friction, local wear, effect of local fillet, half-space assumptions.
- Longer lasting surface coatings have clear cost benefits.
- EoB and near edge of bedding locations can be life limiting features.
- Prediction of stresses near edge of bedding in vibration is problematic.
    - ➢Use of locked contact can be misleading



Locked contact during vibration. Stress from fillet and EOB and fillet merge into one stress peak

ABAQUS friction analysis shows separation of fillet and EoB stress. Region close to EoB is now showing a much reduced stress.

Summary of Needs

- **Damping**
  - Stability & Amplitude prediction (including non-linear effects)
  - Friction Properties
  - Validation of System Behaviour
  - Interpretation of measured results (in engine)
  - Rotor dynamics for stability
- **Frequency**
  - Effect of blade dampers is already under control
  - Snubbers / Interlocks (mainly for fleet support)
  - Whole engine at high frequencies – accessories
- **Stress**
  - Edge of bedding stress including steady stress and vibration.
  - Surface treatments, coatings
  - Wear