HOT SPOTS IN TURBOEXPANDER BEARINGS: CASE HISTORY, STABILITY ANALYSIS, MEASUREMENTS AND OPERATIONAL EXPERIENCE

Joachim Schmied, DELTA JS

Josef Pozivil, Cryostar SAS

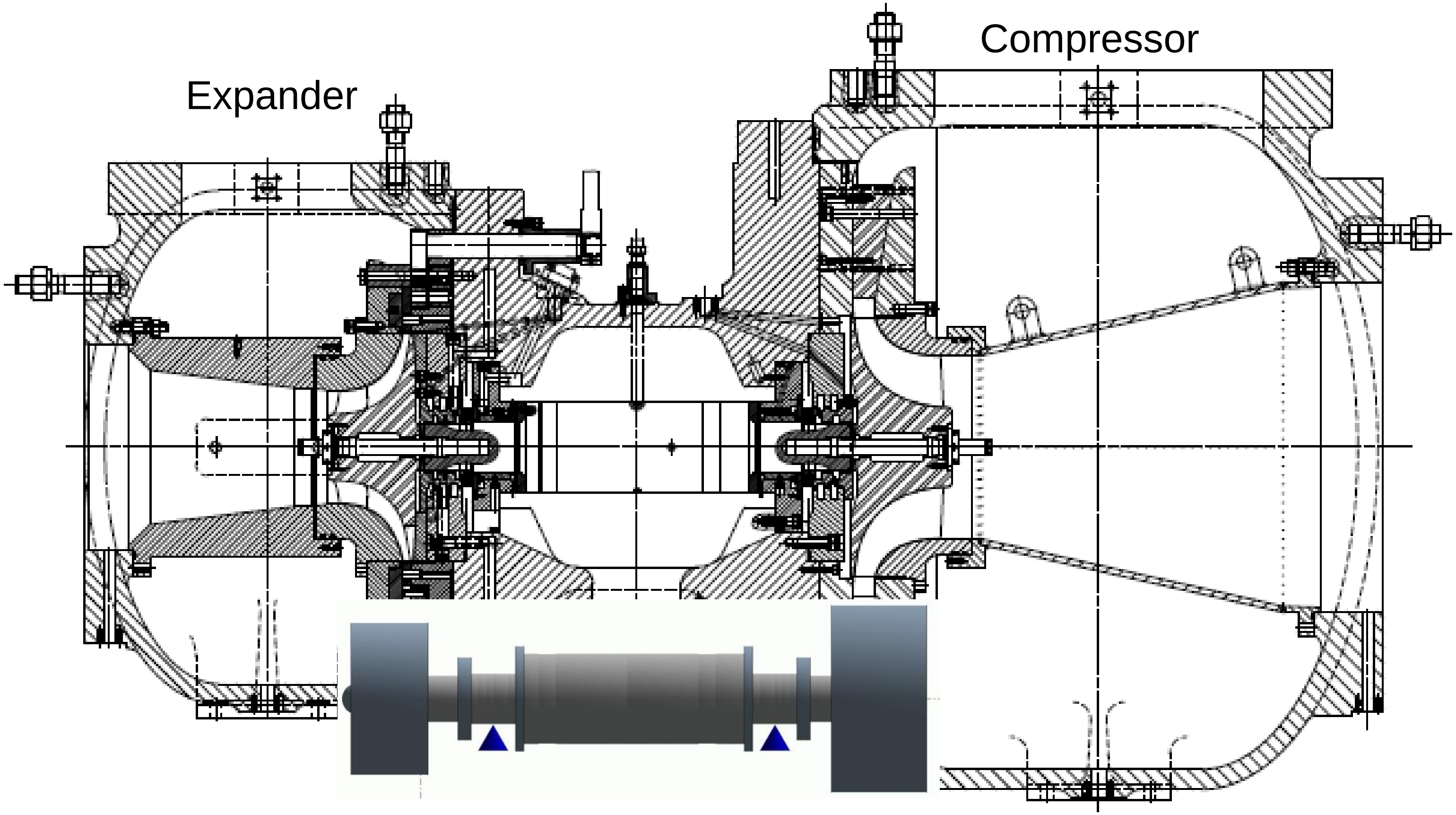
HOT SPOTS IN TURBOEXPANDER BEARINGS

- ★ **DESCRIPTION OF THE MACHINE**
- ★ **ROTORDYNAMIC BEHAVIOR (ANALYSIS AND TEST)**
- ★ **THE HOT SPOT PHENOMENON**
- ★ **ANALYSED AND TESTED MODIFICATIONS**
- ★ **CONCLUSIONS**

DESCRIPTION OF THE MACHINE

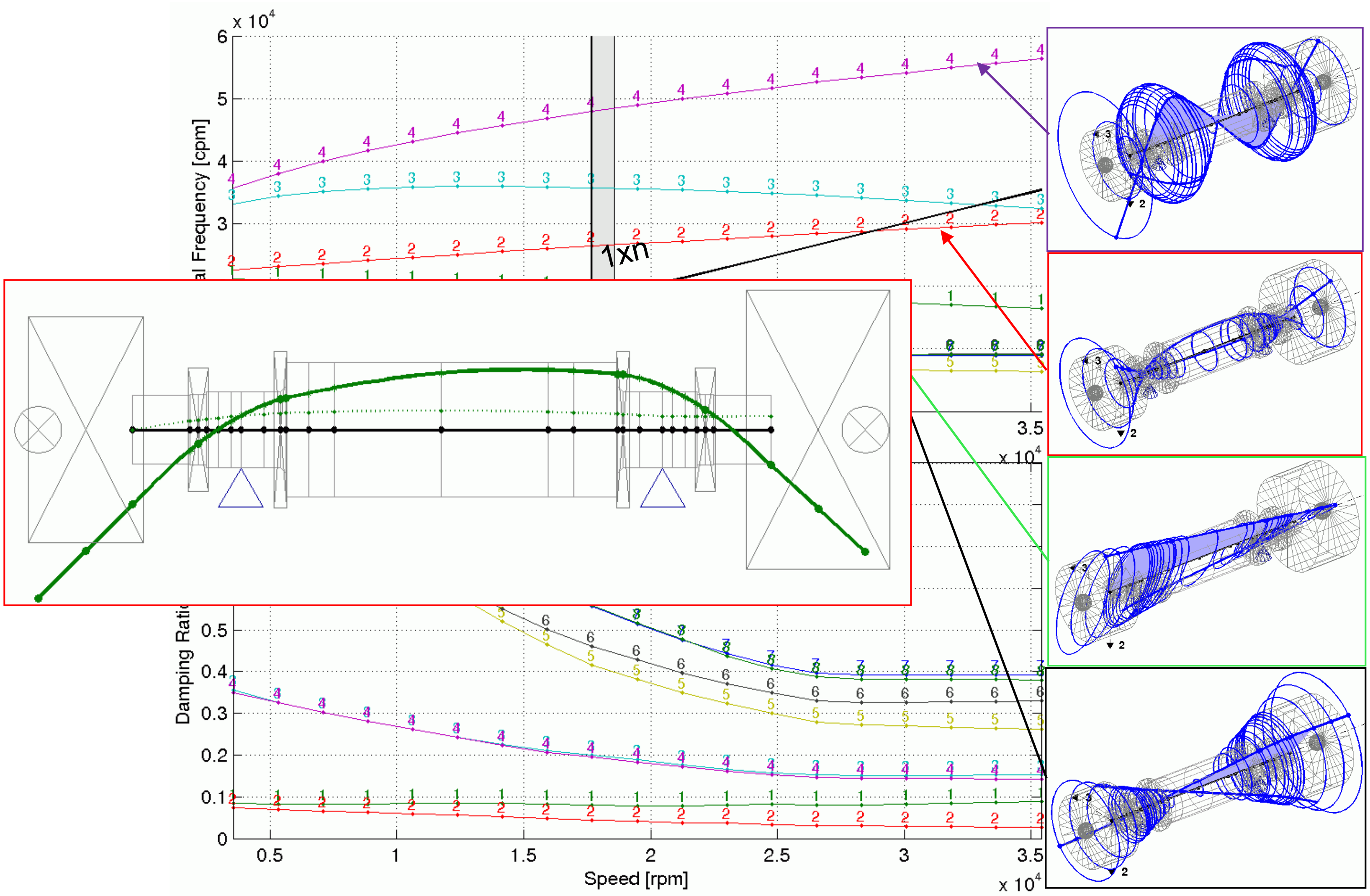
Dual turboexpander 2-TC 400/90 with oil unit and control panel

DESCRIPTION OF THE MACHINE



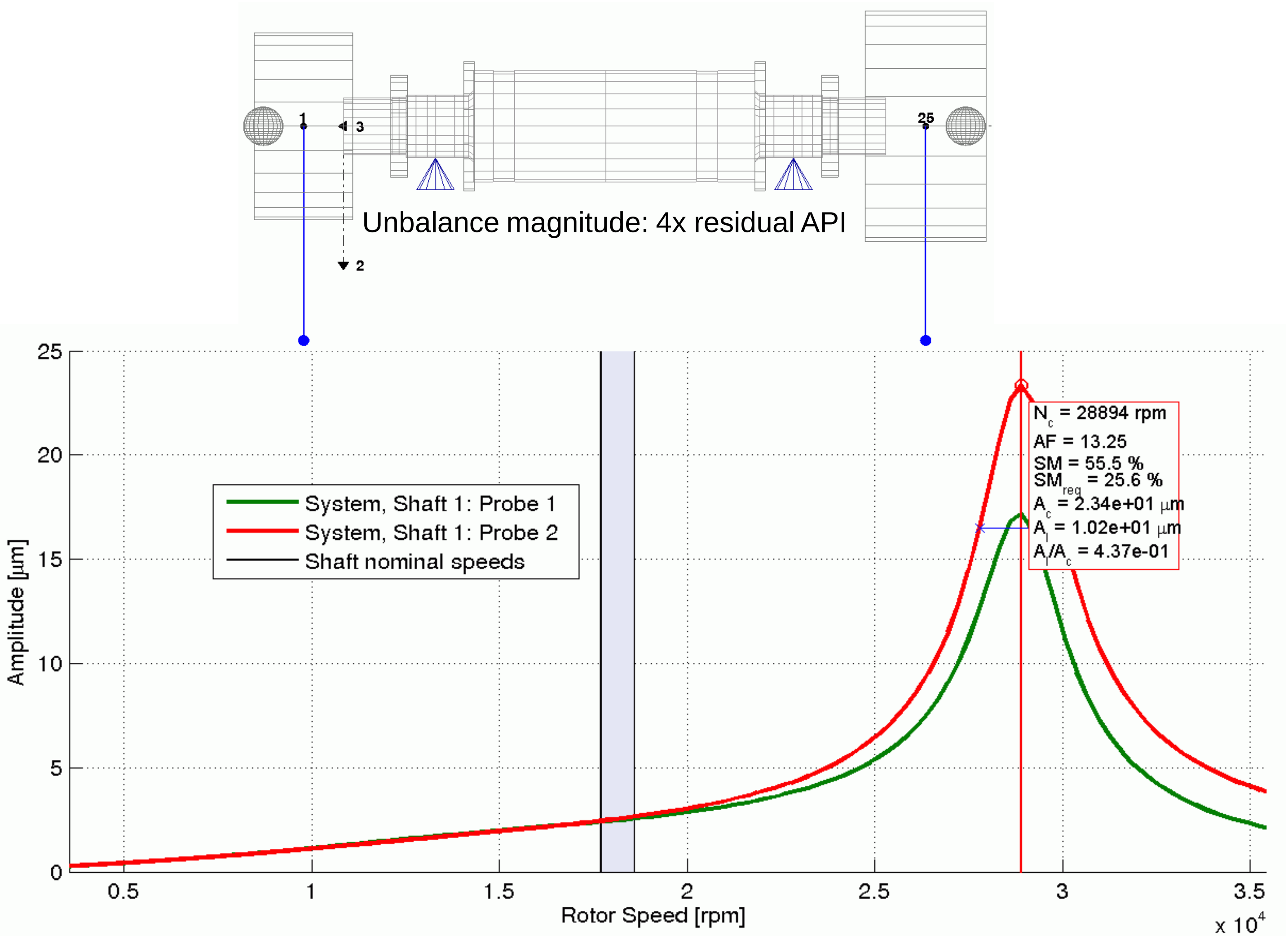
Cross section and rotor model of the turboexpander TC 400/90

ROTOR DYNAMIC BEHAVIOR (ANALYSIS)



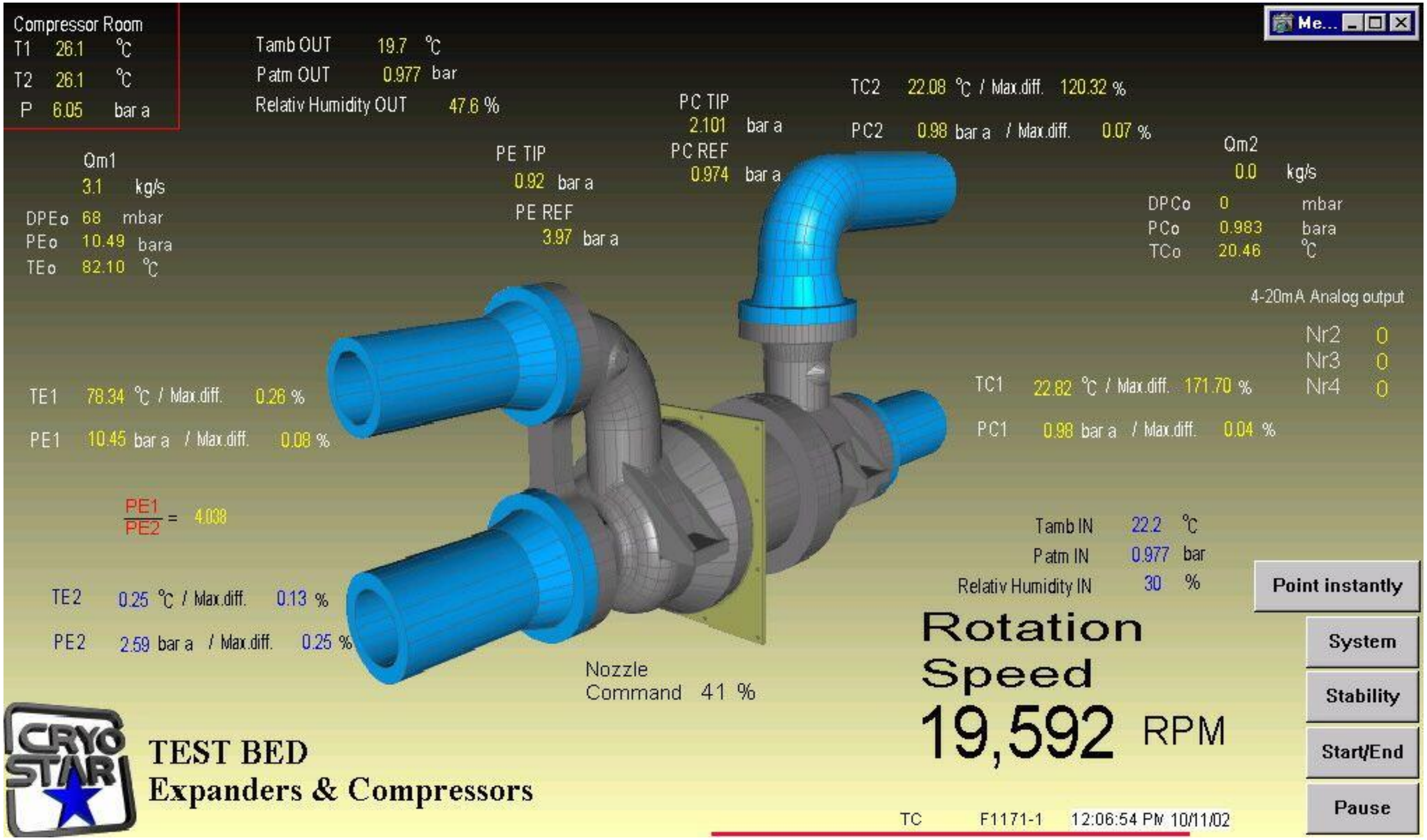
Campbell diagram and mode shapes

ROTOR DYNAMIC BEHAVIOR (ANALYSIS)



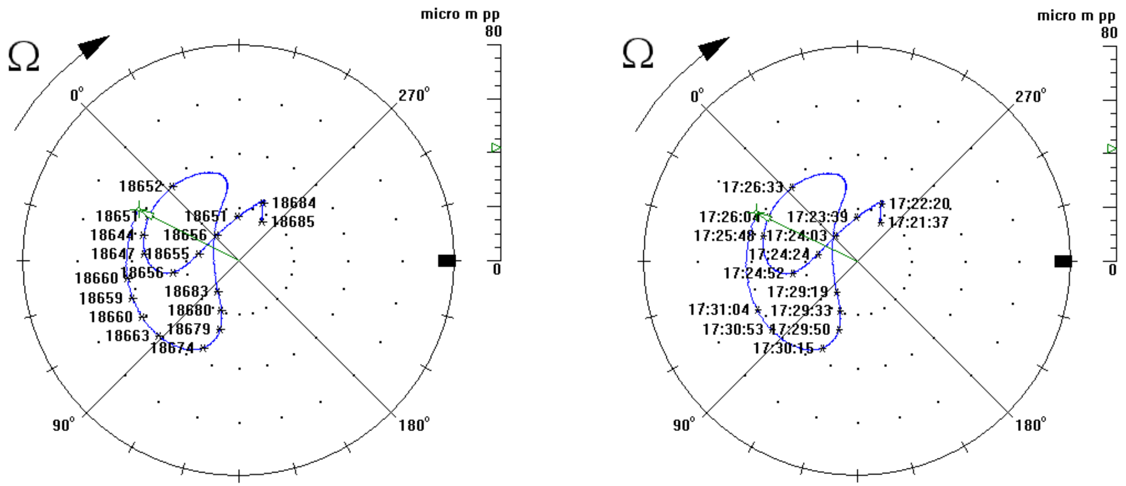
Unbalance response with API evaluation

ROTOR DYNAMIC BEHAVIOR (TEST)

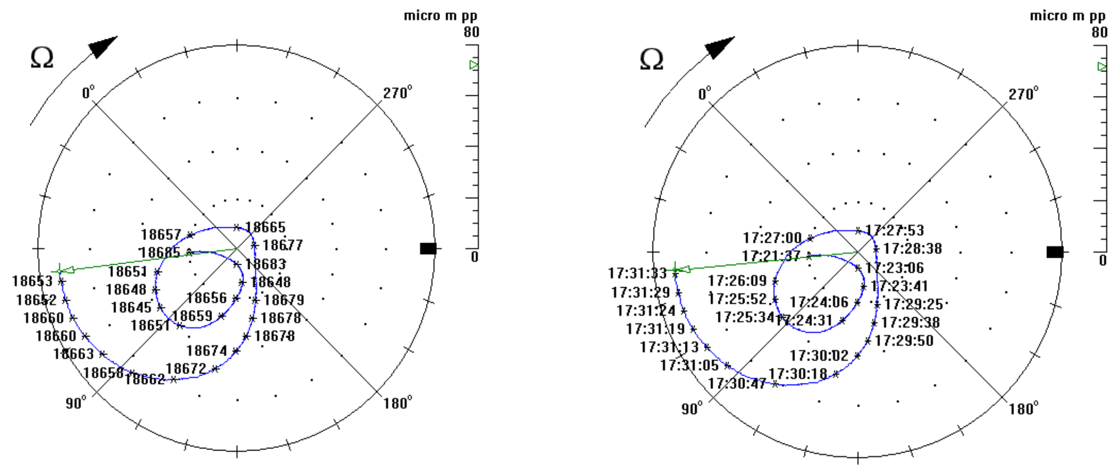


Test bed computer mimic

ROTOR DYNAMIC BEHAVIOR (TEST)

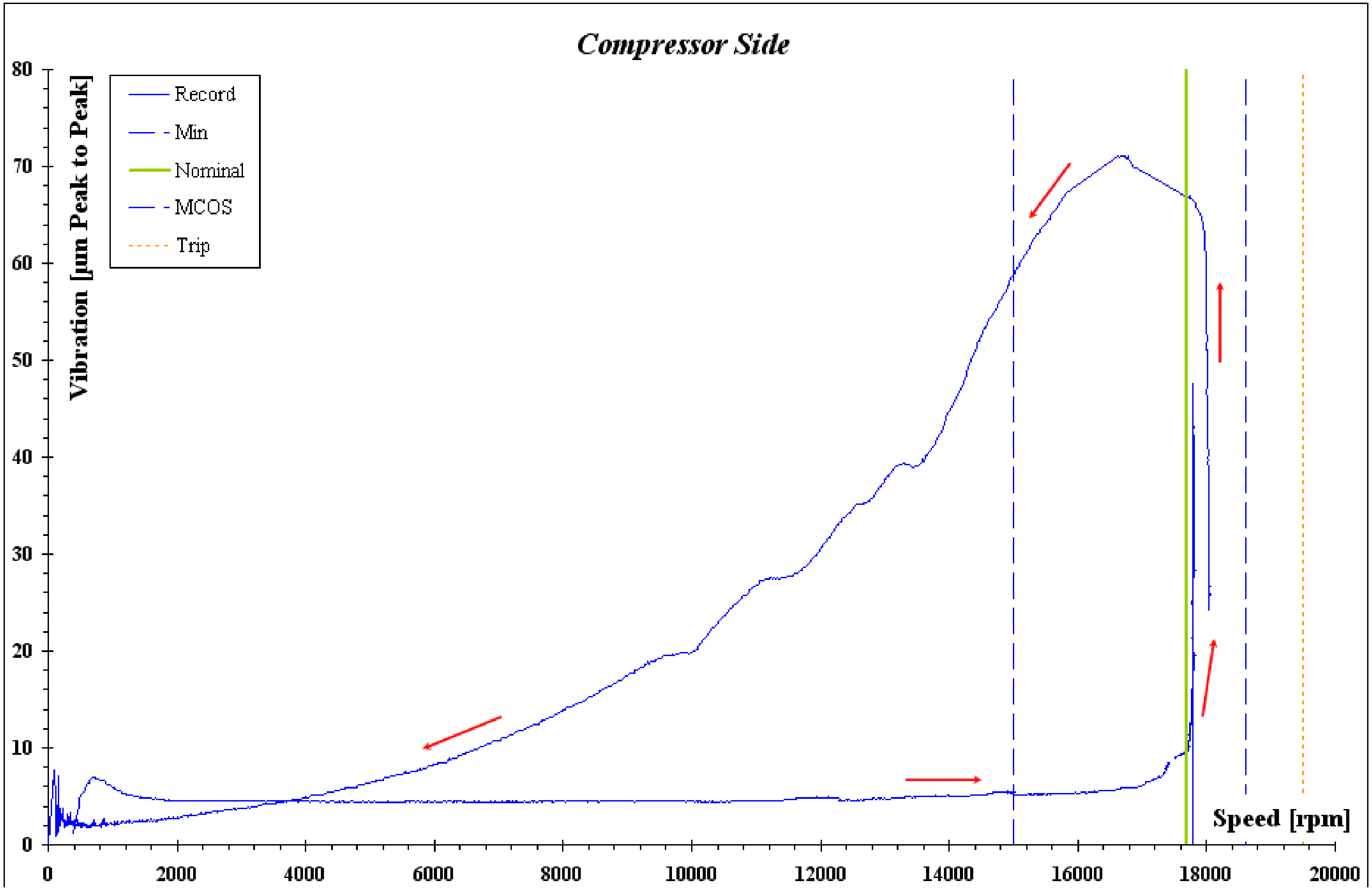


Spiral vibration in 1xN polar plot – expander side



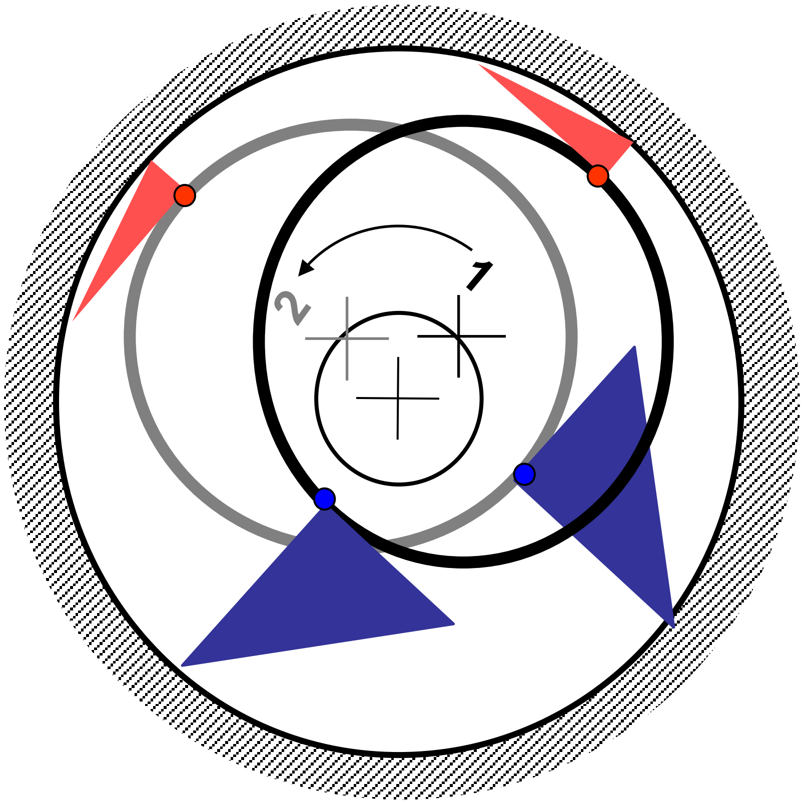
Spiral vibration in 1xN polar plot – compressor side

ROTOR DYNAMIC BEHAVIOR (TEST)



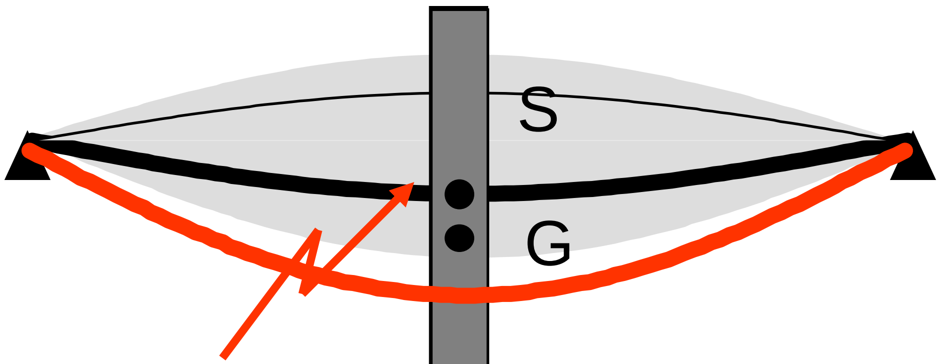
Vibration hysteresis in Bode pot

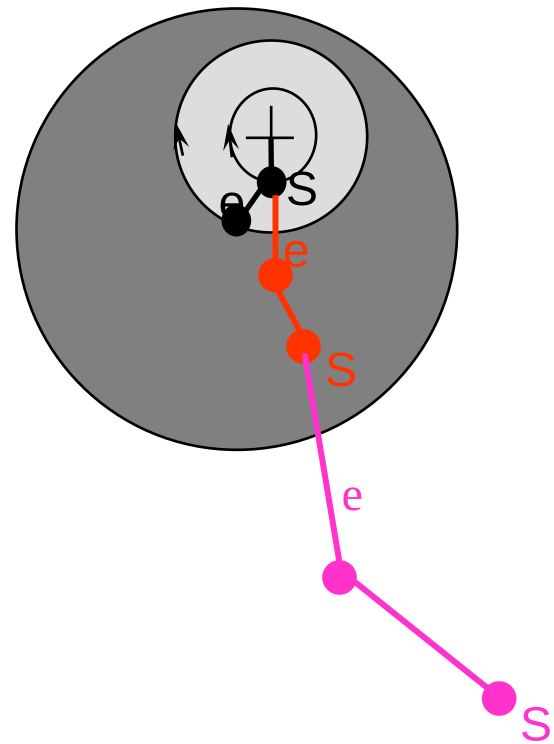
THE HOT SPOT PHENOMENON



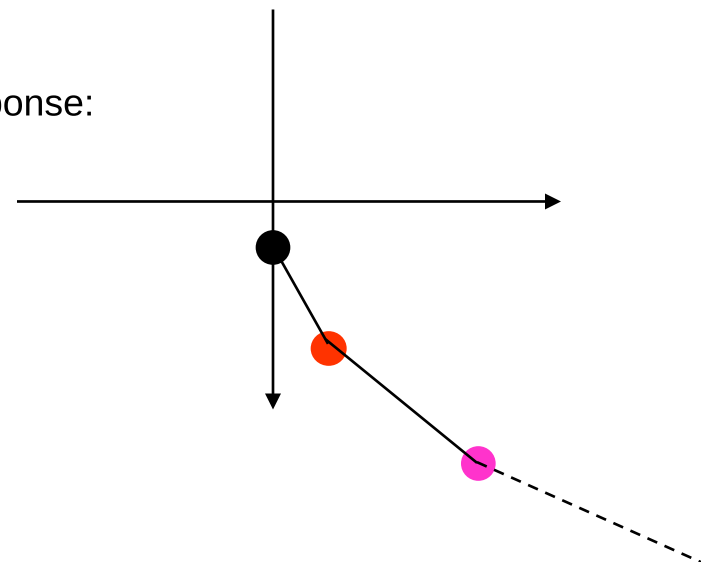
Hot spot mechanism

THE HOT SPOT PHENOMENON



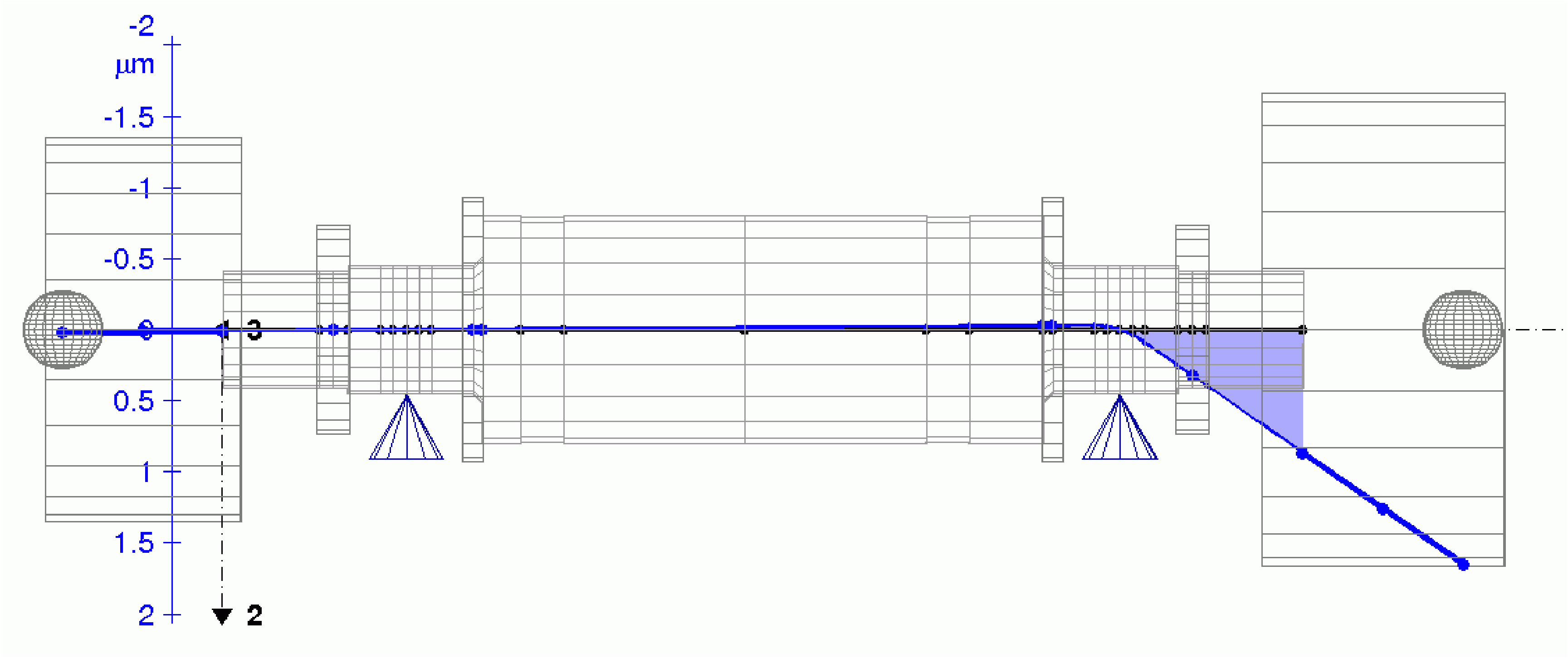


Polar plot of response:



How does the spiral arise ?

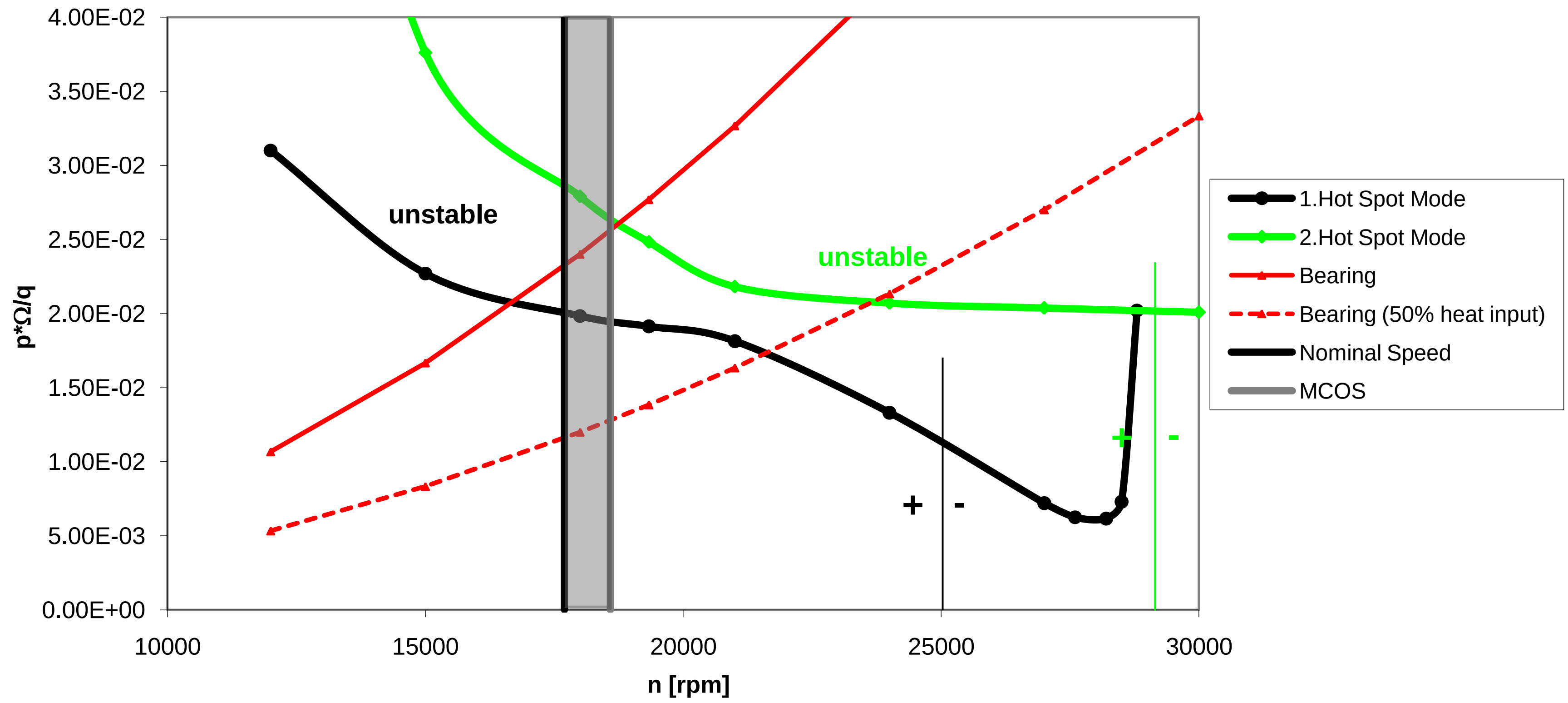
THE HOT SPOT PHENOMENON



Thermal deformation,

1ºC cross sectional temperature difference in comp. bear.

THE HOT SPOT PHENOMENON



Hot spot stability chart

THE HOT SPOT PHENOMENON

★ Simplified formula for the estimation of the heat ratio

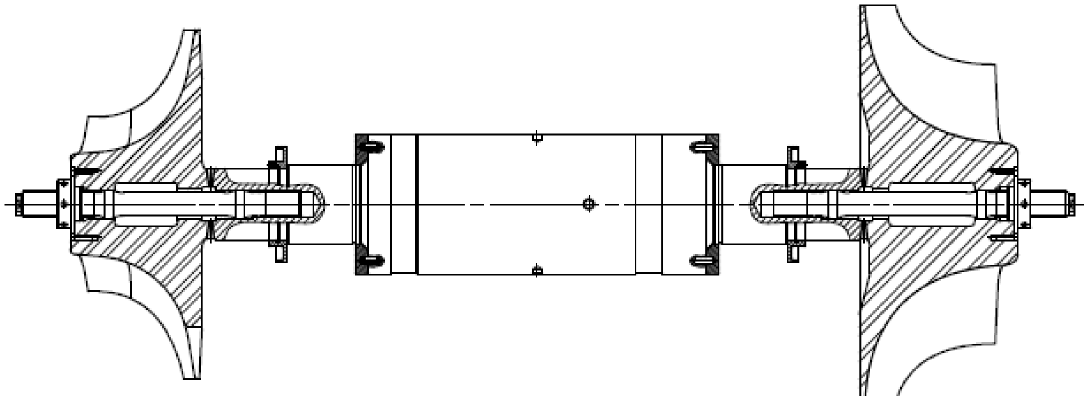
$$\frac{p\Omega}{q} = \frac{u^2 \eta \beta}{\delta^2 \alpha}$$

Symplifications best apply to a cylindrical low loaded (centred) cylindrical bearings.

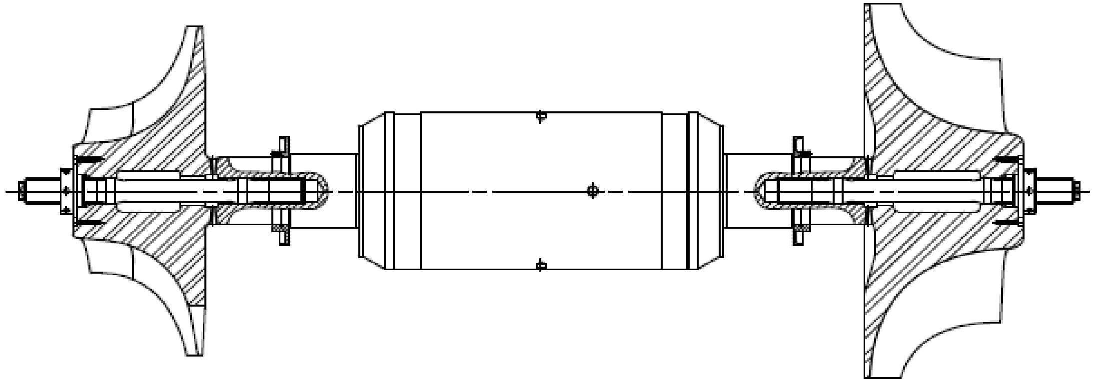
★ Parameters

u: Circumferential shaft velocity
η: Viscosity
β: Relation between thermal deflection and temperature difference (proportional to width)
δ: Clearance
α: Heat transfer coefficient between oil and shaft

ANALYSED AND TESTED MODIFICATIONS



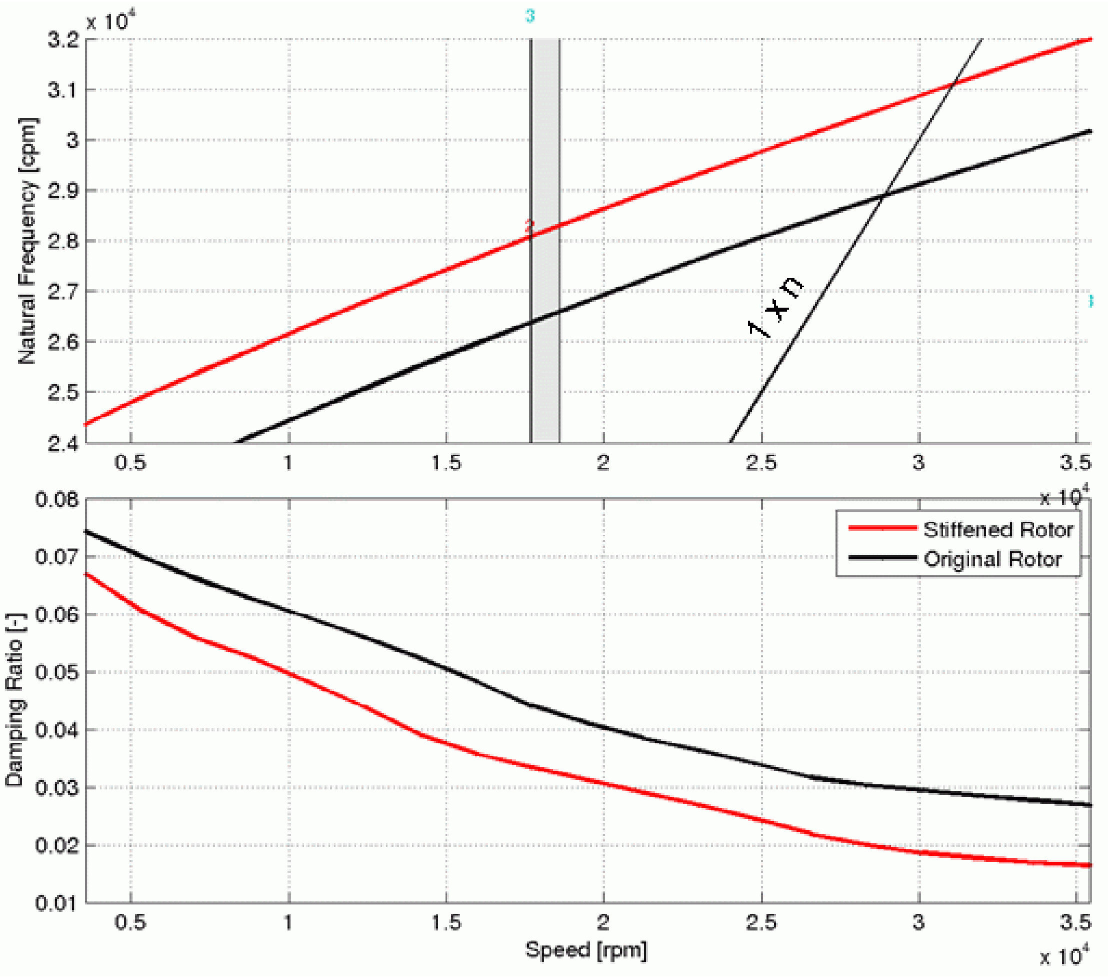
Original rotor



Modified stiffer rotor

ANALYSED AND TESTED MODIFICATIONS

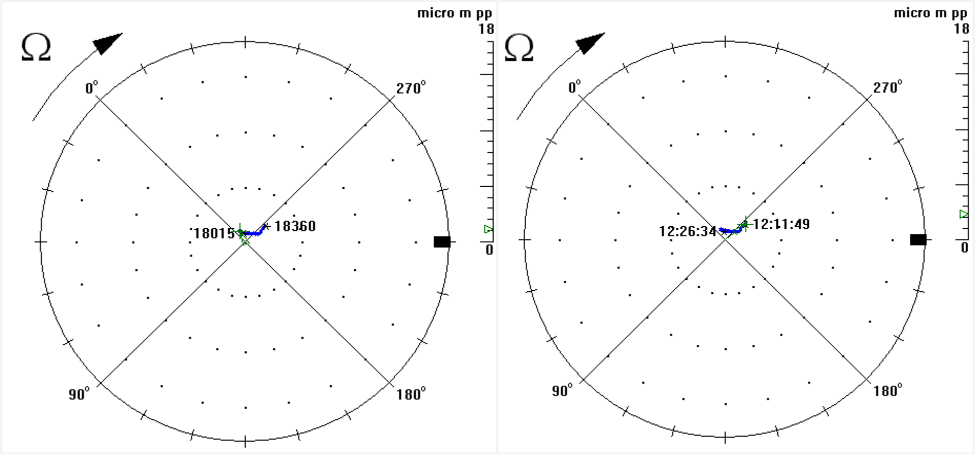
★ **Stiffer rotor → increased separation margin**



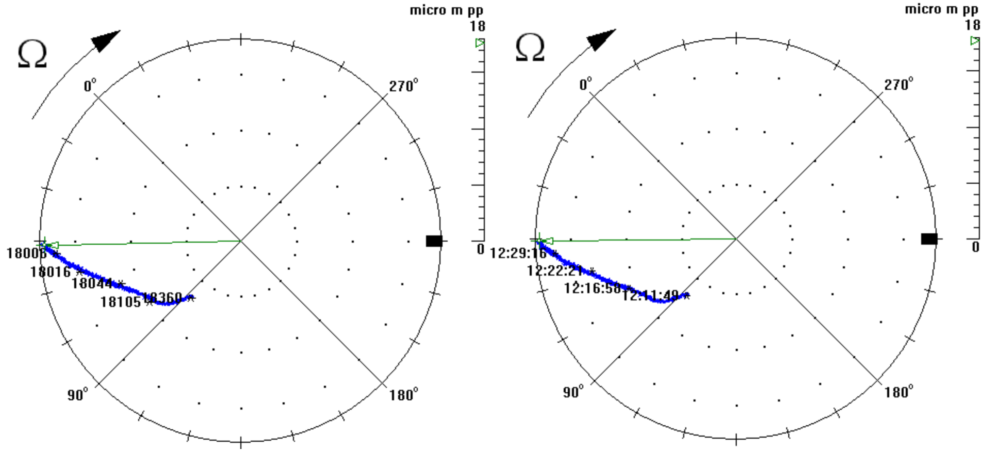
Campbell diagram bending mode

ANALYSED AND TESTED MODIFICATIONS

★ Stiffer rotor



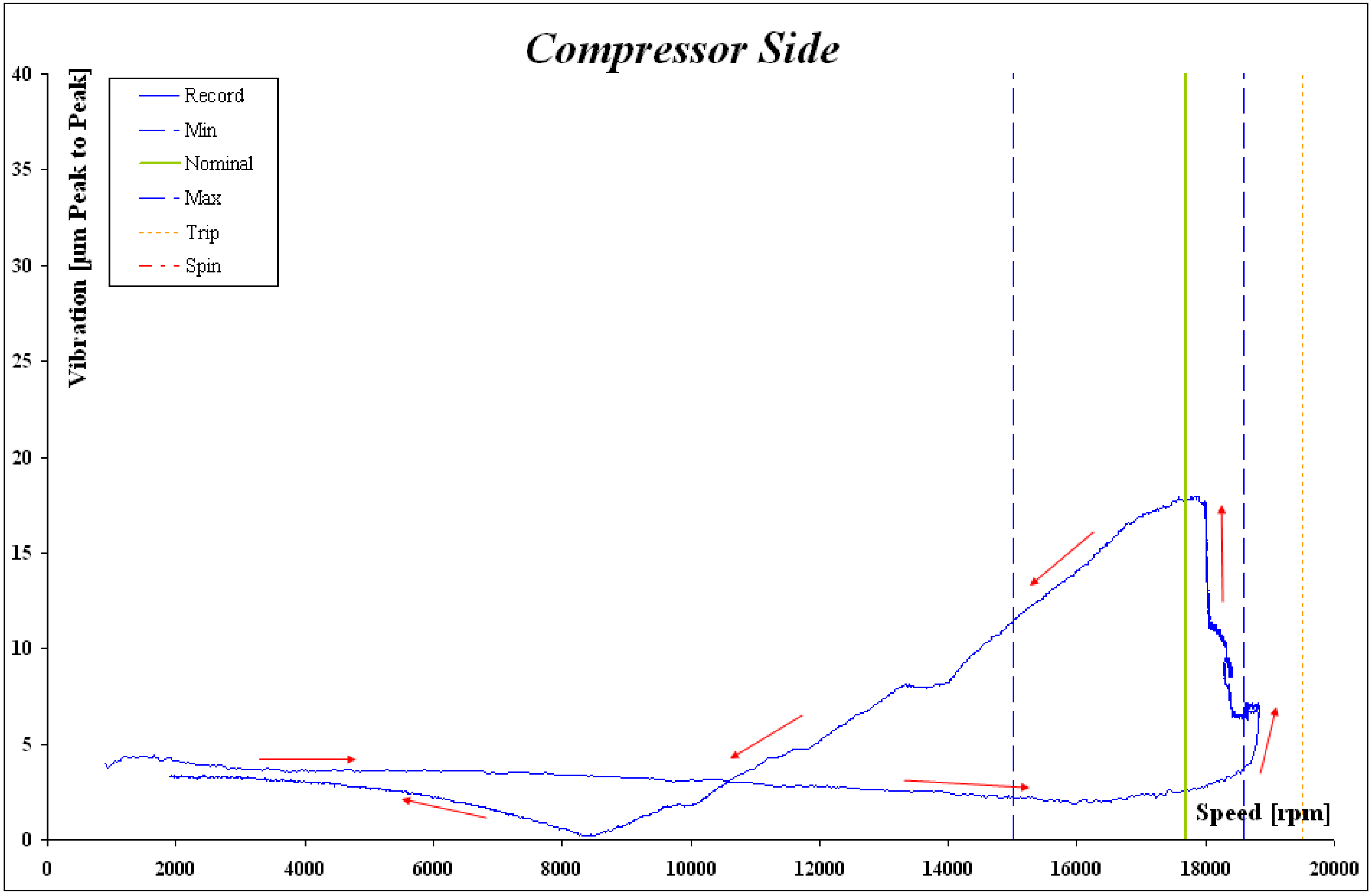
1xN polar plot – expander side



1xN polar plot – compressor side, stiffer rotor

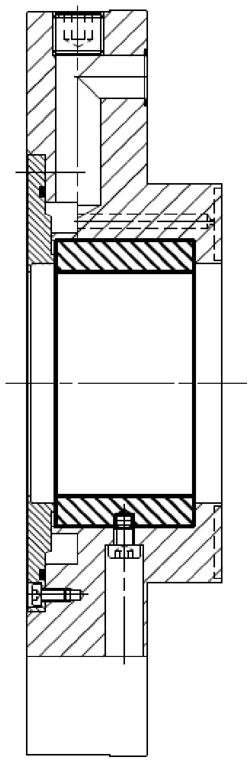
ANALYSED AND TESTED MODIFICATIONS

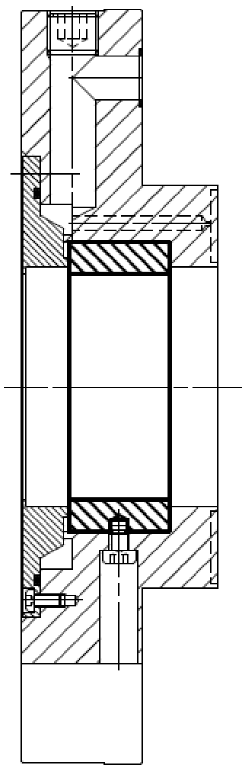
★ **Stiffer rotor**



Vibration hysteresis in Bode pot

ANALYSED AND TESTED MODIFICATIONS

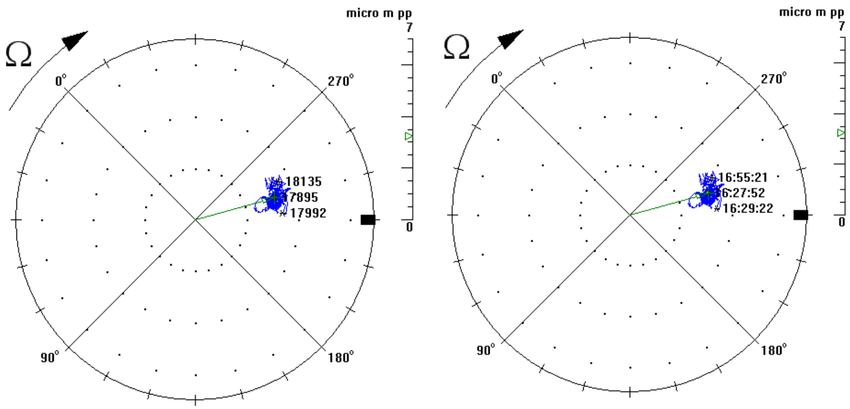




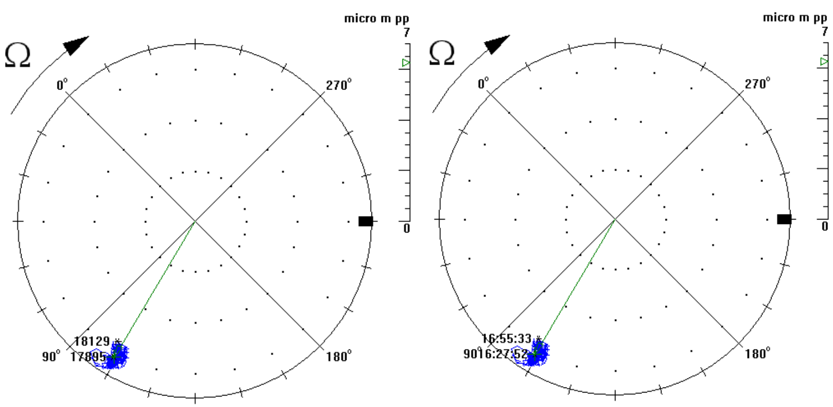
Original 0.6D and modified 0.4D bearing

ANALYSED AND TESTED MODIFICATIONS

★ **Narrow bearings, reduced oil viscosity**



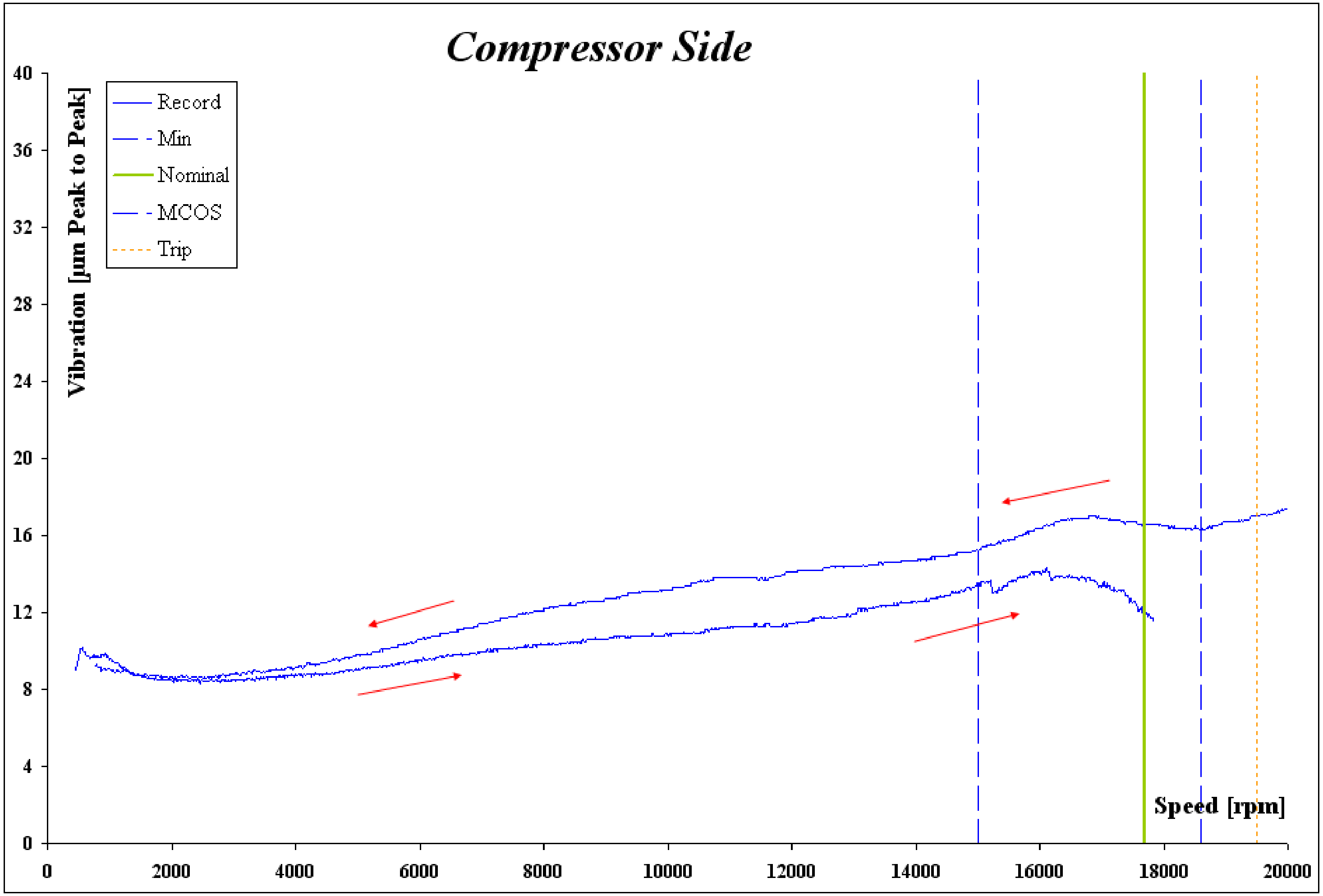
Polar plot – expander side



Polar plot – compressor side

ANALYSED AND TESTED MODIFICATIONS

★ Narrow bearings, reduced oil viscosity



Vibration hysteresis in Bode pot

CONCLUSIONS

- A turboexpander was subject to a vibration problem in spite of its robust design. The problem could be clearly identified as a hot spot phenomenon in the bearing (Morton effect).
- Classical criteria such as separation margin and damping were not sufficient to predict the problem. These criteria were very favourable in the present case.
- The hot spot stability chart helped to assess the risk and corrective measures regarding this phenomenon.
- The introduction of narrower bearings and an oil with lower viscosity completely solved the problem in the present case.
- This solution cannot be generalised for other cases, especially it may not apply in case of higher bearing loads.