Rotor Balancing:
Get the Global Picture!

OROS Webinar

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About Your Presenters

Luke DeSmet

Three years' experience at OROS as the Technical support engineer for North America. Provide technical assistance and complete calibration and repairs for all OROS equipment in that region. Conduct onsite training and data acquisitions. Provide product webinars and represent OROS at trade shows.

Nicolas Denisot

Nicolas is an Application Engineer at OROS since 2011. He is involved in after-sales actions to support a wide OROS customer base on-site, training them and helping them interpret measurement results. In pre-sales, Nicolas has a talent in understanding prospects' need, their testing environment and helps providing the right solution in a variety of fields, including turbomachinery trouble shooting, balancing and modal analysis.

About the Webinar

?

⇒ Please write your questions in the Q&A area

⇒ We will take time to answer at the end of this webinar

⇒ This webinar is being recorded

⇒ You will be able to replay it anytime

Contents

> OROS introduction
> Basics and applications
> Standards and acceptable residual imbalance
> Process and test rig requirements
> Single/Dual plane balancing demo
> Advanced situations
  - Flexible rotor and variable operating speed (demo)
  - Structural resonance (demo)
> Questions and answers

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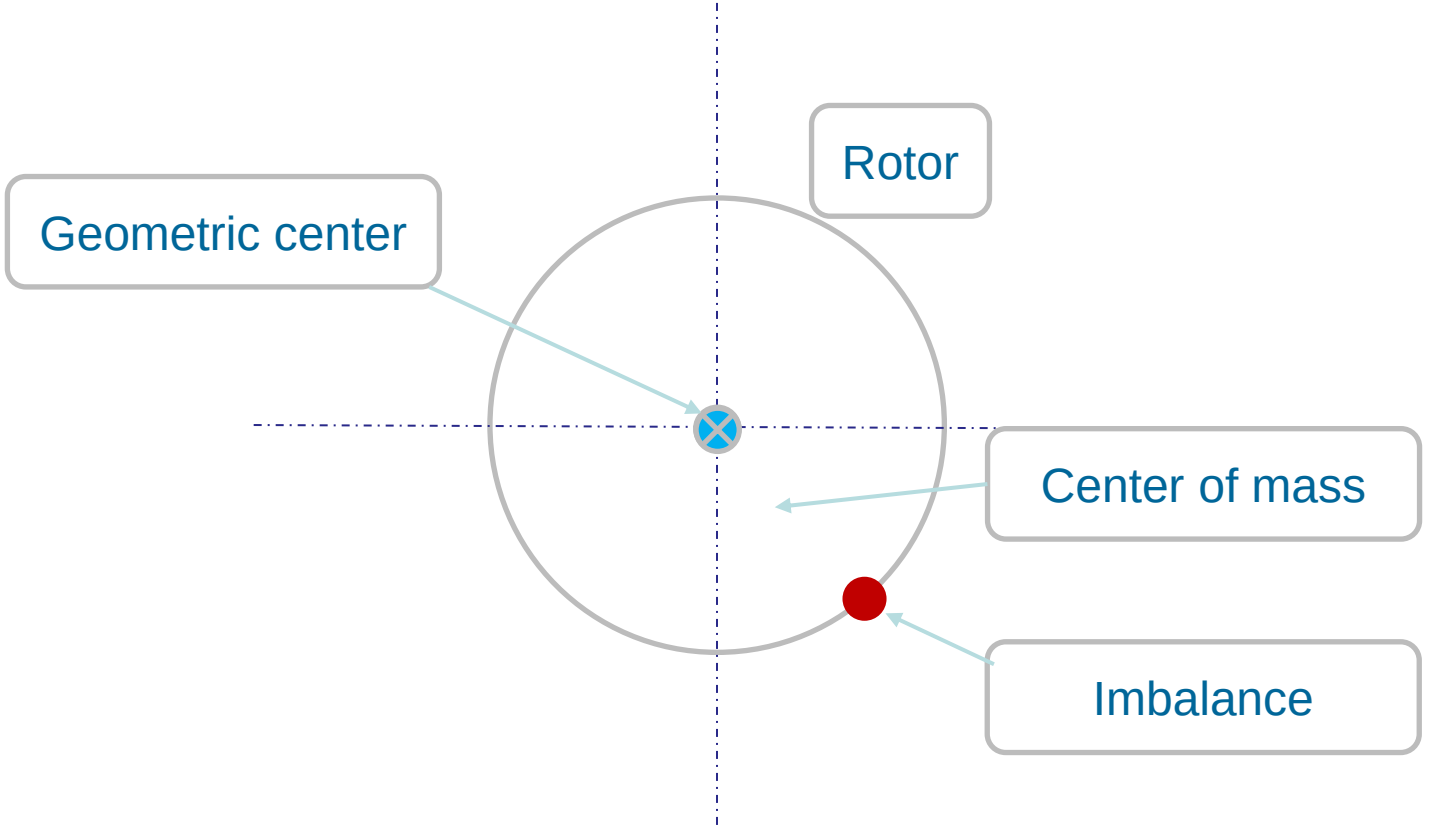
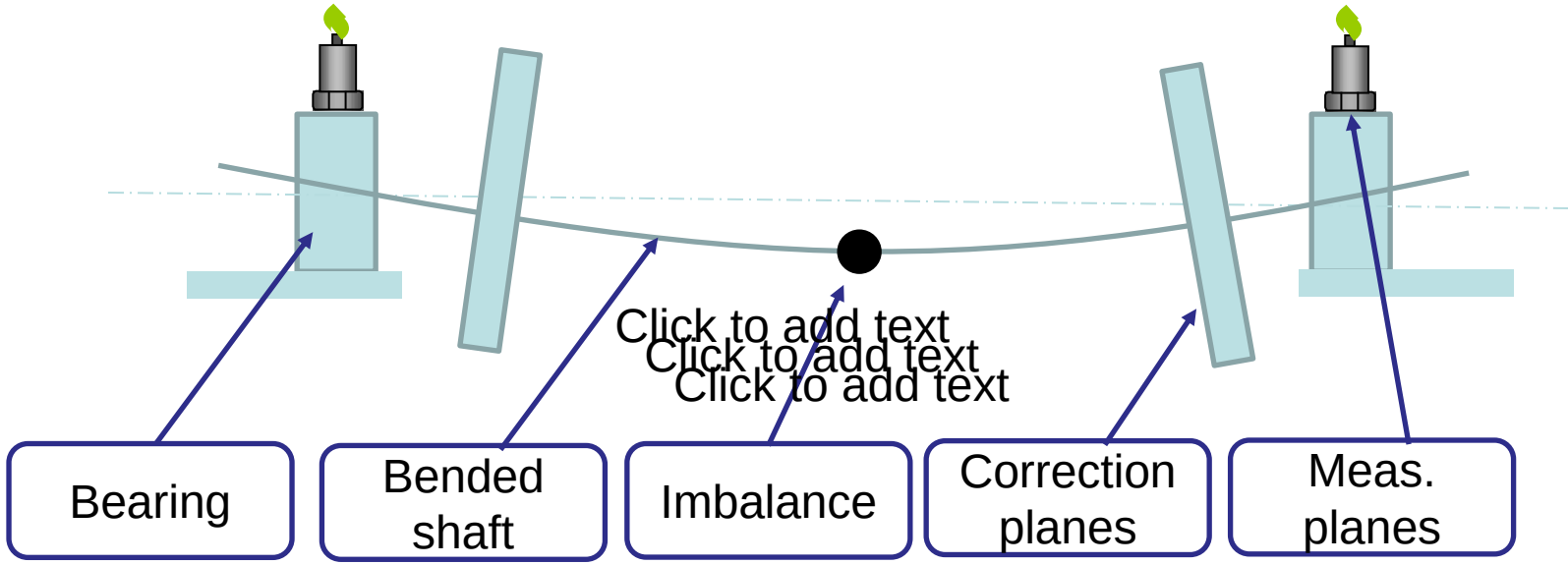
Basics and Application

What is Imbalance?



An Unbalanced rotor is one of the main causes of vibration on rotating machines.

How to Reduce the Imbalance Effect?



Purpose

Balancing process is based on vibration response and computes correction masses to create forces in opposition with the imbalance ones.

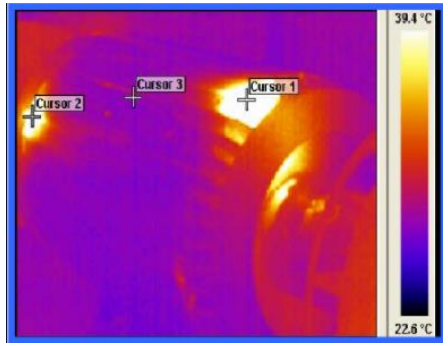
Root Causes

> Mass gain ➔ Dirt build-up

> Mass loss ➔ Wear / cavitation / fasteners or bal. weights loss

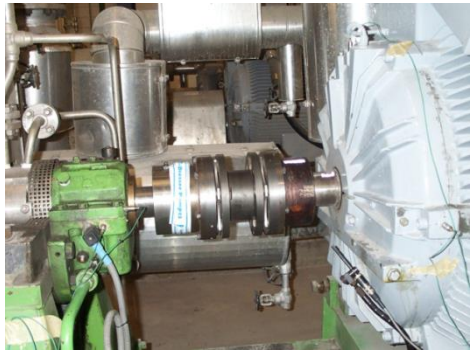
> Geometrical default ➔ Improper manufacturing / bent rotor / poor casting / incorrect roundness

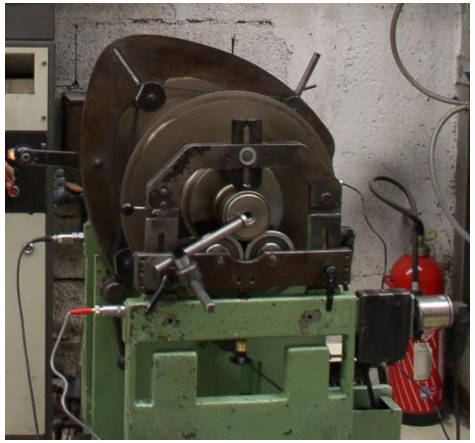
> Hot spot / Thermal balancing ➔ Electrical issue, cannot be fixed with correction masses

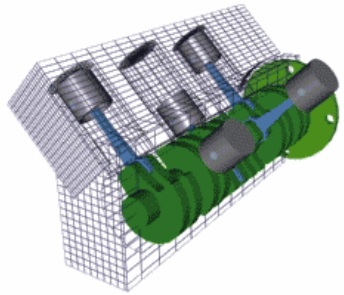


Typical Application

- Turbine & Pump manufacturers
- Rotating car part manufacturers
- Fans & Blowers
- Maintenance services



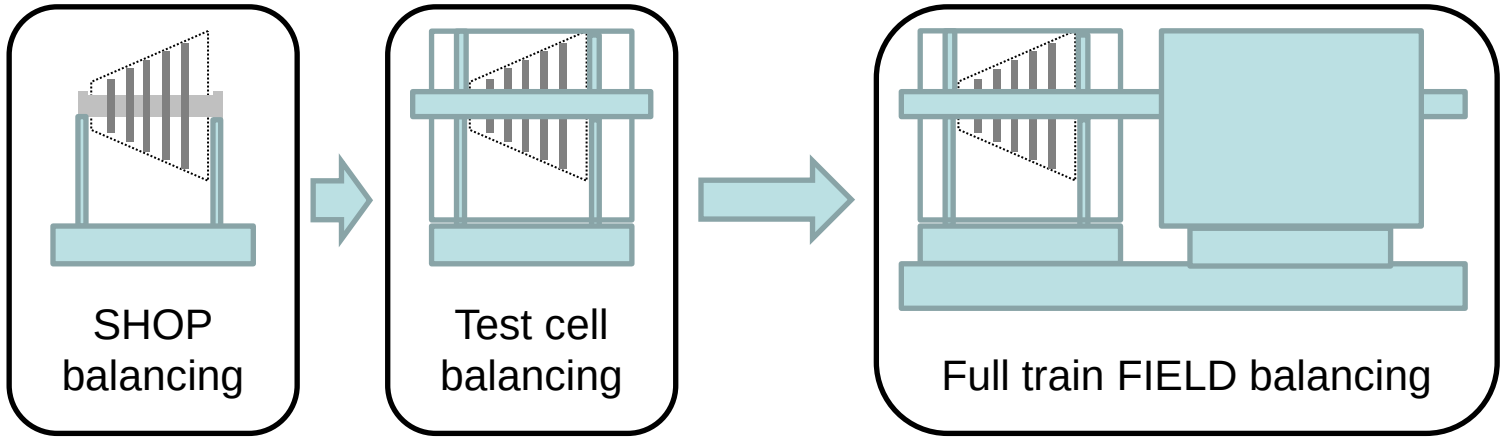


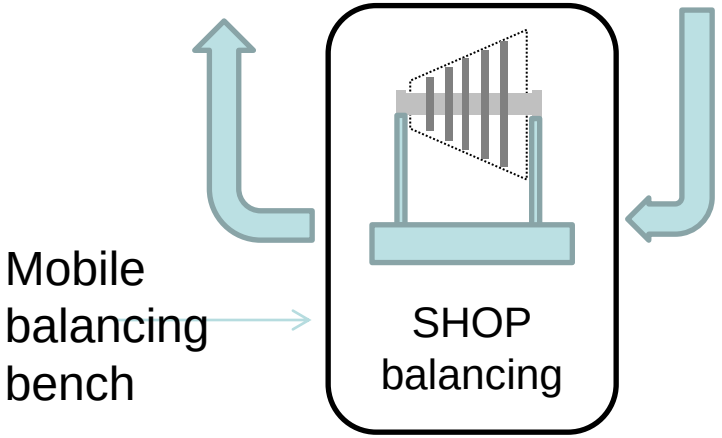


Shop Balancing vs Field Balancing

AT MANUFACTURER FACTORY

AT MACHINE USER SITE

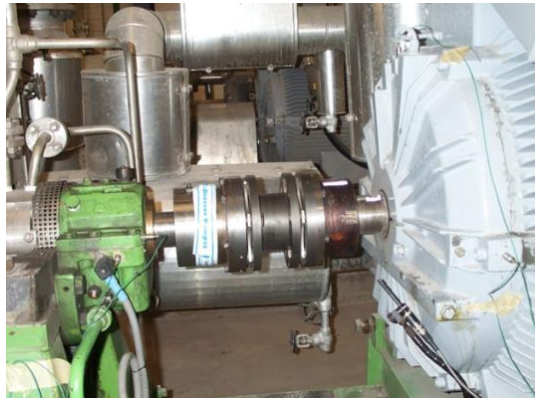




Shop Balancing vs Field Balancing

Shop Balancing

Purpose
Reduce unbalance of production rotor on a test bench. Basically, the process is simple and applied by an operator without high skills in vibration analysis.



Field Balancing

Purpose
Reduce vibration measured by the machine's condition monitoring system. High level on 1X do not always lead to an imbalance issue as the root cause so trouble shooting is sometimes needed.

Balancing Objectives

> Reduce vibration with balancing masses

> Reducing vibrating forces applied to the bearings is crucial to:

- Reduce stress and extend bearing’s life
- Prevent damage on structure (resonance)
- Prevent damage on bearings and seals
- Prevent aggravation of loosness

Balancing Standard

Standard ISO 1940/1

Rotor Types - general examples	Balance quality grade
Aircraft gas turbines	G 6.3
Centrifuges (separators, decanters)	
Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds up to 950 r/min	
Electric motors of shaft heights smaller than 80 mm	
Fans	
Gears	
Machinery, general	
Machine-tools	
Paper machines	
Process plant machines	
Pumps	
Turbo-chargers	
Water turbines	
Compressors	G 2.5
Computer drives	
Electric motors and generators (of at least 80 mm shaft height), of maximum rated speeds above 950 r/min	
Gas turbines and steam turbines	
Machine-tool drives	
Textile machines	

Main standards :ISO 1940/1 - MIL-STD-167 - API 684

Quality Grade vs Admissible Imbalance

$$e_{adm} = \frac{G}{\omega}$$

e_{adm} [µm]: adminissible specific imbal

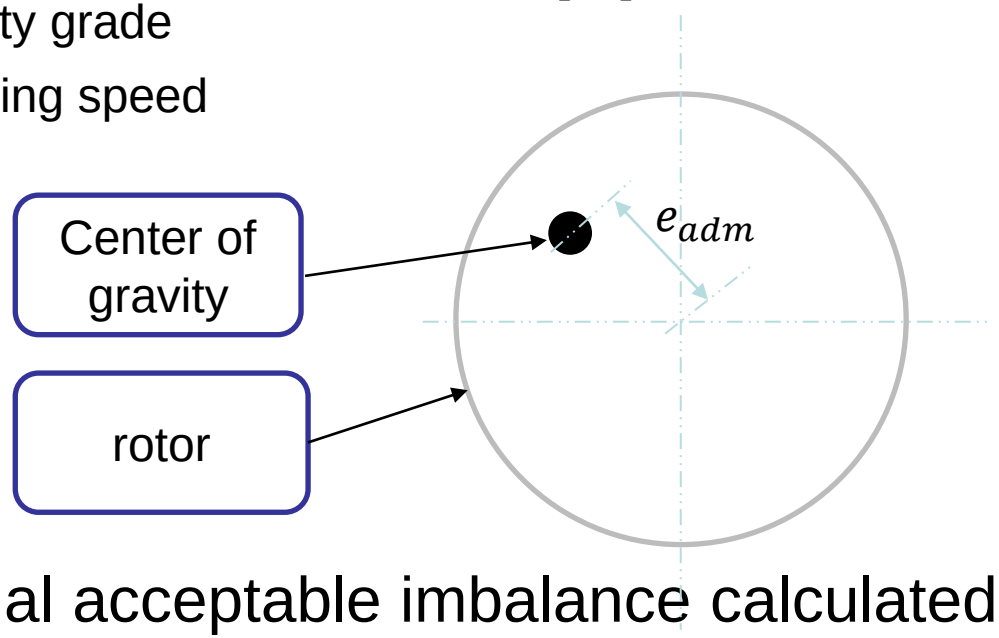
G [mm/s]: quality grade

ω [rad/s] : rotating speed

$$U_{adm} = m \,.\, e_{adm}$$

$U_{adm}[g.mm]$: residual adm. imbal

m [kg]: rotor mass



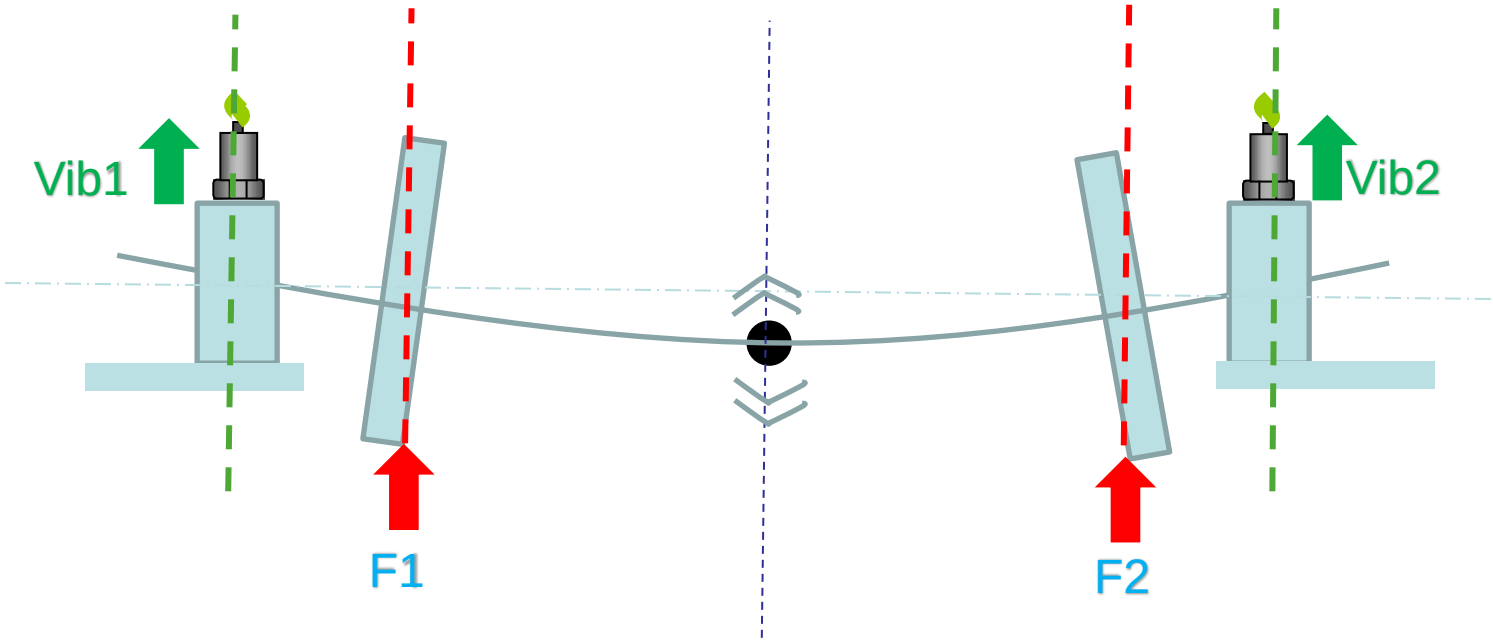
Nominal speed	3000	RPM
Quality class	2,5	mm/s
Weight of the rotor	3	kg
Residual imbalance	11.9	g mm

Calculation in OROS bal. software

> Residual acceptable imbalance calculated included in the standard is based on rotor mass and operating speed

Balancing Process

Act Against Rotor Dynamics



F1 applied through masses

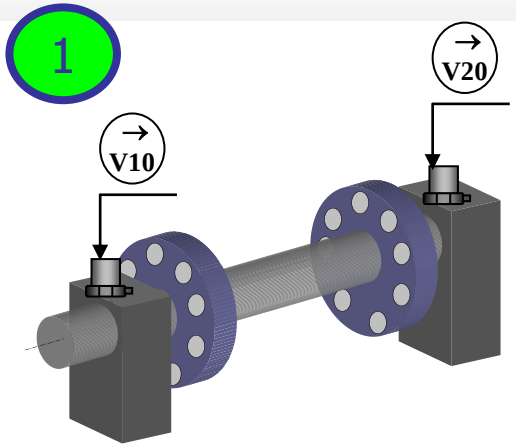
F2 applied through masses

Influence coef matrix

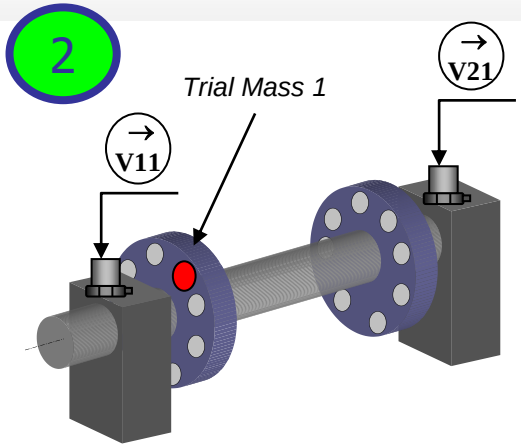
Vib1: response at bearing #1

Vib2: response at bearing #2

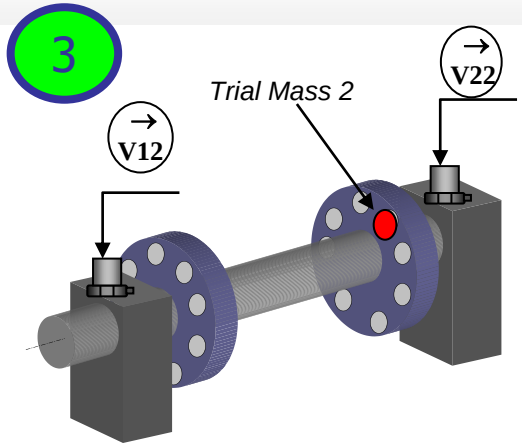
Two Plane Trim Balancing



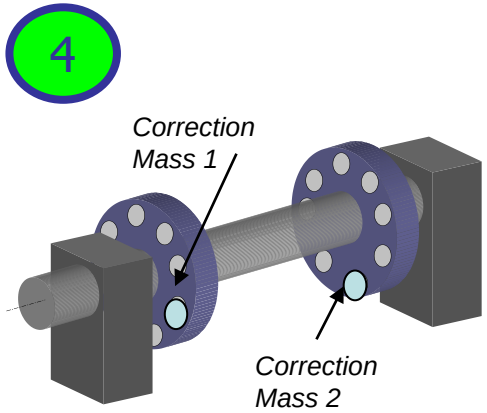
Initial Run



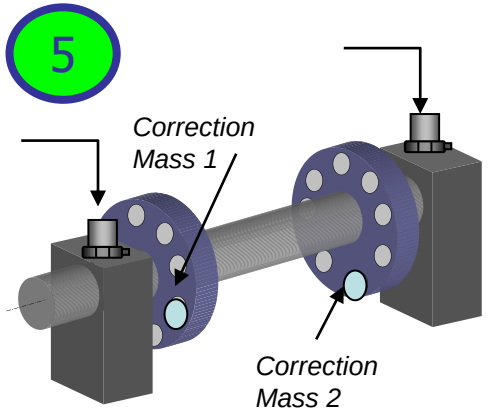
Trial Run 1



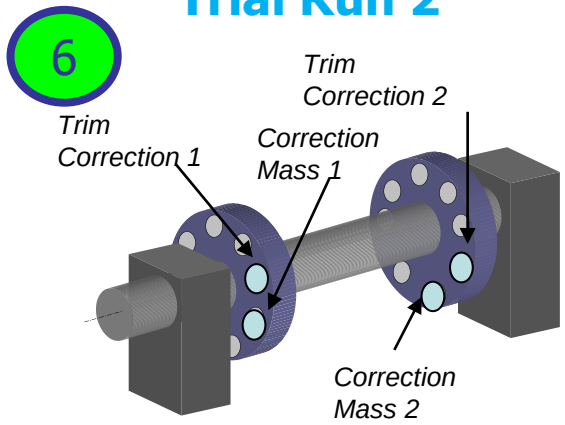
Trial Run 2



Check Run



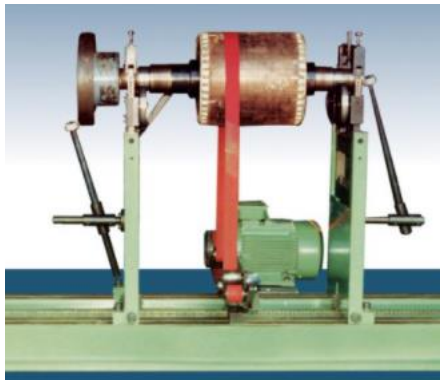
Trim Run



Trim check Run

Required Capabilities for Balance Test Rig

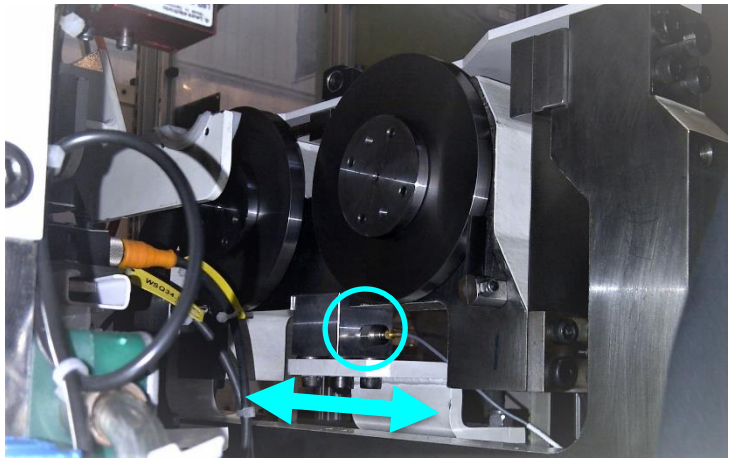
> Test Bench : Uncoupled driving motor - stable speed



> Bearing support : Avoid structural resonances (response must be linear)

> Select the right transducer selection:

- Force cell for fixed bearing
- Accelerometer for moving bearing
- Proximity probes for journal bearing



Sufficient sensitivity & linear response

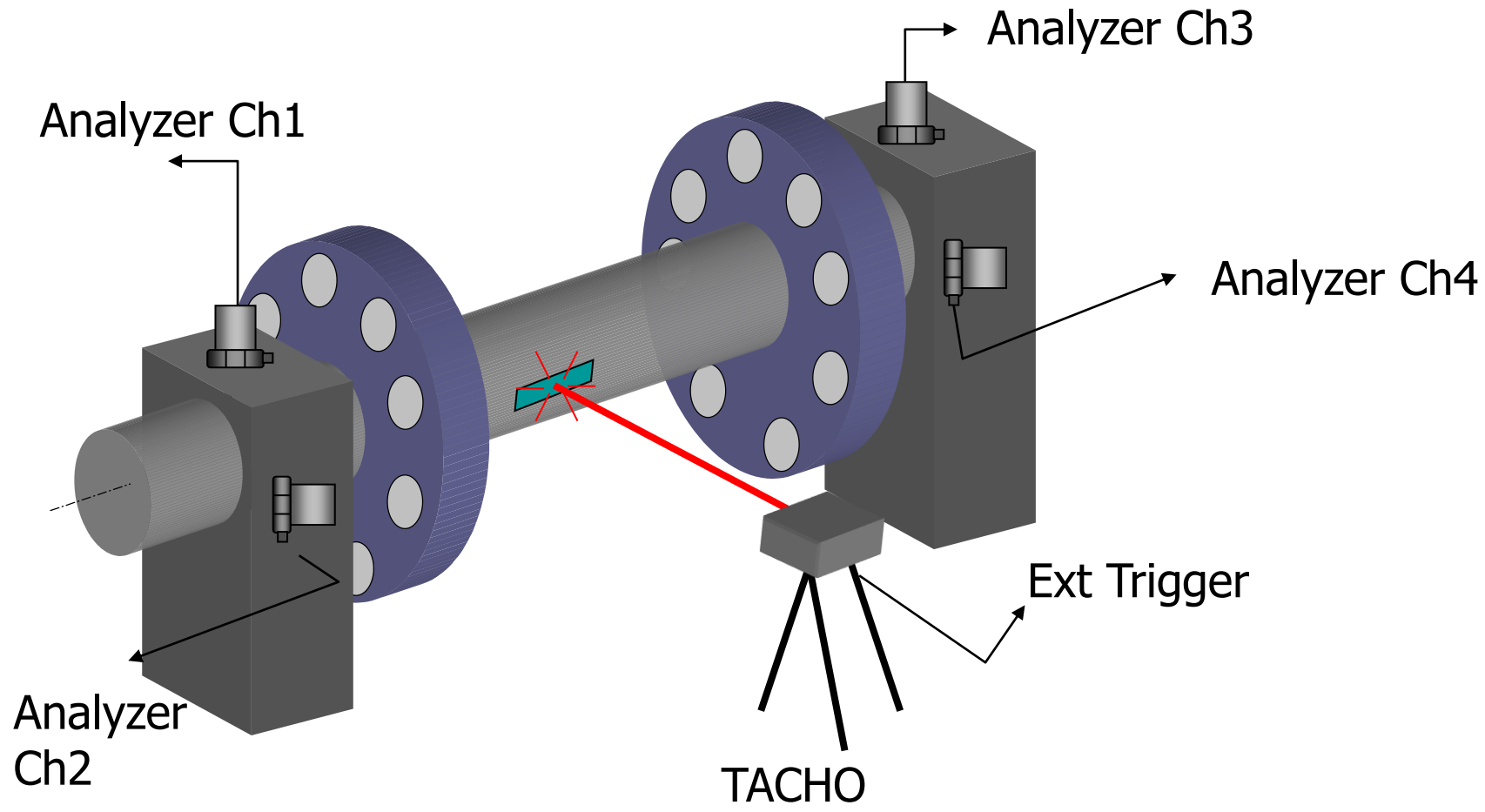
Required Capabilities for Test Rig

- Tachometer : Used as angle reference, electronic responsiveness

Source: Monarch Instrument

> High-end real time analyzer: Order tracking, oversampled tacho inputs, 24 bits resolution

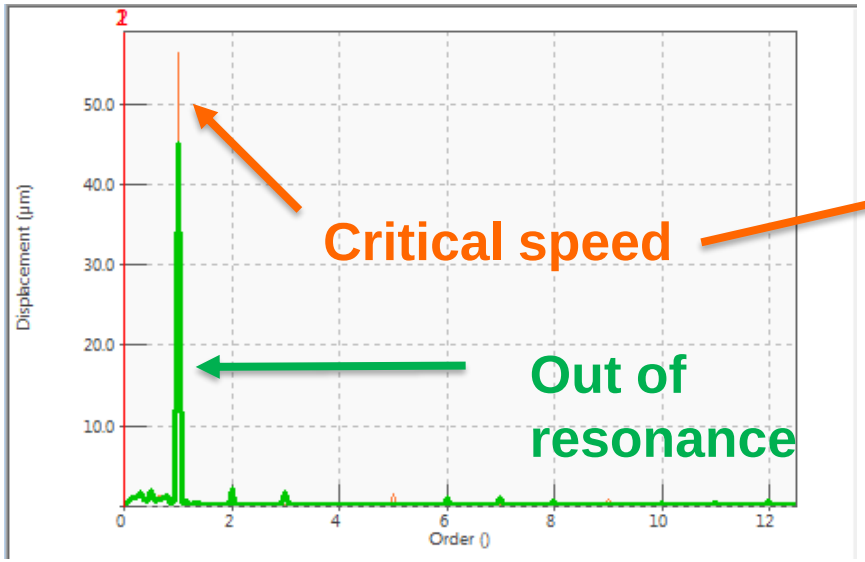
Two Plane Balancing



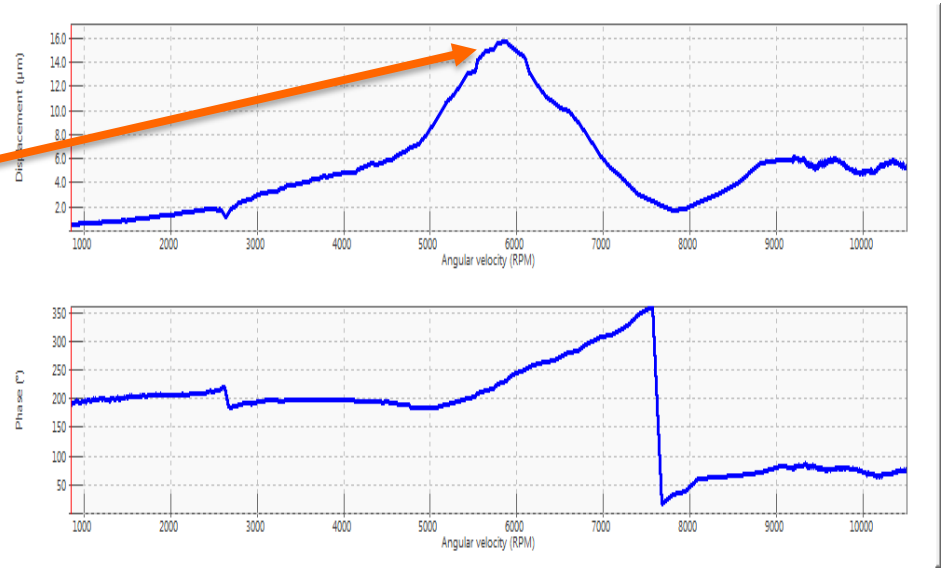
Dual Plane Balancing
Live Demo

Advanced Situations

When Resonance Occurs…



Order spectrum

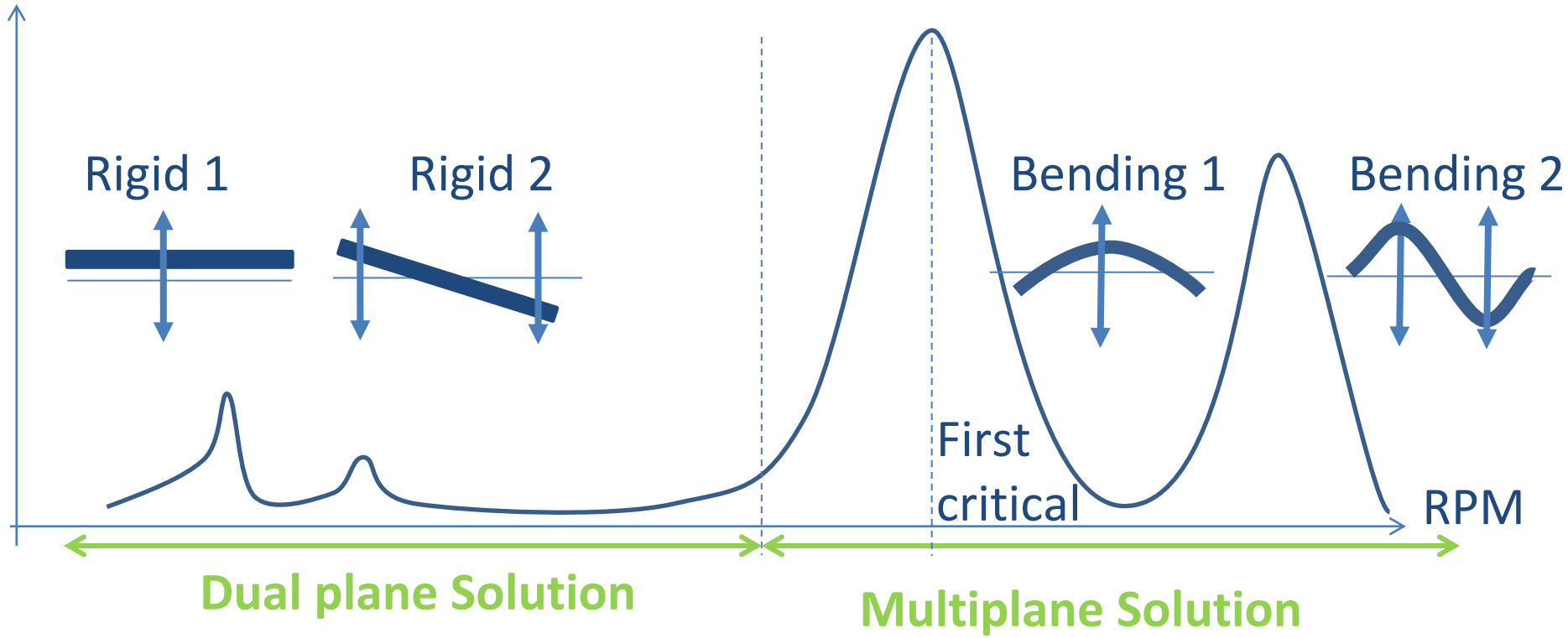


1X Bode Plot

Resonance symptoms:

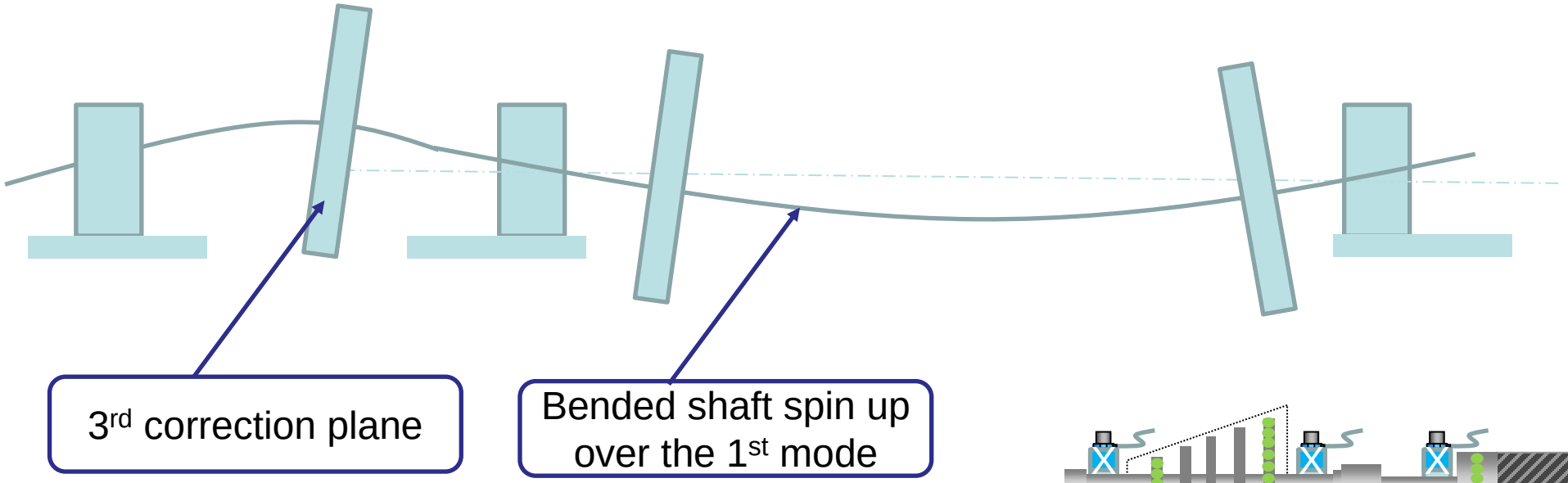
- Phase shift with speed change
- Magnitude shift with speed change
- No linear response to trial masses

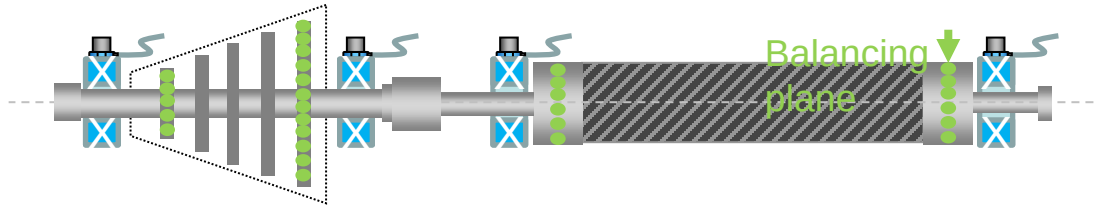
When Rotor is Flexible…



At least 90 % of rotors are rigid. A rotor that operates at a rotational speed below 70% of its critical speed is considered to be a rigid rotor. The critical speed is the speed at which resonance occurs by exciting its natural frequency.

How to Reduce the Imbalance Effect?



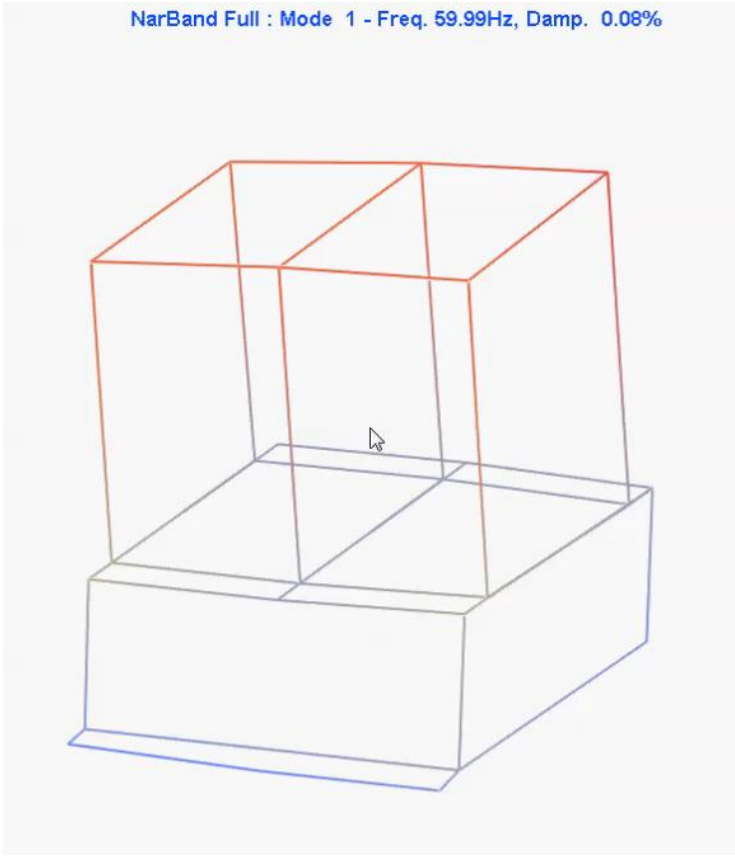


Gas turbine balanced through 4 balancing planes

Flexible shafts require additional planes:
Since rotor line is no longer straight, additional balancing planes are required

Multiplane Balancing
Live Demo

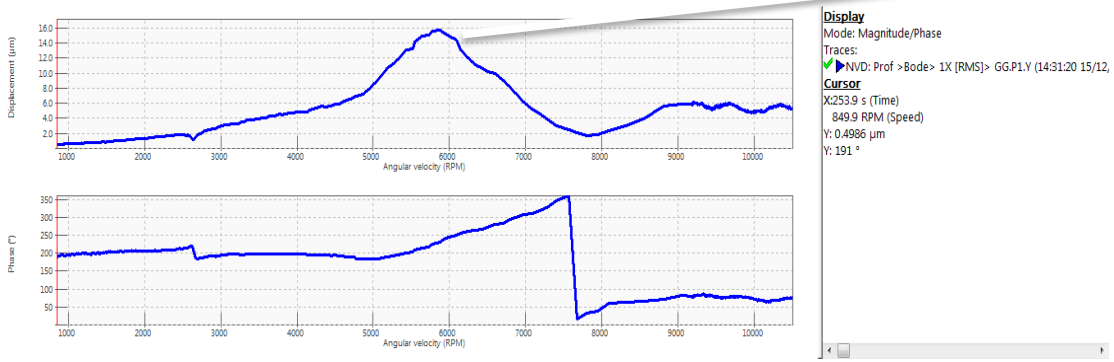
Structural resonance



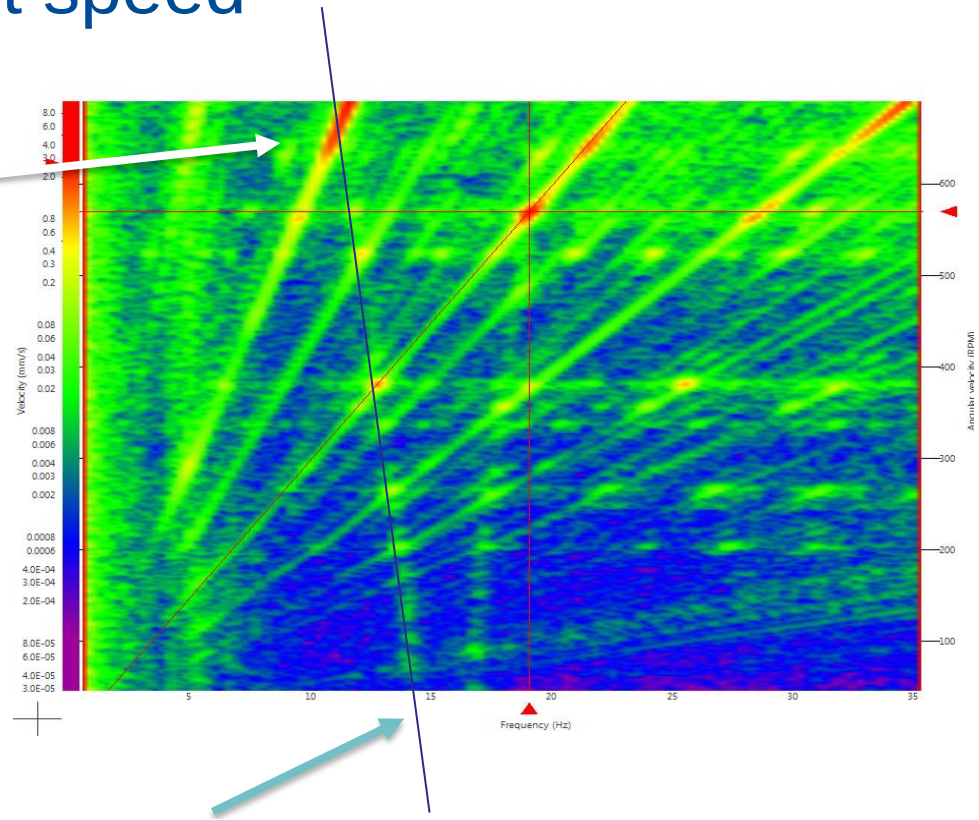
When Resonance Occurs…

- Spectrogram during a transient speed

Critical speed



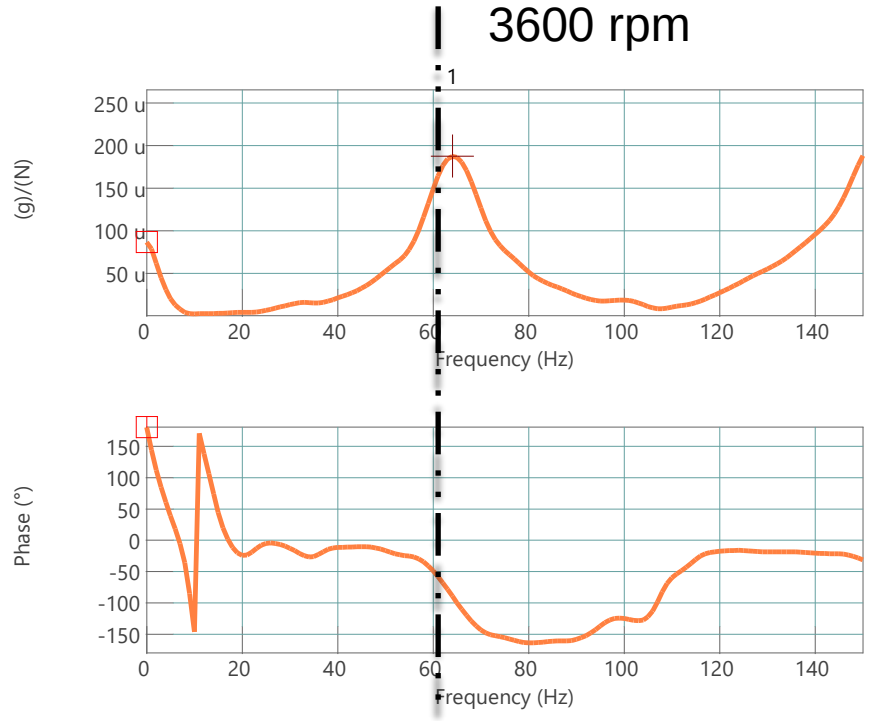
1X Bode plot



Eigen bending mode

When Resonance Occurs…

- Frequency Response Function (FRF) acquired with hammer

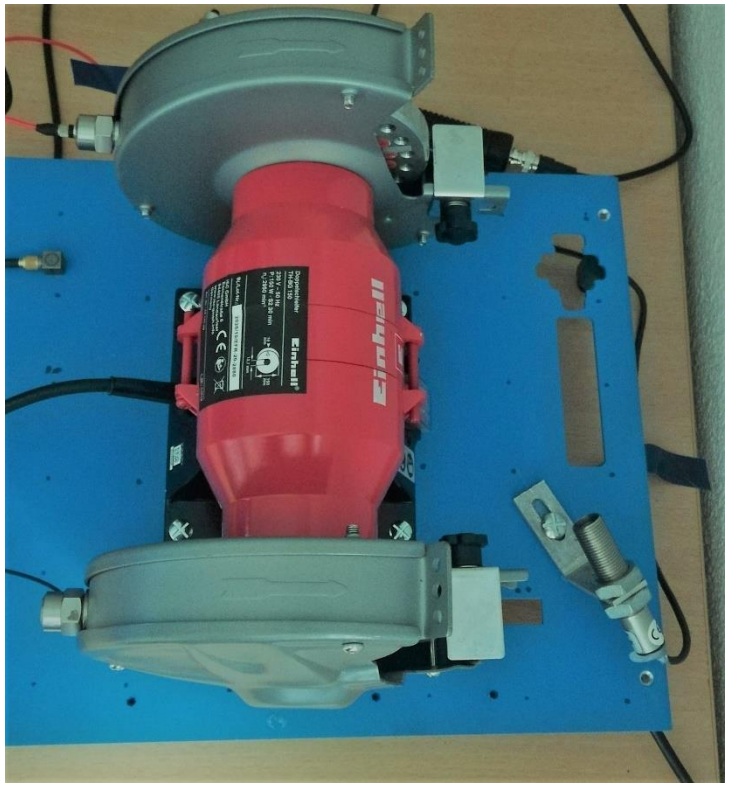


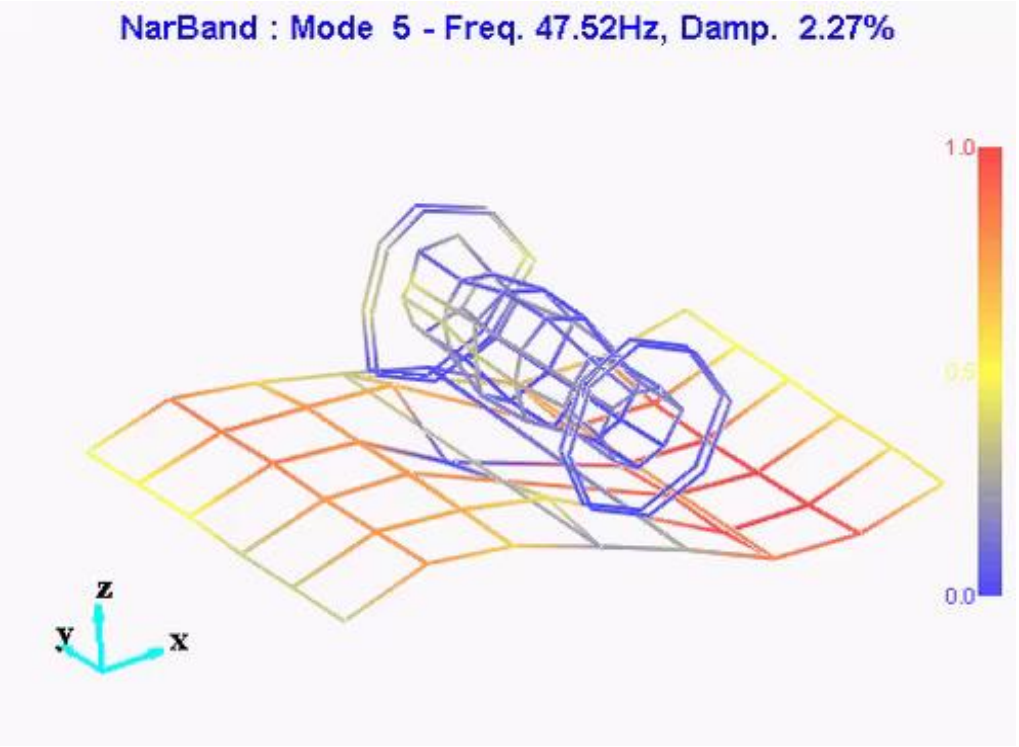
Id	Trace	X	Unit	Y	Unit
1	[4]-ACC Z / [1]-Hammer	64	Hz	187.2	u(g)/(N)

➔ Magnitude / Phase reveal the presence of one mode, close to 60 Hz (operating speed)

Balancing process requires linear response to build up the influence coefficient matrix and provide the right balance masses.

Modal Analysis





based on vertical response ➔imbalance is 10 times reduced
based on horizontal response ➔ imbalance is 2 times reduced

DEMO

> *The webinar about Modal Analysis is available on demand!*

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summary

Solutions for resonance trouble shooting

- 1X Phase deviation and magnitude amplification. Monitoring with polar diagram, Bode plot
- Order / Narrow band Spectrogram during a transient speed
- Bump test and/or modal analysis
- Operating deflection shape (ODS)

Conclusions

Shop Balancing

Bal process shall be fast and simple.
Online software for rigid rotors.

Field Balancing

Efficiency and safety first.
Trouble shooting tools.

Analyzing system and instrumentation

Select the right transducers and connect them to a
High-end and flexible vibration system to fix any complex situations.

Questions & Answers

Upcoming Webinars

> June 2022 – Turbo machine analysis: How to reach a relevant diagnostic

> Nov 2022 – Rotating machine vibrations monitoring and diagnostic

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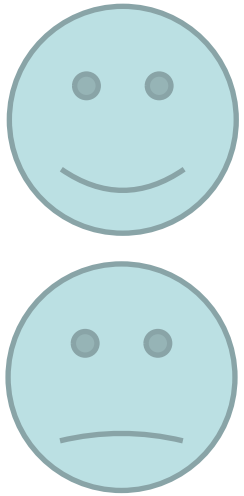

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