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Test set-up contribution into a Generator Mounted Epicyclic Gear mechanical running test performance

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Authors Bios

Nick Glover has worked for Allen Gears for 22 years since completing a Technical Apprenticeship with the company. For 15 years he worked within the Test environment, conducting and analyzing Noise and Vibration Surveys on Epicyclic, Parallel Shaft and Marine Gears, both during FATs and trouble shooting in the field. The variety of Gears was not only limited to Allen Gears Design and Manufacture, but also included Gearboxes from several other OEMs.

Gaspare Maragioglio is currently the Power Transmission Engineering Leader at Baker Hughes. He has 19 years of experience in rotating equipment, supporting R&D programs, test department for full speed full load string test, as well as to site commissioning for trouble shooting and RCA.
Mr. Maragioglio has a degree in Mechanical Engineering and before joining BH he had a research assignment at University College London. He is currently member of API613 Task Force and the ATPS Advisor Committee.

Short Abstract

This case study is describing the observations and the troubles shooting relative to a mechanical running test carried out on a Generator Mounted Epicyclic Gearbox. The specific gear architecture is requiring a full integration into the generator frame, thus the use of a pedestal dummy system is required to replicate the generator rotor and casing during the gear validation test.

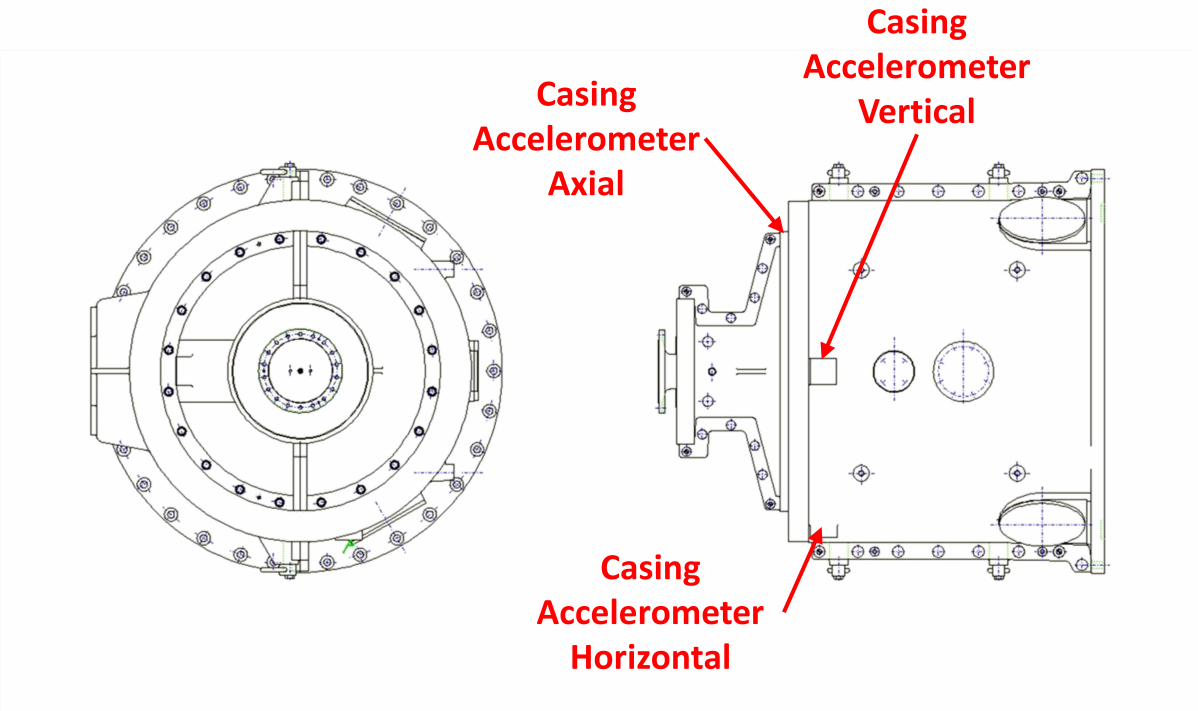
The authors will provide a comprehensive overview of the test bench set-up, test scope/procedure, findings and relevant corrective actions, with a deep dive on the lessons learnt about the observed modal structure interactions.

Final recommendations will follow about the best practices to prevent similar systems interactions issues.

Scope of this Case Study: Highlight the importance of system integration analysis

1. Problem Statement

Gear casing vibrations over MRT acceptance criteria defined by test procedure



	Casing Vibration Acceleration (g Peak)		Casing Vibration Velocity (mm/sec rms)	
	Measured 95% speed	Acceptance criteria	Measured 95% speed	Acceptance criteria
HS V	1.4	2.5	3.9	1.8
HS A	1.2	2.5	2.8	1.8
HS H	1.0	2.5	11.1	1.8

Refer to next pages for detailed information on trends & frequency content

Three accelerometers are installed on the gear casing to measure the casing vibrations in Axial, Vertical and Horizontal direction

1. Problem Statement

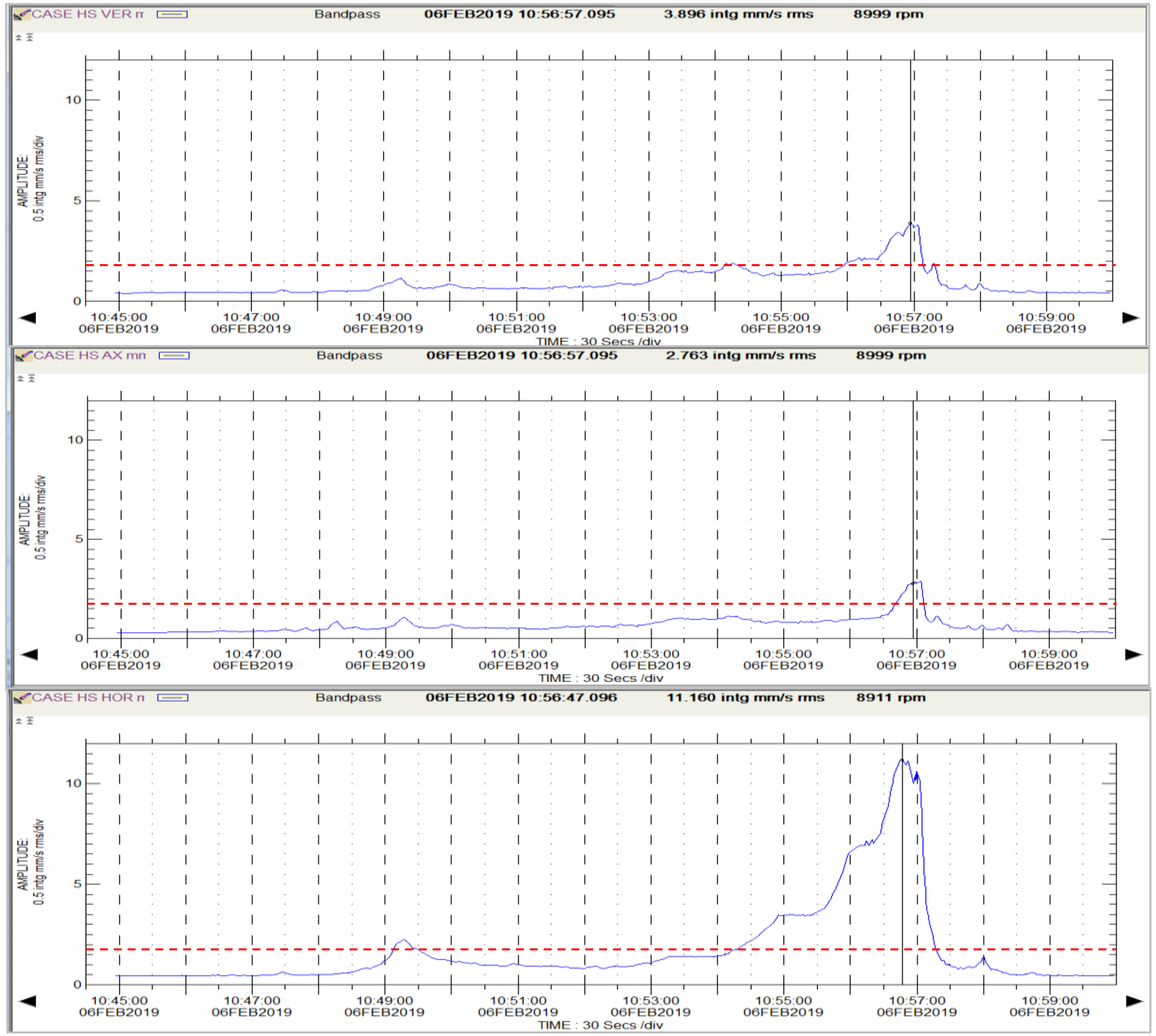
During first internal mechanical running test, gear casing vibrations observed over the acceptance criteria @ 95% speed:

HS V → 3.89 mm/sec rms

HS A → 2.76 mm/sec rms

HS H → 11.1 mm/sec rms

High vibrations prevented to reach the nominal speed. The frequency analysis shows the LSS 1x Rev as main component.

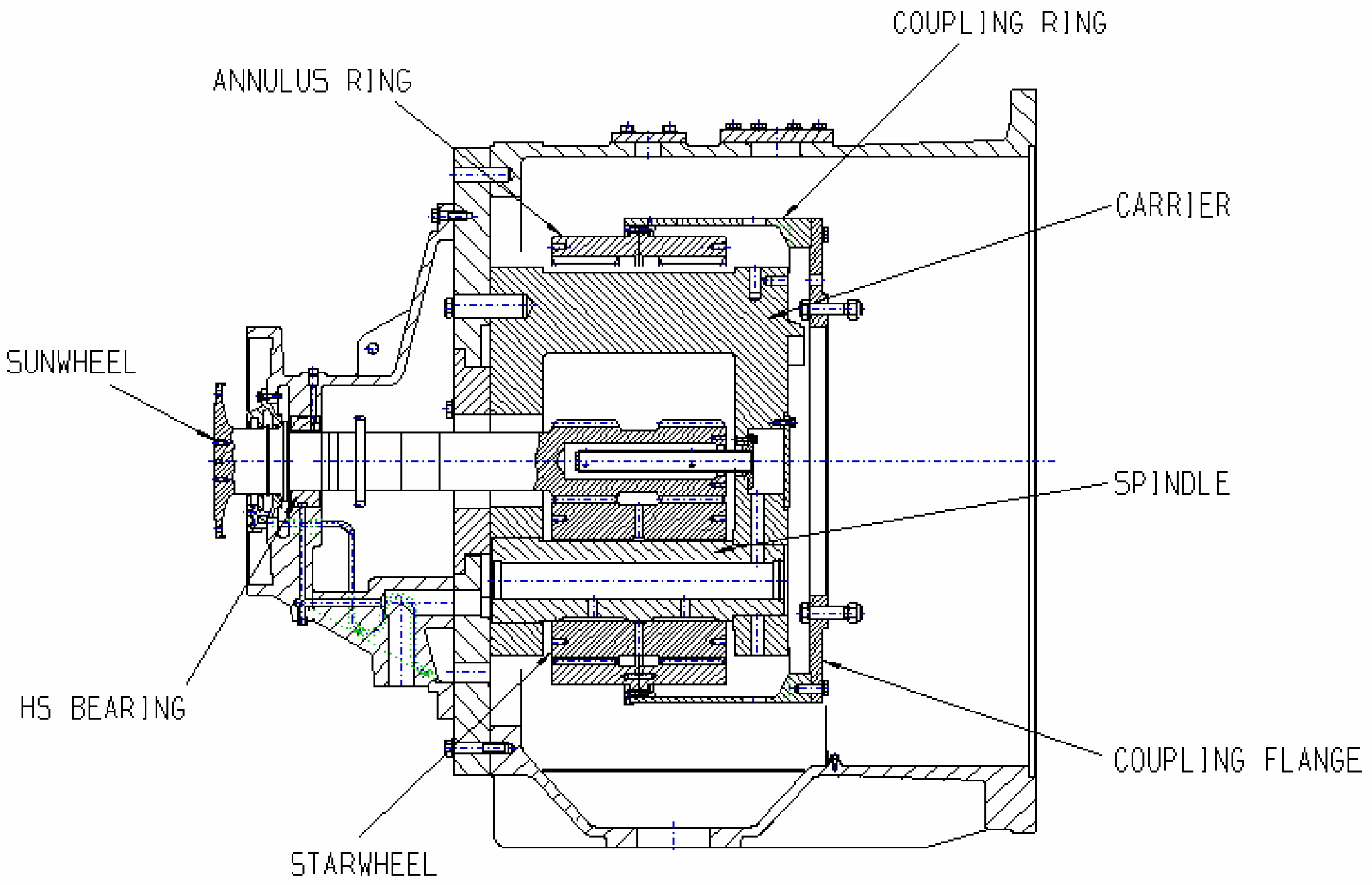


Casing vibration trends – from top to bottom: Vertical – Axial - Horizontal

2. Gear Data

- Rated Power 16600 kW
- Input speed 9514 rpm
- Output speed 1800 rpm
- AGMA SF 1.3
- Driver Gas Turbine
- Driven 60Hz Generator

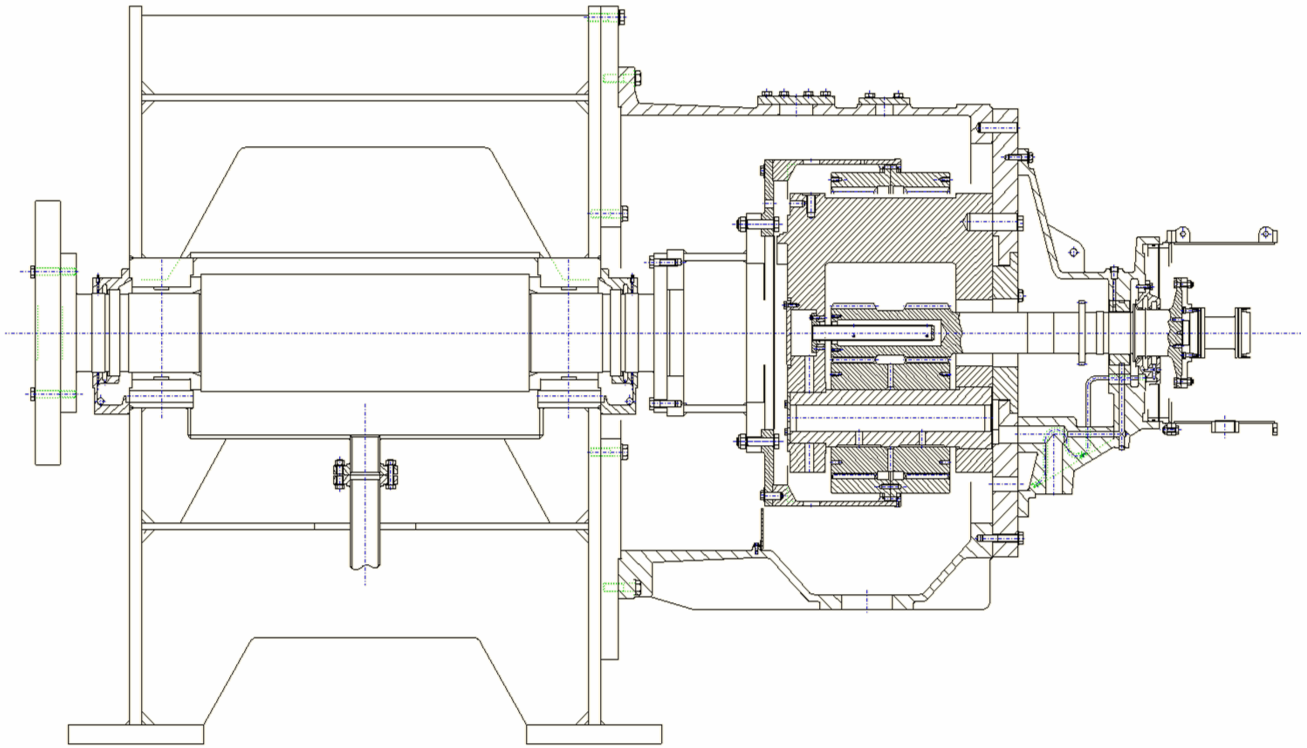
- Single Bearing Sunwheel
- Star Epicyclic Gear.



3. Test Set-up

The specific Epicyclic Gearbox is installed overhang on the Generator casing, so the MRT arrangement is such that the gearbox is installed on a dedicated pedestal system, to replicate the package configuration.

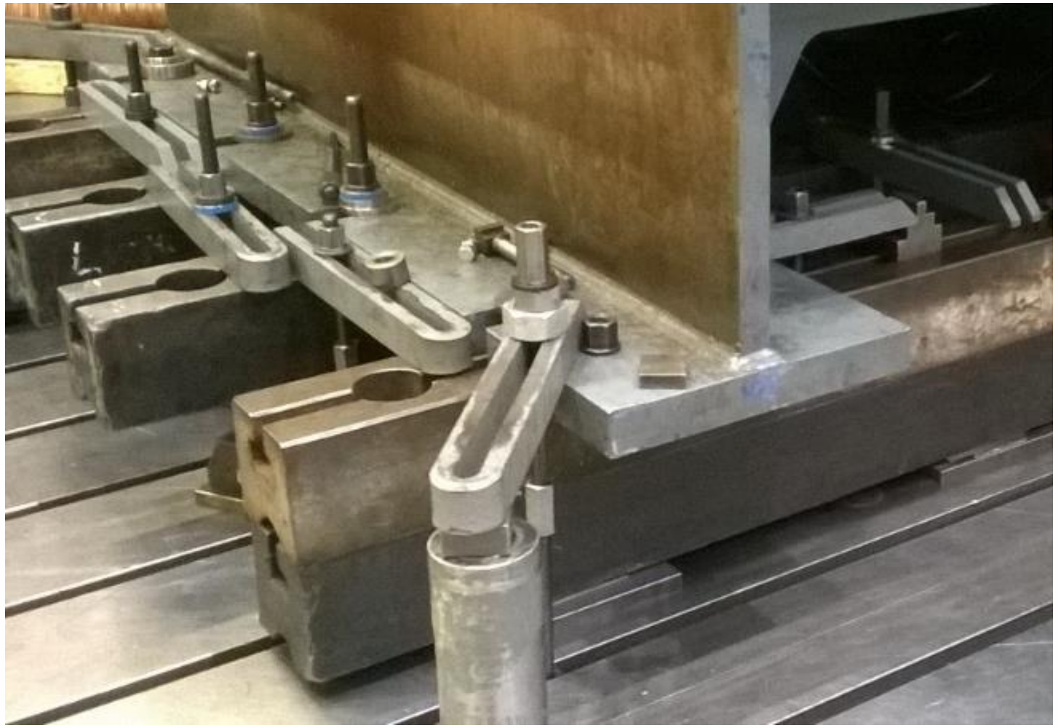
The pedestal consists of a casing and a shaft rotating in two journal fluid dynamic bearings. The shaft is bolted directly to the Gear low speed shaft assembly.



The pedestal structure is then bolted to the test bench floor through several foundation bolts.

3. Test Set-up

Due to the test equipment arrangement on the test bench, like the electric drive motor and the step-up gearbox, their shaft-line height was higher than the pedestal shaft-line height.



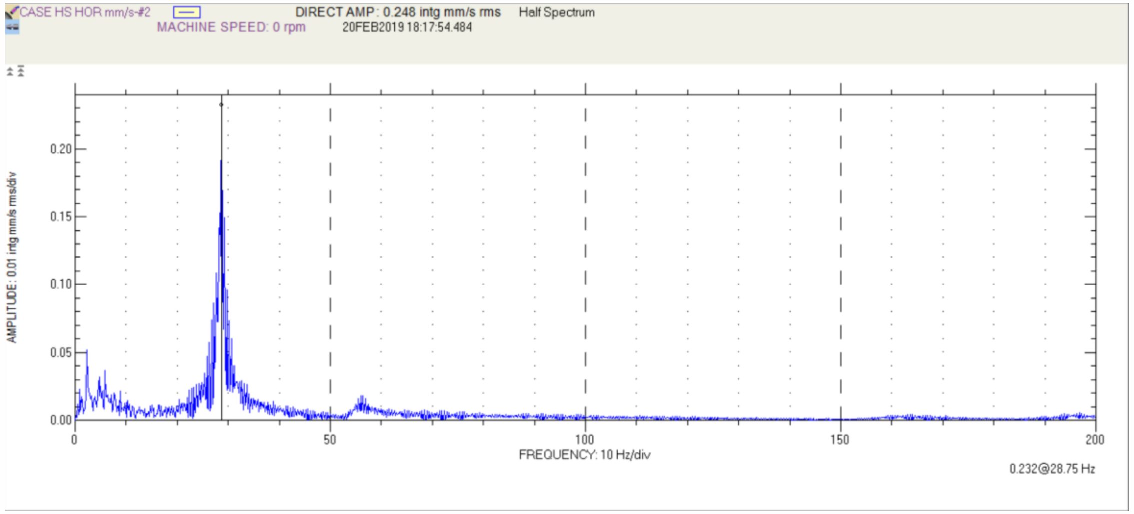
To align the Gear to be tested, and the test bench equipment, the test bench operators decided to install the pedestal on a package of still beams and shims.

This arrangement can heavily affect the support stiffness, being the equivalent stiffness

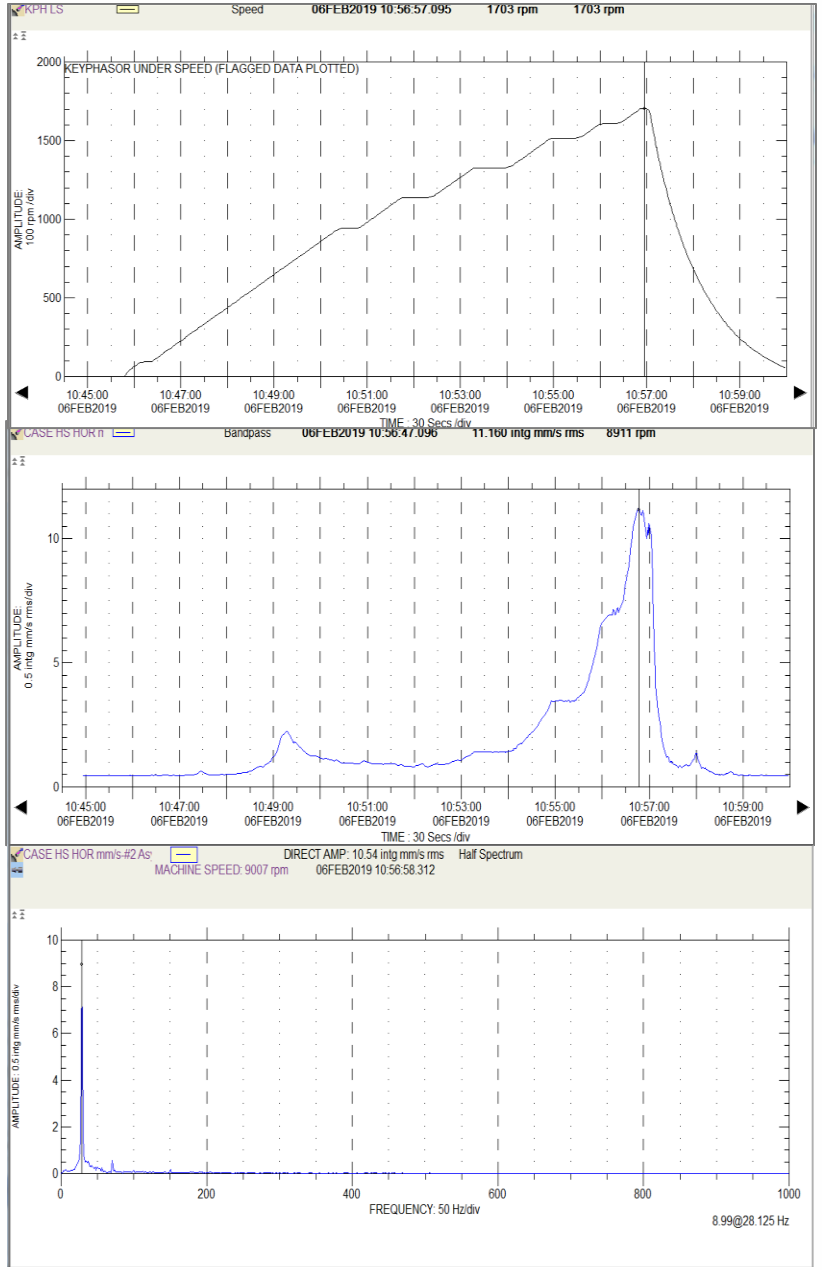
$K_{eq} = \left(\sum_{i=1}^{n} \frac{1}{K_i}\right)^{-1}$ with K_i the stiffness of component "i" of support package

4. Cause-effects Analysis

The observed vibration form and frequency contents were consistent with a lack of stiffness in the structural chain. The pedestal clamping configuration was found defiantly prone to impact the support stiffness (greater flexibility → lower natural frequency, which fell within the operating speed range, therefore prone to be excited by the LSS 1x Rev).



Bump-test response showed a NF @28.75Hz → LSS 1xRev @ 95% speed

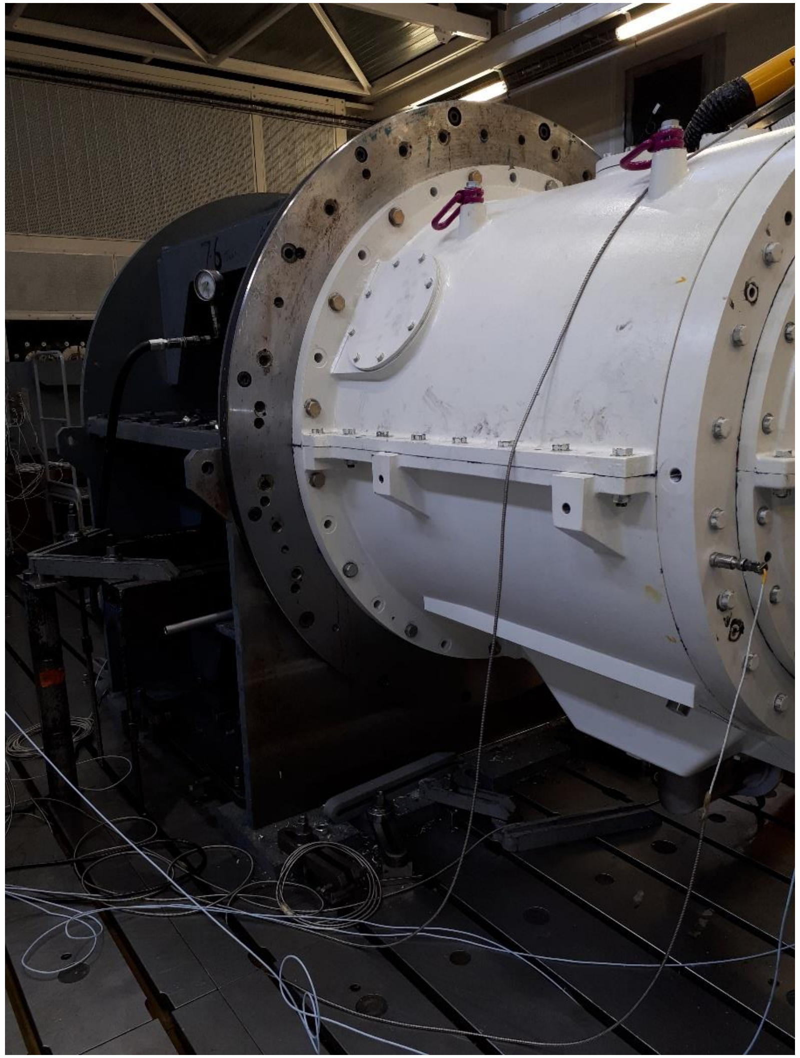


Speed and horizontal vibs trend plus vibs spectrum

5. Corrective Actions

The electric drive motor and the step-up gearbox were moved on new supports to match their shaft-line height with the pedestal shaft-line height.

In this new test equipment arrangement, the gear pedestal was installed directly onto the test bench floor, removing in this way the bad contribution of still beams and shims package.



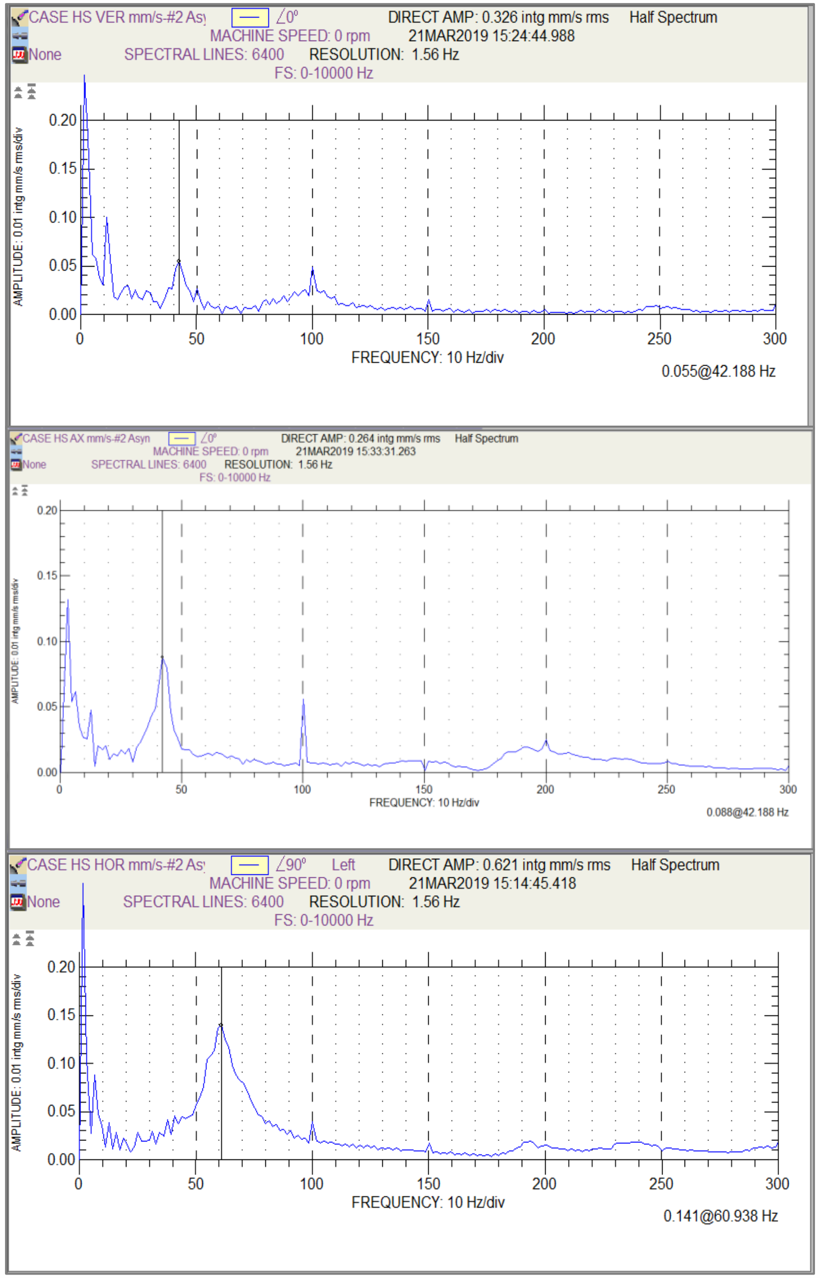
5. Corrective Actions

The improved test set-up, now in line to the best practices, allowed to move the pedestal system structural natural frequencies to:

- 42.2Hz (V)
- 42.2Hz (A)
- 60.9Hz (H)

Measurements carried out through bump-test.

Successive test runs validated the identified cause-effect relationship.

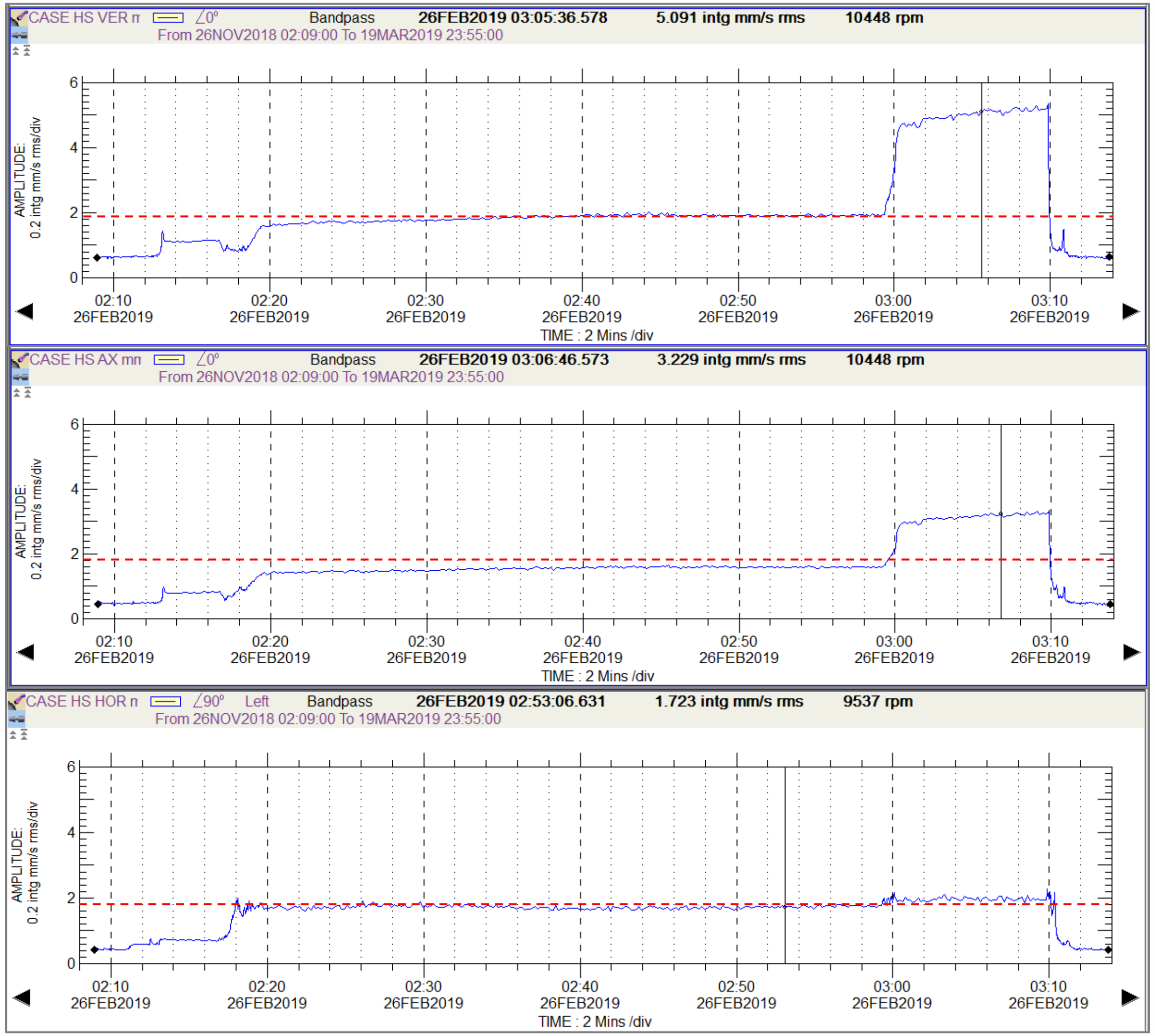


Bump-test response in Ver. – Ax. – Hor. direction

6. Corrective actions validation

The gearbox vibration level was much improved.
Vertical, axial and horizontal vibrations @100% speed are now right on test acceptance limits.

	Casing Vibration Acceleration (g Peak)		Casing Vibration Velocity (mm/sec rms)	
	Measured 100% speed	Acceptance criteria	Measured 100% speed	Acceptance criteria
HS V	1.8	2.5	1.8	1.8
HS A	1.6	2.5	1.6	1.8
HS H	2.1	2.5	1.8	1.8

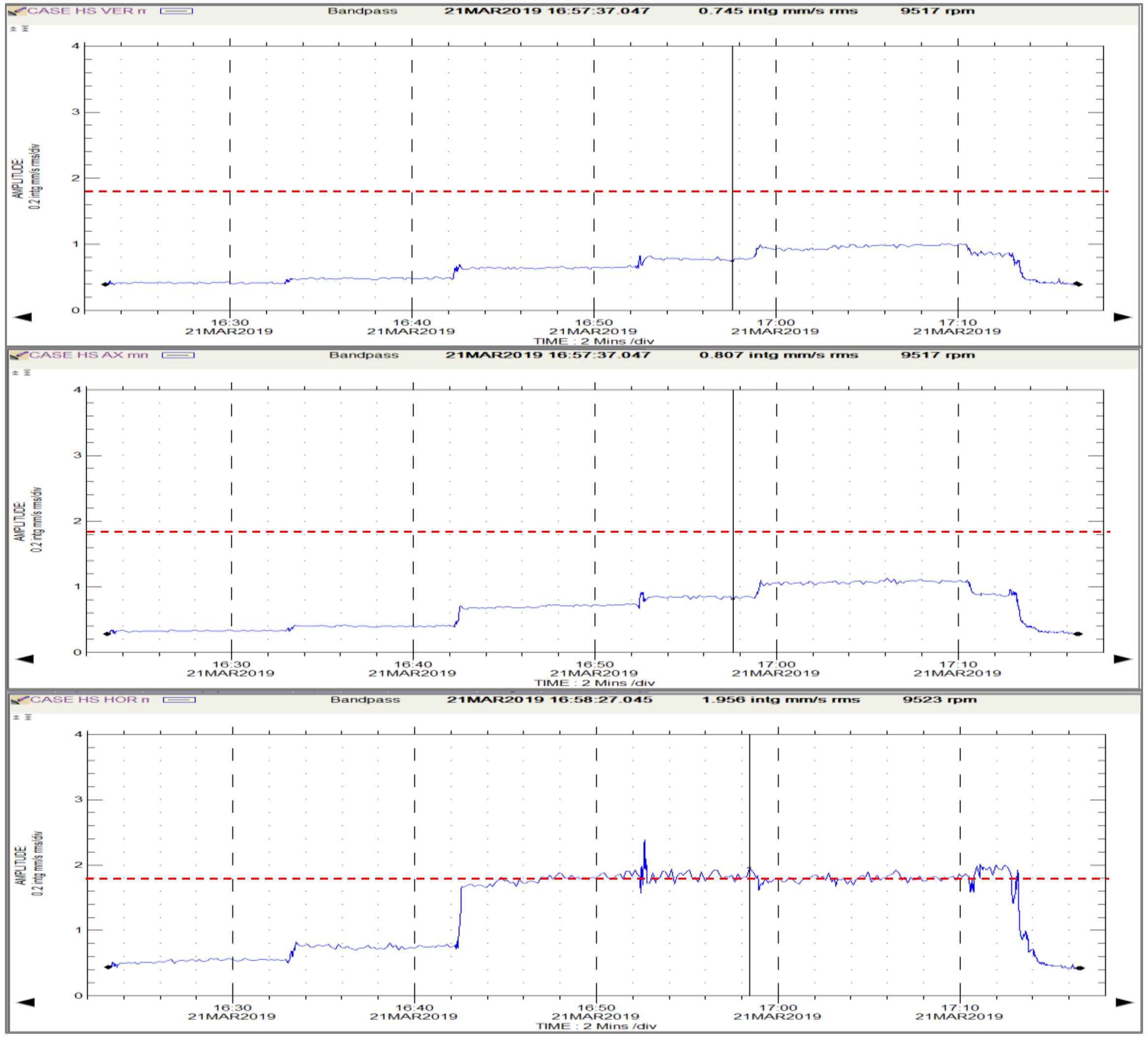


Casing vibration trends – from top to bottom: Vertical – Axial - Horizontal

6. Corrective actions validation

In order to improved the vibration at overspeed, the LS rotating parts balance has been further improved.
Vertical and axial vibrations are now well inside test limits, horizontal right on limit.

	Casing Vibration Acceleration (g Peak)		Casing Vibration Velocity (mm/sec rms)	
	Measured 110% speed	Acceptance criteria	Measured 110% speed	Acceptance criteria
HS V	1.4	2.5	0.8	1.8
HS A	1.4	2.5	0.9	1.8
HS H	1.9	2.5	1.8	1.8



Casing vibration trends – from top to bottom: Vertical – Axial - Horizontal

7. Conclusions & Lessons Learnt

The test set-up was identified as the main cause of observed abnormal vibrations.
In particular, the gear pedestal support, as originally set, was introducing a lack of stiffness in the structural chain, which brought the structural natural frequency to fall within the operative speed range, so prone to be excited by the LSS 1x Rev.
This simple interaction phenomenon could have been easily identified through a bump-test in situ, or through a detailed structure modal analysis, rather than through a trial and error approach.

The lessons learnt is that modal structure interactions can occur every time we have new structure arrangement, and therefore that they must be assessed in advance, through the available tools or analysis.


Thank You !