Detection of Isolated Vibration Spectrum Patterns Generated in Hull and Shafting Lines Which Result Shipboard Faults

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Abstract

The origin of shipboard hull vibrations is dominantly determined by vessels propulsion system, main machinery, auxiliary systems, pumps, breaking of the waves at the ship hull, etc. When the ships are classified on various sizes and limitations, they demonstrate multiple characteristics of vibration signatures mainly based on the functionality of main machinery and ships' hull. The vibration signatures generated from hull is a clear representation of the ships health and crew habitability.
The paper is focused on to a case study that the hull of a naval vessel which had undergone a major repair was inspected for suitability for further use in terms of vibration and habitability. The transferred vibration signature of the vessel was analyzed using vibration spectra in machinery and hull aspects. The measuring was done simultaneously with multi-channel measurements of the vessels vibrations at few characteristic positions.

Sea trials at following variable conditions had been carried out onboard the selected vessel.
Sea State: 2-3;
Loading Condition: Half Load;
Wind Condition: Moderate< 15 knots;
Sea Direction: Ahead, Astern

Keywords: Shipboard vibration; vibration spectrum; habitability; vibration analyser

1. Introduction

Shipboard hull vibration phenomena are caused mainly by the following sources of excitation:

a. the propeller (periodic vibration)
b. engine and auxiliary machinery (periodic vibration)
c. effects of the sea (random vibration)

Mainly the propulsion package of the ship (main engine, gear box, shafting and propeller) creates almost 85% of the shipboard vibration, which is invariably undesirable for ship and crew. But, a complete counter action or elimination is not at all possible. A comparative reduction to keep parameters in acceptable range is always possible with introduction of a proper vibration monitoring and damping system, which is also a great challenge. Early detection of developing hull and shafting problems will not only save money but will enable the crew to avoid any catastrophic failures which might result a complete shutdown in system.

In this particular instance the vessel was examined for further use based on vibration levels as per ISO 6954: 2000 standard and vibration spectrums.

2. Methodology

Vibrations of the vessel are analyzed using Fast Fourier Transform (FFT) algorithm in two frequency bands, the first from 0 to 200 Hz, and the second from 0 to 2 kHz. Taking into account the overall linear dimensions of the vessel, low frequency range of the vibrations is of particular interest, and therefore the limits of the above frequency bands are defined. Particular interest is in the low frequency band, which is defined from zero to 200 Hz. Vibrations were measured during the movement of the vessel in the measuring points defined.

2.1 Vibration Analyser and Software

The trial team used 02 Nos vibration data analysers (Frequency Range: 0 – 40,000 Hz) integrated with supported software system. The averaging used is 5 times and FFT uses Hanning window method for data filtering. One analyser is having two channels and the sampling frequency for each channel is 102.4 kHz.

2.2 Measurement Conditions

Measurement data is obtained, during performance sea trials of the ship. The data was recorded at following uniform and favourable measurement conditions:

a. Free-route test on a straight course: The ship sailed on a straight course with minimum rudder deflection. (i.e. +/- 2 degrees Port to Stbd rudder angle)
b. Constant representative engine output; Generally the power output on the propeller shaft(s) shall correspond to contractual normal seagoing condition, or at least 85% of maximum continuous power available on the propeller shaft(s). All other machinery was run under normal operating conditions during the tests.
c. Sea state 3 or less
d. Full immersion of the propeller
e. Water depth not less than five times the draught of the ship

2.3 Measurement Procedure (As per ISO 6954: 2000)

a. Measurements were recorded in all three directions at a minimum of two locations on each deck. At other locations, measurements are only required in the vertical direction.

b. The combined frequency weighting curve according to ISO 2631-2 was applied to all measurements irrespective of their direction.

c. The frequency range evaluated was 1 Hz to 10000 Hz. (Analysed separately in low, medium and high frequency ranges)

d. The measurement duration was above 1 min. for all machinery locations. For hull locations measurement duration of at least 2 min is required.

e. The result of each measurement shall be the overall frequency-weighted r.m.s. value.

A similar procedure is applicable for the frequency weighting of velocity spectra. The highest value in any direction could be used for the evaluation of habitability in another study.

2.4 International Standards Followed

Following international standards have been adhered during the data recording and conduct of sea trials.

a. ISO 10816-1, "Mechanical vibration-Evaluation of machine vibration by measurements on non-rotating parts, Part 1: General guidelines".
b. ISO 6954: 2000, "Guidelines for the measurement, Reporting and Evaluation of Vibration with regard to Habitability on Passenger and Merchant Ships"
c. ISO 20283-2: 2008, "Mechanical vibration-Measurement of Vibration on Ships, Part 2: Measurement of Structural Vibration"

Following rules and classifications published by Det Nortske Veritas (DNV) in "Rules for Classification of Ships" July 2004 (Revised in July 2009) also considered during the data recording and conduct of sea trials.

a. Part 6 Chapter 11 – Hull Monitoring Systems
b. Part 6 Chapter 15 – Vibration Class

2.5 Locations for Data Recording

Table 1. Locations onboard Ship

Sr No	Location	Direction
Machinery Locations		
1	Gear Box Free End (G/B F/E)	Vertical Horizontal Axial
2	Gear Box Drive End (G/B D/E)	Vertical Horizontal Axial
3	Main Engine Free End (M/E F/E)	Vertical Horizontal Axial
4	Main Engine Drive End (M/E D/E)	Vertical Horizontal Axial
5	Self-Aligned Bearing	Radial Oblique
6	Plummer Block	Vertical Horizontal Axial
Hull Locations		
7	Rudder Top (P/S)	Longitudinal Transverse
8	Steering Compartment (P/S 04 positions)	Vertical
9	Mast	Vertical Longitudinal Transverse

2.6 Loading Condition of the Ship

Table 2. Loading Condition

Sr No	Description	Half Load
1	Fuel (Low Sulphur Diesel)	5500 ltrs
2	Lubrication Oil	600 ltrs
3	Fresh Water	3000 ltrs
4	Crew	32

2.7 Ships Particulars

Length overall	-	42m
Length between perpendiculars	-	39.04m
Breadth, moulded (max)	-	5.3m
Depth to main deck at mid ship	-	2.1m
Draught Fwd	-	1.4m
Aft	-	1.6m
Displacement at full load	-	146 Ton
Trial displacement (half load)	-	1700 Ton
Max. Speed at 100% engine	-	23 kn (knots)
Class	-	Fast Gun Boat

2.7.1 Main Engine Particulars

Number of Engines	-	04
Fwd Engine Power Output	-	895 kW
Aft Engine Power Output	-	840 kW

Image 1: Naval Vessel subjected to inspection

3. Conduct of Sea Trials and Salient Results

The trial team mainly focused on recording data at two fixed engine RPMs and analysing the spectrums resulted from earmarked machinery and hull locations. The salient defect patterns observed from the spectrums (0-200 Hz) are as follows,

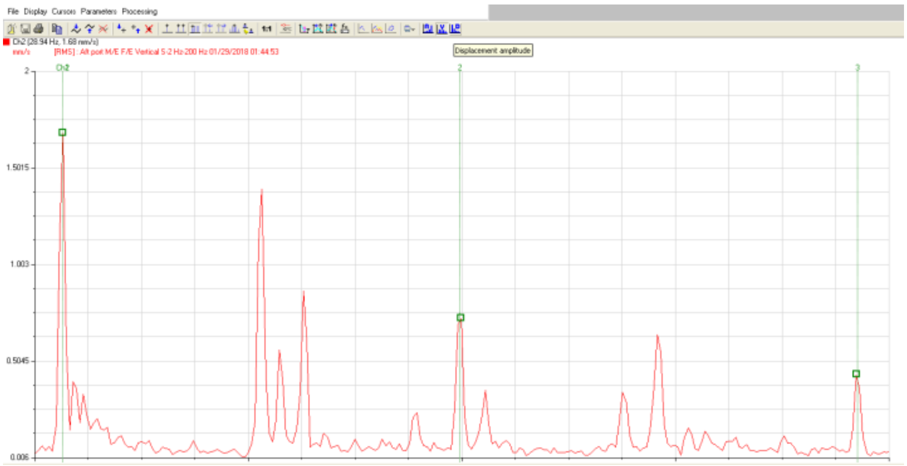

Figure 1.1 Aft Port M/E Free end vertical at 1740 RPM - Angular Misalignment

Observation: High axial vibration amplitude. Pattern of typically high 1 X and 2 X with lowering 3 X, 4 X visible at engine RPM (29 Hz).

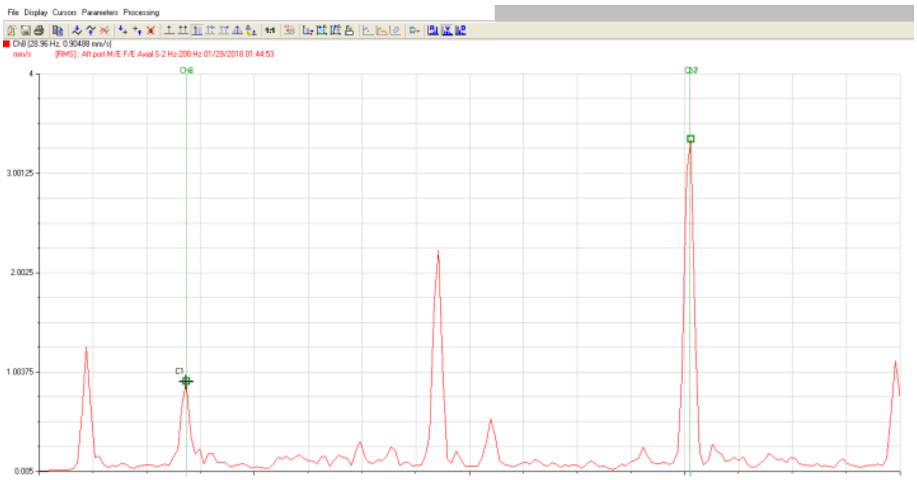

Figure 1.2 Aft Port M/E Free end axial at 1740 RPM-Structural Looseness

Observation: Phase unstable with many harmonics. Clearly visible ½ X with 1 ½ X and 2 X pattern. Many harmonics after 3 X.

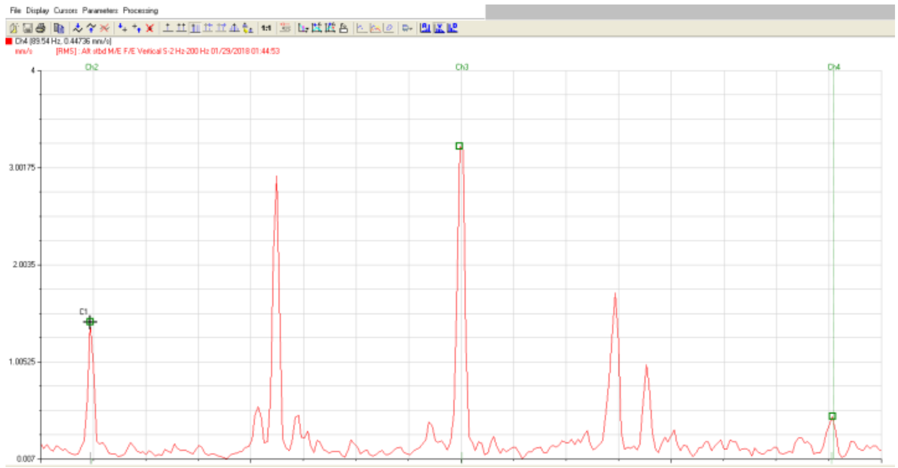

Figure 1.3 Aft Stbd M/E Free end vertical at 1740 RPM-Offset Misalignment

Observation: Harmonics pattern persists at 1 X, 2 X, 3 X with comparatively higher 2 X. 1 ½ X and 2 ½ X also visible.

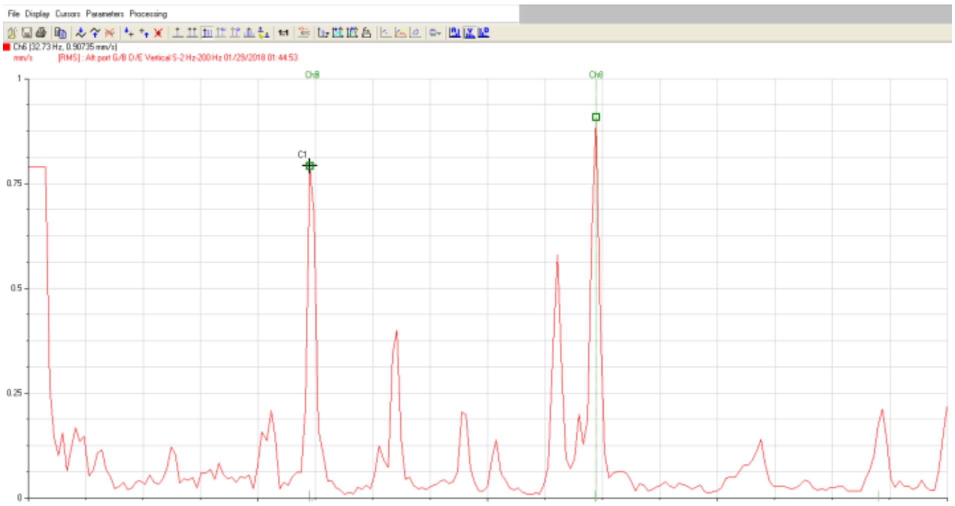

Figure 1.4 Aft Port Gear Box Drive end vertical at 1200 ERPM-Structural Looseness

Observation: Phase unstable with many harmonics. Clearly visible ½ X with 1 ½ X and 2 X pattern. Many harmonics after 3 X.

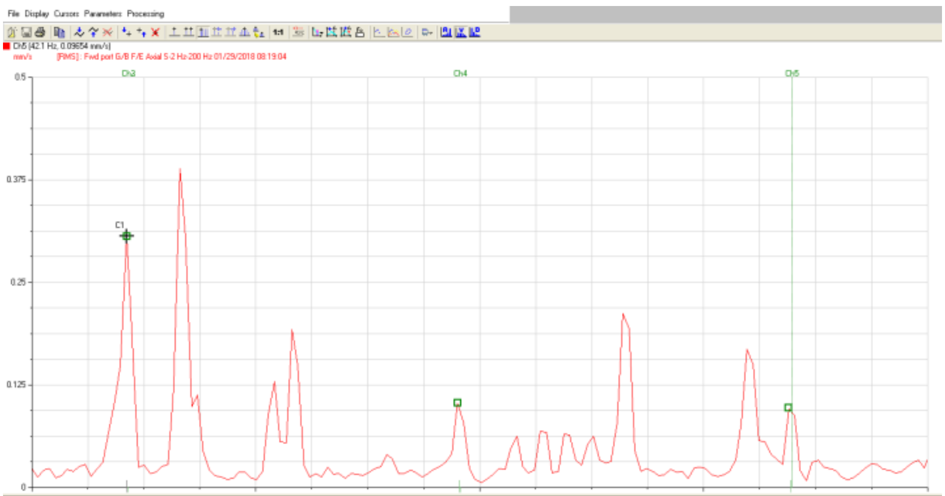

Figure 1.5 Fwd Port Gear Box Free end axial at 800 ERPM- Angular Misalignment

Observation: High axial vibration amplitude. Pattern of typically high 1 X and 2 X with lowering 3 X, 4 X visible at Gear Box rotational RPM

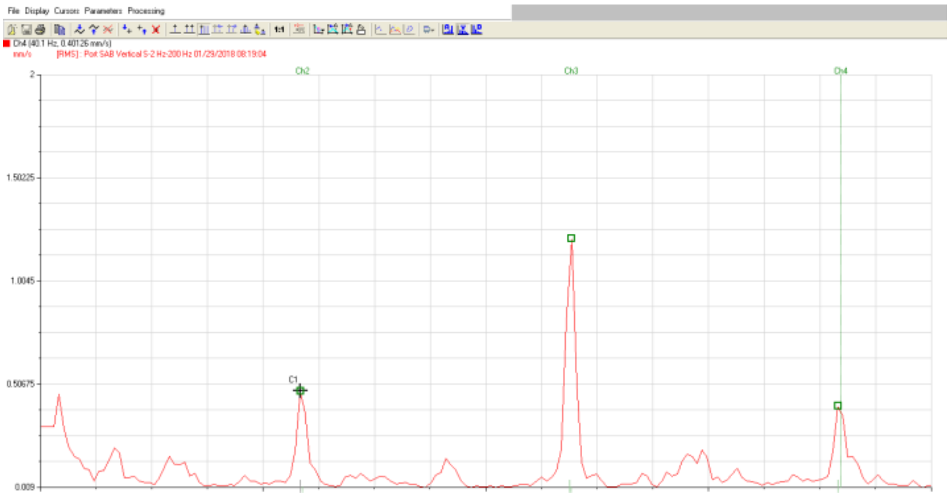

Figure 1.6 Port Self Align Bearing vertical at 800 ERPM- Offset Misalignment

Observation: Harmonics pattern persists at 1 X, 2 X, 3 X with comparatively higher 2 X. 1 ½ X and 2 ½ X also visible.

4. Findings of Results

During spectrum analysis followings were observed;

4.1 Main Engines

a. Angular misalignment inAft Port M/E free end and drive end at 1740 rpm and Aft Stbd M/E drive end at 1740 rpm

b. Structural looseness in Aft Port M/E free end axial at 1740 rpm

c. Offset misalignment in Aft Stbd M/E at 1740 rpm

4.2 Gear boxes

During spectrum analysis followings were observed;

a. Structural looseness in Aft Port G/B drive end vertical at 1200 rpm

b. Offset misalignment in Aft Port G/B drive end (at 1200 rpm) and free end (at 1740 rpm) respectively

c. Offset misalignment in Aft Stbd G/B free end axial at 1740 rpm

d. Angular misalignment in Fwd Port G/B free end axial at 800 & 900 both rpm

4.3 Hull/ Miscellaneous

During spectrum analysis followings were observed;

a. Offset misalignment in Port Self Align Bearing at 800 rpm & 900 rpm
b. Offset misalignment in Stbd Self Align Bearing horizontal in 900 rpm
c. Structural looseness in Port inner gland box at 1740 rpm

Considering the above observations, it was recommended by the trial team to undertake followings for further defect analysis/ rectification.

a. Re-check engine to gear box alignment of both Aft Main engines.
b. Inspect for any deformation of mounting shoes of both Aft main engines and related components.
c. Check the engine mounting and alignment of Fwd Port Main engine
d. Ensure proper alignment of all four shafting

Further, it was evident from the vibration velocities of Port Inner propeller shafts for an excessive shipboard vibration. Hence, it was highly recommended to conduct a specific and proper survey on Port inner propeller shaft and associated components (propeller, rudder, self align bearing, struts and adjacent shell plates near stern tubes) during docking period. Considering past records, it was highlighted that few critical defects had occurred in Port inner shafting system and same observed during vibration spectrum analysis where, the vibration velocity readings in port inner gland box at 1740 rpm shows a structural looseness pattern.

5. Conclusion

The findings had been a scope of guidance for the repair staff to identify the docking repairs / refitting requirement by pin pointing the affected region. Further, the levels of vibrations of the vessel structure and machinery showed a clear cross over beyond alarm thresholds, where attention is critical. The most concerned vibration frequency region was 1- 200 Hz in order to identify hull and machinery spectrum variants. However, the conditions showed the vessel could be deployed few more years after attending minor rectifications during the immediate dry dock period. The vibration spectrum analysis on ships hull and machinery is a clear tool of Condition Based Maintenance (CBM) which is economical and beneficial towards project implementation and planning.

6. Acknowledgement

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