COVER STORY

Advanced Vibration Troubleshooting on A Rotating Equipment

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An advanced vibration troubleshooting on a rotating equipment which is a pump package was done to investigate if there is any motion movement and structural resonance issue on the pump package ***(Figure 1).***

Figure 1 *Pump package overview*

In order to confirm the probability of structural issue, the methods chosen are *Vibration Survey*, *Operational Deflection Shapes (ODS)* using IRIS M Motion Amplification Camera and *Experimental Modal Analysis (EMA)*. SD Advance Engineering Sdn. Bhd. proposed an alternative modal analysis technique named Impact-Synchronous Modal Analysis which allows the analysis to be performed during operation without disturbing the daily operation of the pump package. Nonetheless, the team performed the test offline due to plant was not in full operational stage.

Vibration survey is a method where mapping was done at points of interest across the pump body including circulation line, small-bores connection (17 measurement points) and piping for suction (9 measurement points) and discharge line (13 measurement points) in three directions, *i.e.*, axial, horizontal and vertical directions using tri-axial sensor (***Figures 2, 3, 4).***

Figure 2 *Some of measurement points on the pump body*

Figure 3 *Some of measurement points on pump suction piping*

Figure 4 *Some of measurement points on pump discharge piping*

Performing *ODS* and *EMA* on pump, its support baseplate, circulation line, suction and discharge piping are investigated if there is any motion movement and structural resonance of the pump package.

ODS analysis by motion magnification survey was conducted on-site on the pump package during operation to evaluate the overall motion of pump package with filtered at running speed of 49.25 Hz. ODS analysis was used to understand the deflection pattern of the entire pump package during operation. An example of the video screenshot is provided in ***Figure 5***.

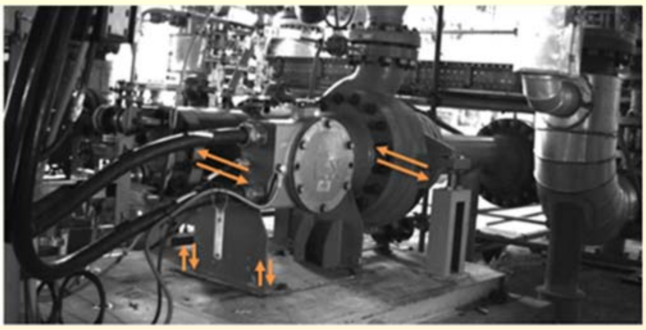

Figure 5 *Screenshot of the pump with illustrated movement direction*

Impact excitation test (under EMA) was carried out on-site to determine the dynamic characteristics which are natural frequencies, mode shape and damping of the pump package during operation. The test covered across the pump body (30 measurement points), suction piping line (12 measurement points) and discharge piping line (17 measurement points).

All the points were inserted to the wire-mesh model of the machine for mode shape representation as shown in ***Figure 6***. Frequency Response Function (FRF) obtained from modal analysis was post-processed using modal identification algorithm to determine the natural frequencies, damping and mode shapes of the entire pump package. This is a useful analysis in identifying the dynamic behaviour of the pump and subsequently the root cause of high vibration due to the structural resonance could be identified.

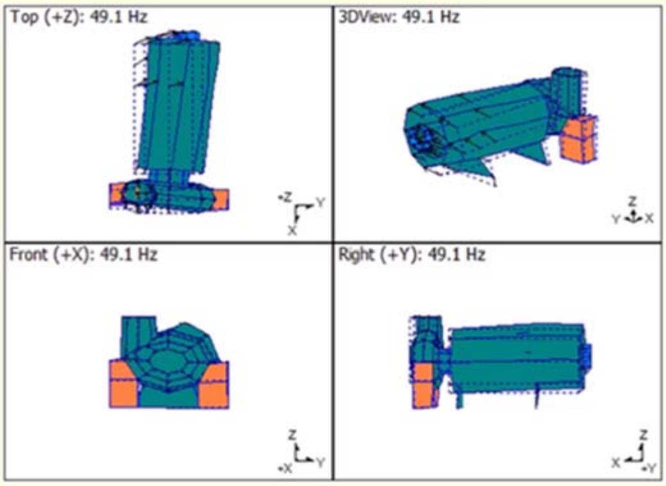

Figure 6 *Wire-mesh model of pump body from four perspective angle [1]*

During the vibration survey and ODS analysis, it was found that the vibration level on the pump is exceeding the maximum allowable vibration level of ISO 10816. Modal analysis also showed that the pump package has a sign of structural resonance issue. The natural frequency peaks of the pump package are within 19 – 65 Hz range which are coincide with the running speeds (around 45.25 Hz). Since the natural peaks were detected within the range of 1X running speed (± 10 %), the best solution was to stiffen the support. However, attention must be given during the modification by adding stiffness to the system to increase the natural frequency peaks by 1X running speed once more. Similar to the resonance issue at Small Bore Connectors (SBCs), by adding a support or braces, it will improve the vibration frequency particularly at 50 Hz.

Therefore, it is recommended to add an additional support or braces in order to hold up the pump body and incoming power supply terminal (***Figure 7***), grout the empty space for additional rigidity of the foundation of skid base (***Figure 8***), re-design the pump support skid size and level to the height of pump skid (***Figure 9***), add or re-positioning the hold down bolts for pump baseplate to avoid flexing at each end (***Figure 10***) and install the support or braces for circulation line, all SBCs and flange (***Figure 11*** and ***12***).

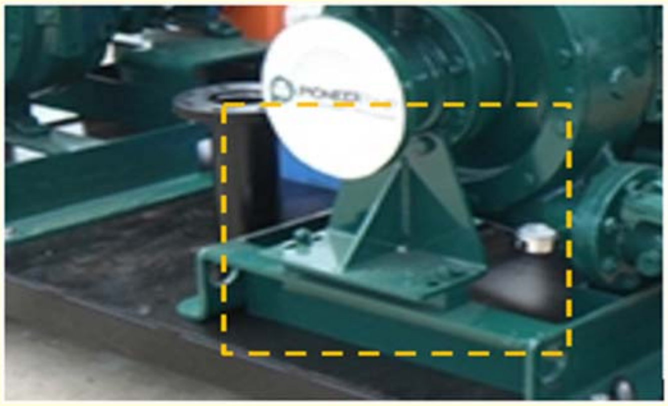

Figure 7 *Example of additional support or braces for overhung design*

Figure 8 *To grout the empty foundation under baseplate (at site)*

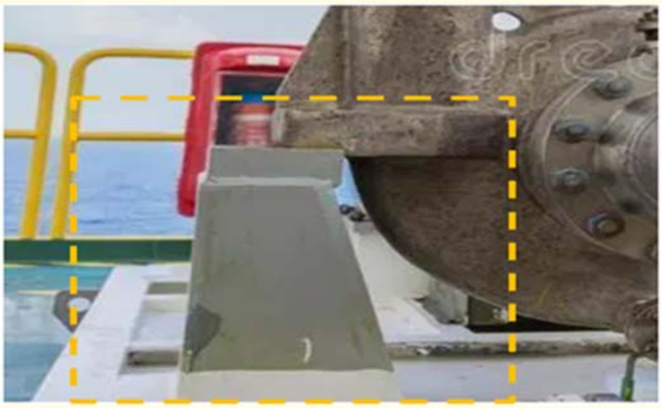

Figure 9 *Example of pump support skid levelled with pump skid*

Figure 10 *To add or re-positioning the hold down bolts*

Figure 11 *Additional support or braces for SBCs or flange*

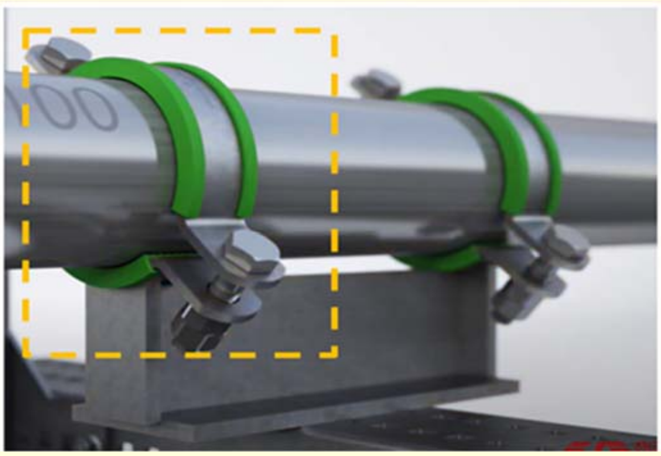

Figure 12 *Additional support or clamp for circulation line* [2]

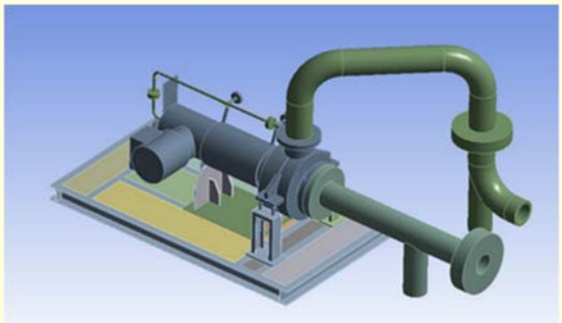

Figure 13 *Full FE model of pump package with piping boundaries* [1]

From EMA, it was found that the natural peak at 49.1 Hz of motor outboard flipping mode which is dominated at motor outboard in horizontal direction and motor support in horizontal and vertical direction, respectively with the vibration survey and motion amplification ODS also showed high vibration in horizontal direction at motor outboard with similar operating deflection motion mainly contributed by this flipping mode.

Structural Dynamic Modification (SDM) was performed utilizing computational mechanics technique which includes Finite Element (FE) modelling, FE Modal Analysis and SDM prior to fabrication with the aim to shift the motor outboard flipping mode away from the excitation frequency of the pump. Such condition rectifies the high vibration problem of the pump package due to the structural dynamic weakness / resonance issue.

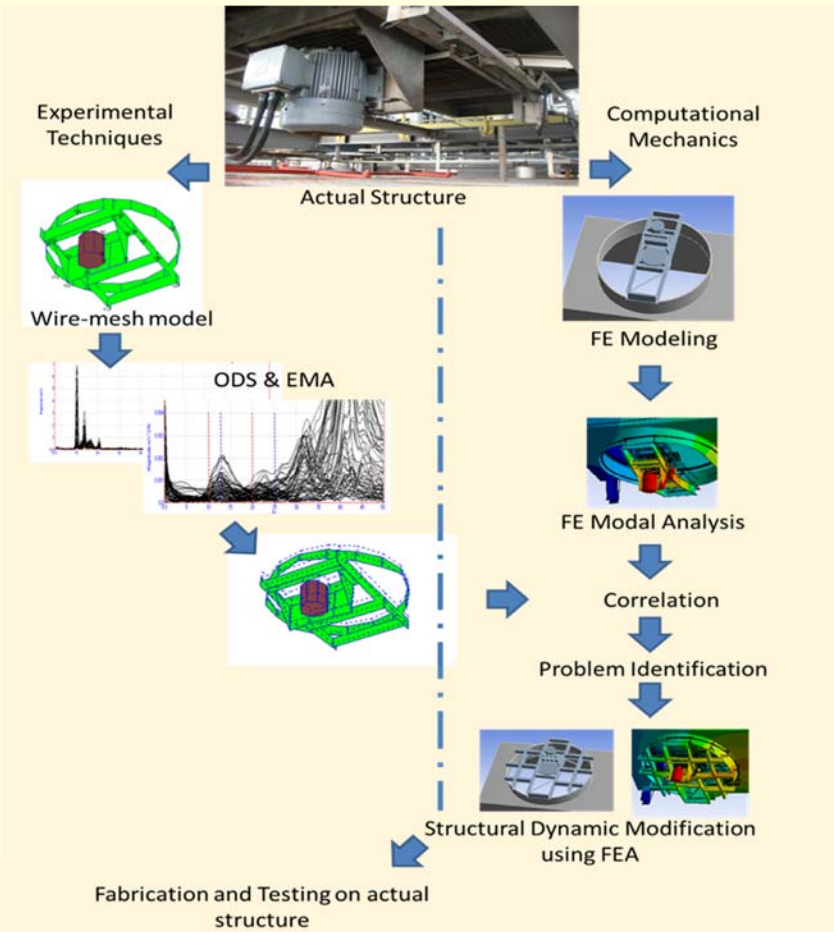

Figure 14 *Structural Dynamic Modification Procedures [1]*

The FE model was first created from the dimensions as per mechanical drawings of the pump package and site measurements of the base plates and the equipment supports (***Figure 13***). The FE model was then validated by including the piping boundaries, *(i.e.,* suction and discharge) to simulate the actual behaviour of the pump package by correlating the dynamic characteristics, (*i.e*., natural frequencies and corresponding mode shapes) of FE Modal Analysis and the EMA results. The correlated FE model under SDM in computational domain allows large number of design modifications without having the unnecessary physical cycles of 'modify-and-test'. Full SDM procedure is as shown in ***Figure 14***.

It was known that the high vibration problem of the pump package was due to the structural dynamic weakness issue / resonance issue caused by the motor outboard flipping mode. This mode is dominant in horizontal direction at motor outboard and there is a flipping motion at the motor outboard support in vertical direction.

The design modifications focus on shifting away the motor outboard flipping mode while ensuring the other lower frequency modes to be far enough from the excitation frequency. Structural resonance issue is rectified after the SDM (***Figure 15***). The proposed SDM consists of a few strengthening structures such as constrain the vertical movement of the motor and pump support plate by welding at all the edges, constrain the horizontal movement of the motor outboard by welding a triangle bracing to the base plate and existing motor support and constrain the horizontal movement of the pump support by replacing a new optimized, lighter and stiffer beam for strengthening support.

By gaining the first experience in a full troubleshooting mission, I was able to perform multiple advanced vibration methods that are proved to be essential in finding solutions for rotating equipment issues.

The combination of measurement and computation is certainly an interesting method to tackle a real problem that takes place in an industrial environment. I am definitely looking forward to a more challenging missions in the near future!

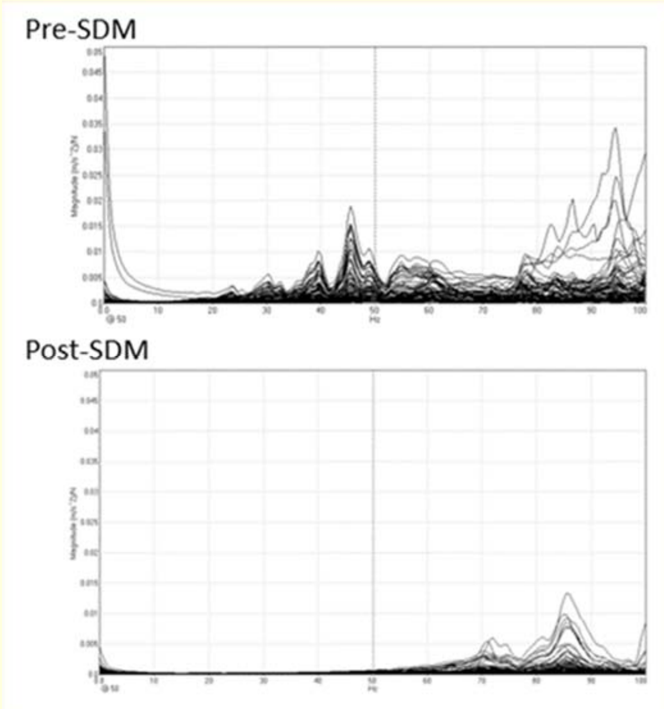

Figure 15 *Pre- & Post-SDM* [1]

References

[1] Serba Dinamik Vibration Completion on Onshore Report - Structural Dynamic Modification of a Pump Package by Ir. Dr. Ong Zhi Chao.

[2] Serba Dinamik Vibration Completion on Onshore Report - Vibration Survey, Motion Magnification Measurement and Experimental Modal Analysis on a Pump Package by Hafiz Harun.

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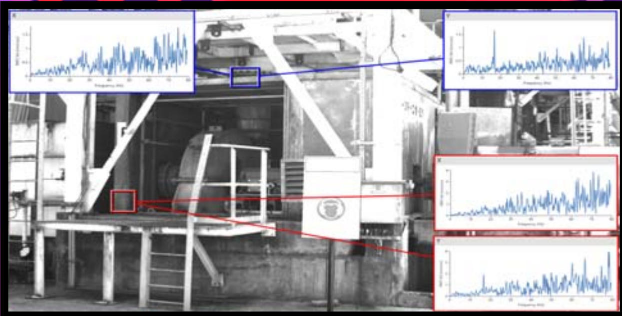
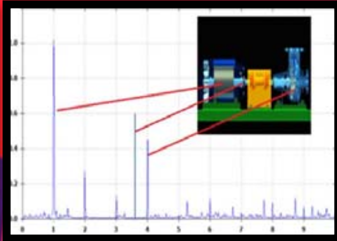
HIGHLIGHTS

- Advanced Vibration Troubleshooting on A Rotating Equipment.
- Application of FTIR Structural Analysis for Dried Coating Failure Investigation in Oil & Gas Industry.
- Utilization of Natural Fiber Towards Structural Applications Under Dynamic Loading Through MWCNT Enhanced Polymer Nanocomposite.





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