Design and Vibration Analysis of Pump Assembly for Two Types of Cushy Mount

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Abstract. This paper is mainly focused on vibration characteristics of pump motor assembly and selecting suitable mount for the assembly using FEA and experimental approach. Pump motor assembly is connected to base structure by mount. Modal and FRF Analysis are performed to study the mode patterns, natural frequencies and vibration response of the entire structure. Experimental study helps to evaluate the vibration amplitude values of the structure. FFT analyser is used to measure the RMS acceleration of the entire assembly, BK (Bruel & kjaer) Connect software is used to extract the data from FFT analyser. Comparison study reveals and evaluates the vibration characteristics of two mounts and the best mount is suggested. The first section in your paper.

Keywords: Modal and FRF Analysis, FFT analyser, BK Connect.

1. Introduction:

Pump-Motor assembly is also known as power unit in injection molding machine. Pump-Motor assembly is placed on the cushion mounts. The type of pump used in this project is “Servo Pump”. They precisely convert electric energy into the hydraulic energy. While the machine is running, the produced vibration is transferred to the cushion mounts. Here Fast Fourier Transform (FFT) Analyzer is used for recording and predicting the data of vibration during experimentation. The first cushion mount is replaced with a second mount and again the analysis is done.

Podugu R et al [1], modal analysis of a centrifugal pump was performed to determine the natural frequencies using finite element approach. The first 10 natural frequencies were compared with centrifugal pump operating speed as per HIS (Hydraulic institute standards). Results showed that first natural frequency of pump 63.25Hz was found matching with pump operating speed of 62.25Hz which
is having very less margin of 1.2%. As per HIS, 10% of variation has to be maintained between natural frequencies and pump operating speed. The model was further modified by adding stiffness to the pump pedestal so that natural frequency was increased to 74.31Hz which was above the limit as per HIS clause. Scheffer C et al [2], this study is an overview of vibration-based condition monitoring techniques for pumps. Vibration study and condition monitoring were used to identify faults in pumps. The main advantage of condition monitoring was to schedule the maintenance in advance. Specific technical problems can be identified and rectified with the implementation of vibration-based techniques which increases reliability and efficiency. Sinha JK [3], modal analysis was performed on the pump assembly to determine the root cause failure of the bearing. The obtained natural frequencies at 67.96Hz was matching with the pump components was found to be the main reason for failure. Analysing complete dynamic characteristics of pump will be beneficial for improving the performance compared to conventional condition monitoring. Tenali N et al [4], this paper states that vibration study and fault diagnosis are efficient techniques to find the defects in rotating shaft. Defects like unbalance, dry friction, misalignment and the surface cracks are the main reasons for vibration. The life of the rotating member can be identified by its peak value. The type of peaks in the spectrum indicates the type of fault. Results concludes that time domain and frequency domain techniques are used to determine the faults in the shaft, frequency domain technique can identify the location of fault. Ganesh et al [5], this study is to diagnosis and resolve vibration problem of vertical centrifugal pump using experimental and numerical approach. FFT analyser, impact hammer was used to carry out experimental vibration and modal analysis. Vertical centrifugal pump along with base frame were modelled using CATIA. Modal and harmonic analysis were performed in ANSYS to evolute natural frequencies and vibration amplitude respectively. Results showed that an error of 5.6% obtained by comparing numerical and experimental values. Peak velocity of 12.3mm/s was measured at coupling cover from experimental vibration analysis. Experimental modal analysis results showed that coupling cover natural frequency of 59.3Hz was close to operating speed. Modification of coupling cover was carried and performed numerical and harmonic analysis and found natural frequency was increased to 137.5Hz and vibration amplitude was reduced to 0.7mm/s.

2. Methodology:

In this research work the methodology as shown in figure 1 is adopted, the vibration analysis is performed on pump motor assembly. Modal analysis is performed on pump motor assembly for two types of cushy mount. Frequency Response Function (FRF) analysis is performed by exciting the pump assembly with 1G acceleration as an input at all the mounting points and the frequency range of 0-100Hz. Here the experimentation is done using FFT analyser and the results of two mounts are compared then the best mount is suggested.

![Figure 1. Methodology](image-url)
3. Geometry:

3D model of pump and motor assembly is modelled using Solidworks and it is shown in figure 2.

![Figure 2. Pump-Motor Assembly](image)

4. Meshing:

Finite element meshing of the pump motor assembly is done using Hypermesh. Here the type of mesh used is 3D tetra mesh with an element size of ten. After meshing, it is need to ensure that the mesh of each component should not intersect and penetrate with another components. And also, element quality (tetcollapse) of the mesh generated checked. Here the weld and bolt connections are used for connecting the different components of the geometry. Finite element meshed model is shown in figure 3 with total number of Elements: 717848 (Tetra Mesh).

![Figure 3. Enlarged View of Meshing](image)

| Material       | Density (kg/m^3) | Poisson's Ratio | Young's modulus (GPa) |
|----------------|------------------|-----------------|-----------------------|
| Pump FE410     | 7860             | 0.285           | 210                   |
| Motor FE410    | 7860             | 0.285           | 210                   |
| Coupling SS304 | 8000             | 0.29            | 193                   |
| Safety Manifold SG400 | 7200 | 0.26            | 175                   |
| Suction Pipe   | SG400            | 7200            | 0.26                  | 175                   |
| Flange         | SG400            | 7200            | 0.26                  | 175                   |
5. Boundary Conditions:
The following boundary conditions are used for the vibration analysis:
Eight mounting points are restricted in all DOF.
Frequency range: 0-100 Hz.
Excited Acceleration: 1g (For FRF).
Figure 4 shows the pump-motor assembly with applied boundary conditions.

Figure 4. Pump Assembly Showing Constraints

6. Results:
6.1. Modal Analysis Results:
The results obtained through modal analysis are shown in figures 5 to 8 for respectively mode 1 to mode 4. The corresponding frequencies for mode 1 to mode 4 are given table 2.

Figure 5. Mode 1 shows the bending mode along X-axis at 17.59 Hz.
Figure 6. Mode 2 shows the lateral mode along Z-axis at 23.20 Hz.

Figure 7. Mode 3 shows the vertical mode along Y-axis at 40.41 Hz.

Figure 8. Mode 4 shows the twisting mode along X & Y-axis at 45.74 Hz.
6.2. FRF Analysis Results:
Operating Frequency of Pump-Motor Assembly – 41.66Hz
The Frequency response analysis is done and the critical points are identified shown in Figure.8. 
In X-Direction the peak values are observed at point 1 and 4 with frequency 42Hz. (Figure.9) 
In Y-Direction the peak values are observed at point 4 and 1 with frequency 60Hz. (Figure.10) 
In Z-Direction the peak values are observed at point 4, 1, 3 and 2 with frequency 61Hz. (Figure.11)

| Mode   | Frequency(Hz) | Type of Mode          |
|--------|---------------|-----------------------|
| Mode 1 | 17.59         | Bending mode along X-axis |
| Mode 2 | 23.20         | Lateral mode along Z-axis   |
| Mode 3 | 40.41         | Vertical mode along Y-axis   |
| Mode 4 | 45.74         | Twisting mode along X & Y-axis   |

![Table 2. Natural frequency for mode 1 to mode 4](image)

![Figure 9. Critical points identified from FRF Analysis Results](image)

![Figure 10. Acceleration Vs Frequency (X-Direction)](image)
Figure 11. Acceleration Vs Frequency (Y-Direction)

Figure 12. Acceleration Vs Frequency (Z-Direction)

7. Experimental Set Up:
Experimentation is done and the values are recorded at the critical points attained from FRF analysis. Here the FFT analyser and BK connect software are used for recording and analysing the experimental data.

Figure 13. Experimental Setup

Figure 14. Pump-Motor Assembly with First Mount
Figure 15. Data Acquisition System

Figure 16. Measuring Point

Figure 17. Second Mount
7.1 Experimental Results:
First Mount Results:

Figure 18. Acceleration Bar Graph in X-Direction

Figure 19. Acceleration Bar Graph in Y-Direction

Figure 20. Acceleration Bar Graph in Z-Direction

Second Mount Results:
Figure 21. Acceleration Bar Graph in X-Direction for Second Mount

Figure 22. Acceleration Bar Graph in Y-Direction for Second Mount

Figure 23. Acceleration Bar Graph in Z-Direction for Second Mount

Table 3. Comparison of First and Second Mount Results at Machine Base

| Point | Acceleration (m/s²) |
|-------|---------------------|
|       | X-Direction | Y-Direction | Z-Direction |
|       | First Mount | Second Mount | First Mount | Second Mount | First Mount | Second Mount |
| 1     | 260.74 | 76.98 | 207.52 | 4.25 | 212.3 | 15.78 |
| 2     | 473.97 | 312.09 | 228.66 | 37.17 | 72.14 | 68.46 |
| 3     | 1101.81 | 161.79 | 28.1 | 21.24 | 1477.7 | 48.18 |
| 4     | 76.28 | 70.86 | 37.01 | 12.32 | 354.38 | 11.97 |

| Point | Acceleration (m/s²) |
|-------|---------------------|
|       | X-Direction | Y-Direction | Z-Direction |
|       | First Mount | Second Mount | First Mount | Second Mount | First Mount | Second Mount |
| 1a    | 32.48 | 0.45 | 1.26 | 0.53 | 1.43 | 0.07 |
| 2a    | 2.13 | 0.84 | 1.76 | 0.2 | 1.55 | 0.08 |
| 3a    | 5.02 | 0.48 | 1.06 | 0.39 | 2.54 | 0.07 |
| 4a    | 13.17 | 0.26 | 1.36 | 0.31 | 2.1 | 0.1 |
8. Conclusion:
From Table 2. Comparison of first and second mount results at cushy mount points, the acceleration values of first mount are higher than second mount in all three directions. From Table 3. Comparison of first and second mount results at machine base points, the acceleration values of first mount are higher than second mount in all three directions.
Considering the results of first and second mount at both the cushy mount and machine base points, the second mount is better than the first mount.

References
[1] Podugu R, Kumar JS, Ramanamurthy B, Kumar N. A modal approach for vibration analysis and condition monitoring of a centrifugal pump. International Journal of Engineering Science and Technology (IJEST). 2011;10.
[2] Scheffer C. Pump condition monitoring through vibration analysis. InPumps: Maintenance, Design, and Reliability Conference 2008 Apr 2 (pp. 1135-1146).
[3] Sinha JK, Rao AR. Vibration based diagnosis of a centrifugal pump. Structural Health Monitoring. 2006 Dec;5(4):325-32.
[4] Tenali N, Babu PR and Kumar KC. Vibrational Analysis in Condition Monitoring and faults Diagnosis of Rotating Shaft-Over View. International Journal of Advanced Engineering Research and Science.;4(1).
[5] Ganesh, Potnuru, and S. Rama Krishna. "Diagnosis and Resolution of Vibration Issues in Vertical Centrifugal Pump." Journal of Failure Analysis and Prevention (2020): 1-10.
[6] Patidar S and Soni PK. An overview on vibration analysis techniques for the diagnosis of rolling element bearing faults. International Journal of Engineering Trends and Technology (IJETT). 2013 May;4(5):1804-9.
[7] Farokhzad S, Bakhtyari N and Ahmadi H. Vibration signals analysis and condition monitoring of centrifugal pump. Technical Journal of Engineering and Applied Sciences. 2013; 1081:1081.
[8] Onari MM, and Boyadjis PA. Solving structural vibration problems using operating deflection shape and finite element analysis. In Proceedings of the Twenty-fifth International Pump Users Symposium 2009 pp. 85-102.