Analysis of composite raft mount for vibration reduction of a centrifugal pump

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Abstract: The noise induced by centrifugal pump is one of the main concerns in the design and optimization of onboard equipment for ships and submarines. In this work, an attempt has been made to estimate the natural frequency of centrifugal pump with an ordinary conventional steel material foundation. Later, the conventional foundation is replaced with composite material with carbon reinforcement. The vibration studies are accomplished by using FE software ANSYS 18.1. The natural frequencies of centrifugal pump with steel foundation are compared with natural frequencies of centrifugal pump with composite raft foundation. It is observed that the natural frequencies are enhanced by providing composite material foundation.

Keywords: centrifugal pump, Natural frequency, Composite raft foundation, ANSYS

1. Introduction

The possible reason of centrifugal pump and its associated system vibration is unbalance of mechanical rotating parts of pump, driver natural frequency, resonance, flow induced vibrations, hydraulic resonance in piping. The centrifugal pumps are mostly used by many industries and the problem encountered with the centrifugal pump is the generation of sounds during the working. The Rotating parts, unbalanced mass, flowing medium vibrations and resonance in supported piping’s are main attributing factors for vibrations in this category.

Many authors showed a path to estimate the natural frequency of the centrifugal pump. Ahmed Ramadhan Al-Obaid [1] showed one solution to the present problem. The authors detected and diagnosed the cavitation of centrifugal pump by applying vibration studies. Speed and flow rate are the important parameters while characterizing the cavitation phenomenon. The natural frequency of the centrifugal pump can be estimated with Finite element method. This is proved by estimating natural frequency of the pump by treating above mentioned parameters [2]. A multistage centrifugal pump includes many parameters that control the performance. An optimized design is required to get good performance. Similar attempts were made to optimize the design using Energy Loss Model(ELM) and Computational Fluid Dynamics (CFD).
Different grid numbers, turbulence models, convergence precisions, and surface roughness are calculated for a typical multistage centrifugal pump was proposed [3]. The demand of reducing vibration and underwater noise caused by the air compressor, the design of an isolation device with the floating raft is described based on the comprehension of the excitation source. FEA models of the vibration isolation system in case of test bank status and installation in ship were established separately by means of the software ANSYS. The vibration modes, the transmission characteristics of the system as well as the shock response were analyzed [4] Flow-induced noise is a significant concern for the design and operation of centrifugal pumps. The negative impacts of flow-induced noise on operating stability have been shown in many cases [5]. With these insights an analysis is performed to understand the effect of composite foundation for centrifugal pump vibrations.

2. Finite Element Modelling

2.1 Geometrical Model

Centrifugal pump is modelled in Pro-e software and the IGS file is imported into ANSYS Workbench 18.1. Fig.2.1 depicts the model geometry considered for the present work. Finite element model of the present study is presented in Fig.2.2. No of elements on the FE model are 1,84,433.

![Figure 2.1. Centrifugal Pump Geometrical Model with conventional mount](image-url)
2.2 Modal analysis

To predict the natural frequencies of centrifugal pump, the bottom part of the supporting member is fixed and mode shapes are extracted. The analysis is performed by considering the all the parts with the stainless steel and protecting cover is made with aluminium alloy. The stainless steel Young’s modulus is 210GPa, Poisson’s ratio is 0.3.

Loading and boundary conditions: The bottom supporting structure is constrained in all aspects. As the lowest part of the pump is fixed to the ground, the FE model bottom displacement is arrested in all directions i.e X, Y and Z. The fine mesh option is used to perform the present analysis.

Table 2.1. Natural frequency of the centrifugal pump

| Mode No | Natural Frequency (Hz) |
|---------|------------------------|
| 1       | 57.471                 |
| 2       | 142.91                 |
| 3       | 172.18                 |
| 4       | 203.14                 |
| 5       | 206.85                 |
| 6       | 240.76                 |
Figure 2.3. Total deformation in mode-1

Figure 2.4. Total deformation in mode-2

Figure 2.5. Total deformation in mode-3

Figure 2.6. Total deformation in mode-4

Figure 2.7. Total deformation in mode-5

Figure 2.8. Total deformation in mode-6
3. Composite material support for base of the Centrifugal pump:

The present model considered for the study is analysis for composite base. The composite base with 5mm is modelled and carbon unidirectional fiber reinforced epoxy composite properties are attributed and the fiber direction is parallel to the global Z-axis of the pump. The model analysis is performed and the stiffness of the centrifugal pump is estimated from FE results.

3.1 Composite material properties

The carbon epoxy composite [5] is an orthotropic composite in the X-direction. The modulus of elasticity is 61340Mpa,

\( E_x = 61340 \text{Mpa} \), \( E_y = 61340 \text{Mpa} \) and \( E_z = 6900 \text{Mpa} \).

\( \mu_{xy} = 0.04 \), \( \mu_{yz} = \mu_{xy} = 0.3 \)

![Composite Base](image.png)

Figure 3.1. Centrifugal pump with composite base mount

Form the study it can be observed that by utilizing composite raft base, the Natural Frequency is increased. The strength to weight and stiffness to weight ratio is more for composite material as a result, the natural frequency is more for composite materials foundation than conventional materials.
Table 3.1. Natural frequency of the pump with composite base

| Mode No | Frequency (Hz) |
|---------|----------------|
| 1       | 204.54         |
| 2       | 324.18         |
| 3       | 476.74         |
| 4       | 654.7          |
| 5       | 679.41         |
| 6       | 724.16         |

Figure 3.2. Total deformation in mode-1

Figure 3.3. Total deformation in mode-6
4. Conclusions

Analysis on the centrifugal pump natural frequencies was conducted out by using ANSYS. The following are the conclusions derived from the present study

- The natural frequency of centrifugal pump with composite foundation is improved when compared to steel foundation
- Composite mount is suggested for reducing the vibration of centrifugal pump
- The composite mount can be used in ships and submarines to reduce the vibration signature and improve stealth

References

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