Experimental validation of vibration characteristics of selected centrifugal pump

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Abstract – *Vibration refers to mechanical oscillations about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road.*

A dynamic system is a combination of matter which possesses mass and whose parts are capable of relative motion. All bodies possessing mass and elasticity are capable of vibration. The mass is inherent in the body, and the elasticity is due to relative motion of the parts of the body. In every centrifugal pump, dynamic forces of mechanical and hydraulic origin are present and a certain vibration and noise is therefore inevitable. This paper tries to evaluate the vibration characteristics of selected centrifugal pump and various ways to eliminate the vibrations of pump.

Key Words*: *Centrifugal Pump, vibrations, isolators.

1. INTRODUCTION:

In every centrifugal pump, dynamic forces of mechanical and hydraulic origin are present and a certain vibration and noise is therefore inevitable. To ensure the safety of the pump and associated plant components, the vibration and noise must be kept within certain limits. If the mechanical state of the pump and its drive are good, the inflow conditions are in order and the duty point is admissible, these limits can be observed without difficulty. Higher vibrations ultimately results in decreased component life due to cyclic loads, lower bearing life, distortion to foundation, frequent seal failures[2] etc. Similarly noise has got huge impact on working environment and comfort conditions of an individual. Exact diagnosis of vibration and noise sources is very difficult in centrifugal pumps as this may be generated due to system or the equipment itself. It has been made to address some general causes of noise and vibrations, its diagnosis and remedies in centrifugal pumps. [3]

The sources of vibration in centrifugal pumps can be categorized into three types Mechanical causes, Hydraulic causes.

Mechanical Causes of Vibrations:

The mechanical causes of vibrations includes –

1. Unbalanced rotating components,
2. Damaged impellers and non concentric shaft sleeves
3. Bent or warped shaft
4. Pump and driver misalignment,
5. Pipe strain (either by design or as a result of thermal growth),
6. Inadequacy of foundations or poorly designed foundations
7. Thermal growth of various components, especially shafts, Rubbing parts Worn or loose bearings, loose parts, loosely held holding down bolts, Damaged parts.

Hydraulic Causes of Vibrations:

The hydraulic causes of vibrations includes –

1. Operating pump at other than best efficiency point (BEP)
2. Impeller vane running too close to the pump cutwater
3. Internal recirculation
4. Air entrapment into the system
5. Turbulence in the system (non laminar flow),
6. Water hammer.

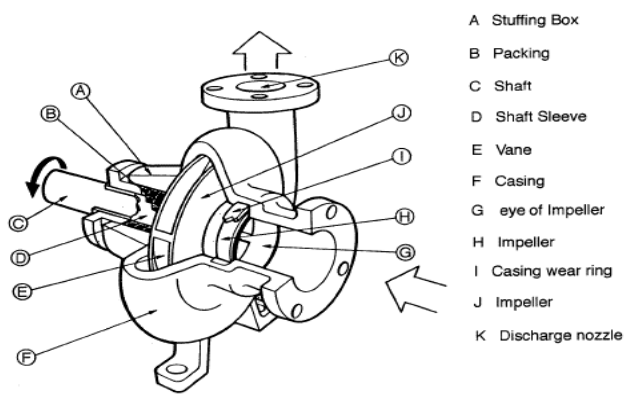

Fig.1geometry of centrifugal pump

2. LITERARURE REVIEW:

The natural frequency, mode shapes to corresponding frequency, shock, random and harmonic behavior of centrifugal pump is identified.by Naveen Varma et.al [1]The basic principal of operation for a centrifugal pump is that a shaft is mounted on a rotating impeller inside a housing (volute) imparts energy to the fluid being moved. Centrifugal pumps utilize centrifugal force (thus their name) to increase the velocity of the fluid as it passes through the impeller and exits at the tip or periphery of the impeller. This action converts mechanical energy (shaft torque) into kinetic energy by acceleration of the fluid to a higher velocity and pressure (potential energy). It is necessary to be concerned about the vibrations because it has a major effect on the performance of Centrifugal pump. This vibration reduces the expected life of the pump components. As maintenance is the art of prolonging the useful operating condition of equipment

The modal analysis of centrifugal pump and its assembly is performed using FEM technology by RamanaPodugu et.al. [2]The mathematical model and FEA model are built for the centrifugal casing and simulation is made to find the pump natural frequencies. First of CAD model of centrifugal pump is prepared in any CAD software then it is simulated and first ten natural frequencies are determined then vibration measurements are taken at the bearings of the pump in axial, horizontal and vertical directions by bump test the data were recorded using spectrum analyzer from the frequency response we can find the resonance condition. To avoid the resonance condition the first natural frequency needs to be increased which is done by providing necessary stiffness. The modified design is tested for FEA analysis the increase of stiffness of pump assembly will increase frequency of centrifugal pump. Thus the dynamic characteristics of the centrifugal pumps are improved.

The vibrations and noise in centrifugal pumps, its causes or sources and the diagnosis methods are studied by Ravindra Birajdar et.al [3] there are mainly two types of causes of vibration in centrifugal pump that is mechanical causes and hydraulic causes. Once the sources of vibration are known then actual measurement of vibration is done. While taking measurement of vibration location of vibration mount is important. The measured vibration data is analyzed by using vibration spectrum for every sources of vibration spectrum analysis is done .With the appropriate implementation of vibration and noise diagnosis techniques, pumps can operate with higher reliability and efficiency.

The finite element analysis software is utilized by Michael Tompkins et.al. [4] to first calculate the natural frequency of the pump/motor structure, and then potential modifications are modeled to determine their impact on eliminating harmful resonance. Reactor recirculation motor generator lube oil twin screw pumps are commonly found in nuclear power plants and throughout industry. In a vertical mounting configuration in which the electric motor is bolted atop the twin screw pump in an unsupported manner the natural frequency of the pump/motor structure can be quite low, resulting in damaging vibration. When a structure's natural frequency coincides at or near the operating speed, or multiple thereof, a phenomena known as resonance can occur. Resonance can occur when a driving force, in this case minor imbalances in either the motor vibration.

3. METHODOLOGY:

- To study the different vibration characteristics of centrifugal pump.
- Measurement of vibration parameters existing in a selected
  centrifugal pump.
- Development of suitable methodology to reduce vibration.
- Development of suitable model by using any appropriate modelling software like CATIA V5 or equivalent.
- To carry out dynamic analysis of developed model by ANSYS.

3.1 Measurement of vibrations:

Vibrations are measured existing in a selected centrifugal pump

Direction of measurement	Frequency(Hz)	Acceleration Amplitude(m/s^2)
Vertical	278.4	10.28
Axial	425	0.43
Transverse	277	12.5

Table1.Measurement of vibration existing in a centrifugal Pump

3.2 Development of suitable methodology to reduce vibration

In many practical situations, it is possible to reduce but not eliminate the dynamic forces that cause vibrations. Several methods can be used to control vibrations. Among them, the following are important

1. By controlling the natural frequencies of the system and avoiding resonance under external excitations.
2. By preventing excessive response of the system, even at resonance by introducing a damping or energy-dissipating mechanism.
3. By reducing the transmission of the excitation forces from one part of the machine to another, by the use of vibration isolators.
4. By reducing the response of the system, by the addition of an auxiliary mass neutralizer or vibration absorber.

From above methods to control vibration third method i.e use of vibration isolatoris implemented for which 4 different types of isolators are selected which are as follows

1.Circular Isolator (2.5" Diameter)
2.Circular Isolator (1.5" Diameter)
3.Grooved Isolator
4.Tapered Isolator

Fig.2 Circular Isolator with 2.5"diameter

Fig.3 Grooved Isolator

Fig.4 Circular Isolator with 1.5" diameter

Fig.5 Tapered Isolator

3.3 Experimental Results

Experimentation gives real insight of the system. In order to find out actual results experimentation is necessary because in theoretical analysis behaviour of system parameters considered is linear.

Elements of Experimental Setup

A) Accelerometer
B) Four Channel FFT Analyzer

Fig 2 Accelerometer

Fig.3 FFT Analyzer

A) Analysis of vibration measurement data:

Vibrations measurements are taken along three directions Axial, Vertical and Transverse.

There are many different methods available for analyzing vibration data. The most basic method involves displaying the vibration data in the frequency domain also called the vibration spectrum. The frequency of the vibration is the number of vibration cycles per time unit. The vibration spectrum is fundamental to vibration monitoring, because it yields the information that is effectively hidden in the vibration waveform. Vibration spectra can be represented in various different ways, of which the Fast Fourier Transform (FFT)

B) Hammer Test:

This test is carried out to Investigate Natural Frequencies for each type of Isolators.Each Isolator do have its own characteristic against vibration. For which it needs to be investigated through Hammer Test. From this test conclusion over frequency can be drawn. As per requirement of this project isolator should minimize vibration amplitude as well as higher 1st Fundamental frequency should be there of their own so it's resonance will be avoided. Small test setup is created for it in which a fixed mass of 10 Kg is mounted over each isolator and each is tested to get first frequency. Below is test setup for it.

4. RESULTS:

Following are the results obtained from vibration measurements taken in axial, vertical and transverse directions for four different types of isolators. vibration levels are below the threshold values with 1st Fundamental frequency being highest for same. 2.5" diameter isolator is used as baseline isolator which shown better vibration results. Same isolator is being used for creating grooves. Rubber Die is modified to achieve proper grooves for each isolator. Grooves have shown significant impact on 1st Fundamental frequency as the stiffness is getting added for each groove whereas on contrary side the vibration amplitude still remains low.

Table-2 Acceleration amplitudes for different types of isolators in different directions

Type of Isolators	Vertical Acceleration (m/s^2)	Axial Acceleration (m/s^2)	Transverse Acceleration (m/s^2)
Without Isolator	10.28	0.43	12.5
2.5" dia. Circular	4.48	1.17	1.67
Grooved Round	3.5	7.33	1.58
Tapered Round	17.8	3.56	6.56
1.5" dia. Circular	10.2	0.88	3.67

Table 3 First Fundamental Frequencies for different types of Isolators

Types of Isolator	First Fundamental Frequency Hz
2.5" Dia. Circular Isolator	62.25
Grooved Round Isolator	134.27
Tapered Isolator	68.35
1" Dia.Circular Isolator	113.52

5. Conclusion:

From this work it is concluded that

1) In order to isolate the vibration in centrifugal pump various types of isolators are studied. Circular with two different diameters, tapered and Grooved isolators are used for study.Investigation proves better results for Grooved Isolator; Vibration acceleration amplitude is reduced with grooved isolator compared with vibration acceleration results of pump without isolators.

2) From hammer test it is found that for grooved isolator first fundamental frequency is higher as compared with other types of isolators so that resonance condition will be avoided.

3) From results it is found that Grooved round isolators are very good at isolating the vibrations of centrifugal pump, so it is recommended for use with centrifugal pump to reduce the vibrations.

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