"VIBRATION IN VERTICAL CENTRIFUGAL PUMP"

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ABSTRACT

In popl CAN III plant there is a problem of vibration in a vertical turbine P19501 pump's of cooling tower of CNAIII plant. But for the solution of that vibration problem we should have some knowledge of pump operation and working and the possible causes of vibration in pump. We should find some basic causes of vibration in pump by searching in pump handbooks. The Engineers at popl use different tool to find vibration in pump and use spectrum graph to find magnitude of pump. They show us some method how to identify vibration in pumps and give us some specific knowledge about vibration causes in pumps, how to identify its magnitude and how to reduce vibration in pumps. So in our IDP we find out the solution for reducing vibration in vertical turbine centrifugal pump (P19501).So first in our IDP we enumerate some methods of identifying vibration in pump and some possible cause of vibration. We found out that the possible cause of vibration in pump is due to its structure and it is due to either weight of the motor placed at higher cause maximum vibration or due to improper misalignment between upper and lower base part of pump. So we use some methods to reduce it and it is explain in our IDP.

1. Introduction

Centrifugal pumps are a sub-class of dynamic axisymmetric work-absorbing turbo machinery. Centrifugal pumps are used to transport liquids/fluids by the conversion of the rotational kinetic energy to the hydro dynamics energy of the liquid flow. The rotational energy typically comes from an engine or electric motor or turbine. In the typical simple case, the fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radically outward into a diffuser or volute chamber (casing), from where it exits.

1.1 Working of centrifugal pump

A centrifugal pump converts mechanical energy from a motor to energy of a moving fluid. A portion of the energy goes into kinetic energy of the fluid motion, and some into potential energy, represented by fluid pressure (Hydraulic head) or by lifting the fluid, against gravity, to a higher altitude.

The transfer of energy from the mechanical rotation of the impeller to the motion and pressure of the fluid is usually described in terms of centrifugal force, especially in older sources written before the modern concept of centrifugal force as a fictitious force in a rotating reference frame was well articulated. The concept of centrifugal force is not actually required to describe the action of the centrifugal pump

1.2 Types of centrifugal pumps

Centrifugal pumps can be grouped into several types using Different criteria such as its design, construction, application, service, compliance with a national or industry standard, etc. Thus one specific pump can belong to different groups and often times this becomes descriptive of the pump itself. Some of these groups are:

1. End suction pumps 2. In-line pumps 3. Double suction pumps 4.Vertical multistage

5. Horizontal multistage pumps 6. Submersible pumps 7. Self-priming pumps 8. Axial-flow pumps

2. Introduction to vibration

When any elastic body such as spring, shaft or beam, is displaced from the equilibrium position by the application of external forces and then released, it commences cyclic motion. Such cyclic motion of a system, due to elastic deformation under the action of external forces, is known as vibration. All bodies possessing mass and elasticity are capable of vibration.

2.1 Definition

Vibration is a term that describes oscillation of mechanical system about its mean position. It is defined by the frequency and amplitude. Either the motion of a physical object or structure or, alternatively, an oscillating force applied to a mechanical system is vibration in a generic sense.

2.2 Types of Vibration

Free vibration

Free vibration occurs when a mechanical system is set off with an initial input and then allowed to vibrate freely. Examples of this type of vibration are pulling a child back on a swing and then letting go or hitting a tuning fork and letting it ring. The mechanical system will then vibrate at one or more of its "natural frequency" and damp down to zero.

Forced vibration

Forced vibration is when an alternating force or motion is applied to a mechanical system. Examples of this type of vibration include a shaking washing machine due to an imbalance, transportation vibration (caused by truck engine, springs, road, etc.), or the vibration of a building during an earthquake, pump vibration. In forced vibration the frequency of the vibration is the frequency of the force or motion applied, with order of magnitude being dependent on the actual mechanical system.

2.3 Terminology of vibration.

Frequency

The cyclic movement in a given unit of time. The units of frequency are:
RPM = revolutions or cycles per minute. Hertz (Hz) = revolutions or cycle per second.
These are related by the formula: F = frequency in hertz = RPM/60.

Amplitude

The magnitude of dynamic motion of vibration. Amplitude is typically expressed in terms of either
Peak to Peak: 0 to Peak: RMS (Root Mean Square).
The sketch below illustrates the relationship of these three units of measurement associated with amplitude.

Fundamental Frequency

Fundamental frequency is the primary rotating speed of the machine or shaft being monitored and usually referred to as the running speed of the machine.
You will also see the fundamental frequency referred to as 1 x RPM, or as Hz, using as an example an 1800 RPM motor this would be 30 Hz (1 x 1800/60). The fundamental frequency is important because many machinery faults such as misalignment or unbalance occur at some multiple of the fundamental frequency, for example misalignment at 1 x fundamental frequency.

Harmonics

These are the vibration signals having frequencies that are exact multiples of the fundamental frequency (i.e. 1 x F, 2 x F, 3 x F etc.).Time signal Spectrum

Displacement (D)

Displacement is the actual physical movement of a vibrating surface.
Displacement is usually expressed in mils (thousands of an inch) or microns. When measuring displacement, we are interested in the Peak to Peak displacement which is the total distance from the upper limited to the lower limits of travel.

Velocity (V)
Velocity is the speed at which displacement occurs. We define velocity as the rate of change in the relative position. Velocity is usually measured in mm/sec RMS, or inches/sec RMS.
Acceleration (A)
Acceleration is the rate of change of velocity. This we can simply define as the change of velocity in a period of time or change in rate of velocity. Acceleration is usually measured in g's of gravitational force.
Stiffness (K)
It is the force required to produce unit displacement in the direction of applied force.

K = , N/m

FFT (Fast Fourier Transform)
FFT is predominantly the most used tool in analysis of spectral data with respect to vibration analysis of machine components. Fourier transform is a mathematical operation which decomposes a time domain function into its frequency domain components.
2.4 Vibration measuring instrument
Essentially VibXpert (probe) is a modular system which can be configured to perform a number of Vibration related tasks including:

FFT analysis	Orbit analysis	Dynamic Balancing
Built-in ISO standards	Visual inspection data	Time signal analysis
In built bearing database	Data collection	2 channel FFT analysis

Probe(VibXpert)

(0-600)RPM	µm (Displacement)
(600-3000)RPM	mm/sec (Velocity)
(3000)RPM	mm /sec² (Acceleration)

2.5 Vibration magnitude analysis
When the vibration readings, taken by the vibration measuring instrument at a different points and in a different directions, are gathered and analyzed then it is found out that the vibration magnitude are greater than the critical limit. Thus the engineers come to the conclusion that there is problem of vibration in the pump. It should be noted that the critical limit of the pump is decided by the ISO standard depending upon the structure and working speed of the pump.
Critical limit of the pump
Preferable 0 to 6.0 mm/sec Most preferable 6 to 12.3 mm/secStill acceptable 12.3 to 16.0 mm/sec Not acceptable >16.00 mm/sec
2.6 Causes of vibrations pumps

Unbalanced rotating components.	Damaged impellers and non concentric shaft sleeves.
Bent or warped shaft.	Pump and driver misalignment,
Pipe strain (either by design)	Inadequacy of foundations or poorly designed foundations
Thermal growth of various components,	Rubbing parts
Worn or loose bearings, loose parts,	Loosely held holding down bolts
Damaged parts.	Operating pump at other than best efficiency point (BEP)
Vaporization of the product	Impeller vane running too close to the pump cutwater
Internal recirculation	

3. Steps taken to reduce vibration
3.1 Motor imbalance
First, to reduce the vibration due to motor imbalance engineers have disconnected the motor from the pump and then the dynamic balancing of the rotor of the motor is done. By balancing the rotor, a very minor reduction in the magnitude of vibration is found out. Thus one can conclude that rotor imbalance is not the major cause of the vibration.
3.2 Alignment pump or driving units
After balancing rotor, engineers have checked that whether there is proper alignment of the pump and motor or not. If there is a misalignment of pump and motor then also it creates vibration. For that they have separated the pump and motor and then checked the proper alignment and joined them properly.
3.2.1 Radial alignment
Clamp a dial gauge on one of the couplings or to the shaft. The plunger resting on the rim of the other half coupling. Set the dial zero. Rotate the coupling and note the reading at each quarter revolution. Any variation in the readings

indicates the deviation from alignment and the position of one of the units must be adjusted until the readings at each quarter revolution are identical or within the tolerances given below.

3.2.2 Angular alignment

Angular alignment for vertical pumps is totally dependent on the accuracy of levelling of sole plate and motor stool, since any adjustment at later stage is practically not feasible. However one can check the angular alignment as follows. After isolating the driven unit from its power supply, clamp two dial indicators are dramatically opposite points on one half coupling or to the shaft behind it with the plunger resting on the back of the other half coupling. Rotate the coupling unit the gauges are in line vertically and set the dial to read zero. Rotate the coupling by 180 and record the readings on each gauge. The readings should be identical, though not necessarily zero. Either positive or negative readings are acceptable provided they are equally positive or negative. Adjust the position of one of the units if necessary. Rotate the couplings unit the gauges are in the line horizontally and adjust the dial to zero. Repeat the operation outlined above by rotating the coupling by 180°.

4. METHOD OF REDUCING VIBRATION

4.1 Introduction

The manufacturer proposed several different alternatives to shift the structural resonance and reduce the amplitude of the operating vibration. Since the second natural frequency coincided with the operating speed, a possible solution involved increasing the flexibility of the pump discharge head.

Two methods can be adopted to reduce the pump vibration in this case.

To give the proper strength to the base stool.

To add the extra mass to the motor.

4.1.1 BY GIVING EXTRA STRENGTH TO BASE STOOL: -

When the base stool strength increased then there is a obvious change in its frequency of vibration So that the frequency of vibration of base stool does not match with frequency of vibration of motor So that the vibration due to resonance decreases.

4.1.2 BY ADDING EXTRA MASS TO THE MOTOR: -

When the mass in the motor increases then also an obvious change in the frequency of vibration of motor is found out by changing the frequency of motor this frequency does not match with the frequency of base stool thus the resonance do not occur and vibration due to resonance decreases

Now, we have adopting 1st method by giving extra strength or increase stiffness of base stool.

Fig.1 base stool with 4 ribs

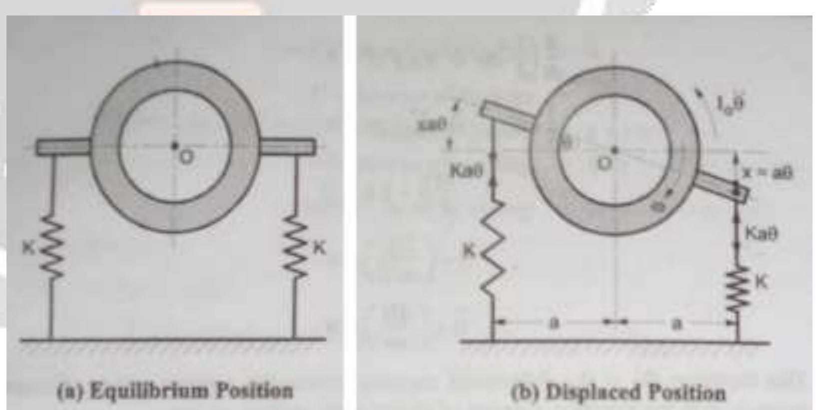


Fig.2 Motor supported with 4 ribs

Electric motor supported by 4 ribs each having stiffness k, mass moment of inertia of motor about the axis of rotation is I0 ,

Motor rotate through an angle ‘θ’ in clockwise direction due to which two left hand ribs are stretched by distance x, and two right hand ribs compressed by same distance x as shown in fig.

Equilibrium method:

∑ [Inertia torque + External torques] = 0

This equation is he differential equation of motion for a given system after providing ribs, comparing with fundamental equation of simple harmonic motion, we get

Therefore, natural frequency of vibration for given system after providing ribs,

Find Moment of inertia of ribs,
Stiffness of ribs K =
Natural frequency of vibration for given system after providing ribs,

$$fn(\text{system with ribs}) \neq fn(\text{motor})$$

so, resonance problem does not occurs

5. Modal analysis

5.1 Introduction

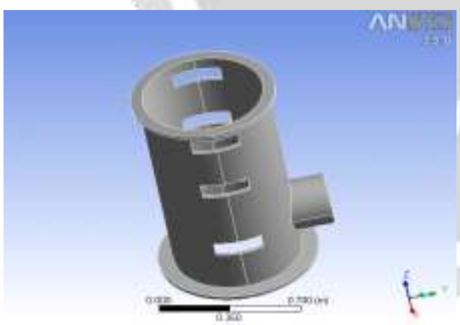
A modal analysis determines the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component. It can also serve as a starting point for another, more detailed, dynamic analysis, such as a transient dynamic analysis, a harmonic response analysis, or a spectrum analysis. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. We can also perform a modal analysis on a pre stressed structure, such as a spinning turbine blade.

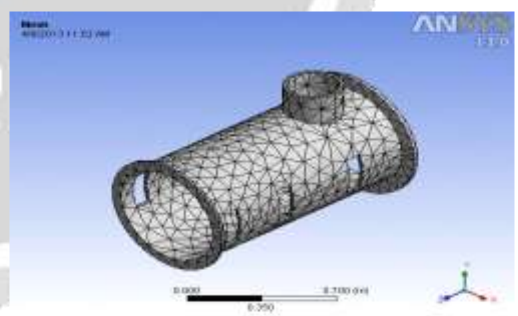
5.2 Points to Remember

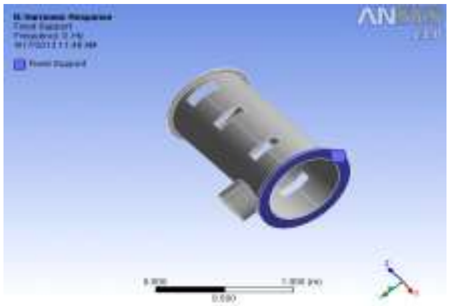
Only linear behaviour is valid in a modal analysis.
Damping is ignored in a modal analysis.
Any applied loads are ignored.
Prestressed modal analysis requires performing a static structural analysis first. In the modal analysis you can use the HYPERLINK "http://www.kxcad.net/ansys/ANSYS/workbench/ds_Define_Initial_Condition_step.html"Initial Condition HYPERLINK "http://www.kxcad.net/ansys/ANSYS/workbench/ds_Define_Initial_Condition_step.html" object to point to the Static Structural analysis to include prestress effects.

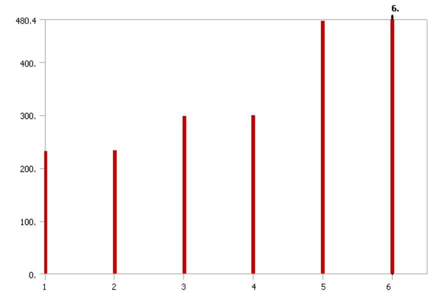
5.3 Benefits modal analysis

Allows the design to avoid resonant vibrations or to vibrate at a specified frequency (speakers, for example).
Gives engineers an idea of how the design will respond to different types of dynamic loads.
Helps in calculating solution controls (time steps, etc.) for other dynamic analyses.
Recommendation: Because a structure’s vibration characteristics determine how it responds to any type of dynamic load, always perform a modal analysis first before trying any other dynamic analysis.
8.5 Modal analysis of base stool structure
Step1 Attach Geometry
Open the model in Simulation and set up a modal analysis.







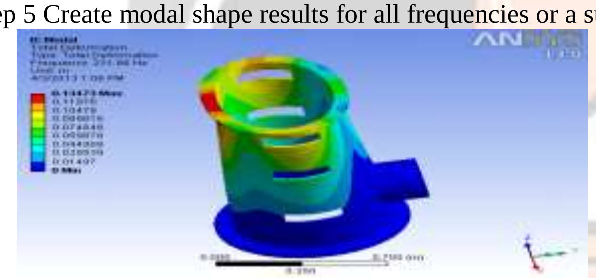


Mode	Frequency [Hz]
1.	231.86
2.	233.3
3.	297.72
4.	298.74
5.	477.77
6.	480.4

Table 1 modal frequency

Fig.3 Result of frequency corresponding to 6 modes

Step 5 Create modal shape results for all frequencies or a subset of the frequencies.



6. Define Initial Condition

Initial condition is not applicable for Harmonic Response analyses.

7. Apply Loads and Supports

The following loads are allowed in a harmonic response analysis:

Acceleration
Pressure
Force (applied to a face, edge, or vertex)
Bearing Load
Moment
Given (Specified) Displacement
Remote Force
Remote Displacement
Line Pressure

10. Solve

Solution Information continuously updates any listing output from the solver and provides valuable information on the behavior of the structure during the analysis.

8. Review Results

Two types of results can be requested for harmonic response analyses: Contour plots of results at a particular frequency and phase angle or graphs. Contour plots include stress, elastic strain, and deformation, and are basically the same as those for other analyses.

9.1 Harmonic analysis of base stool structure

In this harmonic frequency response analysis, frequency range need to be set up from zero to 1.2 times the frequency of the tenth vibration mode.

From this result, 0-576 Hz frequency range is applied

In the harmonic frequency response analysis, the fixed support is exactly same condition in Figure 8. In this analysis, force is applied to the upper portion of base stool for a frequency range from zero to 1.2 times the frequency of the sixth vibration mode.

Harmonic analysis step is same as modal analysis, in harmonic analysis most important thing is force applied on a structure so it’s give forced vibration of the structure. Harmonic analysis of base stool which step as same only forced applied on upper surface so,

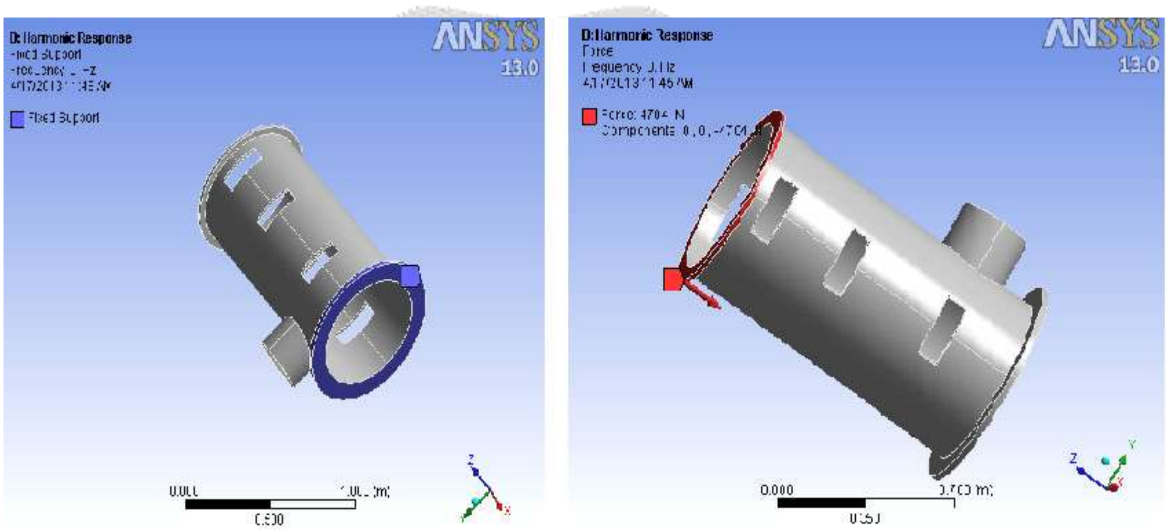
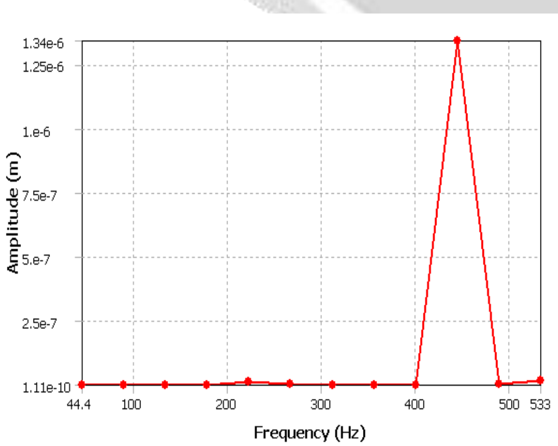
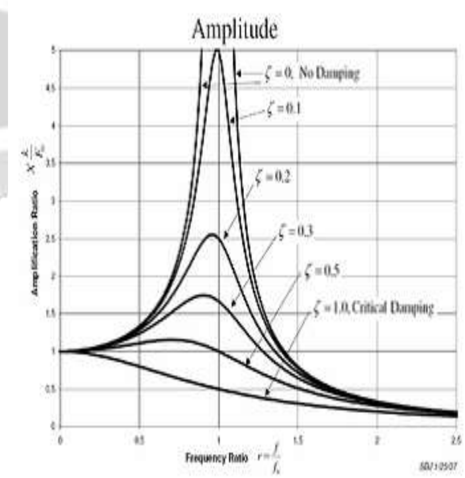


Fig.4 boundary condition in harmonic analysis

Harmonic analysis we have find phase response for total deformation and stres





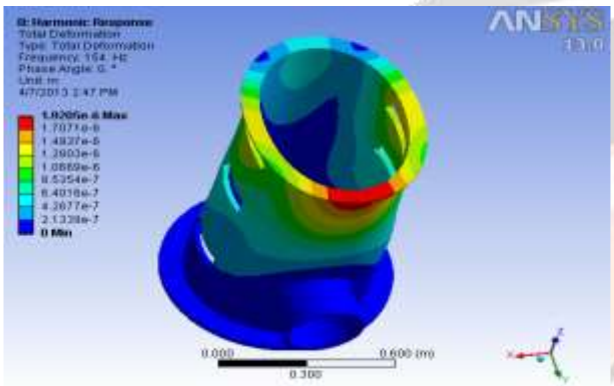
amplitude VS frequency ratio

10. provide 5 ribs on base stool

Mode	Frequency [Hz]
1.	215.36
2.	227.42
.	244.56
4.	247.28
5.	396.8
6.	444.58

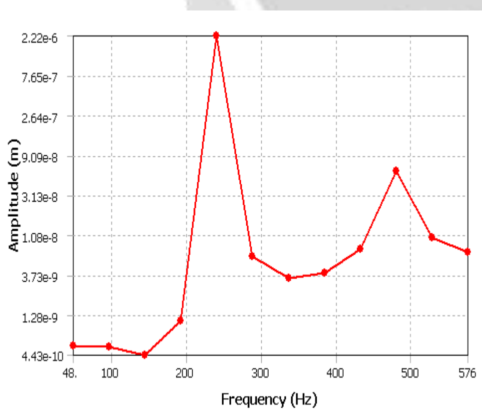
Result of frequency corresponding to 6 modes

Create modal shape results



Harmonic analysis

4. CONCLUSIONS



amplitude VS harmonic forced frequency

Resonance problem will solved.

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