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VIBRATION ANALYSIS OF VERTICAL PUMPS

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ABSTRACT

Vibrations are always critical characteristics of rotating machinery's. In many cases, vibration results in deterioration and failure of rotating machineries like pumps. Vibration study is important to identify the natural frequency of the machinery and detects any resonance problems in centrifugal pumps. Higher vibration affects performance and lifetime of pumps. Hence vibration becomes an essential criterion to be studied and monitored during operation of rotating machineries. In this project vibrations of vertically suspended Process pumps are analyzed to identify natural frequency and also to check whether the pump vibrations are within allowable limits. Vibrations are measured using velocity transducer and the FFT spectrum is obtained. FFT spectrums at different positions are analyzed to identify the high amplitude vibration and their corresponding frequency. Identified frequency is used to predict the root cause of the fault by comparison with the calculated fault frequencies. Since each fault produces unique vibration patterns, the spectrum obtained can be compared to those patterns and final root cause for high amplitude vibrations is found. Final root cause found is listed and justified. Methods to rectify or eliminate the root cause for higher vibrations are suggested and justified through manual calculations and software analysis.

KEYWORDS: FFT, Pumps

Centrifugal pumps are the most versatile and most widely used machines of rotating mechanical equipment in power generation and oil industries. Approximately pumps consume more than 25% of turbo machinery equipment electrical power used throughout industry. Centrifugal pumps works on the basic principal that an impeller mounted on a shaft inside a volute casing imparts energy to the fluid for movement of fluid from one place to other. As the fluid moves through the impeller its velocity is increased due to the centrifugal force produced by rotation of the impeller. The mechanical energy supplied to the shaft is converted into kinetic energy which increases the velocity of fluid and pressure energy of the fluid. Vibration is used as the quality control tool to identify low frequency dynamic conditions such as mechanical looseness, imbalance, structural resonance, misalignment, soft foot, bent shaft, excessive bearing wear, or damaged rotor vanes. Since most rotating component problems are exhibited as excessive vibration, vibration signals are used to indicate machine's mechanical Condition. Also, each mechanical problem or defect produces a unique vibration pattern. Therefore, we analyze the pattern of vibration the machine is exhibiting to identify its cause and develop appropriate repair steps. The key focus of this project is to identify the high amplitude vibration in the vibration spectrum obtained during different test points in vertical pumps and find the root cause of the problem. Methods to reduce the high amplitude vibration are suggested based on the root cause found.

LITERATURE REVIEW

Farokhzad et. al., 2013, In this paper Vibration is recorded in different conditions like normal pump, pump with broken impeller and pump with leakage faults. A centrifugal pump is tested by varying the types of impeller. The vibration signature obtained is compared with vibration signature of healthy pump in normal operating condition. It has been observed that there is a significant variation between the vibrations with respect to the different operating condition. This Paper finally plots an Amplitude VS Time graph to compare overall vibrations of machine in healthy, broken impeller and leakage condition. Vibration spectrum obtained was compared with the theoretical fault signatures to find out the reason for the problem. Thus RMS values of the broken impeller were found to be in critical status and the frequency peak obtained was in close range with the calculated value of Impeller Mesh frequency.

Kesler J.D., 2014, Technical Associates of Charlotte, This article predicts the ways of detecting pump problems using vibration analysis. A list of common pump problems like cavitation, pump flow pulsation, Bent pump shaft, Shaft Misalignment, imbalance in rotor and bearing problems were listed. Under each problem the ways of predicting those faults in vibration spectrum obtained was clearly listed and explained. For each problem the problematic frequencies where the peak will occur was

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mentioned and their corresponding phase difference if available was also explained in this article.

Donald R. Smith and Glenn M. Woodward, In this paper vibration analysis is done on vertical cooling water pumps which are experiencing higher vibration levels and frequent part failures. Vibration field data indicated that there is resonance between the reed frequency and rotating speed of the pumps. The pump model is given an external excitation to determine the reed frequency of pump. Then the pump stiffness is varied by loosening the bolts and it indicated a reduction in vibration amplitude of the pump. This test indicated that mechanical stiffness varies directly proportional to the reed frequency of the system. Short term modifications like attachment of temporary braces to increase the damping effects were made which reduced the pump vibrations significantly. But these options didn't provide a permanent solution due to practical difficulties. Hence modifications were done to move the natural frequency further from the operating speed. Natural frequency was reduced from the operating speed by attaching Neoprene isolator pads. In another method reed frequency of the pump is increased from the operating frequency by additional bolts rigidly attached to the base plates. Both the methods used for reducing the pump vibrations have their own advantages and disadvantages. Further tests on the pump revealed that stiffening the pump bases greatly reduced the pump vibrations and the pump failures were reduced.

Felten D., 2003, In this article Bearing defects in Rolling element bearings and sleeve bearings were explained clearly and the ways of detecting them in Vibration signature were explained. Defect frequencies like Fundamental train frequency, Ball spin frequency, outer race Ball pass frequency and Inner race Ball pass frequency were explained and their respective formulas to find their value using bearing geometry were listed. Identification of mechanical looseness in vibration spectrum and their respective causes were indicated. Clearance problems and their expected fault frequencies in the spectrum were also explained in this article.

VERTICAL PUMPS

These pump models are suspended vertically, thus, require a small area for installation. These pumps have flange ratings between 300 to 600.These pumps are generally used for vessel or pit drainage. They have Capacity up to 1750 m3/h and Head up to 1500 m. These pumps can operate fluids with temperature range -104º C to 350ºC.These type of pumps are used in oil refineries and petrochemical industries. This Project is done on multistage vertical pump model VS6. VS6 is a vertically suspended with double casing diffuser type pump. This pump has a side-side nozzle orientation and Bearings & mechanical seal can be removed without disconnecting suction line and discharge piping line or moving the driver. Axial force balancing is with the help of balance holes. Residual axial thrust & rotor weight is balanced by thrust bearing in pump.

PUMP VIBRATIONS

In real world, pump performance is reduced due to excessive vibrations. The various components of pumps which fail due to vibrations are listed below:

- Radial movement of the shaft has direct impact on seal packing. This can cause excessive leakage, excessive sleeve and shaft wear also.
- Bearings are selected based on its ability to withstand radial loads and axial loads. But, they are not selected based on the vibration that can cause defects in bearing surfaces.
- Allowable tolerances like clearance in impeller setting and wear ring are sensitive to vibrations. Bearing internal clearances are measured in one by of thousands of an inch. (mils)
- Shaft movement is directly proportional to Strength of the mechanical seal. Vibration can cause seal face damage and chipping of carbon surface. Vibration also causes looseness in set screws which results in sliding on to the shaft, which results in opening of the lapped seal faces.
- Wear rings, bushings and impellers can be damaged by vibration.
- Bearing seals are affected by radial movement of shaft. This may lead to Shaft damage and failure of seal will result. Seals operate with a very close tolerance. Excessive movement can damage these tolerances also.
- Due to excess vibrations pump and motor holding bolts become loose.

MECHANICALLY INDUCED VIBRATIONS

Pump operating speed is 1200 RPM and fault frequencies are calculated based on operating speed.

Table 1: Mechanical causes

CAUSES	AMPLITUDE	PHASE DIFFERENCE	NOTES BASED ON PHASE SHIFT	FAULT FREQUENCY (CPM) FOR N=1200RPM
Unbalance or Imbalance	1*N and its harmonics(less than 15% 1*N) are present in radial direction	90 to 90± 30 between horizontal and vertical direction of radial reading		1200
	Ratio of magnitude of 1*N in horizontal and vertical direction readings must be 1:1/1:3/3:1	0 between horizontal direction of two opposite ends of bearings	static unbalance	1200
	1*N in Radial ≥ 1*N in Axial (may change in case of overhung)	180 between horizontal direction of two opposite ends of bearings	couple unbalance	1200
In case of overhung mass	Same high axial and radial readings	0 between axial measurements across the machine		
Shaft Misalignment	High 2*N value in radial direction Value of 2*N is 50 to 200% of 1*N	180 across coupling or machine in axial direction	angular misalignment	1200,2400
	High 1*N value in axial direction	180 across coupling or machine in radial direction 0 or 180 between horizontal and vertical position of same bearing	Parallel misalignment	1200
	Multiple harmonics from 2*N to 10*N in axial direction		Severe misalignment	2400,3600,4800, 6000,7200,8400, 9600,10800
Bearing misalignment in the housing		Difference in phase readings in 4 radial directions of the bearing		
Looseness	Multiple harmonics (1*N, 2*N, 3*N, ….) and Sub harmonics (0.5*N, 1.5*N, 2.5*N, 3.5*N...)		Harmonics peaks may decrease in amplitude(2*N in vertical position may be high)	600,1800,3000,4200,5400,6600,7800,9000,10200, 11400
	Series of 3+ harmonics with magnitudes 20% 1*N and 4*N is distinctive	4*N is out of phase with N	Bearing is loose on the housing	4800
Bent shaft	Higher 2*N magnitude Value of 2*N is 50 to 200% of 1*N	Radial measurements are in phase(0)		1200,2400
	Higher 1*N in axial direction	180 with shaft across the machine in axial direction		1200
Bearing Problems	Non-synchronous peaks (hump)at (9*N,10*N)		Early stage detection possible in acceleration enveloping spectral analysis	10800,12000
Soft foot	Peaks at frequencies unrelated to N Peaks at second Harmonics 2*N			2400
Rubs	Series of spectral lines with Natural frequency at center or center frequency = no. of hits*N		Difference between peaks of spectral lines is 1*N	1200

OPERATING PARAMETERS

Table 2: Operating Parameters

Rated Duty Point	Motor Rating
Q - 1287.66m^3 / hr	V - 4KV
H - 251.6 m	Rating - 1225KW
N - 1200 RPM	M - 10000kg
P_{in} - 1091.8KW	$Torque_{rated}$ - 9940Nm
N_{su} - 6	Vibration level - Below 2.54mm/sec
N_{st} - 8	Condition - No Load
	Location - Bearing Housing
	Reed Frequency - 17HZ

MEASUREMENT PARAMETERS SETUP IN FFT ANALYZER

Measurement at various test points except shut-off

Operating Speed [N] - 1200 RPM - 20 HZ

Measurement Range - 5HZ to 1000HZ [300 CPM to 60000 CPM]

Spectral Lines - 400

Spectral Resolution - 3.0 HZ [150 CPM]

Vibration Measurement Locations

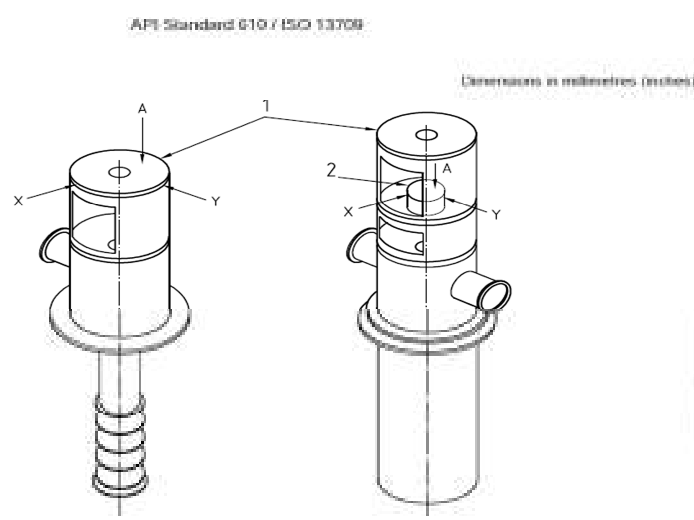

Figure 1: Vibration Measurement locations vertically suspended type

1- Driver mounting surface

2- Pump bearing housing

A- Axial direction

X, Y- Radial direction

Vibration Readings

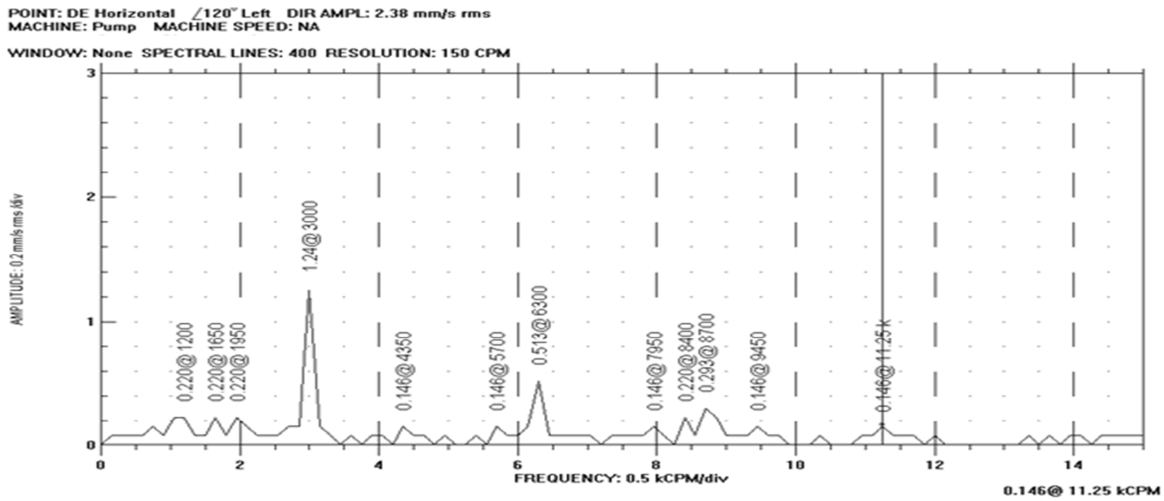

Figure 2: Horizontal X

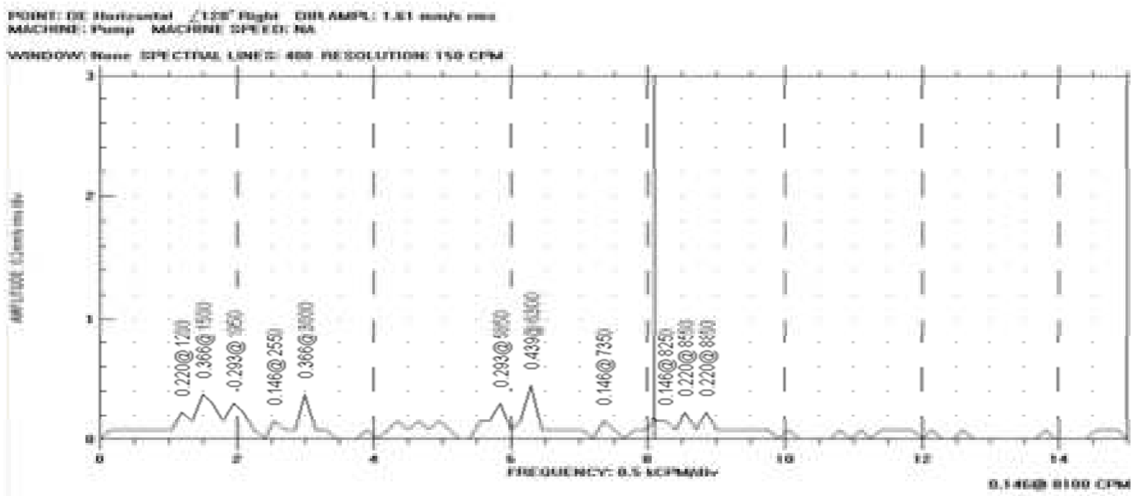

Figure 3: Horizontal Y

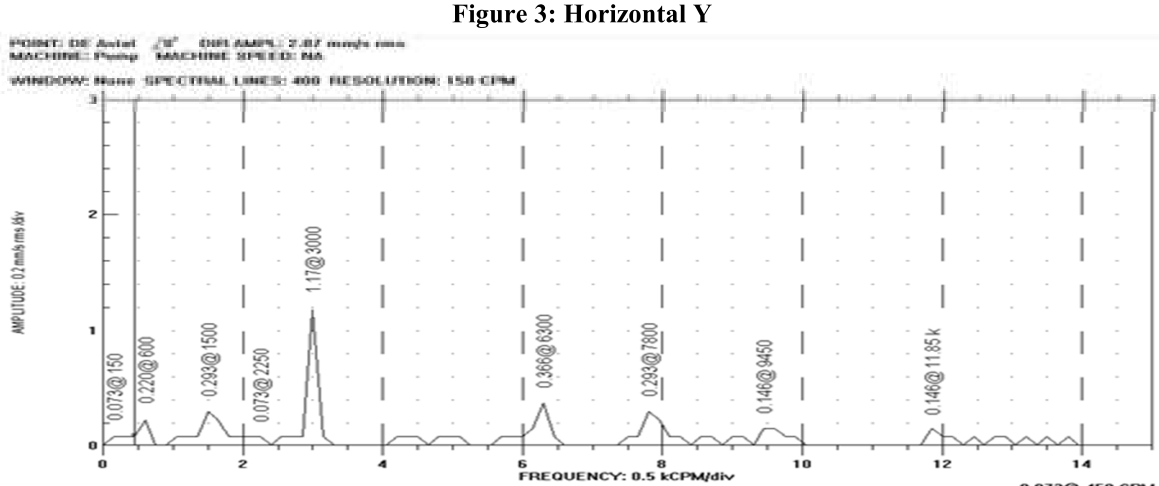

Figure 4: Axial A

CONCLUSION

From the Vibration Signature we observe that multiple sub harmonics are present and it can also be seen that harmonics peaks are decreasing in amplitude form the first dominant peak which is 2.5*N. In vertical position vibration spectrum 2*N peak is seen as dominant peak. Thus, analysis of the entire three vibration spectrum clearly depicts the patterns of Mechanical Looseness. Loose mounting bolts will also cause mechanical looseness. Cracks in base frame or bearing house will also accounts for mechanical looseness. Upon investigation loose mounting bolts are found and corrected.

FUTURE WORK

Mechanical looseness may also occur due to excessive clearance. As an assembly setup certain amount of clearance is provided for rotor components. Clearance is provided as per the diameter of rotor component. These clearance values are to be rechecked and possibility of reduction in vibration by varying the clearance values is to be investigated in future.

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