Effect Of Unbalance On Performance Of Centrifugal Pump

Sanjay Taneja

Abstract: Hydraulics Machines of some kind are used in nearly every aspect of our daily lives; from the pumps and machine we use at home, to the industrial machinery used to manufacture, material handling nearly every product we use on a daily basis. When a machine fails or breaks down, the consequences can range from annoyance to financial disaster, or personal injury and possible lose of life. For this reason, the early detection, identification and correction of machinery problems is paramount to anyone involved in the maintenance of industrial machinery to insure continued, safe and productive operation..Of course, it's natural for machines to vibrate. Even machines in the best of operating condition will have some vibration because of small, minor defects. Therefore, each machine will have a level of vibration that may be regarded as normal or inherent. However, when machinery vibration increases or becomes excessive, some mechanical trouble is usually the reason. Vibration does not increase or become excessive for no reason at all. Something causes it - unbalance, misalignment, worn gears or bearings, looseness, etc. This paper focuses on the machinery (Centrifugal pump) vibration due to unbalance and the technological effect on its performance. This study is done to evaluate the performance of the centrifugal pump on different unbalance masses. Some times these studies are quite helpful in order to equip better design of pump so that there should be minimum effect on its performance due to unbalance.

Keywords: vibration, eccentricity, misalignment, hydraulic machines, impeller, resonance, static unbalance

Abbreviations: ltr-liter, hr-hour, pr-pressure

1- INTRODUCTION

It is necessary to be interested in vibration in centrifugal pumps because it has a major effect on the performance. Generally, increasing vibration levels indicate a premature failure, which always means that the equipment has started to destroy itself. It is so because excessive vibrations are the outcome of some system malfunction. It is expected that all pumps will vibrate due to response from excitation forces, such as residual rotor unbalance, turbulent liquid flow, pressure pulsations, cavitations, and/or pump wear, improper foundation. The magnitude of the vibration will be amplified if the vibration frequency approaches the resonant frequency of a major pump, foundation and/or piping component. Generally higher vibration levels (amplitudes) are indicative of faults developing in mechanical equipment. The sources of vibration in centrifugal pumps can be categorized into three types Mechanical causes, Hydraulic causes & Peripheral causes.

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1- Mechanical Causes of Vibrations

The mechanical causes of vibrations includes –

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

2- Hydraulic Causes of Vibrations

The hydraulic causes of vibrations includes –

- Operating pump at other than best efficiency point (BEP)
- Vaporization of the product
- Impeller vane running too close to the pump cutwater
- Internal recirculation
- Air entrapment into the system through vortexing etc.
- Turbulence in the system (non laminar flow),
- Water hammer.

3- Peripheral Causes of Vibrations

The peripheral causes of vibrations includes –

- Harmonic vibration from nearby equipment or drivers.
- Operating the pump at a critical speed
- Temporary seizing of seal faces (this can occur if you are pumping a non lubricating fluid
- Impeller vane running too close to the pump cutwater

- Internal recirculation
- Air entrapment into the system through vortexing etc.
- Turbulence in the system (non laminar flow),
- Water hammer.

2-LITERATURE SURVEY

Pump components and rotor unbalance have been scrutinized in recent years by both users and manufacturers. While it may appear that more restrictive (lower) unbalance levels may automatically result in lower vibrations and longer machine life. Nelik and Jackson (1995) indicated such was not the case but their research showed that hydraulic unbalance contributes much more significantly to vibration than mechanical unbalance. ISO 1940/1 (1986) specifies balancing quality grades (G levels) for various types of rotating equipments. For pumps general recommendation is G-6.3 but some users and manufacturers specify G-2.5 for better performances of fan in pumps.

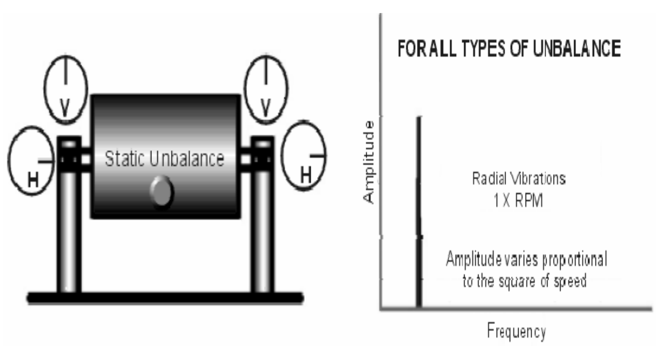
3-EFFECT OF UNBALANCE

In this paper covering issue is only unbalance effect on the performance of pump out of all mechanical causes explained above. Although it is essential to discuss all mechanical causes to get some positive conclusions.

3.1 Unbalance

Vibration caused by mass imbalance in rotating machinery is an important engineering problem. The objective of balancing is to reduce rotor vibration to a practical minimum. Reducing rotor vibrations generally increases the service life of the rotating machinery. The fundamental difference between a centrifugal sewage pump impeller and those of its clear water cousins is its ability to pass solid materials that would normally clod later. Due to the unbalance in the impeller, vibration occurs and leads to decrease in fluid velocity and local pressure which may cause an undesirable turbulence and possible cavitations. Hence, to remove the unbalance in rotor is necessary.

Fig 1



3.2 Eccentricity

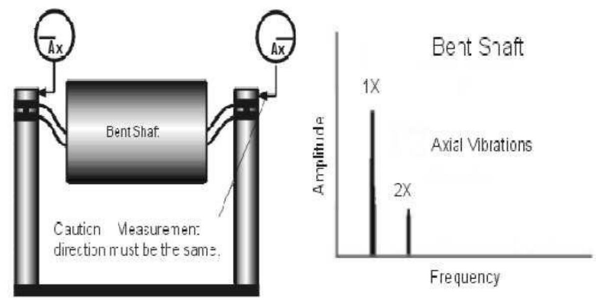
Eccentricity occurs when the centre of rotation is at an offset from the geometric centerline, and this may happen if the pump impeller is eccentric due to a manufacturing or assembly error. In the vibration spectrum, the maximum amplitude occurs at 1× rpm of the eccentric component, and will vary with the load even at constant speeds. In the horizontal direction, a phase shift of 90° will be observed.

3.3 Bent Shaft

When a bent shaft is encountered with a pump, the vibrations in the radial as well as in the axial direction will be high. Axial vibrations may be higher than the radial vibrations. The spectrum will normally have 1× and 2× components, as shown in Figure 2. If the:

- Amplitude of 1× rpm is dominant, then the bend is near the shaft centre
- Amplitude of 2× rpm is dominant, then the bend is near the shaft end. The phase will be 180° apart in the axial direction and in the radial direction. This means that when the probe is moved from vertical plane to horizontal plane, there will be no change in the phase reading.

Fig2



3.4- Pump and motor misalignment

There are basically two types of misalignment that can occur between the motor and the pump:

- Angular misalignment – the shaft centerlines of the two shafts meet at angle
- Parallel misalignment – the shaft centerlines of the two machines are parallel

As shown in Figure 3, angular misalignment primarily subjects the motor and pump shafts to axial vibrations at the 1× rpm frequency. A pure angular misalignment is rare, and thus, misalignment is rarely seen just as 1× rpm peak. Typically, there will be high axial vibrations with both 1× and 2× rpm. However, it is not unusual for 1×, 2× or 3× to dominate. These symptoms may also indicate coupling problems (e.g. looseness) as well. A 180° phase difference will be observed when measuring the axial phase on the bearings across the coupling, as shown in Figure 3.Parallel misalignment results in two hits per rotation; and, therefore a 2× rpm vibration in the radial direction. Parallel misalignment has similar vibration symptoms compared to angular misalignment, but shows high radial vibration that approaches a 180° phase difference across the coupling. As before, a pure parallel misalignment is rare and is commonly observed to be in conjunction with angular misalignment. Thus, both the 1× and 2× peaks will typically be observed. When the parallel misalignment is predominant, 2× is often larger than 1×, but its amplitude relative to 1× may often be dictated by the coupling type. When either angular or parallel misalignment becomes severe, it can generate high amplitude peaks at much higher harmonics (3× to 8×) or even a whole series of high frequency harmonics.

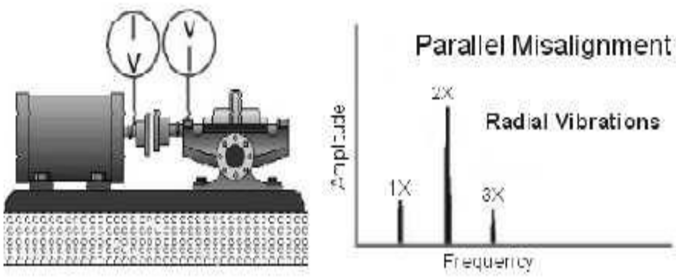


Fig-3

4- SIGNIFICANCE OF VIBRATION FREQUENCY

To illustrate the importance of vibration frequency, assume that a machine, consisting of a fan operating at 2400 RPM and belt driven by a motor operating at 3600 RPM, is vibrating excessively at a measured frequency of 2400 CPM (1 x fan RPM), this clearly indicates that the fan is the source of the vibration and not the motor or belts. Knowing this simple fact has eliminated literally hundreds of other possible causes of vibration.

Typical 1 x RPM vibration can be attributed to:
Unbalance
Eccentric Pulley
Misalignment
Bent shaft
Looseness
Distortion - soft feet or piping strain
Bad Belts - if belt RPM
Resonance
Reciprocating forces
Electrical problems

Determining that the frequency of excessive vibration is 2400 CPM (1 x fan RPM) has reduced the number of possible causes from literally hundreds to only ten (10) possible causes. A little common sense can reduce this number of possible causes even further. First, since the vibration frequency is not related to the rotating speed (RPM) of the drive belts, belt problems can be eliminated as a possible cause. Secondly, since this is not a reciprocating machine such as reciprocating compressor or engine, the possibility of reciprocating forces can be eliminated from the remaining list. Finally, since the frequency is not related to the drive motor in any way, the possibility of electrical problems can be eliminated. Now, the number of possible causes of excessive vibration has been reduced to only seven (7) by simply knowing that the vibration frequency is 1 x RPM of the fan. Vibration analysis is truly a process of elimination. Additional tests and measurements can be taken to further reduce the number of possible causes of a vibration problem. However, it should be obvious that knowing the frequency of vibration and how the frequency relates to the rotating speed of the machine components is truly the first step in the analysis process. Of course, not all machinery problems will generate vibration at a frequency equal to the rotating speed (1x RPM) of the machine. Some problems such as looseness, misalignment, resonance and reciprocating forces can often generate vibration at frequencies of 2x, 3x and sometimes higher multiples of RPM.

5-OBSERVATIONS

Experimental rig is shown in figure 4. Initially Observations are taken in normal conditions and Final observations are taken after introducing unbalance on fan of a centrifugal pump.

Experimental set up includes
Make-Crompton greaves
Self priming moonset pump (Made in India)
Kw/hp-0.37/0.5
Voltage-220±6%
Speed-2780 rpm
Current-2.8 amp
Capacitor-10μF,440V
Type-Mini win-Π
Size-25x25 mm
Duty-S1
Head-6/28.5m
Discharge-2600/570 lph
1 phase-AC-50HZ
Insulation B class
Specifications of pressure gauges
Vacuum gauge-0 – 760 mm of hg
Delivery gauge-0-7 kg/cm²
Temperature-0-150 degree centigrade
Collection of water is measured by beaker of capacity 2000ml.
Time is taken by stop watch
Initial observations
Temperature of water= 29.5 degree centigrade

Table-1

S.NO.	RPM	SUCTION PR. in mm of hg	DELIVERY PR. in kg/cm²	DISCHARGE	DISCHARGE PER minute
1	2818	130 mm of hg	1.6	7.2 ltr in 14.47 seconds	29.85 ltr
2	2815	130 mm of hg	1.6	7.14 ltr in 14.41 seconds	29.72 ltr

Average of 29.85 and 29.72 comes 29.785 ltr per minute
Discharge per hour will be 29.785x60=1787.10 ltr.

Fig-4 on previous page (7) shows experimental rig.

Fig-5 (unbalance weight on fan of pump)

Observation after introducing unbalanced mass on fan side of centrifugal pump

S. NO	RPM	UNBALANCED MASS	SUCTION PR. IN mm of hg	DELIVERY PR. IN kg/cm²	DISCHARGE	DISCHARGE PER minute
1	2822	5 gm	130	1.5	7.040 ltr in 14.31 seconds	29.51 ltr
2	2815	10 gm	130	1.5	6.915 ltr in 14.41 seconds	28.79 ltr
3	2818	20 gm	130	1.5	6870 ltr in14.56 seconds	28.31 ltr

Discharge in first case (5 gm unbalance)=29.51x60=1770.6 ltr per hour
Distance of unbalanced weight from centre of pump=5.2 cm
(Unbalance in gm cm=26)
Discharge in second case (10 gm unbalance)=28.79x60=1727.4 ltr per hour
(Unbalance in gm cm=52)
Discharge in third case (20 gm unbalance)=x60=1698.6 ltr per hour
(Unbalance in gm cm=104)

6-CONCLUSION AND FUTURE SCOPE

Hydraulic power is proportional to multiplication of discharge and head, it means if by introducing unbalance on the machine any of these parameters increases by any no of times, power will also be decreased by that no of times.

P α Q H
P=POWER
Q=DISCHARGE
H=HEAD

It is clear that after introducing unbalance there is almost negligible effect on suction and delivery pressure heads but Effect on discharge is quite significant. Actual discharge of pump is 1787 ltr per hour. After introducing unbalance there is a considerable reduction in Discharge and in case of 20 gm unbalance it comes 1698 ltr per hour. It means discharge is reduced by 90 ltr in one hour which is a quite significant. It clearly shows power of pump will be reduced by 5%.

5.1 Future scope*:*

Everything that rotates needs to be in a state of balance to ensure smooth running when in operation. Precision balancing is essential to the manufacture of rotating equipment and to the repair and renovation of installed machines. As machine speeds increase, the effects of unbalance become more detrimental. Modern technology allows for accurate balancing to be performed both in the field and in the workshop. Further area of this study can be extended for analyzing the effect of unbalances on several types of hydraulic machines of different nature such as machines of different application in hydro power generation and rotating parts as mixer, grinder, axles in automobile etc. It will also be immensely helpful in the areas of increasing life of critical machines such as power generation machines (turbine and other moving parts), dental drills, hydro machines, turbo chargers etc. Sometimes these analysis are also providing important tips for changing the design Of specific machine.(such as changing the bearing position inside the housing) to minimize the effect of unbalance. Now it can be understood by this analysis that there is a significant impact of unbalance on performance of a hydraulic machines(pump) so sometimes it is essential to equip/modify design in such a way so that better performance can be achieved by keeping minimum unbalance.(with in lesser quality grade)

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