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Experimental Study of Unbalance in Shaft Rotor System Using Vibration Signature Analysis

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ABSTRACT

Rotor unbalance and shaft misalignment are major concerns in rotating machinery. In order to understand the dynamic characteristics of these machinery faults a model of complete motor flexible coupling rotor system capable of describing these failures was developed. Unbalance is the most cause of machine vibration, an unbalanced rotor always cause more vibration and generates excessive force in the bearing area and reduces the life of the machine. Experimental studies were performed on a rotor to predict the unbalance in rotor. The vibrations were measured at different speeds using FFT [Fast Fourier Transform], detection of the various effects of vibration signature such as unbalance, misalignment, and crack that may lead to downtime. Vibration analysis therefore helps in monitoring the health of a rotating component. Vibration signature also helps to alert equipment operators of engine health condition. It could be useful to prevent the breakdown [resonance].

Keywords: Rotor, Unbalance, Vibration, FFT.

INTRODUCTION

Rotating machinery is a basic part in any industry. In real systems, faults are unavoidable due to the errors in manufacturing; Faults may develop in the system due to the operating conditions such as heat generation, looseness, wear, etc. Failure of the rotor system has safety implications along with economical considerations. Hence, rotating machinery needs to be monitored continuously for the faults. Greatest challenge in the area of condition monitoring is the diagnosis of a fault before it becomes critical.

Unbalance: Unequal distribution of mass in a rotating member is the cause of unbalance which leads to centrifugal forces in radial direction. Unbalance system, there are many disadvantages of unbalance system When a system is rotating due to unbalanced mass unnecessary vibration occurs, further it may generate unwanted noise, excessive stress in machine elements and reduce the reliability of rotating parts, also high bearing thrust generated, this may cause failure in the bearing system within short period.

Balancing: The technique of correcting or eliminating unwanted inertia forces and moments is called as balancing. Balancing simply involves moving the centre of gravity to the centre of rotation. Everything in balancing is related to the rotating mass, its radius, its speed & resulting energy content. Rotating components such as wheels, flywheels, fans, motors, turbines, etc. also need to be balanced. In similar way reciprocating components such as I.C. Engine, Compressors etc need to be balancing.

Unbalance & Vibration: Unbalance occurs in the rotating machine when the mass centerline & the geometric center do not coincide on each other. Unbalanced rotor generates vibration which may damage their components. In order to extend the life of machine, vibration due to unbalance must be reduced to acceptable level. Despite the ability to reduce the unbalance to low levels, these levels or limits must be defined.

Unbalance amount is expressed as:

$U=m*r$

Where,

m=unbalance mass (in kg)

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r= distance from unbalance mass to shaft or rotor center line (in m)

The unbalance force generating the vibration is expressed as:

$F= m*r*\omega^2$

Where, F= force (N)

m= mass (kg)

r= radius (m)

ω= speed (radian/sec)

Unbalance vibration = Unbalance force / Dynamic stiffness.

METHODOLOGY

1. Study of the definition, function, background and areas of rotor unbalance
2. Study of the detailed review in previous work
3. Design & development of experimental setup
4. Tests run on model using FFT analyzer
5. Conclusion

EXPERIMENTAL SETUP

Description of Experimental Set up: Experimental set up is as shown in following figure. It consists of a 1 H.P. 3 phase A.C. induction motor used to drive the MS rotor mounted on the middle of the shaft having 40 mm diameter with the help of fixed flange coupling. VFD (Variable Frequency Drive) is used to control the speed of motor from 0 to 2800 rpm for variable speed.

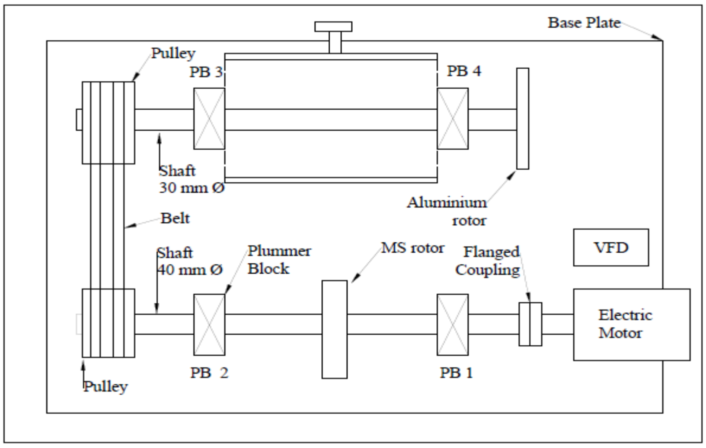


Figure1. *Line diagram, top view of experimental setup*

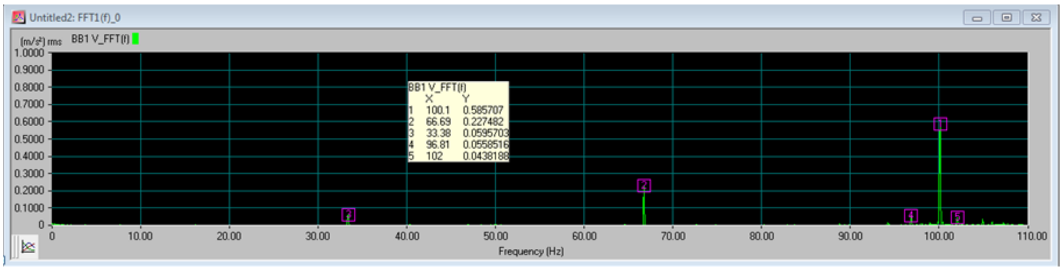
A fixed flange coupling size of 5 inch is used to connect the motor drive end to the MS rotor shaft and two Plummer blocks (PB 1 & PB 2) for shaft having 40 mm diameter & two Plummer blocks (PB 3 & PB 4) for shaft having 30 mm diameter to support and guide the rotating shaft. MS rotor having outer diameter of 212 mm, inner diameter of 40 mm and thickness is 16.5 mm & aluminum rotor having outer diameter of 200 mm, inner diameter of 28 mm and thickness is12 mm which is located at the end of the shaft having 30 mm diameter. MS plate size of 800 mm length, 700 mm width & 12 mm thickness used as a base plate for all equipments of set up are fixed. First Shaft connected to coupling is of 40 mm diameter & 450 mm in length and Second Shaft is of 30 mm diameter and 550 mm length linked to first shaft with the help of V pulley by belt drive. Small pulley of 90 mm outer diameter & 35 mm width is located at the end of 40 mm diameter shaft and the larger pulley of 180 mm diameter & 35 mm width is located on 30 mm diameter end of the shaft. The instrument used for measuring vibrations in terms of acceleration is FFT.

Figure2. *Photograph of experimental setup*

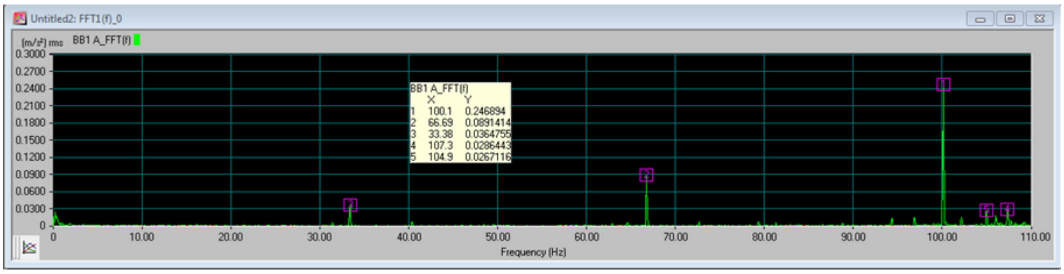
Experimental Procedure: Experimental set up of line diagram and photographs are shown in above figures. This set up is used for measuring vibrations in terms of acceleration. Vibration signals at Plummer block no. 1 & 2 were measured by FFT with the help of uniaccelerometer at vertical, axial and horizontal location. In shaft rotor system rpm at 500, 1000, 1500 and 2000 of different speeds for 1X frequency in balanced and unbalanced condition readings were taken by FFT. In which unbalance is created by unbalance mass of 34 gram is used. FFT Instrument with software used in this system is of Bruel & Kjaer with RT Pro Photon Plus.

Experimental Observations:

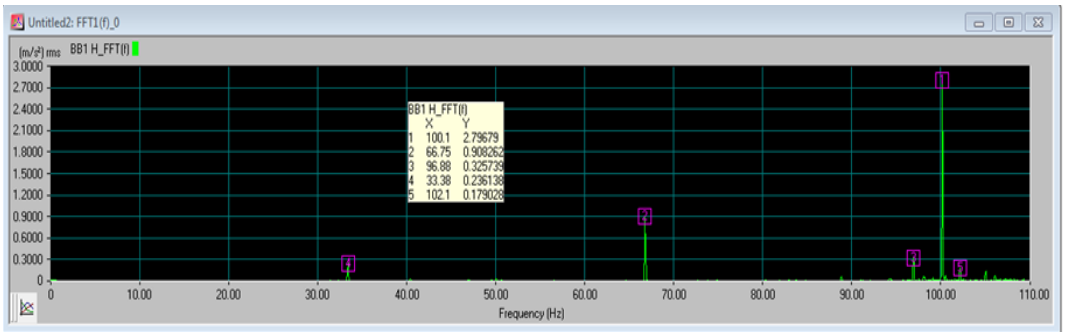
Balanced Spectrum at 2000 RPM Speed for Different Location at Plummer Block No. 1



Spectrum at Plummer block no.1 balanced 2000 rpm Vertical

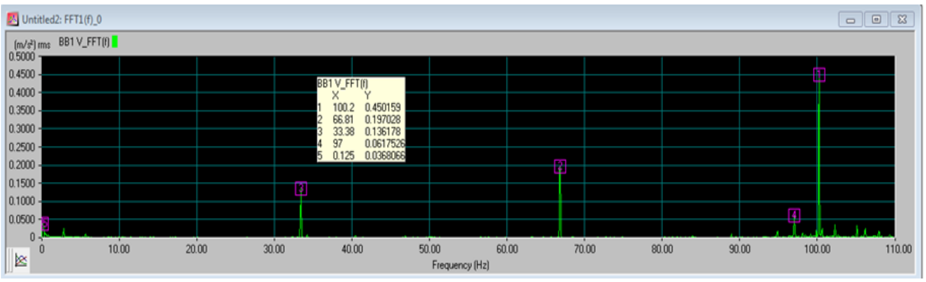


Spectrum at Plummer block no.1 balanced 2000 rpm Axial

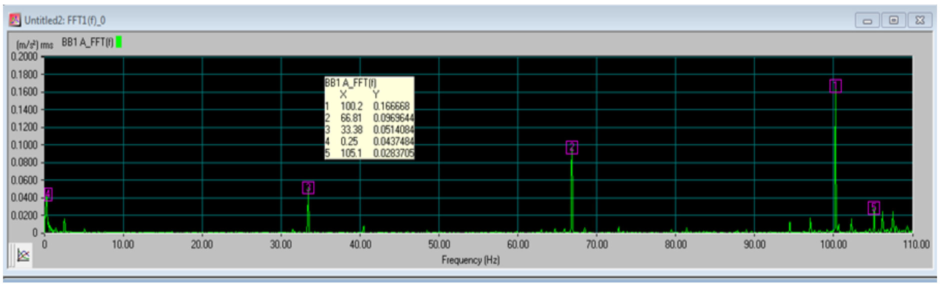


Spectrum at Plummer block no.1 balanced 2000 rpm Horizontal

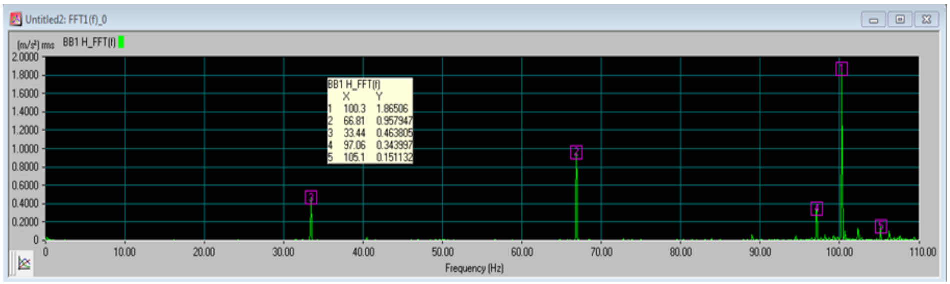
Unbalanced Spectrum at 2000 RPM Speed for Different Location at Plummer Block No. 1



Spectrum at Plummer block no.1 unbalanced 2000 rpm Vertical



Spectrum at Plummer block no.1 unbalanced 2000 rpm Axial



Spectrum at Plummer block no.1 unbalanced 2000 rpm Horizontal

RESULTS & DISCUSSION

Vibration Readings at Plummer Block No. 1 Balanced and Unbalanced Conditions

Table1. *Comparison of Vibration Readings at Plummer Block No.1*

Speed of MS rotor in rpm	Acceleration in m/s^2 at Balanced Condition			Acceleration in m/s^2 at Unbalanced Condition		
	Vertical	Axial	Horizontal	Vertical	Axial	Horizontal
500	0.0076	0.0024	0.0241	0.0063	0.0023	0.028
1000	0.0255	0.0106	0.097	0.0241	0.0072	0.102
1500	0.042	0.019	0.192	0.0631	0.022	0.2065
2000	0.059	0.036	0.236	0.1361	0.0514	0.4638

Comparison Graphs of Acceleration in m/s^2 Verses Speed in RPM at Plummer Block No. 1 Balanced and Unbalanced Conditions for Vertical, Axial & Horizontal Accelerometer Position:

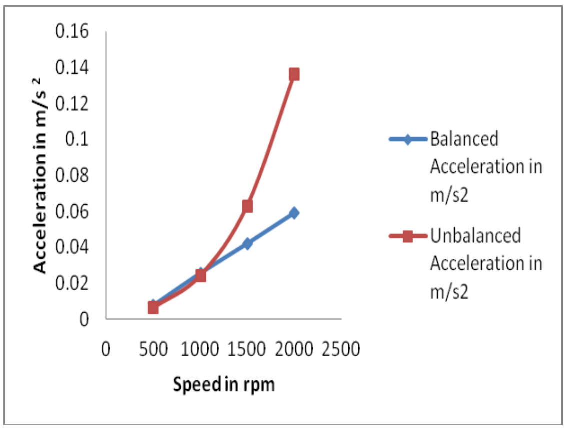


Figure3. *Graph for comparison of balanced & unbalanced vertical position*

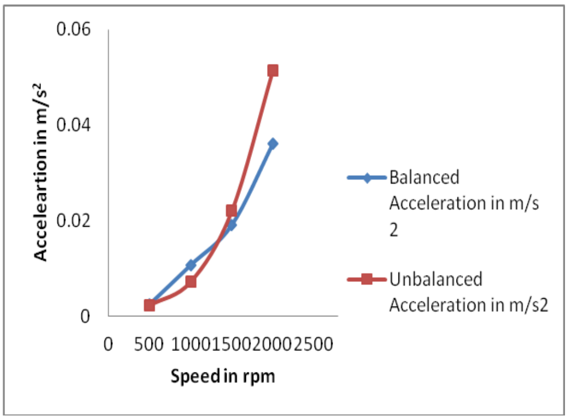


Figure4. *Graph for comparison of balanced & unbalanced axial position*

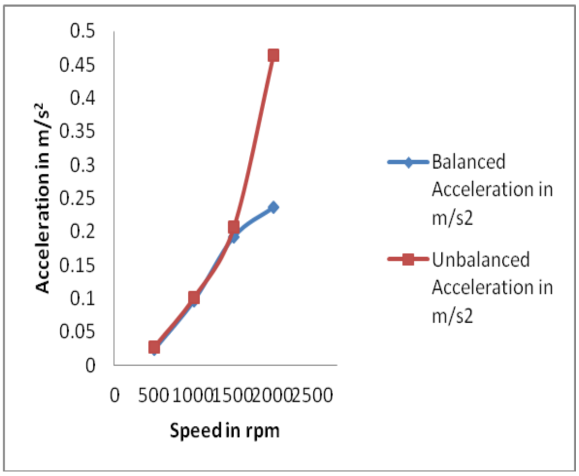


Figure5. *Graph for comparison of balanced & unbalanced horizontal position*

Vibration Readings at Plummer Block No. 2 Balanced and Unbalanced Conditions

Table2. *Comparison of Vibration Readings at Plummer Block No.2*

Speed of rotor in rpm	Acceleration in m/s^2 at Balanced Condition			Acceleration in m/s^2 at Unbalanced Condition		
	Vertical	Axial	Horizontal	Vertical	Axial	Horizontal
500	0.003	0.0093	0.0138	0.003	0.0081	0.016
1000	0.0105	0.0469	0.059	0.0087	0.031	0.102
1500	0.02	0.13	0.142	0.0292	0.1021	0.151
2000	0.034	0.397	0.213	0.0644	0.2802	0.387

Comparison Graphs of Acceleration in m/s^2 Verses Speed in RPM at Plummer Block No. 2 Balanced and Unbalanced Conditions for Vertical, Axial & Horizontal Accelerometer Position:

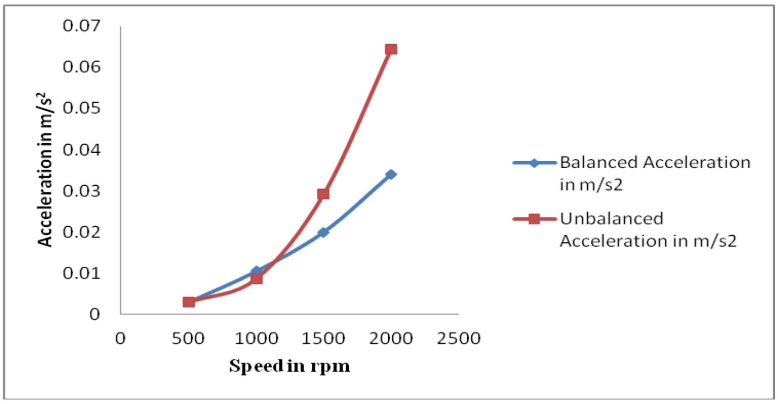


Figure6. *Graph for comparison of balanced & unbalanced vertical position*

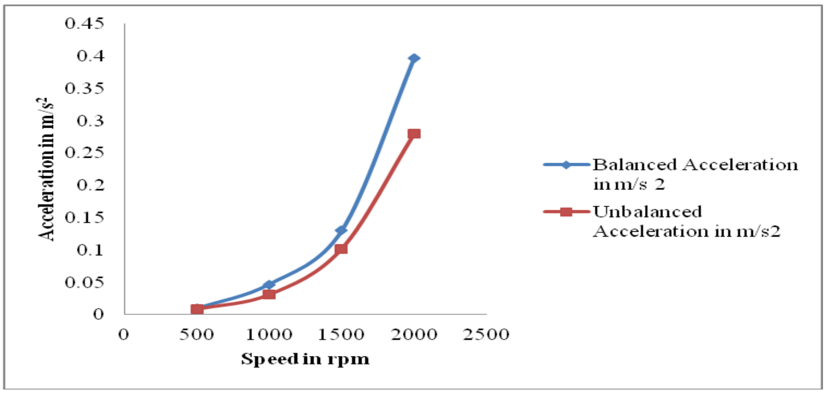


Figure7. *Graph for comparison of balanced & unbalanced axial position*

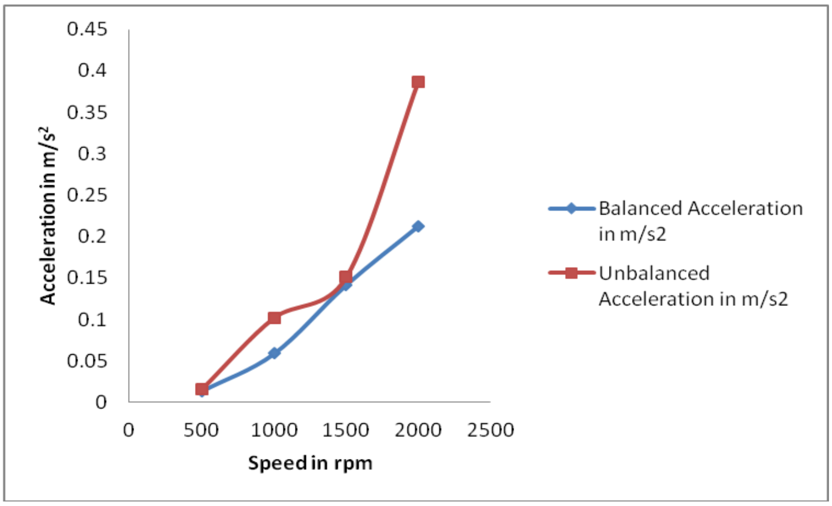


Figure8. *Graph for comparison of balanced & unbalanced horizontal position*

CONCLUSION

As the speed increases the amplitude at 1X is also increases. This increase in amplitude value is because of increase of centrifugal force. Here we found that at Plummer block no.2 (near to pulley) in axial direction the acceleration value is more in balanced condition rather than unbalanced condition. An important thing we found here is that the highest value of overall RMS accelerations for vibration is higher in horizontal direction of Plummer block no.1(near to motor) than Plummer block no.2 (near to pulley). Some of spectrums for different locations at 2000 rpm are shown in experimental observations in this paper, like that all experimentation was carried out for the remaining speeds shown in table 1 & table 2. As amplitude increases with speed an unbalance force is also increases at horizontal direction of Plummer block that may cause a breakdown of bearing of the rotor system in future. Therefore vibration analysis helps in monitoring the health of a rotating component. Vibration signature also helps to alert equipment operators of engine health condition. It could be useful to prevent the breakdown [resonance]

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