International Journal of Modern Engineering Research (IJMER)
www.ijmer.com Vol.2, Issue.6, Nov-Dec. 2012 pp-4026-4029 ISSN: 2249-6645

Bearing Life Improvement of Centrifugal Blowers by Vibration Analysis

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Abstract: *This study work is proposed to carry out vibration analysis of heavy duty centrifugal Blowers & bearing failure analysis. The life of bearing can be improved by carrying corrective actions on blower & modifying its accessories like Plumber block to prevent bearing failure. The proposed work is planned in following phases Preparation of measuring instrument for data collection (PRUFTECK VIBROEXPERT METER) Collection of data from various locations on blower surfaces in different directions. Data analysis is done on the basis of spectral plot, amplitude against frequencies with the help of prufteck vibroexpert meter. In comparison of vibration spectral with experimental actions are carried out under the vibration severity standard, the chart results of rectification will be compared with spectral plot & corrective action. The results will be compared with initial condition & condition monitoring schedule is prepared for avoiding premature failure of equipment.*
Standard schedule for maintaining basic condition of variables of equipment like as CBM /TBM will be planned to avoid premature failure of the bearing.

Index Terms*: Blower Vibration Data Collection, Spectral plot analysis, analysis of bearing structure, Corrective actions on equipment,, Comparison of results & Standardize the method*

I. INTRODUCTION

The Report Contents
1] Blower readings with Vibro-meter
2] Blower problem Diagnosis
3] Bearing & Plumber block analysis
4] Bearing failure analysis
5] Bearing with Wavy leaf spring analysis

Scope: This Report contains fault diagnosis with the analysis and recommendations for corrective actions. These all are supported by spectrum plots for each point of the equipment identified as being deviated. A color coding system is employed, as per ISO standard which make it easy to understand the criticality of the fault and how quickly it needs to be investigated & rectified.

Measurement: An overall vibration reading of displacement & velocity are measured in micron & mm/sec respectively, A RMS values are used to determine general mechanical and electrical fault within rotating machinery.

Equipment Used: PRUFTECHNIK VIBXPERT DUAL CHANNEL ANALYZER

Fig-1.Structure of Centrifugal Blower

II. BLOWER STRUCTURAL ANALYSIS

Machine vibration has several categories of causes that we have discovered after so many repairs, but it is useful now to review them to gain more confidence in the diagnosis. The actual structure of blower shown in Fig 1.

The Major categories of diagnoses are –
- Design defects
- Manufacturing defects
- Operational stresses
- Maintenance actions
- Aging

Design defects are mostly structural related with active resonances built-in because of improper sizing and proportioning of the parts statically, the structure seems good, but it remains dynamically weak. This is not discovered until the machine is energized and brought up to the required speed. This is more common than it should be, but the designers are not well equipped to predict or test for natural frequencies. In addition, the owners' foundation or base has a significant effect on natural frequencies, which the designer has little control over. Hence, resonances are best detected during startup testing and corrected on-site with strategic stiffeners added. Manufacturing defects are built-in during the casting, machining, heat-treating, and assembly processes. They are latent defects that may show up in the first 24-hours of running, or they may not be obvious during the run-in period, appearing years later. The machine does not survive to a normal life expectancy as vibration may or may not be present.

An example is residual stresses in a shaft that gradually distorts the shaft over a period of years. Manufacturing defects are difficult to control, impossible to predict, and elusive to fix. The best strategy to deal with both design defects and manufacturing defects is to insist on start up vibration testing with limits of acceptability in accordance.

Here in Table1 we have tabulated velocity & shock pulse readings on plumber block at drive end & non drive end in axial, horizontal & vertical direction at threshold .The Colour coding is used to classify vibration severity as per ISO 10816, as good, satisfactory, unsatisfactory & unacceptable from green to red mark indicates alarming zone. This experiment conducted on 110 Kw capacity blowers with Prufteck Vibroexpert Meter.

Table1.Velocity & shock pulse reading with alarm code

BAJAJ AUTO LIMITED / CHAKKAN PAINT SHOP / PETROL TANK LINE- PRIMER COAT EXHAUST FAN / FAN:

Measpoint	Task	Value	Unit	Threshold	Level +1	Class	Code	%
Non Drive Horizontal	101 Overall velocity >600 (rms)	3.08	mm/s	2.30	4.50		P	34
	106 Shock pulse m. >120 (dBm)	17	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	6	dBsv		10		N	
Non Drive Vertical	101 Overall velocity >600 (rms)	2.70	mm/s	2.30	4.50		P	17
	106 Shock pulse m. >120 (dBm)	22	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	12	dBsv	10	15		W	19
Non Drive Axial	101 Overall velocity >600 (rms)	7.17	mm/s	7.10	-		A	1
	106 Shock pulse m. >120 (dBm)	14	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	6	dBsv		10		N	
Drive Horizontal	101 Overall velocity >600 (rms)	3.94	mm/s	2.30	4.50		P	71
	106 Shock pulse m. >120 (dBm)	9	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	-3	dBsv		10		N	
Drive Vertical	101 Overall velocity >600 (rms)	3.42	mm/s	2.30	4.50		P	49
	106 Shock pulse m. >120 (dBm)	18	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	8	dBsv		10		N	
Drive Axial	101 Overall velocity >600 (rms)	7.27	mm/s	7.10	-		A	2
	106 Shock pulse m. >120 (dBm)	17	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	8	dBsv		10		N	

BAJAJ AUTO LIMITED / CHAKKAN PAINT SHOP / PETROL TANK LINE- PRIMER COAT EXHAUST FAN / MOTOR:

Measpoint	Task	Value	Unit	Threshold	Level +1	Class	Code	%
Drive Horizontal	101 Overall velocity >600 (rms)	1.99	mm/s		2.30		N	
	106 Shock pulse m. >120 (dBm)	10	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	1	dBsv		10		N	
Drive Vertical	101 Overall velocity >600 (rms)	4.78	mm/s	4.50	7.10		W	6
	106 Shock pulse m. >120 (dBm)	15	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	5	dBsv		10		N	
Drive Axial	101 Overall velocity >600 (rms)	5.32	mm/s	4.50	7.10		W	18
	106 Shock pulse m. >120 (dBm)	16	dBsv		25		N	
	106 Shock pulse m. >120 (dBc)	7	dBsv		10		N	

The analysis of the data indicates that the excessive operational stresses on blower are developed due to material buildup or erosion, which changes the balance condition, or thermal expansion that changes component alignment. Both of these cause high dynamic loads at the bearings which lead to accelerated wear out. These defects are easily detected with periodic vibration measurements and there are well established methods to correct them on site. Our maintenance actions, or interactions, are the most common cause of blower failure. It is well known in the repair business that a blower machine never goes back together the same way. Some of this is due to rough handling, but some is simply the fact that field repair is less controlled than the original factory build. The field environment is darker, dirtier, and less precise tooling is available to control fits and alignments. The repair is usually rushed by management. It is surprisingly difficult to install a bearing into aluminium housing in the field and not get it crooked. The first question to ask in vibration analysis is "What recent maintenance activity has occurred on this machine?" other maintenance activities that affect on blower vibration are-

- Excessive localized heating, like welding on a shaft
- Too high belt tension
- Shaft, or bearing, misalignment
- Substandard replacement parts
- Coupling, or other component, binding
- Lack of lubrication
- Loose hardware
- Replacing hardware with different weights that Affects on balance
- Re-assembling hardware in different orientations (also affect on balance)
- Hammering on a bearing
- Unclean, or burred, precision machine surfaces

Aging effects are only be detected with long term vibration monitoring. The two dominant aging effects are residual stress relaxation and softening of structural joints. The residual stresses left behind in machine components are always relieve themselves over time. This process is accelerated at higher temperature of shaft, being long and slender component, are particularly vulnerable to bowing. The symptoms are an increase in 1x RPM balance condition and beating up of the bearings. Bearing replacements do not restore the original smooth running condition, and mass balancing is unsuccessful, until the shaft is replaced.

All joints soften over time, and joints are the weak links in any structure. These are the prominent symptom of lowering of the natural frequencies of the machine. This has usually first detected with high vibration when the lowest natural frequency drops down into the operating speed range of the machine.

III. BALANCING & ALIGNING METHOD

This is well known that blower vibration related problems are corrected in place. The corrective methods are well experienced undergoing the trouble shooting of the blower problem in depth. These are listed here to close this discussion.

- Disassembly, visual inspection, cleaning, and re-assembly fix some elusive problems without knowing
- Bearing replacement
- Identifying other bad parts and replacing them
- Mass balancing
- Alignment
- Lubrication is just greasing noisy bearings to Quiet them, but changing the lubrication schedule Extent their lives
- Structural stiffening to raise natural frequencies.
- Mass loading and stiffening reduces any Measured vibration

If blower has lower motion, it may increase local stresses at the bearings resulting in faster bearing wear. This is to be used only as a last resort when nothing else works and measured motion must be lowered.

The Fig-2 gives the velocity (mm/sec) trend of 110kw blower from Dec-2007 to June-2012 with alarming zone

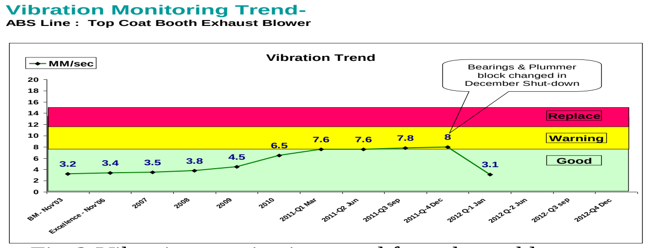

Fig-2.Vibration monitoring trend for exhaust blower 110 Kw capacities

Finally, a few blowers are still generating excessive vibration, the cause has not been discovered nor corrected, and they have not shaken themselves apart yet. Some blowers are just rough characters and it is neither necessary nor desirable to retrain them. As long as the vibration amplitude remains stable, it is safe to continue to operate at elevated levels, thus avoiding repair cost and downtime. Regular vibration monitoring has allowed machines to operate longer into the wear out cycle without fear of failure.

IV. FFT SPECTRUM

The prufteck vibroexpert meter is the simplest, and least expensive, is an overall meter. It provides not only frequency information, but also overall amplitudes for the analysis of data. It is useful for trending or comparison measurements on similar machines, but for diagnosing problems on machines, it is best left turned off. The other two major vibration instruments are tuneable filters and FFT (Fast Fourier Transform) analyzers. Analyzer is a misnomer because analysis is a human function. An electronic "analyzer" does not analyze. It only measures and display electrical signals. The electrical signals from accelerometers and velocity transducers are very small AC voltages, typically millivolts. Hence, the tuneable filters and FFT instruments are nothing more than fancy AC voltmeters with a frequency display axis. Any of these two major vibration measuring instruments, from any manufacturer, can be used effectively to diagnose machine vibrations. No specific instrument or manufacturer has a unique connection to a higher intelligence. As it's FFT spectrum is shown in Fig-3

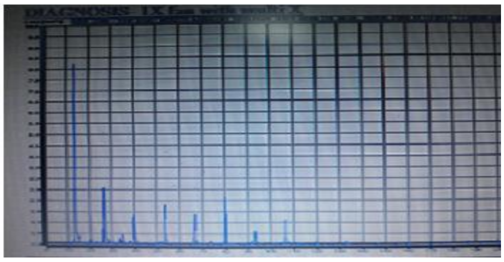

Fig- 3.FFT Spectrum for blower vibration

However, some are an order of magnitude or two more complicated to use by design. The instrument in use is the least significant factor in diagnosis. The instrument operator and the methods employed are the most significant.

The fundamental method of using a vibration instrument is to conduct a survey of the entire blower system; driver, driven, and any intermediary machines such as gearboxes & pulleys of belt drive.

Fig- 4.Frequency verses time graph for exhaust Blower 110 Kw capacity

The spectrum shown in Fig-4 implies that the displacement varies with outer race wear in Axial, vertical, horizontal direction as rotor moves under centrifugal forces. Which lifts the shaft from impeller side causes reducing amplitude the displacement for non drive end to drive end.

The velocity of vibration depends upon the shaft speed, type of bearing, type of drive supporting distance of the shaft within the bearing & cantilever of the shaft along with the pulley end. The bearing condition can be detected by vibrating parameters trend and the life of bearing can be increased by taking corrective action to prevent extreme condition of the equipment. The bearing & shaft assembly is shown in Fig-5

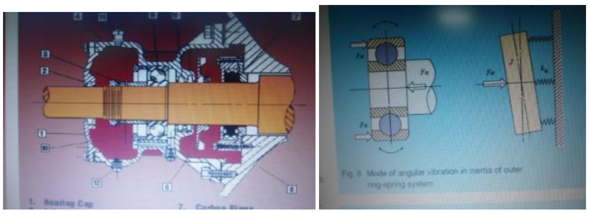

Fig- 5. Bearing assembly & Bearing load of exhaust Blower

4. MATHS & EQUATIONS

1] Ball Pass Frequency for the outer race

=No of Roller x Shaft Speed x 0.4

2] Ball Pass Frequency for the inner race

=No of rollers x Shaft Speed x 0.6

3] Ball pass frequency train race

= Shaft Speed X 0.3

4] Bearing life in Revolutions

$L = (C/W)^{(10/3)} \times 10^6$

C= Basic Load Carrying Capacity

C= W (L/100)

L= 60 X N X LH, Where LH in Hours

W= Equivalent Dynamic Load

L= Life in Revolutions

5] Heat calculation

a) Heat generated due to friction

$Q_g = \mu . W . V$ Watt

μ= Coefficient of friction

W= Load on bearing in N=P x A

V= Speed of journal in RPM

b) Heat dissipated.

$Q_d = C . A (T_b - T_a)$ in Watt

C= Heat dissipation coefficient

A= Projected area of bearing in m2

T_b= Temperature of bearing surface °C

T_a= Temperature of surrounding air °C

$T_b - T_a = 1/2 (T_o - T_a)$

c) Heat conveyed by the oil

$Q_t = M . S . T$ in Watt

M= Mass of oil

S= Specific heat of oil 1840-2100 J/kg°c

T=Temperature difference between outlet & inlet

6] Grease quantity inside bearing

Gg= 0.005 X D X B

Gg=Gram of grease

D=Bearing dia in mm

B= Bearing width

7] Coefficient of friction for bearing is expressed as

μ=Ǿ [ZN/P, d /c, l/d

$\mu = 33/10^8 [ZN/P][d/c]+k$

μ= Coefficient of friction

Ǿ=Functional relationship

Z=Absolute viscosity of lubricant in kg/m-s

N=Speed of journal in RPM

P=Bearing pressure=load/area

d=Diameter of journal

l=Length of bearing

c=Diameteral clearance

k=Factor of correction for end leakage

ZN/P=Bearing characteristic number, dimensionless number, helps to predict bearing performance called Bearing modulus

V. BEARING FAILURE ANALYSIS

The dampening of the bearing inside the plumber block can be absorbed by providing Wavy leaf spring of adequate stiffness which can prevent the transmission of vibrating wave from inner race to outer race through roller by sharing the load as shown in Fig-6. Which minimize the shock impulse influence directly on bearing & plumber block cause the life improvement for certain hour.

A step change in amplitude is symptomatic of an unstable bearing. Examination of the bearings and their supports is in order as soon as practical. A drop in frequency is bad news. It indicates structural softening such as cracks or joint loosening. Slow changes in amplitude from cold to hot running conditions are related to alignment of the shafts.

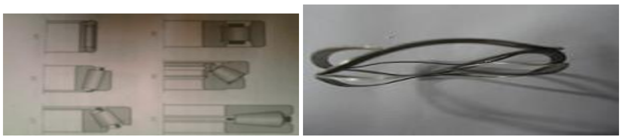

Fig- 6.Bearing with Roller condition & wavy leaf spring

A fourth judgement criterion is operational condition. The load level has a dramatic effect on vibration levels, especially electrical machines such as generators. It is usually assumed in analysis that the machine has no operational problem.

The taper roller bearings are used for heavy duty centrifugal blower mounted with on sleeve with lock nut & washer inside plumber block. Taper roller bearings are designed for carrying radial load. This bearing are specified with 5 digit number as 32224 K C3,32226 K C3 ,K suffix is attached for taper roller bearing only & C3 is attached for bearing clearance, as bearing clearance varies from C1 to C5 for high temperature & high RPM. Material used for taper roller bearing are babbit metal, branze, cast iron & silver.

Bearing clearance is provided for the purpose of adjust thermal expansion, deflection of rollers & provide film thickness in lubrication. This clearance is kept 90 to 120 µm before mounting & expected to reduce by 30 % in assembly, if it increases than this the bearing is to be replaced.

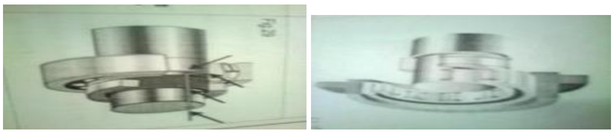

Fig-7.Assembly of taper roller bearing on shaft sleeve With lock nut

The bearing manufacturers are SKF, NTP, FAG & KEYDON. The duplicity in the bearing are easily identified by its finishing standard & clearance value. The clearance is measured with filler gauge & dial gauge, if measured closer to the bearing assembly with dial gauge. Bearing assembly with shaft sleeve & lock nut is shown in Fig-7

The taper roller bearings for heavy duty blowers are fitted by heating the oil upto120°C with induction coil or flame. Lubrication life of this bearing is depend on load, RPM, bearing ID/OD, Width,& bearing mounting method is expressed in equation 6.

These sliding contact bearing should have following properties

1] Compressive & fatigue strength
2] Confirmability
3] Embeddability
4] Bondability
5] Corrosion resistance
6] Higher thermal conductivity & lower expansion

The bearing failure analysis requires following information as

1] Date of mounting & type of bearing
2] Load type, temperature & RPM
3] M/c & bearing surrounding
4] M/c precision/accuracy
5] Frequency of failure
6] Total hours of working
7] Lubrication standard & frequency
8] Condition of bearing & lubricant after removal

VI. CONCLUSION

The vibration analysis of the heavy duty centrifugal blower gives the results as

The bearing life the rotating parts depends upon

1] The bearing characteristic number, ZN/P
2] Running condition-Temperature & RPM under Which the machine runs
3] Bearing load condition as static & dynamic load Carrying capacity
4] Clearance between roller & outer race
5] Heat dissipation capacity of the plumber block & Other accessories
6] Lubrication frequency & standard of lubricant

Generally the vibration parameters as displacement & velocity are depends upon the bearing wear of outer race because of roller hits on surface of the race at high temperature

VII. ACKNOWLEDGEMENT

The author would like to thanks the Institution of Engineers (India) for permission to publish the paper. The author gratefully thanks to Bajaj Auto Ltd, Pune to provide platform for the experiment & Dr.D.Y.Patil College of Engineering, Pune for inspiring the subject choosen.

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BIOGRAPHIES

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