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Measurement and Analysis of Vibrations in Taper Roller Bearing

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ABSTRACT

Vibration produced by taper roller bearings (TRB) can be complex and can result from various geometrical imperfections during the manufacturing processes, defects on the rolling surfaces or geometrical errors in associated components. For bearing manufacturing companies, vibration analysis is the necessary part of quality Control and predictive Maintenance. Vibration testing is prime test for acceptance or rejection of bearings. This paper attempt to show how vibrations are measured &analysed further to show the defect in various components of taper roller bearing which is used for acceptance test of bearing at manufacturing stage. For testing the noise development, the inner ring of the cone being rotated. The produced roll-off roller noise between inner and outer ring is being registered by a noise pick up (MEA 106) and evaluated through Rotas-TMO vibration analyser by DISCOM. The measuring facility comprises of pressure unit with measuring bell and outer ring, bearing lowering facility, spindle with measuring arbor & noise pick up. The spindle is hydrodynamic spindle. The vibrations measured can be analysed further to detect various defects like roller hit mark, roller waviness, IR waviness, IR hit mark etc.

Keywords— Noise pick up, Rotas TMO, Taper Roller Bearing, Vibration

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I. INTRODUCTION

Vibration produced by taper roller bearings can be complex and can result from various geometrical imperfections during the manufacturing processes. For bearing manufacturing companies, vibration analysis is the necessary part of quality Control and predictive Maintenance. Vibration testing is prime test for acceptance or rejection of bearings. Tandon and Choudhury [1] presented a detailed review of vibration and acoustic measurement methods for fault detection of rolling bearings. Vibration is measured and it is divided into various parameters to take a decision of acceptance or rejection of a taper roller bearing. The vibration signal is denoised into indicators like crest factor, RMS value, peak value and its effects can be observed [2].Bearing signals are separated from acquired noise and different frequencies are assigned to different components ,also signals are enhanced. Severity and location of fault can be determined[3].Geometrical imperfections will always be present to varying degrees depending on the accuracy class of the bearing. These are induced cause of varying nature of manufacturing processes. Surface roughness, waviness and discrete defects are present in all components of bearings.Dr S.J.Lacey give an overview of bearing vibration analysis [4].The upgraded vibration testing machine focus on testing the taper roller bearing for vibration under specific conditions and sorting the bearings as good and bad. Use of hydrodynamic spindle can reduce the inherent machine vibration which leads to accurate vibration measurement of bearing [5].Machine component and electronic control selected as per the guidelines from quality technology centre of SKF Austria [6].

II. IMPORTANCEAND NEED FOR TESTING OF BEARING

TRBs find widespread domestic and industrial applications. Proper functioning of these appliances depends, to a great extent, on the smooth and quiet running of the bearings. In industrial applications, these bearings are considered as critical mechanical components and a defect in such a bearing, unless detected in time, causes malfunction and may even leadto catastrophic failure of the machinery. Defects in bearings may arise during use or during the manufacturing process. Therefore detection of these defects is important for condition monitoring as well as quality inspection of bearings. The scope of this paper is to upgrade the old traditional tester & to sort the good & bad bearings based on defects that arise during manufacturing.

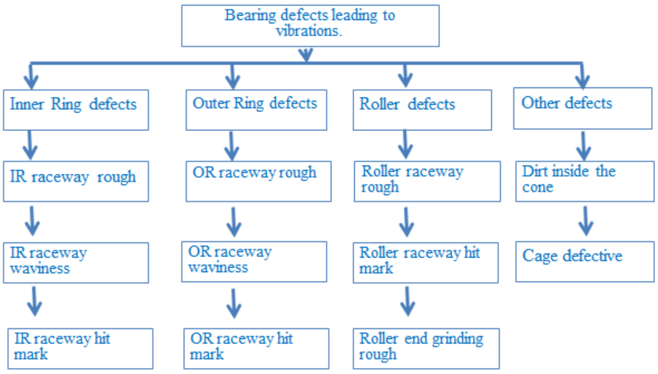
The geometry and surface finish of the roller ends and the area on the flange that makes contact with the roller ends have been optimized to promote and maintain the formation of a lubricant film. This reduces friction and heat generated by the bearing as well as flange wear. The bearings can better maintain preload and run at reduced noise levels.

TRBs are tested thoroughly prior to dispatch. Testing is done to check each factor affecting its performance and service life to have the superior performance and increased service life.

A. Possible Defects In Taper Roller Bearing

The bearings act as a source of noise and vibration due to varying compliance as much as the presence of defects in them, which may be classified into distributed and localized defects. The fact that the load distribution on the bearings varies, as the rolling element set rotates round the rings, causes the bearings to behave themselves as a vibration generator. This behaviour may arise as much as from a geometrically perfect bearing as one which possesses imperfections from manufacture, installation, lubrication or inadequate ambient running conditions or some other factor that may help to cause wear or fatigue.

Following chart shows the various bearing defects which lead to vibrations and which can be sorted by using vibration tester



B. *Methods of Testing TRB*

Different methods are used for detection and diagnosis of bearing defects; they may be broadly classified as follows:

- Vibration and acoustic measurements
- Temperature measurements and
- Wear debris analysis

Among these, vibration measurements are the most widely used. Several techniques have been applied to measure the vibration and acoustic responses from defective bearings. i.e., vibration measurements in time and frequency domains, the shock pulse method, sound pressure and sound intensity techniques and the acoustic emission method.

III.TESTING OF TRB ON UP-GRADED MACHINE

A.Importance andNeed forUpgradation of oldMachine (Maintenance &Asset Management)

The old machine was having its own vibrations generated due to antifriction bearing/bush type spindle having metal to metal contact. This vibration probably were superimposing with the bearing under test, giving rise to false rejection. To overcome this problem it is decided to use spindle with no metal to metal contact with improved lubrication. The advantages of this theme is excellent thrust load carrying capacity with good vibration damping effect and thermal stability leading to improved performance and spindle life. For this it is decided to use either hydrodynamic or hydrostatic spindle. The hydrostatic spindle requires higher pressure and LPM requirement.(P> 50 bar, LPM 30 liter/min) resulting in higher cost of the project. The hydrodynamic spindle requires less pressure and flow rate(2 bar, 10 LPM). For this reason hydrodynamic spindle seems to be more suitable for this application. The machine logic sequence needs redesigning of machine operation sequence for fully automatic operation containing auto loading, segregation and unloading of the bearing cone under test. This requirement calls for use latest pneumatic cylinders and valves which are regularly available and standard items at SKF. This will help to reduce machine cycle time and maintainability. To detect the vibrations in the bearings generated due to surface defects, DISCOM Rotas-TMO vibration analyser is used.

B. Experimental Set Up of Noise Tester

In a bearing, when the inner ring / outer ring rotate, the rollers roll over IR & OR track and the roller ends roll on flange surface. Any form of defect such as roughness, dents on any of these contact surfaces, creates vibration and noise in the bearing. The amount of this vibration in a bearing is directly dependent on the form accuracies of all the contacting surfaces. Better the quality of surfaces, lesser the vibration and better the quality of the bearing. Lesser the vibrations, longer the life of the TRB. Hence, utmost importance is given to vibration testing of TRBs and 100% testing is carried out. Machine layout is shown in the figure 1.

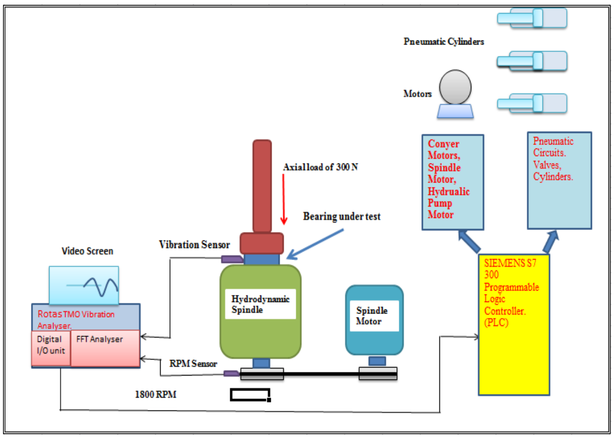


Fig.1 Block diagram of vibration analyser

Vibration analyser comprises of three major systems:

1) Mechanical system
2) Electronic Machine Control system
3) Vibration Sensor and FFT Vibration Analyser

*1)Mechanical System:*Robust mechanical systems are designed for this machine. Hydrodynamic spindle along with the hydraulic pump which supplies 1.5 to 2 bar pressure with 6 LPM flow of oil to the hydrodynamic spindle. The spindle rotates the bearing cone under test. Mechanical system also includes various pneumatic cylinder assemblies which operate on compressed air pressure. Axial loading force cylinder assembly, bearing transfer cylinder mechanism, bearing up down mechanism, bearing ejection system, bearing sorting as good and bad mechanism, vibration transducer attachment, flex link conveyors for bearing inlet and outlet, flat belt driven hydrodynamic spindle and 'A' class vibration motor are used for various functions in the machine.

2) *Electronic Machine Control System:* Electronic control system controls and co-ordinates the logical sequence of various machine functions such as conveyor movements, hydraulic pump start stops, hydrodynamic spindle rotation, and pneumatic cylinder movements. Passing the tested bearing to next operation or rejecting it, based on the digital inputs received from Rotas System. Siemens S7 300 PLC along with 48 digital inputs and 36 outputs is used for this electronic control system. Man Machine Interface (MMI) is also used to vary timing parameters and to see error displays.

3) Vibration Sensor and FFT Vibration Analyser: As per SKF guideline, electromagnetic transducer MEA 106 is selected along with Discom Germany make ROTAS TMO vibration analyser. As shown in the block diagram 2.2, transducer tip is directly in contact with outer ring which transmits vibrations of bearing cone rotating at 1800 RPM. Electrical impulses generated by transducer are amplified and analysed by Rotas TMO unit and compared with predetermined waviness& other parameter limits by FFT analysis. The decision of bearing "good or reject" is conveyed to the PLC through the digital I/O section of the Rotas system.

IV.MACHINE OPERATION

A. Auto Cycle

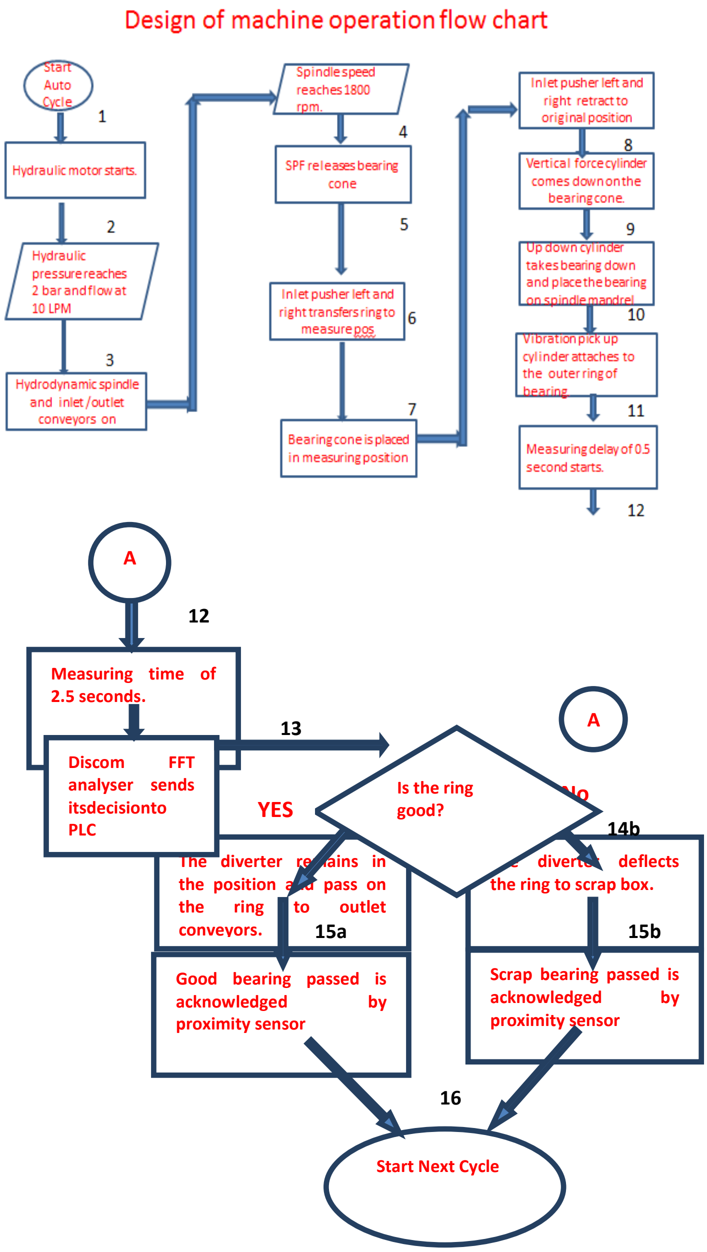
Machine auto cycle is shown in following flow chart.

There are total 16 steps which represent the complete one cycle of the machine. At each step there are either electrical or pneumatic actuators which are actuated in a sequential way. At the end of each cycle a decision is taken by vibration analysis software whether to accept or reject the bearing & same is conveyed to PLC.

B.Measuring Parameters

Discom Rotas System consists of following main parameters of which values are measured.

- Crest: For Inner Ring, Tapered Roller and for mix. Crest value is hint for hit marks on IR,TR while crest mix is a hint for dirt or for defect OR.
- Peak: It is analogous to crest which indicate hit marks or dirt.
- RMS: RMS detects honing error. Mix RMS is a hint for defect OR.
- Waviness Bands: The vibration signal is split into 10 bands. Each band indicates waviness of certain order.



V. VALIDATION OF UPGRADED MACHINE

The vibration levels generated by new hydrodynamic spindle design and Siemens motor with vibration class 'A' are extremely low. It substantially reduces chances of vibration interference with bearing cone under test.
With these improvements SKF carried out validation test for HBUT type 1024.The SKF has its own method for validation of bearings on vibration analyser which determines repeatability or reproducibility of the vibration analyser.
In this validation test 30 bearing samples were manufactured. Out of these 30 samples, 22 samples were, good bearings and 8 samples were, rejected bearings deliberately manufactured.
The rejected bearings were classified as below,

Bearing with IR hit mark 2 nos.
Bearing with roller hit mark 2 nos.
Bearing with IR waviness 2 nos.
Bearing without IR honing 2 nos.

Good and bad bearing samples were tested on an off line vibration analyser which is a reference equipment and marked with green and red colour dots.

After this preparations, the set of good and bad bearings were tested on upgraded machine randomly 2 times and 60 observations were noted. Below table shows the result

TABLEI.
VALIDATION RESULT

Set 1			Set 2		
Sr. No.	Bearing Description	MVR Result	Sr. No.	Bearing Description	MVR Result
1	Good 1	Pass	1	Good 13	Pass
2	Good 2	Pass	2	Good 14	Pass
3	Good 3	Pass	3	Good 15	Pass
4	Good 4	Pass	4	Good 16	Pass
5	IR hit 1	Fail	5	Good 17	Pass
6	Good 5	Pass	6	Roller hit 1	Fail
7	Roller hit 1	Fail	7	IR unhoned 1	Fail
8	IR unhoned 1	Fail	8	Good 1	Pass
9	Good 6	Pass	9	Good 2	Pass
10	Good 7	Pass	10	Good 3	Pass
11	Good 8	Pass	11	Good 4	Pass
12	Good 9	Pass	12	Good 5	Pass
13	Good 10	Pass	13	IR hit 1	Fail
14	Good 11	Pass	14	Good 6	Pass
15	Good 12	Pass	15	Good 7	Pass
16	Roller hit 2	Fail	16	Good 8	Pass
17	IR unhoned 2	Fail	17	Good 9	Pass
18	Good 13	Pass	18	Good 10	Pass
19	Good 14	Pass	19	Good 11	Pass
20	Good 15	Pass	20	Good 12	Pass
21	Good 16	Pass	21	IR hit 2	Fail
22	Good 17	Pass	22	IR waviness 1	Fail
23	IR hit 2	Fail	23	Good 19	Pass
24	IR waviness 1	Fail	24	Good 20	Pass
25	IR waviness 2	Fail	25	Good 21	Pass
26	Good 18	Fail	26	Good 22	Pass
27	Good 19	Pass	27	IR waviness 2	Fail
28	Good 20	Pass	28	Good 18	Pass
29	Good 21	Pass	29	Roller hit 2	Fail
30	Good 22	Pass	30	IR unhoned 2	Fail

In the table above, one deviation found in the set 1, reading no.26.Here the good ring is rejected falsely. After analysis, the vibration analyser reading for waviness was slightly outside the limit value. As per the SKF quality team, the reproducibility of segregation is 98.3% and is acceptable as it is above 95%.The SKF quality team accepted the machine.

VI. RESULTS AND MEASUREMENTS

A. Upgradation and Improvements

In this project, upgradation and improvements are carried out in following areas,

- Use of hydrodynamic spindle and vibration class 'A' motor.
- Design of various systems like cone loading and unloading, cone positioning, cone up down, transducer attachment and bearing rejection mechanism.
- Developing machine logic sequence.
- Designing and selection pneumatic and hydraulic components & circuits.

B. Measurement of Vibration Parameters

After successful implementation the changes and installation of the machine following results are obtained. The results are shown for taper roller bearing 29749F having the parameters as:

Bore diameter= 38.112mm
Outer diameter= 65.107mm
No. of rollers= 21nos.
Roller angle=2^0 40
Outer ring angle= 12 degree 30 minutes.

All these parameters are entered in ROTAS software system and limits are entered based on SKF D-10 standard.The fig.2 shows the snapshot of display screen.

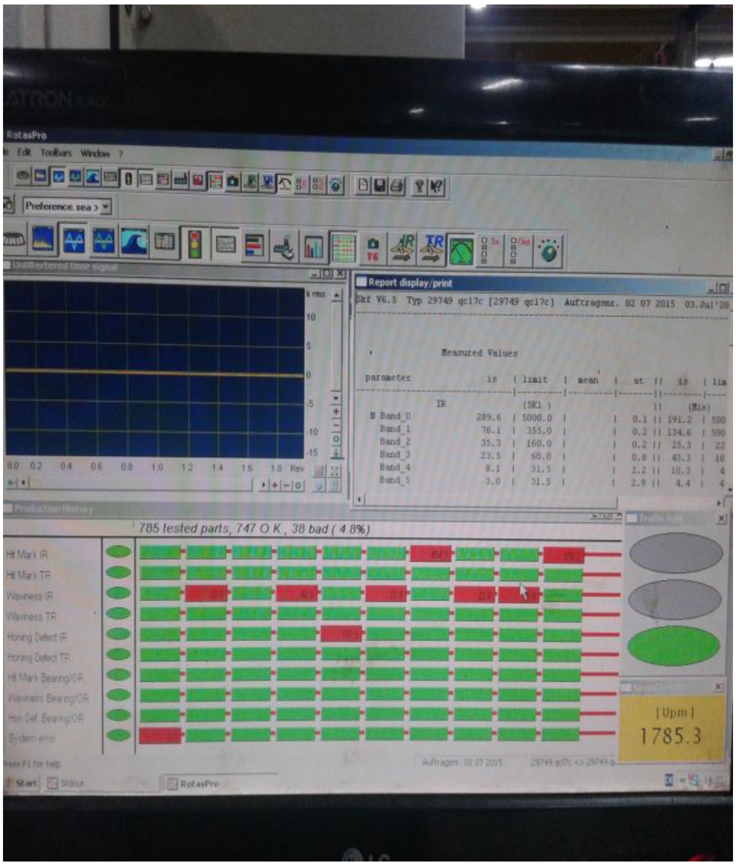


Fig.2 Snapshot of display screen

Table no.II shows the measured values for accepted and rejected bearing. There are three channels viz.

- SK1 for inner ring
- SK2 for taper roller

- Mix channel for outer ring

TABLEII
MEASURED VALUES OF VIBRATION PARAMETERS FOR TAPER ROLLER BEARING 29749F

Parameter	Limit	Accepted Brg	Rejected Brg
Inner Ring, Channel:SK1			
Band 0	5000	236.7	373.7
Band 1	355	107.7	69.9
Band 2	160	24.2	61.8
Band 3	60	30.2	66.2
Band 4	31.5	5.5	16.4
Band 5	31.5	3.2	3.8
Band 6	10	1.6	1.4
Band 7	22.4	1.7	1.2
Band 8	18	1.4	1
Band 9	14	0.7	0.8
Crest	5.6	3.6	2.9
RMS	100	39.4	101.9
Peak	355	112.5	242.3
Tapered Roller, Channel:SK2			
Band 0	5000	66.8	101
Band 1	355	14.5	25.6
Band 2	160	39.1	39.3
Band 3	60	18.2	18.5
Band 4	31.5	5.8	6.4
Band 5	31.5	2.6	4.7
Band 6	31.5	2.1	2.8
Band 7	22.4	1.7	2.6
Band 8	18	2	2
Crest	5.6	4.5	3.4
RMS	160	72.4	77.6
Peak	560	243.5	213.4
Outer Ring, Channel: Mix			
Band 0	5000	28.2	47.8
Band 1	5000	155.8	259.2
Band 2	100	28.2	54.4
Band 3	100	8.4	19.7
Band 4	40	8.1	16.1
Band 5	40	5.5	6.1
Band 6	40	3.2	3
Band 7	20	2.8	2.3
Band 8	16	2.4	1.5
Band 9	16	1.2	0.7

C. *Acceptance and Rejection Criteria for Vibration Test*

The bearing is considered to be passed through vibration test if measured values of all parameters arewithin specified limits. This bearing is accepted and sends to next station. The bearing is rejected if any of the measured parameter is out of the specified limit. If more than one parameter exceeds the specified limit, then prominent parameter error is shown on display. In above measurement result there are two parameters of Inner ring which exceed the limits but Band 3 parameter is prominent over RMS value so display will show that bearing is rejected for waviness, such bearing is rejected through rejection chute and send to scarp box.

VII.CONCLUSION

Based on the upgradation carried out on Vibration measurement and analysis machine it can be concluded that inherent vibrations of machine can be reduced by using hydrodynamic spindle instead of antifriction bearing spindle. Furthermore the bearing vibration signal can be divided into different vibration measuring parameters which are assigned to different bearing defects. By using suitable software programme the defect in each bearing component is displayed directly. By setting specific limits the bearings can be sorted as accepted or rejected by measuring various vibration parameters through vibration test.

ACKNOWLEDGMENT

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