International Journal of Advance Research and Innovation
Vol. 2(4), Oct-Dec 2014, pp. 118-121
Doi: 10.51976/ijari.241417
www.gla.ac.in/journals/ijari

Article Info

Received: 10 Oct 2014 | Revised Submission: 25 Oct 2014 | Accepted: 20 Nov 2014 | Available Online: 15 Dec 2014

Analysis of Ball Bearings under Dynamic Loading Using Non-Destructive Technique of Thermography

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ABSTRACT

Roller bearing defect is a major factor of failure in rotating machinery that affects proper functioning of system which results in substantial time and economic losses. Therefore, condition monitoring of roller bearing is important and the study of severity of defects are necessarily required in order to avoid catastrophic consequences. Defects monitoring during dynamic loading conditions of rotational machineries with the use of contactless, non-destructive infrared thermographic method is proposed. By using a rotating ball bearing, passive thermographic experiment was performed as an alternative technique to proceed the condition monitoring. Based on the results, the temperature characteristics of the ball bearing under dynamic loading conditions were analyzed thoroughly. Also, a comparison of these results was done for different bearings with characteristic defects. As a result, it was confirmed that infrared thermography method could be adopted to monitor and diagnose the faults by evaluating quantitatively and qualitatively the temperature characteristics according to the condition of the ball bearing.

Keywords: *Thermographic; Inspection; Ball Bearing; Dynamic Loading; Ball Defect; Outer Race Defect; Defect Evaluation; Quantitative Imaging.*

1.0 Introduction

Through past decades, non-destructive inspection technology has been widely used and its leveraging range is continuously growing trend. Recently, quantitative inspection for machinery equipment and facilities with shock or vibrations with rotating have been required and the application of infrared thermograph technology as a useful measurement tool for its own heat dissipations was useful, in which a non-destructive testing (NDT) as a passive infrared thermography was applied. [1] Since infrared thermographic technology with high performances in sensitivity and resolution could scan a large area at the same time as one of non-destructive tastings, this infrared technology extended its applications including to detect cracks, delamination of defects. As a methodology of faults monitoring with several advantages such as real-time detection and remote detection, it could be applied into the area of automotive, aerospace industry and nuclear plants. At these days, the applications of infrared applications were quickly expanded to the field of fault detection techniques and its utilizations of condition monitoring for the diagnosis were widely increased [2]. In this study, using the infrared thermography method for the diagnosis of ball during operation, evaluation of fault detection was carried out by experiments.

Thermographic NDT techniques have been used in a variety of applications, e.g. the inspection of subsurface defects and features, the identification of thermo-physical properties and the detection of coating thickness and hidden structures. In the 1980s, Vavilov and Taylor [2] discussed the principles of thermal NDT, describing its ability to provide quantitative information about hidden defects or features in a material.[3, 4] When the material includes voids or pores in its structure, its thermal conductivity and density decrease, and the thermal diffusivity is altered, so the conduction of heat through the material is affected. IR thermography is an effective tool for condition monitoring of different machine like reciprocating air compressor. This technique allows to monitor the machine under running condition and analyse its working condition

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for temperature and thermal patters. Infrared gun and thermocouple [8] are used in sequence and further analysis is done by techniques such as Finite Element Method. Thermography is a noncontact tool [9] for measuring surface temperature of machine as well as is used as a tool in fine physical experiments in order to analyze thermo-physical phenomena. Unlike vibration analysis [10], thermography measures the surface temperature of an object; the temperature difference between the defect and the normal part indicates the size and location of the defect.

2.0 Experimental Setup

An experimental test model is used to predict defects in roller bearings as shown. The test model consists of a shaft with motor attached to its end. Shafts having radial loading are provided the positioning with accuracy and stability. The design incorporated two coupling discs and two roller bearing attachments over rotating shaft. The whole system is placed on base frame which has shock absorbing springs attached on its legs .The unique feature of the model is that independent motor drives the system. This permits the damaged and undamaged bearing signals to be observed simultaneously. Essential parts of ball bearings are inner race, outer race, the balls, and the separator. The inner (or ring) is fitted on a shaft and has a groove in which the balls ride. The inner race rotates with the same speed as that of the shaft. The outer race is usually a non-rotating member and also has a groove to guide and support the balls. The separator prevents the contact between the balls and thus reduces friction, wear and noise. The roller bearing is tested at constant speed of 1500 rpm with cylindrical roller bearing of type SKF 1205 EKTN9. The details of the bearings used in present analysis are given in table.

Two types of bearing defects, namely, ball defect and outer race defects were studied. Experimental tests were carried out on two sets of bearings. Initially new bearing (good bearing) was fixed in the test rig and signals were recorded using Fluke Ti400 infrared camera. The good bearing was replaced by defective bearing and signals were recorded for each one of the case separately under the same standard condition. Temperature waveform identifies exact nature of defects in bearings.

2.1 Figure and Table

Fig: 1. CAD model of experimental setup. A vibration analyzer is attached on the roller bearing attachment on the free end of the rotating shaft

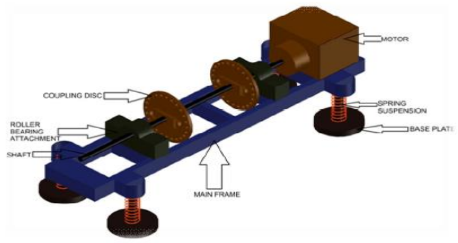

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Table: 1. Roller Bearing Specifications

Bearing Model	SKF 1205 EKTN9
Clearance	Standard
Brand	SKF
Limiting Speed	18000 rpm
Width	15 mm
Outside Diameter	52 mm
Inside Diameter	25 mm
Bore Type	Taper
Mass	0.14 Kg

3.0 Results and Discussions

3.1 IR Analysis for different ball bearings

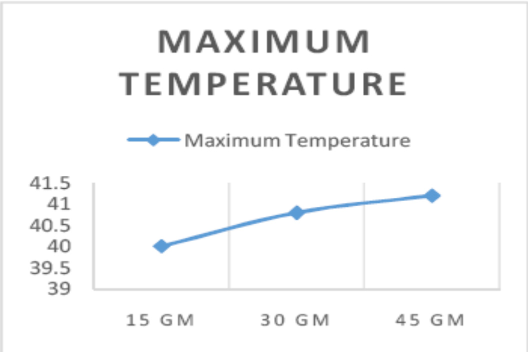
Table: 2. Readings for Maximum TemperatureType of bearing Maximum Temperature

Type of bearing	Maximum Temperature
Ball defect	42.2
Outer race defect	40.9
Normal bearing	39.1

The maximum temperature is highest in ball bearing with ball defect while it is lowest in normal bearing. Comparing the two defects, it can be noted that maximum temperature is higher in ball defect than the bearing with outer race defect and thus it can be concluded that condition of instability is more with bearing having ball defect.

3.2 IR Analysis of mass imbalance with bearing having ball defect

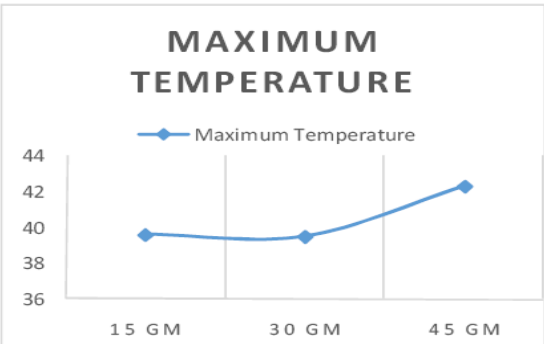
Fig: 2. Curve Representing Variation of Maximum Temperature with Weights Used for Mass Imbalance with a Ball Bearing having Ball Defect



The weights are applied to imbalance the coupling discs. For analysis, the mass imbalance condition wassimulated with two ball bearings. The curve shows anincreasing trend as the weight increases. This is due to result of increase in radial force with increase in mass. Thus vibrations produced were highest in case of 45 gm mass and maximum temperature was recorded. Even though the weights differ by common difference of 15 gm, the slope of curve decreases after 30 gm weight. Thus the maximum temperature change decreases with increase in weight.

3.3 IR Analysis of mass imbalance on normal bearing

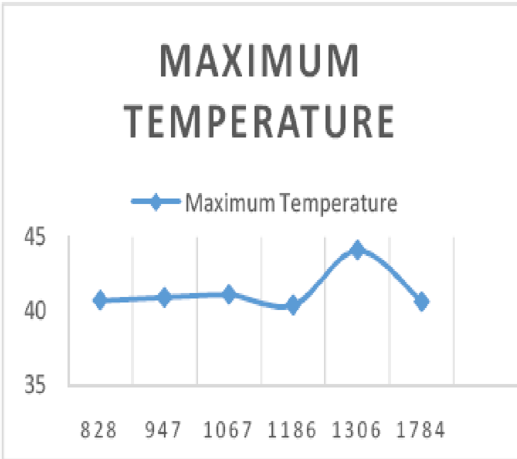
Fig: 3. Variation of Maximum Temperature with Weights under Mass Imbalance Condition



The curve shows an increasing trend with increase in weight. Thus it can be inferred that as weight increases, the radial forces increase and this increases instability of couplings and causes its heating. The rise in temperature is low in smaller weights but increase more in case heavier weights are applied. This condition is opposite to that of bearing with ball defect. Thus we can differ between normal bearing and defected bearing.

3.4 IR Analysis of the effect of rotational speed (RPM) on temperature

Fig: 4. Variation of Maximum Temperature with Rotational Speed



The curve in general shows an increasing trend, if two ambiguous cases at 1186 and 1784 RPM are neglected. This can be explained by the fact that when rotational speed is increased the system comes under increased loading. Thus, the friction and heating increases

4.0 Conclusions

In this research, the temperature characteristics according to the abrasion stages of the ball bearing under dynamic loading conditions were analyzed through the infrared thermography method. Based on these results, the contactless, non-destructive real-time monitoring and abnormality diagnosis using the infrared thermography method will be applicable and useful for condition monitoring of rotating machine elements in the future.

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