Infrared Thermographic NDT for the Fault Diagnosis of Bearing with Foreign Substances inside under Loading Condition

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Abstract
Fault diagnoses during dynamic loading condition of which ball bearing as rotational machineries has foreign materials inside the bearing was conducted by the use of contactless, non-destructive infrared thermographic NDT. Among typical foreign substances inserted into the bearing, fine sands and iron powder were applied. For a rotating deep-grooved ball bearing, passive thermographic experiment was performed to monitor the thermal distributions as the fault monitoring. As experimental procedures, the temperature characteristics of the ball bearing under dynamic loading conditions were considered. As infrared thermographic NDT results, it was confirmed that infrared thermography method could be adapted into monitor and diagnose the early fault instrument for bearing failure by evaluating quantitatively the temperature characteristics according to the loading condition of the ball bearing.

Keywords: Infrared thermographic NDT, Rotational machinery, Bearing, Dynamic loading, Fault diagnosis, Quantitative evaluation

1. 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 equipments 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 fault diagnosis under the 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 thermographic non-destructive testing for the fault diagnosis of ball with foreign substances inside during its dynamic operation, evaluation of fault detection was quantitatively carried out by experiments.

2. Experimental configurations

2.1 Infrared thermographic test
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.

Unlike ESPI, thermography measures the surface temperature of an object; the temperature difference between the defect and the sound part indicates the size and location of the defect. In this we have used an IR camera (model SC650 by Flir Corp.).

2.2 Experimental conditions of defected bearing

An experiment was performed by using of B6004 applied as the test piece. In general, B60XX series at most industrial fields are widely used in the insulation deep groove ball bearing.[5-7] Both Fig’s of 1 and 2 show the thermography system used in this experiment and the circular disc for the loading condition of ball bearing, respectively. From Table1 indicates the physical configuration of each ball bearing used in this experiment. As a experimental works including the electric power device, the each bearing and housing were installed between a power and supported for the measured bearing in order to simple support.

![Fig. 1 Experimental apparatus for bearing test](image1)

![Fug. 2 Photo of loading disk of 3 kg](image2)

<table>
<thead>
<tr>
<th>Table 1 Specifications experimental apparatus</th>
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<tr>
<td>Bearing Type</td>
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<td>B6004 (2RSC3)</td>
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2.3 Experimental procedures

In the shape of bearing used in the general body of revolution, the condition of experiment was assumed as the normality, insertion of foreign substances inside the bearing of iron power, including disc loading conditions. And then, the temperature characteristics were observed during the experiment. By using the APM - SC08 ADK Servo Motor of 1HP with power of 800W, the experimental procedures under dynamic loadings was performed at 2000 rpm. The meshes as foreign substances inserted into the bearing for artificially manufactured are as follows.

<table>
<thead>
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<th>Table 2 Physical specifications of foreign substance</th>
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<tr>
<td>Substances</td>
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<td>Mesh dimension</td>
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<td>Weight for defects</td>
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3. Results and Discussions

The infrared thermographic NDT inspection was conducted by using SC650 as indicated at Table 1. Fig. 1 shows the results of the experiment in case which SIC mesh with 40 μm of 0.1 g, 0.2, and 0.3g weight under disk loading condition of 3 kg. As the result of experiment, it was generated that it made the high temperature rising at the 10 second band and the tendency to be more and more increased over time. From the comparison with normal state which there was no defect condition at all, failure diagnoses are clearly indicated from both loading and inside substances of bearing. For thermographic measurements, the experiments were performed until the equilibrium temperature after the temperature rose. 20 frames per a minute was measured.

From the experimental result of Fig. 4, qualitative detection was carried out under the fixed speed of 2,000 rpm with 3 kg loading and for each different mesh size of a substance. And, from the comparison with normal condition, the size of foreign substance effects much higher compared to the amount of foreign substance.

![Fig. 3 Temperatures for substance amounts](image1)

![Fig. 4 Temperatures for substance size](image2)

From thermographic NDT diagnosis as shown from Figs’ of 3 and 4, the failure assessment conducted by using the infrared thermographic diagnosis method and thermal characteristics under harsh operation in several defect conditions were analysed thoroughly. As practical industrial sites, it is not easy to early detect the failure due to sudden temperature rising occurred in short time and have problems to solve this fast detection.

However, this problem was solved by applying the infrared thermography technology which has benefits at non-contact and scanning method. As shown in figures above, the quantitative data were obtained from the results of the experiment with B6004 by using thermographic NDT. From these figures, each experimental condition applied to the bearing type of B6004 could be useful to diagnose the failure detection. Also, these results of the other bearing came out with thess, similarly.

4. Conclusions
In this study, the faults from machinery with foreign substances inserted inside the bearing under dynamic mode was measured by using the infrared thermography technology. Also, the real-time temperature distributions obtained from the infrared thermographic NDT were distinguished from the size and amount of substances inside the bearing.

Even though there were various measuring method as traditional method for failure diagnosis, it was confirmed to apply the infrared thermographic NDT technology was possible to be applicable as early detection instrument. In addition, as comparisons to failure diagnosis, it was found that it was much faster when the size of substance was bigger and requires more frames rather than low resolution in thermography camera. And, as further research, it will be possible with delicate data processing and imaging analysis under more investigation for the bearing, too.

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References