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Fault Diagnosis of Ball Bearings within Rotational Machines Using the Infrared Thermography Method

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Abstract In this paper, the novel approach for the fault diagnosis of the bearing equipped with rotational mechanical facilities was studied. As research works, by applying the ball bearing used extensively in many industrial fields, experiments were conducted in order to propose the new prognostic method about the condition monitoring for the rotational bodies based on the condition analysis of infrared thermography. Also, by using the vibration spectrum analysis, the real time monitoring was performed. As results, it was confirmed that infrared thermography method could be adapted into monitor and diagnose the fault for bearing by evaluating quantitatively and qualitatively the temperature characteristics according to the condition of the ball bearing.

Keywords: Condition Monitoring, Bearing, Frequency Analysis, Infrared Thermography, Fault Analysis, Rotational Facilities

1. Introduction

Recently, the fault inspection system is one of the most important part in the industrial field (Kim, et al., 2001). According to the inspection method, it is divided into contact inspection and non-contact inspection. In the case of contact inspection, the testing device configuration is difficult, and it has the disadvantage that it has to contacts the device to the object directly. non-contact method doesn't contact to the object directly. So, a restriction is less than contact method when using. In addition, the specific diagnosis of the defect site is possible. Therefore, in this research, an experiment was performed by using the infrared thermography technology that is the one of non-contact testing methods.

All objects emit the infrared radiation energy in more than the absolute temperature 0K. The emitted infrared radiation energy is measured by using the infrared rays image device. This infrared rays image device takes a photograph of the thermal image of the surface. And, it is the method that estimate the temperature distribution or the instantaneous change of the internal condition of the objects using interpretation(Choi and Kim, 2004). The infrared thermography test is an experimental method that uses the infrared thermography camera. It is easy to use and provides the environment which enables convenient inspection of exact data(Kim, et al., 1997).

In addition, the method can be gained the data by the temperature distribution of the machine system and thermal change. So, it distinguishes a defect due to over temperature change and is extensively utilized in the medical

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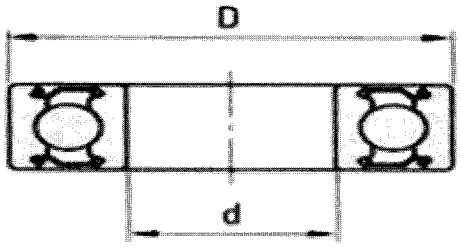


Fig. 1 Schematic of deep grove ball bearing

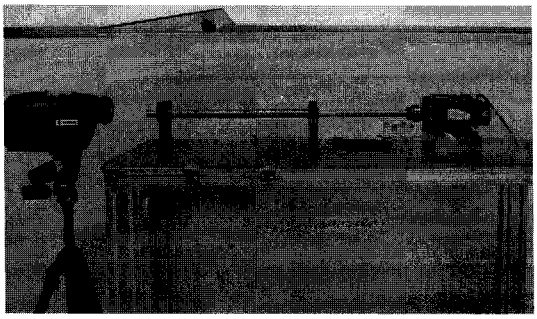


Fig. 2 Rotation laboratory device

Table 1 Specifications and dimensions of ball bearing (unit: mm)

Bearing Name	Out Diameter. (D)	In Diameter. (d)	Ball Diameter	ball Number
B6004	42	20	5.05	9
B6204	47	20	6.65	8
B6304	52	20	7.90	7

science, space, weather, engineering and manufacturing.

In this research, an inspection method using the infrared thermography device is useful as the bearing fault sensing method in comparison with other methods due to many advantages which are safe and possible to measure long distance at high speed(Kim, et al., 2008) due to the non-contact.

2. Experimental Configuration

An experiment was performed by using B6004, B6204, and B6304 as the test piece. B60XX series are the most widely used in the insulation deep groove ball bearing. Table 1 and Fig. 1 shows the bearing standard and the shape of the ball bearing used in this experiment, respectively.

Fig. 2 is shown the simple device configuration used in this experiment. The bearing B6804 and housing were installed between a power and a measuring bearing in order to simple support. In the shape of bearing used in the general body of revolution, the condition of experiment was assumed as the normality, loss of lubricating oil and spalling state(Kim, et al., 2010). And then the temperature characteristics were observed during the experiment. By using the APM - SC08 ADK Servo Motor of 1 HP on 800 W, the experiment was performed in 1000, 2000, 3000 rpm, respectively.

The bulletproof glass was used to perform the experiment in consideration of the safety of the part connected to the motor, axis and bearing. The Realwave analyzer was used to compare reliability, accuracy of the infrared thermography technology and consideration of outstanding performance rather than the existing method of diagnosis. The model of the infrared camera used for this experiment is the model of Silver 450 M (Cedip Co.)

3. A Result and Consideration

3.1 The Fault Analysis by the Vibration Test

In this research, the experiment was performed with the frequency analysis method which is commonly used in order to compare the difference between the reliability evaluation and an existing method prior to the method of measurement using the infrared thermography camera. Fig. 3 shows the configuration of the laboratory device. This device is directly attached to an accelerometer through the housing supporting the bearing, that is the object being measured.

This testing device receives a transmission of data on a real time basis and analyzes the graph coming out and determines an abnormality in the

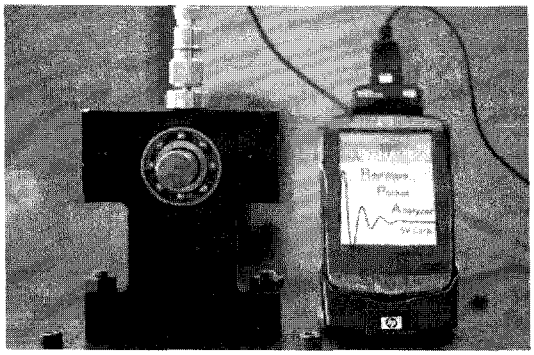


Fig. 3 The frequency diagnostic test

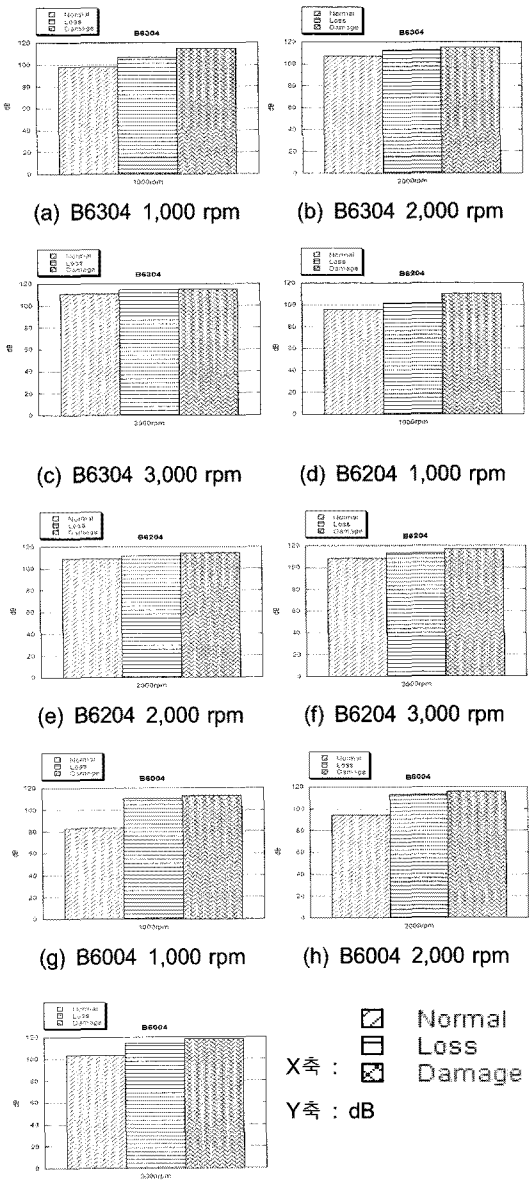
Table 2 Specifications of realwave analyzer

Main features
1Channel Analog Input(+TTL Pulse Tacho Input)
IEPE Type, AC Voltage Type Transducer Connection
Sampling Frequency(MAX) : 32768 Hz
Input Voltage Range : ±5 V(PEAK)
Dynamic Range - Sound level meter : 20~134 dB(50mV/Pa * 10Gain) - Vibration meter : 45~160 dB(50mV/g * 10Gain)
Digital Gain : 2x, 4x, 8x, 16x, 32x, 64x
ADC SNR : 100 dB more
Analysis band frequency : 0.5 Hz~16 kHz(3 dB)
Interface : CF Card Type II
Data save - Wave File : For 1 hour of running - VLM, SLM Data File : 64days(4GB)

frequency, which size lead to the return value about the size according to the specific frequency. However, this experiment has the disadvantage of being the contact. Also, the incidental facility according to the experiment has to be mounted to the instrument. So, it has to be redesigned due to the unnecessary element brought by the setup.

The experiment was performed by using the realwave analyzer and accelerometer. Table 3 shows the result of the experiment. As the result of experiment, it was generated that it made the high sound pressure in 0 ~ 6,000 Hz band and the tendency to be more and more decreased by the high frequency over time. And, the whole

Table 3 The result of the frequency analysis



(a) B6304 1,000 rpm (b) B6304 2,000 rpm

(c) B6304 3,000 rpm (d) B6204 1,000 rpm

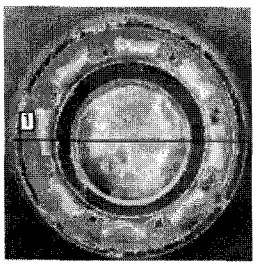
(e) B6204 2,000 rpm (f) B6204 3,000 rpm

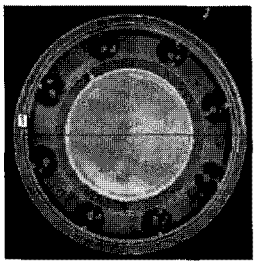
(g) B6004 1,000 rpm (h) B6004 2,000 rpm

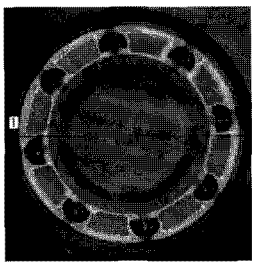
(i) B6004 3,000r pm

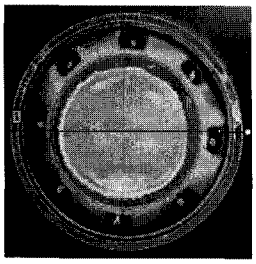
sound pressure could confirm that the sound pressure was decreased with the high frequency in the low frequency over time and it was enhanced in comparison with the normal condition.

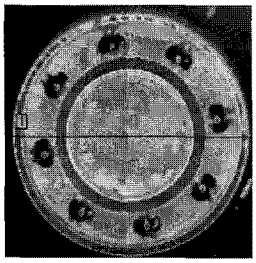
At Table 3, the X-axis shows the Hz and the Y-axis shows the size. Also, the definite difference according to each conditions is seen from the sound pressure(dB) of the frequency level.

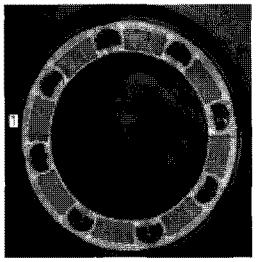

(a) B6204 1,000 rpm normal

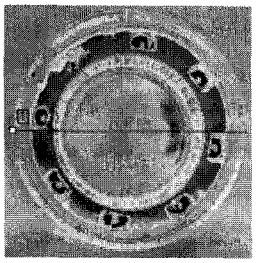

(b) B6204 1,000 rpm loss

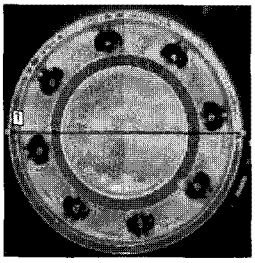

(c) B6204 1,000 rpm Spalling


(d) B6204 2,000 rpm normal


(e) B6204 2,000 rpm loss


(f) B6204 2,000 rpm Spalling


(g) B6204 3,000 rpm normal


(h) B6204 3,000 rpm loss

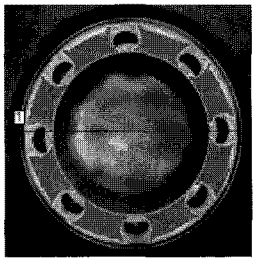

(i) B6204 3,000 rpm Spalling

Fig. 4 The result of measurement of B6204

3.2 The Infrared Thermography Bearing Diagnosis

The experiment were performed until the equilibrium temperature after the temperature rose. 50 frame per a second was measured. And, it was performed by the speed of 1,000 rpm, 2,000 rpm, 3,000 rpm as normal condition, lubricating oil loss condition, and spalling condition of B6004, B6204 and B6304 ball bearings.

Fig. 4 shows the photo from the results of the experiment with B6204. In the correlation of the color come out in an image, temperature is high as it comes close to the red and low as it comes close to the blue.

Table 4 shows the result of the experiments. As shown in Table 4, it indicated to analyze the normal condition, lubricating oil loss condition, spalling condition. In the results, the temperature of lubricating oil loss condition was little higher than the temperature of the normal condition.

On the other hand, in the spalling condition of dried lubrication where the friction is generated in the intrados, outer-race, ball due to the lost lubricating oil, the generation of heat which is higher than the normal condition and lubricating oil loss condition was generated.

In Fig. 5 and Fig. 6, each figure shows comparison of the frequency diagnosis method and infrared thermography diagnosis method research and the result was analyzed. However, this problem was solved by applying the infrared thermography technology which has benefits at non-contact and scanning method. From Fig. 5 and 6, each experimental method was applied to the bearing type of B6304. Also, the results of the other bearing came out with this similarly.

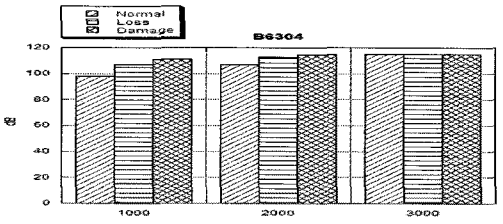


Fig. 5 The result of frequency analysis method of B6304

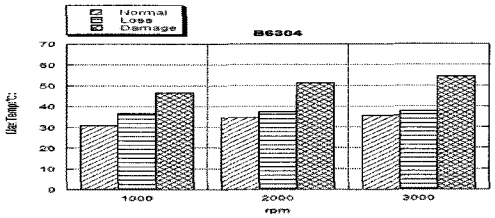
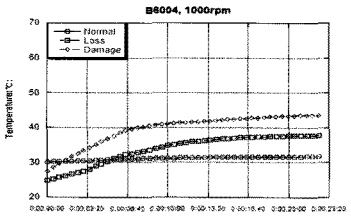
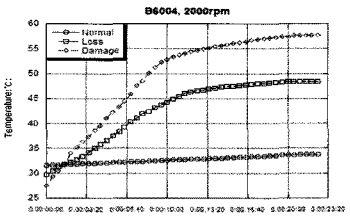


Fig. 6 The result of infrared thermography method of B6304

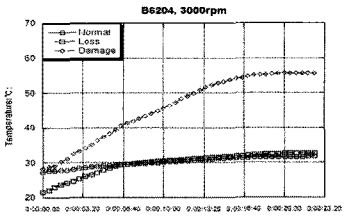
Table 4 The result of measurement of B6304, B6204 and B6004



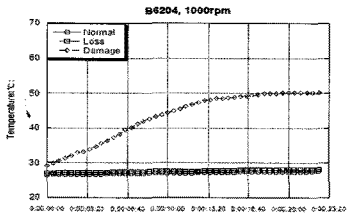
(a) B6004 1,000 rpm



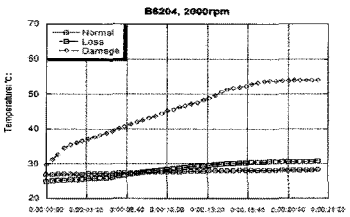
(b) B6004 2,000 rpm



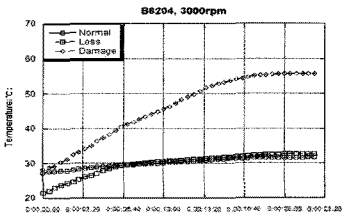
(c) B6004 3,000 rpm



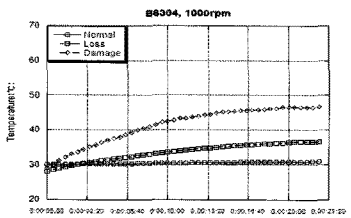
(d) B6204 1,000 rpm



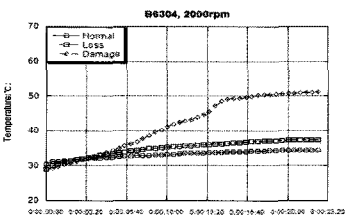
(e) B6204 2,000 rpm



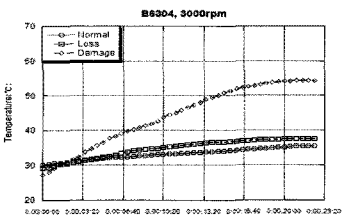
(f) B6204 3,000 rpm



(g) B6304 1,000 rpm



(h) B6304 2,000 rpm



(i) B6304 3,000 rpm

4. Conclusion

In this research, the data measured by using the infrared thermography technology was comparatively analyzed with data measured by using the existing frequency diagnosis method. As to the reliability analysis of the infrared thermography camera, the accuracy about the fault site was confirmed. And the measured data in this experiment was more clear than the data from the existing method.

Also, the thermography displayed by the real-time temperature image was distinguished. In addition, when measuring with the existing method of diagnosis, it's possible to know only about there is damage or not, but it's difficult to investigate exact damaged parts for the bearing. Therefore, the bearing should be disjointed to know about the exact damaged parts. As conclusion, it could be applyed to the machinery condition monitoring with a body of revolution and the abnormal diagnosis real time monitoring.

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