Development of maintenance technology for rotating equipment: Condition based maintenance by shock pulse method
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ABSTRACT

Rotating equipments, such as blowers and pumps, play an important role for securing safety of the Tokai Reprocessing Plant. Bearings in the rotating equipments are important machine components for stable operation. The most important controlled item for the bearings management is to maintain lubrication system consistently. Oil slick thickness in the bearings can be quantitatively confirmed by the shock pulse method, though it was difficult with conventional vibration method. This method contributes more efficient monitoring technique in diagnosing the bearings.

PREFACE

In the Tokai Reprocessing Plant (TRP), lots of blowers are used to enclose radioactive materials in a controlled area, and pumps are used for cooling water circulation to keep appropriate temperature in high-level radioactive liquid waste vessels. These rotating equipments play an important role in safety management of the nuclear facilities, therefore, they should be in stable conditions all the time.

These rotating equipments use electrical motors as drive source, and the torque of the motor is used to rotate impeller connected with the shaft, so that rotating equipments carry the ventilation air and cooling water.

The bearings are installed in such rotary shafts. These are fixed on the mold of the electric motor and a Pedestal of the blower, and the shaft is supported with it.

In order to run rotating equipments stability, it is very important to manage the installation and the lubrication of the bearings. It is necessary to monitoring the bearing damage caused by inadequate lubrication as well as unbalance and miss-alignment.

Therefore, the shock pulse method, which is widely used for diagnosis of the bearings, is applied to assess the deterioration of rolling bearing.

This report shows concerning of the management with shock pulse method.

CURRENT STATE AND PROBLEM OF BEARINGS MANAGEMENT

Troubles of the rotating equipments in the Tokai Reprocessing Plant

According to the evaluation of past maintenance data obtained in the Tokai Reprocessing Plant, it was found that approximately 90% of troubles caused by the bearings at the rotating equipment.

As a result of the broken bearing observation, it was found that approximately 96% of troubles caused by the bearings at the rotating equipment, in which the appropriate lubrication was not kept in almost case. [1]

It is very important for stable operation of the rotating equipment to keep appropriate lubrication in bearings. Therefore, it is necessary to improve the monitoring system for the bearing condition.

The measurement by the vibration method can not find the lubrication quantitatively, which has been used in the Tokai Reprocessing Plant.

Therefore, it is necessary that the monitoring for the bearing is improved to be able to monitor quantitatively.
**Past Management of bearing**

In the Tokai Reprocessing Plant, the rotating equipment had been checked its soundness with measuring the vibration, surface temperature and sound detection of bearings, periodically. The vibration of bearings is measured by personal vibration monitor.

The skilled persons check every 260 rotating equipments with the vibration measurement. So it takes a long interval, one to three months. And, the measurement data could not be obtained continuously. Therefore, the bearings troubles were happened by the inadequate lubrication, because the sign of bearing’s troubles could not be found timely.

![Figure 1 - Bearing broken factor](image)

**Structure and lubrication of bearings**

The bearings consist of rolling elements, inner ring and outer ring as shown figure-2. Rolling elements are rotated on the raceway of inner or outer ring.

The contact point or line, which is formed contacting the rolling element and the raceway, is sustained the operating weight of the rotating objects such as the shaft or impeller. In the bearings, the lubricant oil or grease works as smooth operation. This lubricant makes a thick oil slick between the rolling element and raceway. The oil slick prevents a directly contact from the rolling element and the raceway, so the rolling element rolls smoothly.

Also, lubrication makes another effect to put out an abrasion metal powder, and it deteriorated from the raceway. Therefore, managing the lubrication is important for managing the bearings. Figure-3 shows the state of the oil slick of the bearing inside.

The rolling element in the bearings gives the big pressure to the lubricant because of its high speed rotation as an oil pressure. Then the viscosity of lubricant is increased by the pressure, which makes possible to form the enough oil slick on the raceway.

![Figure 2 - Outline of bearings structure](image)
Problem of bearings management by vibration method

In TRP, in case of the large vibration was detected by the vibration method, the bearings is replaced a new one immediately. When the acceleration was found to be increased by measuring the vibration, the condition of the bearing is judged in sufficient lubrication. Otherwise, the oil or grease was added. However, the vibration monitoring method is not enough to find inadequate bearings before it had been broken. When the defective bearing was examined, there are a lot of factors that the defective lubrication was caused, a flaking, pressure mark and discoloration on the raceway. Also, the diagnosis of vibration method must be considered vibrations from rotating equipments, as well as vibrations from bearings. Sound detection as well as the difference in the result of a measurement is caused by experiment of skilled person. It is difficult to manage quantitatively lubrication of bearings, because the management is depended on experiment and ability of skilled person.
APPLYING THE SHOCK PULSE METHOD

Vibration and pressure wave occurring in bearings

The rolling element on the raceway as shown in Figure-5 is monitoring vibration caused by the kinetic energy between the rolling element and the raceway. This method detects its defect with monitoring the vibration, if it is getting larger. It is well known that pressure waves are generated hitting the raceway by the rolling element. Therefore, measurement of pressure wave form is applicable to monitoring the condition of the bearings.

1) Iron ball collides with iron plate

2) Pressure wave occurs in the moment which iron ball impacted to plate

3) Iron plate vibrates by delivering the kinetic energy of iron ball after occurring pressure wave.

Figure 5 - Occurring pressure wave and vibration in bearing

Relation between pressure wave and oil slick thickness

The pressure waves in bearings are generated hitting the minute surface-roughness of raceway with rolling element. Therefore, the volume of pressure wave decreases by forming the oil slick between the rolling element and the raceway. This means that the oil slick thickness is related in the volume of pressure wave. Figure-6 shows the relation between pressure wave and damage in bearings. Figure-6(1) shows when the appropriate lubrication on the raceway, the pressure wave is small. And when the oil slick in the bearings decreases, the averaged pressure wave as shown figure-6(2) becomes large. And the projecting pressure wave as shown figure-6(3) is generated in the case of the damage in bearing. The way to understand the state of in bearings is by monitoring the pressure wave of these cases.
Lubrication management applying the shock pulse method

Table.1 shows an example to adjust the shock pulse method to the bearing diagnosis in the rotating equipment. This example is a result of diagnosis to the bearing which generated the irregular allophone by the vibration and shock pulse method. As a result of the measurement, an amplitude measured by the vibration method was about 85$\mu$m, it was high than about 120$\mu$m of exchange standard value. But a value of velocity and acceleration measured by vibration method was not an unusual value than a normal value. On the other hand, the bearing was diagnosed in a trouble, because the value of LR (as the pressure wave of large intensity) is so high in the shock pulse method. When the state in the bearing generating an irregular allophone was found, the flaking is occurred in the bearing as shown in the Fig.7. This is said that the shock pulse method can diagnose the bearing easily. As the result of measurement by the shock pulse method, the intensity of a pressure wave can check, whether a damage or defective lubrication has been generated in the bearing. In case of damaged, it had been replaced to new one. When the state of the bearing is checked a defective lubrication, oil will be supplied until an oil slick formed in the bearing. Therefore bearings should be managed by the diagnosis of vibration method, because there is a possibility the deterioration of the fatiguing or wearing bearing does not generate a high pressure wave.

<table>
<thead>
<tr>
<th>Spec of bearing</th>
<th>Bearing type : 6312</th>
<th>Rotational speed : 858rpm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vibration method</td>
<td>85 68 2.8 2.3 1 1</td>
<td></td>
</tr>
<tr>
<td>Shock pulse method</td>
<td>31 -2</td>
<td></td>
</tr>
<tr>
<td>Amp ($\mu$m)</td>
<td>Vel (mm/s)</td>
<td>Acc (m/s²)</td>
</tr>
<tr>
<td>LR$^{*1}$</td>
<td>HR$^{*2}$</td>
<td></td>
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</tbody>
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Table 1 - Result of measurement for the bearing with allophone
The Fig.8 shows an example of the diagnosis by shock pulse method. A result of the diagnosis by the shock pulse method, if the usual oil slick is formed in the bearing, the diagnosis value is displayed in the excellent area, the point “a” at the Fig.8. So, if there is a defective lubrication in the bearing, the diagnosis value is displayed in the attentive area, the point “b” at the Fig.8. Also, if the damage as shown in the Fig.7 was generated in the bearing, the diagnosis value is displayed in the cautionary area, the point “c” at the Fig.8. Therefore, the state of bearing is diagnosed about the damage or defective lubrication.

Fig.9 shows the change of the pressure wave before and after the supply of lubricant, when the diagnosis of the bearing requires the supply of lubricant for forming the oil slick. The period of “a” shows the high-pressure wave has been generated, because there is not the reasonable amount of lubricant on the raceway. So it is judged the reasonable oil slick is not maintained. The period of “b” at the Fig.9 shows the reasonable oil slick has been maintained, because the pressure wave was decreased as a result of injecting the reasonable amount of lubricant. Therefore, it is enable the state of the oil slick before and after the supply of lubricant by the shock pulse method. However, measuring the pressure wave directly and a short measuring interval as well as measuring by the vibration method spend much manpower. So, we constructed the remote monitoring system which is able to observe intensively data of measure transmitted by installing the shock pulse sensors on bearings of rotating equipments beforehand. Figure-10 shows the outline of the remote monitoring system by the shock pulse method.
EFFECT OF APPLYING SHOCK PULSE METHOD

The shock pulse method has been applied to monitoring soundness of eighteen rotating equipments, such as blowers in important TRP for safety, which had been required long time for examine, from 2002. The data of shock pulse monitor set at each blower has been sent to operation room at utility facility at TRP. It makes possible to monitor the conditions of each blower. After applying of this system, we obtained following advantages;

1) The monitoring blowers were possible to keep appropriately the lubrication of bearings. There has been no replacement of damaged bearings, because lubricants were added timely.
2) Checking instruments with vibration and sound detection was necessary to skilled engineer. However shock pulse method made possible to check conditions of damage of the rolling elements, as well as oil thickness, without skilled person.
3) Based on this system, conditions of blowers are possible to do the tendency management because the monitoring data of several blowers are obtained simultaneously and continuously.

CONCLUSION

The lubrication management of bearings is indispensible for stable operating of the rotating equipments. And the Shock pulse method has been applied to the management for very important rotating equipment at Tokai Reprocessing Plant. This method make possible to detect its soundness by quantitatively-assessed monitoring data without experiment by skilled person. As a result, it is possible to maintain the appropriate lubrication by adding the lubricant. Improvement of maintenance ability is made by being combined with shock pulse method and conventional vibration method.
REFERENCES

2) JAITC LTD, 1999 [in Japanese]