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CONDITION MONITORING OF ROLLING ELEMENT BEARINGS

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INTRODUCTION

MODERN INDUSTRY literally runs on rolling element bearings. Rolling element or anti-friction bearings have a limited life, directly influenced by such factors as their mountings, operational load condition and the routine maintenance they receive. To avoid plant breakdown due to plant failure and the subsequent consequential damage, plant engineers have two options open to them.

1. To replace bearings after a set number of hours and well within the bearing manufacturer's recommended lifetime. If this particular technique is used some bearings will fail before the set number of hours have been reached and other bearings will be unnecessarily replaced.
2. To monitor either periodically or continuously the condition of the bearing and only replace the bearing, regardless of time used, when the monitoring technique indicates imminent failure.

Until recently, the most common method for condition monitoring relied on either temperature, vibration or noise measurement. Unfortunately all of these methods suffer in that by the time a significant change has occurred to be quantifiable, the bearing is probably on the verge of collapse.

THE SPM METHOD FOR BEARING CONDITION MONITORING

Considering the limitations of temperature, vibration or noise measurement, a unique concept of bearing condition monitoring was developed approximately ten years ago by the SPM Instrument AB of Sweden. This concept is called the Shock Pulse Method.

The Shock Pulse Method (SPM) operates on the principle of measuring the magnitude of mechanical impact which will occur when damage is present and when the bearing surface collides with this damage. Due to the minor surface roughness present in any new anti-friction bearing there will be a series of small mechanical impacts even in a new perfectly installed situation. Experience has shown that the value of the mechanical impact of shock pulse over the effective safe working life of a bearing will increase by something like 1000 times over the shock value that is due to the new surface roughness.

Because of the large dynamic range of the Shock Pulse Method, it is possible to monitor the condition of a bearing right the way through its normal operating life, and utilizing various evaluation rules, the plant engineer is able to plan bearing replacement in a very systematic fashion.

To be able to measure the mechanical impact or shock pulse only, without being influenced by other factors such as vibration signals, the Shock Pulse Method utilizes a piezo-electric transducer which is tuned mechanically and electrically to a resonant frequency of 32kHz.

CONDITION MONITORING OF ROLLING ELEMENT BEARINGS

Fig 1 shows a typical electric motor bearing with a transducer coupled to the bearing housing; as the bearing rotates, the vibrational signals present in all machinery will set up a low frequency signal, typically less than 20kHz as shown. When mechanical impacts due to the damaged bearing surface collision occur, the transducer will resonate and give a damped transient output superimposed on the vibration signal as shown. The magnitude of the damped transient will be directly proportional to the magnitude of the mechanical impact.

Because the damped transient is of a well defined frequency, it is possible to electronically filter out all other signals, i.e. low frequency vibration. The measurement and analysis of the maximum value of this damped transient is the principle behind the Shock Pulse Method for condition monitoring of anti-friction bearings.

The running surfaces of a bearing always have a certain roughness. When the bearing rotates, this surface roughness or a surface defect will cause mechanical impacts between the rolling elements of the bearing. The magnitude of these impacts is dependent on the surface condition and the peripheral speed of the bearing (rev/min and size) (in Fig 1 rev/min = 750, bearing iD = 40mm initial value of shocks dB_i=10).

Using the SPM Method, it is possible to measure the shocks caused by the above-mentioned surface roughness and then follow the progress of the bearing condition from the first sign of a deterioration through the different steps of increasing damage, until the bearing has to be replaced.

To simplify the readout of the large measuring range, the readings are given in dBsv (absolute decibel shock value) or dB_N (normalized decibel shock value). dB_N is the increase in measured value from the initially measured value of a correctly mounted and operated bearing. This initial value is called dB_i. The three different shock values have the following relation to each other.

$$dB_N = dB_{sv} = dB_i$$

Empirical testing has made it possible to relate the increase in measured shock value to the conditions in a bearing. This relationship is indicated also in Fig 1.

As mentioned earlier, the measured values and consequently also the initial values of dB_i are dependent on the speed and size of the bearing. Empirical tests and practical use show that the dB_i values can be calculated from the bearing shaft diameter and rev/min as shown.

The resultant dB_N has been proved empirically to relate to the true operational condition of the bearing in the following fashion:

dB_N less than 20 none or insignificant damage.

dB_N 20-35 early warning of damage under development.

dB_N 35+ visible damage.

dB_N 50+ risk of breakdown.

In practical terms, these bands, the first two designated green good, and yellow caution, the last two designated red damage, would indicate to the plant engineer what action is necessary. If periodic measurements are taken and plotted as shown in Fig 2 a practical decision can be taken as to when bearing replacement is necessary.

SPM INSTRUMENT TYPES

The SPM Instrument programme includes three basic instrument types:-

1. A simple to use hand-held periodic monitor, designated SPM type 43A (Fig 3).
2. A portable instrument with diagnostic recording facilities, designated SPM type 21A (Fig 4).
3. A continuously installed preprogrammed surveillance unit, designated SPM type 32B (Fig 5).

The SPM transducer is available in different forms depending upon the practical application.

Considering the first simplest instrument type 43A; the transducer may be of the permanently installed type cabled to an accessible point for connection to the instrument, of the bayonet quick-fit coupled type, particularly useful when the machine in test is vibrating heavily, or of the point contact type, of particular use for monitoring a large number of machines without having to prepare the bearings in any way.

The instrument type 43A is programmable for shaft speed and shaft diameter and thus dB_i as shown and shock value which exceeds the threshold set on the dB_N scale will give a sound output which can easily be identified with the ear-phone attachment. The SPM instrument type 21A can only be used with the permanently installed transducer or quick-fit coupled transducer but has the facility for recording or display of the shock value spectrum for analysis purposes. The measured shock value is displayed on a meter relating to dB_{sv} from which must be subtracted the expected dB_i to obtain the operational state of the bearing.

Either instrument 43A or 21A may be operated up to 100 metres from the measuring point.

The SPM system type 32B, which operates on a pre-programmed warning or trip condition, is ideally suited to super-critical installations where unexpected bearing breakdown could cause heavy consequential damage.

APPLICATIONS

Bearing condition monitoring with the SPM system has many fields of application. Economical considerations will determine which bearings should be monitored but quality and safety are also often factors of concern. Some typical applications are described.

The ability to predict the dB_i values makes possible quality control of newly installed bearings. Incorrect mounting will cause internal overload within the bearing and thereby an increase in readings. The capability used by machine manufacturers, allows potential trouble spots to be detected before delivery, which is essential for the future reliability and service demand of the machine equipment.

The SPM system is a natural aid in normal maintenance and repair work. Instead of preventive measures like replacing bearings before their lifetime has run out, it is possible to plan maintenance activities with respect to the actual machine condition. In practice, many users have been able to avoid costly replacements as the bearings (through SPM measurements) proved to be in a good condition. In some cases insurance companies have permitted an extension of inspection intervals, provided that the bearing conditions were properly monitored.

Condition monitoring of bearings will give increased security against unplanned machine shutdown. The SPM system will detect incipient damage so that necessary measures can be planned well in advance and carried out during a scheduled machine shutdown. This feature is of great importance in the process industry, where there are few scheduled shutdowns and any extra shutdown may cause considerable losses in production.

In many more cases than those mentioned previously, the SPM method has proved to be extremely profitable and it is now recognized as one of the best means to monitor bearing condition. The user is protected against surprises caused by bearing damage and the possible production and efficiency losses are reduced to a minimum.