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Verification of the operating condition of stationary industrial gearbox through analysis of dynamic signal, measured on the pinion bearing housing

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ABSTRACT

In order to ensure quality maintenance of rotary machinery, proper interpretation of the malfunction causes is required. The behaviour of the mechanical components of the machinery is often reflected in vibrations responding to the action of internal as well as external forces. The paper focuses on the issues of the application of the tools of technical diagnostics in verification of the technical condition of two-stage bevel-spur gearbox operating in difficult conditions of paper industry. Pinion bearing dismantled from malfunctioned gearbox was analysed. After repair, measurements were performed in order to determine the dynamic properties of the bearings. The values measured on the machine after repair were compared in two operating modes - depending on motor rotation speed. The acquired values of dynamic parameters and temperature (after repair) were in correlation to the condition found on the malfunctioned bearing (after dismantling form the malfunctioned gearbox).

1. Introduction

Modern maintenance strategy prefers proactive approach. Proactive maintenance is based on continuous activity, involving the monitoring and management of the basic causes of the malfunctions. It represents a strategy that uses corrective action to prevent the occurrence of malfunctions, whereas these activities are focused on the causes of malfunctions. This includes preventive as well as predictive maintenance. This can be used to achieve an environment that supports extended service life of the technical system. Proactive maintenance method is used to eliminate unnecessary maintenance, unnecessary general overhauls, unscheduled down time and excessive stock of spare parts. Across all industrial segments, proactive maintenance methods presently save thousands or even millions of dollars on machinery maintenance costs every year. This concept of saving large volumes of maintenance may often be considered erroneous. According to DuPont, "maintenance represents the biggest individual cost in their plants: In many companies, this cost often exceeds the net annual profit." Considering that up to 90% of maintenance work in some companies involves costly (and adversely affecting productivity) repairs after malfunctions, it is easy to see the benefits of such maintenance strategy. Maintenance of consequent (post-malfunction) and preventive type involves significant financial requirements. Therefore predictive maintenance is being implemented. This concept holds that repairs of machinery should be performed only on those parts and only when absolutely necessary. Predictive maintenance requires Condition Monitoring, i.e. monitoring of the symptoms of developing faults. This type of maintenance uses instruments of technical diagnostics, implemented across all pieces of machinery within the plant. Its effectiveness is greatly dependent on human factor, used technology and used instrumentation. The processes include vibration diagnostics, tribology, thermo-diagnostics, defectoscopy, etc. A successful implementation may bring cost savings of up to one half of standard maintenance costs. Long term analysis discovered that most failures repeat and have unique underlying cause [1–3].

Proactive maintenance involves all components of predictive maintenance, focusing not only on the current symptoms of machine condition (e.g. failed bearings), but also on the search and elimination of the causes of this undesirable condition (e.g. bearing failed due to improper set-up of the machine).

2. Diagnostics of rotary machines

Technical diagnostics uses various methods to serve the needs of machinery diagnostics. However, the measurements are often

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not interpreted or are interpreted incorrectly. For example, in diagnostics of vibrations, forces and energies are often neglected, which cause fatigue damage to machine components, reducing their service life. This may mean, for instance, that double force reduces the service life of bearings to 1/8 and the service life of the machinery is reduced from 5 to 10 years to several months [1].

Bearing diagnostics is a demanding field. Bearing damage may be a result of incorrect lubrication, water - contaminated lubricant, excessive forces, lubricant oxidation or degradation of additives. The bearing may be installed with excessive offset or overheated during installation, lubrication may be excessive or insufficient. All of these factors may shorten the service life of the technical system by several hours or even months [1].

In order to ensure quality maintenance of rotary machinery, proper interpretation of the causes of failures is required.

The behaviour of the mechanical components of the machinery is often reflected in vibrations responding to the action of internal as well as external forces. As most failures of rotary machines result in excessive vibrations, vibrations signals are used as indicators of the mechanical condition of machines. Every mechanical failure or defect generates a specific profile of vibrations. In order to be able to determine the cause and choose the appropriate remedy, it is necessary to identify the "type". Analysis of vibration signals focuses on two components - amplitude and frequency. Vibration frequency is an indication of the frequency of a particular occurrence over a certain time period (vibration cycle representing a single occurrence). Failure type may be indicated by the frequency of vibrations. When frequency of vibrations is determined, this may bring a clearer picture of the cause of the vibrations.

The amplitude is the magnitude of the vibration signal. Amplitude of the vibration signal corresponds to the severity of the failure. This depends on the type of the machine and is related to the level of vibrations of "good" or "new" machine.

Total vibrations represent total vibration energy measured within a particular frequency range. When total vibrations exceed normal level, it can be said that there is "something" that causes these excessive values. Vibrations of most machines have typical levels. When the machine is in a good technical condition, the frequency spectrum of vibrations has a characteristic shape. This frequency spectrum (frequency dependence of amplitude) may be considered a "vibration signature" of the machine, which can be obtained using frequency analysis of its mechanical vibrations.

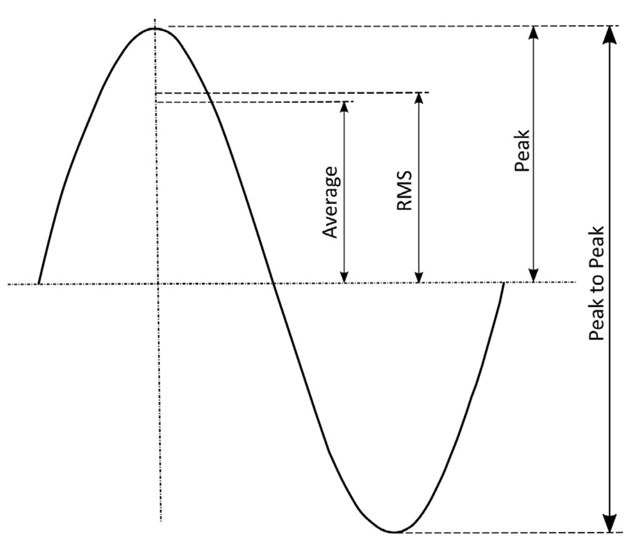

Fig. 1. Total vibrations parameters.

Vibrations are considered the best operating parameter that can be used to assess low-frequency dynamic conditions such as imbalance, misalignment, mechanical play in bearings, structural resonance, insufficient rigidity of foundations, deformation of shaft, excessive bearing wear or fractured rotor vanes. Frequency range used to perform the measurement of total vibrations, depends on the type of the used monitoring device. Some data collectors have a predefined frequency range over which total vibrations are measured. Other data collectors enable the user to select frequency range.

There is an ongoing discussion on what frequency range is best for the measurement of overall vibrations (although the ISO standard has been established already). It is important that the values being compared from a single location are measured over the same frequency range [1,4].

Measurement of overall vibrations applies the following parameters (Fig. 1) [1]:

- Peak value
- Peak to peak
- Average value
- Effective value (RMS)

3. Diagnostics of roller bearings - crest factor

Crest factor coefficient represents the basic method used in the diagnostics of rolling bearings. The method is based on the measurement of effective and peak vibrations and on the calculation of the PEAK/RMS ratio (Fig. 2). Since the ratio of the two values is analysed, this method is independent of the type of bearings and shaft speed.

Crest factor is a sensitive parameter for the occurrence of mechanical damage to the bearings, identified at the initial stage (5).

4. Rolling bearing diagnostics – HF (high frequency emission)

The measurement of HF is based on the fact that the energy of vibration increases across all frequency ranges with increasing damage. This parameter is also very sensitive to failure of lubrication. Emitted high-frequency energy is analysed with respect to the effective value and expressed in units of g (9,81 m/s^2). The values of g_{RMS} are dependent on the shaft rotating speed. Schematic shown in Fig. 3 is applied to the evaluation of the severity of the failure. The HF parameter is highly sensitive to lubrication faults. It indicates insufficient lubrication as well as the presence of mechanical contamination in lubricant [5].

4. Diagnostics of rolling bearings - envelope analysis

Another common method of vibration analysis is envelope analysis, which belongs to modulation methods group. The input signal is processed by modulator, that creates signal envelope. Thus, the energy contained in the signal is increased artificially and it is possible to apply for example effective value measurement (ENV RMS), which is more sensitive to damage than the effective value calculated from the signal before modulation. Envelope analysis is a method that not only indicates damage to the bearings, but in association with FFT analysis, it also enables to determine which part of the bearing is damaged. Inner and outer rings, rolling elements and bearing cage are identified for this purpose. As each of these components has different relative speed with respect to the shaft, it is possible to determine the frequencies where the failure shows. The following equations are used to calculate the failure frequency [5]: