USE OF MULTIPARAMETRIC DIAGNOSTICS IN PREDICTIVE MAINTENANCE

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The present article describes how to use multiparametric diagnostics in maintenance. First, the maintenance is defined and its history is briefly analysed. Subsequently, the maintenance is divided according to current considerations. It is stated that the proactive maintenance represents the state-of-the-art approach to maintenance management. The use of multiparametric diagnostics, such as vibration analysis, electrodiagnostics, tribodiagnostics, etc., is mentioned. A special attention in the present article is paid to the examples of the use of diagnostics in dynamic and static measurements. The so-called route diagnostics focusing on vibrations, as well as diagnostics of current and voltage values, power input monitoring, spectral analysis of current, and temperature, flow and pressure measurements are mentioned. The measurements of insulation resistance and other parameters of the device drive are also given. The text is supplemented with several pictures showing the results of specific diagnostic measurements from industrial practice.

KEYWORDS
predictive maintenance, vibration analysis, multiparametric diagnostics, trending of broadband vibration values, insulation resistance, polarization index, winding impact test

1 INTRODUCTION TO MAINTENANCE

In recent years, maintenance issues have been at the forefront of companies' interest.

Maintenance is generally a combination of all technical, technological, managerial, economic and administrative activities aimed at maintaining the condition or restoring to the condition in which the machine (device) can perform the required function. This previously neglected area plays a particularly important role as it is one of the supporting production processes that contribute to the increase in productivity and reduction of operating costs. [Ben-Daya 2009]

Similarly, such as any scientific discipline, also the maintenance has gone through its historical development. The basic and oldest type is the maintenance after the failure. With this maintenance strategy, a failure regularly occurs, and maintenance then resolves the consequences. Thus, the entire service life of the object is used, but at the expense of longer and, above all, unplanned shutdowns, high repair costs, redundancy of spare parts, negative impact on production quality, environment and safety. [Legat 2013]

Further development of maintenance was focused on the elimination of random failures through regular inspections, check-ups and repairs, often unnecessary and costly, i.e. on implementation of preventative maintenance performed at predetermined intervals (according to calendar or operating hours, number of cycles, etc.). [Opocenska 2016] During this maintenance, the intervention on the object is deliberately carried out before the risk of failure exceeds the acceptable limit, with the frequency of preventive activities often being determined only by estimation, regardless of the actual condition of the object under consideration. With some objects, failures arise despite preventive activities, but often, on the contrary, it turns out that preventive activities were carried out completely unnecessarily. It is therefore important to look for the optimum between the maintenance costs and the costs that would result from a machine failure, in particular the loss of preparedness. [Legat 2013]

Gradually, maintenance came to the phase when it began to deal with the technical condition of the device. In this phase, due to the methods of technical diagnostics, the maintenance can be scheduled even before the device fails or its required functions are limited. Maintenance according to the technical condition can be divided in compliance with the standard [CSN EN 13306] into diagnostic maintenance, predictive maintenance, and proactive maintenance.

A diagnostic maintenance or condition maintenance is based on the monitoring of characteristics or parameters and the subsequent maintenance activities taken. Traditional monitoring methods of device condition include the methods based on noise, leakage, overheating, surface deterioration, etc. These are the indicators of the device condition that use the subjective perceptions of human senses. Currently, due to the technical development of scanners and sensors, the physical properties of the device can be better monitored. At the same time, the methods used for the evaluation of the obtained data are becoming more perfect, allowing for better determination of technical condition of the device. [Legat 2013]

Predictive maintenance or maintenance based on the assumed condition is already a rather advanced management strategy for maintenance. It uses the ability to accurately evaluate the information provided to predict a future device condition. [Legat 2013] Therefore, maintenance is only carried out when the technical lifetime of the component is almost exhausted but before an unexpected accident occurs due to the failure of this component. [Nemecek]

Proactive maintenance is the state-of-the-art managerial approach to the maintenance and aims to make this process more efficient and cost-effective. It differs from all of the above-mentioned methods by not only investigating the current condition, its future development and prevention of failures, but also by trying to analyse and eliminate the causes of these failures. [Masin 2015] Proactive maintenance is based on the revelation that certain failures are repeated regularly and have clear causes, and in essence, it is a search for the ways how to eliminate or at least to delay the respective problem. [Nemecek]

In the Industry 4.0 concept, which is currently a fairly hot topic, the above-mentioned predictive and proactive maintenance will prevail with the use of intelligent sensor networks and the intelligent use of sensory data. The goal will be to plan the maintenance in advance so as to limit unplanned shutdowns of the individual machines. [MPO]

2 METHODS OF MULTIPARAMETRIC DIAGNOSTICS

Many methods of multiparametric diagnostics are used to predict the development of failures; today, these methods are used for both the long-term monitoring of the machine condition and also in search for the causes of failure of these machines.

To diagnose mechanical failures, the most common method is diagnostics of vibrations. This method offers several options. One of them is to monitor the trend (Fig.1) for broadband values of speed and acceleration of vibrations. A selection of

value and frequency band is very important for the evaluation of the device condition. Vibration speeds within the band up to 1kHz exhibit failures, such as imbalance, defective machine set-up, resonance, shaft deflection, etc. Defects of bearings, gearing, etc. are best found at higher frequencies of vibration acceleration or in an acceleration envelope using various frequency filters.
Today's methods allow for trending of not only the above-mentioned broadband values, but also, directly, failure frequencies of the machine parts.
From the analysis of vibrations, the evolution of machinery failure can be determined. In addition to monitoring the vibration trend, it is advisable to monitor the temperature of machine parts using resistance temperature sensors (e.g. operating temperatures of bearings and gearbox, inlet and outlet temperatures of lubricants, cooling water and air) or thermographic images.
Another application of multiparametric diagnostics is an analysis of motor power supply (dynamic measurement) which enables us to identify failures such as various voltage and current asymmetries, idle power loading, overloading of machinery, defects of asynchronous rotors, frequency converters, starters, etc. Devices are also monitored for pressures and flows of lubricants and coolants, where a reduction in pressure or flow of the lubricating medium may indicate e.g. clogging of a cleaning filter. Then, for example, we can determine, using a tribodiagnostic analysis of lubricants, wear of a particular machinery component on the basis of a particular material found in the lubricant.
During shutdowns and service inspections, we perform static tests on driving motors where we measure, for example, ohmic and insulating resistance of motor windings, polarization indices, loss factors, winding insulation strength, impact tests or partial discharges.

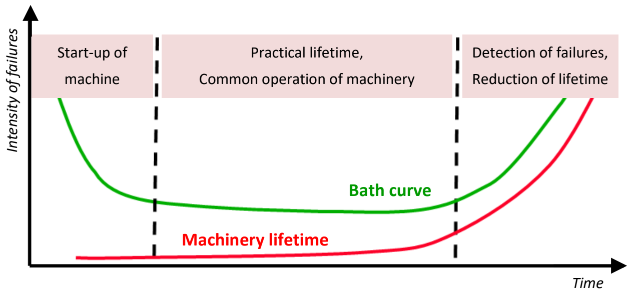

Figure 1. Trend of values – bath curve of machinery lifetime

Based on these tests and monitoring of the measured values over time, we can predict various wear of individual parts of the device and an increase in the potential risk of unplanned shutdown of the machine. Early intervention then prevents large production losses due to unplanned shutdowns of the machine and also reduces the cost of machine repair.

3 EXAMPLE OF USE OF MULTIPARAMETRIC DIAGNOSTICS

An example of multiparametric diagnostics can be the setting of the predictive maintenance methodology of the grinding production line and supporting equipment where one part of measurements is performed under ordinary operation and the other part during the service shutdown.

3.1 Dynamic measurement

Dynamic measurements are performed under ordinary operation of the machine. If we do not have ON-LINE diagnostics installed on the device, we do so at regular intervals, the so-called "route diagnostics". In this case, we mostly perform vibration, temperature, pressure, flow, and power supply and voltage measurements. It is important to set up a route (Fig. 2) and to determine the measurement points and measured variables to be monitored.

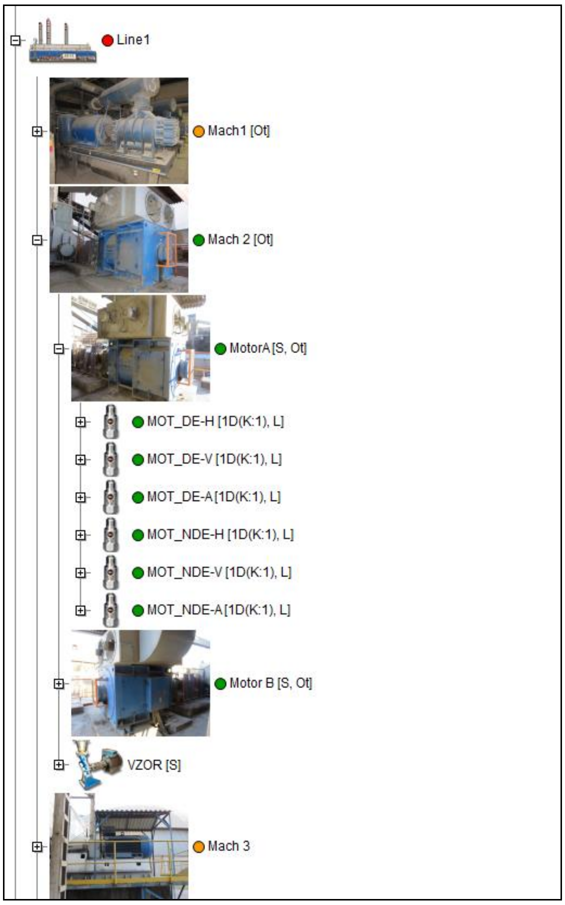

Figure 2. Example of setting the route for vibration measurement

Another important factor for selecting the appropriate diagnostics is a selection of proper method and measured parameters for monitoring of particular failures. An example may be the evaluation of vibrations using broadband value trending. Fig. 3 shows vibration velocity measurements up to 1 kHz and acceleration of vibrations up to 16 kHz.

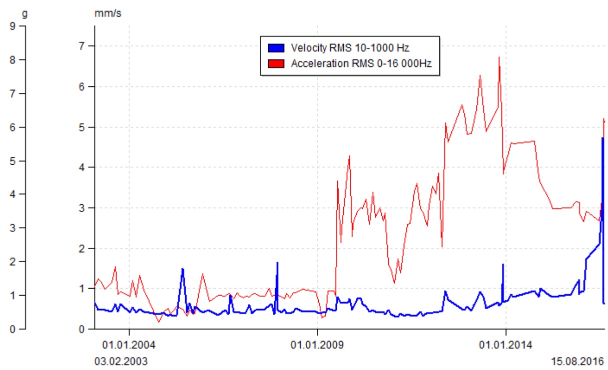

Figure 3. Example of speed and acceleration monitoring

From this figure, it is clear that the vibration acceleration (red colour) responded to the bearing defect much earlier than the vibration velocity (blue), when, as early as in the case of serious damage of the bearing, the vibration velocity responded very late, and its growth was very rapid. From the trend, it is also clear that if we have a parameter for evaluating certain defects properly defined, we will be able to predict the onset of failure well in advance and, therefore, to plan the maintenance of the machinery.

Another advantage of vibration monitoring is to track the trend of certain frequencies in the vibration spectrum. Here we can see the evolution of specific failures of the machinery. Fig. 4 shows a cascade of failure evolution of the outer ring of fan bearing. To monitor the evolution of failure, we can set the alarm values directly for the particular failure frequency of the device.

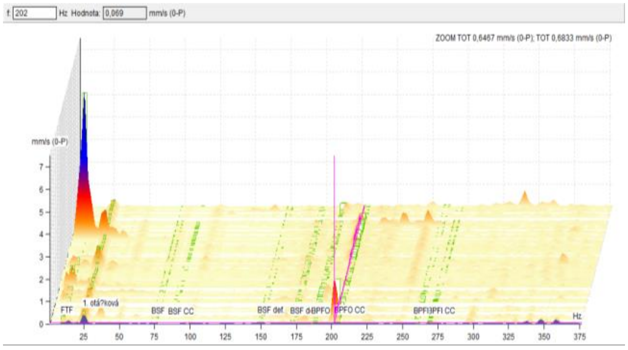

Figure 4. Evolution of the outer ring bearing failure

Similarly, we can record other parameters (dynamic), such as current and voltage values, power supply monitoring, spectral analysis of current, temperature, flowand pressure measurements.

3.2 *Static measurements*

This measurement is usually performed during service shutdowns of the machinery. One of the most common diagnostic measurements is usually the measurement of insulation resistance and other parameters in the drive of the device.

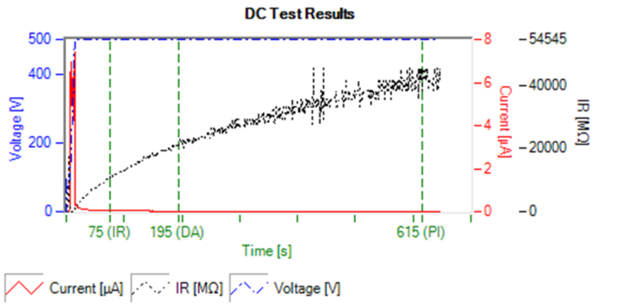

Figure 5. Example of measurement of insulation resistance and winding polarization index

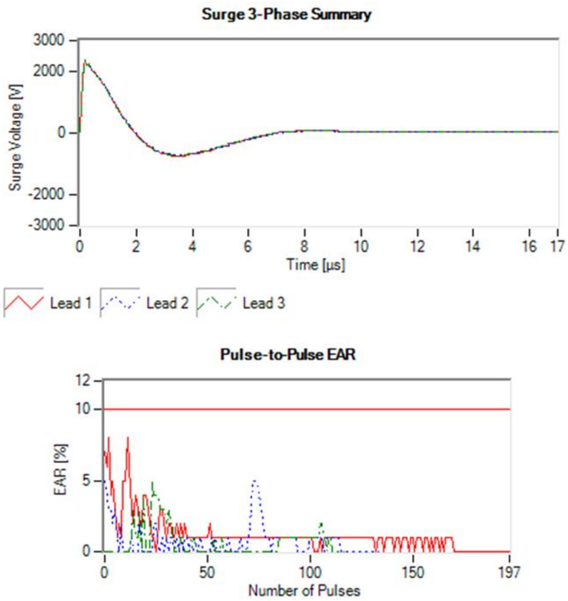

Figure 6. Impact test of winding (steep wave test)

We then record the measured results into trends and monitor the evolution of these measured parameters. An example may again be the measurement of static parameters of the asynchronous motor driving the machinery (Fig.5, Fig.6, Fig.7). However, we should not forget that certain measured parameters, such as winding insulation resistance, depend on the instantaneous temperature during measurement. In order to be able to compare the results for trending, we need to adjust the reference temperature, which is most often 20 ° C or 40 ° C.

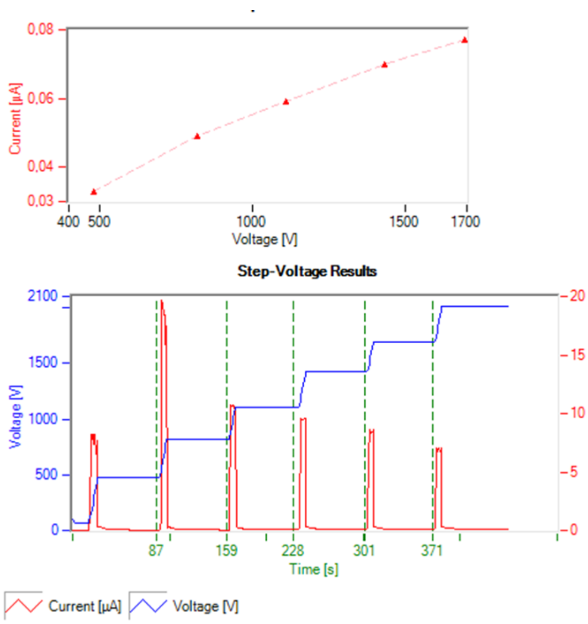

Figure 7. Step test – Dependence of leakage currents on voltage

4 CONCLUSION

For today's industry, the importance of multiparametric diagnostics is crucial. Many companies, where serious damage or financial loss can be caused to their machinery due to an insignificant defect, implement the regular route diagnostics or a more advanced ON-LINE multiparametric diagnostics.

The advantage of any diagnostics is that we do not necessarily wait until a failure occurs or a device totally breaks down, but we can try to timely detect the signs of failure onset or wear of the machinery. This timely revelation will help us to duly plan the repair without significant production constraints, to provide the necessary spare parts in advance and, ultimately, to achieve an overall reduction in the costs of maintenance and machinery operation, and to avoid financial losses in production.

This article solves the possibilities of prompt detection of faults of machinery and drives. The described diagnostics and its disciplines - vibration analysis, electro-diagnostics and other - serve this purpose. The above also serves as a guide how to use diagnostics in industry in predictive and proactive machine maintenance.

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