Analysis of tribological damages of plain bearings

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Abstract. Tribological processes and failure of plain bearings significantly affect the availability, adaptability, reliability and productivity of modern technology, maintenance costs, energy costs and the costs of modern production. The research of tribological processes and failure of plain bearings should indicate the possible causes and the necessary measures to be applied in order to reduce the tribological processes and failure of plain bearings. In this paper, possible causes of tribological processes and failure of plain bearings were analyzed. Having in mind the most important causes of tribological processes and failure, a proposal for monitoring the condition is given.

1. Introduction

The development of modern mechanical engineering is significantly related to the development of plain bearings. The correctness and reliability of machines and devices depend on the correctness of the moving parts, of which the plain bearings are the most important elements [1,2,3,4]. Tribological processes and failure of these vital elements can cause long delays in the process-oriented complex production systems that usually result in large financial costs in the business of companies, and also include legal liability [3,5]. Today, in the world extraordinary attention is devoted to the improvement of procedures for the prediction of tribological processes and the failure of technical systems and mechanical elements.

Plain bearings have a significant application in heavy mechanical engineering in the production of mills, turbines, crushers, etc. They are applied where it is not possible to use roller bearings, such as inaccessible places where the bearings should be two-part. Also, plain bearings are used for sleeves below 15 mm and above 300 mm, and also in assemblies where roller bearings will create vibrations and noise. The advantage of plain bearings is reflected in their load and stability. Plain bearings have been greatly improved. New materials are used for the manufacture of plain bearings, lubrication and cooling systems have been improved, the load capacity has increased, etc. Research on the wear and failure of plain bearings are numerous and they are presented in literature through various classifications, research of causes, manifestations and corrective measures, lubricant impact studies, diagnostic and research procedures [2,3]. Tribological research and the application of knowledge from tribology [2,6,7,8,9,10] both in the construction process and in the production and exploitation of plain bearings represent the necessity of the modern industry if its today's requirements are considered: economic use of materials, rational energy consumption and increased reliability of plain bearings.

2. Analysis of plain bearings wear and damage

Today there are clearly defined classifications of damage and failure for individual and the most important machine elements, and therefore for plain bearings. All documents and technical information are focused on identifying the modes of failure and determining the cause of the failure. The mode of failure is defined as the physical and/or chemical process that leads to the loss of a given function and the phenomena or symptoms that are caused by the failure process. Causes of failure are those conditions that lead to a registered failure.

In order to reduce the delay due to the failure of the plain bearings of the TE power plant Gacko, it was necessary to analyze tribological processes and damages. At TE power plant Gacko turbine K-330-240 and generator TVV 320/2 were installed. Figure 1 shows the disposition diagram of the turbogenerator. The TE power plant Gacko is disconnected from the drive after switching on the sub-frequency and grounded 100% protection of the generator stator, due to the disappearance of 400 kV and 110 kV voltages. The lubrication pumps of the turbogenerator of the DC voltage did not switch on. The sealing pumps of DC generators have been switched on by activating the automatic start of the reserve. Nine minutes after the disappearance 400 KV voltage comes and then the own power supply of power plant is turned on. Voltage 110 KV comes a minute later, after which the power supply state is normalized. During the stopping of the turbogenerator with the reduction of the vacuum, the flow of oil from gravity reservoirs to all plain bearings was activated. This paper presents a part of tribological research, damage and causes of plain bearing failure. Tribological processes and damage on a plain bearing number seven were analyzed. Figure 2 shows the vibration trends during normal stopping of the turbogenerator from 2950 rpm to 0 rpm. The display of the basic induction frequency (1x) on the plain bearing during interruption is given in figure 3. It shows a high vibration speed of 15 mm/s. Due to the touch of the rotor and the stator during the reduction of the rotation of the rotor, inadequate damping occurred.

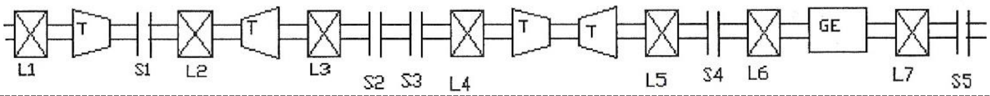

Figure 1. Disposition scheme of the plant.

During the stopping of the turbogenerator, the temperature of the plain bearing has an increasing trend, and after a few minutes the trend of decreasing and stabilizing. After establishing a regulatory lubrication system, the temperature of the plain bearing continues with the trend of increase. The absolute vibration of the turbogenerator of plain bearing has a leap after the unit is switched off to the resonant revolutions of turbine rotor and the rotor of the aggregate.

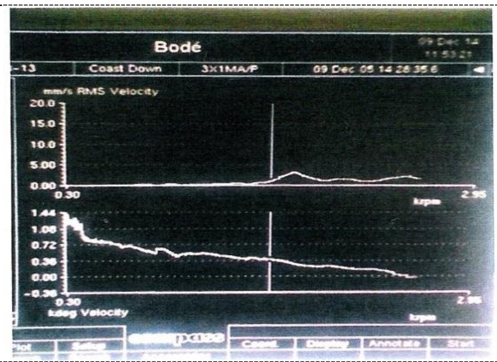

Figure 2. Diagram of the basic induction frequency of vibrations in the vertical direction on the plain bearing number 7 during the normal stop of the turbogenerator.

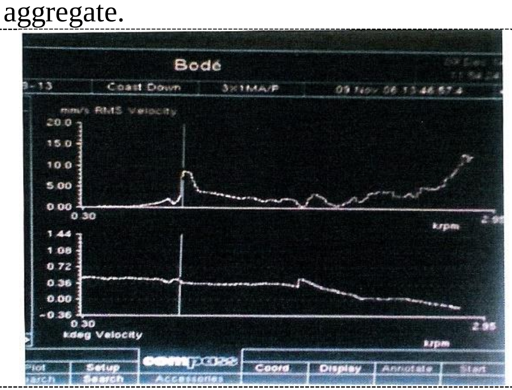

Figure 3. Diagram of the basic induction frequency of vibrations of zhe plain bearing number 7 during interruption.

On the plain bearing, the sensors of the relative rotor vibrations were not installed, so the rotation of the generator rotor during the emergency stop could not be monitored. The aggregate was stopped for 15 minutes, and after turning on the lubrication pumps of the turbogenerator plain bearings, the turning device was switched on to rotate the turbo generator with 3-5 rpm. After stopping the aggregate, cooling the turbine and switching off the lubrication system, the plain bearing and corresponding joint were opened. Damage of the joint is not registered. Greater damage was detected on the plain bearing. White metal was melted at bearings number 6, number 7 and number 8. On the journal of the generator rotor the rills were noticed which depths are about 2 mm in two rows with a total width of about 80 mm (figure 4). In the figure 4 traces of damage on the journal are visible, as well as belts of increased hardness (darkened areas). All damages are in the middle of the trigger journal. Circular surfaces are treated parts of the journal during the previous deviation at the places of residual cracks after the fine machining. The plain bearing journal was repaired and control of surface cracks was performed.

White metal deposits settled in the oil inlet on the right half (to the excitation), as can be seen in figure 5. Due to the closing of the part of the oil supply channel, partial interruption of the lubricating oil supply occurred and removal of the metal from the surface of the journal occurred in that part.

Figure 4. Damage of journal in the bearing zone.

Figure 5. Damage of bearing brass no. 7.

On the journal of the generator axle in the zone of segment bearing number 8 (journal diameter is Φ200 mm) the surface was damaged and the cracks were noticed as shown in figure 6. Due to the appearance of cracks, the continuation of the rotor is unusable and a new one was made of steel 34CrNiMo6 according to the existing documentation. The adaptation of bearing brass to the bearing journal number 7 is shown in figure 7.

Figure 6. Damage of axle extension of the generator.

Figure 7. Adaptation of bearing brass to the bearing journal number 7.

Vibration intensity of bearings number 1 and 3 of was directly dependent on the load on the block. This is clearly seen on the spectral overview of vibrations of bearing before the block power is reduced (figure 8). On the half-harmonic 1/2X vibration rate is 1 mm/s, and at 3/2X it is about 0.8mm/s. As the power of the block was reduced vibrations decreased, at a speed of about 7-8 mm/s to a value of 6-7 mm / s. The component of the vibration on the half-harmonic 1/2X, 3/2X, 5/2X disappeared (figure 9).

In order to reduce the turbine's vibration level, a reduction in block power from 240-250 to 210-230 MW was carried out, i.e., the boiler was power from an electric power pump instead of turbocharging pump.

In an electric power pump mode with a load of 210-230 MW, the vibrations of the turbines are lowered to the B class for this type of device and, with additional control limits, the block operation is further extended.

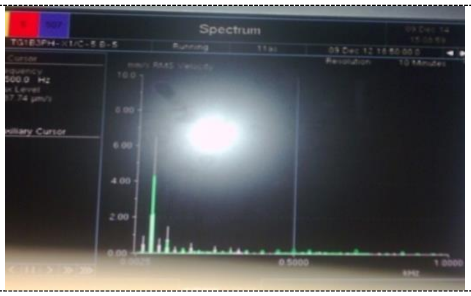

Figure 8. Spectral diagram of vibration of bearing number 3 horizontally before reducing the block power.

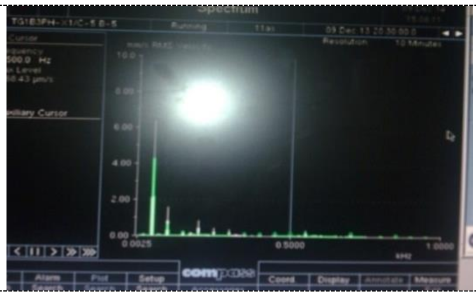

Figure 9. Spectral diagram of vibrations of bearing number 3 horizontally after reducing the block power.

The block was stopped in order to determine the cause of the increased level of vibrations of the turbine bearings number 1 and 3. After cooling the turbine, the turbogenerator bearings were opened and an overview was performed. On the first bearing, there are visible traces of damage on the part of the white metal surface on the lower half of the insert (figure 10). The removal of white metal on the lower half of the surface of the plain bearing due to the failure of the rotor of 0.16 mm is also visible. According to the character of the damage, it is clear that it is an electro-erosion corrosion that occurs due to the breakdown of the vortex currents from the rotor to the stator part (contact surface of the bearing brass number 1). The rehabilitation consists of showering of the bearing surface, adjustments to the caliber and re-assembly.

In the figure 11 the trends of vibrations of the plain bearing at the time of the turbogenerator stopping from 2950 rpm to 0 rpm are shown. They were recorded by the Compass Schenk turbogenerator control system. The second speed peak of the total vibration level up to 10 mm/s is at 900 rpm, i.e. on the critical rotational speed of the generator rotor. Based on the vibrations during the turbogenerator stopping, it can be noticed that the aggregate on the plain bearing already at a speed of 2950 rpm., immediately after switching off the block, it had a contact of the rotor with the stator part.

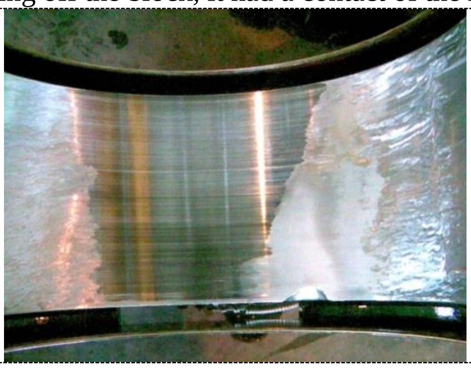

Figure 10. Damage of the lower half of the bearing brass due to electro-erosion corrosion.

Figure 11. Diagram of the level of total vibrations on the plain bearing during stopping the turbogenerator.

The analyzed turbogenerator plain bearing has a reservoir for emergency lubrication, whose task is to prevent break-down of the journal of turbine rotor and generator. The bearing brass on the generator has been completely damaged. It can be noticed a significant damage of the journal.

Based on the analysis, it could be concluded that the resulting damages were the result of an irregular operation of the emergency oil reservoir. By analyzing the data from the figure of the control system, as well as the vibration monitoring system of the turbogenerator, it can be ascertained:

- the vibration of the plain bearing has increased sharply to 15 mm/s for 50 seconds after the unit has been switched off after the critical revolutions of the generator have passed
- the mentioned vibrations initiate on the contact of the rotor with the stator part of the plain bearing
- it is obvious that there are reasons that influence the shutdown regime of the generator rotor when problems arise due to the disappearance of the forced lubrication system.

3. Conclusion

Tribological processes are the main causes of damage and malfunction of plain bearings. Systematic study of the process of wear, standardization of tribometric methods and the development of real data on the tribological characteristics of the most important types of materials used today for plain bearings is significant field of research in the field of damage of plain bearings.

There are a number of causes that can lead to plain bearing failure. The most common cause of failure is inadequate and insufficient lubrication of the plain bearing.

Maintenance according to the condition, i.e. proactive maintenance of the entire system, including plain bearings, will provide significant technical and economic effects.

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