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MEASURING CLEANING CLASS OF OIL AFTER TRIBOLOGICAL TESTING

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Abstract: *A lot of literature is devoted to the identification of wear particles obtained in order to monitor the status of technical systems and the analysis of wear. The biggest influence on the process of wear have solid particles having a size equal to the size of the gap, but have little impact particles whose size is three times smaller than the size of the gap. Today, various physicochemical methods and tribological methods are using for diagnosing tribomechanical system. The paper presents analysis of oil samples containing particles resulting from wear after tribological tests on a sample of lead tin bronze CuPb22Sn1,5 and homogeneous material alloy ZA27 sliding speed V = 1 m / s and three different values of normal force Fn = 10 dN, Fn = 15 dN i Fn = 20 dN. Mobile instrument for on-site oil analysis have been used in the tests.*

Keywords: *particles, contamination, friction, wear, standard.*

1. INTRODUCTION

Tribological problems in the moving parts of the technical system are the main causes of failure, so the special attention is paid to reducing friction and wear and lubrication in these systems. Due to the tribological processes in the contact zones tribomechanical system creates gaps greater than allowed. In case of increased gap in tribomechanical system problems arise reaching the working pressure, rapid warming, an increase in noise level, rapid wear of structural components, and a range of other phenomena. The choice of materials, lubrication and tribology properly construct can be an effective tool for reducing friction, wear the tribomechanical systems.

The reliability of the moving parts of the technical system significantly affects the purity of the working fluid contaminated water and destructive solid particles of different origin, composition, size and shape. Elevated levels of wear and tear cause a significant increase in the concentration and size of particles worn. Solid particles of contaminants significantly affect the operation tribomechanical system in which the present mechanism of contactless sealing.

Contamination of the working fluid by solid particles ranging in size from a few nanometers to a few micrometers is responsible for increasing the wear and catastrophic failures tribomechanical system. Wear, which can cause contamination such as abrasion, surface cutting, flaking, fatigue, and even scraping depends on the operational conditions and the mechanical properties of particles.

Contamination of the lubricating oil in the broadest sense, encompasses all the processes that lead to changes in its characteristics, and structural and functional degradation. Contamination of the lubricating oil leads to a minor or major damage and dysfunction of the technical system of which it is an integral part, since oil, performing his function, comes in contact with all components of the system.

2. NEGATIVE INFLUENCE OF THE CONTAMINANTS

Mechanical impurities and water present in primary form, external contaminants introduced into the tribomechanically system from the environment. Products of chemical reactions have been generated within the system.

Mechanical impurities are the most common source of contamination of oil and basic cause of the process of wear of contact surfaces in the system which lubricates.

The primary form of mechanical impurities penetrate into the technical system from the environment, causing contamination of the oil, stimulate the tribological processes in the system and degradation of the lubricating oil resulting in secondary contamination (products of wear process in the system).

Solid contaminants can occur during manufacturing and assembly process can be generated by wear, enter from the outside, introduced during the maintenance and repair of technical systems. In all contacts between the mechanical elements is constantly a large number of contaminants, which reduce the service life of the analyzed components, mechanisms and machines.

The mechanism of action of solid particles on the wear behavior, performance and service life of components is multiple and complex. The particles in the fluid flow through components tribomechanical system, a part of them comes to the surface in contact and accelerates the process of wear and tear.

All cases of operation the particles can be reduced to elemental contact base area, which is stationary, rotating or moving translationally with solid particles carried by the fluid. On that occasion, give rise to different wear processes, most often abrasive, and less erosive wear.

Large particles (up to a millimeter) have been often included in the mechanical system due to ineffective sealing between the mechanical system and the external environment, so that in this way the system were entering the air, dust, sand, metal shavings, etc.

The consequences of increased oil contamination can cause, if present [1]:

- coarse particles (>15 µm) - surprised outbursts component,
- fine dirt (5-15 µm) — wear and damage to components,
- fine dirt (<2-5 µm) - sediment accumulation of soluble and oil-soluble, rapid aging oil,
- water in oil - corrosion, increased wear and damage to components, accelerated aging oil.

Oils and lubricants often contain such contaminants that have been either generated within the tribomechanical system or entered from the external environment. Contaminant particles may be entered in the tribological contact between the elements in contact and damage the mating surfaces of the elements within them. A large number of such individual defects can cause great damage to the elements and the technical system as a whole.

Lubricating oil in addition to the basic role of the separation elements and the reduction of friction and wear tribomechanical system can give us important information about the state of the technical system. Lubricating oil is an important element of many technical systems over an extended period of time performs various important functions. Analysis of lubricating oil includes a large number of tests whose primary objective is to determine the ability of an oil to carry out functions which it is intended. These tests also provide us with important information on the state of the technical system and all its components that come into contact with lubricating oil [2].

The oil in the lubrication system always contains some level of particulate contamination. The oil can be contaminated even get started tribomechanical system. Bearings with the sliding elements are especially susceptible to damage caused by the particles contained in the oil. This is because the skate on smooth surfaces and require a thin oil film separating in order to function properly. Worn particles are usually larger than the thickness of the oil film, so when they are caught in contact deplete the touchpad. This leads to the initiation of cracks which later lead to fatigue or to abrasive wear [3].

Analysis of the lubricating oil is a set of well-known and widely used procedures for many years routinely used in the context of all known concepts maintenance of technical systems, as well as completely new, recently developed technologies.

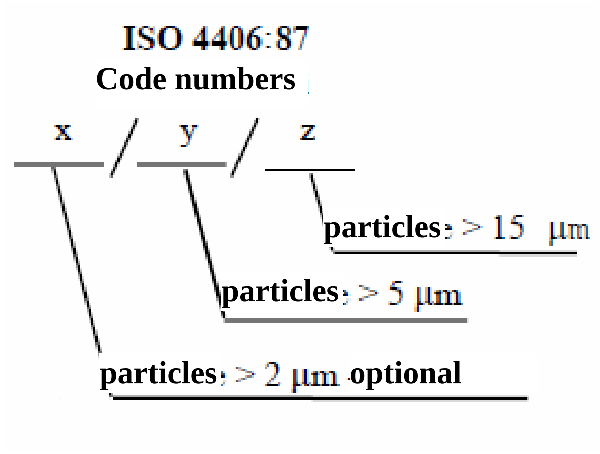
3. SYSTEM DEFINITION BY CLASS OF PURITY STANDARD

Due to contamination of the working fluid must be given special attention, it is very important to know and understand the standards and interpretation of the content of solid particles in the working fluid. There are a number of different tests in the analysis of the oil used in the assessment of his condition. The test should cover the area of interest that is the impurities in the lubricant. For the assessment of oil contamination by solid particles in accordance with ISO 4406 and NAS 1638 (National Aerospace Standard) standards used electronic particle counters. The generally accepted and commonly used method to determine the level of contamination of the working fluid by solid particles is defined by the ISO 4406 [3, 4].

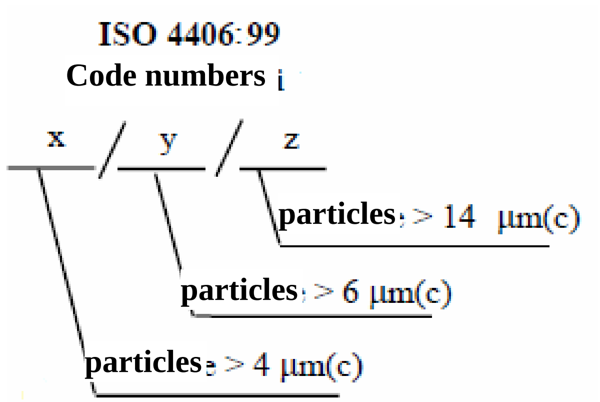
As a result of many similar studies, ISO has developed a universal standard for measuring and marking the level of contamination in the fluid known as ISO cleanliness codes, such as in 4406: 1999. Measurement of the number and size of particles in a sample fluid, followed by the addition of ISO code from the table. The code is then compared with a set code for a given mechanical system, which is determined based on the allowable degree of wear and optimal working life [3, 4].

Contamination of the working fluid by solid particles has been determined by assigning a corresponding code number according to a defined standard. It should be noted that different standards have different code numbers for the same class of cleanliness of the working fluid.

Classification of solid particles by the earlier ISO 4406 occurred within the 24 code groups of 1 to 24, according to a new standard from the year 1999 (the same code 4406) carried out in 29 groups of 0 to 28. The previous standard counts the number of solid particle size of 5 and 15 micrometres (optionally subsequently introduced and the size of 2 microns) in 100 ml of the sample, while new in 1 ml oil samples counted solid particles size 4, 6 and 14 micrometres (c) measured in three dimensions (Picture 1 and 2) [3, 4,5].



Picture 1. Class of cleanliness according to the old ISO standard



Picture 2. Class of cleanliness according to the new ISO standard

When defining the number of solid particles in the oil sample should be borne in mind that it is still calculating the total number of particles larger than the size indicated.

This means that the number of solid particles in the size [5]:

- 4 µm, inclusive of all solid particles greater than and equal to 4 µm, and the particles of a size 6 i 14 µm;
- 6 µm, inclusive of all solid particles greater than and equal to 6 µm, and the particles of a size 14 µm;
- 14 µm, inclusive of all solid particles greater than and equal 14 µm.

The number of particles can be determined by a laser or the optical method. Laser method gives the amount, size and distribution of the particles, whereas the optical and method provides identification. Use a combination of both methods. The results of determining the amount of the particles is usually expressed by the ISO scale of purity.

When checking oil condition in practice it is necessary to respect the applicable technical standards and measurement methods in the field of hydraulic systems and the state of lubrication system. Diagnostic equipment should be in accordance with applicable standards, tested both in laboratory and in field conditions and suitable for the purpose. Measured values are kepting at checkpoints, processed and displayed.

There are several tests that have been developed for the purpose of conducting the analysis of particulate contamination of the oil. To perform these tests have been well developed and they are still being intensively developed instruments and equipment, in the laboratory, as well as those for the implementation of on-site analysis.

Long is the analysis of lubricating oil has been based solely on the use of specialized laboratory services. The appearance of the first mobile instrument for on-site analysis of lubricating oil was a significant progress that has brought many benefits such as:

- analysis in real time,
- the current results of the procedures carried out oil analysis,
- possibility of unlimited repeatability of measurements, if necessary,
- measurement and analysis conducted by people who know the equipment and machinery,
- a significant reduction in costs related to laboratory services, sampling and shipment of samples,
- reducing the opportunities for the emergence of errors and contamination of samples,
- the ability to control the input oil and,
- significantly shorter time between the implementation of contamination control and proper maintenance actions.

This method of oil analysis is a fast, efficient and cost-effective with high sensitivity and thanks to the benefits that owns represents a powerful predictor of cancellation of technical systems.

4. EXPERIMENT

Based on tests of tribological properties of lead tin bronze CuPb22Sn1,5 and alloys ZA27 the speed slading V=1 m/s and three different values of normal force Fn=10 dN, Fn=15 dN i Fn=20 dN, came to the conclusion that they should check the presence of these particles in the contaminated oil.

Detection of particles in the oil was carried out at the Faculty of Mechanical Engineering in Kragujevac.

Equipment that is used consists of: sensors, measuring devices, peristaltic pump, systems for data acquisition in the computer, software and computer equipment for data storage. The equipment is easy to operate in real time to obtain reliable and accurate information about the level of cleanliness of the working fluid according to standard ISO 4406:1999.

The measuring system is shown in Picture 3. This measuring system enables measuring the amount of particulate matter, temperature and relative humidity.

Picture 3. Measuring system

Analysis equipment today is standard equipment for oil analysis laboratories, which provides information on the state relatively quickly and accurately.

The device for determining the degree of purity of the oil contains:
- sensor part (located in the device),
- source of laser diffraction of rays those passing between the working fluid stream (particles passing by detectors, are covering it generates a voltage proportional to the size / number of particles),
- section for signal processing and
- part to show results.

The device is a high performance, designed to provide precise measurement results. The device counts particles with high resolution in four particle size channels, available via the interface data for the report in real time on PC, purity according to standard ISO 4406:1999 for particle size classes > 4 µm, > 6 µm, > 14 i > 24 µm that are displayed on the screen of the instrument. (Picture 4).

In order to lead particles in the test device a peristaltic pump Seko PR7 (3.5 W) is used. The peristaltic pump has been designed to transfer the contaminated oil without additional contamination. The working principle of the peristaltic pump is to be inside a circular shield pump is a rubber hose pressed 2 diametrical opposite rollers which are located on the shaft. Rollers is pushing oil, so it's a very small impact on the oil to be transferred. The oil has been transferred within the hose is 7 l / h with pressure up to 0.1 bar.

The measured values are collected and processed by using software that was created in Windows applications.

The software allows the creation of new data has been performed on the basis of the measured value. Software quality reflects in the review work environment that provides numerical and graphical representation of the signal.

Undissolved air in the fluid mass presents in the form of bubbles, and it needs to be forced out of the fluid in the ultrasonic tubs. In the absence of ultrasonic tub bubbles gently squeeze the circular motion of the sample. Thus, small particles by this method have been evenly distributed in the sample oils creating a homogeneous environments.

Improperly prepared samples can easily ruin the previously carefully prepared conditions for testing.

Collecting oil sample has been carried out in safe conditions and in a manner that does not introduce dust and other impurities in the sample. Pump for sample extraction of oil from the vessel after a tribological test was using properly in order to avoid further contamination of the oil sample, and each sample was labeling before testing.

The amount of sample was diluting with hydraulic oil up to 200 ml and allowed to flow through a small capillary tube that moves through the field of sensors. The laser sensor measures the size and quantity of particles in the contaminated oil every 10 sec.

During the experiment data measured sizes displayed on the monitor screen and saved on computer disk.

This application allows:
- collecting device data continuously over time,
- display (numerically and graphically) the value of the measured values in real-time,
- creating data files measured values stored on the disk of a computer and
- display of measurement results.

Measuring the amount of particles carried in the device via laser sensors every 10 seconds per 32 signal after each sample.

There have been measured only basic parameters: the amount and particle size, temperature and relative humidity.

The device detects small and large particles up to 24 microns. These coarse particles of 24 microns are particularly important because they represent the first indicators of increased wear intensity.

The oil sample has been excited so that each particle emits or absorbs a certain amount of energy, that indicates the concentration of particles in the oil.

Results represent the concentration of all dissolved and metal particles. The results include a report on the size and amount of particles as well as the temperature and relative humidity.

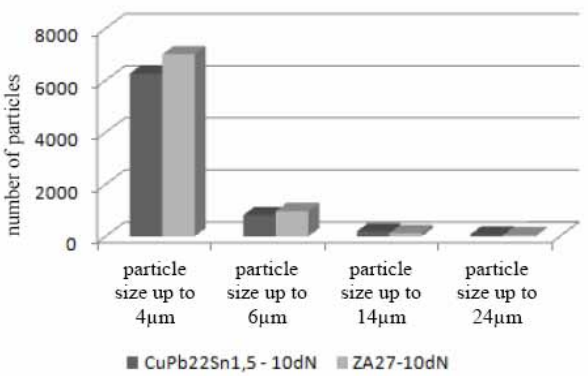
Picture 4. Measuring the purity class

5. ANALYSIS OF THE RESULTS

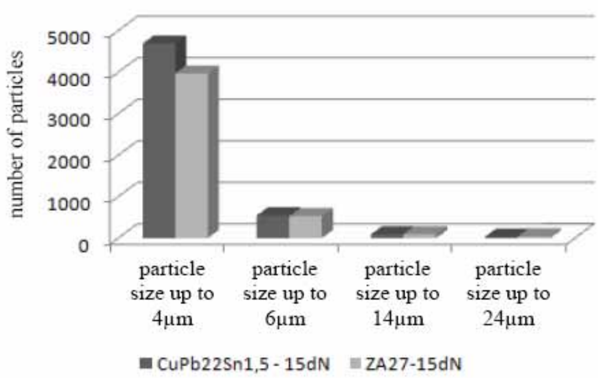
Based on the results of measurements of oil-contaminated particles leaded tin bronze alloy ZA27 CuPb22Sn1,5 and determination of the number of particles arithmetic mean, a set of obtained data are shown in Table 1.

Table 1. Class of cleanliness according to the standard ISO 4406:1999

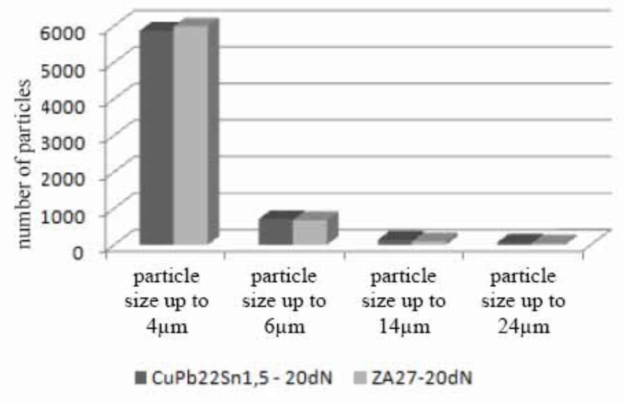
Sample	ISO - to 4µm	ISO - to 6µm	ISO - to 14µm	ISO - to 24µm	particle size up to 4µm	particle size up to 6µm	particle size up to 14µm	particle size up to 24µm
CuPb22Sn1,5-10dN	20	17	15	13	6264	822	193	75
CuPb22Sn1,5-15dN	19	16	14	12	4688	545	90	34
CuPb22Sn1,5-20dN	20	17	14	13	5866	707	140	62
ZA27-10dN	20	17	14	13	7006	976	134	48
ZA27-15dN	19	16	14	12	3968	530	93	40
ZA27-20dN	20	17	14	12	5988	676	97	37



Picture 5. Number of particles from 4µm to 24µm for CuPbSn1,5 and ZA27 with loads 10dN



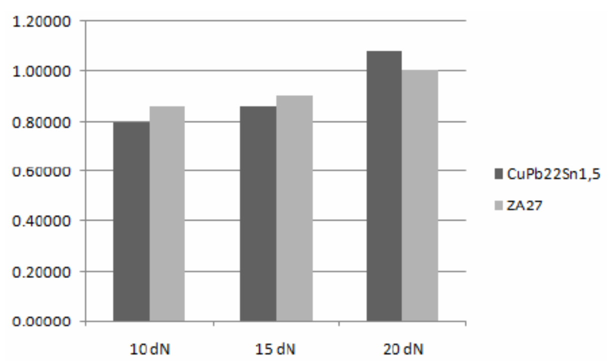
Picture 6. Number of particles from 4µm to 24µm for CuPbSn1,5 i ZA27 with loads 15dN



Picture 7. Number of particles from 4μm to 24μm for CuPbSn1,5 i ZA27 with loads 20dN

In Picture 5, 6 and 7 comparative results of the particle size of the alloy of lead and tin bronze CuPb22Sn1,5 A27 depending on the normal force at tribological test lubricated are presenting with histograms.

After tribological tests on a universal measuring microscope UIM-21 have been obtained measurement results widths wear on contact surfaces leaded tin bronze alloy ZA27 CuPb22Sn1,5 and loads in the normal force Fn = 10 dN, dN = 15 Fn Fn i = 20 dN. (Figure 8.)



Picture 8. Tread wear leaded tin bronze CuPb22Sn1,5 ZA27 alloys in the function of normal force.

Taking into account the results of tribological tests and the results of wear track width on the basis of the results of the experiment and the number of particles conclude:

- track width is greater in alloys ZA27 at normal force Fn = 10 dN and Fn = 15 dN in a lower normal force Fn = 20 dN,
- at the normal force Fn = 10 dN track width is greater in ZA27 alloy and the number of particles larger than 4 μm and 6 μm,
- at the normal force Fn = 15 dN track width is greater in ZA27 alloy and the number of particles larger than 14 μm and 24 μm,
- at the normal force Fn = 20 dN track width is greater in ZA27 alloy and the number of particles larger than 6 μm, 14 μm and 24 μm.

Also, based on the tabulation (Table 1) it can be concluded that the concentration of particles CuPb22Sn1,5 and alloys ZA27 minimum load in the normal force Fn = 15 dN.

5. CONCLUSION

The paper analyzes the presence of particles in the contaminated fluid after tribological tests leaded tin bronze CuPb22Sn1,5 and alloy ZA27 the speed sliding V=1 m/s and three different values of normal force Fn=10 dN, Fn=15 dN and Fn=20 dN.

Applying this measurement and combining the rationale behind the analysis of fine and coarse particles in the contaminated oil, depending on the mode of tribological tests can also get complete image analysis worn particles of a certain tribomechanical system. On this basis, it can be concluded what measures and procedures should be undertaken in the stage of construction and operation in order to achieve an optimum service life and minimal maintenance costs of the technical system.

Modern methods of constructing technical systems must take into consideration tribological processes that occur during their use, but the tribological properly construct their imperative.

This test may represent a diagnostic-forecasting technique that provides a convenient way of assessing the exact on-line status lubricated parts in contact without switching the technical system.

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