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APPLICATION OF MOBILE DEVICE FOR OIL ANALYSIS

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Abstract: *For years, the implementation of the oil analysis was limited to a specialized laboratories, but the emergence of proactive maintenance concept, cause intensive development of devices and sensors that strive in direction of miniaturization, automation, performance enhancement and creation of multi-functional diagnostic systems. Proactive maintenance strategy involves continuous monitoring and control of the basic failure causes, among which oil contamination stands out as the most common, serious and generally widely accepted cause of failures in the industry. In this paper is shown part of measurement results obtained with mobile device for oil analysis, which allows us to determine the concentration of wear particles and water in oil. All measurements are done on pin on plate reciprocating tribometer. There are shown results for 4 characteristic working regimes.*

Keywords: *Oil contamination, oil analysis, wear particle, water in oil, reciprocating tribometer*

1. INTRODUCTION

For a number of years oil analysis was widely accepted as one of the standard methods for the condition monitoring of technical systems, primary focused on determining the optimal replacement point for lubricants and oils [1]. As almost changeless factor, there was accepted that oil analysis is mainly laboratory based activity, owing to the complexity of the equipment and expertise of staff that carried out the analysis and interpret test results. Practical experiences in our country shows that this classic concept of oil analysis in industry, based on the use of specialized laboratory services, had a relatively limited use, usually only for special and highly responsible systems, and it failed to become viable as a widely accepted practice [2].

The appearance of proactive maintenance concept caused significant changes in the way that maintenance experts treat oil analysis. Proactive maintenance is focused on identification of failure root causes instead on early signs and symptoms of failures, like predictive maintenance. Although the number of potential failure root causes is large, it is shown that only 10% of all root causes is responsible for over the 90% of failures [3]. With clear identification of failure root causes it is possible to eliminate or minimize the causes that lead to a failure. The result is extended service life of technical systems and significant reduction in maintenance costs. In that sense, any activity aimed on determining the failure root cause is considered as a proactive.

There are a very few mechanical systems that do not require any lubrication. A large number of surveys and studies conducted in laboratory or in industrial surrounding have a unique conclusion, that the degradation of contact surfaces will cause a failure of technical systems in more than 70% of cases [2]. These results are a cause of complete redefinition of the oil analysis position in modern industrial practice. It got one of the central places within the concept of proactive maintenance strategy. Oil analysis has became one of the key tools in monitoring of occurrence, intensity and development of tribological processes within complex technical systems, as well as for diagnosis and monitoring of various forms of oil and lubricant contamination in industry.

Global industry development in last decade is characterized by initiating various projects and programs focused at defining, achieving and maintaining the low levels of industrial oil and lubricant contamination. The results are greater savings, achieved by reducing downtime, extending component and system life and significantly reduced oil consumption [4-7,10]. This period is characterized by intensive development of devices and sensors that strive in the direction of miniaturization, automation, performance enhancement and creation of multifunctional diagnostic systems. It should also be noted that the main manufacturers of instruments and equipment have a leading position not only in practical, but also in the theoretical and scientific work. They have strong research teams that constantly move the limits and make improvements and enhancements. The fact that the basic standards and regulations in this area are changed very frequently present sufficient evidence on the dynamics of changes and the existence of a space for further research and development.

2. OIL CONTAMINATION

The term contamination in hydraulic systems includes all the processes that lead to temporary or permanent changes of exploitation characteristics of hydraulic oil, in terms of changes in its physical and chemical properties, structural and functional degradation. Any unwanted and harmful element (in solid, liquid or gaseous state) located in the hydraulic oil has negative consequences for the system and its called contaminant [11]. Oil spreads contamination particles to all components in hydraulic systems and, depending on the severity level, inevitably causes minor or major damages and functional disorders in the entire hydraulic system.

Main contaminants of hydraulic systems are:

- mechanical particles,
- water and
- products of chemical reactions and fluid degradation.

Among these basic contaminants there is a strong cause - effect connection. For example, increasing of the water content in the working fluid directly affects the dynamics and intensity of chemical processes, where the solid particles in a fluid behave as catalysts. On the other hand, water in hydraulic system causes the development of corrosion process, which results in the creation of mechanical particles. Water also affects the reduction of oil viscosity and leads to intensive wear processes. Mechanical particles and water are external contaminants that are entered into the system from the environment. Products of chemical reactions are generated within the system itself. Presence of these contaminants in hydraulic oil leads to degradation of its basic characteristics, which also results in increasing the intensity of wear process and secondary contaminants origination.

This paper describes development and application of a mobile device for oil analysis which allows us to monitor two of three main contaminants in hydraulic system, namely: mechanical particles and water.

3. MOBILE DEVICE FOR OIL ANALYSIS

The basic idea for development of a mobile device (Figure 1) for on-line and in-line analysis of industrial oils contamination is essentially based on the use of currently available sensing elements to determine the concentration of solid particles and water in oil, as the most important diagnostic parameters. Mobile device for oil analysis (MDOA) contain two sensors:

- Automatic Particle Counter (APC), with laser diode as light source (light blockage type of APC) which perform quantification and measure concentration of solid particles in oil giving result according to ISO 4406 standard cleanness codes for 4, 6, 14 μm and additionally for 21 μm, with resolution of 0.1 ISO code. Result could also be presented in form of cumulative number of particles for each size range.
- Capacitance sensor for water in oil monitoring which measure water content relative to the saturation concentration. Its output is a_w parameter (water activity, ie. water in oil saturation level) as measure of saturation level in the range of 0 to 100%. (0% absence of water, 100% fluid is fully saturated with water).

Complete controlling of MDOA is done using a miniature touch panel PC with Windows CE operating system. Detailed description of MDOA is given in [7,10].

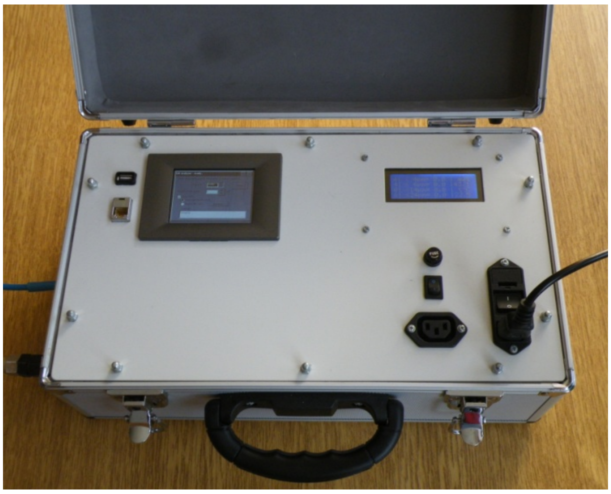

Figure 1. Mobile device for oil-analysis

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% Comment
%
% Time[s] Ch1iso Ch2iso Ch3iso Ch4iso Cumul1 Cumul2 Cumul3 Cumul4 Temp1[C] Temp[C] aw[%]
-------------------------------------------------------------------------------------------
     0.00  22.70  20.00  18.00  16.50  34000   5150   1317    494       30   24.53 39.91
    10.00  22.70  20.00  18.00  16.40  34000   5100   1286    465       30   24.69 40.04
    20.00  22.70  20.00  18.00  16.30  35000   5036   1298    436       30   24.69 40.17
    30.00  22.70  20.00  17.90  16.30  34000   5025   1254    436       30   24.69 40.17
    40.00  22.70  19.90  17.80  16.20  34000   4847   1175    408       30   24.69 40.17
    50.00  22.60  19.90  17.70  16.20  32000   4762   1143    389       30   24.69 40.17
    60.00  22.70  20.00  17.90  16.40  34000   5068   1271    461       30   24.69 40.29
    70.00  22.60  19.90  17.90  16.30  33000   4879   1241    444       30   24.69 40.29
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Figure 2. Form of the output text file with measurement results

The measurements results are saved as a text file (Figure 3) which is adopted to the format that can be further processed in appropriate software for advanced data analysis (Excel, Matlab...). Columns in the file contains data about measurement time, ISO 4406 codes and corresponding cumulative numbers of particles, oil temperature value and saturation parameter of oil with water.

4. MEASUREMENT RESULTS

Results of oil contamination measurements using MDOA will be shown through laboratory test examples on tribometer with reciprocating motion, type pin-on-plate (Figure 3) [7].

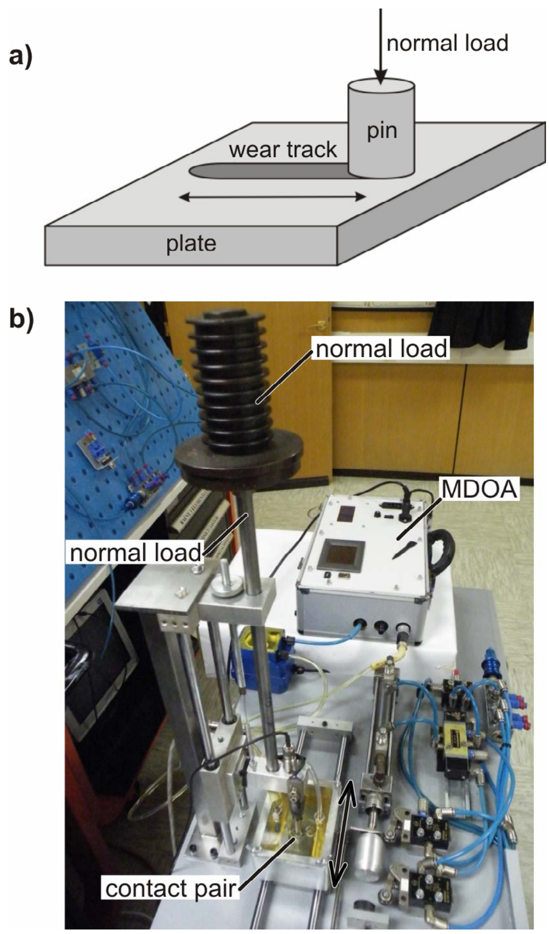

Figure 3. a) Contact type pin-on plate, b) used reciprocating tribometer

Normal load in the vertical direction was 20 N. The lever which was used to transfer the normal load to the pin on the plate is constructed in that way that also represents the dynamometer to measure the force of friction in the contact zone. Reciprocating motion is provided by a pneumatic cylinder and accompanying pneumatic installation. The tribometer is complete with a pneumatic cycle counter.

Contact pair is in the aluminium container with volume of 500 ml, which is filled with oil to 1/3 of its height. In the transparent cover are mounted suction and discharge pipes which allow oil circulation in the container. Suction line takes oil from the bottom of the container, while the returning line back oil to the surface, providing a mix of oil during the experiment. Peristaltic pump generates circulation of oil through the system (contact pair – container – MDOA). The pump is constructed in the way that its functioning does not introduce additional contamination of the tested oils.

Material of the pin and plate is 1.0501 according to standard EN 10027. Pin is circular in cross section area, P=160 mm^2. The material is not heat-treated and has a hardness of 25-30 HRC. Contact surfaces are grinded (Ra = 0.4μm).

This experiment shows results of oil contamination parameter measurements in next characteristic working regimes:

- running-in regime,
- regime of increased contamination by solid particles,
- regime of decreased contamination by solid particles and
- regime of increased contamination by water

4.1 Running-in regime

Work in the running-in regime is characterized by intensive tribological processes and higher internal generation of contamination. Experiment is held for 20,000 cycles. Figure 4 shows the diagram of friction coefficient and the curve that shows the change of oil contamination by solid particles.

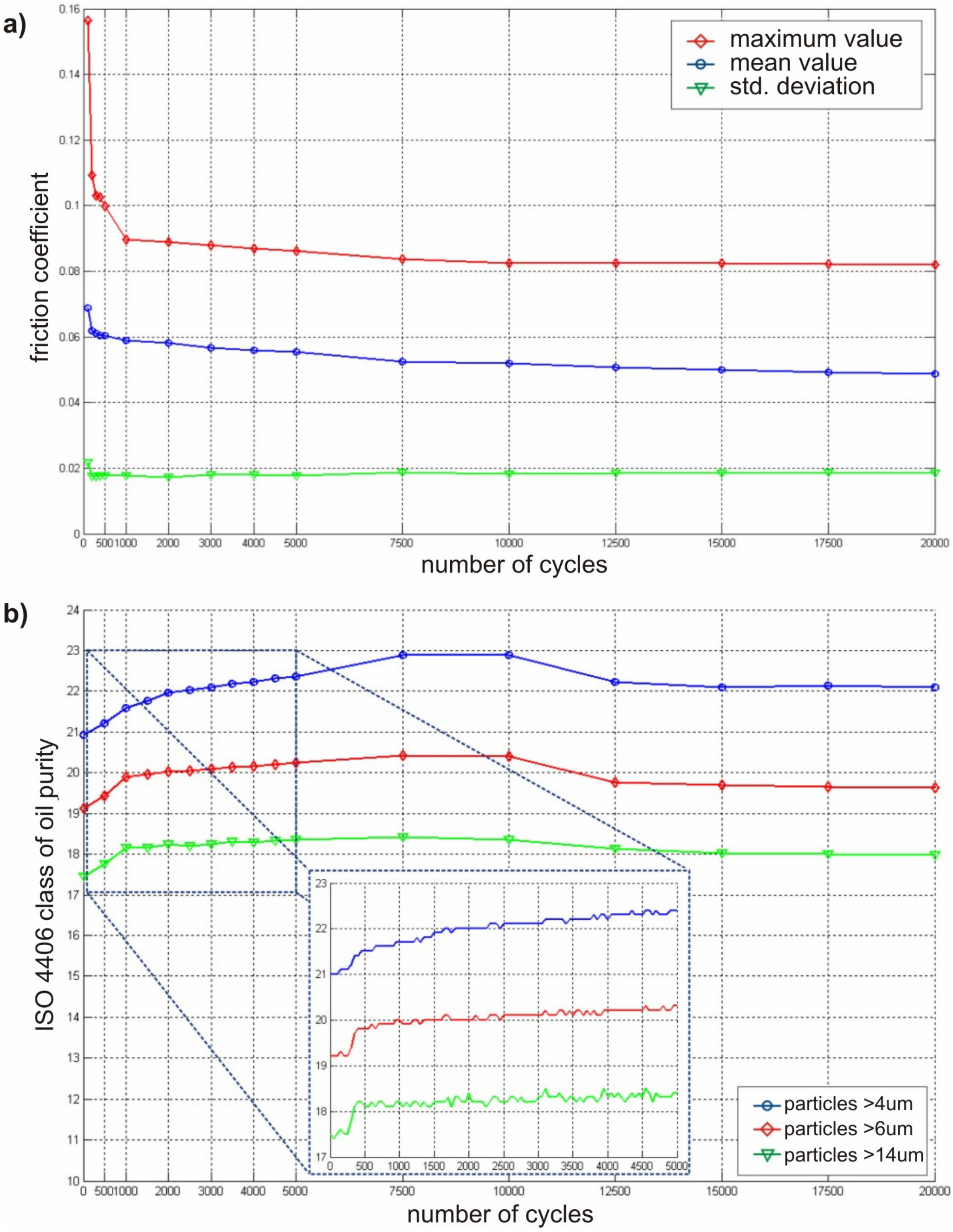

Figure 4. Running-in regime, a) friction coefficient, b) diagram of oil contamination by solid particles

Start of the testing and contact of new tribological pair is characterized by higher values of friction coefficient. Trend parameters of the friction coefficient change, exponentially decrease until the middle test period, after which they keep almost constant value.

As was expected, oil contamination by solid particles has trend of rapid increment at the start of the experiment, as a result of intensive wear during running-in process of tribological pair. After reaching the maximum value of contamination (between 7,500 and 10,000 cycles), there can be noticed a trend of slight decrease in the level of contamination, until it achieve a stable value at the end of the test. This leads to deposition of particles generated during the experiment.

4.2 Regime of increased contamination by solid particles

Contamination of the system by solid particles was performed by direct addition of abrasives in the contact zone of tribological pair. As a source of contamination, an industrial abrasive with declared grit size of 5 µm was used.

Contaminated oil prepared in this was gradually added to the oil in the system and followed by constant monitoring of contamination increase. Figure 5 shows an example of the contamination increment process in the system by the addition of contaminated oil (Added 3 times).

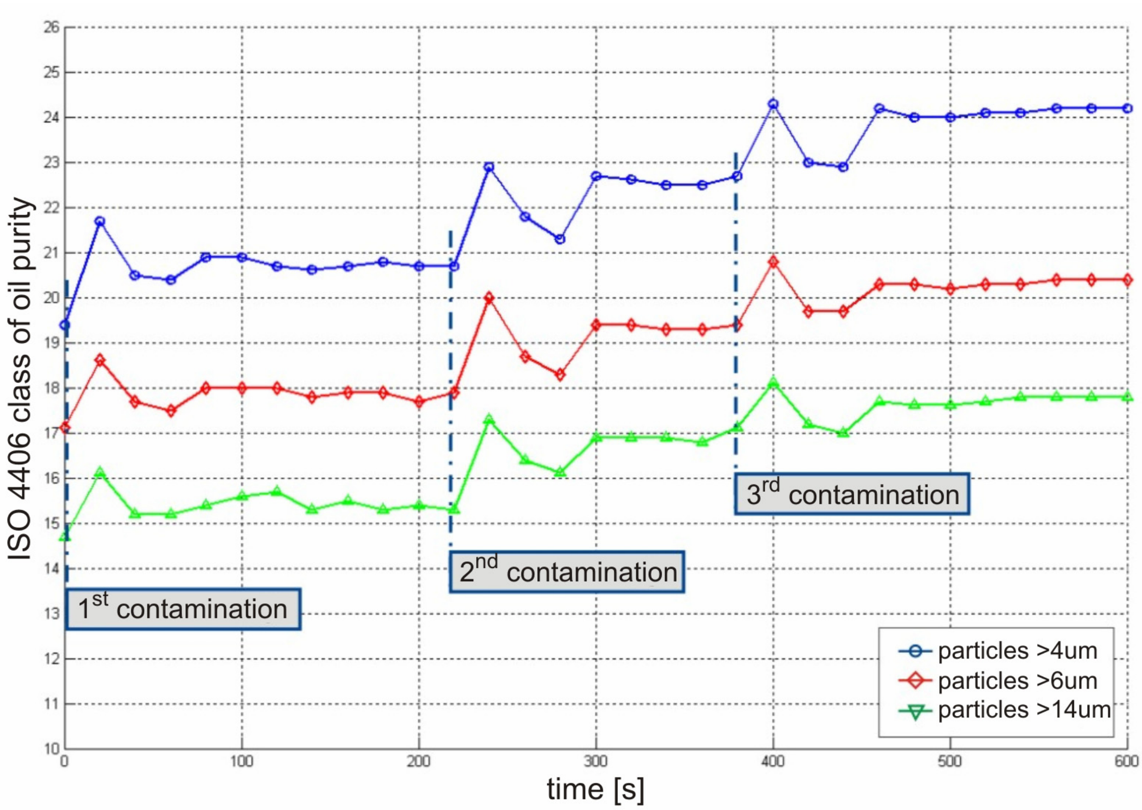

Figure 5. Process of increased oil contamination in the system

4.3 Regime of decreased contamination by solid particles

Reduction of the level of oil contamination by solid particles is done by placing oil filters in the system. Measurement of oil contamination during this regime is shown in Figure 6 and the results show that filtering decreases contamination from level 29.0/23.1/21.2 down to level 19.0/14.4/13.2 during the 4000 cycles.

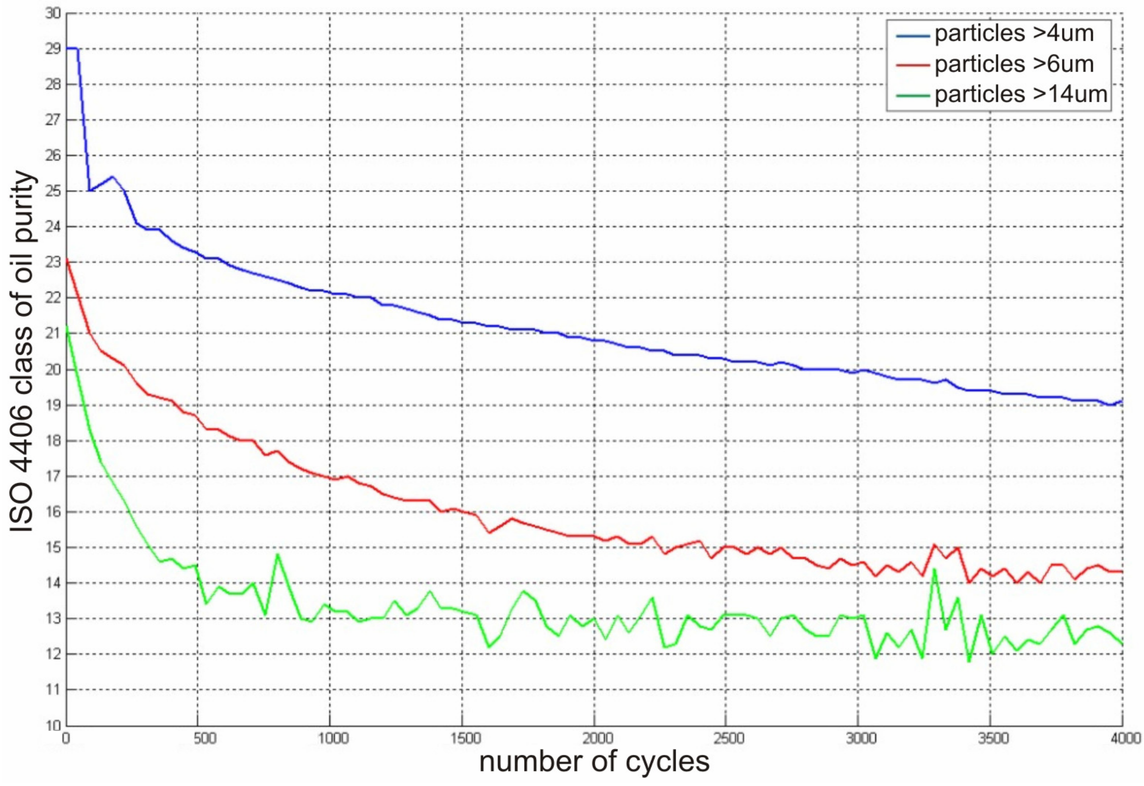

Figure 6. Diagram of changes in oil contamination by solid particles in the filtration regime

4.4 Regime of increased contamination by water

This testing considered intensive increment of system contamination by water with response monitoring of measured parameters. Previously prepared 50 ml of 10% mixture of pure oil and regular water (45 ml oil and 5 ml of water) which was then slowly added to the system. Total entry into the system was 40 ml of this suspension, accordingly 4 ml of water. In this way, by the end of the test, total concentration of water in oil was raised to about 2%, which is 10 times of the recommended maximum allowable value.

Raising level of oil contamination with water was followed with parameter a_w, which is called water in oil saturation level. Changes in diagram of this parameter during testing are shown in Figure 7.

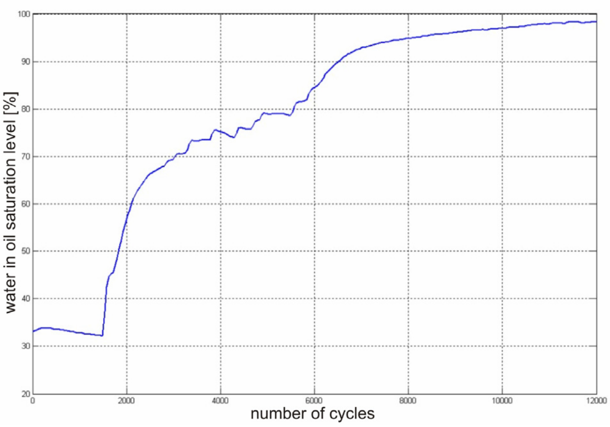

Figure 7. Diagram of changes of water in oil saturation level - a_w

5. CONCLUSION

Presented results of experimental studies show that the level of oil contamination by solid particles and water in oil saturation level are the parameters that have adequate and timely response to the occurrence of any change in the system. Considering the nature of these parameters and their sensitivity to any changes, proactive maintenance strategy can be achieved by following of their changes.

In addition, mobile device for oil analysis has enabled the measurement of selected parameters with high precision, repeatability and high response speed, so that all phenomena and processes are clearly and unambiguously identified.

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