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RESEARCH

Development of Mobile Device for Oil Analysis

This paper presents the results of project focused on development and practical application of mobile instrument for on-site analysis of industrial oils. 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. Using the sensor elements to determine the concentration of wear particles and water in oil, the prototype of mobile device for contamination control of mineral oil is developed. It meets the general and specific set of technical and technological requirements, has a favourable price and upgrade option.

Keywords: *oil analysis, contamination, water in oil, mobile device, proactive maintenance*

1. INTRODUCTION

For a number of years oil analysis was widely accepted as one of the standard methods for the maintenance 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 who 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.

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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]. 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

In simple terms, oil analysis consider contamination monitoring of oils and lubricants, investigation of changes in physical and chemical properties and wear debris. Beyond this basic division, there are several hundred different test methods which are developed, defined and standardized, with over a thousand parameters that can be tracked and analyzed. For a years, this fact presented a fundamental problem for practitioners, who had a large number of data to look for the right information and indicators. This is certainly one of the main reasons for the relatively limited use of oil analysis in everyday industrial practice.

Detailed studies and research have shown that, among the numerous parameters which defines the state of oil and lubricants, a dozen of them are fundamental which analyses are essential for the greatest number of different technical systems. In the part related to monitoring of oil contamination, two key parameters are contamination by solid particles and water contamination [2]. Solid particles in oil, regardless of their structure and origin, are a basic cause of tribological degradation process, and on the other side they present a clear indicator of the tribological process intensity and characteristics. Water in oil is the main cause for appearance of corrosive processes on the contact surfaces. In addition, it has a very negative impact on the basic physical and chemical properties of oil. For certain types of industrial oils, such as transformer isolator's oil, water is the main and most harmful form of contamination [5].

3. OIL ANALYSIS

Oil analysis can be conducted on-site or off-line in the laboratory (see Figure 1).

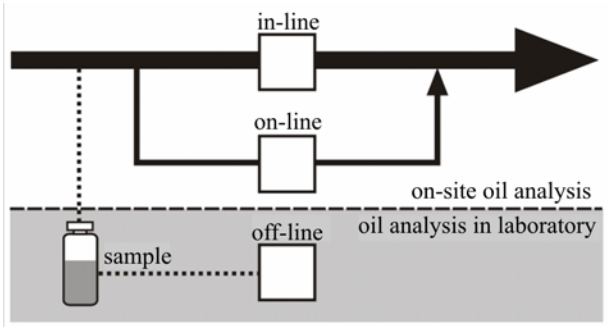

Figure 1. Methods of oil analysis

For a long period of time, oil analysis relied on the commercial laboratory services. Introduction of the first mobile instruments for on-site [6] and on-line [7] oil contamination monitoring was a huge step forward with numerous of advantages. Here are just a few of them [8]:

- immediate results of oil analysis procedures,
- possibility of immediate re-test when it is necessary,
- measurements and analysis is done by the people who know the most about equipment and machines,
- significant costs reduction due to laboratory costs, sampling and sending the samples,
- reduction of possibility for mistakes and sample contamination,
- possibility for incoming oil control and
- much shorter time between performing contamination control and appropriate maintenance activity.

The use of portable instruments for oil analysis is a big step forward in integration of tribology in everyday technical practice. They become un-avoidable tool for the implementation of modern maintenance methods, and above all, for the concept of proactive maintenance.

By defining the priorities and the significance of diagnostic parameters, the introduction of on-line and on-site oil analysis is a reasonable step towards improving the maintenance process.

For most potential users, automatic particle counters (APC) for determining the oil contamination by solid particles, presents the primary choice for on-site oil analysis equipment. These devices operate on the principle of photo-sensitive sensor which is obscured by particles from a sample of oil that passes through the instrument. Each particle that passes through the sensor is counted and quantified by the size. Measurement result is shown in the ISO 4406 code of cleanliness, as well as through the average number of particles in each class.

Various forms of sensors and instruments for on-site and on-line control of the water concentration in oil are also developed. Operating principle of these instruments is based on determining the oil saturation point (in relative scale from 0% - no water in oil up to 100% - oil saturated with water). In contrast to standard laboratory methods for determining water content in percent or ppm values, this method of water concentration monitoring does not depend of oil type. It has significant comparative advantages that represents, so called index of activities, which on very clear and simple way defines the vulnerability of a given technical system by water in oil, regardless of the system characteristics and its relative sensitivity to volumetric water content.

4. DEVELOPMENT OF A MOBILE DEVICE FOR OIL ANALYSIS

The basic idea for development of a mobile device for on-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. In order to design an integrated, multi-purpose diagnostic device it was necessary to integrate several elements and systems [9]:

- Sensors for the concentration of solid particles and water in oil in a single sensor module.
- Sampling and recirculation system of oil through the sensor module, which allows the use of device in systems where the oil is not under the pressure, so it is necessary external circulation pump.
- Data acquisition and processing system that integrates information from the both sensor elements in order to display and save results.
- Connecting the previous system with a computer in terms of designing and producing hardware-software interface for transferring measurement data to a computer.
- Software package for collecting and displaying the results of measurement, specially designed for the Windows environment.
- Appropriate portable housing - a suitcase with the power supply and the corresponding connecting element which has the task to unify the previously described sensors, systems and elements into a single mobile device, properly protected from external influences.

4.1 Description of the technical system

The conceptual design of a mobile device for oil analysis is shown in Figure 2. The basic modules of a device and their interconnections can be seen in the picture. If we use device for on-line analysis, directly on a real hydraulic system, it is connected to the input 2 via hoses with quick couplings for a hydraulic lines where the pressure is up to 50 bar and flow up to 40 l/min. Device can be connected in the same way on a mobile systems for oil filtration.

If device is used in the off-line mode with previously taken oil samples, oil flow through the device (from 150 to 200 ml/min) is provided via an external peristaltic pump to the Input 1 (see Figure 2). Peristaltic pumps have such a working principle that provides a zero internal generation of particles which ensures protection from further sample contamination during the testing.

The oil in a device passes through the sensor unit with sensors for particle counting and water concentrations in oil and exits through the Output port. Signals from these two sensors are collected by the data acquisition and processing hardware system and forwarded to 3.5" touch sensitive panel computer.

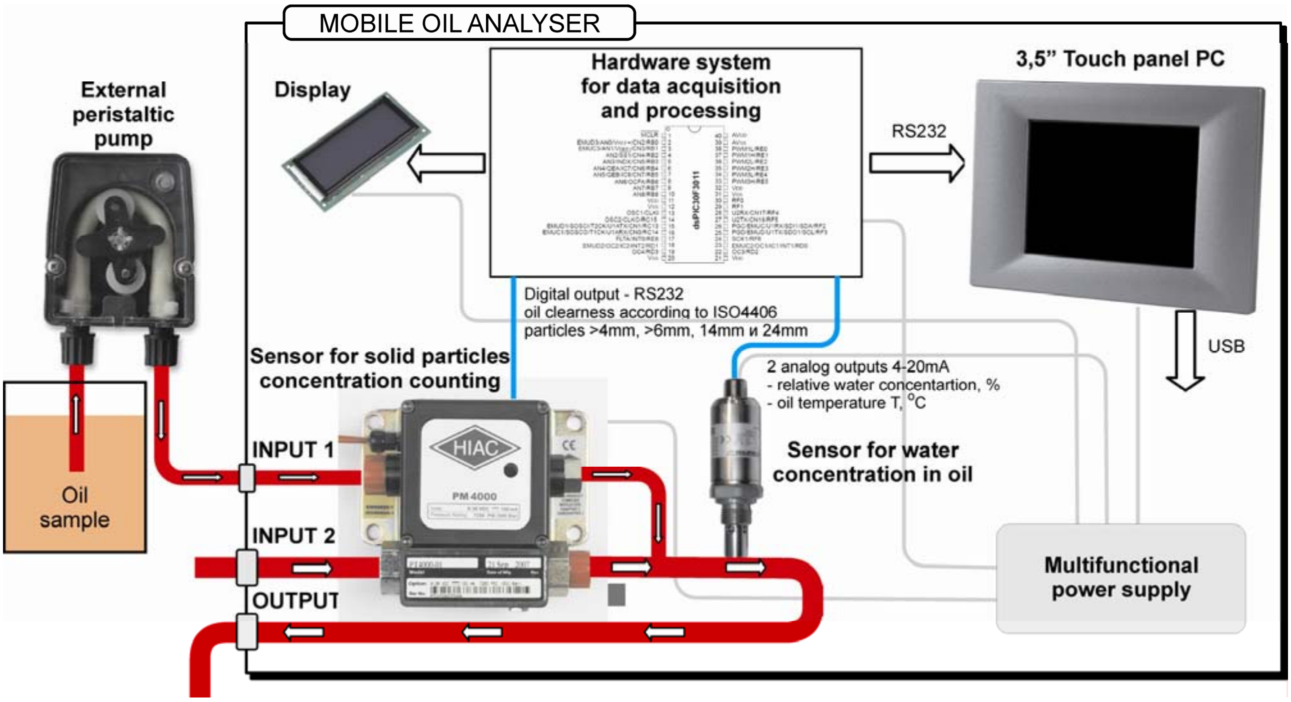

Figure 2. Conceptual design of mobile device for oil analysis

4.2 Hardware components

Figure 3 shows the practically realised demonstration model with all previously defined components and systems integrated.

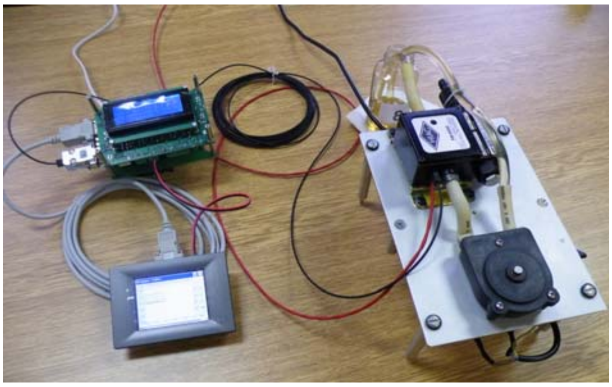

Figure 3. Demonstration model

Hardware system for data acquisition and processing is specifically designed and developed. It is microprocessor based electronic circuit that collects analog and digital signals from the measuring sensors, processes the results and prepares it for storage and display. In addition, hardware system has a high level of flexibility and possibility for further expansion (work with additional sensors). It allows user to display the results of measurement on a standard dot matrix or monochrome graphical display, as well as on a different types of advanced industrial computers, touch panel and display. Version of the standard dot matrix display allows simple illustration of current values of all measured data (see Figure 4).

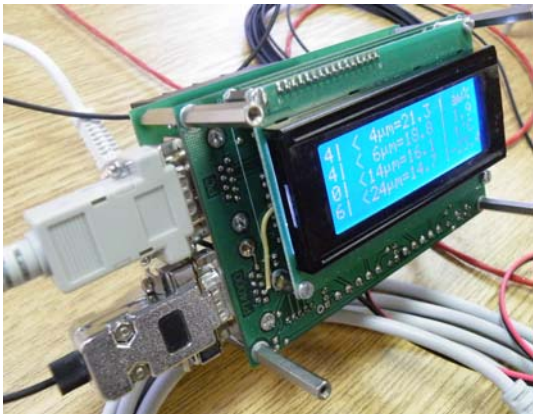

Figure 4. Hardware system for data acquisition and signal processing

Figure 5. 3.5" touch sensitive panel PC

Displaying the results in a graphic form, their storage and transfer to a PC is achieved using an industrial PC with 3.5" touch sensitive panel (see Figure 5).

This compact device gives user a wide range of possibilities and it is very useful and significant upgrade of equipment for oil analysis.

Data acquisition software

Specially developed software that runs on Windows CE operating system is used to work with 3.5" touch sensitive panel PC. It allows user to display the results of a real-time measurements in the form of graphics or numbers (see Figure 6). The measurement results are saved as a text file and as such they can be transferred to any other computer for further processing.

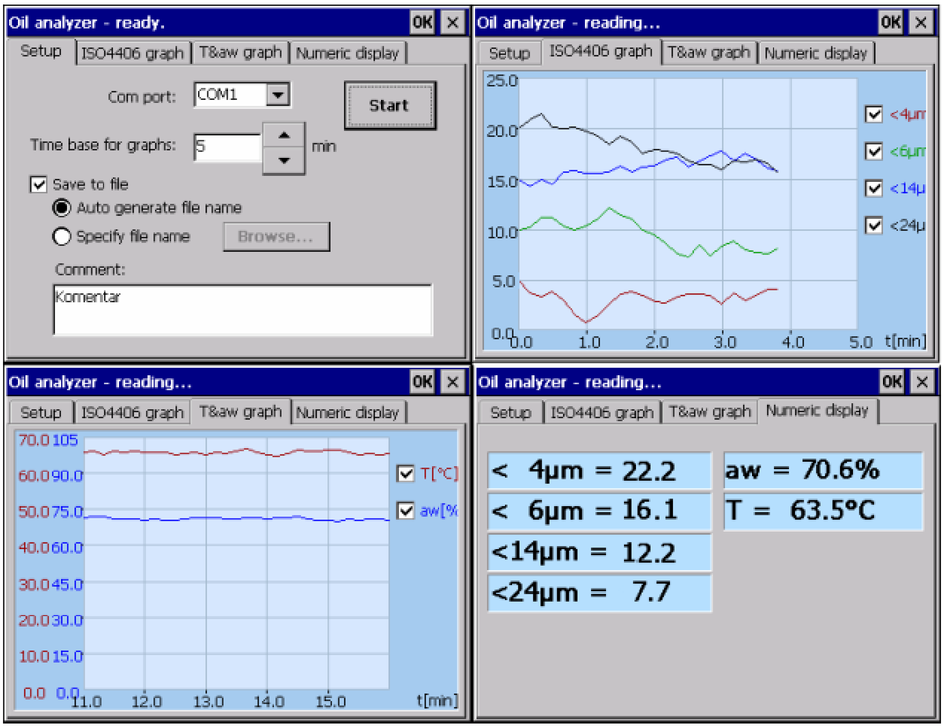

Figure 6. Oil Analyzer software

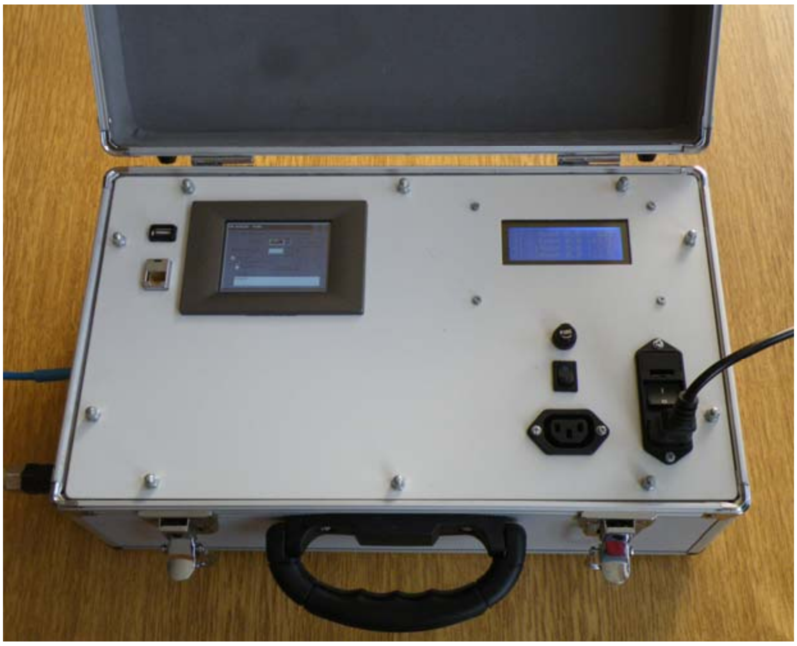

Figure 7. The final appearance of the instrument integrated into a suitcase

Figure 7 shows the final look of the instrument with all elements integrated into a suitcase adapted for industrial conditions.

The result of realized activities is a prototype of an integrated national mobile device for contamination control of mineral oil that meets the general and specific set of technical and technological requirements and has many advanced features [9]:

- monitoring the level of oil contamination by solid particles in accordance with the requirements of ISO 4406,
- monitoring the level of oil contamination with water and defining the water content in % and the factor of water activity in oil,
- compact design adapted for on-site work,
- ability of the device to work on-line directly connected to the oils installations of lower and medium pressure,
- ability to work in off-line regime in laboratory conditions with the previously taken samples of oil,
- integrated view of all results in alphanumeric display panel,
- displaying the results in a graphic form changeable over time on a display,
- option to save results of measurement using the internal memory device,
- ability to communicate with a computer and transfer the measurement results.

5. CONCLUSION

Development of a mobile device for on-line oil analysis has many comparative advantages over the devices of similar characteristics, that can be found on the market. A few of them are:

- Combining a sensors for oil contamination monitoring by solid particles and water in a single device, original solution is achieved, that is not standard in the world market. It also has an option to further upgrade, for example, oil viscosity sensor can be added.
- Relatively high prize of a similar devices is one of the main reasons for their limited use. Accordingly, special attention was paid to design a solution that has a very favourable commercial price. This is achieved by a combination of compact industrial sensors and functional upgrades that are easily accessible and have a low price.
- The integration of various working systems (in-line work on systems with high and low pressure, on-line work on systems with no oil pressure, working with oil samples in bottles and other containers, work with devices for treatment of oil, working in laboratories with tribometers) presents an original and universal solution that significantly expands the possible application areas.
- Development of specially adapted software package for data acquisition and processing, facilitates much broader use of a device, since it is available to the broadest range of users.

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