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Proactive Approach to Oil Maintenance Strategy

RESEARCH

This paper presents primary idea and some initial results of project focused on development and implementation of instruments and equipment for industrial oils condition monitoring and purification. Those activities incorporate in wider goals of establishing proactive maintenance concept and technology in everyday industrial practice. Proactive maintenance strategy, involves continuous monitoring and controlling of machine failure root causes, and among them mainly contamination as clearly the most common, serious and most recognized failure cause in industry. To ensure all necessary equipment and instruments for proactive maintenance concept implementation, this project is establish with main goals of development of cost effective on-site oil analysis instrument for particle and water contamination monitoring, based on adequate sensors available on world market. Other direction in project realization is construction of multifunctional mobile device for industrial oils purification. Through the realization of this project Center for Terotechnology, Faculty of Mechanical Engineering, Kragujevac intent to complete its maintenance equipment and technology potential and resources.

Keywords*: oil analysis, proactive maintenance, oil purification*

1. INTRODUCTION

For number of years oil analysis was widely accepted as one of basic preventive maintenance routine procedure, primary focused on determining the optimum change point for lubricants and oils. As almost unchangeable factor there was accepted, that oil analysis is mainly laboratory based activity owing to the complexity of the equipment and the specialized technicians and skills required to interpret the analysis results.

Huge changes in production technology and increased pressure on maintenance function in direction on significant costs reduction, led to development of predictive maintenance theory, methodology, instrumentation and practice as a way to additional savings over preventive maintenance. Implementation of various portable instruments for condition monitoring (as a main predictive maintenance "tool") in everyday industrial practice, has been effective at recognizing the symptoms of impending machine failure. The major benefit is the availability of an earlier warning, from a few hours to a few days, which reduces the number of breakdown or catastrophic failures. Predictive maintenance is usually implemented concurrently with preventive maintenance and targets both the warning signs of impending failure and the recognition of small failures that begin the chain reaction that leads to big failures.

There is absolutely no doubt that vibration monitoring has enjoyed a far greater presence as the technique of choice for predictive maintenance then any other available (including thermography and oil analysis for instance). There are a number of reasons for this, but one of the main reason is that oil has always been perceived as a cheap commodity within the maintenance budget by comparison to rotating equipment. A cost justification for predictive maintenance on critical machinery invariably highlights the bearing condition as the main indices to potential system failure, as well as the bearing being a relatively higher cost item to replace. By comparison, the lubricant and industrial oils are a cheap, easily replaced commodity.

Other, very important factor is development of wide rang of portable, low – cost instruments for basic vibration measurement together with computerized systems or data collector diagnostic systems with large number of various function for FFT, CPB, SPM and other complex analysis of vibration signals. All those instruments are capable for real time, on-site and on-line measurements and analysis, while on the other hand analysis of oil and lubricant samples relied on the laboratory services.

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Introduction of proactive maintenance strategy, some 20 years ago, caused significant changes in a way that maintenance experts and technicians think and talk about oil analysis. Proactive maintenance has now received worldwide attention as the single most important means of achieving savings unsurpassed by conventional maintenance techniques. This strategy bring out failure proactive philosophy based on activities for avoiding the underlying conditions that lead to machine faults and degradation. Proactive maintenance is focused on failure root causes instead on early signs and symptoms of failures like predictive maintenance. While the root causes of failure are many it is generally accepted that 10 percent of the causes of failure are responsible for 90 percent of the occurrences.

By addressing the root cause, the conditions promoting ultimate failure are either eliminated or reduced to minimize the onset or accelerated progression towards failure. The result is that the system enjoys an extended life and the maintenance costs are thus reduced. Any activity aimed at addressing the root cause of failure is accepted as proactive. For instance balancing and alignment of rotating equipment are an example of proactive maintenance activities. By setting these two parameters correctly, the consequential failure owing to vibration damage is eliminated or at least postponed significantly.

This time there is also no doubt that group of activities named as oil analysis are primary technique of choice for proactive maintenance. Great number of studies and investigations, with illustrative laboratory proofs and field confirmations, have mutual conclusion that contamination is clearly the most common and serious failure culprit. Therefore, the logical, first step in proactive maintenance is the implementation of rigorous contamination control programs for lubrication fluids, hydraulic fluids, coolants, air, and fuels.

2. OIL CONTAMINTION

There are very few systems that do not, in some way or another, require lubrication. Proactive monitoring of the lubricant has been seen as an ideal method of determining lubricant level of contamination and need for purification or replacement. Good example for those is large family of various industrial oils and among them hydraulic oils and systems.

It has been shown that minimum 75 – 80 % of hydraulic system failures are due to oil and oil contamination. Oil contamination in the hydraulic system influences seriously the hydraulic system, components and hydraulic oil. A recent study by Nissan Motors of Japan attributed 85% of hydraulic equipment failures to contamination. Nippon Steel, Japan found that over a 5 year period from, there was an 80% reduction in hydraulic pumps replacements, and a 75% reduction in oil consumption through a proactive maintenance and contamination control program. Kawasaki Steel, Japan found that over a similar 5 year period fluid consumption was reduced on 20% of the consumption at the start of the project, and the breakdown frequency was just 4% of the original levels. Research by the British Hydromechanics Research Association (BHRA) and National Engineering Laboratory indicated potential life extension factors of 10 to 50 times were possible on a variety of hydraulic equipment depending on oil contamination level. Similar to that Oklahoma State University reports that when fluid is maintained 10 times cleaner hydraulic pump life can be extended by 50 times.

Contamination can be defined as any unwanted substance or energy that enters or contacts the oil. Contaminants enter a hydraulic system in a variety of ways. They may be:

- built-in during manufacturing and assembly process
- internally generated during operation, and
- ingested from outside the system during operation.

If not properly flushed out, contaminants from manufacturing and assembly will be left in the system. These contaminants include dust, welding slag, rubber particles from hoses and seals, sand from castings, and metal debris from machined components. Also, when fluid is initially added to the system, a certain amount of contamination often comes with it. Typically, this contamination includes various kinds of solid particles and water.

During system operation various kind of particles enters through breather caps, imperfect seals, and any other openings. System operation also generates internal contamination. This occurs as components wear debris and chemical byproducts from fluid and additive breakdown due to heat or chemical reactions. Such materials then react with component surfaces to create even more contaminants. Contaminants can be harmful to system operation, safety, service life, and/or reliability. In addition to causing direct wear, contaminants act as catalysts in the processes of component and fluid deterioration. Some of them are highly destructive to the oil, its additives, and machine surfaces. It is often overlooked as a source of failure because its impact is usually slow and imperceptible yet, given time, the damage is analogous to eating the machine up from the inside out.

Particles, moisture, soot, heat, air, glycol, fuel, detergents, and process fluids are all contaminants commonly found in industrial lubricants and hydraulic fluids. However, it’s particle contamination that is widely recognized as the most destructive to the oil and machine. The central strategy to its success in reducing maintenance costs and increasing machine reliability is on-line monitoring particle contamination.

The ISO Cleanliness Code, ISO 4406, is the most widely used International standard for representing the contamination level of hydraulic fluids. This standard uses a code system to quantify contaminant levels by particle size in micrometers (µm) and to establish the relationship between particle counts and cleanliness in hydraulic fluids. After introduction in 1987. it has been revised two times in 1996 and 1999. According to first version ISO 4406 classification was a two number code, e.g., 14/12, based on the number of particles greater than 5 µm and 15 µm respectively. It was expanded to three numbers in ISO FDIS 4406 in 1996 by the addition of a code number representing the number of particles greater than 2 µm. The new ISO 4406:1999 standard provides a 3-part code to represent the number of particles per milliliter of fluid greater than or equal to 4 µm, 6 µm, and 14 µm, respectively.

Moisture or water in oil is obviously second most destructive oil contaminant. Water contamination in lubricating oil accelerates the natural oxidation that normally takes place in the oil. Even when additives are used to retard the natural process, the presence of water will degrade the effectiveness of certain additives potentially leading to tight emulsions and the formation of sediment in the oil. In addition, water in lubricating oil increases the risk of microbial attack and contributes to further loss of oil performance and thereby to corrosion of the components in the various oil systems.

Water in oil can be present in dissolved or free form. When the water content reaches the saturation point of that oil, it separates out and free water is formed. The ability of oil to hold water in solution depend on the oil type, its age, and additives present. Free water formation is critical in terms of problems related to water in oil. When water is no longer dissolved in the oil, then corrosion and wearing of equipment increase rapidly. For this reason, it is important that moisture content is kept safely below the saturation point.

3. ON-SITE OIL ANALYSIS

Whenever a proactive maintenance strategy is applied, three steps are necessary to ensure that its benefits are achieved. The first step is simply to set a target, or standard, associated with each root cause, and in case of industrial oils it is cleanliness levels. Second step include all necessary activities for purification and protection of industrial oils in order to achieve target cleanliness. Third step is based on continues contamination control activities on monitoring and controlling of achieved fluid cleanliness.

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

- full ownership and control under test instruments,
- immediate results of oil analysis procedures,
- immediate re-test when it is necessary,
- tests and analysis is done by the people who know the most about these machines,
- significant costs reduction (laboratory costs, sampling and sending of samples),
- reduction of possibility for mistakes and sample contamination
- possibility for control incoming lubricants,
- much shorter time between performing contamination control and appropriate maintenance reaction

Use of the portable oil contamination instruments provides great help in implementation of proactive maintenance concept. Maintenance operators can simply walk from machine to machine checking fluid contaminant levels and compare them to target baselines. Maintenance work orders can then be issued to correct critical systems.

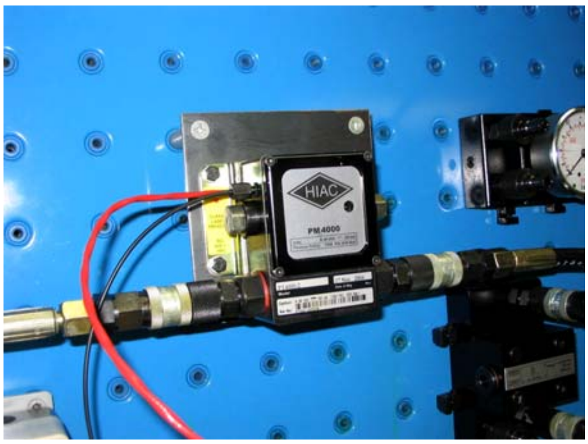

Figure 1: Online particle counter

For many users automatic particle counters are the first choice for on-site oil analysis instrument. The reasons are obvious; a particle counter is perhaps the most versatile tool in implementation of proactive maintenance concept. Those instruments basically work on principle of light sensitive sensor blockage while liquid sample flows trough instrument. Each particle passing the sensor will be detected and counted according to size. The number and size distribution of each measurement is reported, as well as the average values. Results are presented in ISO 4406 3-part oil cleanness code and average particle number in each size category. Among its many uses, an onsite particle counter can be used to:

- Ensure cleanliness of new fluids,
- Verify performance of in-service filters,
- Warn of incipient wear,
- Identify seal and breather failures,
- Monitor roll-off cleanliness of new and rebuilt components,
- Identify the need for filter change, and

During realization of this project there were a number of experiments and measurements performed for purposes of analyzing various hydraulic components behavior regarding oil cleanness level and components liability for particles emition. On Figure 2 one hydraulic laboratory installation is shown with equipment for continuous on-line monitoring of oil particle contamination level. Results from those experiments are very important for understanding of various phenomena and rightness in real industrial systems with hydraulic and other kind of mineral oils.

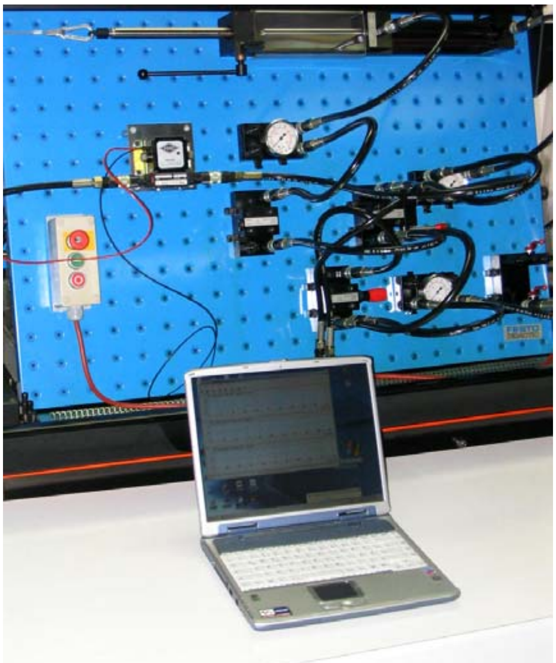

Figure 2: Laboratory hydraulic installation with equipment for particle contamination monitoring

Various sensors and transmitters for on-site and on-line water in oil monitoring are also available. Those instruments working principle is based on determination of oil saturation point or measuring of so called water activity (in relative scale form 0% – no water present to 100% - oil is saturated with water). In contrast to traditional measurement techniques, water activity measurement is independent of oil type.

4. DEVELOPING OF MOBILE OIL PURIFICATION DEVICE

In order to achieve desired target cleanliness level it is necessary to perform various activities for purification and protection of industrial oils. There are many technologies developed for those purposes.

Filtration is normally mainly used activity for reduction of solid particle contamination because various filtration systems can be very effective in achieving and maintaining industrial oil cleanliness targets. Portable filtration system are very popular solution that can be used at scheduled intervals, or in response to increasing contamination trends from oil analysis data. Portable systems can also be used for pre filtering new oil before or during system charging. Cartridge and spin-on type filters are common on this type of equipment, so users easily change to the appropriate filter element for the specific cleanliness target of each machine or machine class being serviced.

Because the sources of water contamination are so numerous and ubiquitous, eliminating all sources of moisture ingestion can be very difficult. Removing water from oil can also be a challenging task, but there are several methods available. Each method has advantages and disadvantages, so each must be carefully evaluated for the particular application.

Designing of portable oil purification device was done after detailed analysis of methods that are used in industrial practice, of world trends and of rigorous demands defined by standards in this area. The goal was to design the device with properties as follows:

- high efficiency of the purification process
- joining of the most important procedures at one device
- economic working process
- mobility and small dimensions
- flexibility for implementation with various types of industrial oils
- easy handling and maintenance
- satisfaction of rigorous ecology criteria

Device design is based on standard portable filter aggregate with added modulus with carefully chosen and processed absorbent filling. The device can be used in field and in workshops or utilities. It can process industrial oils from reservoirs, tanks or directly in machines.

Figure 3: Mobile oil purification device

Device flexibility is in possibility of its combination with other units and systems for oil contamination control and purification. By selection of certain absorbent filling, device can be adjusted to various oil purification and regeneration procedures. Absorbents are granulated, neutral to all oil kind of oils and with large absorption capacity.

Standard device type has the absorbent type of aluminum origin, with zeolite structure with extensive power to absorb water (up to 18% of its volume). Absorbents for removal of oil degradation process products and for lowering of its acidity can be used, beside the standard type absorbents. Special kind of clay, processed previously, and certain granulated absorbents of aluminum origin in zeolite form, belong in this group of materials, also. Absorbent materials that have the capability to reduce acidity of mineral oils are often called ionic inverters, though this name points to materials which have the possibility to "exchange" the acid molecule with water molecule.

From aspect of working methodology, procedure of oil regeneration and purification with removal of degradation products and acids, is significantly slower compared to classic methods of filtration and dehydration. Oil flows through the device with low speed (in order to obtain longer contact with absorbents materials necessary for proper procedure) and it is recommended that complete volume of oil do several passes with pauses after each passage.

Due to efficiency and economic aspects of purification process, this device can be broadly applied in area of hydraulic oils, transformer insulating oils and many other industrial oils. Depending on the design of specific system, purification process parameters and types of absorbent materials and mechanical filters are defined.

Integration of on-site contamination monitoring instruments and mobile oil purification device result in excellent proactive maintenance tool with numerous of advantages:

- 2 in 1, diagnostic and treatment in one system
- instantly available informations about oil cleanliness before, during and after purification process
- precise information about achieving of desired cleanliness level
- possibilities for much precise definition of purification process technology and methodology (selection of filtration elements, dehydration materials...)
- evaluation of filtration elements efficiency

5. CONCLUSIONS

Oil analysis is possibly the most valuable technology in proactive maintenance approach. This paper has introduced basic facts about proactive maintenance and its implementation in hydraulic systems and other technical systems with oils and lubricants. Some initial results of project focused on development and implementation of instruments and equipment for industrial oils condition monitoring and purification (filtration and dehidratation). has also been presented.

REFERENCES

[1] Troyer, D. D., Fitch J. C., Oil Analysis Basic, Noria Corporation, 1999.

[2] Fitch, J.C., What Particles Mean and Why They Need To Be Monitored and Controlled, Reliability Week Conference Proceedings, September, 1998.

[3] M K Williamson, A Low Cost On-Site Oil Analysis Strategy, Entek IRD International.

[4] Zhang Qisheng, Zhao Jingyi, Li Shuli, Why Oil Needs On-line Monitoring, Fluid Transmission and Control Institute, Yanshan University, Qinhuangdao, P.R.China

[5] Peter Rossi, A Cost-Effective Online Particle Contamination/Condition Monitor, Pacific Scientific Instrumen