BALKANTRIB'O5
5th INTERNATIONAL CONFERENCE ON TRIBOLOGY
JUNE.15-18. 2005
Kragujevac, Serbia and Montenegro

OIL MONITORING AND PROACTIVE MAINTENANCE

Miroslav Babic, University of Kragujevac, Faculty of Mechanical Engineering, Kragujevac

Abstract
The proactive maintenance is based on failure proactive philosophy by avoiding the underlying conditions that lead to machine faults and degradation.
Proactive corrective actions aimed at failure root causes, not just symptoms of failures. While the root causes of failure are many it is generally accepted that contamination of oil is the most frequent root cause of lubricated systems failures. Thus fluid contamination control is established as an essential technique to implementing proactive maintenance.
This article discusses the mayor aspects of implementing a proactive successful oil monitoring program.

KEY WORDS: *Oil monitoring, proactive maintenance*

1. INTRODUCTION

Lubricating oil directly participates in the contact processes of elements, which relatively move. That provides a specific importance of oil, both from the aspect of functioning and the aspect of maintenance of technical system. Namely, oil directly protects contact elements against intensive tribological processes of friction and wear and other damaging actions, while on the other hand it also has the important role in the indirect protection in preventing the system failures and down times [1 - 9].

The latter role is related to the maintenance process based on to system condition. The lubricating oil, like blood in human body, collects and carries information on the condition of the system's "health" (as well as on hazards to that condition), from the aspect of tribological and other processes of degradation and contamination [1 - 5]. That can be used very successfully in the monitoring process for early detection of undesired changes in the system, as well as the very roots of processes that lead to those changes and for undertaking the corrective maintenance activities before the onset of failure. Considering that, the oil monitoring technique is becoming the key element in condition based maintenance (predictive or proactive) and of maintenance based on reliability.

One can say that, by oil monitoring through various analysis techniques, the data are obtained that are necessary for the whole system diagnostics, namely data about: a) wear products in oil, b) physical-chemical characteristics of oil and c) degree and type of oil contamination. Certainly, concrete monitoring programs, which are based on selected approaches to condition based maintenance objectives, are usually more focused to some of the named individual groups of information.

Contamination control represents the foundation stone of the proactive maintenance. Namely, the proactive alarms, which are warning the user about the abnormal conditions, from the aspect of the basic causes of degradation of oil and mechanical systems, are the most frequently defined relative to the degree of oil contamination by solid and technical contaminants. The proactive concept is, in this case, based on monitoring of the oil purity, which is conducted in regular intervals and it is a basis for checking the reaching of the set objective concerning purity level and, if necessary, for undertaking the activities for stabilizing the purity.

Proactive alarms, based on aimed purity, do not cover the degradation state of lubricating oil (as well as of hydraulic oil). Due to that, the proactive alarms from the aspect of condition are being used, which are related to relevant physical-chemical characteristics of oils and they represent the aging limits.

2. FUNDAMENTALS OF THE PROACTIVE MAINTENANCE CONCEPT

Requirements for determination of ways to improve the economic performances of companies through the maintenance, which represents one of the rare controlled inputs, coused shift in maintenance philosophy (related to failure) from active to proactive one.

Contrary to predictive and preventive maintenance, in proactive one, the corrective activities are being undertaken, with appearance of root causes of degradation and failure, and not based on appearance of symptoms of existing damages and forecoming failures (predictive), or based on plan – regardless of the real system state (preventive).

The substance of the proactive approach, form the strategy aspect, monitoring objective, applied monitoring techniques and realized effects, is shown in *Figure* 1, and in comparison to predictive - older, more known and present approach to condition based maintenance. The majority of failures of technical systems, has as a basis, one or several fundamental causes. Some of them comes from: inadequate design, inadequate installation, improper adjustment and balancing, overloads, overheating, oil contamination by abrasive particles or oil contamination by water.

Though, as numerated, there exist numerous fundamental causes of failure, or at least one assumes that they exist, it is generally accepted that only 10 % of them are responsible for 90 % of failures [1, 3]. Very frequently, the symptoms of failure mask the root cause or they are presumed themselves to be the cause. Thus, for instance, for instantaneous failure, one usually blames poor quality or wrong choice of lubricant. On the other hand, the root cause is most probably, contamination of lubricant or inadequate installation of bearing.

The data that are now available, based on research in laboratory and production conditions, clearly show that, when the system is well designed and manufactured, the lubricating oil contamination with abrasive particles and water represents the most serious cause of failures [8].

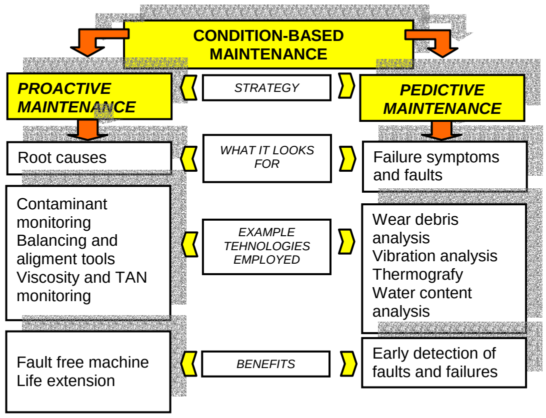

Figure 1: *Comparison of predictive and proactive maintenance concepts [5,8]*

Taking that into account, the logical basic approach of the proactive maintenance of technical system is based on the implementation of rigorous oil control program.

3. PROACTIVE ALARMS

Proactive alarms alert the user about abnormal conditions, related to control of the root causes of degradation of oil and the mechanical system. They are crucial for the proactive maintenance philosophy, which is based on establishing the targets and managing lubricant conditions within those targets [5,8].

The strategic reqirement of the proactive alarms is that they should be adjusted to levels which generate improvement, relative to the previous state, or to secure maintaining the level whose performances were previously optimized, in accordance with the optimization objectives.

Within the framework of the proactive domain, the two types of alrm limits are being used:

- Goal based targets and
- Aging limits.

3.1. Goal based targets

These limits have the character of a target, and they are applied for parameter control, like contamination, with the primary objective to achive life extension of the system (*Figure 2*).

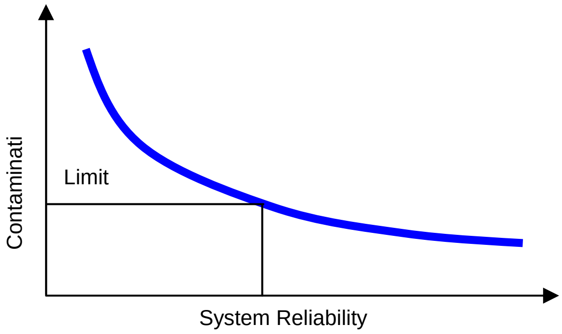

Figure 2: *Goal based target [8]*

The contamination control, based on which the proactive maintenance is usually founded, as already explained earlier, begins with establisment of the oil purity level. The target level of the technical system purity system should be chosen in accordance with its inherent sensittivity to contamination, to various direct or indirect down time costs, function's responsibility, effect on environment, etc. There, the typical system manufacturers' recommendations could be sufficient also for fulfillimg the specific needs and objectives, from the aspect of user's productivity.

For instance, in hydraulic system, which operates with the purity level *ISO 18/15* the life extension is expected to be three times, if the purity level is raised to *ISO 15/12*. The limit adjustment to *ISO 15/12* represents the target that is based on the set goal. Consequently, if the system operates at oil purity *ISO 15/12*, and loss of control leads to reaching the contamination level of *ISO 18/15*, one can expect the negative effect of three times increased wear during the period of the increased contamination.

The tendency for the system to be returned to purity level *ISO 15/12* is thus motivated by the specific objective, so this is the goal based limit.

This type of limit is usually applied to number of particles, humidity conent, glycol level, quantity of the dissolved fuel in oil, TAN and other primary causes of the change ion the system sate.

3.2. Aging limits

The second type of the proactive alarm is related to progressive aging of using lubricant or hydraulic fluids (*Figure 3*).

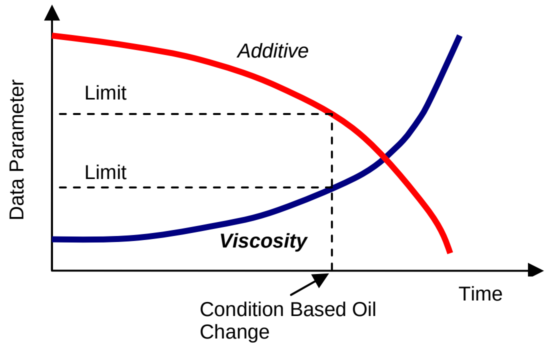

Figure 3: *Aging limits [8]*

Since the moment when the exploitation of the new oil begins, its chemical and physical charateristics begin to deviate from the state defined by the oil formulation. Some characteristics are changing very slowly, and some dramatically.

Limits based on oil deterioration represent aging limits. Such limits can be effectively applied to parameters like TAN/TBN, viscosity, FTIR (oxidation, nitration, sulphatization and aditives), as well as the dielectric constant.

Examples of definition of the both types of the proactive limits, on two levels – the warning level, the precaution level, and the critical condition level are shown in Table 1.

Table 1. Examples of proactive limits [8]

Limits based on objectives realization			Limits based on oil aging		
Oil characteristics	**Caution alarms**	**Critical condition alarms**	**Oil characteristics**	**Caution alarms**	**Critical condition alarms**
Purity	14/11	16/13	Viscosity	+ 5 %	+ 10 %
Moisture	200 *ppm*	600 *ppm*	RBOT	30 %	60 %
TAN	0,2	0,4	FTIR Ox	0,3	1,0
Fuel	1,5 %	5 %	Zinc	- 15 %	- 30 %
Glycol	200 *ppm*	400 *ppm*	Calcium	- 10 %	- 20 %
Ash	2 %	5 %	TBN	50 %	70 %

Table 2. Comparison of basic types of maintenance based on analogy with human body medicine[9]

Maintenance strategy	Necessary techniques	Analogy with human health
Corrective maintenance	Large maintenance budget	Hearth attack
Preventive maintenance	Periodic replacement of components	By-pass or transplant
Predictive maintenance	Monitoring of vibrations, heath, wear products and adjustments	Detection of hearth diseases by the ECG or other techniques
Proactive maintenance	Monitoring of the contamination conditions corrections as the basic condition for degradation and failures	Monitoring of cholesterol and blod pressure by controlled diet

4. PARALLEL BETWEEN MEDICINE AND MAINTENANCE STRATEGY

The human body offers many parallels with maintenance of mechanical systems. Actually, based on the proper nalysis of medicine the useful hints can be obtained for the maintenance strategy [5,9].

Namely, the largest number of technical systems (manufacturibg equipment, transportation means, etc.) same as human body have their functions based on application of various fluids. These fluids, like the lubricatingoils, hydraulic oils, fuels, coolants and air, carry contaminants with them and bring them into the system. Abnormal presence of contaminants in the system represent the basic cause for degradation of the system componenets, what leads to failure and shortening of the service life. Appearance of this cause usually occurs long before the detection of the undesired condition symptoms.

The high level of contamination is similar to high cholesterol level and high blood pressure in the human organism. In both cases, contamination and cholesterol (namely the high blood pressure) are the conditions that can be corrected. Not undertaking the corrective activities in both cases inevitably causes the degradation processes (with the degradation symptoms), shortening of the service life and cesation of functioning.

Based on the analogy of the hunam organism with the technocal system it is possible to describe various concepts of maintenance and explain the essence of the proactive maintenance (*Table 2*). The corrective maintenance of the technical system is analogous to the phenomenon of reaction to heart attack at humans. Waiting for appearance of indicators of this vital phenomenon results in need for the fast diagnostics and undertaking the resuscitation. At that moment there is usually not enough time for careful acquiring and analysis of data on condition and reliable dignostocs of the situation, but inevitably one undertakes radical, swift and most expensive procedures. After sucessfully performed action, usually the permanent negative consequences remain, both for health and service life. Those are exactly the situations that both doctors and maintenance engineers want to avoid.

comparison of maintenance with medicine fo the human body exactly points to defficiency of approach of the preventive maintenance according to plan. Namely, normally no doctor would suggest surgical procedures on critical organs, only due to age. It is also illogical to prescribe the replacemnt of the system's components and reparation based only on plansm without data on system condition.

The majority of surgical procedures, like hearth surgeries, are being scheduled based on the nondestructive tests, like ECG, which suggest the presence of a problem. The information obtained by tests are then being checked and the dignosis is being established, based on which the surgery is being planned, in the non-emergency conditions. in this way the probability of the sucessfull outcome is being increased. This is just the objective of the predictive maintenance. By gathering information on the techincal system condition, one can make an effective dignosis. In non-emergency conditions, based on that the logical maintenance activities can be planned.

The majority of doctors today recommend the proactive approach in maintaining the good health. It is very widely publicized that the holesterol and high blood pressure are predecessors of the serious health problems, like the hearth attack. Their appearance does not represent the symptoms of the disorder that is to happen, but basic cause of it. Through routine control of the basic causes, today the risk of later serious health problems can be reduced.

The doctors recommend regular checkups of presence and quantity of «contaminants», which are damaging to human health. When their presence superceeds the permissible level, the measures are prescribed to eliminate those basic causes of the health disorder. This is the logic of the proactive approach to health care. The technical systems can be maintained in the analogous way. Br regular monitoring of the contamination by solid particles and water, it is possible to undertake the corrective measures on time, in order to eliminate contamination and risk to system's reliability.

5. BASIC STEPS OF IMPLEMENTATION OF THE PROACTIVE CONTAMINATION CONTROL

The contamination control represents the foundation stone of the proactive maintenance and can be implemented through three simple steps [9]:

1. Maintain the target levels of each system's and fluid's purity.
2. Choose and instal the filtering equipment (or improve the existing from the filtration aspect).
3. Conduct monitoring of the fluid's purity in regular intervals, based on which the control of reaching the objectives is being done, and, if necessary, undertake the activities to stabilize the purity.

These steps are symbolically presented in *Figure 2* y necessity of overcoming the three cosecutive stairs, but withoput possibility to skip any of them.

The target level of the technical system purity ought to be chosen in accordance with its inherent sensitivity to contamination, various direct and indirect down time costs, funcional responsibility, and effect on environment. The typical system manufacturers' recommendations could be sufficient also for fulfillimg the specific needs and objectives, form the aspect of user's productivity.

When, after the careful analysis, once the target purity level is established, activities should be focused to its achievement and prreservation. The contamination control should, by no means, be misunderstood for instalation of the expensive filters, since it has much broader significance. To realize that, one should keep in mind that elimination of contaminants, which once have penetrated into the system fluid, costs about *10* times more than preventing their penetration.

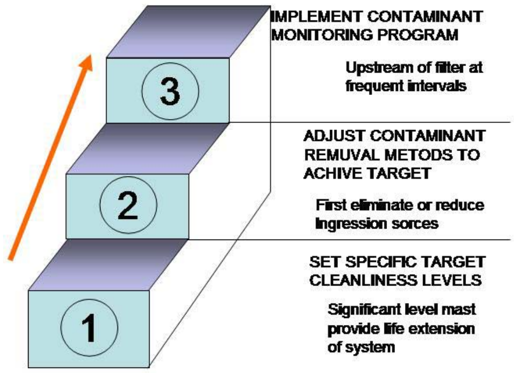

Figure 4: *Steps of fluid contamination proactive control*

For extraction of contaminats, i.e., for oil refinemet, responsible are filters and filter systems. To realize the desired level of purity in practice, it is necessary to take account of their condition, and, if necessary, perform their improvement. This does not have to mean application of the best or the most expensive filters, but utilizing the convenient filters in adequate manner with achieving the set objective.

6. CONTAMINATION MONITORING – CRITICAL FEEDBACK

Once the target purity level is achieved it has to be the subject of monitoring in order to ensure its mainaining. This actually is the heart and soul of the proactive maintenance. Just as the doctor, who does not consider that the holesterol level in the human body is static, thus the maintenance manager must ensure the agressive contamination monitoring to secure the contamination control in the technical system.

To implement the contamination control, its level is being checked at several critical points:

- Reception of the new oil from supplier
- Storage
- Replenishing or substitution of oil
- Building in the new components and

- Exploitation process

with application of the corresponding standards, procedures and instrumentation.

The contamination control starts even before introducing the fluid into thesystem. The new fluid, whose pysical-chemical characteristics are very good, does not necessarily have to be sufficiently pure to be used directly. Namely, in the manufacturing process, manipulation, transport and storage, oil is exposed to very high risk to be contaminated by all the types of contaminants, same as in exploitation. due to that, it is necessary to established the very rigorous dealing and checking procedures. In the contrary case, the adequate report with results of checking is being delivered to supplier and the receiving of the shipment is refused.

When oil passes the input check, the control of the oil purity level becomes the responsibility of the user. To respond to requirements for preserving the purity, it is necessary to set the standards for oil storage in large reservoires. In large number of cases it is necessary to perform changes in the storage manners or in the environment where the oil is being stored. Also, it is, in some cases, necessary to require the filtration systems for refinement of the stored oil. These changes ought to have the form of operational procedures, which are mandatory for all. besides that, to ensure the preservation of the necessary purity level, the stored oil must be the subject of monitoring.

Furing the transport from the reservoir to equipment in which it is used, oil is exposed to high resik of introducing the contaminants. Due to that, the replenishing and substitution of oil are the very rigid procedures, prescribed for each technical system and for each step from the reservoir opening on. To ensure the maintaining of the required purity level, in many cases the mobile systems, equiped with adequate refinement systems, are used for transfer of oil from storage to equipment, which is lubricated.

When the reparation is performed, or replacement of the system's components, like jonits, bearings, pumps, housings and other components, the special attention is needed so they would not be the cause of introducing the contaminants into the system. The cleaning procedures and components testings before the installation, as well as the control of the way of installation, can significantly reduce their service life.

The system is during exploitation charatctreized by exceptional dynamicity. It is not unusual that the contamination changes for two to three orders of magnitude during the day, or even within one hour. Due to that the solid particles and moisture, which penetrate into the system, can very fast reach the alarming level. If that is detected on time, during the routine monitoring, then it is inevitable to correct the main causes of contaminants penetration, like damaged joints, vents in the lubricating system, etc.

7. CONCLUSIONS

The difference between the traditional and contemporary monitoring philosophy of thelubricating oil can be expressed as the difference between the orientation to determination of the system element, which is in the failure state, and orientation to determination of the system elements, which are adequate for furter continuous utilization. In this way, the first approach has as a goal to reduce the secondary cosequences of failure, while the second one eliminates unnecessary maintenance activities, in which way the high economic effects are ensured.

The lubricating oil contamination by abrasive particles and water represent the most frequent and the most serious cause of failures of the lubricated tribomechanical systems. Considering that, the proactive maintenance of energetic plants is based on properly conceived oil monitoring program in tribomechanical systems. Prior to that, it is necessary to establish the target purity levels and choose and instal the necessary equipment for filtering. based on the monitoring results, the chekup is performed of the objectives achievements and, if necessary, the activities for purity stabilization are being undertaken.

Many companies conduct certain forms of used oils monitoring, but they usually overlook the real goals of thoseprograms, or they come up with the inadequate conclusions, based on the test analyses. The management program effectiveness is not measured by that which tests, what number of tests and how often are they conducted, but by the effect that the program has on the productivity and profitability of organization.

REFERENCES

[1] Babić M., Oil monitoring – key of maintenance, YUNG 2002, September Novi Sad, 2002. 25 – 27.

[2] Babić M, Lazić M., Defining principles of oil condition alarms and limits, ITC 2003, 08 – 10 October, Beograd, 2003.

[3] Babić M., Users guide for lubrications control, Electric Power Industry of Serbia, Quality Center, 2003.

[4] Babić M., Oil monitoring, IRMES 2004, September, Kragujevac, 67 – 73.

[5] Babić M., Oil monitoring, Faculty of Mechanical Engineering, Kragujevac, 2004.

[6] Fitch C. James., P.E., Proactive Maintenance can Yield More than a 10-Fold Savings Over Conventional Predictive/Preventive MaintenancePrograms, http://www.maintenanceresources.com/ReferenceLibrary/OilAnalysis/oa-pm.htm

[7] Toms A. L., Machenery Oil Analysis, Methods, Automation and Benefits, Second Editions, COSTAL, Virginia Beach, Virginia

[8] Troyer D., Fitch J., Oil Analysis Basics, Noria Corporation, 1999.

[9] TroyerD., Contamination Monitoringfor MaximumUptime, http://www.maintenanceresources.com/ReferenceLibrary/OilAnalysis/oa-cm.htm