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Viscosity Monitoring and Analysis for Rotating Machineries

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ABSTRACT: Lubricants used in machines degrade with time. This may be caused by load, contamination and operating environment. Proper monitoring and analysis of the state of the lubricant is required to keep the machine in good condition and to minimize the cost of maintenance. This research is concerned with the application of lubrication standards to ensure proper operation of rotating equipment. The methods outlined include monitoring, analysis and comparison with lubricant performance standards. The method when rightly applied can signal wear, level of contamination and chemistry of the lubricant. Viscosity monitoring and analysis is useful to determine the state of the lubricant and hence the health of the machine, which is useful in taking maintenance decisions. With proper monitoring and analysis of the lubricant in rotating equipment, safety is ensured in addition to reduction of unforeseen failures and the cost of maintenance of the machines.

KEY WORDS: Condition monitoring, lubricant, rotating machineries, severity, viscosity.

1.0 INTRODUCTION

Maintenance is the act of preserving the life of an asset. It is the means of ensuring that the equipment is in a suitable condition at all times to perform the designated functions. It is the only means that equipment or plant can be put in shape to fulfill management goals and objectives. Such objectives include proving quality product at the right time to the customers without compromising safety and legal issues. The maintenance practice adopted by a firm depends on its philosophy. Its philosophy might be to promote proactive maintenance or to keep a minimum workforce or to reduce emergency maintenance to a management stipulated level. It is clear that poor maintenance will not allow the business objectives of the organization to be met. The balance sheet of the company will be affected by poor maintenance practice. The shareholders may withdraw their shares if the company is not doing well, the customers may shift focus to another similar product and the company may be liquidated. This shows that maintenance is a very important component for business success. Poor maintenance will manifest in incessant equipment failure, downtime, unavailability, unreliability, poor maintainability and productivity.

Therefore with the growing competition in the business world and competition, companies must apply new maintenance methods to be alive and well in their businesses. Maintenance can be broadly divided into preventive maintenance and corrective maintenance. Corrective allows equipment to run to failure. In preventive maintenance, two methods of applications are possible. One is the use of data collected over time on the equipment to manage the health of the equipment or to use condition monitoring instruments to directly monitor the health of the equipment. Whichever method is chosen depends on the criticality of failure- on cost and safety. This is where Reliability centered Maintenance (RCM) plays an important part. In RCM the functions and usefulness of parts of the equipment are taken into consideration .The aim is improving the reliability of the asset. Reliability is one of the important indices in maintenance measurement.

Reliability is the ability of the asset to perform its intended function in a specified period of time. For an example if power was to deliver 2000 kW of power hour and it is delivering less than this, it is considered unreliable. The power plant may be available like in this case, but it is not reliable. Therefore the power plant can be considered productive, if it both reliable and available. Availability is measured by computing the uptime, divided by the uptime and the downtime. Another good index of maintenance management is maintainability. Maintainability measures the ease to bring back the equipment to life. It measures how fast the equipment can be repaired and get back to operations. It is affected by design. The figure of merit is the maintainability rate.

Failures of machines in the industry can be classified as mechanical, thermal or chemical .Mechanical failure may be due to bad or worn out bearings, creep of materials at high temperatures subjected to stresses, fatigue of machines members, excessive force due to misalignment and unbalance rotors, excessive induced vibrations caused by eddies and turbulence while fluid is flowing. In order to anticipate mechanical failures, the maintenance team must be equipped with instruments such as meter, shockpules meter, vibration analyzer, mechanical or electrical strain

gauge, and ultrasonic flow detector [1]
A vibration analyst measures the amplitude of vibration at different frequencies so as to know the reason for undue high vibrations [2]. A mechanical or electrical strain gauge measures deflection of critical structural parts like foundations, column etc. An ultrasonic flow detector detects minute cracks [3]. Thermal failures are due to overheating because of the following reasons: electrical insulation failures, lack of lubrication, inadequate cooling. In order to anticipate thermal failures, maintenance team must be equipped with instruments such as infrared thermometer and thermo vision. An infrared thermometer detects hot spots in bearings and other parts of the machinery by remote sensing. A thermo vision is an instrument, which scans the surface of a particular piece of equipment with infrared thermometer and displays on the video screen. Chemical failures may be due to corrosion or erosion as a result of failure of protective linings like glass, rubber, etc. These may also be due to highly corrosive or corrosive fluids containing abrasive particles. In order to anticipate chemical failures, the maintenance team must be equipped with instrument such as ultrasonic flow meter, ultrasonic leak detectors, ultrasonic or eddy current meter, An ultrasonic flow meter measures flow of liquids in pipes, heat exchangers etc. to know the extent of shocking, etc. An instrument leak detector helps to detect gases at high pressure, which cannot be otherwise seen or heard. An ultrasonic or eddy current thickness meter measures the thickness of paints, coatings, etc. It can be used also to measure the thickness of pipes and tubes for finding out wear rates.

The major causes of plant deterioration are overheating, deformation or cracks growth, corrosion and erosion, wear and electrical motor fault, which can be effectively monitored by thermal analysis, vibration analysis, corrosion analysis and erosion monitoring, lubricant analysis and motor flux leakage respectively [4]. A condition monitoring technique need not be sophisticated and expensive. There are simple and equally effective techniques, which most establishments could conveniently handle. These techniques are presented below.

Overheating due to motor overload or electrical components, switch gear, thyristors, etc bearing with poor lubrication, damage, overload, misalignment and transmission component with poor lubrication, overload or incorrect assembly can easily be detected from changes in the temperature at the nearest surface. A simple method of surface temperature measurement is the hand held thermometer using thermistor or thermocouple sensor. The most common and the cheapest are pocket-size units giving unambiguous digital readout from plug-in or permanently attached sensors. These pocket size units are robust, but their main draw back in predictive maintenance is contact problems with the probe. When using this pocket size unit measurement must be made at similar periods after start-up. A simple method of surface measurement in high temperature situations is the infrared radiation meter, which can be used by unskilled inspectors to locate hot or cold spots [3]. The heats detectors constructed so as to restrict the viewing angle, typically $2^{\circ} - 10^{\circ}$ cone. They usually require no cables or connections. Labels are cheap and can be replaced at each inspection. Labels are easy to attach, they are insensitive to maltreatment. Crayons and paints exist as alternatives to labels. For periodic inspections labels with indicators straddling the normal operating temperatures are the most ideal. For example such labels attached to the covers of electric motors would give clear indication of heating. Label has up to eight indicators, which change irreversibly from pearl grey to black when its critical temperature is reached.

Deformation or crack growth due to over stressing can usually be detected by vibration analysis. Vibration analysis offers the widest potential for fault detection and diagnosis, but is limited by the complexity of the monitoring equipment. The purchase and use of these instruments in the industrial system may represent some problems, since the instrument are costly and require special skill to operate them. A simple method of vibration measurement is the shock pulse measurement technique for monitoring rolling element bearings. In the shock pulse meter the shock value is determined from a circular slide rule control which is rotated until the shocks produce an available signal. The shock pulse instrument has no meter display and no range changes. The cabling is robust and the transducer has been made relatively insensitive to location.

The simplest method of vibration analysis is to use stethoscope or rods to transmit the sound or vibration to the ear, but their use are limited to qualitative assessment of the characteristics of the vibration. Vibration monitoring method has the potential to uncover over 70% of mechanical faults in equipment [5]. Vibration severity chart for machineries is available at [6].

Corrosion and erosion of inner surfaces are the most insidious types of plant deterioration [6].Casing thickness should always be monitored in order to avoid sudden and inadequate warning failures. The simplest method of casing thickness monitoring is to drill very small diameter holes to a predetermined distance from the inner surface. When corrosion has reached the end of the holes the liquid contained in the casing will then escape indicating the eminence of failure. For the integrity of the plant to be ensured, regular monitoring of the tell tale holes must be carried out. The existence of the tell tale hole in the casing being monitored will raise the stress locally.

The most common source of movement in the industry is the electric motors which drive conveyors, machines, pumps, etc. Electric motors are the most common cause of plant shut down. Failure in an electric motor can be classified under two broad categories, namely mechanical deterioration and electrical malfunction. Mechanical deterioration includes bearing degradation and motor distortion while electrical malfunction includes phase failures and short-circuiting. Both mechanical distortion and electrical malfunction can be easily detected by monitoring the flux leakage from gap between the motor and the stator windings. It can be monitored by attaching search oil permanently to the motor [3]. This does not require major disassembly but may result in the removal of the motor and covers. In this condition monitoring technique, a meter is available to be plugged into the search oil terminals giving two readings - one sensitive to electrical faults and the other indicative of any other likely faults. Researches on motor flus leakage have been conducted by [8] and [9].

The condition of the lubricant can be used to detect the damage at the interface between parts with relative movement. The simplest techniques are the mass use of filters and magnetic plugs. The filters and magnetic plugs meet all the requirement of the ideal condition monitoring technique. The simplest method of lubricant analysis is the examination of the filter placed to protect the system. Certainly, filters placed in the separate return line will give maximum information. An alternative method of lubricant analysis involved the use of magnetic plugs, which can be fitted in the return lines from the oil tank near the return flow.

It is important that the returning oil should flow around the magnetic plug and that the magnetic plug should be easy to remove. Units incorporating a self-closing valve to seal the system whilst the magnetic probe removed are available. During examination of the filter or plug, the total mass of the debris accumulation should be recorded. Before examination under a binocular microscope with magnification of about 200, the debris should be washed and then dried out on filter paper or attached to cello tape. The essence of this examination is to find and categorize the larger particles. The larger particles are indicative of failure of a washed surface rather than an acceptable wear [7].Lubricant analysis has been developed to provide detail diagnostic information, for example the type of component that is filing can be determined after categorizing the size, shape and general appearance of the larger particle.

Guidelines on CM monitoring technique have been provided by [10].There is some simple conditions monitoring techniques, which would indicate the malfunctioning of components or systems but cannot explain the cause of such deterioration. These include proximity analysis, position analysis, displacement analysis and speed analysis. Proximity analysis- the measurement of small gaps and clearance using calipers, feeler gauges, micrometer etc. Position analysis involves position measurement using simple equipment such as venire calipers, height gauge, etc. Displacement analysis involves the measurement of linear and angular displacement using simple equipment such as venire calipers, height gauge, etc. Speed analysis involves the determination of changes in speed of moving elements such as conveyors using tachometers. The measurement of changes in the proximity, position, displacement and speed of equipment if well analyzed can give a good idea of the "health" condition of the equipment.

Most standard plant equipment such as boilers are now provided with condition indicating instrument such as temperatures gauges, pressure gauge, motor current meter, torque recorders, flow meters etc. Regular monitoring of this condition indicating instrument and feedback of information by the operators can give long-term indication of equipment deterioration. Daily condition monitoring activities of the equipment should be done by the operators of the equipment before starting the work on the shift. The operators should check all gauges, meters and recorders and their reading recorded before starting the day's work. The operators should also be able to interpret condition monitoring data so as to be able to assist maintenance team in the speedy investigation and rectification of defects. The success of a condition-monitoring programme for equipment depends largely on the operators of the equipment [11].

Thus, as far as possible, one operator for each equipment should be allotted, and when the same equipment is used in more than one shift one operator for each equipment for each shift be allotted. Data collection standard procedure in conjunction with little knowledge of the task performer lead to incorrect diagnosis causing bad decision making [11].The advantage of this system is that an operator gets used to the sound working of his equipment and notices any change immediately, which is a predictive or condition monitoring maintenance strategy by itself. The first step in the planning of a condition monitoring programme is the selection of equipment and malfunctions to be monitored. It will be very illogical to monitor all equipment for possible malfunctions. In fact it would even be uneconomical to attempt such. The selection of equipment for condition monitoring should depend on the benefits expected from such exercise as condition monitoring involves cost in terms of time, money and personnel resources. Constant time interval monitoring or inspection is realistic from the practical point of view.

Asset inspection is an important approach to acquiring information for CBM decision-making. An inspection can incur additional costs. Some inspection methods even insist on the shutdown of the asset. Therefore inspection should be well conducted to reduce cost and enhance asset availability [12].

Equipment inspection can be performed continuously or on discrete time points. In practice continuous asset monitoring is often technically or economically not possible, hence most CBM methods adopt discrete inspections [13].

II. METHODOLOGY

The suitable method for this research is by periodic inspection of the of the lubricant used for rotating machineries such as gas generator and engines of the centrifugal pumps and such heavy duty system. It involves monitoring the viscosity of the lubricants and comparing it with the severity for each class of equipment. These machines are used in the flow stations for crude oil transportation by international oil companies (IOC) in and operators of marginal fields Nigeria. Its application is not limited to those already mentioned also suitable for critical machines like the gas turbines. Mathematical methods [14] or other models can be developed to determine the optimum monitoring interval to minimize the equipment maintenance cost.

A typical severity chart for lubricant is shown in Table 1.

Table 1: Performance Standard for Lube Oil Analysis

Performance Standard										
Severity Legend	**Severity Code**	**Parameters**								
		Wear			**Contamination**			**Chemistry**		
		Wear	Ferrous IDX super clean system Turbine	Ferrous IDX {regular com pump, gear box engine	Contamination	Water (%)	Contam. IDX	Chemistry	Chemical IDX	DV VISC % Change -%
High fault	Critical 5	71-100	(+ -) 50	200	71-100	0.3000	(+ -) 50	71-100	(+ -) 50	50.0
Low fault	Alarm 4	41-70	(+ -) 40	100	41-70	0.2000	(+ -) 40	41-70	(+ -) 40	40.0
High Alert	Alert 3	21-40	(+ -) 30	60	21-40	0.1000	(+ -) 30	21-40	(+ -) 30	30.0
Low Alert	Observation 2	1--20	(+ -) 15	30	1--20	0.0100	(+ -) 15	1--20	(+ -) 15	15.0
Normal	Normal 1	0	(+ -) 10	15	0	0.0000	(+ -) 10	0	(+ -) 10	10.0
Target	Zero 0	0	0	0	0	0.0000	0	0	0	0.0

Severity codes: 5, critical; 4 , Alarm; 3, Alert, 2 , Observation; 1, Normal

Table 2: Severity Indices and representations

Severity Legend	Severity Codes	Colour codes	Remarks
High fault	Critical 5	Red	Not acceptable
Low fault	Alarm 4	Purple	Unsatisfactory/ permissible
High Alert	Alert 3	Yellow	Satisfactory/ acceptable
Low Alert	Observation 2	Blue	Very satisfactory
Normal	Normal 1	Green	Good
Target	Zero 0	White	Excellent

III. DISCUSSION

Viscosity results for the rotating system such as turbines, gas compressor, pumps or gear box can be monitored in intervals of three months [14] and recorded.

The trends obtained from the monitoring and analysis should be compared with Table 1 in terms of wear, contamination and chemistry. There is classification of wear- for turbine, pump and gear box; level of water contamination and chemistry. In terms of severity code, the target is 0, with a code of zero; normal has a code of 1; low alert has a code of 2 which calls for observation; high alert has a code of 3, which calls for warning, low fault has 4, which is warning and high fault has 5, which is critical, indicating possible failure of the equipment.

The ideal operational requirement for the equipment will be for the viscosity index to be zero. This is possible during initial life of the machine when it is newly installed and operated. It is the ideal expectation and target or a score of 100% for the performance of the lubricant. However as the machine is in continuous it is expected wear and tear the machine parts will come into play and thus the code of 1 is an accepted limit. It is the normal alert condition and will serve a good purpose for the operation of the machines. If the condition of the machine while monitoring shifts to 2, the low alert, it is an indicating that failure has increased at a low level. It calls for observations of the machines and the nature of operating load should be markedly observed. It is an indication that noticeable failure has begun. In this case, maintenance department should be aware and alert. Spare part of the item of interest should be checked and ensured are available or awaiting arrival. The required skilled personnel or consultant should be checked and known to be available. The next alert expected is high alert from this point. Thus when the machine monitoring condition is 3, high alert is initiated. It is an indication that deterioration is in progress and maintenance and store departments should put their resources together. It is expected that in few months ahead that a fault alert (code 4) will happen. At this point vibration, heat, sound as practical evidence of failure may be accomplished. It is an indication that the equipment is seriously deteriorating and needing maintenance action. The next phase is code 5 showing the criticality of the machine condition. At this point marked noticeable metals are observed in the lubricant, which can be felt by hand. It is a high sign that the equipment is most likely to fail in the shortest period of time. The output of the equipment is will drop drastically and the equipment will fail. Maintenance must be carried out once this stage is research. Planning should have started at an early stage, mobilizing men and materials to restore the equipment to an acceptable operating condition.

Table 2 shows the colour codes and the indicators by the electrical circuit. It is the visual aid for easy monitoring. Target is white, normal is green; low alert blue; high alert yellow; low fault purple and high fault red.

IV Conclusion

Viscosity monitoring and analysis is useful to determine the state of the lubricant and hence the health of the machine. It can help to determine the level of wear of the machine, contamination with water or other fluids and the general chemistry. The classification of the condition of the lubricant both in numerical codes and colour codes as shown in Tables 1 and Table 2 makes it easy for the operators to easily know the condition of the lubricant as it changes. The dual coding also ensure matching and comparison. It is the lever for taking maintenance decision. With proper monitoring and analysis of the lubricant in rotating equipment, safety is ensured in addition to reduction of unforeseen failures and reducing the cost of maintenance of the machines. Viscosity monitoring is thus a good method of off/on line condition based maintenance and highly suitable for critical machines. The method is also simple and can be used for other simple rotating machineries.

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