"Condition Monitoring of gear oil using wear debris analysis technique"

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Abstract Gear oil is a fluid lubricant used in gears (gearboxes) for reduction of friction and wear of the gear tooth surfaces, removal of the heat generated by the operating gear and corrosion protection of the gear parts. Gear oil provide reliable, efficient (low friction), low maintenance operation of gears at different speeds, temperature, oil contaminations. The aim of this work is to investigate the effectiveness of the wear debris analysis of gear oil. Energy efficient oil is becoming popular. This is due to global increase in environmental awareness combined with the potential of reducing operating cost. Gear box is one of the most important part of the any machines or motor vehicle. Oil used in gear box plays an very important role during the working of gear box. The present work investigates and studies the effects of wear particles on the gear oil. In this work the quality of gear oil which was changed after different kilometer are investigate. For this Spectrophotometer oil analysis program (SOAP), Rotary particle depositor oil analysis (RPD), Microscopic test pH value of all sample. Viscosity test, flash point and fire point, Sulphur test, filter gram analysis litmus paper test (Color test) acid test are used for wear particles which is suspended in gear oil these test are very useful in gear oil analysis and provide important information about the condition of gear box. As the blood is very important for human being as oil is also important of any machine. The quality of any oil is adversely affected the operating cost and our all efficiency over all aim of this work is to find out the quality of gear oil at the various running condition. Which is very helpful for predicting and diagnosing the effect of wear particle on gear box.

Keywords: *Wear debris analysis, gear box, condition monitoring, viscosity, Flash Point & Fire point.*

1.Introduction

Oil monitoring is a key component of successful condition monitoring programmes. It can be used as a predictive and proactive tool to identify the wear modes of rubbing parts and diagnose the faults in machinery. By analyzing the oil sample, the residual life of used gear oil is determined and a fault in the machine has to be prematurely shut down. Some important gear oil properties such as proper viscosity, ability to withstand extreme pressures, thermal and oxidation stability, corrosion and rust protection, compatibility with seal materials must be present in safe limit for proper working of gear box. The increasing trend towards predictive maintenance has led to the development of a vast number of machine condition monitoring techniques of the techniques oil analysis is the distinct and most radily used method in determining mechanical failures in common components of industrial machinery such as gears and bearings. Low operating temperatures', low power losses and high effectiveness are major issues in modern gear box. In which gear oil can have significant influence the most important power loss mechanisms inside a gear box are due take place by wear debris particles present in the oil. Oil and lubricants are as important as blood for human being such oil and lubricants analysis is widely used in condition monitoring of lubricants mechanism and hydraulic system

Source of Contaminants can be grouped in to following categories-

(i) **Built in contamination :** Here include built in manufacturing debris permanent debris and other damage which occur during run in etc.

(ii) **Internally generated contamination :** These particles are usually wear debris from gears, bearings or other components resulting from micro pitting, micro pitting adhesion components resulting corrosion wear mode.

(iii) **Ingressed Contamination :** These may in dude moisture, acids or other fluids and different kind of fumes and gasses from atmosphere when air with in the gear box expands and contacts during normal heating and cooling ingress is often possible to faulty filters or breathers or from faulty such and packing etc.

(iv) **Contamination added during maintenance**: These are takes place due to using improper maintenance programme. All though current research is based in the wear debris analysis of gear oil (Maruti alto). This research a number of gear oil sample collected from Mruti alto gear box. The total running distance for every gear sample are different.

The innovation of this project is the date collection by using numerical methods visual methods, filter debris analysis and some chemical test for wear debris analysis. The objective of this work were to investigate the effective here of wear debris analysis in the diagnosis of gear box. The results obtained from wear debris analysis provide important information about the condition of gear box. This information are used the analysis the condition of the gear because when the rate of were is high or low type of wear and also find out the components of gear box. Which are highly subjected to the wear. The aim is to classify all these practical are according to their morphological attribute of size, Shape, edge, details thickness ratio, color texture and by using his classification these by predict wear failure modes in he gear box and utilized this information to prevent the gear box. From possible future trouble.

2. Previous research

A large range of literature on the topic of gear oil analysis exists, as demonstrated by X.P. Yan, C.H. Zhao, Z.Y. Lu, X.C. Zhou, H.L. Xiao [14], has present that oil monitoring is referred to as wear particle debris analysis and physical analysis of lubricants properties. V. Macian, R. Payri, B. Tormos, L. Montoro [17], has presents the development of a method which analyzes metallic wear debris and contaminants found to be present in fuels used by Diesel engines. B. J. Roylance [15], has introduced the science and application of ferrography embraces both the engineering and medical fields and this has led to new and exciting ways of understanding the associated phenomena and

how to extract the best information for the advancement of the subject matter.John A. Williams [16], has describes that each of the various processes by which material can be lost from a surface in service leaves its fingerprint both in the topography of the worn surface and in the size, shape and number of the particles which make up the wear debris.
X.P. Yan, C.H. Zhao, Z.Y. Lu, X.C. Zhou, H.L. Xiao [14], has present that oil monitoring is referred to as wear particle debris analysis and physical analysis of lubricants properties. Information technology, such as database technology, image processing, expert system, data fusion and multi-agent system such as management database, computer-aided wear particle analysis software used in oil monitoring. The basic principles and models of information technologies used in this field are presented. Information technology has changed the way in which oil monitoring is carried out over the past 10 years. Database technology, image processing, expert systems and network technology makes the oil-monitoring system more intelligent. Many oil-monitoring system have been utilized as an aid to monitoring the condition of industrial machinery, and in practice the application of the analysis software increases markedly the speed of analysis.There are still many problems needing to be solved in the future. Especially, remote on-line oil monitoring, automated identification of wear particles and the realization of intelligent diagnosis are still the important and interesting research areas. Although knowledge base and case base have been constructed, the quantity of the analysis rules is still sufficiently adequate for its purpose. In future, data mining is one area of fruitful research. From the system database, the relationship between the functions of the wear particle and the fault condition need to be established. In the meantime, the analysis principle of data fusion will be applied with the other processes of oil monitoring.The research results are very encouraging because it makes oil monitoring more practical, more convenient and more efficient. It should now be applied into oil monitoring more widely in industry.

V. Macian, R. Payri, B. Tormos, L. Montoro [17], has presents the development of a method which analyzes metallic wear debris and contaminants found to be present in fuels used by Diesel engines. The particles have been isolated by isolated by following two complementary methods; firstly, a magnetic separation method and then a filtering method using membranes. Particles are subsequently characterized by means of optical and electron microscopy, where it is possible to establish the type and severity of the wear, as well as establishing how the mechanism parts are actually affected by wear.The described analysis techniques is presented as an efficient diagnosis tool to detect failures in the operation of the fuel injection systems in Diesel engines. It would be necessary to carry out a follow-up of the particles present in the fuel, and it is not possible to introduce a filtering element downstream of the high pressure pump due to the high pressures supplied. The introduction of analysis devices in the fuel return outlet is therefore proposed. In this way, an increase in the number of particles in the fuel may be detected, which would be indicative of any abnormal wear or of any contaminants entering from the outside.

M. Scherge, J.M. Martin, K. Pohlmann [18], has investigated that wear particles found in ultra-low wear rate experiments were analyzed in order to understand the wear mechanism. Using a sophisticated particle separation method, the debris were separated from the oil and then analyzed using transmission electron microscopy accompanied by electron diffraction for chemical characterization.Wear particles derived from fully formulated motor oil were analyzed after realistic tribological stressing. The majority of the particles have a size of about 250nm. The particles contain all the elements present in both solids, environment and oil. Most of the particles are amorphous. However, crystalline particles exist originating from chemical reactions that lead to new compounds, as for instance $CaCO_3$, but do not originate form crystalline metallic surfaces. TEM analysis suggests that when a tribological film is formed its thickness should be less than 30 nm.

B. J. Roylance [15], has introduced the science and application of ferrography embraces both the engineering and medical fields and this has led to new and exciting ways of understanding the associated phenomena and how to extract the best information for the advancement of the subject matter.The purpose of this special issue is to provide an overview of some of the principal developments that have taken place over the past three decades, thereby placing on record what is widely acknowledged to be one of the most significant development in the field of wear debris technology.This overview of past developments in ferrography would not be complete without some speculation abut the future. There is a need to continue to develop methods that can remove the tedium of manual operation in preparing and analyzing samples. Some laboratories that experience large throughputs of samples incorporate automated procedures. With increased rate of staff turnover in many industries, it is important to provide good interpretative material backed up by through training of operating personnel. The enlarged use of computerized procedures for recording information, performing analysis, assisting with training programmes, and in gaining subsequent 'on-the-job' experience, is already available and will continue to develop as maintenance personnel become more computer-orientated and dependent.In setting down an overview of three decades of development and achievement in ferrography, it is far from being an exhaustive treatment of the subject matter. However, it is to be hoped that it has provided some insight into the way the story has unfolded so far and makes a fitting tribute to the originators of ferrography, without whom none of it would have been possible.The contributions of the other participants in this special issue will bring the story up to-date as they describe the more recent developments that are helping to ensure that ferrography continues to remain in the forefront of wear-related condition-based maintenance techniques.

John A. Williams [16], has describes that each of the various processes by which material can be lost from a surface in service leaves its fingerprint both in the topography of the worn surface and in the size, shape and number of the particles which make up the wear debris. To use debris examination as a diagnostic aid in assessing the health of operating plant, which may contain many tribological contacts, requires not only careful and standardized procedures for debris extraction and observation but also an appreciation of the mechanisms by which wear occurs and the regimes in which wear occurs and the regimes in which each of the contacts of interest operates when displayed on an appropriate operational map.When material is lost from a loaded surface either entirely or principally through some form of mechanical interaction the concentration, size and shape of the debris particles carry important information about the state of surfaces from which they were generated and thus, by implication, the potential life of the contact and of the equipment of which this forms a part. The full exploitation of this information and the ability to be able to predict quantitatively the future performance or life requires an understanding of the sources and mechanisms of generation of the extracted and sampled particulate debris. In many cases, it is instructive to display the running conditions of a given contact on some form of operational or wear map. This both enables the implications for wear of changes in design, material or operating parameters to be assessed and allows sensible correlations to be made between laboratory-based experimental investigations and observations in the field.

S. Ebersbach, Z. Peng, N. J. Kessissoglou [1], has investigate the effectiveness of combining both vibration analysis and wear debris analysis in an integrated machine condition monitoring maintenance program. To this end, a series of studies was conducted on a spur gearbox test rig.In this study of constant and cyclic overload conditions being imposed onto a spur gearbox system, the correlation of the two techniques concerning the resulting gear faults was found to be very good. Each technique added more evidence to complete a diagnosis of the gearbox system. Which proved to be correct upon inspection of the gearbox. The detection strengths of vibration analysis were found to be in the detection of fault conditions, while wear debris analysis can reveal the wear modes of the gearbox.

Future work will investigate the correlation of the two techniques when multiple gear faults exist. The data will be for the development of a combined artificial neural network and expert system for fault diagnosis in machine condition monitoring.

Surapol Raadnui [19], has provides a general overview of developments and progress in quantitative computer image analysis as applied to wear particle identification/classification technology, over the last two decades. Since many technical disciplines are involved in this ‘infant-stage’ technical area, an attempt is made to put into perspective mechanical failure prediction/diagnosis and prevention through quantitative wear particle morphological analysis.The identification of quantitative morphological features of wear particles is an important aspect of wear particle image analysis. Wear particle feature extraction is the next step to determine the morphological properties. To achieve this goal requires the setting up of hyperspace in order to find an efficient and appropriate method for analyzing each variable and then to define the acceptable regions in the hyperspace. This depends on the tribological system under investigation. The secret of successful quantitative wear debris analysis is to avoid getting lost in the hyperspace of too many quantitative parameters. By recognizing that the human ‘expert eye’ is the best wear particle analysis tool, the most effective way to exploit the power of image analysis techniques is to imitate as closely as possible the very same attributes.

Z. Peng, N.J. Kessissoglou, M. Cox [20], has describes that vibration and wear debris analyses are the two main conditions monitoring techniques for machinery maintenance and fault diagnosis. These two techniques have their unique advantages and disadvantages’ associated with the monitoring and fault diagnosis of machinery. When these techniques are conducted independently, only a portion of machine faults are typically diagnosed.Vibration analysis and oil analysis are the most effective techniques for monitoring the health of machinery. They offer complementary strengths in root cause analysis of machine failure, and are natural allies in diagnosing machine condition. They reinforce indications seen in each technology, and have unique diagnostic strengths in highlighting specific wear conditions. In this study, two condition monitoring techniques, namely wear debris analysis and vibration analysis, have been used to identify wear in a worm gearbox under various controlled experimental conditions. Wear mechanisms include the detection of rubbing, metal-to-metal contact, and boundary lubrication breakdown. Results have shown that these two independent condition monitoring techniques, a more reliable assessment of the condition of the test rig can be made. Meanwhile, the two techniques have their individual advantages. Wear debris analysis provides further insight on the wear rate and mechanism of the gears. Vibration analysis has provided quick and reliable information on the condition of the bearings. Integration of these two condition monitoring techniques in all tests conducted on the worm gearbox resulted in a comprehensive diagnosis of the machinery condition. Future research is planned to further examine the relationship between the two techniques during active machine faults, and examples from other machinery and components that are commonly encountered in industry.

C.Q. Yuan, Z. Peng, X.C. Zhou, X.P. Yan [21], has describes that when a machine is in operation, two moving surfaces interact to generate a large amount of wear particles. The wear debris generated inside the machine or contaminants from outside plays important roles in both two-body and three-body wear. For all mining and port machinery, their lubricants are very likely to be polluted by contaminants such as silica and other metallic debris such as iron and nickel. In order to seek a deeper understanding of the effects of different contaminants on wear process, this project investigated sliding wear processes when silica powder and iron powder exist in lubricants.Four sliding wear tests have been conducted on the pin-on-disc tester to investigate sliding wear processes when the silica and iron powder exist in the N32 lubricant. Visual inspection, ferrography analysis, the particle quantity analysis using a particle analyzer, and numerical surface analysis using CLSM were used to study the wear particles and wear surfaces. The following main conclusions can be summarized.Contaminants added to the lubricant play an important role in wear processes. The hard silica powder has a strong cutting effect, generating abrasive wear to accelerate the wear process. The wear rate of the ball sample becomes higher when the silica powder gets involved in the wear process. The involvement of the low hardness iron powder has played a role of reducing wear in the wear processes. The wear rate of the ball sample decreases when the soft iron particles are added to the lubricant. When the silica and the soft iron powder are mixed in the lubricant, the cutting role of the silica powder is weakened by the presence of the soft iron powder.

It is believed that the findings gained from this study and observation on the progress of the wear processes are significant. Some hard particles such as silica and soft contaminants coexist inevitably in the lubricant of these machines. To evaluate the operating condition of machinery and develop a strategy to maintain the machinery in a healthy condition, we need to understand fully how hard and soft contaminants influence the wear processes. Further studies using gearboxes in mining machinery with contaminants will provide more insight into how these particles affect wear processes in practice. The authors will report their findings in due course.

W. J. Bartz [22], has gives a consideration in this work are limited to fuel economy improvement by using other engine and gear oils that increase mechanical efficiency by reducing friction. It is the objective of this paper, based on the efficiency relationship of engines and gears to evaluate the order of magnitude of fuel reductions by lubricants.

First of all it must be taken into account that the fuel consumption of a car depends on a set of parameters only partly related to the lubricants. Mostly, their influence is much more pronounced than that o the lubricant itself.

3. Data collection & Experimentations

For this study all the gear oil sample are collected from Perm Motors ,Gwalior as shown in Table No-1.The grade of gear oil which is used in the gear box is 75w90.

Table 1 . Gear oil samples

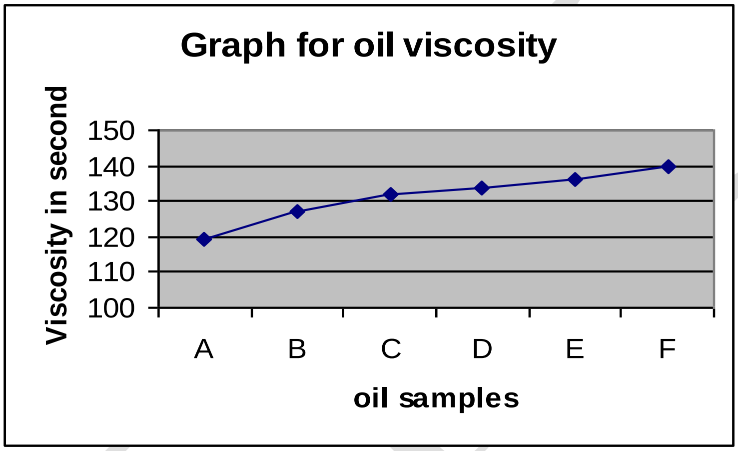
S.No.	Sample Code	Reg. No.	Source	Total running
1.	**A**	Fresh for Maruti Alto	Gear Box (Maruti alto)	Fresh Oil
2.	**B**	MP03/CA/0582	Gear Box (Maruti alto)	20720 Km.
3.	**C**	MP07/OC/0780	Gear Box (Maruti alto)	20993 Km.
4.	**D**	MP02/CO/0304	Gear Box (Maruti alto)	24575 Km.
5.	**E**	MP06/CA/0582	Gear Box (Maruti alto)	41635 Km.
6.	**F**	MP07/EA/2227	Gear Box (Maruti alto)	81506 Km.

3.1 Viscosity Test :

Viscosity monitoring is an important part of oil/lubricant monitoring on decrease in viscosity may indicate oil dilution or contamination by water or other fluids and increase in viscosity may indicate thermal breakdown and oxidation of oil or using wrong oil. Viscosity is defined on the property of a fluid which offers resistance to the movement at one layer of fluid own other adjacent layer of the fluid. Temperature affects the viscosity. The viscosity of liquids decrease with the increase of temperature. In this test for find out the value of viscosity of each gear oil samples a specially designed apparatus used which is known on “Redwood viscometer”. It gives the viscosity of each oil in second. (i) Clean the viscometer up properly dry it to remove any traces of solvent. (ii) Used the viscometer with the help of laving screw? (iii) Fill the outer bath with water for determining the viscosity at 300 ^{0}C and below. (iv) Place the ball value on the jet to close it and pour the text oil in to the cup up to the tip of indicator. (v) Place a clean dry Kohhrausch flask immediately below and directly in line with discharging. (vi) Insert a clean thermometer and a stirrer in the cup and cover it with a lid. (vii) Heat the water filled in the bath slowly with constant stirring when the oil in the cup attaching a desired temperature stop the heating. (viii) Lift the ball value and start the stop watch oil reaches the 50 ml mark on the neck of receiving flask. (x) Record the time taken for 50 ml of the oil to collect in the flask. (xi) Repeat the experiment to get more reading.The viscosity of oil samples are shown in Table No-2.

Table 2 . Viscosity of oil samples

S.No.	Sample Code	Viscosity in Second
1.	**A**	119
2.	B	127
3.	C	132
4.	D	134
5.	E	136
6.	F	140



3.2 pH test :

pH measures the amount of acidity or alkalinity using a numerical scale between 0 and 14.A pH value of 0 is most acidic. A pH 7 is neutral and values above 7 are referred to as basic or alkaline. The test of these oil samples show the pH value 7 for all the gear oil samples. Hence pH test indicates that samples are neutral.

3.3 Litmus paper test :

Litmus paper is used to test a liquid as acidic. Basic. Or neutral. This experiment is relatively inexpensive to do because the cost of litmus paper strips is low. The red strips look more pink than red and if they are dipped into a basic solutioin they will turn blue. The blue strips may look a more purple than blue, but they will turn pink (red) when dipped into an acidic solution. If the red and blue strips are dipped into a solution and they do not change in colour then the solution is neutral. Water is usually a neutral solution. One of the problems with conducting this experiment is to use solution that are acidic or basic, but not dangerous. When litmus paper dipped in to these oil sample, litmus paper did not turn their colour. It indicates that oil sample is neutral.

3.4 Filter gram Test:

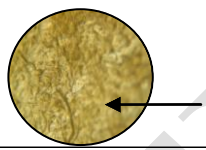
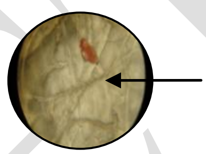
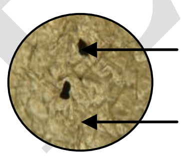
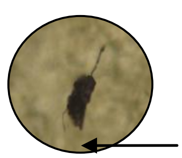
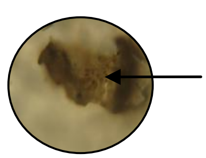
Filter gram analysis is the microscopic examination of wear particles taken from oil sample. A filter gram can identify particles from 3µ to over 1000 µ. A filter gram analysis of an gear oil sample can be a very useful addition to the more traditional methods of condition monitoring. The sample to examined in dissolved in a solvent

(D.M.S.O, Dimethayel Sulpha Oxide) and filtered through a very fine membrane filter. The wear debris and other contaminants in the oil are captured on the membrane for examination under a high power microscope. The filter gram report gives an analysis of the size and composition of all the particles found as well as the wear mechanism which generated the metallic particles. In this analysis what man Grade No.-41 filter paper used. Specification of filter paper are given below.

Porosity - Coarse
Flow rate - Fast
Particle retention - 20 – 25 um
Particle detecting capacity - Iron and Aluminum hydroxide

The wear particles detect in oil samples are shown in Table No-3.

Table 3. Microscopic view of oil samples

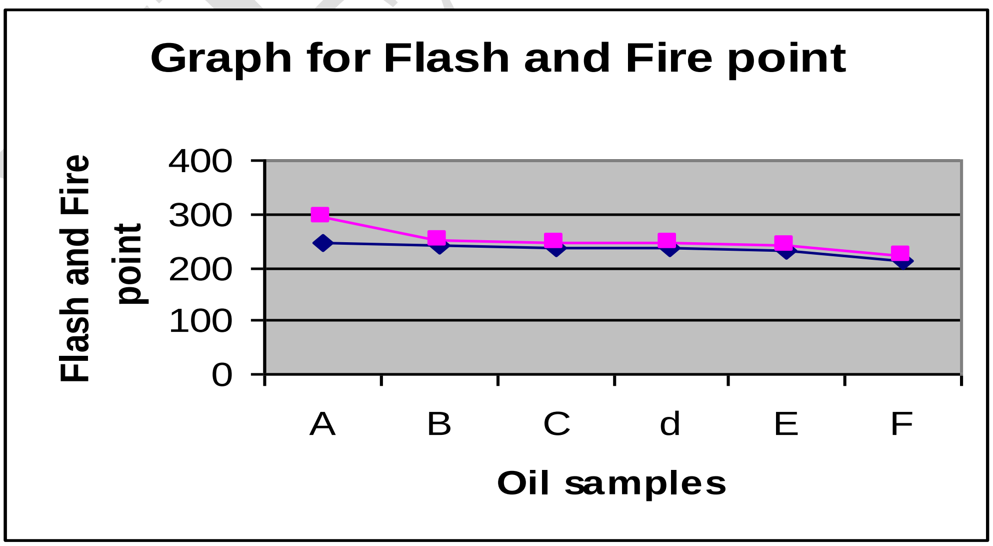
Sample code	Microscopic View	Remark
A		No wear particle have been seen
B		Small sliding particles are seen
C		Cutting particles have been seen
D		Wear particles with sharp edge have been seen
E		Laminar particles have been seen
F		Fatigue particles have been seen

3.5 Flash and fire point test :

The flash point is often used as descriptive characteristic of liquid fuel and it is also used to help characterize the fire hazards of liquids. The flash point of a volatile liquid in the lowest temperature at which it can vaporize to form an ignitable mixture in air. At the flash point, the vapor may cease to burn when the source of ignition in removed. The fire point a higher temperature is defined on the temperature at which the vapor continues to burn after being ignited neither the flash point nor the fire point is related to the 0020temperature of the ignition source or as the burning liquid which are much higher. For find out the flash and fire point of oil samples here are Pansky Martens apparatus used. Which is closed up texters. Where the vapors above the liquid. Are not in temperature equilibrium with the liquid. The oil samples are poured into cup. The cups are sealed with a lid through which the ignition source can be introduced. When oil reads its flash point it gives the flash when a ignition source read us it neck. After same time oil reaches its fire point at which it gives the flame of fire for few second. These temperature are carefully noted. The flash points and fire points obtained from the above test is shown in Table No-4.

Table 4. Flash point & Fire point of oil samples

S.No.	Sample code	Flash point in ^{0}c	Fire Point in ^{0}c
1.	A	245	295
2.	B	240	250
3.	C	238	248
4.	D	235	245
5.	E	233	240
6.	F	213	220

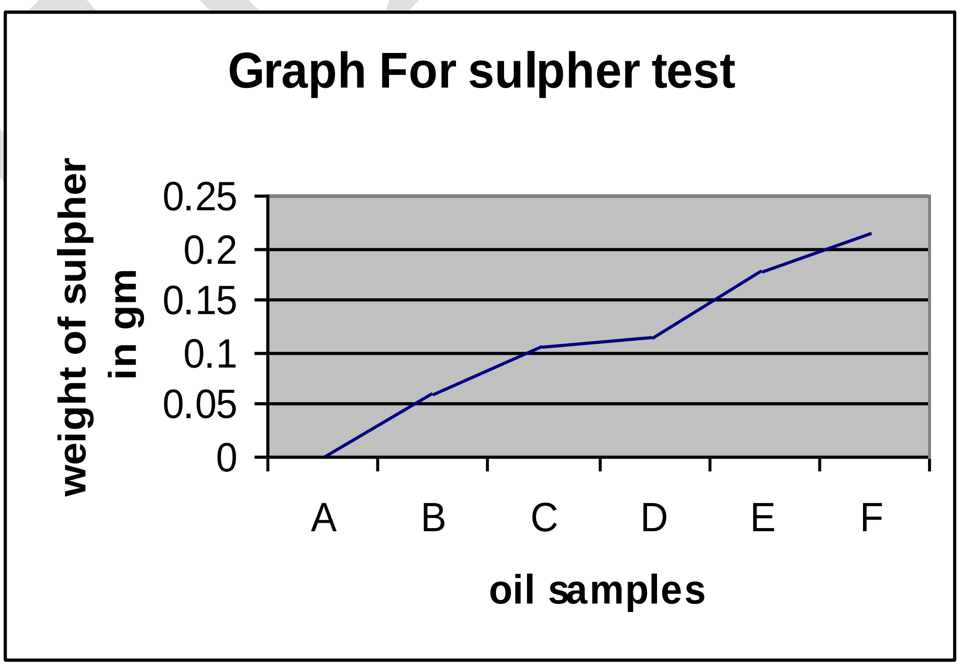


3.6 Sulphur Test:

Sulphur test is most important approaches to find out the presence of engrossed contamination in adversity affected the quality of gear oil. For finds out the presence of sulphur in this that gravimetric analysis adopted. For this each oil samples (50 mal) mixed with solution of HCl and water. The quantity of HCl and water remain same (100 ml each) These all mixed with carefully. Now the solution of oil in heated near about 30 min. After that time the dilute solution of oil cooled in presence of air. When it becomes cool. The solution of ($BaCl_2$ + H_2O) mixed with the concentrated solution. After mixing it a white precipitate are shown in the bottom of flask. After it the solution filtered through the filter paper. When the filtration complete a thick layer of wet sulphur present on the filter paper. This filter paper are burn in a silica crucible at the temperature (600 ^{0}C) for this a electric oven is used. and temperature 600 ^{0}C is fixed by the regulator. After burning the ash of sulphur remaining in the crucible. The weight of ash (sulphur) weighted by a electronic apparatus. The whole process in repeats for each gear oil sample. Following data are collected by performing these test.weight ofsulphur presents in each oil samples are shown in Table No 4.

Table 5. Weight of sulphur in oil samples

S.No.	Sample code	Weight of oil in gm	Weight of Sulphur in gm	Remark
1.	**A**	2	-	No sulphur content found
2.	B	2	0.0590	-
3.	C	2	0.1042	-
4.	D	2	0.1150	-
5.	E	2	0.1765	-
6.	F	2	0.2134	-



3.7 Water content test :

Water content test of gear oil samples are performed for find out the presence of ingressed contamination. These may include moisture acid or other fluids and different kind of fumes and gasses from atmosphere. In water content test each samples of gear oil are takes in a flask and heated at 200 ^{0}C. At this temperature oil boiled and their chemical properties changes. Oil heated and fumes are take off from gear oil. At this stage it visually inspected that there are no water content present in the gear oil sample.results of water content tests are shown in Table No 5.

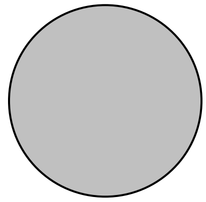
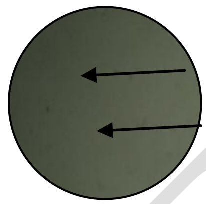
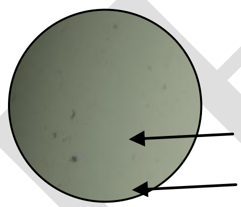
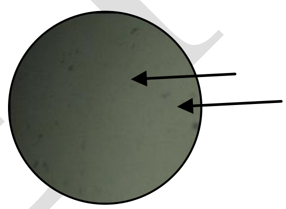
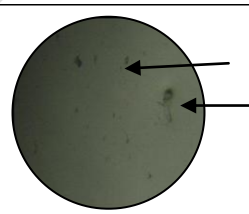
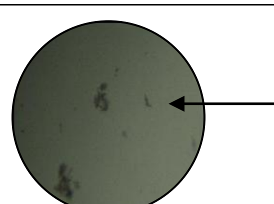
Table 6. Water content tests results

S.No.	Sample code	Test Temperature	Remark
1.	A	300^{0} c	No water content found
2.	B	300^{0} c	No water content found
3.	C	300^{0} c	No water content found
4.	D	300^{0} c	No water content found
5.	E	300^{0} c	No water content found
6.	F	300^{0} c	No water content found

3.8 Rotary particle depositor (Ferrography) :

The RPD rotary ferrograph offers a rapid and simple method of debris separation and particles size analysis. A measured volume of sample is applied by particle to a glass substrate located on a rotating magnet assembly. Particles of debris an deposited radically an three concentric rings by the combined effects of rotational, magnetic and gravitational forces. The RPD combines magnetic and centrifugal separation. It is faster than both the analytical ferrography and direct reading ferrography techniques and prevents an oil sample ready for microscopy in about 20 minutes. In this test RPD rotary ferrograph does not require the sample to be diluted and does not suffer from interference due to carbonaceous material in the sample. Removal of the lubricant by solvent washing and drying gives a stable well separated deposit pattern ready for examination by electron microscope. In this test each gear oil sample of 30 ml will takes for R.P.D. After 30 minutes R.P.D. instruments made a glass slide which were examined by the optical electron microscope which gives the following result as shown in Table No 6.

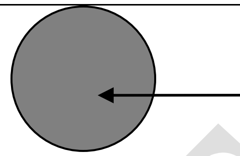
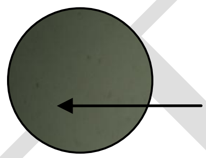
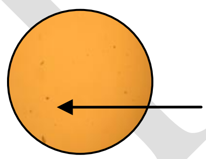
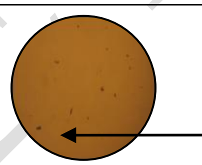
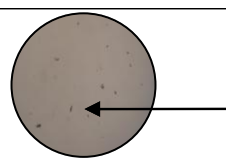
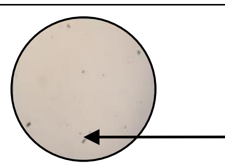
Table 7. Microscopic analysis of oil samples

S.No.	Sample Code	Microscopic view	Remark
1.	A		No particle has been seen
2.	B		A ring of small particle have been seen
3.	C		Particle size and edge very sharp
4.	D		Particle size and density is high
5.	E		A ring of big particle have been seen
6.	F		Very big particle have been seen

3.9 Microscopic Test:

In this test visual detection of wear particles are made by with the help of electro optical microscope for this a number of slides are made of each gear oil sample. Which are carried under microscope. In this test microscope used have a some special features which gives information about the particles size, shape and particles density. Which are very helpful for finding out the condition of gear oil. Microscopic view of all samples are shown in Table No 7.

Table 8. Microscopic view of oil samples

S.No.	Sample code	Microscopic view	Remark
1.	A		No particle have been seen
2.	B		Very small particle have been seen
3.	C		Particle density is high
4.	D		Particle size and density are big
5.	E		Big particle with sharp edge have been seen
6.	F		Particles density and size is very high

3.10 Spectroscopic Oil Analysis Program (SOAP)

It is a procedures for extracting fluid samples from operating systems and analyzing them spectroscopically to determines the concentration of key elements represented in the entrained fluid contaminant. Molecular spectroscopy uses principles of chemical physics to determine molecule concentrations. This has some distinct benefits for tracking additives. First, because molecular concentrations are being measured directly, additive decomposition, like the hydrolysis of ZDDP cited above, become immediately apparent. Secondly, many molecular spectroscopic may cover a multitude of analytical techniques, such as Fourier transform infrared (FTIR) and gas chromatography etc.

Spectroscopy is the most widely applied technique for debris monitoring. It provides a quantitative, multi-elemental analysis of wear debris in lubricating oil. The elemental concentration of as many as 20 elements are reported in parts per million (ppm). Wear metals such as iron, aluminum, chromium, copper, tin, lead, silver, titanium and nickel are detectable, as well as lubricant additives such as calcium, barium, zinc, phosphorus, magnesium, boron and molybdenum. Certain contaminants such as silicon, sodium and potassium are also routinely detected.

Table 9. Standard Table

S. No.	Sample ID	Type	Concentration	WL631	Wgt. Factor
1	10	STANDARD	10	.014	1
2	20	STANDARD	20	.029	1
3	30	STANDARD	30	.042	1

Standard Curve

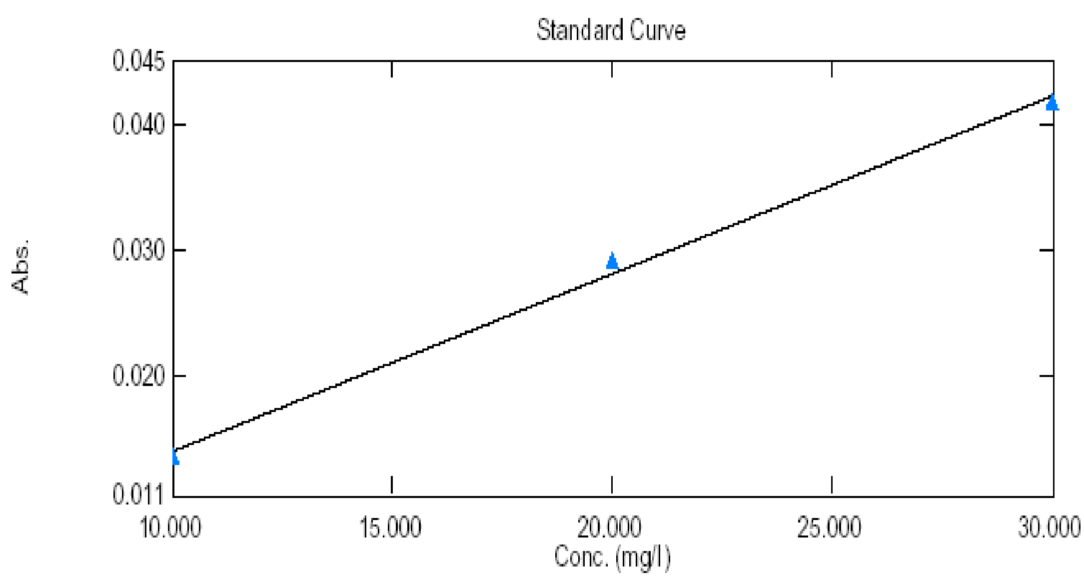
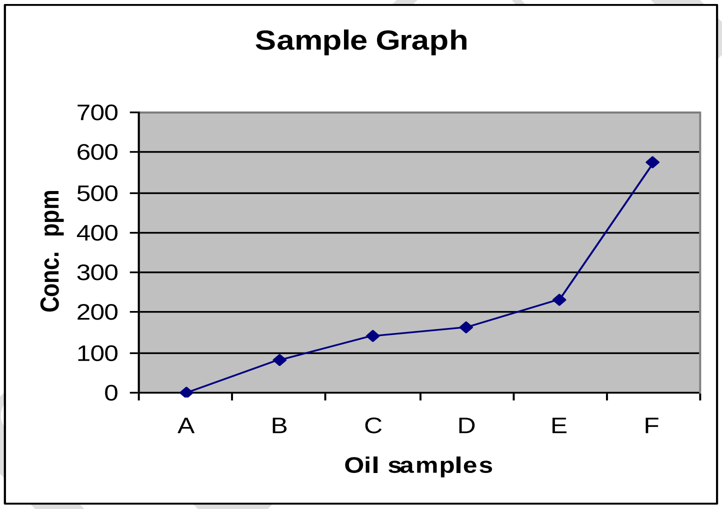


Table 10. Sample Table

S. No.	Sample code	Conc. p.p.m.	Wl631
1	A	0	0
2	B	80.568	.114
3	C	143.386	.203
4	D	161.443	.228
5	E	230.801	.326
6	F	574.772	.812



Results shows that % of carbon increases as the total running of Vehicles is increases.

3.11 Total Acid Number Analysis

Measures the total amount of acidic material present in the lubricant. Generally, an increase in TAN above that of the new product indicates oil oxidation or contamination with an acidic product. The results are expressed as a numeric value corresponding to the amount of the alkaline chemical potassium hydroxide required to neutralize theacid in one gram of sample. In chemistry, **acid value** (or "neutralization number" or "acid number" or "acidity") is the mass of potassium hydroxide (KOH) in milligrams that is required to neutralize one gram of chemical substance. The acid number is a measure of the amount of carboxylic acid groups in a chemical compound, such as a fatty acid, or in a mixture of compounds. In a typical procedure, a known amount of sample dissolved in organic solvent is titrated with a solution of potassium hydroxide with known concentration and with phenolphthalein as a color indicator.The acid number is used to quantify the amount of acid present, for example in a sample of biodiesel. It is the quantity of base, expressed in milligrams of potassium hydroxide, that is required to neutralize the acidic constituents in 1 g of sample. Acid no. of oil samples are shown in Table No 11.

Table 11. Total Acid Number of oil samples

S. No.	Sample code	Presence of acid yes/No	Acidity in mg/KOH
1	A	YES	.15
2	B	YES	.18
3	C	YES	.30
4	D	YES	.60
5	E	YES	1.2
6	F	YES	1.5

4. Conclusion

Oil analysis is the most effective techniques for monitoring the health of machinery. They offer complementary strengths in root cause analysis of machine failure, and are natural allies in diagnosing machine condition. They reinforce indications seen in each technology, and have unique diagnostic strengths in highlighting specific wear conditions. Wear mechanisms include the detection of rubbing, metal-to-metal contact, and boundary lubrication breakdown. The oil analysis was initially run under regular interval during machines life. A series of tests were then conducted under the operating hours of machine. Period of tests were every months. Oil samples were regularly collected. Numerical data produced by oil analyses were compared with another sample, in order to quantify the effectiveness of the results of oil condition monitoring technique. Results of oil analysis showed that there were significant different between viscosity characteristics of oil during time period.

The wear debris monitoring method access the nature of the particles generated when components wear. They can indicate exact nature of gear oil and gearbox problem by performing above test information about the particles are obtained. It indicates the amount of debris present in gear oil, size distribution of debris particles, physical from of the debris, chemical condition of gear oil and application of chemical analysis of debris. From test it is clear that the viscosity of each samples are continuous increases which shows thermal breakdown and oxidation of oil or using wrong oil. Filtergram test of oil

samples shows presence of ferrous particles, shape, size and density which also increases as the total running of vehicle is increased. Microscopic test R.P.D. test indicates the density, size, shape of debris particles. Water content test clear that there is no water content present in the gear oil. Flash and Fire point test shows that the thermal property of oil samples are regularly down. The excess presence of sulpher in gear oil creates many problems inside the gear box.
Thus the above and tests being imposed on to a gear oil sample that shows that there are correlation presence between each tests. Result obtained from above study are very helpful for finding the condition of gear oil as well as condition of gear box of Maruti alto wear debris analysis can reveal the wear mode of gear box.

Correlation of oil condition monitoring and fault diagnosis-

Oil analysis technique has been used to assess the condition of the reciprocating motor and diagnose any problems of that. The results from oil analysis of this experimental research indicated some defaults of diesel motor. Oil analysis of diesel motor could discover fault on piston, piston rings, top end bearing, fix bearing, crankcase, and most important fault of motor. The correlation between the oil analysis and fault diagnosis was excellent, as oil condition technique was able to pick up on different issues, thus presenting a broader picture of the machine condition. Oil analysis detected a continuing motor defect, mechanical damage and wear debris materials. Oil analysis technique was capable in covering a wider range of machine diagnostics and faults within the diesel motor.

Future work will investigate the correlation of wear particles analysis with an advanced program. So that it can indicates the condition of gear oil in on line position which is very helpful for predicting and diagnosing the health of gear oil and faults of gear box. In the continuation of this work following work can be considered for future research and investigation.

1. Development of expert system with these extracted features.
2. The other condition monitoring approaches as temperature monitoring, noise monitoring, vibration monitoring can be apply.
3. Generalized defect detection.

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