

WEAR RATE MEASUREMENT (IC ENGINE) USING LUBRICANT OIL TESTING METHOD

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ABSTRACT

Diesel engines are generally used for the automobile vehicles. These engine are the heart of the all the vehicles. Maintenance is the most important aspect for increasing Engine life which in turn increases the life of vehicle. Engine performances are directly depends upon the health of its components like piston, cylinder, cylinder head, crankshaft, cam shaft, connecting rod etc. Engines performances are also depend upon its lubricating oil. In this study, main aim is to the heath monitoring of the diesel engine components through the study of engine oil. In this paper the quality of engine oil which was changed, after different kilometers are measured. For this purpose Viscosity Test, Flash Point and Fire Point and Sulpher Test are used for the analysis of wear debris particles which is suspended in engine oil. These methods are very useful in engine oil analysis and provide important information about the condition of engine and whether it is needed to replace or maintain and it will also helpful for cost control. If the rates of these wear debris particles are high then it will indicate that engine is not in good condition and will require maintenance work. The aim of this paper is the condition monitoring of engine by preventing it to the upcoming failure through the study and analysis of the wear particles suspended in the engine oil since engine made through different particles such as engine block made from cast iron, piston made from the Aluminum alloy, crankshaft made from Cast iron etc. allow to determine where the chances of failure occur in the engine as the life of vehicle increases in term of Kilometers.

Keywords: *Condition monitoring Diesel Engine, lubrication monitoring, wear particle analysis, rotary particle depositor, microscope, viscosity.*

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1. INTRODUCTION

Oil monitoring is a key component of successful condition monitoring programs [6]. It can be used as a predictive and proactive tool to identify the wear modes of rubbing parts and diagnose the faults in machinery. [1] It is a method of predicting the health of equipment in a non-intrusive way, by the study of wear particles. The continuous trending of wear rate monitors the performance of engine / engine components and provides early warning and diagnosis. Oil condition monitoring can sense danger earlier than Vibration technique [2]. This technique holds good for both oil and grease samples. By analyzing the oil sample, the residual life of used oil is determined and a fault in the machine can be diagnosed before the machine has to be prematurely shut down. Sliding adhesive wear particles are found in most lubricating oils. They are an indication of normal wear.

The aim is to classify all these particulars according to their morphological attribute of size, shape, edge details thickness ratio, color texture and by using this classification there by predict wear failure modes in the engine and utilized this information to prevent the engine from possible future trouble. So in this way it is clear that the aim of this paper is to reduce maintenance work which in term also reduce all the expenditure which are used for maintain a Vehicle's engine in a working able condition.

2. TESTING METHOD

2.1 SPECTROMETRIC OIL ANALYSIS PROGRAMS

2.1.1 Introduction

A spectrophotometer is a device to measure light intensity at different wavelengths. It produces light with a light source, and after the light passes through a subject, the light is diffracted into a spectrum which is detected by a sensor and interpreted into results we can use. The output of a spectrophotometer is usually a graph of light intensity versus wavelength. It is a maintenance tool which is used to check the condition of the oil lubricated mechanical systems (Examples: Motors, Engines, Gear boxes, Hydraulic systems). The systems can be kept under surveillance without dismantling them. Abnormally worn compounds can be localized and replaced before a catastrophic failure occurs. The quantity and type of wear metals in sample of lubricating oil is determined. The quantity can indicate something about the magnitude of the wear and the type of wear metals can reveal which component is wearing out.

Data collected to generate this graph can typically be saved as a table of wavelengths and

2.1.2 Method Description

Spectrophotometer oil analysis is perhaps one of the more commonly used techniques for the determination of certain elements by either atomic emission or atomic absorption spectroscopy. While the techniques is readily automated to achieve a fast throughput of sample 1, 2 and has morphology of the wear debris and is sensitive to particles sizes 10 ~m 13[9].

2.1.3 Spectrophotometer Instrument

All spectrophotometer instruments designed to measure the absorption of radiant energy have the basic components as follows.

1. A stable monochromatic;
2. A wavelength selector to isolate a desired wavelength from the source (filter or source of radiant energy (Light) :
3. Transparent container (cuvette) for the sample and the blank;
4. A radiation detector (phototube) to convert the radiant energy received to a measurable signal; and a readout device that displays the signal from the detector.

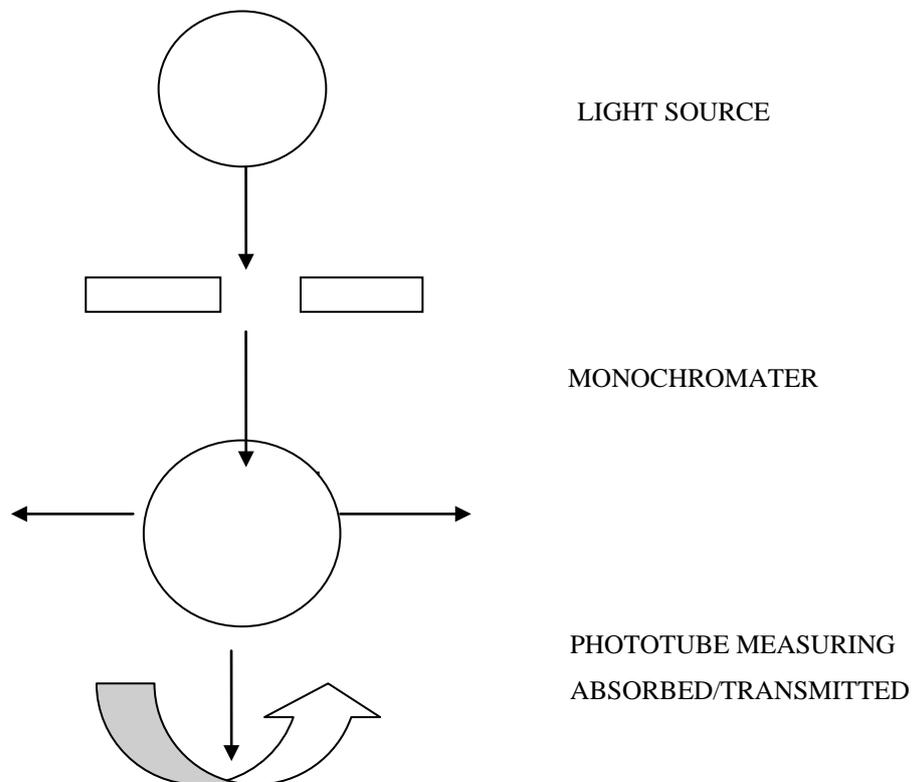


Figure 2.1: Component of Spectrophotometer

2.1.4 Working

When a beam of monochromatic light passes through a transparent medium, part of the light is absorbed and the transmitted beam has a lower intensity than the intensity of the incident

beam. Solutions are placed in containers (called "cuvettes") whose material is transparent: quartz is commonly used, but for visible light, one also uses disposable cuvettes made of polystyrene or polycarbonate.

The Transmittance, T of the solution is defined as the ratio of the intensities of the transmitted beam, I to the intensity, I_0 of the incident beam:

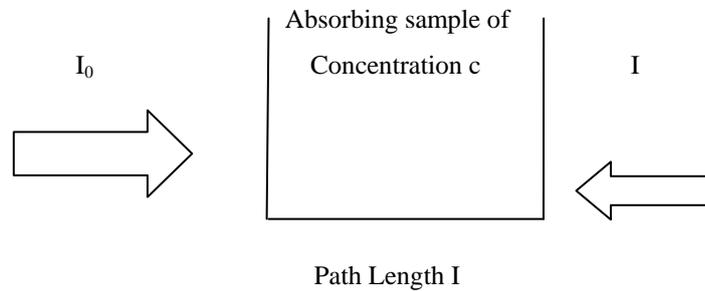


Figure 4.2: Beer–Lambert absorption of a beam of light as it travels through a cuvette of width l .

$$T = I/I_0$$

The Absorbance, α of a solution is defined as $\alpha = -\log_{10} T$. Since α is a logarithmic function, it is dimensionless.

The Beer-Lambert law states that the absorbance is directly proportional to the path length, l of the sample and its concentration c . These relation are usually written as

$$\alpha = \epsilon l c$$

Where

α = absorbance (no unit, since $\alpha = \log_{10} T = \log_{10} I_0 / I$)

ϵ = molar absorptivity (with units of $L \text{ mol}^{-1} \text{ cm}^{-1}$)

l = path length of the sample i.e. the path length of the cuvette in which the sample is contained

c = concentration of the compound in solution, expressed in mol L^{-1}

2.2 Rotary Particle Depositor

Rotary particle depositor is the low cost method of separating the debris particle from the sample of engine oil by the use of Millipore filter. That this result in the collection of all the contaminants in the lubricant sometimes tends to confuse matters. The concentration of wear particles is measured with an instruments called as Particle Quantifier or Debris Tester, which utilize the eddy current principles to measure small quantities of ferrous particles. The Interpretation of the information gathered, particularly that on characteristics such as shape

and size, require a degree of expertise that can be generated through the supplementary techniques such as Ferrography or Rotary particle depositor. [10].

2.2.1 Working

The RPD Rotary Ferro graph offers a rapid and simple method of debris separation and particle size analysis. A measured volume of lubricant sample is filled in the burette. Then switch on the power of RPD machine. When magnet and glass slide (substrate) assembly start to rotate at desired speed start allowing drop by drop lubricating sample oil on the glass slide by the means of nozzle fitted on burette. Keep the machine turn on till the end of lubricating oil in the burette. Particles of debris are deposited radially as three concentric rings by the combined effects of rotational, magnetic and gravitational forces. It should be noted that lubricating oil sample is well shacked before filling in burette.

2.3 Flash Point and Fire Point

Flash point is the lowest temperature at which the oil lubricant gives off enough vapours that ignite for a moments when a tiny flame brought near it, while fire points is the lowest temperature at which a vapours of the oil burns continuously for at least five seconds, when a tiny flame is brought near it. A good lubricant should have flash points at least above the temperature at which it is to be used. The flash and fire points are usually determined by using “PENSKY-MARTEN’S APPARATUS”.

This apparatus consist of:

2.3.1 Oil Cup

An oil cup is about 5 cm in diameter and 5.5 mm deep. The level to which oil is filled marked inside the cup. The cup is provided with the four opening of the standard size. Through one of these passes a thermometer; while the second opening is used for introducing test flame.

2.3.2. Shutter

Shutter is the lever mechanism, provided at the top of the cup. By moving the shutter, opening in the lid opens and flame is dipped in to this opening, thereby burning the flame over the oil surface.

2.3.3 Flame exposure device

It is a tiny flame, connected to the shutter by a lever mechanism.

2.3.4 Air Bath

Oil cup is supported by its flange over an air bath which is heated by a heater.

2.3.5 Pilot Burner

As the test flame is introduced in the opening, it gets extinguished, but when the test flame is returned to its original position, it is automatically lighted by the pilot burner.

2.3.6 Working

Oil under examination is filled up to the mark in the oil cup and then heated by the heater. Stirrer is worked between tests at a rate of about 1 to 2 revolution per second. Heat is applied so as to raise the oil temperature by about 5°C per minute. At every 1°C rise of temperature, test flame is introduced for a moment, by working the shutter. The temperature, at which a distinct flash (a combination of weak sound and light) appears inside the cup, is recorded as the flash point. The heating is continues thereafter and then test flame is applied as before. When the oil ignites the continuous to burn at least 5 seconds, the temperature reading is then recorded as the fire point of the oil.

2.4 Viscosity

Viscosity is a measure of the resistance of a fluid which is being deformed by either shear stress or tensile stress. In everyday terms (and for fluids only), viscosity is "thickness" or "internal friction". Thus, water is "thin", having a lower viscosity, while honey is "thick", having a higher viscosity. Put simply, the less viscous the fluid is, the greater its ease of movement (fluidity)[3].

Viscosity of lubricating oil is determined with the help of an apparatus known as Viscometer. In a viscometer a known volume of lubricant is allowed to flow, from a given height, through standard capillary tube under its own weight and the time of flow in second is recorded. The time in seconds is proportional to the true viscosity [5]. The results are expressed in terms of time taken by oil to flow through particular instruments. For example, if time of flow of oil through Redwood viscometer at 90°C is 120 Seconds, then its viscosity is 120 Redwood seconds at 90°C.

2.4.1 Procedure

Test of viscosity determination is very simple. First of all oil is filled up to the mark in the oil cup, and then this cup is heated by the water bath. Insert thermometer in the oil cup and note down the time of oil. As temperature of oil reaches at 99°C, remove the valve rod from the jet opening. Hence oil is falling down in the beaker (50 ml in size) which is already placed just beneath of oil cup. Time required to fill the beaker is known as the viscosity of the respective oil. Same procedure is applied for all the samples and determines their viscosity.

2.5 Litmus Paper Test

This test is very much simpler as compare to other test. In this test litmus paper is required for the examination of oil. Some drops of lubricating oil are applied on it and then allow it for drying. After drying it give different colour for different sample of lubricant. In this test paper

colour moves toward the dark black from the light brown. Following figure shows the result of litmus paper test.

2.6 Sulphur Test

If sulphur present in considerable amount in the lubricating oil it promotes corrosion. The corrosion test shows the amount of sulphur contents.

2.6.1 Procedure

Sulphur test is one of the important tests. For this 2 gm. weighted sample of lubricant are used (*i.e.* in this dissertation sulphur test are used for 2 gm. oil samples). First of all, weight of crucible is determined by the universal weighing machine. Net amount of sample are then mixed with the dilute HCl. Then heats up this mixture for 30 minute and then allow the mixture for cooling about 30 minute. Then mix the saturated solution of BaCl₂ (which work as the indicator) in this solution. If sulphur is present in the mixture then solution changes their colour otherwise not. If sulphur is present then an arrangement of conical flask and funnel are made. Watt men filter paper is placed on the top the arrangement (*i.e.* funnel) and applies solution on it. Liquid is filtered by filter paper and only sulphur is present on it. Then allow this paper for dry. When the paper is dried then put is on the crucible and burn the filter paper. When the filter paper is burnt, again weight the crucible. Subtract the pre-determined value of the crucible from it. Result weight shows the sulphur present in the 2 gm. sample. Similar procedure is applied for the entire sample and determined the sulphur present in all sample.

2.7 Moisture Content Test

This test is somewhat simple test as compare to other tests of this paper. This test gives quick **result**. In this test weighted sample of lubricant are taken in the beaker and heats up either by means of the gas burner or by means of the heater. For this test 5 gm. of each sample are taken. During this moisture content test, samples of engine oil are then heated up until the oil sample of **engine** smoke began to leave. If at this time sample of oil gives splatter of water which indicates the appearance of moisture in the sample otherwise sample are free from moisture. Similar procedure is applied for all the sample of oil.

2.8 Filter Gram Analysis

Filter gram analysis is the microscopic examination of wear particles taken from an oil sample or **filter** medium. A Filter gram can identify particles from 3 microns to over 1,000 microns. Particle size, wear factor and identification are reported in graphs and include two scaled photographs highlighting critical points in a sample. Positive confirmation is

assured to differentiate between **chemical** leaching and mechanical wear.

2.8.1 Procedure

A filter gram analysis of an oil sample can be a very useful addition to the more traditional methods of condition monitoring. The sample to be examined is dissolved in a solvent (Di methyl Sulphoxide) and filtered through a very fine membrane filter (watt men filter of 41 no). Filter papers used in the examination are capable of measuring the particle of size more than 22 **microns**. The wear debris and other contaminants in the oil are captured on the membrane for examination under a high power microscope[8]. The filter gram report gives an analysis of the size and composition of all the particles found as well as the wear mechanism which generate the metallic particles. Photographs of selected particles are presented on the report. Debris recovered from filter media can also be analyzed by these techniques.

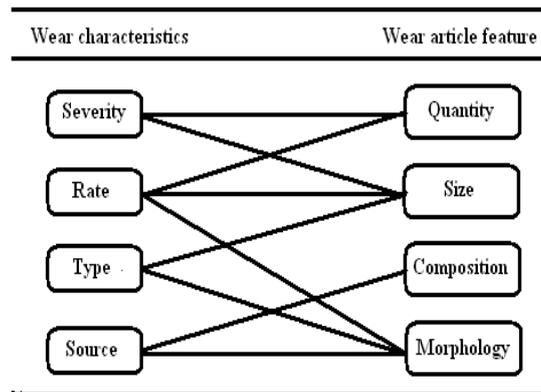
2.9 Infrared Technology

Infrared thermography has been used as a condition monitoring tool for over a decade. The technology provides thermal images that could help the experts in detecting faults in electrical and mechanical systems. In spite of its capabilities, infrared thermography has not found its way **into** autonomous systems. The main reason for this is the high cost of the technology. A typical **infrared** camera could cost more than £40 000 or far more. A recent drive to reduce the cost of **the** technology has had only a limited effect. Most of the available infrared systems in the market are designed as portable systems for measuring and saving data. The low-cost infrared imager used in the present research work is type IRI1002, produced by IRISYS Limited. The infrared **multipoint** radiometer is an uncooled pyro electric system. The pyro electric detectors generate a charge on every pixel that is proportional to the change in the infrared radiation received as a result of change in temperature of the viewed objects. Imagers of this type require a constantly **changing** image signal, and thus the imager has a mechanical chopper to generate a continuous **change** in infrared radiation.

The difference between the chopper and the open-view infrared radiation produces a corresponding charge which is converted into a voltage and amplified to produce a thermal representation of the object.

2.10 Wear Debris Analysis

Relationship between wear characteristics and wear particle features are shown in the following table. 4: Relationship between wear characteristics and wear particle features [7]



The technique of Wear Debris Analysis is gaining popularity in the field of Condition Based Maintenance. WDA is a method of predicting the health of equipment in a non-intrusive way, by the study of wear particles. The continuous trending of wear rate monitors the performance of Machine / Machine components and provides early warning and diagnosis. Oil condition monitoring can sense danger earlier than Vibration technique. This technique holds good for both oil and grease samples.

2.11 pH Test

PH is the measure of hydrogen ion activity. It is used to express the intensity of acidic or alkaline **condition** of a solution. pH is the relative acidity or basicity of a substance. This value is important information to have in many situations as the pH level of a substance dictates its safety, chemical reactivity and effects on the environment. Everyone from chemical engineers to home gardeners can make use of the pH information for a specific substance. This value is so important that the ability to test the pH of a substance, such as oil, has been around for many years and can easily be accomplished. pH of lubricating oil sample can be determined by electrometrically or colorimetrically.

2.11.1 Procedure

Following step shows the method of ph test:

1. Remove a universal indicator strip from its container.
2. Dip one end of the universal indicator strip into the oil for which you want to test the **pH level**.
3. Set the universal indicator on a dry surface for 60 seconds to allow the pH reading to take **place**.
4. Compare the changed color of the universal indicator paper to that of the pH chart that accompanied the paper's packaging.

5. Match the new color of the universal indicator paper to that of the chart to find an exact pH match.

3. Data Collection and Experimental Setting

All data of sample are collected from the Prem Motors Gwalior, and these all sample are belongs to the engine oil of (diesel engine) Maruti Swift Details of all samples are described below [4]: Details of engine components are given in Table : 1

S.No.	Characteristics	Description
1.	Engine Type	DIESEL
2.	Cylinder Type	Four Cylinder Engine
3.	Bore	74 (mm)
4.	Stroke	75.5 (mm)
5.	Maximum Power	87Bhp at 6000 rpm
6.	Maximum Torque	114Nm at 4000 rpm
7.	Cylinder	Inline

Following Table 2: shows the all the details of oil (in terms of kilometers) which are used for the investigation.

Sample Code	Vehicle	Total Vehicle Runs
1.		0 (unused)
2.	MP07-mJ-7777	1500
3.	MP06-CA-1687	3000
4.	MP07-CA-4425	5000
5.	MP07-CC-6022	8000
6.	MP07-CC-3050	10000
7.	MP07-CC-4510	12000
8.	MP07-CA-4209	15000

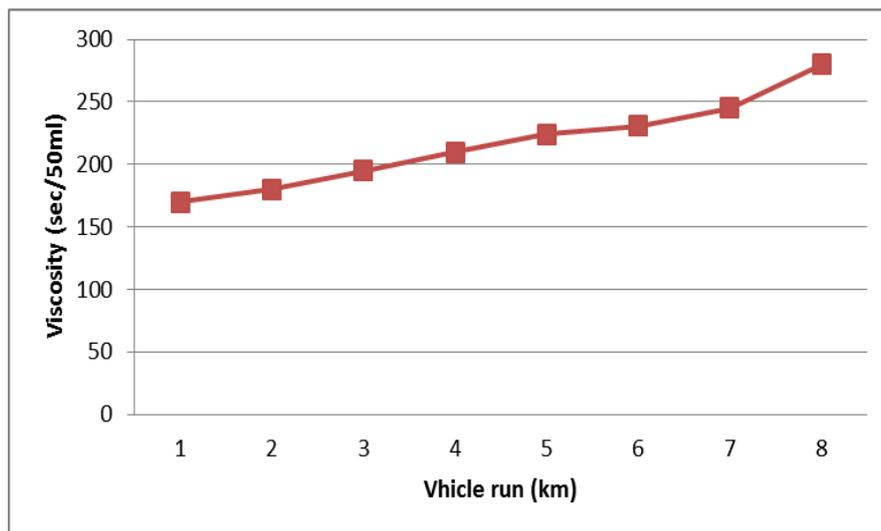
4. TESTING RESULTS

4.1 Viscosity Test

Viscosity of lubrication oil of all the vehicles which was used for the investigation, are listed below in the following table in this test viscosity of the oil are determined at 99.9° C. It is clear with the help of above viscosity test that as vehicle life increases (in term of running kilometer) the viscosity of the engine-oil also increases.

Table: 3

Sample	Investigated
1	170 Sec/50ml
2	183 Sec/50ml
3	195 Sec/50ml
4	210 Sec/50ml
5	224 Sec/50ml
6	231 Sec/50ml
7	245 Sec/50ml
8	280 Sec/50ml



4.2 Sulphur test

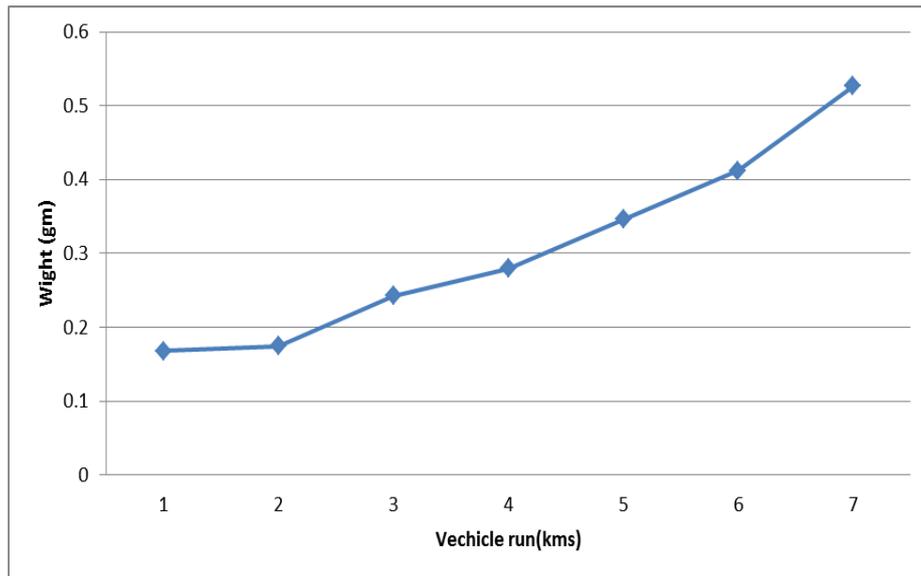
Sulphur test are carried out through Gravimetric Analyst is. Following table 8 shows the result of sulphur test.

Weight of crucible= 16.1140

Table: 4

Sample	Weight of	Weight of Sulphur
1	16.2718	0.1678
2	16.2986	0.1745
3	16.3764	0.2424
4	16.4308	0.2792
5	16.5098	0.3458
6	16.5462	0.4122
7	16.6209	0.5269

Following figure shows the graphs for the Sulphur weight found in the entire oil sample



It is clear from the above table that weight of sulphur increases as the vehicle runs increases

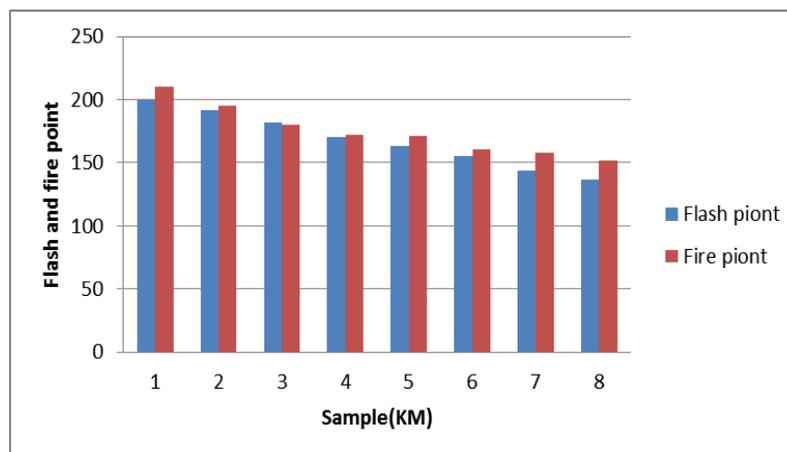
4.3 Flash point and fire point test

Flash point and fire point of the entire engine oil sample which was used for the investigation are listed below.

TABLE: 4

Sample	Flash Point	Fire Point
1.	200	210
2.	192	195
3.	182	180
4.	170	172
5.	163	171
6.	155	161
7.	144	158
8.	137	152

Following figure shows the relationship between flash points and fire point of all oil samples.



4.4 MOISTURE CONTENT TEST

TABLE: 5- Moisture Content

Sample code	Remarks
1.	Moisture not found
2.	Moisture not found
3.	Moisture not found
4.	Moisture not found
5.	Moisture not found
6.	Moisture not found
7.	Moisture not found
8.	Moisture not found

It is clear from the test that no moisture presents in any sample. This also indicates that there is no leakage in the engine. Hence it is clear that vehicles whose oil was used for the investigation are from moisture.

4.5 SOAP TEST

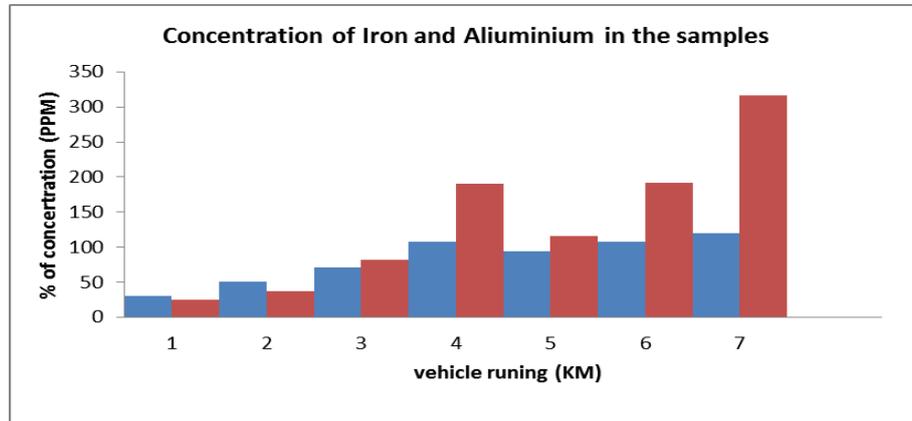
Concentration of aluminum and iron particles is shown in the following table.

TABLE-6 Concentration of Iron and Aluminum

Sample code	IRON		ALUMINIUM	
	CONCENTRATION	WAVELENGTH (WL608.0)	CONCENTRATION	WAVELENGTH (WL634.0)
2.	35.45	0.261	5.012	0.004
3.	50.123	0.321	30.457	0.017
4.	60.29	0.264	80	0.072
5.	80.187	0.428	110.174	0.0769
6.	99.76	0.603	190.125	0.417
7.	101.205	0.606	190.786	0.122
8.	115.325	0.766	216.23	0.236

It is clear from SOAP analysis, Concentration of Aluminum and Iron particles has increased with vehicle runs. So that the parts of engine which was made from aluminum and iron, wear rate increased with vehicle run.

Concentration of Iron and Aluminum in the samples



4.6 pH TEST-

Table-7 pH test result

SAMPLE CODE	VEHICLE REGISTRATION NO	pH VALUE	REMARKS
1.	Unused oil	6.5	Free acid Negligible
2.	MP07- MJ-7777	7.0	Free acid Negligible
3.	MP06-CA-1687	7.5	Free acid Negligible
4.	MP07-CA-4425	7.0	Free acid Negligible
5.	MP07-CC-6022	5.0	More free Acid -Adulteration -Contamination
6.	MP07-CC-3050	8.0	Basic (more OH ⁻) -Adulteration -Contamination
7.	MP07-CC-4510	8.2	Basic (more OH ⁻) -Adulteration -Contamination
8.	MPO9-CA-4209	10	Basic (more OH ⁻) -Adulteration -Contamination

On the basis of pH test it is clear that as the vehicle life increases free acid increases, and the rate of Adulteration and Contamination are also increases.

4.6.1 Significance-

Table: 8 Significance of pH value

pH value of sample	Significance
6.5-7.5	Contamination are not there
6.5	Natural Good
8-10	Basic (more OH ⁻) Contamination are there
5	Contamination is there No of free acid increases Adulteration.

5. CONCLUSION

IC engines are generally used for the automobile vehicles. These engines are important for the Automobile as like the heart for human being. As the heart of human being is fail whole system of body also failed. So for successful operation of vehicle engine should perform its intended function properly. There are lots of methods are available for the monitoring of engines performance such as vibration monitoring, acoustic monitoring, oil monitoring etc. This dissertation is totally based on oil monitoring.

Oil analysis is the most effective techniques for monitoring the health of engine. They offer complementary strengths in root cause analysis of engine failure, and are natural allies in diagnosing engine condition. They reinforce indications seen in each technology, and have unique diagnostic strengths in highlighting specific wear conditions. The following few conclusions could be highlighted;

1. It is clear from the *pH test*, as the vehicle life increases rate of free acid increases, and the rate of Adulteration and Contamination are also increases.
2. In the *litmus paper test*, colour of strips are becoming dark as the running of vehicle which also have same meaning that debris particles are closely placed with each other in this way the colour of strips are dark. This also means that the quality of engine oil has been continuously decreased.
3. In the *microscopic analysis*, rate of particle deposition has increased with the vehicle runs. Since Microscopic analysis is suitable for ferrous and non-ferrous particles hence this analysis concludes that rate of ferrous and non-ferrous particles have been continuously increased with the vehicle runs i.e. the quality of oil decreased.

4. *Moisture content test* is very important test for engine's point of view. This test concludes that no moisture has present in the lubrication oil. This also indicates that engines of vehicle whose oil are used for the investigation are free from any types of moisture.
5. In the *Flash point and Fire point*, burring temperature of engine oil continuously decreased, *i.e.* the flash point and fire point of engine oil samples are continuously decreased with the vehicle runs. This indicates that engine oil will also burn with the fuel and this is not a good symptom for safe running of the engine.
6. In *SOAP*, concentration of Iron and Aluminium particles has increased with respect to vehicle runs, which in terms increases the viscosity of the oil *i.e.* the quality of the oil continuously decreased with the vehicle runs.
7. In the sulphur *test*, it is proved with the Gravimetric analysis that the rate of sulphur presence is increased with vehicle runs.
8. It is clear with the *viscosity test*, the viscosity of the engine oil increased with vehicle run, which indicates that the rate of particle deposition increased with the vehicle runs *i.e.* more debris particles are suspended in the engine oil with the vehicle runs
9. It is clear with the *filter gram analysis* that the presences of non-ferrous particles are increased with the running of vehicle, *i.e.* the quality of engine oil continuously decreased with the vehicle runs.

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