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A Study of Variation in Viscosity–Temperature Relationship with Time of Use of Lubricant

Nitish Kumar Sah[1], Pooja Nand[2], Manoj Kumar[3]

[1, 2,3]*Mechanical Engineering Department, BIT Sindri, India*

Abstract - *Lubricants are used to reduce friction and wear in machine parts with surfaces in relative motion. Viscosity is one of the most important property of the lubricant. The load bearing capacity of the lubricant depends on its viscosity. Viscosity is highly dependent on temperature hence while selecting a oil the viscosity of the oil at normal temperature, the temperature of the application and a proper viscosity temperature relationship is desired. A number of viscosity temperature relationship are available. Oil deteriorates with use time, so the viscosity of the oil also gets changed. Very few work is available to investigate the variation of viscosity temperature relationship with the time of use. It is highly desirable in deciding whether the oil has reached its limit of useful life and needs a replacement. The present work attempts to investigate the viscosity time relationship of a lubricating oil used in drill rig. Chronological samples have been collected and using one of the common available Viscosity-Temperature relationship, the variation in this relationship with time has been studied.*

Key Words: **lubricant, lubricating oil, viscosity, temperature, age**

1. INTRODUCTION

Lubricants are used to reduce friction and wear at the interface of two surfaces in relative motion. It is also used to transfer heat, clean the surface, prevent the surface from contamination and reduce noise & vibration etc. It also used as a medium to detect the condition of machines. Generally lubricating oil contains either mineral base or synthetic base oil and less than 10% additives. There are so many physical and chemical properties of lubricating oil like viscosity, oxidation stability, thermal stability, viscosity index, evaporation and volatility, flash point, pour point etc. Out of all these properties viscosity is the most important property of lubricant. It is defined as the internal resistance offered by one layer of fluid to the adjacent fluid layer. It decides the ability of the lubricant to form the film on the surfaces and the load bearing capacity of the lubricant film. Higher the viscosity more will be load bearing capacity. But, High viscous oil required to more power for sheared it and because of that power losses will be higher and more heat is generated and as result increase in temperature of the contacting surfaces which lead to the failure of machine component parts. Viscosity of different oil varies at different rates with temperature and shear rate. Therefore the knowledge of the characteristics of viscosity of lubricating oil is very important in the design and prediction of the behaviour of mechanical components. A lubricant in service is subjected to a wide range of conditions which can degrade its base oil and additive. Such factors include heat, moisture, internal or external contamination, process ingredients. Bair scott., et. al., (2001) shows the variation of viscosity and pressure for both very short times of shear and compression and long times of shear and compression. And compared with Hertz zone of EHL (Elastohydrodynamic Lubrication) films for the viscous regime of traction. Yunus syarifah., et. al., (2013) compare the viscosity index and wear elements such as lead(Pb) Iron(Fe) Aluminum(Al) Silver(Ag) Tin(Sn) and Copper(Cu) of two engine oil Perodua Genuine (PG) oil SAE5W-30 and Castrol Magnatec (CM) oil SAE5W-30 using optical emission spectrometer. Oyedeko.K.F.K. Akinyemi., et. al., (2018) found the trend of viscosity variation with temperature so that a suitable lubricating oil for petrol automotive engines could be selected. Jakobsen M.O., et. al.,(2020) done analysis on grease lubricated ball bearing run under load which initiated the vibration. And show a correlation between lubrication ratio and spectral kurtosis for a given frequency band. Singh A.K., et. al., (2006) have studied the variation of viscosity with temperature and time. They have attempted to find viscosity-temperature-time correlation for heavy earth moving equipments used in coal mines.

2. The Case Study

To investigate the trend of viscosity-temperature variation with time for lubricant used in generator set, a viscosity-temperature relation is used which is given by Walther's, to find correlation between them. For this work, engine oil samples were collected from a drilling rig generator set provide power to E-1400-16, used in land drilling rigs application at Oil & Natural Gas Corporation (ONGC) Rajahmundary Asset. A drilling rig is an integrated system that drills wells to explore crude oil and natural gas from mother earth's subsurface. At drilling rigs there were four set of generator which equipped with Cummins make engine. Hence to operate all the main components of drilling rigs needs power which supplied by this Cummins make engines. Engine oil sample collected from Cummins make engine (model KTA50G3) and it is a 4-stroke, V-16 cylinder Diesel engine. Its engine capacity is 1430 KVA. Engine oil used in these Cummins make engine was multi grade SAE15W 40, which had a scheduled drain off time 500 hours. Five samples were collected including fresh oil.

3. Plan of Work

Equipment selection

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Chronological selection of oil samples

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Labelling of samples

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Find out viscosity of sample at different temperature by experiment

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Find out viscosity of sample at different temperature by Viscosity-temperature relationship

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Plot viscosity-temperature relationship

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Correlation analysis and developing trend line equation

4. Experimental setup

The viscosity engine oil was measured in millPascal-second (mPa-s) at temperature (in °C) 20 , 30, 40, 50, 60, 70, and 80 using SVM 3000 Stabinger Viscometer. This viscometer is a rotational viscometer, works on the Couette principle with a rapidly rotating outer tube and an inner measuring bob which rotates more slowly. Only from 2.5 ml of samples it determines dynamic viscosity, kinematic viscosity and density oils. Kinematic viscosity is commonly used to represent the viscosity of lubricating oils. In order to calculate the kinematic viscosity from the dynamic viscosity, the density of the sample must be known. For this reason, SVM 3000 also has a density measuring cell that employs the well-known oscillating U-tube principle. Both cells are filled in one cycle. The measurements are carried out simultaneously.

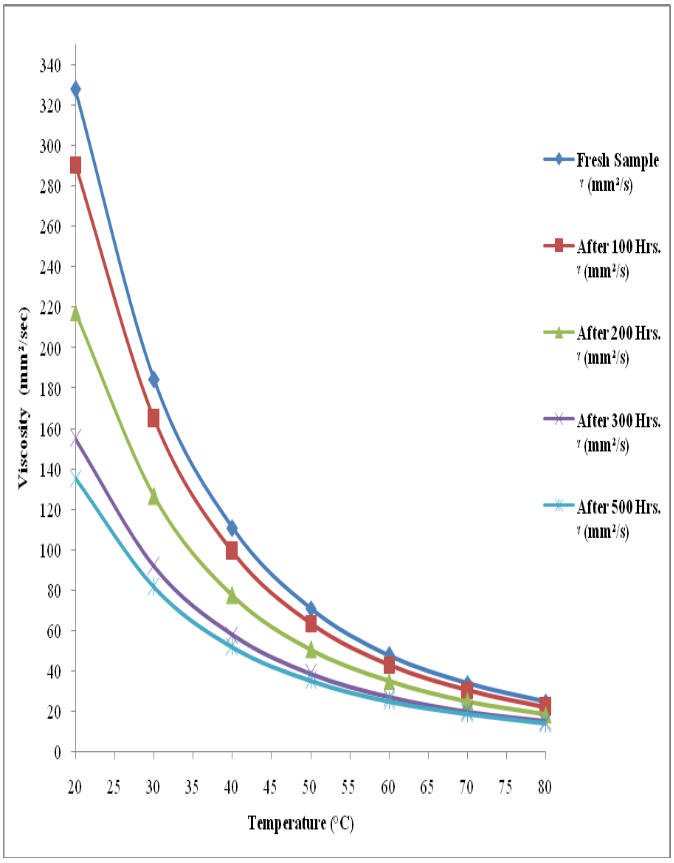
Fig – 1: Stabinger Viscometer

5. Results and discussions

Viscosity of all the samples found in the laboratory at different temperature and at different time.

Table 1. Viscosity at different temperature at different age of lubricant

Temp (°C)	0 hrs	100 hrs	200 hrs	300 hrs	500 hrs
20	327.75	290.43	217.149	155.05	135.27
30	184.09	164.74	126.39	91.70	81.357
40	110.68	99.189	77.34	57.706	51.851
50	70.842	63.560	50.551	38.514	35.073
60	47.817	42.945	34.840	26.955	24.953
70	33.764	30.332	24.961	19.690	18.777
80	24.760	22.211	18.414	14.949	13.690



Graph- 1: Viscosity at different temperature at different age of lubricant

Table 1 show the viscosity at different temperature and at different age of lubricant. Graph 1 shows the graphical representation of the above data.

We can deduce from the preceding experimental and graphical data that the viscosity of engine oil reduces as temperature rises for different ages of lubricant used in generator sets. So we can say that the viscosity also varies with the age (or we can say time) of the lubricant. As a result, viscosity varies with both temperature and time. And we know that from the previous research work, the Walther's equation for variation of viscosity-temperature gives the more accurate result than other viscosity-temperature relation.

So finally we will use Walther equation for finding the viscosity-temperature-time relationship.

Walther's equation in a general form:

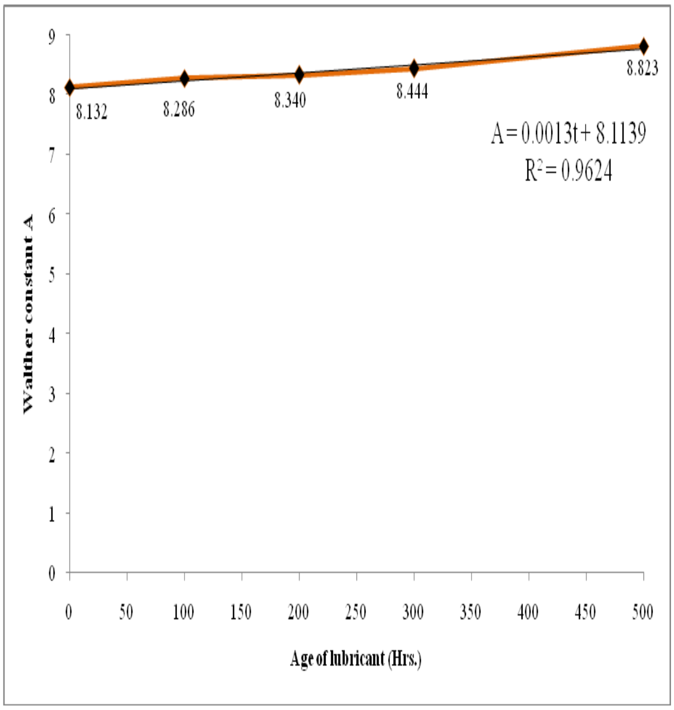
$$\log_{10}\log_{10}(\nu + 0.7) = A - B\log_{10}T \quad (1)$$

Where A and B are constants and varies with the age of lubricant, ν be the kinematic viscosity in mm^2/s and T be the temperature in Kelvin. The constants A and B calculated for the viscosity at temperature 30°C and 60°C for all samples at their respective age using Walther's equation.

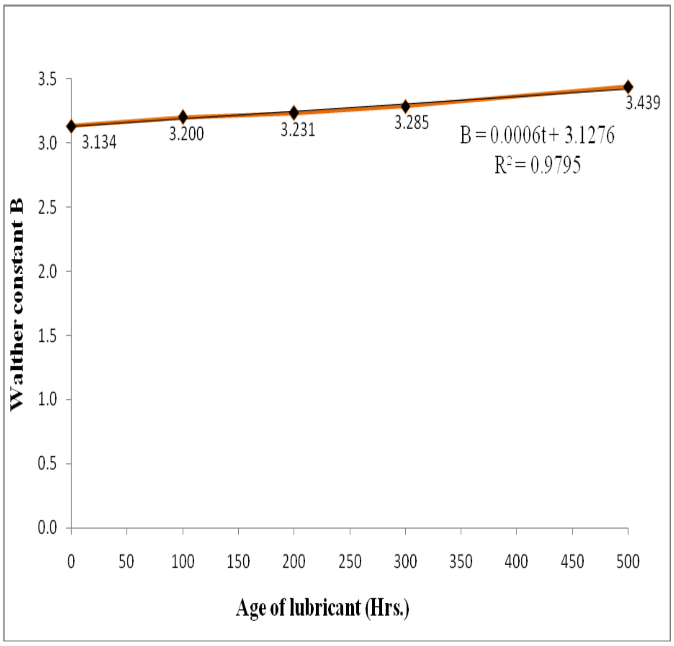
Table 2. Variation of Walther's constants A and B with age of lubricant

Age of lubricant (hrs)	Walther's constant A	Walther's constant B
0	8.132	3.134
100	8.286	3.20
200	8.340	3.231
300	8.444	3.285
500	8.823	3.439

The value of Walther's constant A and B increases with time of use of lubricant. The correlation and correlation coefficient of constant A and B with age of lubricant was calculated using Micro Soft Excel.



Graph-2: Variation of Walther Constant A with age of lubricant



Graph-3: Variation of Walther Constant B with age of lubricant

From the figure 5.2 and 5.3 it can be clearly seen that constant A and B varies with time, almost linearly.

These equations can be presented as:

$$A = 0.0013t + 8.1139 \quad (2)$$

And $$B = 0.0006t + 3.1276 \quad (3)$$

Where t be the time (or say age) in hours

As a result, the final expression, which shows the viscosity-temperature-time relationships of engine oil in terms of time (t), can be written as:

$$\log_{10}\log_{10}(\nu + 0.7) = (0.0013t + 8.1139) - (0.0006t + 3.1276)\log_{10}(T) \quad (4)$$

Table-3: Comparison of Walther's constant A and B

SAE 15W40 Engine oil (Present work)	SAE 15W40 Dumper oil (Previous work) [10]
A = 0.0013t + 8.1139 R^2 = 0.9624	A = -0.0051t + 7.8625 R^2 = 0.9772
B = 0.0006t + 3.1276 R^2 = 0.9795	B = -0.002t + 3.0279 R^2 = 0.9794

The value of Walther constant A and B for the same grade of oil (SAE 15W40) are different which are used in different application. The above correlation shows that the Walther's constant A and B has a good correlation with the time of use of lubricant and the values of correlation coefficient in both the cases are almost same. But slop for the SAE 15W40 Engine oil is positive and slop for the SAE 15W40 Dumper oil is negative. So constant A and B are strongly dependent on time and applications.

6. CONCLUSIONS

Walther constant A and B both varies with time, seen from the experimental data. So the variation of viscosity depends on temperature as well as time of use of lubricant. The final expression, which shows the viscosity-temperature-time relationship is-

$$\log_{10}\log_{10}(\nu + 0.7) = (0.0013t + 8.1139) - (0.0006t + 3.1276)\log_{10}(T)$$

Using the above expression, we can determine the viscosity of a lubricant at any temperature and time. The given formula is only for the engine oil SAE 15W40 used in a Cummins engine (KTA 50 G) to provide power to a generator set i.e. a specific type of oil used in a particular environment.

The value of Walther constant A and B, which depends on time, are different for the generator set engine oil (SAE15W 40) used in land drilling rigs application and open-cast coal mine dumper engine oil (SAE15W 40). It can be concluded from this study that variation of viscosity depends on temperature, time and application of lubricants. The study of variation of viscosities with temperature and time will assist the designers/manufacturers to suggested the use of appropriate grade of lubricating oil for a particular system.

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