

The Effect of Temperature and Mass on the viscosity of Oil Fluid by Falling Ball Method

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Abstract

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Viscosity is an important property of a fluid that indicates resistance to flow due to internal friction forces between molecules. This study aims to measure the viscosity of five types of oil using the falling ball method based on the principle of Stokes' Law and analyze the effect of temperature on viscosity values. A metal ball was dropped into the oil liquid in a transparent tube, and the travel time of the ball was recorded at five temperature variations: 30°C, 40°C, 50°C, 60°C, and 70°C. The measurement results showed that the higher the temperature of the liquid, the lower the viscosity. The average viscosity obtained was 131.764 cm²/s, with the highest value at 30°C. Among the oil brands tested, Oli(D) showed the highest viscosity at all temperatures. The study also found that increasing the number of dropped balls can increase the temperature of the liquid due to friction, which in turn decreases the viscosity. Thus, the dropped ball method proved to be effective in viscosity measurement, although accuracy is highly dependent on the accuracy of time recording. This research also confirms the importance of selecting lubricants that are suitable for viscosity characteristics for machinery and industrial applications.

Keywords: viskositas, oli, metode bola jatuh, suhu, Hukum Stokes, pelumas

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INTRODUCTION

Viscosity or viscosity is an important property of a fluid that indicates the resistance to flow due to internal frictional forces between molecules. The amount of viscosity affects fluid flow behavior and is a key parameter in many engineering applications, including engine lubrication systems. In the automotive world, lubricants play an important role in reducing friction and wear of engine components. Therefore, the selection of lubricants cannot be done carelessly, but must be adjusted to the characteristics of the engine and the required viscosity.

Viscosity measurement can be done by various methods, including the falling ball method, capillary pipe, concentric cylinder, and rotating cone plate. Of all these methods, the falling ball method is one of the simplest and most widely used. The working principle of this method refers to Stokes' Law, by observing the speed at which a small ball falls through a fluid. The viscosity experiment aims to determine the viscosity coefficient of a liquid by utilizing the principle of Stokes' Law (Susanti & Asmoro, 2019). In this experiment, a metal ball is dropped into a fluid placed inside a glass tube. Fluids characterized by viscosity, such as automotive lubricants (oil), are an example of an important application in viscosity

testing. This experiment is part of the basic physics practicum and forms the basis of understanding measurement techniques for students.

The measurement method is based on Stokes' Law, where a solid ball is released into a liquid to calculate viscosity. This research also aims to design an ideal viscosity measuring device, in order to obtain more accurate viscosity coefficient data according to Stokes' Law equation. Although this method is quite efficient, its measurement accuracy is highly dependent on the detection speed of the ball drop time, which is often very fast, requiring sensitive and precise timing devices.

A fluid that has a dynamic viscosity coefficient (μ) that is affected by temperature and pressure, but not by the size of the velocity gradient, is called a Newtonian fluid. In this fluid, the relationship between shear stress and velocity gradient forms a graph in the form of a straight line passing through the zero point, which shows the nature of its dynamic viscosity (Sahaya et al., 2016).

Each type of fluid has a different viscosity coefficient value, depending on its molecular structure, temperature, and other external factors. For example, oil has a higher viscosity than water, while glycerin has an even greater viscosity. To accurately determine the viscosity value of a fluid, a suitable measurement method is required. One method that is widely used due to its simplicity is the falling ball method. This method works by dropping a small ball into the fluid, then measuring the time it takes for the ball to reach its terminal velocity. The calculation of viscosity in this method refers to the principle of Stokes' Law, which describes the frictional force of a fluid against objects moving in it (Madliyani et al., 2019).

Although simple, the falling ball method has limitations, especially in terms of measurement speed and the accuracy of recording the time the ball falls. Therefore, a tool capable of recording time with high precision is needed so that the viscosity measurement results are reliable (Soebyakto, M. Fajar Sidiq, 2017). In addition, viscosity is also affected by time and temperature, which can change the internal structure of the fluid and affect its flowability. There is a relationship between the viscosity of a liquid and the falling time of an object in the falling ball method, where the more viscous a liquid is, the longer it takes for the ball to reach the bottom. In addition, as more balls are dropped, the friction increases, causing the temperature of the liquid to rise. As a result, the speed of the falling ball increases and the viscosity of the liquid decreases (Lubis, 2018).

Based on this, this study aims to measure the viscosity of fluids (especially oil) using the falling ball method and analyze the effect of time on viscosity changes. The results obtained are expected to contribute to a more thorough understanding of fluid characteristics and their application in the selection of lubricants suitable for machine and industrial needs.

RESEARCH METHOD

This research uses the experimental method, which aims to identify the cause-and-effect relationship between one or more dependent variables by manipulating independent variables under controlled conditions. In this study, there are three types of variables, namely Independent variables are factors that are manipulated or changed to see their effect on the dependent variable. In this study,

the independent variables include: vernier caliper, micrometer, digital scale, meter, measuring cup, viscosity test kit, temperature. The dependent variable is the result or output measured as a result of manipulating the independent variable. In this study, what is observed is the result of measurement using a meter (as an indicator of the effect of viscosity on the speed of falling balls, for example). Control variables are variables that are kept constant so as not to affect the results of the study. In this case, the oil fluid used becomes a consistent control variable.

The main materials in this study were oil fluids of five different brands, namely: Oil(A), Oil(B), Oil(C), Oil(D), Oil(E). All materials were obtained from a yellow shop (online) and a motorcycle workshop located in Roko Klodran Indah, Jalan Adi Sumarmo No. 3, Karanganyar Regency, Central Java. The tools used in this study include: Micrometer, Stopwatch, Digital scales (balance sheet), Solid metal ball (gotri), Meter, Measuring cup.

The working principle of the falling ball viscometer is based on measuring the time taken by a solid ball to move vertically down a glass tube containing a liquid that does not move. The value of the coefficient of viscosity of the liquid is calculated based on the principle of Stokes' Law used in this method (Putri et al., 2015). The method used is the falling ball method with the principle of Stokes' law, finding the viscosity value of a liquid using the equation:

$$\mu = \frac{(\rho_b - \rho_o) \times g \times D^2}{18v} \quad (1)$$

The research data were collected through a series of stages as follows (1) all tools and materials to be used were prepared and cleaned to ensure that there was no contamination affecting the results. (2) The equipment was assembled according to the configuration in Figure 1. The temperature of the liquid was measured before the experiment began, with the temperature variations used being 30°C, 40°C, 50°C, 60°C, and 70°C. (3) The beaker glass used as an oil container was weighed first in an empty state. Then, 250 ml of liquid (oil) was poured into the beaker and weighed again to obtain the total mass. (4) The diameter of the metal ball was measured using a screw micrometer. Each ball was weighed using a digital balance both in empty condition and after being placed in the container to obtain the total mass. (5) The metal ball was picked up using tweezers and dropped into a transparent tube filled with liquid. The stopwatch was started simultaneously when the ball was dropped at the 0 cm position and stopped when the ball reached the 20 cm position. The travel time of the ball within this range was recorded as the main data. Each experiment was repeated twice for each combination of temperature and ball size to obtain more accurate and reliable data.

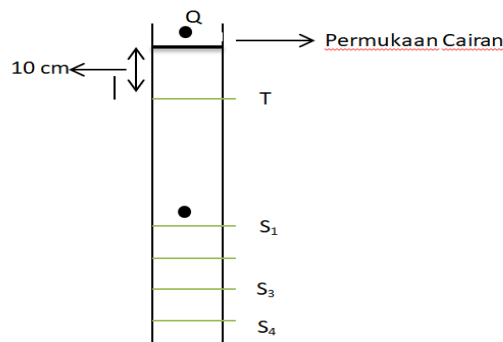


Figure 1. Set-up of the experimental equipment

RESEARCH RESULTS AND DISCUSSION

The following are research data for the fluid used in the form of liquid oil: liquid volume 200 ml, ball $r^2 = 0.27 \text{ cm}^2$, dr-average = 0.54 cm, ball mass = 5.4 g, temperature = 30 ° C, 40 ° C, 50 ° C, 60 ° C, 70 ° C. $B_j \text{ oil} = 1.462 \text{ g/cm}^3$, $da_{qt} = 0.9957 \text{ g/cm}^3$. From the calculation results, the volume of the ball = 8241 cm^3 , the density of the ball $\rho_b = 0.00065 \text{ g/cm}^3$, the density of the oil liquid ($\rho_o = 1.45571 \text{ g/cm}^3$.

Table 1. Velocity and mass density data of liquid

Suhu	Rapat Massa dan Kecepatan									
	Oli(A) (s)	ρ	Oli (B) (s)	ρ	Oli (C) (s)	P	Oli(D) (s)	P	Oli(E) (s)	ρ
30° C	1,69	1,45 5	1,6	1,45 5	1,6 2	1,45 5	1,6	1,45 5	1,62	1,45 5
40° C	1,7	1,45	1,6 2	1,45	1,6 2	1,45	1,6	1,45	1,62	1,45
50° C	1,83	1,44 4	1,6 2	1,44 4	1,6 2	1,44 4	1,62	1,44 4	1,63	1,44 4
60° C	1,87	1,43 7	1,6 9	1,43 7	1,6 4	1,43 7	1,62	1,43 7	1,64	1,43 7
70° C	1,92	1,42 8	1,7 7	1,42 8	1,6 4	1,42 8	1,64	1,42 8	1,64	1,42 8

Table 2: Oil liquid viscosity data

Suhu	Viskositas (cm^2/s)				
	Oli(A)	Oli (B)	Oli (C)	Oli(D)	Oli(E)
30°	130,759	138,114	136,409	138,114	136,409
40°	129,546	135,943	135,943	137,643	135,943
50°	119,834	135,368	135,368	135,368	134,537
60°	116,701	129,131	133,067	134,71	133,067
70°	112,945	122,517	132,228	132,228	132,228

Based on the results of the study, it is known that the oil liquid has a fairly high viscosity level. This can be seen from the calculation of the average viscosity of the oil liquid obtained through the falling ball method, which is 131.764 cm^2/s . From the experimental data, it can be seen that the higher the temperature of the liquid, the lower the viscosity value. This is in accordance with the theory that an increase in temperature causes a decrease in the cohesion force between molecules in the liquid, so that the liquid becomes easier to flow.

In general, the highest viscosity value is obtained at 30°C and tends to decrease as the temperature increases up to 70°C. Therefore, it can be concluded that temperature is the main factor affecting oil viscosity.

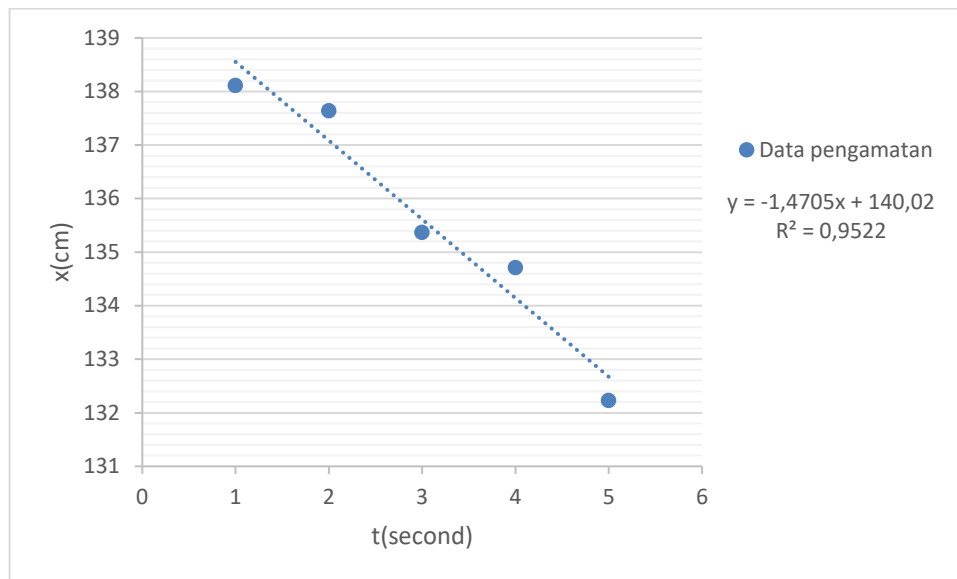


Figure 2. Comparison of distance and time of oil (D)

When compared between oil types, oil (D) shows relatively high viscosity values at all temperatures, indicating that it is more viscous than other oils. The high viscosity causes the ball drop time to be longer, as the frictional force between the ball and the liquid is greater.

In addition, as the number of balls dropped increases, there is an increase in the temperature of the liquid due to the friction generated. This leads to a decrease in the viscosity of the liquid and an increase in the speed at which the ball falls.

CONCLUSION

This study successfully demonstrated that the viscosity of a liquid, especially oil, can be effectively measured using the falling ball method based on the principle of Stokes' Law. The experimental results show that the viscosity of a liquid decreases as the temperature increases, which is due to the reduction of the cohesion force between molecules in the fluid. The average viscosity obtained from various oil brands is $131.764 \text{ cm}^2/\text{s}$, with the highest value at 30°C and continues to decrease up to 70°C .

From the comparison between oil types, oil (D) showed the highest viscosity across the entire temperature range, indicating greater viscosity than the other brands. In addition, the experiment also showed that increasing the number of dropped balls can increase the temperature of the liquid due to friction, which in turn decreases the viscosity and accelerates the ball dropping speed.

Thus, the dropped ball method proved to be simple yet quite accurate in measuring the viscosity of liquids, although its accuracy is highly dependent on the precision of the time measurement. This research also confirms the importance of temperature as a major factor affecting viscosity, as well as the importance of selecting the appropriate lubricant based on its viscosity characteristics to support optimal engine performance.

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