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Analysis of the Temperature Effect on the Liquids Viscosity

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Abstract: This study aims to analyse the effect of temperature on the viscosity of liquid water and cooking oil using the experimental method. Viscosity is a measure of the viscosity of a liquid and can be affected by temperature. In this study, a series of experiments were conducted using water and cooking oil as test materials. The samples were tested for viscosity at different temperatures using a thermometer. Experiments were conducted at several varying temperatures, ranging from room temperature to temperature after heating. The viscosity test results were correlated with temperature and analysed to see the pattern of change. Based on the analysis results, it can be concluded whether the viscosity of water and cooking oil increases or decreases as the temperature increases. In addition, it was found that there is a difference in viscosity response between water and cooking oil to temperature changes. The results of this study show the influence between temperature and viscosity of liquids, especially water and cooking oil.

Keywords: cooking oil, liquid, temperature, viscosity, water.

Introduction

Viscosity is a central concept in the study of fluid physics. Scientists and researchers study viscosity as a fundamental property of fluids and in the context of Newtonian or non-Newtonian laws. One of the properties of liquids is viscous where liquids have different viscosity coefficients, for example, the viscosity of cooking oil is different from the viscosity of water. The effect of temperature on the viscosity of liquids is a phenomenon that is widely observed and studied in physics and chemistry.

Fluid is a term used to describe a substance that has the ability to flow. This includes liquids and gases. Fluids have properties that set them apart from solids, such as the ability to take the shape of the container that contains them and to flow easily. Molecularly, fluids are composed of randomly organized particles, which can interact with each other by means of attractive forces, such as gravitational attraction or electric forces. Particles in a fluid have relatively high freedom of movement, so they can change position and move easily when a force is applied.

Liquid fluids, such as water or oil, have a fixed volume but can flow. Liquid particles move closer to each other compared to particles in gases. Gaseous fluids, such as air or nitrogen, have a variable volume and can fill all available space. Gas particles have greater freedom of movement and can move more easily than particles in liquids. The properties of fluids, including viscosity, density, pressure, and flow, play an important role in many fields of science and engineering, including physics, chemistry, mechanical engineering, and many more. An understanding of fluid behavior is essential in the design of piping systems, refrigeration equipment, aerodynamics, and many other applications.

The effect of temperature on viscosity has significant implications in various fields and applications. In the oil and gas industry, understanding the change in viscosity of crude oil with temperature can aid in efficient transport and processing. In the pharmaceutical field, the effect of temperature on drug viscosity can affect the consistency, stability, and absorption ability of drugs by the body. In addition, an understanding of the effect of temperature on viscosity is also important in the design of tools and systems that use liquids. For example, in engine lubrication systems, selecting a lubricant that has the correct viscosity at different operating temperatures is critical to maintaining engine performance and life.

1. Viscosity

Viscosity (thickness) comes from the word Viscous (Soedojo, 1986). If a material is heated before it becomes liquid, it first becomes viscous, that is, it becomes soft and can flow slowly. Viscosity can be thought of as the internal motion of a fluid (Sears & Zemansky, 1982)

Viscosity is a measure that states the thickness of a fluid which states the size of the friction in the fluid. The greater the viscosity of the fluid, the more difficult it is for the fluid to flow, and also shows the more difficult it is for an object to move in the fluid (Aryanti and Agus, 2010). Therefore, some liquids can flow quickly but some flow slowly. Slow-flowing fluids such as glycerin, honey, and also oil, this is because they have a large viscosity. So the viscosity determines the speed at which the liquid flows (Halliday and Resnick, 2000)

Viscosity is a quantity that measures the thickness of a fluid. Up to this point, we have assumed that the fluid is not viscous. However, in truth, all fluids have a viscosity, including gases. To demonstrate the presence of fluid viscosity, see Figure 1.1. The fluid is placed between two parallel plates. One plate is moved with a constant velocity v in a direction parallel to the two plates.

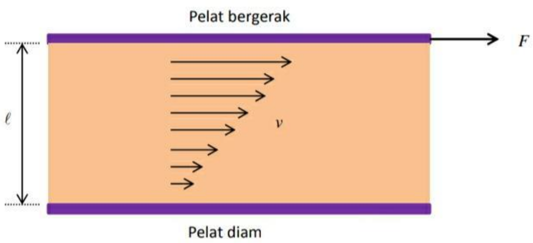

Figure 1. Determining Fluid Viscosity

The fluid surface that is in contact with the plate remains stationary while that in contact with the moving plate also moves with a velocity (v) as well. As a result, a velocity gradient is formed. The fluid layer that is closer to the moving plate has a greater velocity. To maintain this speed, it is necessary to have a force F that satisfies:

$$F = \frac{\eta\, A\, v}{l}$$

With A the cross-sectional area of the object, l the distance between the two plates, F the force required to keep the plates moving relative to the velocity v, and η a constant called the fluid viscosity coefficient. The unit of viscosity is Ns/m^2. When expressed in CGS units, the unit for viscosity is dyne s/cm2. This unit is also called poise (P). Generally, the viscosity coefficient is expressed in cP (centipoises = 0.001 P) (Mikrajuddin, 2016).

Fluids in the real world have internal friction of a certain value, which is called viscosity. Viscosity exists in both liquids and gases and is basically the frictional force between adjacent layers in the fluid, when the layers move past each other. In liquids, viscosity results from electrical cohesive forces (acting) between the molecules. In gases, viscosity arises from collisions between molecules. The viscosity of various fluids can be expressed quantitatively by the viscosity coefficient η (Giancoli, 2014).

One way to determine the viscosity coefficient of a fluid was formulated by J. L. Poiseuille (1799 - 1869). The poise unit for the viscosity coefficient is taken from its name. We can determine the viscosity coefficient of a fluid by flowing the fluid into a pipe with a certain cross-sectional area. In order for the fluid to flow, there must be a pressure difference between the two ends of the pipe. The fluid discharge flowing through the pipe fulfills the Poiseuille equation:

$$Q = \frac{\pi\, r^4\, \Delta P}{8\, \eta\, L}$$

With, Q is the flow rate of the fluid, r is the cross-sectional radius of the pipe, L is the length of the pipe, and ΔP is the pressure difference between the two ends of the pipe (Mikrajuddin, 2016). This relationship is important in the design of the piping system and syringe. Needle size is far more important than thumb pressure in determining the flow rate of the needle; controlling the needle diameter has the same effect as increasing the thumb force sixteen times. (Young & Freeman, 2001).

2. Stokes Law

Stokes law can also be used to determine the viscosity coefficient of a fluid. An object moving in a fluid experiences a frictional force that is opposite to the direction of the object's motion. The magnitude of the frictional force depends on the relative velocity of the object to the fluid and the shape of the object. For a spherical object, the magnitude of the frictional force obeys Stokes' law:

$$F = 6\, \pi\, \eta\, r\, v$$

With F the frictional force on the object by the fluid, r the radius of the ball, and v the speed of the ball relative to the fluid.

If a spherical object is dropped in a fluid, the object will initially move down with an increasing

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speed due to the acceleration due to gravity. At one point the speed of the object does not change anymore. This speed is called the terminal speed. The forces acting on an object while it is falling are the downward weight force, the upward lifting force of Archimedes, and the Stokes force which opposes the direction of motion (also upward). When terminal velocity is reached, the three forces are balanced. Based on the terminal velocity of the ball, we can determine the viscosity of the fluid. Look at Figure 2.

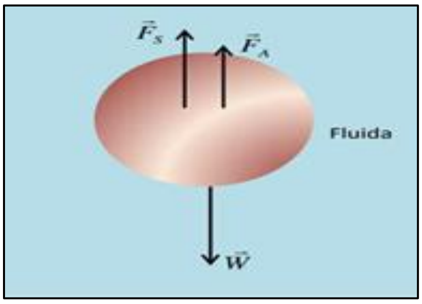

Figure 2. The force acting on a ball that falls into the fluid

The magnitude of the object's gravity (weight):

$$w = m\,g = \rho_b\,V\,g$$

$$\mathrm{w} = \rho_b \left(\frac{4\pi}{3}\,r^3\right) g$$

The magnitude of Archimedes force:

$$F_A = \rho_f\,V\,g$$

$$F_A = \rho_f \left(\frac{4\pi}{3}\,r^3\right) g$$

The magnitude of stokes force:

$$F_s = 6\,\pi\,\eta\,r\,v)$$

When the object reaches terminal velocity, the three forces above satisfy the equation:

$$W = F_A + F_s$$

$$\rho_b \left(\frac{4\pi}{3}\,r^3\right) g = \rho_f \left(\frac{4\pi}{3}\,r^3\right) g + 6\,\pi\,\eta\,r\,v$$

$$\frac{4\pi}{3}\,r^3 \left(\rho_b - \rho_f\right) = 6\,\pi\,\eta\,r\,v$$

$$\rho_b - \rho_f = \frac{9}{2}\,\frac{\eta\,v}{r^2}$$

The density of the ball, the density of the fluid, and the radius of the ball are certain. So by measuring the terminal velocity, the fluid viscosity coefficient can be calculated. So we have two ways of determining the viscosity of a fluid. First by flowing through the pipe and calculating using Poiseuille's law or dropping a ball whose density and dimensions are known then measuring the ball's terminal velocity. Terminal velocity will be reached when the ball is far enough from its initial location to be released into the fluid.

3. Temperature

Temperature is a quantity that expresses the degree of heat and cold of an object and the tool used to measure temperature is a thermometer. In everyday life, people tend to use the sense of touch to measure temperature. But with the development of technology, a thermometer was created to measure temperature validly. (Hidayati, 2011)

Temperature indicates the degree of heat in objects. Simply put, the higher the temperature of an object, the hotter it is. Microscopically, temperature shows the energy possessed by an object. Every atom in an object moves, both in the form of displacement and movement in place in the form of vibrations. The higher the energy of the atoms that make up the object, the higher the temperature of the object. Temperature is usually defined as a measure or degree of hotness or coldness of an object or system. Hot objects have a high temperature, while cold objects have a low temperature (Fathulrohman, 2018).).

4. Cooking Oil

One example of a fluid that can be used to explain viscosity is cooking oil. Cooking oil is an example of a fluid that is closely related to students' daily lives so it is hoped that it will make it easier for students to understand viscosity material. Cooking oil is a food ingredient with the main composition of triglycerides derived from vegetable ingredients except for palm oil, with or without chemical changes, including hydrogenation, cooling and has gone through a refinement/refining process used for frying (National Standardization Agency, 2013)

Oil is a food substance that is important for the needs of the human body. In addition, oil is also a source of energy where one gram of oil can produce 9 kcal (Winarno, 2002). Oil (vegetable) contains unsaturated fatty acids and some essential fatty acids such as oleic, linoleic, and linolenic acids (Ketaren, 1986). Cooking oil is a fat that is liquid at room temperature. Cooking oil is a food ingredient with the main composition of triglycerides derived from vegetable ingredients, with or without chemical changes, and has gone through a refined or purified process used for frying (Chatzilazarou et al., 2006).

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Factors that affect viscosity are temperature, solution concentration, dissolved molecular weight, and pressure. So viscosity is inversely proportional to temperature. If the temperature rises, the viscosity will decrease, and vice versa.

Based on research conducted by Yudhittiara et al. (2017) it is known that the level of students' understanding of the concept regarding the viscosity sub-chapter and its units is 0%, the level of students' understanding but lack of confidence is 2%, the level of students' misconceptions is 25.5% and the level of students' ignorance of concepts is 72.5%. This shows that most students still do not understand the material viscosity and its units. This is caused by factors of the learning system, students' way of thinking, learning textbooks, experience, and in-depth knowledge (Yudiattara et al., 2017: 89).

This property, known as fluid viscosity, is a measure of a fluid's resistance to deformation or deformation. The viscosity of a gas increases with increasing temperature because the greater the molecular activity as the temperature increases. Whereas in liquids, the distance between molecules is much smaller than in gases, so the molecular cohesion there is very strong. Increasing temperature reduces molecular cohesion and this is manifested in the form of reduced viscosity of the fluid (Olson, 1993). This study aims to analyze the effect of temperature on the viscosity coefficient of liquid cooking oil and water with variations in temperature (Mikrajuddin. 2016).

Methode

The method used in this study is to use the experimental method. In this study, the effect of temperature on the viscosity of water and cooking oil will be tested directly starting with the water temperature from room temperature 25°C and 60°C. Cooking oil temperature, 27°C and 40°C

Data collection was carried out in May 2023. The tools and materials used in this study consisted of heaters, stopwatches, thermometers, marbles, glass bottles (1 liter), water, and cooking oil. The working steps are as follows:

1). Prepare tools and materials.
2). Liquids are measured at room temperature using a thermometer.
3). The liquid is poured into the pan to be heated and the temperature is measured.
4). The liquid substance is poured into a glass bottle.
5). Test the viscosity. Marbles and stopwatch at the ready. The marbles are dropped into the bottle while the stopwatch is activated.
6). The stopwatch is stopped when the marble drops to the bottom of the bottle.

The results of the observations are entered into the table, then the velocity and viscosity values are calculated.

Result and Discussion

After doing research on several types of liquid substances, namely water and cooking oil. This liquid substance is first heated to varying temperatures. In cooking oil, the room temperature is 27°C and after heating it becomes 40°C.

Table 1: Temperature, time, speed of falling marbles, and cooking oil viscosity coefficient

Temp (°C)	time (s)	Speed of Falling (m/s)	Coefficient Viscosity (Ns/m^2)
27	0,64	$3{,}125\ x\ 10^{-2}$	100,906
40	0,133	$1{,}503\ x\ 10^{-2}$	209,801

In water the room temperature is 25°C and the temperature after being heated is 60°C.

Table 2: Temperature, time, speed of falling marbles, and water viscosity coefficient.

Temp (°C)	time (s)	Speed of Falling (m/s)	Coefficient Viscosity (Ns/m^2)
25	0,13	$1{,}538\ x\ 10^{-2}$	204,402
60	0,13	$1{,}538\ x\ 10^{-2}$	204,402

From this research experiment to determine the viscosity or viscosity of a predetermined liquid, the results obtained can be used as a benchmark in the discussion. The effect of the diameter on the speed of the marble when it is dropped is that the larger the diameter of the marble, the faster the ball falls. However, it really depends on the mass of the marble itself. If marbles of different masses are dropped into a liquid, the marble with the largest mass will experience the greatest velocity. This happens because the weight of the object will be affected by the speed of the earth's gravity. So objects that have a large mass will also have a large weight and have a large acceleration and velocity.

The effect of viscosity on the speed of falling marbles is that the thicker a liquid or fluid, the greater the power to slow down the fall of marbles, so that the thicker a liquid, the slower the movement of objects falling in it. Conversely, the more dilute a liquid or fluid, the faster the object is dropped into it.

While the effect of the mass of an object dropped into a liquid or fluid on the speed of falling marbles is that the greater the mass of the object, the greater the fall of the object. From this it can be seen that the mass of an object dropped into a liquid (fluid) is directly proportional to the speed at which the ball falls into the fluid (liquid).

As for the relationship between viscosity and the speed of the object, namely the greater the speed of the object, it can be ascertained that the value of the viscosity coefficient is getting smaller. And vice versa, the smaller the speed or speed of an object, the greater the value of the viscosity coefficient, so that the value of the viscosity is inversely proportional to the object's speed. This theory was proven in experiments using cooking oil, cooking oil research consisted of two situations, namely the room temperature of 27°C and the temperature after heating to 40°C. The value of the speed of falling marbles at 40°C is higher than the value of the speed of falling marbles at 27°C. So the temperature viscosity value is 40°C higher.

In the experiments conducted, there are many factors that cause deficiencies. One example, wherein an experiment to determine the viscosity was carried out by several people. This affects the results of experiments, for example in calculating and recording the travel time of objects in fluids. The researcher pressed the Stopwatch button too quickly so that the recorded time did not match the actual time and the other one might have been recorded slower in pressing the Stopwatch so that he had already passed the target or target. At the time of heating the water, the researchers did not heat the water for a long time so it was less than optimal and no viscosity occurred. As a result, the results obtained are not appropriate and less accurate.

Conclusion

Based on the experiments that have been carried out, temperature has an effect on the viscosity coefficient of liquids, namely cooking oil. Heated cooking oil underwent a change in viscosity, but in this study heated water did not experience a change in viscosity, this was due to the less high temperature of the heat produced. In addition, water is a very dilute liquid.

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