An Analysis of Viscosity Measurement

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ABSTRACT: ***The viscous forces produced by compression (or dilatation) are addressed by the coefficient of viscosity. In the lack of data on its magnitude in liquids, hydrodynamics has traditionally assumed that the coefficient of dilatational viscosity, n', may be approximated by the ideal gas value n = - 2n/3, where n is the coefficient of shear viscosity. The non-periodic motion of the fluid in the vicinity of a sound source is reliant on the two coefficients of viscosity, and a technique for determining values for dilatational viscosity has been devised based on Eckhart's theory of acoustical streaming. The dilatational viscosity coefficient was found to be positive in sign and larger in magnitude than the shear viscosity coefficient. The dilatational viscosity of water, for example, was found to be 2.4 centipoise, whereas that of carbon disulphide was discovered to be more than 200 centipoise. For the liquids examined, there is no connection between sheer magnitude and dilatational viscosities. The temperature dependence of dilatational and shear viscosity in this material is similar, according to temperature variations measured on water.***

KEYWORDS: Fluid, Liquid, Motion, Viscometer, Viscosity.

1. INTRODUCTION

Viscosity is a measurement of a fluid's resistance to deformation under shear force. It's often referred to as pouring resistance or flow behavior. Viscosity is a measurement of fluid friction that represents a fluid's internal resistance to flow. The ultimate viscosity is crucial in the processing step! The viscosity of certain liquids is a material constant that is solely affected by temperature and pressure. Newtonian liquids are the name given to this class of materials. All fluids, including liquids and gases, have some degree of viscosity. Viscosity can be thought of as fluid friction; just as friction between two solids resists motion of one over the other while allowing acceleration of one relative to the other (e.g., friction between the wheels of an automobile and a highway), viscosity resists solid motion through a fluid while allowing a propeller or other device to accelerate [1].

1.1 Velocity gradient:

When a fluid moves through a nozzle or a solid object moves through a fluid, the layer of fluid in direct communication with the pipe's sides or the object's surface tries to be in the same state of motion as the object with which it is in contact; that is, the layer of fluid along the pipe's side is at rest, while that in contact with the moving object is carried along at the same speed. If the velocity difference between the fluid at the pipe's edges and the fluid in the center, or between the moving item and the fluid through which it is moving, is not too large, the fluid flows in continuous, smooth layers; the flow is laminar [2]. A velocity gradient is defined as the difference in velocity between adjacent layers of a fluid and is expressed as v/x, where v is the velocity difference and x is the distance between the layers. A force F is required to maintain one layer of fluid moving faster than the neighbouring layer, resulting in a shearing stress F/A, where A is the surface area in contact with the layer being moved.

1.2 Coefficient of viscosity:

The coefficient of viscosity, or Fx /Av, is a measure of the fluid's viscosity and is equal to the shearing stress divided by the velocity gradient. The poise is the CGS unit for measuring the coefficient of viscosity. Experiments have demonstrated that the coefficient of viscosity of liquids reduces as temperature rises, while the coefficient of viscosity of gases rises as temperature rises. When the temperature of a liquid rises, the bonds between molecules weaken, and because these bonds contribute to viscosity, the coefficient decreases. Intermolecular forces in gases, on the other hand, are less significant in viscosity than molecule collisions, and rising temperature increases the number of collisions, thereby raising the coefficient of viscosity. The viscosity of a gas is independent of the density of a gas, according to the kinetic theory of gases. In laminar flow, viscosity is the main source of resistance to motion. When the velocity of the flow reaches a point where it becomes turbulent, pressure differences caused by eddy currents, rather than viscosity, constitute the main barrier to motion [3].

1.3 Dynamic Viscosity:

The Greek sign for dynamic viscosity is (eta). Shear viscosity is another name for this property. Newton's Law is reformulated to produce dynamic viscosity.

1.4 Kinematic Viscosity:

Kinematic viscosity (ν) describes a substance's flow behavior under the influence of Earth's gravity. It is dynamic viscosity divided by density (ρ) which is defined as mass per volume. The quantity mass carries the gravitational influence. Kinematic viscosity is widely established due to historical reasons: Gravity as the driving force does not require any elaborate technical equipment. It is simply available everywhere on earth.

$$\nu = \frac{\eta}{\rho}\left[\frac{m^2}{s}\right] \qquad \rho = \frac{m}{V}\left[\frac{kg}{m^3}\right]$$

1.5 Relative Viscosity:

When evaluating polymers in solutions, relative viscosity is an essential metric to consider. There is a clear connection between molar mass and viscosity in most polymers. The molar mass may be determined by measuring the viscosity. The viscosity of the polymer solution increases as the molar mass increases. One of the most significant quality criteria for polymers is molar mass. Even though most polymer solutions are non-Newtonian fluids, they behave like Newtonian fluids when the shear rate is kept low enough. By dividing the viscosity of the polymer solution by the viscosity of the pure solvent , the relative viscosity is determined [4].

1.6 Measuring the viscosity:

The condition (properties of matter) or fluidity of a liquid or gas may be determined by measuring viscosity. It is used in quality control and different phases of research and development in a variety of sectors, including food, chemical, pharmaceutical, petrochemical, cosmetics, paint, ink, coatings, oil, and automobiles. The viscosity of a liquid, for example, is an essential characteristic for constructing plant pipes or moving crude oil or chemical agents via a pipeline. Photo resist fluid is used in the manufacturing of printed circuit boards, cathode-ray tubes, and flat liquid crystal displays in the electronic engineering sector. Controlling the viscosity of photo resist fluid is critical for determining the final product's quality, performance, and yield. Controlling optimal viscosity has also been identified as a way to decrease production costs in such sectors.

The viscosity coefficient, commonly known as viscosity, is a measurement of a fluid's resistance to flow. It is a material constant that indicates the degree of a fluid's fluidity. In most cases, viscosity is exclusively related with liquid. Gas possesses viscidity as well, however since it is a low viscid fluid, the barrier to flow may be disregarded. Almost all liquids have viscidity and are viscous fluids. When a drum container filled with water is rotated on its vertical central axis, the water that was at rest at first begins to move as it is pulled by the container's inner wall, eventually whirling entirely along with the container as if it were a single rigid body. This is due to the force (resistance) produced on the water's surface and the container's inner wall in the direction of the flow (movement). The viscosity of a fluid that produces this type of force is called viscosity [5].

1.7 Types of viscometers:

A) Sine-wave Vibro Viscometer:

The amplitude changes in response to the amount of frictional force generated by the viscidity between the sensor plates and the sample when the spring plates vibrate at a uniform frequency. The electrical current that causes the vibration of the spring plates is controlled by the vibro viscometer to achieve consistent amplitude. The driving electric current for vibrating the spring plates at a consistent frequency to create equal amplitude is exactly proportional to the viscosity of each sample because the frictional force of viscidity is directly proportional to the viscosity. The driving electric current is measured by the vibro viscometer, and the viscosity is determined by the positive correlation between the driving electric current and the viscosity[6].

i. Calibration:

A standard viscosity fluid or a sample with a known viscosity may be used to calibrate the viscometer. The viscometer's accuracy may be maintained at all times thanks to calibration. The measurement results acquired by the SV series viscometer may be merged with those obtained by another kind of viscometer by calibrating a real sample and utilizing the viscosity value obtained by another type of viscometer as a correction value. When testing viscosity around 1 mPas, the calibration is simplified (SV-10 only).

The use of purified water for simplified calibration is a one-key procedure. The SV-10 includes a built-in function that uses the temperature sensor to detect the temperature of the purified water and calculates the viscosity of the purified water at that temperature. At this point, be cautious not to introduce bubbles into the mixture, since this will change the viscosity value. Windows communication tools are standard. WinCT-Viscosity Communication tools for Windows As part of the package, WinCT-Viscosity (CDROM) is included. The graphing software RsVisco is included on the CD-ROM, which imports the data to a computer and shows the findings as a graph in real time. Changes in viscosity over time and temperature dependence of viscosity may be readily seen using RsVisco, and the resulting data can be stored in files.

ii. Precautions:

Place the viscometer somewhere where the temperature and humidity aren't too high. At 45-60 percent relative humidity, the optimum operating temperature is 25°C 2°C. Install the viscometer where there are no significant fluctuations in temperature or humidity for accurate measurements. Install the viscometer where it will not be influenced by heaters or air conditioners and will not be exposed to direct sunlight. Place the viscometer in a dust-free area. Install the viscometer away from any magnetic-field-producing equipment. The tuning-fork vibration method is used by the viscometer. As a result, minimize external vibration as much as possible, particularly while measuring low viscosity. Keep liquid spills and excessive dust away from the internal components. The viscometer should not be disassembled. Acclimate the viscometer to the measuring environment when accurate measurement is needed. Connect the AC adapter and warm up the viscometer for one hour or longer after installation.

(a) During usage:

Adjust the leveling feet such that the center of the narrow portion of the right and left sensor plates is on the liquid surface to level the sample's surface. The viscosity of a liquid varies with temperature and ranges from -2 to -10 percent per degree Celsius. For an accurate measurement, take into account variations in the liquid temperature. Before taking any measurements, be sure to calibrate with a standard viscosity fluid or pure water. If the measurement is going to take a lengthy time, conduct calibration as needed. The temperature of the sample may vary when the sensor plates and temperature sensor are placed in it. After inserting the sensor plates and the temperature sensor, let the sample alone for a time to verify that the sample temperature does not change. Then begin taking measurements. When utilizing the AC adapter, make sure the power supply is steady. To press the keys, just use your finger. Keys may be damaged by using a sharp object such as a pen.

The polycarbonate (PC) sample cup is not suitable for use with organic solvents. Do not use the auxiliary sample cup while using organic solvents as a sample fluid. Use a commercially available glass beaker or the glass sample cup (AX-SV-35) that is supplied separately. The shield may be lifted or lowered. As a result, even when using a beaker, the viscosity may be determined with a little quantity of material.

(b) After use:

Using alcohol, remove any remaining sample material from the sensor plates, temperature sensor, and protection. A measurement mistake will occur if the sensor plates, temperature sensor, and protection are used with the remnant of an earlier sample still attached. To prevent bending the sensor plates, clean them carefully. Stainless steel is used for the sensor plates and the temperature sensor (SUS304). The surface is 24K gold plated.

B) Rotational Viscometer:

A sample is placed into a motorized cylindrical rotor that rotates at a steady speed. The measuring technique used by the rotational viscometer implies that viscosity is exactly related to the operating torque needed to create a constant rotating motion. The running torque produced by the viscosity and the twist of the spring are balanced when the rotation becomes stable. The spring's twist angle is related to the sample's viscosity, and an index of this is shown on the scale. The digital value of the viscosity coefficient converted from running torque is shown on certain devices. This Viscometer works in the same way as all other rotational viscometers: a spindle (cylinder or disk) is immersed in the material to be tested, and the force required to overcome the resistance to rotation or flow is measured. The spindle (cylinder or disk) is linked to the motor shaft, which rotates at a set speed, via a spring. The spindle's departure angle from the measuring spring is detected electrically, yielding a torque value. The torque value obtained with the Viscometer is dependent on the spindle's rotational speed and geometry, yielding a direct measurement of the viscosity value in mPas/cP. The resistance to a substance's movement varies proportionately to the speed or size of the spindle, depending on its viscosity. Considering speed and spindle type, the viscometer has been calibrated to provide viscosity values in mPas or cP. Within the instrument's broad range, the combination of various speeds and spindles allows for excellent viscosity readings.

C) Capillary viscometer:

The laminar flow of liquid runs through a cylindrical capillary tube in a capillary viscometer. The flow rate of the fluid passing through the capillary tube and the pressure difference between both ends of the capillary tube are used to calculate viscosity. Because this measuring technique is based on physical principles, it is referred to as absolute viscosity measurement. Another kind of capillary viscometer is a glass capillary viscometer with a simple concept and construction. The concept has been utilized for a long time and has been significantly improved over time due to its simplicity. The kinetic viscosity of a sample may be determined with this capillary viscometer by monitoring the time it takes for a certain quantity of sample to flow freely through the capillary tube. The viscosity constant is assigned to each viscometer after calibration with a Viscosity Standard Fluid. The capillary viscometer has a simple concept and construction. To obtain reliable readings, however, the interior of the capillary viscometer must be kept extremely clean. Before each measurement, clean it with a cleaning agent such as benzene, then clean it again with acetone, and then rinse it with pure water. In addition, between cleanings, the capillary tube must be well dried. Because glass is sensitive to thermal expansion or contraction under the effect of temperature, particularly in lower viscosity levels, temperature control is also necessary. These thermal influences may cause measurement inaccuracies. Because the viscosity is calculated from the observed result obtained as kinetic viscosity, you must also measure the density of the measuring sample beforehand.

D) Falling-Ball Viscometer:

The falling-ball viscometer determines viscosity by dropping (free-falling) a column- or sphere-shaped rigid body with specified dimensions and density into a sample and measuring the time it takes to fall a certain distance. The viscosity measuring concept based on the law of freefall of a rigid body in a gravitational field. Another kind of device uses the force exerted by the electromagnetic field to measure travel time while horizontally moving a rigid body, such as a piston, in a sample fluid at a constant speed. The viscometer works by measuring the time it takes for a ball of known diameter and density to descend down a glass tube of known diameter and length filled with the fluid to be tested. The time it takes for the ball to travel a distance between two defined lines on the cylindrical tube is linked to the viscosity of the sample liquid. The ball returns when the measurement tube is turned, and the time may be remeasured over the same distance. As a consequence, dynamic viscosity with the standard dimension is obtained (mPa.s). The viscosity of a liquid in a tube determines the velocity of a ball as it falls through it. Gravity, buoyancy, and frictional forces all influence the ball as it travels through the liquid: gravity as a downward force, buoyancy and friction as upward forces.

2. LITERATURE REVIEW

Kono Y et al. discussed Viscosity measurement in which they explained how the most basic transport characteristic regulating magma migration processes in the Earth's core is viscosity. This chapter discusses current developments in falling sphere viscosity measurement of melts at high pressure and temperature utilizing synchrotron X-ray imaging and a large-volume press. The ability of the falling sphere method to assess viscosity is mostly determined by the speed of X-ray imaging. In the early 2000s, the image rate of 30-60 frames per second (fps) employed in typical X-ray imaging in large-volume presses was only appropriate for measuring viscosity of high-viscous melts such polymerized silicate melts and oxide melts. The recent development of ultrafast X-ray imaging with a frame rate of more than 1000 frames per second offers a new method to study the viscosity of low-viscous melts such as carbonate melts, molten salts, and fluids in situ at high pressure and temperature [7].

Khadem A et al. discussed two techniques for viscosity measurements in poultry feedstuffs in which they explained how the viscosity of intestinal contents has been shown to influence digestion and nutrient absorption. In most poultry investigations, intestinal viscosity has only been evaluated after all solid particles have been removed by centrifugation. However, centrifugation may eliminate particles that contribute to viscosity, resulting in a viscosity underestimate. In vitro, two viscosity measuring methods, one with a centrifugation step (Brookfield) and the other without (Haake), were compared to see whether they yielded comparable results for viscosity in feedstuffs [8].

Kitosan M et al. discussed viscosity in which they explained how Different methods, such as Gel Permeation Chromatography (GPC), Static Light Scattering (SLS), and intrinsic viscosity testing, may be used to estimate the molecular weight of chitosan. The intrinsic viscosity measurement technique is a straightforward way to determine the molecular weight of chitosan. At room temperature, different concentrations of chitosan were prepared and measured. The intrinsic viscosity was calculated using the flow time data by projecting the decreased viscosity to zero concentration. Using the Mark-Houwink equation, the intrinsic viscosity was recalculated into the viscosity-average molecular weight [9].

Burns M et al. discussed Viscosity Measurements Using Microfluidic Droplet Length in which they explained how from industrial chemical production to medical diagnostics, viscosity measurements have a broad variety of uses. We have developed a simple droplet-based, water-in-oil continuous viscometer that can measure viscosity changes in 10 seconds or less and consumes less than 1 liter of sample per hour. The viscometer produces droplets under constant pressure using a flow-focusing design. At high ratios of aqueous-inlet to oil-inlet pressure (AIP/OIP), the length of the droplets (Ld) is highly correlated with the aqueous-phase viscosity (aq), yielding a linear relationship between aq and 1/(Ld - Lc), where Lc is the minimum obtainable droplet length and roughly equals the width of the droplet-generating channel.

3. DISCUSSION

In the process sector, measuring and controlling viscosity has become very important. Despite the fact that there are many alternative methods for measuring this parameter, each one tailored to particular process circumstances, choosing the correct one remains a challenge. The viscosity of most industrial fluids is the most important factor affecting the ease and efficiency with which they flow. Any equipment that works over a broad temperature range must be able to handle the lubricant viscosity variations that occur. The viscosity index is a dimensionless number that describes this fluctuation. The smaller the change, the higher the number. This paper discusses several aspects of Viscosity Measurement. Theoretical study confirms the linear connection, and the resultant equations may be utilized to improve the device's design parameters such channel width, depth, and length. The viscometer may be utilized for Newtonian fluids as well as non-Newtonian fluids like Boger fluids and shear thinning fluids by correctly determining the shear rate. The shear rates in these instances are determined by the aqueous phase velocity and may be changed by changing the input pressures. The range of viscosity measurements that may be used is determined by the oil-phase viscosity (oil), and viscosities in the range of 0.01-10 oil can be measured with less than 5% error [10].

4. CONCLUSION

This paper solely focuses on several aspects of Viscosity Measurement. In this several concepts of viscosity such as velocity gradient, several types of viscosity, several types of viscosity measurement tools have been discussed. Viscosity, as a sensitive measure of liquid changes, may be used as a quality-control criterion for quick and easy fluid evaluation. Viscosity measurement is useful for ensuring the quality of liquid goods as well as monitoring the viscosity of clinical fluids as a possible hemodynamic biomarker. Traditional viscometers and their microfluidic equivalents, on the other hand, usually depend on large and costly equipment and lack the ability to do quick and field-deployable viscosity analysis. Viscometers are used in a variety of sensing and monitoring applications, including biochemical optimization, biomedical diagnostics, medicines, and adulteration detection. The viscometers may be utilized in an automated and robust point-of-care scenario if they are realized in a microfluidic environment. Choosing the optimum manufacturing scheme, especially in terms of a simpler procedure, cost, and time, remains one of the continuous difficulties encountered in the creation of microfluidic devices, even after so much progress. A 3D printed electro-micro-fluidic viscometer is shown here (EMV). Under laminar flow, the EMV calculates the viscosity of a reference fluid by comparing the sample fluid's travel time to that of a reference fluid. We discuss various kinds of viscometers, design, materials, and technology in this article.

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