Development of Experimental Setup to Verify the "Newton's Law of Viscosity"

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***Abstract*- The viscosity of a fluid reflects the property of being able to transmit friction forces between particles or to exhibit resistance to shearing flows. For a quantitative characterisation of viscosity of a fluid, the laminar flow is considered when the relative motion between two adjacent layers generates shear stresses. In the case that the magnitude of tangential stress is proportional to velocity gradient on the direction normal to flow, it is said to be a Newtonian behaviour. When the viscosity of the fluid is depending on shear rate, it is called non-Newtonian fluid. The viscosity of real materials can be significantly affected by such variables as shear rate, temperature, pressure, molecular structure, molecular weight and time of shearing.**

Index Terms- Shear stress, velocity gradient, Shear rate, Time of shearing, Newtonian and Non-Newtonian fluid.

1. INTRODUCTION

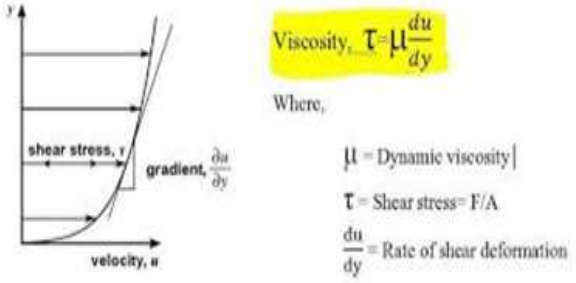
Fluid mechanics is the study of fluids either in motion at rest for both liquids and gases. There is a theory available for fluid flow problems and it should be backed up by experiment. As there are various experimental setup for verifying the different laws and concepts in fluid mechanics such as Bernoulli's theorem, impact of jet etc. but there is no setup to verify Newton's law of viscosity. To know the type of fluid is easy by going through the books and by searching online but it is also important to find out the type of fluid by practically. Fluid flow plays a very important part in the processing of materials. Most Processes are based on the use of fluids, where the rates of heat transfer, mass transfer and chemical reaction, viscosity between two phases depend on the fluid flow phenomena in system.

1.1Viscosity

Viscosity is the internal resistance to flow possessed by a liquid which flow slowly, have high internal resistance. This is because of the strong intermolecular forces.
The liquids which flow rapidly have a low internal resistance this is because of weak internal resistance forces.

1.2 Newton's Law of Viscosity

Newton's Law of viscosity state that "The shear stress on fluid element layer is directly proportional to the rate of shear strain".



1.3 Types of Fluid

Newtonian fluid:- In Newtonian fluid, there is a linear relation between the magnitude of applied shear stress and the resulting rate of deformation.
Non-Newtonian fluid:- In Non-Newtonian fluid, there is no linear relation between the magnitude of applied shear stress and resulting rate of deformation.

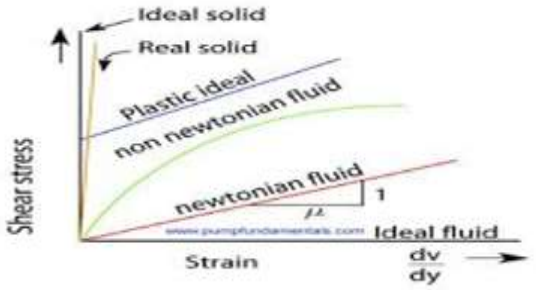
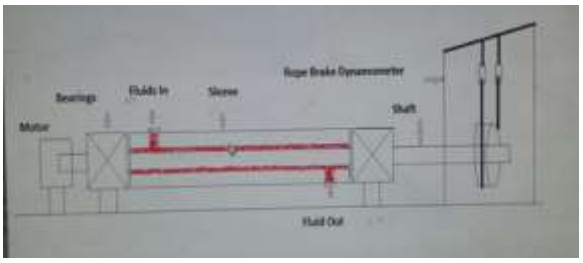


Fig. Curve for different fluids

2. FORMULATION OF WORK



2.1. Objectives

1. To determine the shear stress and rate of shear strain for different fluids.
2. To identify the types of fluid.

2.2 Component used

The selection of component has done according to requirement. Following are the list of component

1. Electric motor (DC) 2.shaft 3.Bearing 4.Sleeve 5.coupling 6.Dynamometer (Rope, Pulley, spring load, Dead weight)

2.3Design Calculation

Following are the general calculation-

Speed=300rpm (maximum design speed)

Maximum force is consider practical for purpose=98.1N

Torque=force× Radius of pulley

=10×9.81×0.1=9.810N-M

Power=2πNT\60=2π×300×9.810/60

=308.22w

Diameter of shaft(d)=π/16×d3×τ

Material for shaft SAE1030

Syt=296mpa=0.3×296=88.88N/M2

9810=π/16×d3×88.8

=8.25=10mm (standard)

Considering bending , increase diameter by 50%

d=10×1.5=15mm.Not considering pulley weight so make it standard=Diameter of shaft=20mm

Length of shaft=700mm

Sr.No	Components	Dimension/specification
1.	Shaft	20×700mm
2.	Electric motor	373watt
3.	Bearing	20mm
4.	Pulley	100mm radius
5.	Rope	10mm diameter
6.	Metal sleeve	29mm diameter

3. PRINCIPLE OF OPERATION

The shaft passes through the metal sleeve and supported by the bearing, as the one end of the shaft is coupled to the motor and other end is passes through pulley of dynamometer. The sleeve has two knobs, one is opening knob and other is closing. The sleeve if filled with certain fluid and close both knobs. As the dc source given to the motor the shaft starts rotating and the fluid in contact with shaft get displace. Because of rotation of shaft it exert shear force on fluid and the speed of is to be measure by using tachometer. At the dynamometer a specific load is applied to stop the rotation of shaft and measure required load to stop the shaft. This operation should carry at different speed and to check how much torque is require to restrict shaft rotation.

Fig. Experimental setup

As shown in fig the one end of shaft is connected to the motor spindle. The sleeve is provided between the two bearing. The bearing are provided for support the shaft. The inlet port is provided at the upper side of sleeve and the two outlet port is provided at the bottom side of the sleeve. At the other end of shaft the rope break dynamometer is provided for measurement of the torque.

3.1 Data Calculation

Formula of Newton's Law of viscosity

τ=μ.du/dy

To verify the type of fluid we have solve both the sides separately.

1. For R.H.S

$\mu.du/dy$

where, μ= Dynamic viscosity of fluid(N.s/M2)

du=Relative velocity(M/S)

$=\pi DN/60$

Where, D= diameter of shaft

N=Speed of shaft

dy=Distance between shaft and sleeve

2. For L.H.S

$\tau=F/A$

Where, τ=Shear Stress(N/M2)

F=Shear force(N)

A=Shear Area(M2)

$=\pi DL$

By solving both the sides separately, if both side become equal i,e.

$\tau=\mu.du/dy$

then the fluid is Newtonian fluid

or

If both sides become unequal i,e.

$\tau \neq \mu.du/dy.$

then the fluid is Non-Newtonian fluid

4. CONCLUSION

As we observed that, shear stress is equal to the rate of shear strain then the fluid is Newtonian, and if the shear stress is not equal to the rate of shear strain then the fluid is Non-Newtonian. These systems are easy to operate. As we perform the experiment on different fluid we can easily calculate the type of fluid. It is use in carried out the experiment in fluid lab.

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