# Design & Development of Viscosity Analyzer

Interim Report

submitted in partial fulfilment

of the requirements for the degree

of

**Bachelor of Science**

in Engineering

Electroincs & Engineering Management

And

Electronics & Telecommunications Engineering

at

**Sri Lanka Technological Campus**

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# Abstract

A timely and innovative technique for measuring liquid viscosity is presented. In this technique, a disk is driven by a constant speed dc shunt motor in the test liquid. Using Arduino programming, the motor current can be changed and the viscosity of any liquid under investigation can be measured by the change. Viscosity is measured based on mathematical concepts that use the difference in motor current. The output voltage is measured using a gain amplifier. Thus, this technique is useful for measuring the viscosity of liquids.

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# Chapter 1

## 1.1Introduction

Viscosity is a measure of a fluid's resistance to flow, or more precisely, it is the ratio of the force required to overcome internal friction between layers of fluid (shearing stress) to the change in speed between layers of fluid (velocity gradient).

## 1.1.1 Background

Knowing the viscosity of a fluid can be quite important when you need to measure viscosity. Many quality control measures are based on viscosity. For example, to maintain consistent quality a ketchup producer needs to maintain the proper viscosity, so the consumer ends up with the product as intended. Paint needs to be able to spread properly but should not be dripping off of the brush. Ink must come out of a nozzle in a precise manner. In other cases, the design and engineering of equipment and systems must take viscosity into consideration to ensure that they will function as required. The sizing of pumps and mixers depends on the design and power of the equipment to handle a given viscosity. In modern conditions, the cost of viscometrical measurements becomes very high since they require quite lot of labor contribution. Put simply: a qualified laboratory assistant in a chemical laboratory currently can take no more than twenty viscosity measurements per day using the capillary viscometer. Hereof it's easy get to specific economic indicators which show that the cost of these measurements becomes very significant only because of operating costs. To these calculations it is necessary to add the possibility of a failure of the measuring nodes; also need take into account that in many cases

washing of nodes can be poor quality, which leads to distortions in measurement results.

## 1.1.2 Aims

Allowing easy and safe Viscosity measurement of any liquid with high efficiency while contributing to economic benefits to the modern technology through development of viscosity Analyzer.

This project hope to measure viscosity using dc shunt motor and rotating disk. On this other way built a software to collect viscosity measurements which we measure from unknown liquids based on the voltage and power supplied to the motor.

## 1.1.3 Objectives

- To design a device to measure viscosity which will contribute for quality checks of liquids in laboratory experiments.
- Introduces to the market as a product with high efficiency at low cost.
- Production of high-quality beverages to be exported in order to obtain economic benefits by minimizing possible errors in measuring the viscosity of a liquid.
- To design a device to measure viscosity
- To get Measurement details pass through Arduino Uno board.
- To collect data with using Microsoft excel and save as CSV file.
- To design GUI applications with using python programming languages.

# Chapter 2

## 2.1 Literature Review

[1] A portable viscometer has been introduced in a work by A.B Hassan et al, for the measurement of bulk viscosity of different Newtonian fluids. It is aimed at making available the instrument in local markets and consequently reducing or eliminating the prohibitive cost of importation. The method employed is the use of a D.C motor to rotate a disc having holes for infra-red light to pass through and fall on a photodiode thus undergoing amplification and this signal being translated on a moving-coil meter as a deflection. The motor speed is kept constant but varies with changes in viscosity of the fluid during stirring, which alter signals being read on the meter. From the results of tests conducted on various sample fluids using data on standard Newtonian fluids as dependable guide the efficiency of the viscometer was 76.5%.

[2]A unique thickness shear mode micro acoustic sensor appropriate for monitoring viscosity-temperature features is provided in a paper by B. Jacoby et al. that reports on the measurement of viscosity. The temperature of the liquid sample may be readily regulated at the sensitive surface thanks to the sensor's integrated heater and temperature sensor. This tiny sensor uses less heating power and produces faster measurement times than traditional viscosity measuring setups. Additionally, the method is less susceptible to temperature differences in the liquid sample. We discuss the design, analysis, and functionality of the first constructed prototype that makes use of this innovative idea in this work.

[3] A new technology has been proposed for viscosity measurements in a work by I. Suleimenovet al, with using mobile applications was suggested. The technology is based on a known method of a viscosity measurement trough defining

characteristics of ball movement in a viscous environment, but its difference that the character of ball movement which setting by an external magnetic field. The technology provides for the processing of primary measurement signals, which taken from measuring inductors, using installed on a smartphone software conjugate with a measuring device. This allows to significantly reduce the cost of equipment which designed to measure viscosity. These systems, designed to measure viscosity, are in fact the first step to create an entire range of different laboratory devices for currently use, including in the chemistry of high molecular weight compounds.

[4] Lynn F. Fuller and associates offer a thermally actuated non-cantilever-beam microelectromechanical viscosity sensor. The suggested device is based on thermally generated vibrations of a basic silicon diaphragm and its dampening by the surrounding fluid. This vibration viscometer uses piezoresistive sensing and thermal actuation through an in-situ resistive heater, both of which make use of CMOS compatible components, making for a low-cost and dependable system. The minimum heater voltage pulse amplitude and time were established by thermal analysis using temperature diodes in the silicon diaphragm in order to minimize heat loss to the test oil that may result in local viscosity changes. Using a commercial cone-and-plate viscometer, viscosity measurements were made and compared to motor oil.

# Chapter 3

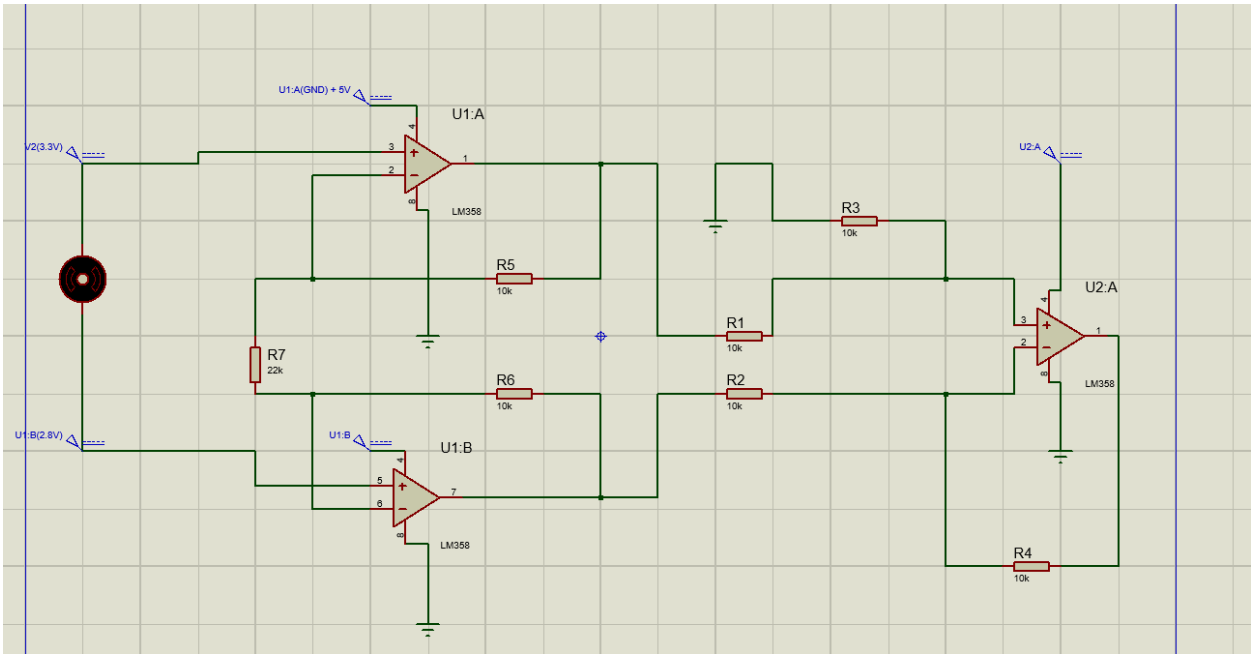
## 3.1 Methodology

### 3.1.1 Working Process

It consists of a closed cylinder of stainless steel. The radius and thickness of the disk were about 5 mm and 0.5 mm, respectively. And we have planned to use dc motor with about 900rpm. For the experiment, a disk of diameter 10 mm was rotated at a constant speed of 900 rpm in the cylinder, completely filled with 20 ml of the sample. The rpm of the constant speed dc shunt motor was measured using a digital tachometer. We are going to take measurements and see process through this software. We have planned to collect data and it means if one time measure viscosity of unknown liquid and we can save it our database and can give it to respective name until we measure the unknown liquid next time.

#### 3.1.1.1 Hardware Implementation

This is our project Circuit diagram. It consists of resisters, Amplifiers and DC supply. This Circuit connects to Arduino uno board to change the currents and voltage of DC motor. As well as We connect the LCD display to Arduino uno board to display the time range, showing result either this system work or not at that time. An amplifier is used to vary the output voltage supplied by the DC shunt motor, which can vary the current supplied to the motor. The connection between the computer and the Arduino uno board is established by connecting the cable through the USB port of both devices. The power supply to the Arduino Uno board is given by the computer. A DC shunt motor rotates the rotating disk and places it on the liquid whose viscosity is to be measured. The torque imparted to the disc by the liquid is inversely proportional to the voltage supplied to the motor, which is inversely proportional to the viscosity of the liquid.




An instrumentation amplifier amplifies the voltage variation and provides a differential output like any other op-amps. But the main feature here is that unlike normal amplifiers, instrument amplifiers have a high input impedance with good gain. This provides the output voltage with fully differential inputs. Op-amps can also be used to build voltage adder and voltage subtractor circuits. The instrumentation amplifier circuit is designed using the op-amp device in the above circuit. Three op-amps are used in the circuit and two LM358 ICs are used. LM358 IC is designed by combining two op-amps. Three LM741 op-amp single packages and one quad package LM324 op-amp are used in this circuit. In the above circuit, op-amp U1(A) and U1(B) act as a voltage buffer and this helps to achieve high input impedance. Op-amp U2(A) acts as a differential op-amp. A differential op-amp uses all resistors as 10k and shows its output voltage as a unity-gain differential amplifier.

This output voltage is the difference in voltage between pin 3 and pin 2 of U2(A).Output voltage of the amplifier circuit we have designed can be calculated using the following formulas.

Vout = (V2-V1) (1+(2R/Rg))

Where, R = resistor circuit

We consider as R = R2=R3=R4=R5=R6=R7 and assume as a R = 10 k.

Rg = gain resistor.

Here Rg = R1 is considered, and its value is taken as 22k.

The value of gain of the amplifier can be calculated from the value of R and Rg

Gain = (1+(2R/Rg))

If we describe the simulation of the instrument amplifier circuit, the difference between the input voltage flowing through the circuit is measured through the following minimization and it is multiplied with the gain and it is produced as the output voltage. V (out) or output voltage can be obtained. When we give 2.8V to V1 and 3.3V to V2 as input voltages and consider value of R as 10k and value of Rg as 22k,

Vout = (V2-V1) (1+(2R/Rg))

= (3.3-2.8) (1+(2x10/22))

= (0.5) *(1.9)

= 0.95V

The output voltage we got is 0.95V which matches the above simulation. So, the gain of the above circuit is 1.9 and the voltage difference is 0.5V. By measuring the voltage across V1 and V2 before these resistors you can see the actual output voltage from the op-amp U1(A) and U1(B) in circuit.

By the input voltage V1 and V2 across resistor Rg.Op-amp provides negative feedback at U1(A) and U1(B).So, we can say that the voltage drop across Rg is equal

to the voltage difference between V1 and V2.Hence equal current flows through both resistors R5 and R6.It is the same as the voltage on pin 3 and pin 2 of op-amp U2(A).Value of R1 can be changed to set the gain in circuit and so the gain of the amplifier can be controlled the voltage by using a single resistor.

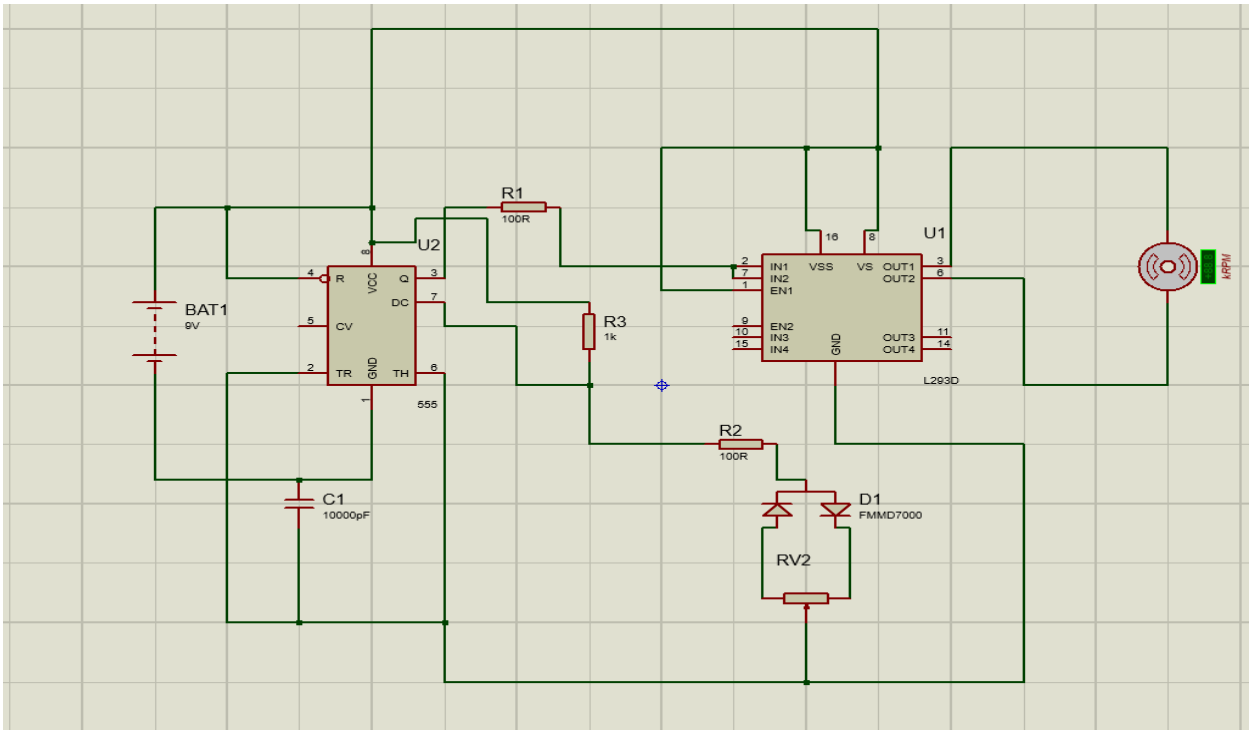



Figure 3.1

The main purpose of the DC Motor Speed CONTROL circuit is to obtain a variable voltage rather than a constant voltage. Here the circuit is designed to get PWM signal based on 555 IC and its components are power supply, DC motor, 555 timer IC, resistor, capacitor, potentiometer, switch, and L293D IC.

555 IC Timer is a timing device and a stable controller. The 555 IC is designed in such a way that precise timing delays or oscillations can be produced through the monolithic timing circuit. An external resistor and capacitor are used to create the time delay, which can control the timing. For stable operation of this as an oscillator, both the free-running frequency and the duty cycle are accurately controlled

complete circuit by two external resistors and one capacitor. The peculiarity of this circuit is that it can be turned off and reset on waves falling through the circuit.

A 555 TIMER IC obtains a DC power supply with a duty ratio. Potentiometers produce a PWM signal that depends on the resistance ratio and can change the voltage gain. A different set of resistors must be loaded and unloaded here on the capacitor due to the potentiometer and diode pair. Thus, the capacitor takes different time to charge and discharge and the output increases when the capacitor is charged and decreases when the capacitor is discharged. Timer PWM is supplied to L239D h-bridge signal pin to drive the DC generator. We get different RMS terminal voltage and rpm with different PWM ratio and thus can be done by setting the PWM second signal pin of the timer to switch the rotation directions.

## 3.1.1.2 Software Implementation

We prepared the circuit in proteus 8 Professional Software.

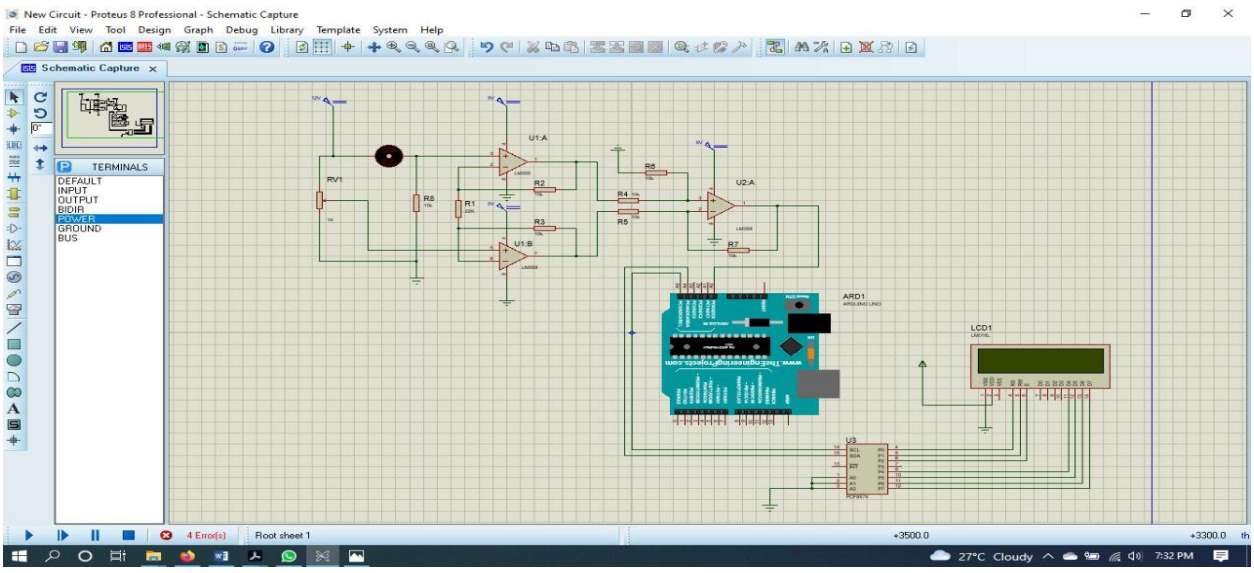



Figure 3.2

When we give power supply to dc shunt motor, then rotating disk rotates on the liquid. We have to do some code in Arduino software for changing variable such as rotating disk speed, angular velocity, current flowing through dc shunt motor. The

Arduino Uno board has an IC and a microcontroller consisting of memory and processor. It is through this IC that the program is sent to the computer and Microcontroller. Since there is no software on the Arduino uno board, you can install a software on the Arduino board through the computer. Here, Programming IDE is used, and the program is developed and uploaded. Before applying the Arduino programming code, the correct board and port must be selected. First check whether the code is correct through the right button and then the data will be transmitted to the Arduino board using the upload button. We connect the LCD display to Arduino uno board to display the time range, showing result either this system work or not. So, we get real time data from Arduino boards to computer. Next, we store data to Microsoft Excel through connecting data screamer function. After that, we save this file with .CSV extension. We read CSV files from using python programming Languages in PyCharm Community Edition 2022 1.4 or Jupiter Notebook Software. When using CSV file data, we generate the real time graph and GUI applications. Finally, we can calculate the liquids of viscosity with using mathematical functions. We can save our values with own name. After that, we measure the same liquid, we can compare with each other. This software implementation has valid international viscosity values of some liquids, then we can measure, and compare is it pure or not.

## 3.1.2. Theoretical Explanation with Mathematical Solutions

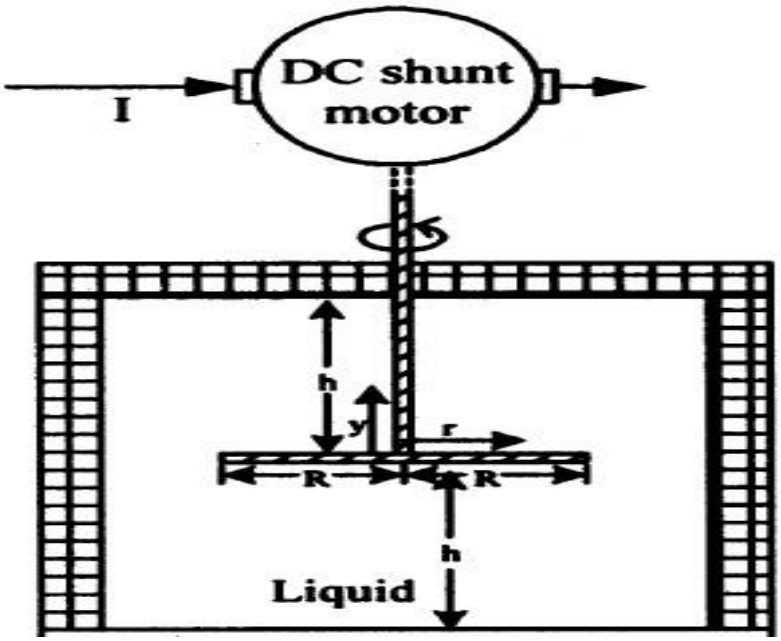



Figure 3.3 - Device Diagram

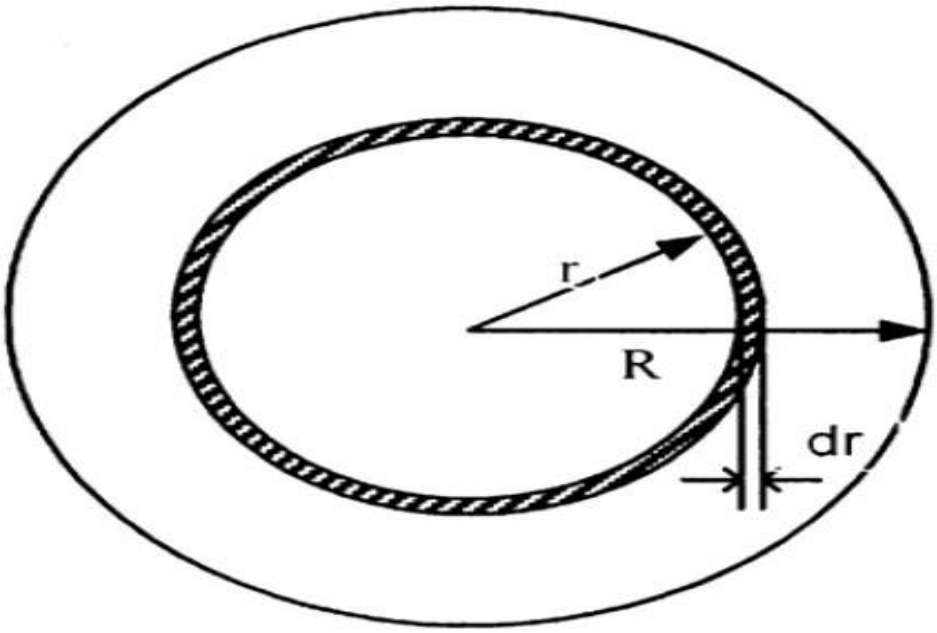



Figure 3.4 - Disk Diagram

- Radius of Rotating Disk – R
- Angular Velocity - $\omega$
- Liquid of Viscosity - μ
- Velocity distribution between the top of disk and bottom surface of the cylinder-

$$u(y, r) = r\,\omega\left(1 - \left\{\frac{y}{h}\right\}\right)$$

- Tangential Stress on the surface of the disk –

$$\tau = \{\mu\left(\frac{\delta u}{\delta y}\right)\}\ y=0$$

- The tangential force - df / infinitesimal thickness dr ->

The tangential force on the ring oof radius of disk and infinitesimal thickness dr on the surface of the disk –

$$df = \mu * (\omega r/h)\ 2\pi r\ dr$$

The differential torque dT generated on the ring:

$$dT = df * r$$

$$dT = (\omega 2\pi\mu / h) * r^3 * dr$$

Torque T on one side of the disk with using above equation:

When we consider the T with the limits zero to R as follows:

$$T = \int_0^{\pi}\left(\frac{\omega 2\pi\mu}{h}\right) r^3 * dr$$

which results

$$T = \frac{\omega\pi\mu\, R4}{2h}$$

When we reject shear on the outer disk edge,

the total torque T(total) on both sides of the disk is twice of the torque T.

So, the total torque T(total) can be represented as

$$T\ (total) = \frac{\omega \pi \mu\ R4}{2h}$$

Assuming x, h, and R as constants

$$T\ (total) = k\mu$$

where $k = \frac{\omega \pi\ R4}{h}$ is a device constant.

The torque generated by dc shunt motor Tm is given by

$$T\ m = T\ L + T\ f$$

where TL and T f denotes usable torque and frictional torque, respectively.

Assuming Tf as constant

$$T\ m\ \alpha\ T\ L$$

Torque available at the motor output drives a load. If the losses are negligible, the electrical power EIcos Φ equals the mechanical power → $T\omega$

$$EI \cos \Phi = T\omega$$

In dc power factor cos/ is unity

$$EI = T\omega$$

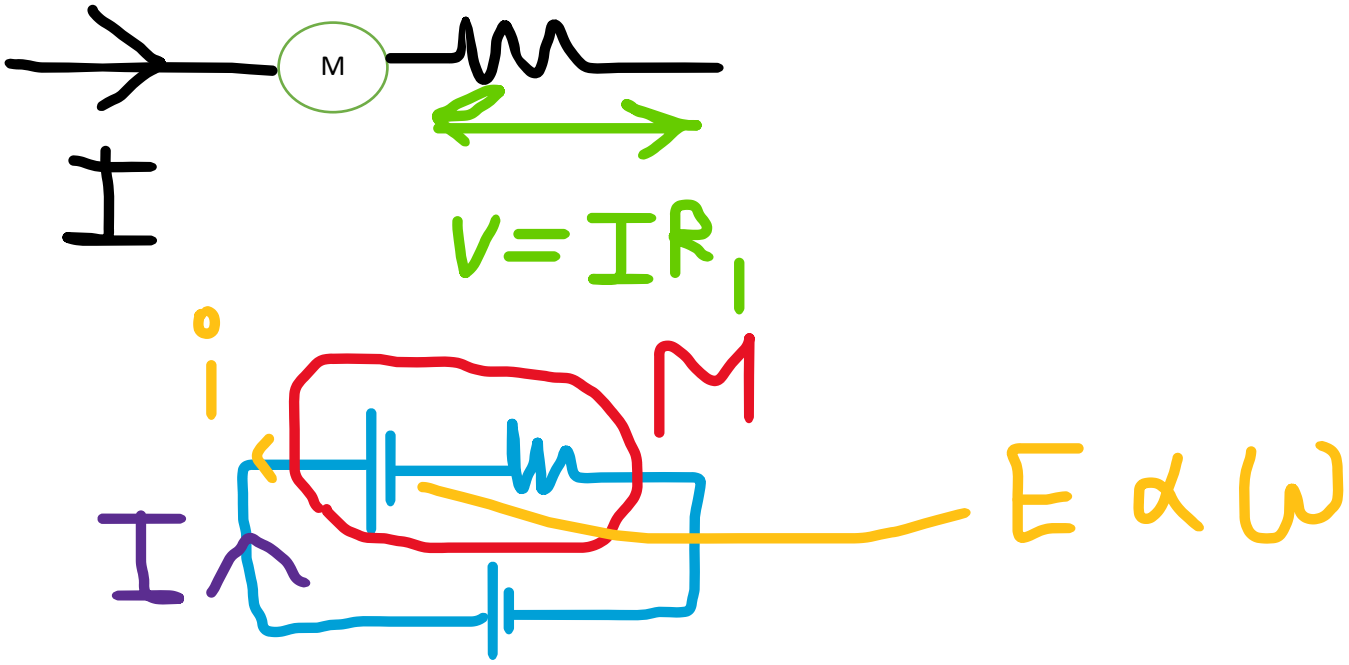
Since supply voltage E and angular velocity x are constants

| $T \alpha I$ |
|---|

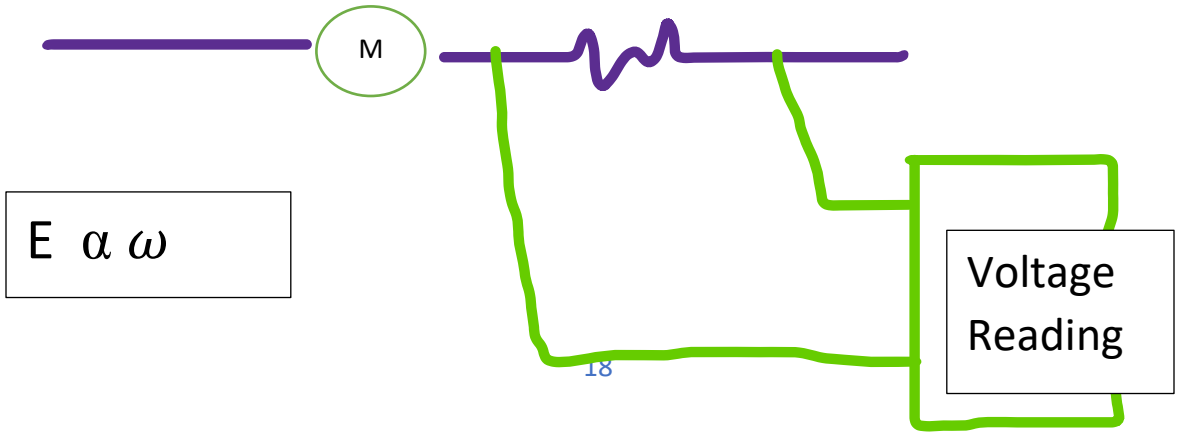
So, we can say that,

| $I \alpha \mu$ |
|---|

Finally, the current of dc shunt motor is directly proportional to the viscosity of the liquid under project testing investigation.




When Folwing current is increased,then motor speed is descreased.



1/ η α ω α I α Voltage reading

1/ η α Voltage reading

| Reading (2) / Reading (1) = η1 / η2 |
|---|

Known viscosity – η1

Unknown viscosity – η2

As we know η1, reading(1), reading(2),

Then we can find η2.It means we can find unknown viscosity of liquid.

This is a comparison of the proposed viscometer's output voltage against data on actual viscosity obtained from a Regular viscometer. A linear association between the two values may be seen on this graph. The output voltage (V) of the proposed methodology may be measured, multiplied by K, and used to determine the viscosity (g) of vegetable oils as described in the following:

$\eta = K \times V$ where $K = 0.0125 \times 10^{-3}$

k is a constant.

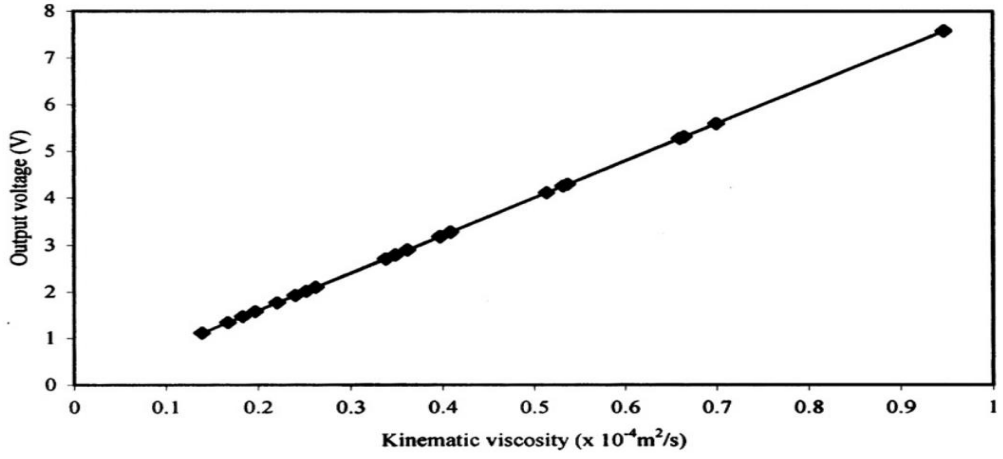



Figure 3.5

## 3.2 Project Timeline

| Design & Development of Viscosity Analyzer | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Activities** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **11** | **12** |
| **Project Selection** | | | | | | | | | | | | |
| **Project Proposal Submission** | | | | | | | | | | | | |
| **Hardware Implementation** | | | | | | | | | | | | |
| **Interim Viva & Presentation** | | | | | | | | | | | | |
| **Software Implementation** | | | | | | | | | | | | |
| **Final Presentation** | | | | | | | | | | | | |
| **Final Demonstration** | | | | | | | | | | | | |

# Chapter 4

## 4.1 Conclusion

### 4.1.1 Summary

Our project can be presented as an approach to measuring viscosity for liquids with voltage control. The output voltage of the proposed system can be observed which multiplied by the constant K. Then we can find to determine the viscosity of the liquid. It is special that the viscosity of various liquids can be recorded in the past and present data in our new system with comparing the configuration of the proposed and current viscometers.

### 4.1.2 Future plan

The proposed method can measure the liquid viscosity by monitoring the output voltage and the flowing current. Other external environmental influences affecting the viscosity of liquids are expected to be identified and avoided and technological solutions available. Looking forward to testing how to minimize splashing of the liquid as the disc moves over the liquid. The system is expected to be evaluated to withstand hazardous and volatile liquids. Looking forward to evaluating the changes to avoid potential performance issues in this system.

# Chapter 5

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