Design, Construction and Testing of a Viscometer

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Abstract *- This paper presents the design and testing of a locally fabricated viscometer. The need for a locally fabricated viscometer to measure the viscosity of lubricants is underpinned by the prohibitive cost of imported laboratory equipment such as the viscometers. The kinematic viscosities ofSAE 40, Palm oil and Soybean oil were measuredusing the fabricated viscometer. Experimentalresults showed that theviscosityof Palm oil and Soybean oil at 40 ^{o}C was40.87 mm^2/s and 32.01mm^2/s respectively. The viscosity of SAE 40 (Engine oil) was 13.65 ± 0.013 mm^2/s (90% confidence level) at 100^{o}C.*

Keyword: *Kinematic viscosity, viscometer, locally fabricated, lubricants, oils.*

I. INTRODUCTION

Viscosity is a measure of a fluid resistance to flow and its knowledge is important in all physical processes involving fluid movement. Viscosity measurements assist in analysing important factors affecting product performance in many industries. The viscosity of both synthetic and mineral oils decreases with increase in temperature. In hydrodynamic bearings, the viscosity of the lubricant is important at the operating bearing pressure.

There are many design variants of viscometers in the literature notable among which are Oscillating-Body Viscometers [1] Oscillating-Disc Viscometer, Oscillating-Cylinder Viscometers [2] Oscillating-Cup Viscometers, Oscillating-Sphere Viscometers, Vibrating-Wire Viscometers, Torsional-Crystal Viscometer, Falling-Sphere Viscometer, Falling-Cylinder Viscometer [3], Rotational viscometers [4], Coaxial cylinder viscometers [5], Parallel disk viscometers [6], Concentric cylinder [7] and Saybolt viscometer which works based on the capillary tube method [8],[9]. Orifice viscometer and Falling ball viscometer were used to determine the viscosity of greasing up oil [10]. A chan U-Tube viscometer was used to determine the viscosity of Tellus 68 oil, a lubricant for the generating unit of Shiroro Power Station in Niger State, Nigeria [11].

Most of the aforementioned viscometers are imported into the Country and are prohibitively high in prices. This calls for the design and fabrication of indigenous viscometers which are relatively lower in prices.

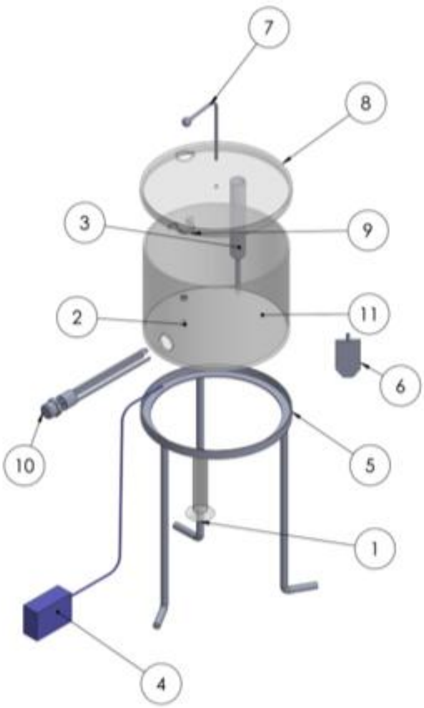
The present work focuses on the design of a locally fabricated viscometer which works by the principle of the Saybolt viscometer. The viscometer was tested using SAE 40 oil, Soybean oil and Palm oil.

II. MATERIALS AND METHODS

The developmental stages of the Viscometer entails designing its components with CAD (Solid works), assembling its components, fabrication of the different parts, assembling theparts to form a functional unit and testing it for the viscosities of some oils.

The viscometer consists of the following parts: a thermometer, a graduated wide receiver flask, a temperature bath, a heater, an oil tube, a thermostat and a tripod stand. Figure 1 shows the exploded view of the viscometer whilst Figure 2 shows its assembly drawing using CAD (Solid Works). A pictorial view of the viscometer is shown in Plate 1.

Plate 1: Pictorial view of the viscometer



11	Water bath	1	Perspex
10	Heater	1	
9	Oil tube holder	1	Perspex
8	Lid	1	Perspex
7	Paddle handle	1	Stainless ste
6	Paddle	1	Perspex
5	Tripo Stand	1	Steel
4	Thermostat	1	
3	Oil tube	1	Glass
2	Cork	1	Rubber
1	Oil Receiver	1	Glass
ITEM NO.	COMPONENT	QUANTITY	MATERIAL

Figure 1: Exploded view of the viscometer

Figure 2: Assembled Saybolt Viscometer

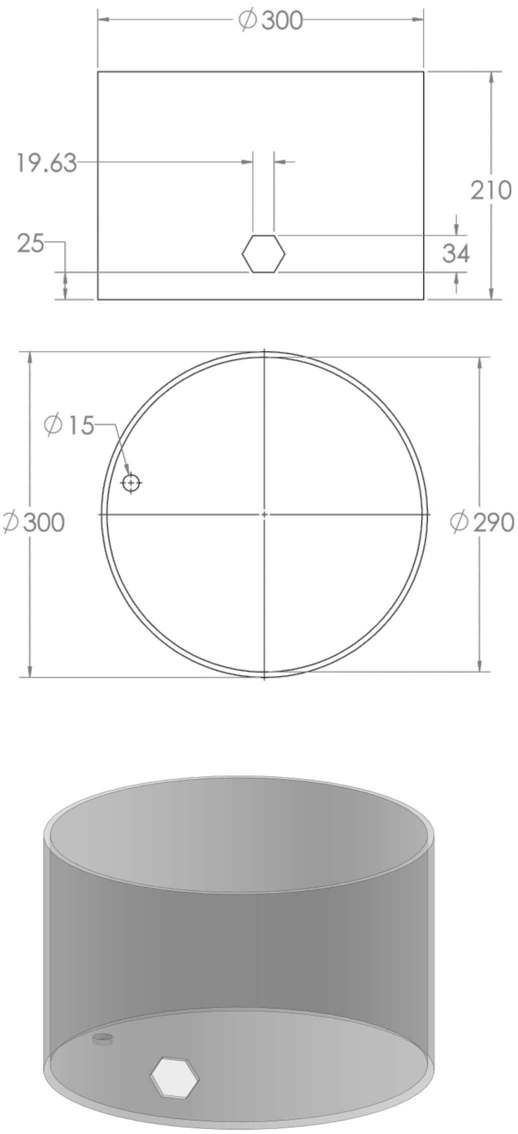


Figure 3: Water Bath

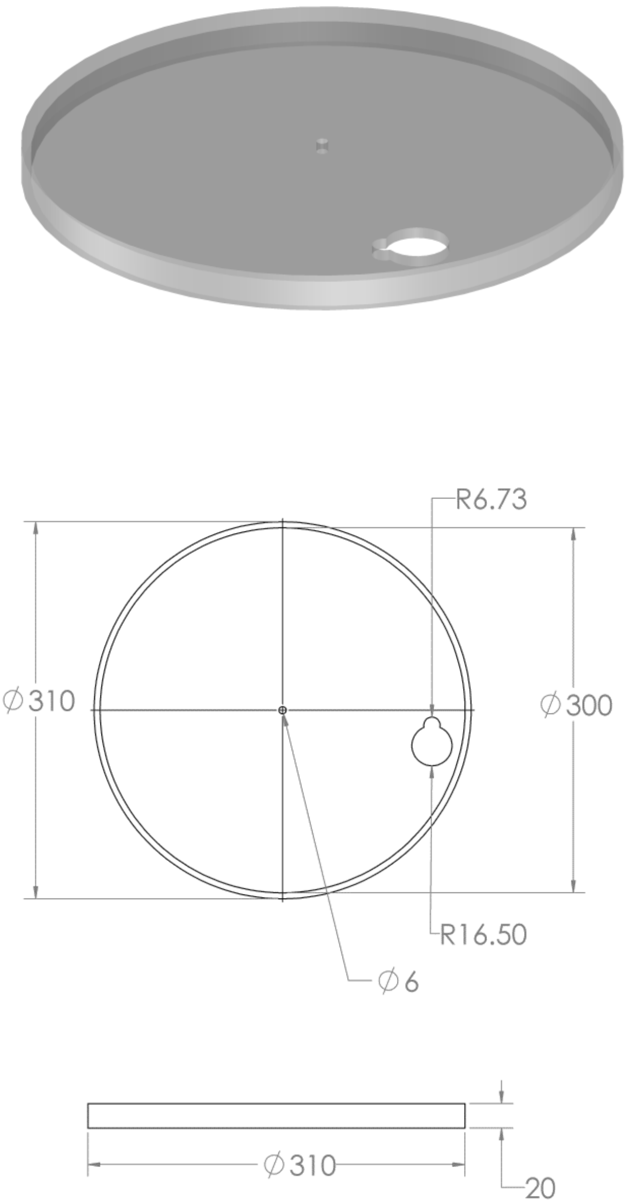


Figure 4: Water Bath's Cover

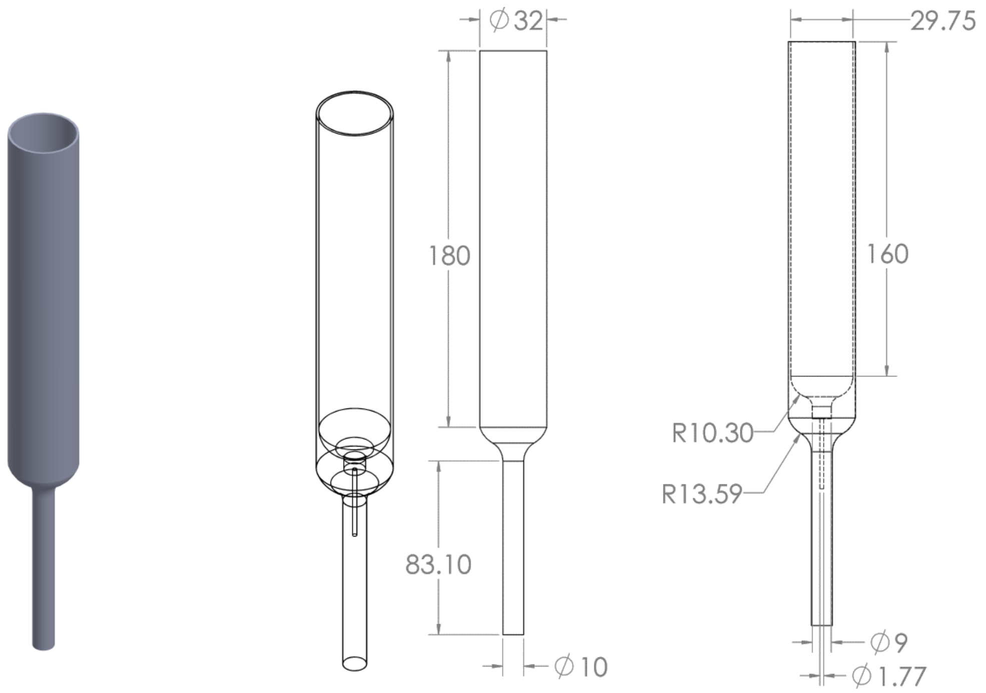


Figure 5: Oil Tube

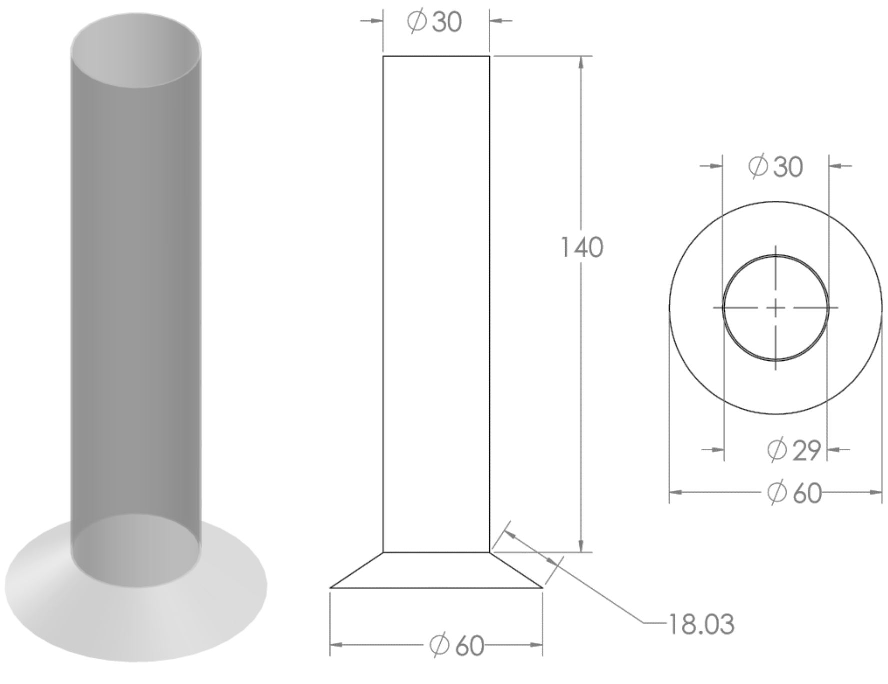


Figure 6: Receiving Flask

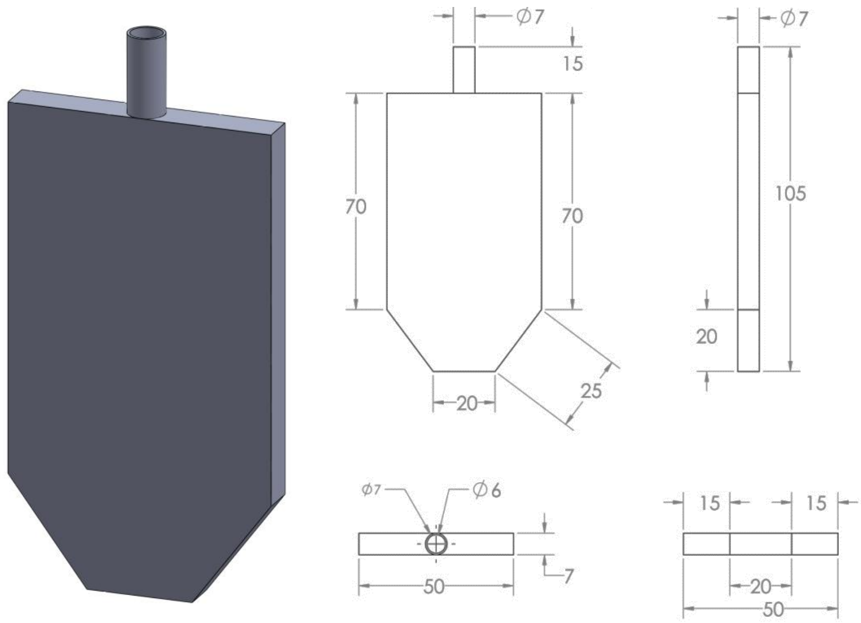


Figure 7: Paddle (Stirrer)

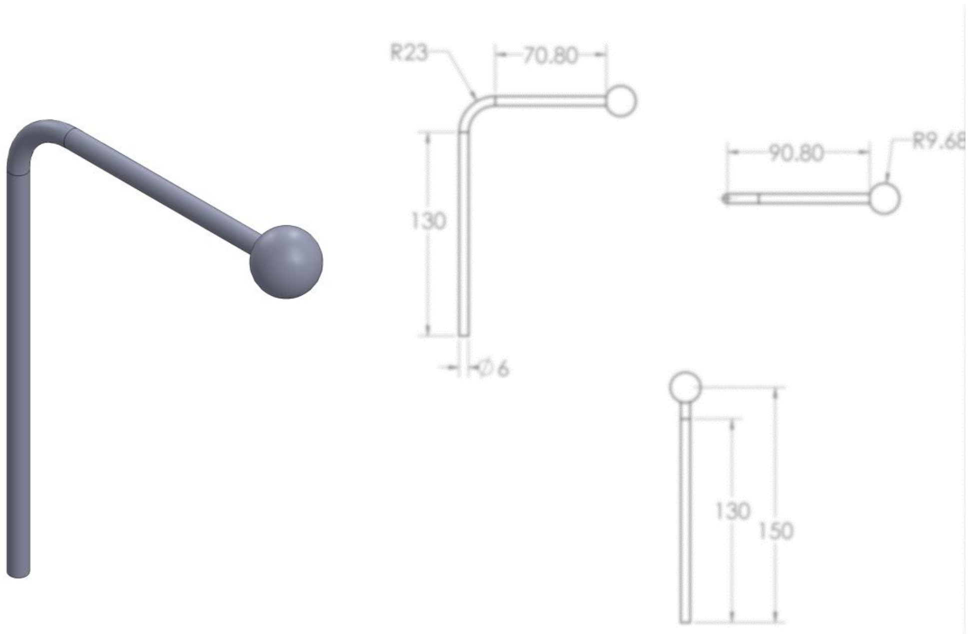


Figure 8: Paddle's Handle

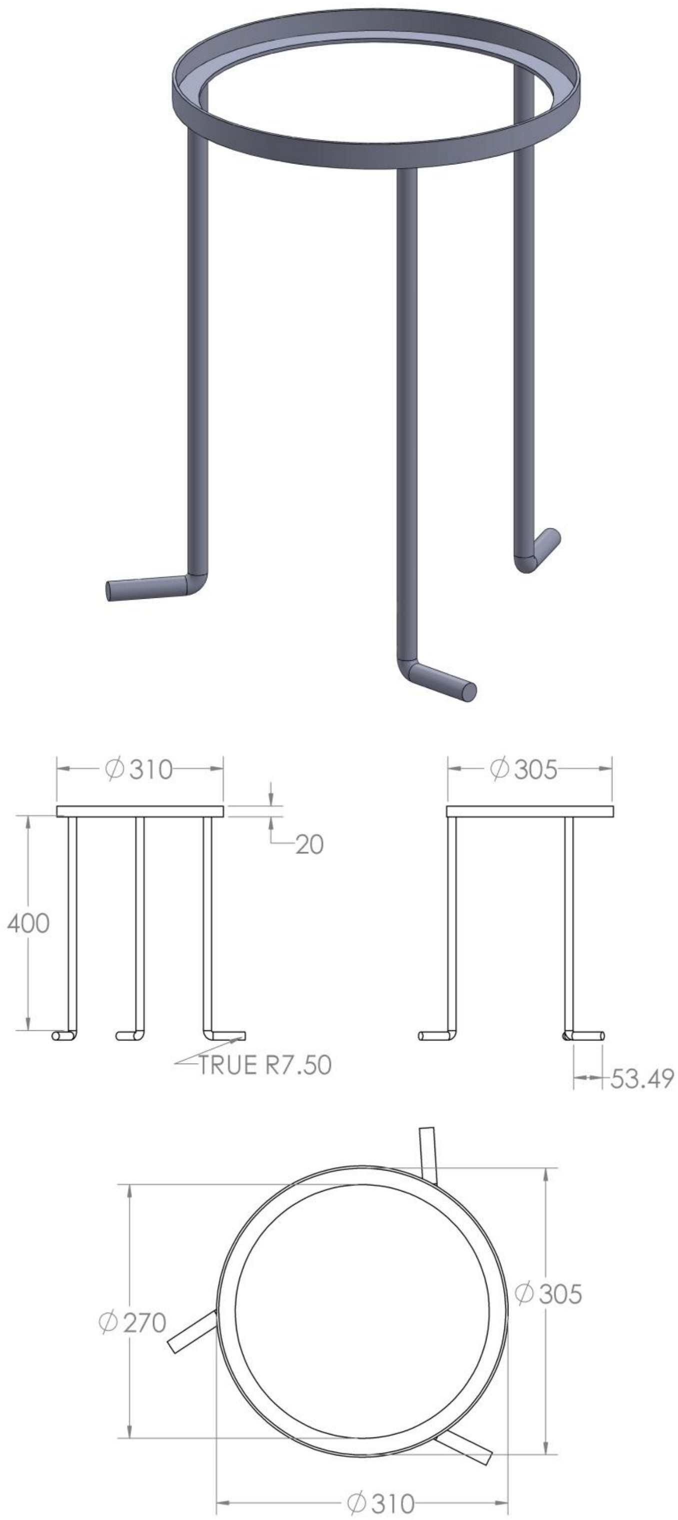


Figure 9: Tripod Stand

A. Process Flow

The components of the viscometer were taken from section to section in the production line. The sections involved include: glass blowing section, electrical section, machining/ welding section and painting section.

Glass Blowing Section

In the glass blowing section, components such as the water bath, paddle, oil tube and the receiving flask were fabricated.

1). Water Bath

The water bath which holds the water to be used during the experiment was fabricated in the glass blowing section. The material used for the bath and its cover was perspex (polymethyl methacrylate). The choice of material was because of its being approximately 10 times stronger, damage resistant and having less weight when compared with glass. The dimensions of the water bath and its coverare shown in Figures 3 and 4.

2). Oil Tube

The oil tube holds the oil whose viscosity is to be measured. The material used for the oil tube was glass. Its dimensions are shown in Figure 5.

3). Receiving Flask (Graduated)

The receiving flask was made of glass and its dimensions are as shown in Figure 6. Its volume was 92 ml.

4). The Paddle

The paddle, made of perspex, was rotated to mix the water to ensure uniform temperature in the water bath. The dimensions of the paddle and its handle are shown in Figures 7 and 8.

Electrical Section

This section was responsible for the development of the temperature regulator and the heater used in the apparatus.

1). Heater and Temperature Regulator

A 220 V – 1.5 kW heater was used to heat the water in the bath. The device used to regulate the amount of heat dissipated by the heater was developed. The regulator components include: a circuit breaker, an LED display for exact setting and reading and a temperature probe. It had a switching capacity of16 A, 220 V, maximum temperature of 100^{o}C and a minimum temperature of 20^{o}C.

Machining/ Welding Section

In the welding section, the joining together of metallic parts such as the tripod stand and the paddle's handle was done using an electric arc welding machine.

1). Tripod Stand

The tripod stand was made of steel and its dimensions are as given in Figure 9.

2). The Paddle Handle

The material used for the handle was also steel. The handle was connected to the paddle through the hole in the lid of the water bath.

B. Experimental Procedures

The oil tube and water bath were cleaned using a suitable solvent.The temperature bath was set to the required temperature and filled with water and stirred to ensure even distribution of temperature.The liquid whose viscosity was to be determined was poured through a sieve to remove every form of impurity that could lead to inaccuracies in the measurements. A little of the sieved liquid was poured through the oil tube to ensure that the oil tube was moist and allowed to drain out through the orifice.The cork was fitted back to the orifice opening and the oil tube filled with the liquid which was stirred until the required temperature was attained. The cork was removed and the liquid was allowed to flow out through the orifice into the graduated wide receiver flask and simultaneously, the stop watch was started. The stop watch was stopped when the liquid reaches the 60ml mark on the wide receiver flask. The viscosity (v) of the liquid, which is a function of the time recorded (t), was calculated using the formula below:

$$v = \left(0.00022018t - \frac{0.1793}{t}\right)(10^{-3})\, m^2/_{s} [12] (1)$$

III. RESULTS AND DISCUSSION

Tables 1 and 2 shows the drainage times and viscosities at different temperatures for Soybean oil and Palm oil respectively.

Table 1: Kinematic viscosity of Soybean oil at different temperatures

Temperature (^{o}C)	Time of drainage for 60ml of Oil t(s)	Kinematic viscosity, v (mm^2/s)
30	168	36.08
40	151	32.01
50	133	28.00
60	116	24.05
70	99	19.88
80	75	14.01
90	59	10.04
100	49	7.20

Table 2: Kinematic viscosities of Palm oil at different temperatures

Temperature (°C)	Time of drainage for 60ml of Oil t(s)	Kinematic viscosity, ν (mm^2/s)
30	217	46.85
40	190	40.87
50	168	35.92
60	142	29.96
70	120	24.81
80	99	20.06
90	79	15.05
100	57	9.30

The experiment for the determination of the viscosity of SAE 40 (Engine oil) at 100°C was carried out seven times. The readings obtained were 13.60, 13.71, 13.70, 13.67, 13.63, 13.64, and 13.59mm^2/s

Mean value, $x_m = \sum x_i$ (2)

Sample standard deviation,

$\sigma = \left[\frac{\sum(x_i - x_m)^2}{n-1}\right]^{1/2}$ (3)

$\Delta = \frac{t\sigma}{n}$ (4)Equations 1 and 2 were used to calculate the mean and the sample standard deviation: 13.65 mm^2/s and 0.0467 mm^2/s respectively.

Degree of freedom, ν = 7 – 1 = 6

Value of student's t at 90% confidence level, t_{90} = 1.943

From equation 3 Δ = (1.943) (0.0467)/7= 0.013

$x = 13.65\,mm^2/s \pm 0.013\,mm^2/s$ (90% confidence level).

Table 3 shows thecomparison of the viscosities obtained in the present work with those in the literature.

Table 3: Comparison of the viscosities of oils obtained in the present work with those in the literature

	Kinematic viscosity, ν (mm^2/s)	
Temperature	**40°C**	**100°C**
Palm oil	40.87	9.30 (present work)
	41.93	8.80[13]
Soybean oil	32.01	7.20 (Present work)
	31.74	7.63 [13]
SAE 40 (Engine oil)		13.70 (Present work)
		12.5 - 16.3 [14]

The kinematic viscosities, at temperatures of 40°C and 100°C, of Palm oil and Soybean oil obtained from the present work compared favourably with those obtained by Atabani *et. al*.,[13] whilst the result of the present work, for SAE 40 at 100°C, compared favourably with that obtained by Iona and Minodora [14].

The kinematic viscosities of the Soybean oil and Palm oil decrease with increasing temperature. Palm oil was more viscous than Soybean oil.

With an increase in temperature, there is typically an increase in the molecular interchange as molecules move faster in higher temperatures. The impact of increasing the temperature of a liquid is to reduce the cohesive forces while simultaneously increasing the rate of molecular interchange. The increase in temperature causes the kinetic or thermal energy to increase and the molecules become more mobile. The attractive binding energy is reduced and therefore the viscosity is reduced.

IV. CONCLUSION

A saybolt viscometer was locally designed, constructed and tested. It was tested using three oil samples (Palm oil, Soybean oil and SAE 40). The results obtained compared favourably with those in the literature. Constructed using perspex (Polymethyl methacrylate)) for the temperature bath and glass for the oil tube, this viscometer provides several advantages over traditional viscometers, this includes, disposability, low cost and simple fabrication. It is also important to note that the saybolt viscometer is only suitable for samples with efflux time, 32 > t< 1000 s.The cost of production of the viscometer was ₦108,000 ($300) which is considerably less than the price of any of the viscometers being imported into the country.

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