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## Faculty of Engineering, Architecture and Science

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| Report Title | Lab 1, Measurement of Dynamic Velocity |
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# **Abstract:**

The objective of this lab was to calculate the dynamic viscosity of gear oil by measuring the terminal velocity of different sized spheres falling through the oil.

# **1.0 Introduction:**

Terminal velocity velocity is defined as the speed at which a free falling object reaches at which point the medium the object is falling through no longer allows for further acceleration. Viscosity measures the “resistance” a fluid provides against flow. Viscosity quantifies the internal friction within the fluid itself. This resistance is represented by sheer stress (τ). The formula for calculating sheer stress (τ) is displayed below.

(1)

Where μ is equal to dynamic viscosity and ∂u/∂yis the gradient. Knowing the sphere reaches terminal velocity means the sum of all forces acting on the sphere will be equal to zero. Using this knowledge we are able to use the following equation.

(2)

Where FD is the drag force, FB is the buoyancy force, and Ws is the weight of the sphere. The upward drag force FD can be calculated using the following equation.

(3)

Where μ is dynamic viscosity, U is steady velocity of the sphere and D is diameter. FB the buoyancy force is calculated using the following formula.

(4)

Where pf is the fluid density. The weight of the sphere can be calculated using the following equation.

(5)

Where ps is the density of the sphere. By substituting equations (3),(4), and (5) into equation (2) solving for dynamic viscosity (μ ) gives the following formula:

(6)

Reynolds number can be calculated using the following equation.

(7)

# 

# **2.0 Apparatus:**

The following equipment was used to perform the experiment:

* Tall graduated cylinder
* Gear oil (SAE 80W-90 GL-5)
* Hydrometer
* Weight scale
* Stopwatch and meter stick
* Weight scale
* Micrometer
* Thermometer
* A large nylon ball, a medium nylon ball, a small nylon ball

# **3.0 Procedure:**

1. At the beginning of test, measure the temperature of the oil
2. Find the specific gravity of the oil using the hydrometer
3. Measure the steady velocity of each sphere in the oil, using a stopwatch
4. Repeat the measurement for the largest sphere to ensure reproducibility

# **4.0 Results and Calculations:**

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## **Sample Calculations and Formulas:**

*Shearing stress:*

= dynamic viscosity

*Dynamic Viscosity:*

D = diameter of sphere

g = gravity

= density of sphere

= density of fluid

U = steady velocity of sphere

* Which is found by displacement over time

*Volume of sphere :*

*Sphere density :*

Before After

*Oil density:*

* Density of water (H2O = )

*Reynolds number:*

Table 2: All calculations results

| Oil Density()()  \*value holds a consistent for all sphere sizes |  | | |
| --- | --- | --- | --- |
| Size of sphere | Small Sphere | Medium Sphere | Large Sphere |
| ()Sphere density() |  |  |  |
| Velocity () |  |  |  |
| Dynamic viscosity () () |  |  |  |
| Reynolds Number(Re) | 0.1380<1 | 0.3364<1 | 0.8901<1 |
| Has the Slow criteria been met | Yes | Yes | Yes |
| The Percentage Error (%) |  |  |  |

Example calculation of sphere density:

Example calculation of velocity:

Example calculation of dynamic viscosity:

Example calculation of Reynolds Number(Re):

Example calculation of Percentage Error:

When comparing the properties of engine oil as listed in property tables with their experimental data, it becomes evident that the average sphere percent error value is low. This implies that temperature does indeed impact dynamic viscosity, although the effect is not very pronounced. The expected dynamic viscosity value is centered around 15.6°C, while their experimental dynamic viscosity measurement was taken at 23°C. Although there exists a temperature difference, it is not particularly substantial. From this analysis, one can conclude that dynamic viscosity tends to decrease as temperatures decrease and vice-versa.

# **5.0 Discussion:**

1. *Did the data for each sphere yield the same dynamic viscosity? If not, why?*

The dynamic velocity for each sized sphere was different due to the fact that they were all calculated to have varying densities and diameters. Both of these values are both used in the dynamic viscosity formula, therefore leading to different dynamic viscosity values in our calculations.

1. *Which size of sphere likely gave the most accurate results? Why?*

To yield the most accurate results for this experiment, we want to use the smallest ball available. The reasoning behind this conclusion is because the smallest ball had the lowest velocity value and diameter, which results in a lower Reynolds number (according to formula 7, ). In this experiment, it is ideal to have a smaller Reynolds Number because that means that there is reduced recirculating flow, which means more predictable fluid flow. This allows for more accurate measurements and calculations to be obtained.

1. *How does your viscosity measurement compare with value in property tables? Give possible reasons for any difference observed.*

The kinematic viscosity value for the Quaker State SAE 80W-90 GL-5 oil @45℃ is 145 mm2/s. To convert this value to dynamic viscosity, we simply multiply it by its density.

Comparing this property table value with our calculated results, we can observe that our calculations yielded a higher viscosity value at a lower temperature (23℃ as mentioned in the video). This corresponds with the fact that temperature and viscosity are inversely proportional. We can’t directly compare our values with the data sheet as they were measured at different temperatures, however, our calculated results seem reasonable for the reasons mentioned above. Inconsistencies between the experimental data and the data sheet may be due to the size of the cylinder used in the experiment, any unintentional spin put on the ball, or inconsistencies in the size of the balls used. The measuring process between this experiment and the data sheet values are different, so there are many possible points of error that can affect the results.

# **6.0 Conclusions:**

In conclusion, this experiment aimed to determine the dynamic viscosity of SAE 80W-90 gear oil using spheres of different sizes. The temperature of the oil was measured to give consistent results, and the specific gravity of the oil was determined. The smallest sphere gave the most accurate dynamic viscosity because Reynold’s number was the lowest out of the three spheres tested. The calculated dynamic viscosity values varied from the values in the property table. This could be due to differences in temperature, microscopic indentations in the spheres and minor differences between the oil tested and the oil in the property table. This could be remedied by using more precise temperature control and more specific oil properties to produce more accurate measurements. Overall, this experiment highlights the importance of the sphere size and the experimental conditions, mainly involving the properties of the oil, used in making meaningful measurements of dynamic viscosity.

# **7.0 References:**

[1]Naylor, D., &amp; Friedman, J. (n.d.). MEC511 Thermodynamics and Fluid Mechanics

Laboratory Manual (R. Buddy, Ed.). Toronto, ON: Toronto Metropolitan University.

[2] “Mec522 Viscosity Measurement Falling Spheres.”, YouTube, 15 June 2021

[3] Shell. (2018, January 16). Quaker State Hi-Performance GearPlus 80W-90 GL-5 Technical Data Sheet. https://shell-livedocs.com/data/published/en/8f3184be-5a64-4ed4-a789-0f4a78dc3ac8.pdf

# **8.0 Appendix:**

Table 3: Shows physical properties of common liquids.