Viscosity Lab Procedure: Teacher Manual

Goals:

- Understand what viscosity is.
- Understand what factors govern viscosity.
- Understand the importance of viscosity in relation to a fuel system.
- Understand how to change the viscosity of fluids.

Objectives:

- Students will test the viscosities of fluids through experimentation.
- Students will collect and record data from their experiments.
- Students will analyze the data by graphing it.
- Students will express their understanding of viscosity and their experiments by answering questions.

Background

Diesel engines

Diesel engines convert chemical potential energy in the form of fuel into mechanical kinetic energy in the form of moving parts. This is achieved through the combustion of fuel into heat, light, and gas in a combustion chamber called a cylinder. When the fuel explodes inside of the cylinder, it forces a piston outward producing mechanical motion. The linear motion of the piston is then converted to rotational motion via a crankshaft. This rotational motion ultimately turns the wheels of a vehicle.

The uniqueness of the diesel engine derives from the fact that compression alone within the cylinder creates sufficient heat to ignite the fuel. This characteristic distinguishes the diesel engine from the gasoline engine, which relies on a spark for the ignition of fuel within the chamber. The high compression of diesel engines causes them to be about 15% more efficient on average than gasoline engines.

Due to their high combustion temperatures, diesel engines have always had the capacity to utilize a variety of fuels. In 1909, a diesel engine fueled by peanut oil was demonstrated at the World Fair in Paris. Using vegetable oil-based fuels mitigates many of the negative impacts associated with fossil fuels including greenhouse gas emissions and dependency on imported oil.

During the early 20th Century, however, as petroleum became less expensive and more available, engineers increasingly designed automobiles to use only petroleum-based fuels. Almost all diesel fuel systems built in the last one hundred years were designed to optimize the properties of petroleum diesel. For an alternative fuel to function effectively in an unmodified diesel automobile, it must duplicate the properties of petroleum diesel. The major physical property affecting the use of vegetable oil in unmodified diesel engines and fuel systems is viscosity.

Viscosity

Viscosity is the resistance of a fluid to flow. It is often referred to as "fluid friction" and commonly thought of as the "thickness" of a fluid. A fluid like honey that is very thick has a high viscosity, and a fluid like water that is relatively thin has a low viscosity. Viscosity is commonly measured in units called Pascal seconds (Pa • s).

In an engine, fuel is delivered to the cylinders via a fuel system. The major components of the fuel system include the fuel tank, fuel lines, the fuel pump, the fuel filter, and fuel injectors. When you pump gas into a vehicle, it enters the fuel tank. Fuel is then pumped out of the tank when you drive, through fuel lines and through the fuel filter to fuel injectors, which inject a fine spray of fuel into the cylinders at exactly the right moment. The fuel then explodes. The components of the fuel system are designed to distribute a certain amount of fuel at a certain rate, which is affected by fuel viscosity.

Viscosity is governed by a combination of three major factors:

- Intermolecular forces
    - The stronger the bonds between molecules, the more viscous the fluid.
- Molecular size
    - Smaller molecules flow past one another more easily than larger molecules.
- Molecular shape
    - This property can be tricky. Sometimes, linear molecules flow more easily past each other than branched molecules. On the other hand, sometimes linear molecules can more easily stack on top of one another than branched molecules, which can increase the intermolecular bonding between linear molecules.

Vegetable oil is typically ten times more viscous than petroleum diesel. Using vegetable oil in an unmodified diesel fuel system would be a lot like shooting vegetable oil through a squirt gun. It won't work very well. Furthermore, it will cause damage to the engine and fuel system. In order to utilize a vegetable oil-based fuel in an unmodified diesel fuel system, the vegetable oil itself must be modified to acquire a viscosity very close to that of petroleum diesel.

Teacher Preparation

In this lab, students will compare the viscosities of vegetable oils and biodiesel at different temperatures. We have suggested WVO, biodiesel, corn oil, and soy oil, but we encourage you to be creative. We advise having pairs of students or small groups conduct trials on only one of the fluids and then comparing the results as a class. It is a good idea to prepare a demonstration in the front of the classroom to show the viscosity of all of the different fluids, in case the students didn't get to see them all during the lab period. Make available at each student work bench each of the items in the Materials list below.

1) Prepare lab stations for each student group with the items listed in the Materials list below.

2) Give one of the samples to each group in a container – note the groups will only perform trials on one of the samples. At the end of the class gather all of the data and share.

3) At the end of class if you wish to calculate viscosity use the equation:

$$n = \frac{2(\Delta p)gr^2}{9v}$$

With this equation n = Viscosity in Pa•s

Δp = the change of the density of the fluid and the sphere

g = acceleration of gravity (9.8 m/s^2)

r = radius of the sphere in meters

v = velocity of the sphere's descent through the liquid in m/s

Materials:

- 1000 mL (glass) graduated cylinder
- 1000 mL sample of one of the following
    - waste vegetable oil
    - biodiesel
    - corn oil
    - soy oil
- Hot plate
- Thermometer
- 1000 mL Erlenmeyer flasks
- Teflon balls (5/16" diameter) Funnel
- Steel wool
- Stopwatch
- Stirring Rod
- Wax pencil

Safety Precautions:

Wear gloves and goggles at all times. When you are handling hot oils wear heat resistant gloves.

Student Procedure:

1. Fill the graduated cylinder with your liquid sample to the 1000 mL mark.
2. Draw two lines on your column with the wax pencil, one near the top of the oil and one near the bottom.
3. Measure the distance between the two lines in meters and record the length below. You will need this measurement later for your data table.

Column height _________ meters

(Note: there are 100 centimeters in one meter)

4. Take the temperature of the liquid at room temperature (in °C) and record in the data table.
5. Use a stopwatch to time the Teflon ball as it drops through the oil. Drop the Teflon ball into the oil and measure the time it takes the ball to travel from the top line to the bottom line. Try to drop the ball as close to the liquid's surface as you can. Conduct total of three trials and record the times in seconds in your data table.
6. Pour the liquid from the graduated cylinder into the Erlenmeyer flask until you have emptied most of the fluid. Before the balls drop, place a sample of steel wool into a funnel to catch the Teflon balls.
7. Heat the liquid in the Erlenmeyer flask on the hot plate to a temperature of 60°C. You can mix the liquid with a stirring rod.
8. Pour the heated liquid from the flask into the graduated cylinder up to 1000 mL mark (Note: oil may have expanded during heating. If so take a new height measurement).

New Column height ___________ meters

8. Drop a Teflon ball into the oil in the cylinder. Using a stopwatch, measure the time it takes the ball to travel from the top line to the bottom line. Try to drop the ball as close to the liquid's surface as you can. Conduct a total of three trials and record the times in seconds in your data table.
9. Transfer the heated liquid to the original Erlenmeyer flask from the beginning and begin your calculations while the liquid cools. Do not clean up the liquid until its temperature has dropped below 50°C.
10. When everyone is finished, collect the data on the other sample liquids from the other groups.

Data Sheet

Sample Material	**Time to travel X-meters in Y-seconds at Room Temperature (_______˚ C)**	**Time to travel X-meters in Y-seconds at 60˚ C**
Waste Vegetable Oil	m/ sec	m/ sec
Biodiesel	m/ sec	m/ sec
Corn Oil	m/ sec	m/ sec
Soy Oil	m/ sec	m/ sec

Questions

1) What factors affected how quickly the ball moved through each of the samples?

   - *The viscosity of the fluid, resulting largely from the shape and size of the component molecules.*
   - *The temperature of the fluid. Higher temperature fluids have a lower viscosity.*

2) Can you hypothesize why the ball moved more quickly through the heated samples than through the samples at room temperature?

3) How did the viscosity of the biodiesel compare to the other samples? Why might this be important when considering it as a fuel to be combusted within engines?

   - *Biodiesel typically has a lower viscosity than vegetable oils at lower temperatures. At higher temps, the viscosities become close. The viscosity of biodiesel in the liquid phase typically changes less than that of vegetable oil as temperature increases.*

4) In addition to viscosity, what are some other important properties or qualities to consider in the development of alternative fuels?

   - *Emissions, environmental impact, energy density, transportability, cost, etc.*

Viscosity Lab Procedure: Student Lab

Introduction

When diesel engines were invented in the late 1800s, they were intended to be able to run on a variety of fuels, and they could. The first diesel engines ran on coal dust, and shortly thereafter, people were running them on peanut oil. Petroleum, however, was rapidly emerging as a relatively cheap and energy dense source of fuel, which it has been for about the past 100 years or so. Today, most diesel vehicles today are designed to operate on petroleum diesel, and their designs optimize the properties of that fuel.

As you probably know, however, petroleum is a non-renewable resource, and it will become less and less available and more and more expensive in the *next* 100 years. Additionally, as you probably also know, it contributes to global climate change and pollution. For those reasons, we're looking for alternative, renewable energy sources. To be used in a modern diesel vehicle, however, these energy sources must duplicate the properties of petroleum diesel fuel, and one of the most important properties to duplicate is *viscosity*.

Viscosity is the resistance of a liquid to flow. A good way of imagining viscosity is to think of pouring out a teaspoon of honey and a teaspoon of water. The honey has a much higher viscosity, or resistance to flow, in comparison to the water.

In this lab you will be comparing the viscosity of multiple oils in order to determine relative viscosity as well as how heating a sample affects the overall viscosity of the sample.

Safety Precautions:

Wear gloves and goggles at all times. When you are handling hot oils wear heat resistant gloves.

Materials:

- 1000 mL
- (glass) graduated cylinder
- 1000 mL sample of one of the following:
  - waste vegetable oil
  - biodiesel
  - corn oil
  - soy oil
- Hot plate
- Thermometer
- 5 x 1000 mL Erlenmeyer flasks
- Teflon balls (5/16” diameter) Funnel
- Steel wool
- Stopwatch
- Stirring Rod

Procedure

1) Fill the graduated cylinder with your liquid sample to the 1000 mL mark.
2) Measure the length of the column of oil in meters and record the length below. You will need this measurement later for your data table.

   Column length _________ meters

   (Note: there are 100 centimeters in one meter)

3) Take the temperature of the liquid at room temperature (in °C) and record in the data table.
4) Drop a Teflon ball into the oil in the cylinder while using a stopwatch to time from when the ball enters the oil to when it hits the bottom of the cylinder. Try to drop the ball as close to the liquid’s surface as you can. Conduct total of three trials and record the times in seconds in your data table.
5) Pour the liquid from the graduated cylinder into the Erlenmeyer flask until you have emptied most of the fluid. Before the balls drop, place a sample of steel wool into a funnel to catch the Teflon balls.
6) Heat the liquid in the Erlenmeyer flask on the hot plate to a temperature of 60°C. You can mix the liquid with a stirring rod to meet the required temperature.
7) Pour the heated liquid from the flask into the graduated cylinder up to 1000 mL mark (Note: oil may have expanded during heating. If so take a new length measurement).

   New Column length ___________ meters

8) Drop a Teflon ball into the oil in the cylinder. Using a stopwatch, time from when the ball enters the oil to when it hits the bottom of the cylinder. Try to drop the ball as close to the liquid’s surface as you can. Conduct total of three trials and record the times in seconds in your data table.
9) Transfer the heated liquid to the original Erlenmeyer flask from the beginning and begin your calculations while the liquid cools. Do not clean up until the liquid temperature has dropped below 50°C.
10) When everyone is finished, collect the data on the other sample liquids from the other groups.

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Corn Oil	m/ sec	m/ sec
Soy Oil	m/ sec	m/ sec

Questions

1) What factors affected how quickly the ball moved through each of the samples?

2) Can you hypothesize why the ball moved more quickly through the heated samples then through the samples at room temperature?

3) How did the viscosity of the biodiesel compare to the other samples? Why might this be important when considering it as a fuel to be combusted within engines?

4) In addition to viscosity, what are some other important properties or qualities to consider in the development of alternative fuels?