UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

Viscosity Test on Waste Vegetable Oil

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Introduction

This report presents the results of viscosity tests performed after construction of the CSL Waste Vegetable Oil Pilot Project system. Oil obtained from a downtown Chinese restaurant was sampled for control as well as through the system. The viscosity of vegetable oil was to be studied using a viscometer. The viscosity of untreated waste vegetable oil was compared with the viscosity of treated waste vegetable oil and temperature dependence was studied for various oils.

Due to the available materials at the construction site, several changes were made to the original design. As can be seen in *Figure 1: Front View of System*, it was changed to place the pump and two filter banks on a beam structure supported by the plastic drums. Rather than being wall mounted, this allows the system to be disassembled into three components for easy transportation and storage. With this configuration, seven oil samples were taken (*Figure 3: Oil in bottles*). The samples are denoted from left to right as Oils 1 through 7.
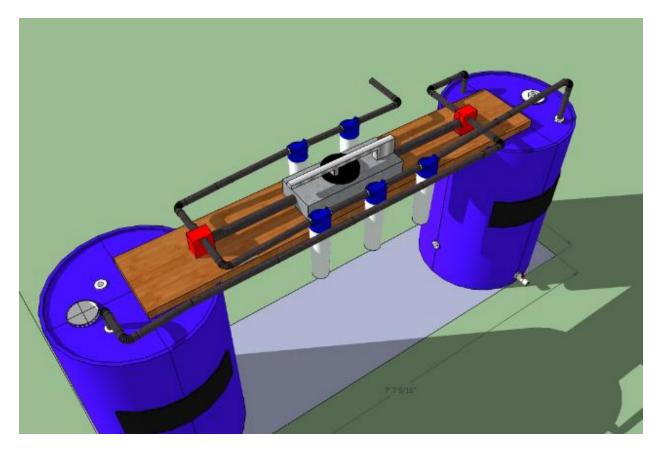

Figure 1: Front View of System

Figure 2: 3/4 View of System

Figure 3: Oil in bottles

Procedure

The viscometer was set up and tested with a standard sample to determine that the apparatus was working correctly. Once it was determined that the viscosity machine was working properly and had the right settings, samples one through seven were tested for three to four minutes each at room temperature (25 C). This was done by thoroughly cleaning the sensors that were to be used, and inserting enough vegetable oil to fill the sensor just above the top (approximately 10 ml). The sensor measured the vegetable oil samples and recorded the data into the attached computer. In order to get accurate results, the machine had to be set to the right sensor and the right frequency (400 rpm). The tests were then run with increasing speed for 1 minute, constant speed for 1 minute, and then decreasing speed for 1 minute to get a good spread of data points. Once the tests were completed, the points were saved to a floppy disk and put into Excel for data plotting. In Excel, a graph of shear stress vs. time gave a slope with the viscosity of the vegetable oils. The temperature dependence was then studied by increasing the temperature of two samples to 50 degrees Celsius and repeating the procedure.

The following table presents the filtration of each sample. Two oils were used. "Clean" oil being considered useable in diesel converted hybrids and "dirty" oil from the restaurant. This gave a basis to establish results from. It should be noted that Oil4 was heated to 27°C without any filtration and showed significantly fewer impurities than Oil3.

Table 1:Filters Used on Samples

Oil Sample Label	Oil Type	Filters Used
Oil1	Clean	Control
Oil2	Clean	50/20/10/5/2
Oil3	Dirty	Control
Oil4	Dirty	Control Heated to 27
Oil5	Dirty	Bag/50/20/10
Oil6	Dirty	Bag/50/20/10/5/2
Oil7	Dirty	Bag/50/20/10 cycled

Results

Complete graphs of individual oil samples can be found in Appendix A. Each oil sample was tested for viscosity at a temperature of 25℃. Additionally, oil samples 2 and 4 were tested at increasing temperatures to 50℃.

Table 2:Oil Sample Viscosities

Oil Sample	Viscosity
Oil1	0.0638
Oil2	0.0619
Oil3	0.0717
Oil4	0.0647
Oil5	0.0605
Oil6	0.0672
Oil7	0.0635

Table 3:Heated Oil Sample Viscosities

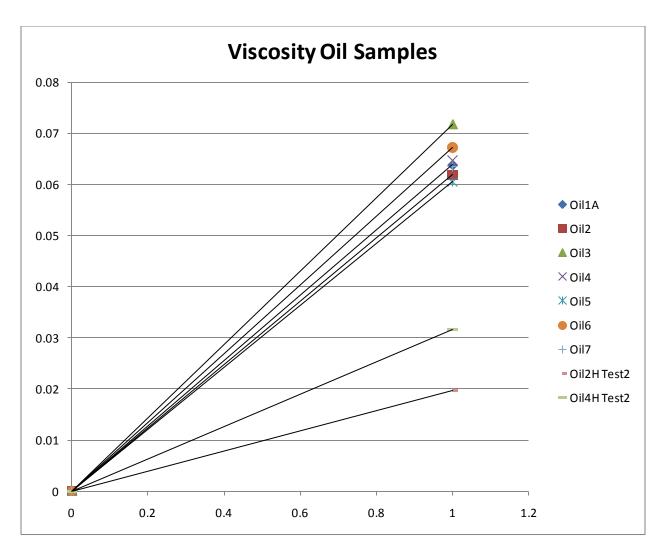| Heated Oil Samples	Viscosity (at 50℃)
Oil2H Test2	0.0197
Oil4H Test2	0.0316

Figure 4: Viscosity Oil Samples

Discussion

The viscosity of a Newtonian fluid arises from shear stresses that occur due to differing velocities within the fluid. The shear stresses within the fluid are proportional to the velocity gradient of the fluid and the viscosity of a fluid. The viscosities of each oil sample show a direct relation between viscosity and suspended particles within the fluid. This is to be expected as viscosity of a fluid is a measure of its resistance to shear or angular deformation (Finnemore and Franzini, 2002). The suspended particles will induce frictional forces that resist the flow of fluid. Thus, by settling and filtering the oil, it is possible to increase its viscosity.

Although the viscosity experiment took place on March 29, 2010, construction of the system and initial testing took place on March 14, 2010. During this time, significant settlement occurred in all samples with the exception of Oil2, the purest oil put through all the filters. Oil3 and Oil4 exhibited the largest degree of settlement that appears as two distinct liquids in the bottles, one which was a murky brown and the other which could not be seen through. All other vegetable oil samples put through the filters also showed settlement, however significantly less in volume.

The samples were filtered at approximately 15 degrees Celsius and tested for viscosity at 25 degrees and 50 degrees. When the oil was heated and run through the system, the final viscosity decreased by about 15% at 25 degrees verses 15 degrees. The large viscosity of the cold oil significantly reduced the effect of the filters on catching particles compared to the lower viscosity heated oil.

Viscosity of the oil was also conducted under temperature changes. Viscosities of typical fluids depend on temperature. As the temperature increases, the viscosities of all liquids decrease because the force of cohesion diminishes with temperature (Finnemore and Franzini, 2002). As expected, the oils showed a decrease in viscosity. Oil2 viscosity decreased by 68% between 25 and 50 degrees Celcius. Likewise, Oil4 decreased in viscosity by 52%. Therefore, heating the vegetable oil before running it through the filtration banks would significantly reduce the shear stress experienced within the oil.

It was observed that pumping the oil through the final 5 and 2 micron filters was very difficult due to the filters physical barrier. By heating the oil and lowering the viscosity of the fluid, less energy from the pump would be required.

Finally, the velocity gradient of the system also has a significant impact on the energy requirements of the pump. By reducing the overall velocity of the oil running through the system, the velocity gradient will be decreased. This would also make the pump use less energy. It is also important that the velocity of the oil be kept low so the fluid will not become turbulent and experience an increase in internal stress.

The accuracy of the viscosity machine may contribute to sources of error. However, these inaccuracies are considered negligible as the purpose of this lab is to show the relative differences in viscosity between samples and not the absolute dynamic viscosity of the samples.

Conclusion

Observations made during testing of the system and results from the laboratory experiments show that several improvements could be made to the system.

It is essential to reduce the amount of particles within the oil as well since solid particles add to the shear stresses within a flowing fluid. By heating the oil, the viscosity of the fluid decreases while the viscosity of the solid particles remains the same. This causes the solid particles to sink through the liquid oil quicker, thus increasing the settlement speed.

We recommend that heating units be included in the system. This would allow lower viscosity of the oil and easier pumping of the oil through the smaller 5 and 2 micron filters. Additionally, the elevated temperature would accelerate the settling process. We also recommend that full settlement be completed before pumping the oil through the smaller micron filters. Without proper settlement, the small filters clog very quickly and the system becomes inefficient.

Further studies on water content, acidity, and cloud point would complete understanding of waste vegetable oil filtration. One of the largest problems for oil as a fuel is water that is added into the combustion chamber. Acidic oil is unfavourable as its corrosiveness can be damaging to pipes and the engine in the vehicle. It would also be useful to conduct time trials on settlement rates of oil that is settled by heat as well as by a combination of heat and filters. This would give an understanding to personal and commercial production process time.
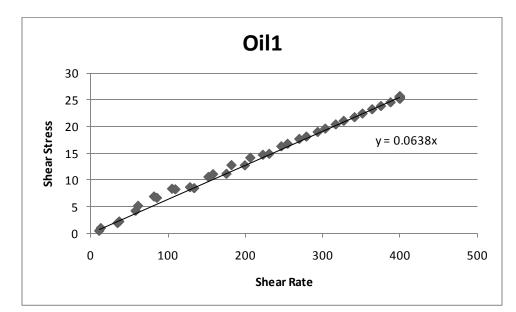
Acknowledgements

References

Finnemore, J., Franzini, J. (2002). *Fluid Mechanics with Engineering Application.* Mc Graw Hill.

Appendix A: Oil Viscosity Graphs

Shear Stress vs. Shear Rate Graphs

Shear stress is measured in Pascals (Pa) and shear rate in inverse seconds (s^{-1})
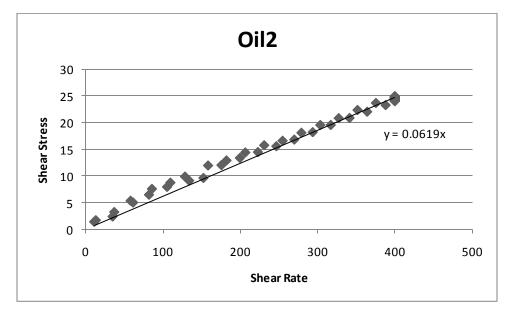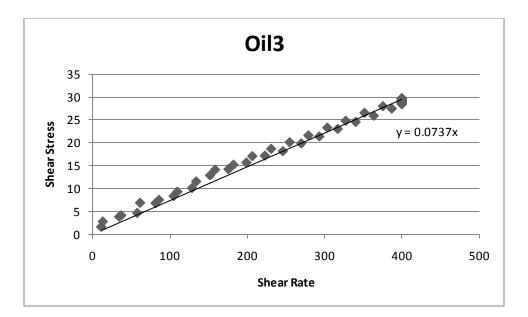

Figure 5:Oil1 Viscosity
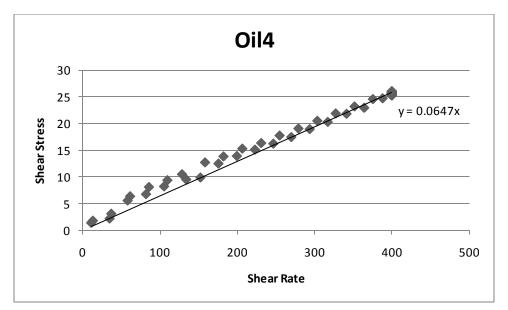

Figure 6: Oil2 Viscosity

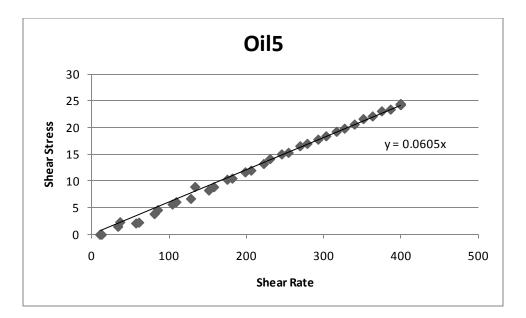**Figure 7: Oil3 Viscosity**
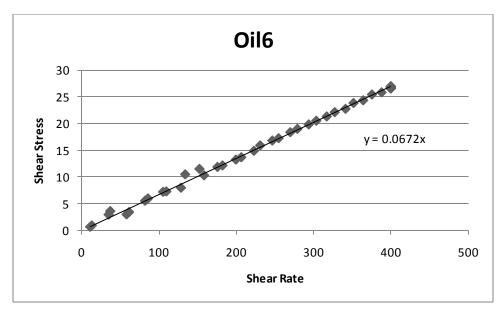

Figure 8: Oil4 Viscosity
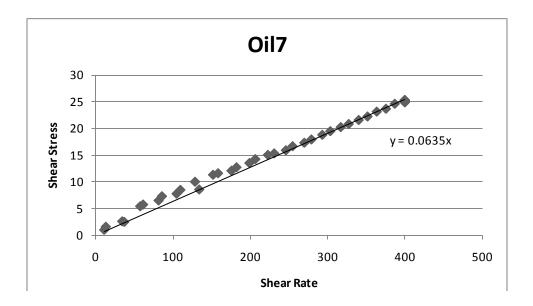
Figure 9: Oil5 Viscosity

Figure 10: Oil6 Viscosity

Figure 11: Oil7 Viscosity

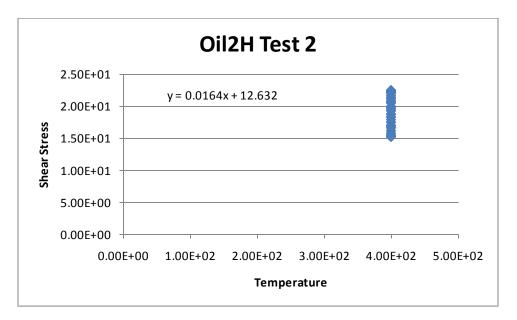# Appendix B: Oil Under Different Heat

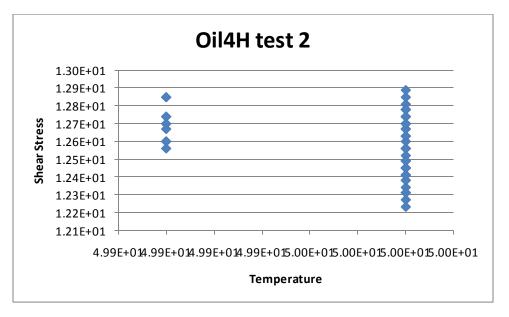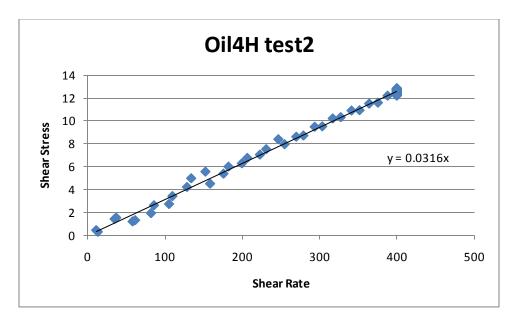Figure 12: Oil2H Test 2 Viscosity

Figure 13: Oil4H Test 2 Viscosity

Figure 14: Oil4H test2 Constant Temperature