BUILDING & VALIDATING A ROTATIONAL VISCOMETER

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INTRODUCTION

Viscosity is often referred to as a fluid's "thickness" or how much it resists deformation due to force. Rotational viscometers measure the amount of torque needed to rotate an object moving through fluid at a known RPM. Using the measured torque, RPM, and dimensions of the device, viscosity can be calculated using the following equation [1].

$$\text{Viscosity} = \frac{(\text{Torque} * \text{Gap Size})}{(15\pi^2 * \text{Radius of Inner Cylinder}^3 * \text{RPM} * \text{Height of Fluid})}$$

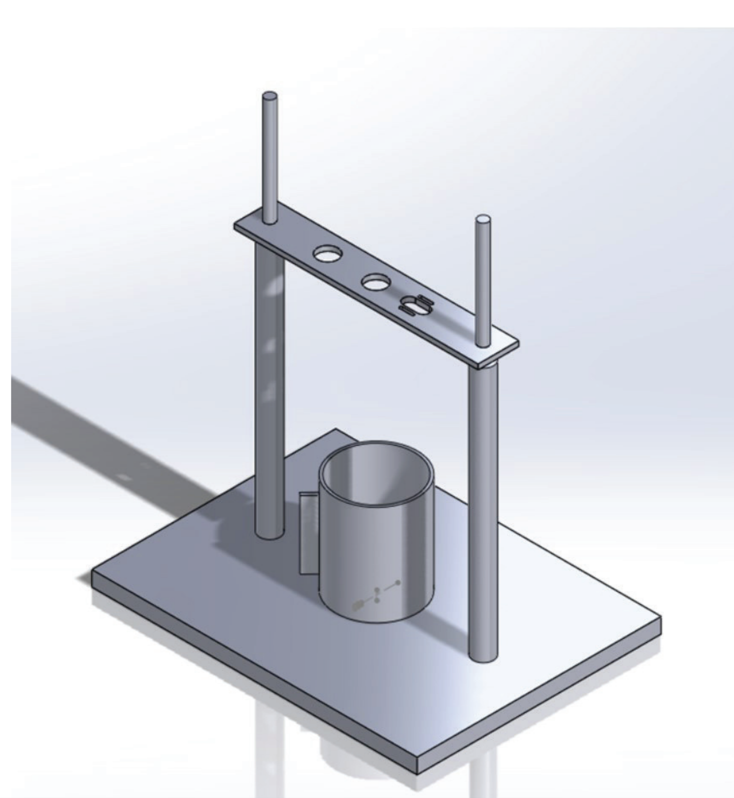
This project was developed to expand on an initial prototype viscometer developed in the fall of 2014. A new design would be conceptualized, fabricated, and tested. This new design had a series of criteria that needed to be met.

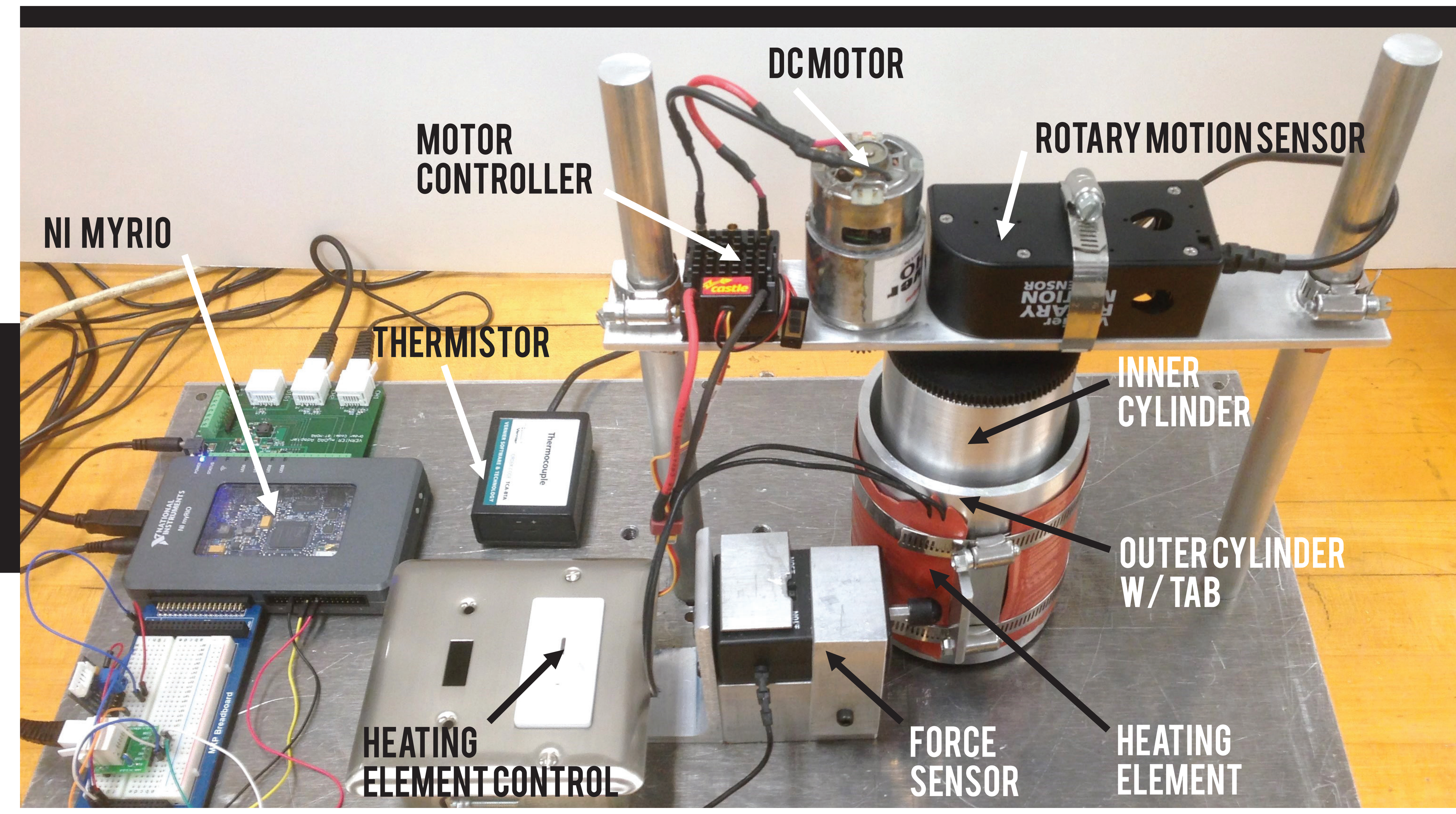
- Designed for future use in ME labs
- Design must be durable, sustainable, and easy to take apart and clean
- Multiple inner cylinders for varying gap sizes
- Rotational system must be able to handle very high viscosity fluids
- Fluid heating capabilities
- Motor control and sensor monitoring all achieved using LabVIEW

In addition to these criteria the project was also designed to attempt to experimentally address whether the measured viscosity varies significantly when the geometry of the viscometer changes.

METHODS & MATERIALS

In order to achieve the goals of the project the majority of the aspects of the design had to be completely overhauled. Aluminum was selected as the primary material for the components as it would meet several of the design criteria including temperature variation, durability, and ease of cleaning. Additionally aluminum would act as an excellent material for heating and cooling.



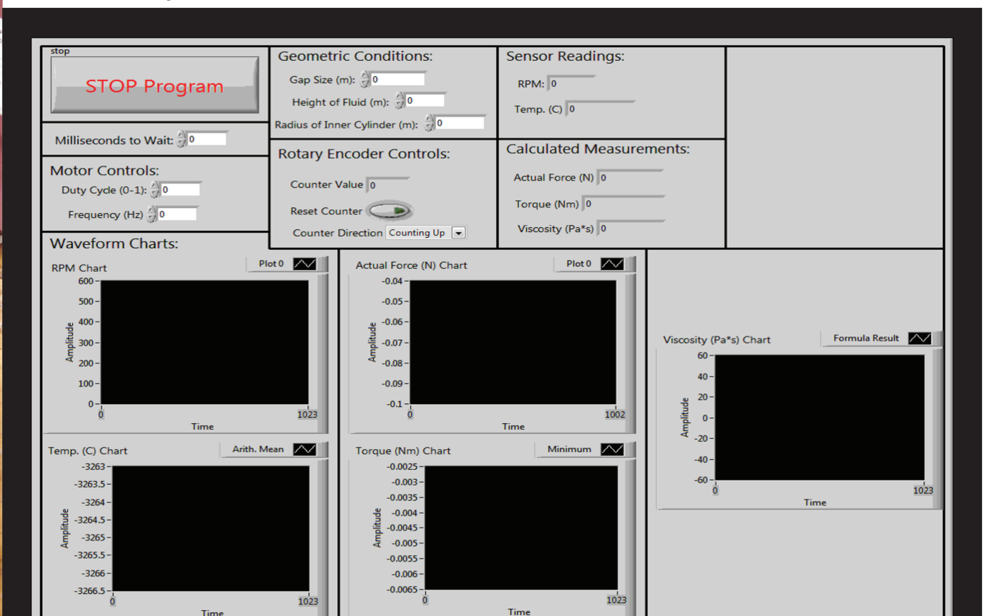


The new design would require a much larger motor in order to rotate the heavier cylinders as well as create enough torque for very high viscosity fluids. In order to have the motor spin the inner cylinder, a gear drive system was incorporated. Using a smaller pinion gear on the motor mated up to a larger gear affixed to the inner cylinder and the rotary encoder, the motor drives the inner cylinder and the rotary encoder registers the RPM.

With the final design solidified, materials were ordered and the fabrication phase began. This was one of the longest phases in the project.

For the viscometer to be able to collect all the necessary data to calculate viscosity, a program, an interface, and sensors needed to be selected. The team decided that the program used would be NI LabVIEW while NI myRIO would be the interface. For the ability to control the motor's RPM and thus the inner cylinder, a motor controller is used to send a signal from the program to the motor.

The LabVIEW program takes in all the signals from the rotary motion encoder, the thermocouple, and the dual range force sensor and allows the team to monitor and collect the measured torque, temperature, and RPM. LabVIEW then uses these values to calculate the fluid's viscosity. This data can then be exported into excel for analysis.



The front panel for the program was set up to be user friendly. The speed of the motor is controlled by the user inputting different frequencies. Any change in the geometry of the rotational viscometer can be input for each test. The program monitors and displays the speed of the inner cylinder and the temperature of the testing fluid. LabVIEW calculates viscosity and the graphic displays shown can be used to export the data collected into excel for analysis.

RESULTS

Overall this project was a success when comparing the projected outcomes to the achieved results. Some of the most interesting results came from comparing known and experimental viscosities over a range of different cylinder sizes used. With this comparison the affect from the varying gaps created by the different cylinder sizes could be monitored. Since viscosity also changes due to temperature, data was also collected over a range of different temperatures. The data in Figure 1. shows the known viscosity value of gycerin (blue) falling between the experimental values of the medium cylinder (orange) and the large cylinder (grey). These results show that the accuracy of the experimental data does vary when the geometry of the viscometer is altered.

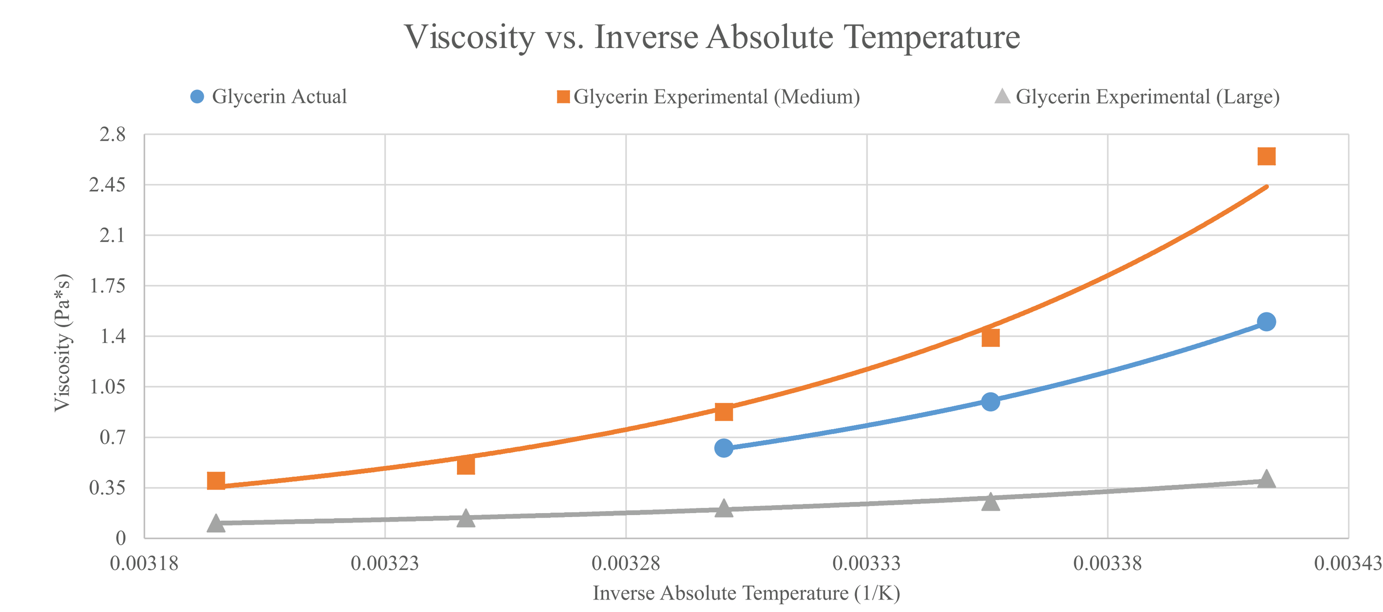


Figure 1.

The constructed viscometer was able to vary temperature, speed, and gap sizes simultaneously while data was collected. The testing fluids utilized varied from low viscous fluids like water to high viscous fluids like glycerin. After the data was collected, a Reynold's number was calculated to determine whether the flow of the fluid was smooth, laminar, or turbulent. Most of the data was laminar so the data was able to be analyzed. However, the small cylinder was unable to generate a torque large enough to be picked up by the force sensor.

DISCUSSION & CONCLUSION

Most of the project's goals were accomplished and the capabilities of the device were explored and verified. However, going forward there are a few key components to the overall design that could be addressed in order to make the device more useable as a viable laboratory piece. A more permanent and tamper resistant housing for the RIO interface and wiring needs to be constructed as well as a clear safety shield over the device when operating. A better solution for monitoring temperature as the current thermistor is too clumbsy and gets caught on the rotating cylinder when placed in the fluid. Although the experimental data does suggest that viscosity varies as the geometry of the viscometer is changed, more experiments should be done with varying geometry on more fluids to verify the results.

ACKNOWLEDGEMENTS

Mr. John Kelley, Mr. Rich Weber, Dr. Michelle Berman, Mr. Mark Morton, Mr. Dan Laudano, Mrs. Jennifer Cherrington

REFERENCES

[1] Viswanath, D., T.K. Ghosh, et al. (2007) Viscosity of Liquids: Theory, Estimation, Experiment, and Data. Springer.
[2] Forsythe, W.E.. (1954; 2003). Smithsonian Physical Tables (9th Revised Edition) - Table 318. Viscosity of Organic Liquids. Knovel.
[3] Stachowiak, Gwidon W. Batchelor, Andrew W.. (2014). Engineering Tribology (4th Edition) - 2.4 Viscosity Index. Elsevier.
[4] http://www.ni.com