Polyoxymethylene Ethers (POMEs) as a High Cetane, Low Suting Biofuel Blendstock for Use in MCCI Engines

ENERGY INSTITUTE COLORADO STATE UNIVERSITY

Colorado Energy Research Collaboratory Partners for Clean Energy

NREL Transforming ENERGY

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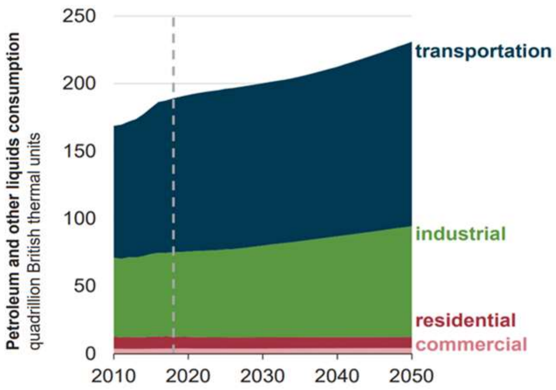
Background and Motivation

- There is an expected continues growth in petroleum fuel consumption especially from heavy-duty freight
- The engines used in heavy-duty freight, Modern Mixing Controlled Compression Ignition (MCCI) diesel engines, create an undesirable amounts of pollutants like NOx that affect our environment and have been proven to result in human health issues that lead to premature deaths (estimated 10.2 million per year).
- Current exhaust solutions are costly and energy intensive to maintain.
- New fuel can be made from renewable biofuels that will reduce carbon emissions and aim to enhance the engine efficiency.

Benefits of using Poly(oxymethylene) ethers (POME) with extended alkyl end groups:

- Enhanced cetane numbers
- Significant soot reduction potential
- Acceptable lower heating values, oxidative stability, and water solubility
- Renewably sourced and lower emissions



Methods/Experimental Setup

Figure 1. Packed Bed Flow reactor used to synthesize fuel

- Base fuel (such as Ethylal) was mixed at a 2:1 mole ratio with Trioxane
- The reaction tube would then be loaded with 5g of catalyst (we used Amberlyst 15)
- This solution would then be pumped through the heated reactor (usually to 40 ℃) using an HPLC pump and outputs the extended end group fuel

Figure 2. Gas Chromatograph used to determine the ratio of the components

- A sample of the fuel would be injected into the Gas Chromatograph which displays its results as a chromatogram on a computer
- The Chromatogram, although unable to determine the substance, was then used to determine the percentage of each component within the fuel

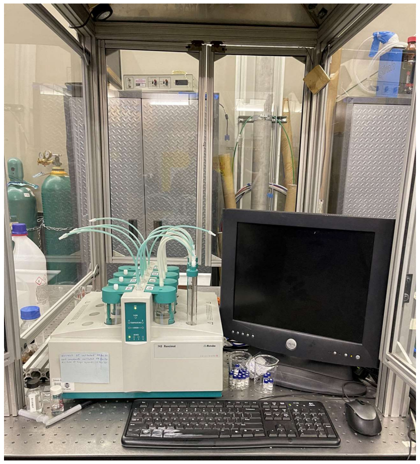


Figure 3. Rancimat used to determine oxidative stability

- Test tube with fuel would be set in a heating block at a specific temperature (usually 50 or 70 ℃)
- Oxygen would be constantly flowing into the fuel and eventually into a glass container with 60ml of distilled water
- Electrodes would then measure the reaction of the fuel with oxygen and heat and measure oxidative stability
- Rancimat would run and record the data that it gathered to the computer.

Results

Here (Figure 4.) we see POME fuels react which we can then compare to see which fuel is the most efficient. We would distill the fuel multiple times and run it through the GC which would give us a percentage of what the fuel was composed of. Then Stephen would go to NREL and find out what the fuel was made up of.

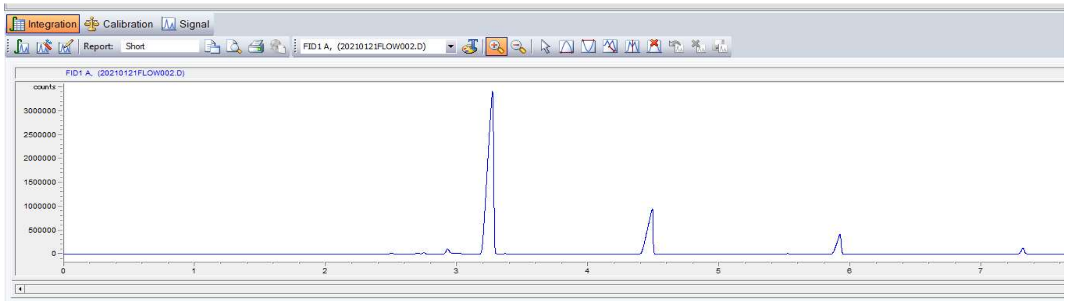
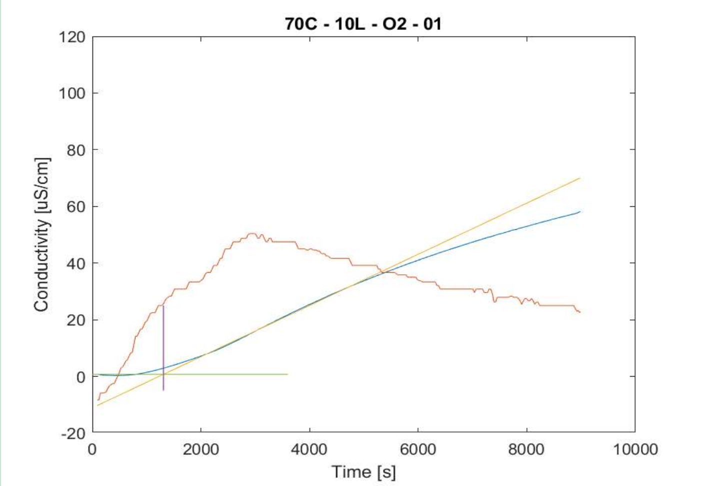


Figure 4. Gas Chromatograph >90% purity of Butylal after distillation process

Key:

- Blue = conductivity measurement
- Red = gradient of the measurement
- Purple = stability time
- Orange and Green = linear fit lines used to calculate the stability time



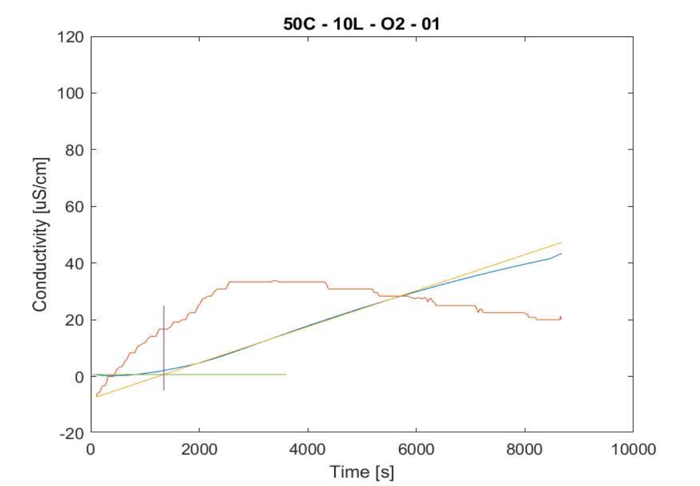


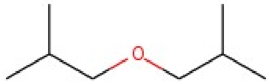
Figure 5 and 6. Sample Oxidative stability plots of a fuel found at different temperatures using the Rancimat

Discussion/Next Steps

The results gathered from this semester have aloud the POME research team to develop a better understanding of which fuels are possible solutions and should be farther studied.

The next steps in the research is to

- Update and repeat the synthesis and characterization prosses with isomer end groups (isobutyl and isopropyl)
- Blend the POME fuels of choice with diesel fuel and characterize the solutions properties such as cold flow properties and water solubilities.
- Scale up the production process to yield more fuel so that engine testing of selected POMEs may begin



Conclusions

The key finding from the POME research this semester is largely centered around the characterization of multiple potential fuels including methylal, ethylal, propylal, and butylal. Based off of our findings the most promising fuels moving forward appear to be those made of prpylal and butylal but more testing is needed to come to a conclusion.

What benefits did you get from you SURE experience?

Darwin:
The benefits of participating in the SURE program that I experienced was learning standard lab procedures and all that encompasses researching. From cleaning glass to working as a team and helping others understand the work that you have done and learning what other have done to come together and reach our goal. I also benefited from the valuable mentorship connection as well as the confidence I gained to reach out and make connections with faculty at CSU and in my engineering major choice.

Alayna:
The SURE program gave me an amazing opportunity to grow and learn in many ways. My work with this program has farther developed my chemistry, engineering, and math skills through direct application in hands on work. Furthermore, this program allowed me to experience research based work, gain knowledge from several individuals working if fields I am interested in, make connections with faculty and grad students, and improve my lab knowledge. My confidence in my research abilities, knowledge, major choice, and my belonging at CSU have been increased significantly throughout this semester.

References & Acknowledgements

[1] Chemical Properties of Isobutyl Ether (CAS 628-55-7), *High Quality Chemical Properties* (2016)
[2] International Energy Outlook 2019, *U.S. Energy Information Administration* (2019)

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Thank you

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