Advanced Liquid Propane Injection Engine (ALPINE)

Any other logos you need to include? NSF? Or???

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Background/Introduction/Motivation

Liquefied petroleum gas (LPG) is an abundant fuel in the United States. It is produced during natural gas extraction ad refining of petroleum. Due to this overabundance, there is a decreased cost for this type of fuel. LPG is mainly a mixture of propane, propene and butene.

Diesel fuel-powered compression ignition engines have been the typical engine used for trucking and transport industries for some time. LPG engines have several advantages over these typical mechanisms. They are lower in cost (as previously mentioned, LPG is readily available), have reduced emissions, and are the clear option to replace traditional engines in the market.

Maximizing efficiency of these engines would allow for fuel costs to outweigh initial price differences, therefore reducing overall cost and providing a viable alternative mechanism for commercial use.

Finally, it is worth noting that simulations were compared to real-word conditions in the rapid combustion machine (RCM) at CSU.

Methods/Experimental Setup

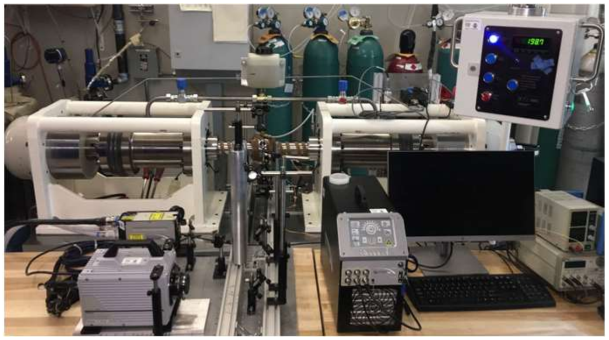


Figure 1. Photograph of the RCM setup

Initial simulations were done using ANSYS Chemkin. These simulations included flame speed tests as well as tests to find idealized pressure changes and things of that nature. A profile was created to help account for error.

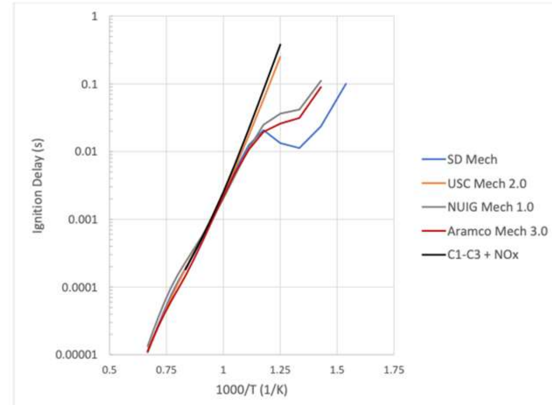


Figure 2. Demonstrated differences in mechanisms running at 30 bar

Detailed Mechanism	Origin	Species	Reactions
AramcoMech3.0 [5]	NUI Galway	581	3.034
NUIGMech1.1 [6]	NUI Galway	2,746	11,279
San Diego Mech [7]	UC San Diego	58	268
USC Mech Version II [8]	University Southern California	111	784
C1-C3 + NOx [9]	Polytechnic University of Milan	159	2,459

Table 1. Mechanisms considered for simulations

The initial RCM conditions were adjusted so thermodynamic conditions at top dead center could be known. Pressure data are recorded using Picoscope 4424 at a rate of 2 MHz. Finally, mixtures used consisted of propane / oxygen / intert gas with various ratios of nitrogen and argon gas.

It was decided that NUIGMech1.1 should be used.

Results

Figure 3 demonstrates the ignition delays for lean, stoichiometric and rich conditions for the mixture. Negative temperature coefficient (NTC) behavior was found to occur for all three mixtures, while the rich mixture had the shortest ignition delay.

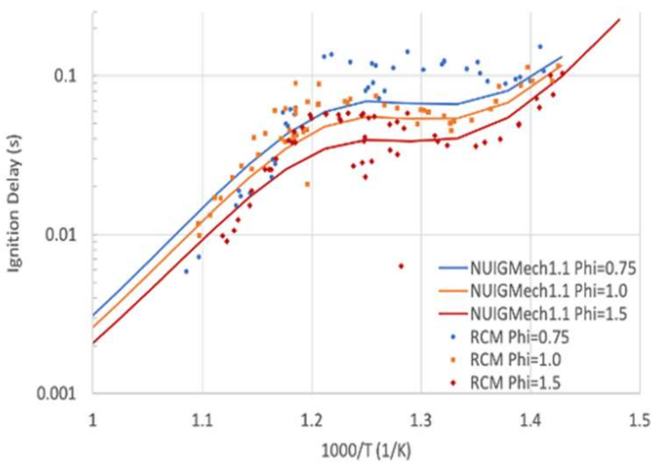


Figure 3. Experimental ignition delay measurements and simulated delays of propane / oxygen / inert mixtures at 24 bar with NUIGMech1.1 mechanism

Compared to the simulation data, the NTC region experimentally appears slightly more severe. In addition, the data suggest stoichiometric had a higher ignition delay at higher temperatures, which disagrees with the simulation data. Further work will be needed to understand this.

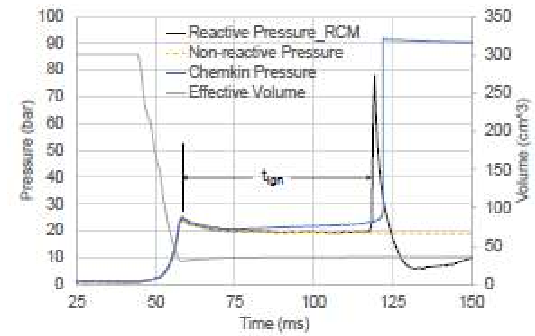


Figure 4. Experimental vs. simulation pressure data with volume of chamber

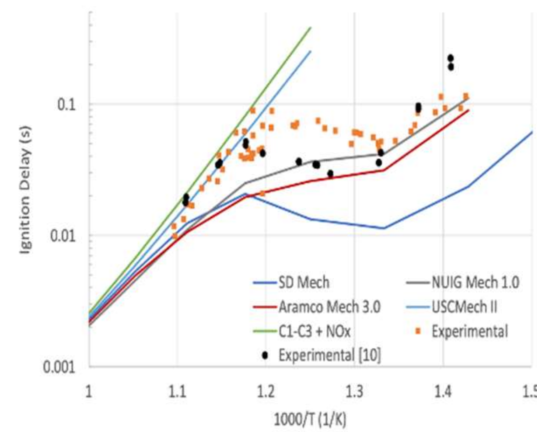


Figure 5. Graph of various mechanisms in comparison to experimental data (orange)

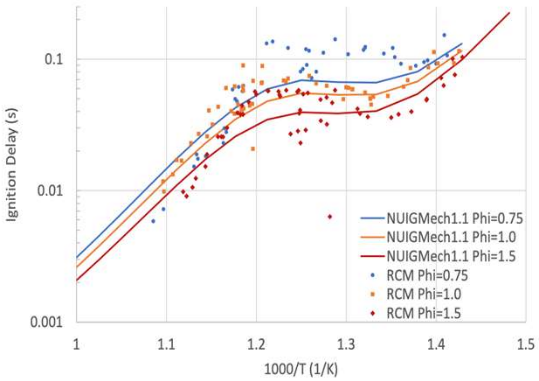
Discussion/Next Steps

Future Steps Include:

- Perform compression ignition RCM experiments using propane with varying exhaust gas recirculation levels and binary fuel mixtures of 80% propane/20% ethane, propene, n-butane, or isobutane [1].
- Further transient volume Chemkin simulations to better represent RCM conditions [1].
- Refine mechanism reduction if current mechanisms do not predict ignition delay or flame speed of future experiments [1].
- Laser spark ignited RCM experiments using similar conditions from ignition delay experiments to measure flame speed and fraction of end gas autoignition [1].

Conclusions

The biggest experimental data were the impact of NTC (Figure 3 below). It was not expected that this region would be as severe as it was, and yet ignition delay dropped considerably between 830 and 750 K.
Results found in this research are just a primary step in the overall process. Further research regarding LPG engines will continue to be done and a mechanism that can accurately model engine conditions will be a necessary development for these projects.



What benefits did you get from you SURE experience?

I absolutely loved my experience. It was fascinating to be a part of legitimate work, and I enjoyed meeting some awesome people.

I think the biggest benefit I got was an understanding of the process used for experiments and procedures. I was able to see how research is done and conclusions are drawn. I also thoroughly enjoyed seeing our results take the form of a graph that had some continuity to it. If nothing else, it was a form of gratification that was reassuring to see.

Finally, I was able to gain a unique viewpoint into a field parallel to my program of study. As a civil engineering student, I would not typically have exposure to an RCM or how combustion works or something of that sort, so being able to work with this material was fascinating.

References & Acknowledgements

Key findings highlighted here! Text, chars and pictures can all be used.

This research was made possible by a grant from the U.S. Department of Energy.

[1] C. Slunecka, A. Zdanowics, S. Bhoite, S. Vaughan, B. Windom, D. Olsen, A.J. Marchese, Autoignition of Premixed Liquefied Petroleum Gas in a Rapid Compression Machine: Experimental Results and Chemical Kinetic Mechanism Reduction, *12th U.S. National Combustion Meeting* (2021).

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Thank you

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