Annual Georgia Environmental Conference

10th Annual Georgia Environmental Conference
Emissions Modeling Optimization of Biodiesel for Automobile DI Compression-Ignition Engines

Jose Moncada[1], Tyler Naes[1], Martin Muiños[2], Shichao Huo[2], Julia Heimberger[2], Dr. Valentin Soloiu[3] – Georgia Southern University
1- Undergraduate Student 2-Graduate Student 3- Combustion and Emissions Professor

Introduction

- Research on alternative energy sources is progressively pursued, seeking for the implementation of biofuels in common automotive vehicles. Ever-depleting fossil fuels cause huge concerns towards the environment given the complications from harmful emissions.
- Biodiesel has increasingly garnered attention due to its renewability and capability of reducing certain emissions. Brassica Carinata, as a biofuel produced from low cost, non-edible biomass feedstock, has become a winter crop in Georgia due to the attention garnered by the U.S. Navy for jet fuel production.
- This study focuses on accurate modeling of exhausts emissions of Brassica Carinata biodiesel (Ca100) in modern direct injection diesel engines through measurement and calculation of vapor and liquid state properties.
- For testing of the biofuel, calibration and development of data acquisition systems can be costly and time consuming. Optimizing a simulation model helps show trends for emissions in the most common to the most specific engines.

Property	Diesel	Carinata
Dynamic Viscosity at 40°C (cP)	2.34	5.05
Cetane number [min]	46	52
Fuel density(g/mL)	0.835	0.875
Lower Heating Value (kJ/g)	42.7	37.1

Property	Diesel	Carinata
Critical Pressure (bar)	24.6	12
Critical Temperature (K)	569.4	780
Thermal Conductivity (W/m-K)	0.08	0.15
Molecular Weight	200	290

TABLE 1: Fuel Properties

Brassica Carinata Analysis

FIGURE 1: Brassica Carinata plant

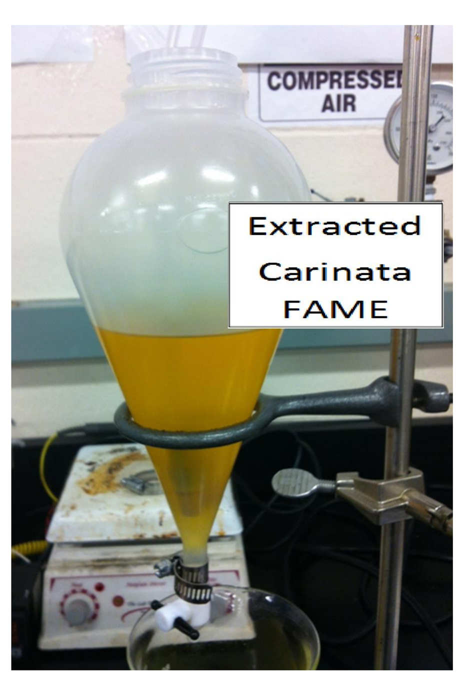

FIGURE 2: Biodiesel product

- Brassica Carinata is one of the most recent choices for production of alternative fuels. Its chemical properties have been found suitable for the production of high quality biodiesel. Under the right conditions, its yields per acre are higher than for regular oilseed crops.
- Carinata FAME (Fatty Acid Methyl Ester) was produced by utilizing a solution of crude Carinata oil, NaOH, and methanol. Extracted FAME was washed, dried, and filtered. The main fuel properties were determined through various equipment that deem it suitable for engine testing. The viscosity and oxidation rate was determined using a rotational viscometer and TGA-DTA analysis. Spray analysis indicated favorable direct injection, which prevents further undesired emissions.
- Based on the chemical composition obtained through a GC-FID analysis, mathematical models such as the Joback method were used to find other properties needed for the modeling of the fuel such as liquid and vapor enthalpy and critical temperature and pressure.

Combustion Modeling Validation

Combustion emissions were found through calibration of a predictive model in GT-Power based on experimental work.

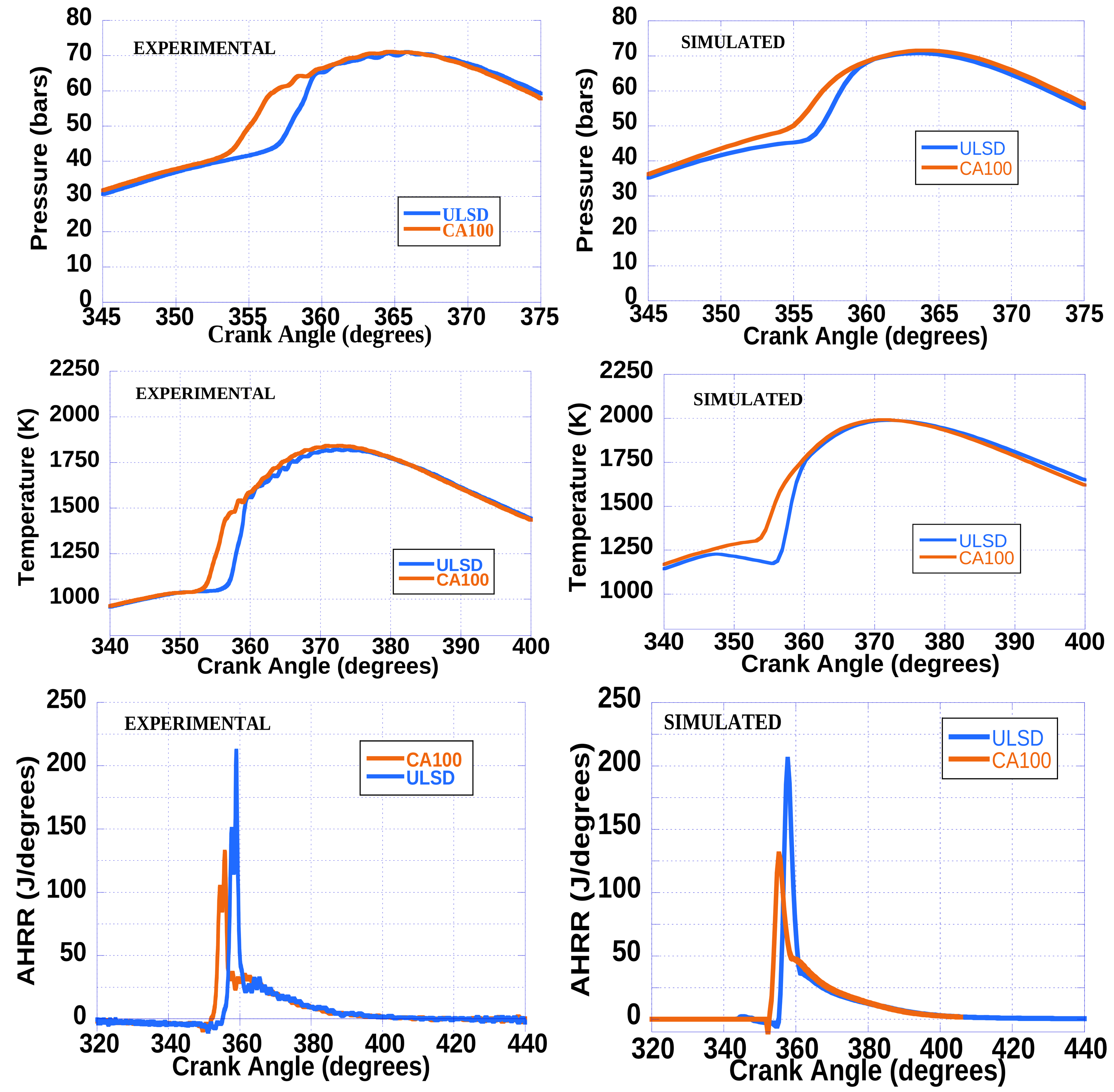

FIGURE 3: Comparison between experimental (left) vs simulated (right) cylinder pressure, temperature, and apparent heat release rate of target engine at 1500 rpm 3 bar BMEP

GT-Power, an one-dimensional engine simulation software, was used to simulate a common direct injection (DI) diesel engine. Simulation is useful for validation of models and prediction of tendencies in experimental work. Through optimization, a validated model can become very accurate and showcase advantages. The developed engine model is naturally-aspirated and uses an accurate injector profile to allow changes in injection timing and pressure.

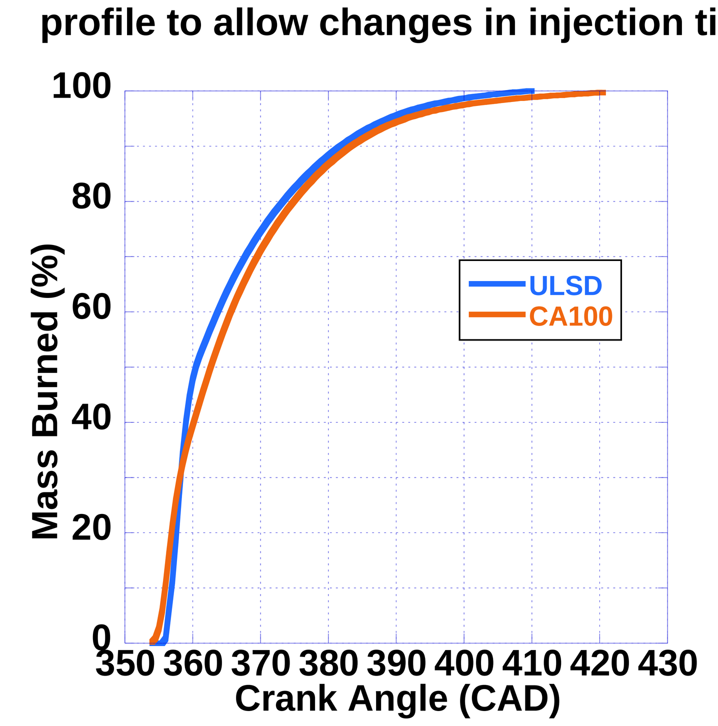

FIGURE 4: Predicted mass burned in the cylinder.

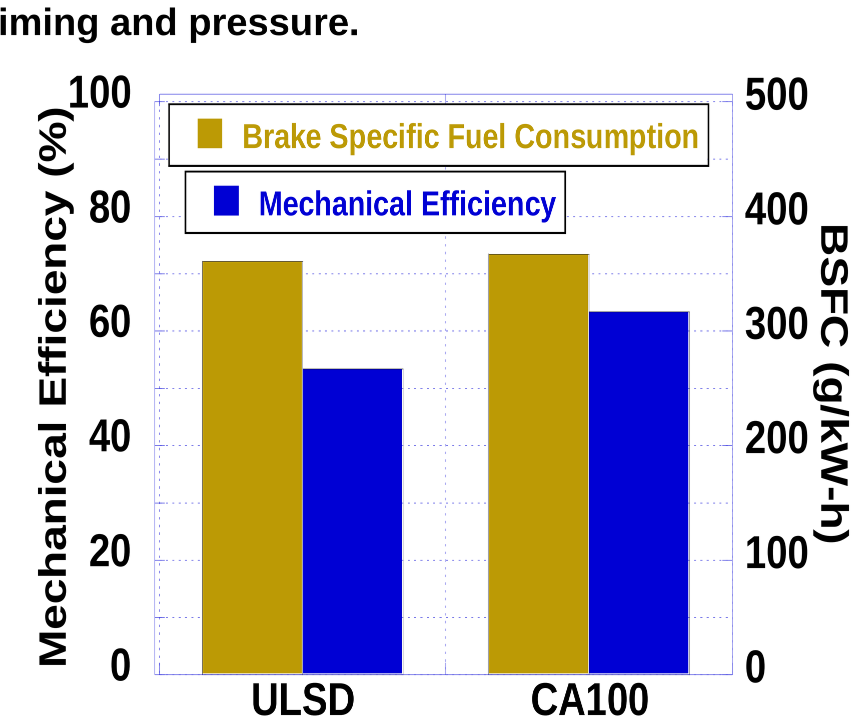

FIGURE 5: Predicted engine efficiencies.

Engine Emissions

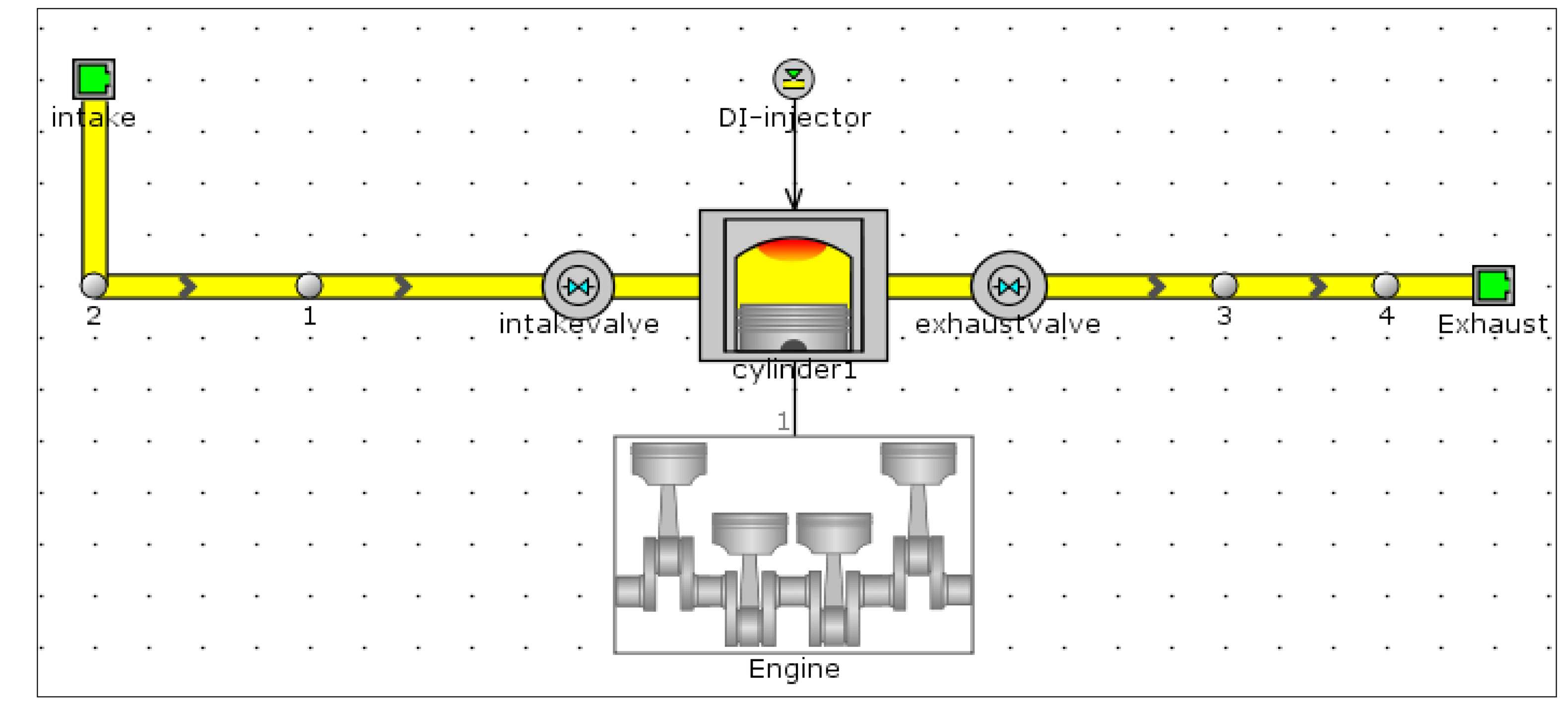

FIGURE 8: Target Engine Model.

The fuel-injection system has a major part in controlling emissions. Many automobiles use mechanical injectors with a set timing and pressure for the main injection. The above model was optimized with a Bosch injector for variable injection timing and pressure. By injecting the fuel later, Carinata Advanced (CA100 ADV) shows better NOx emissions and still keep lower particulate matter concentration.

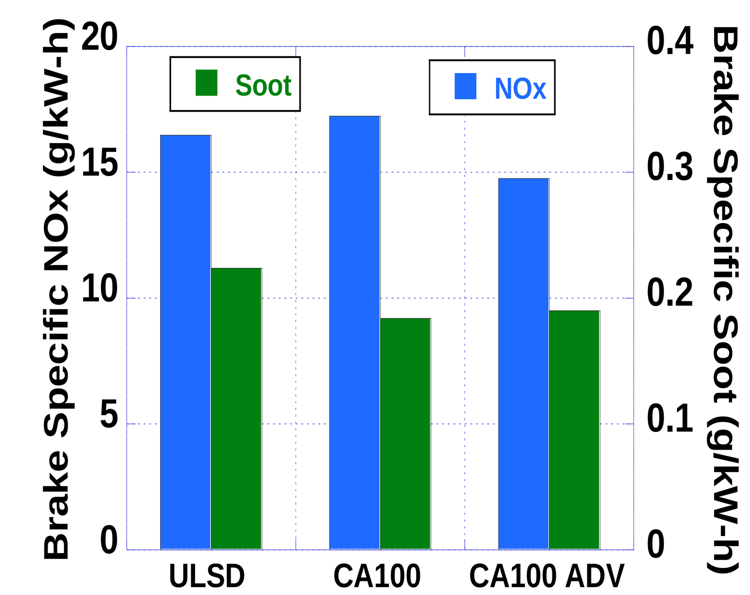

FIGURE 6: Soot and Nitrogen Oxides Emissions

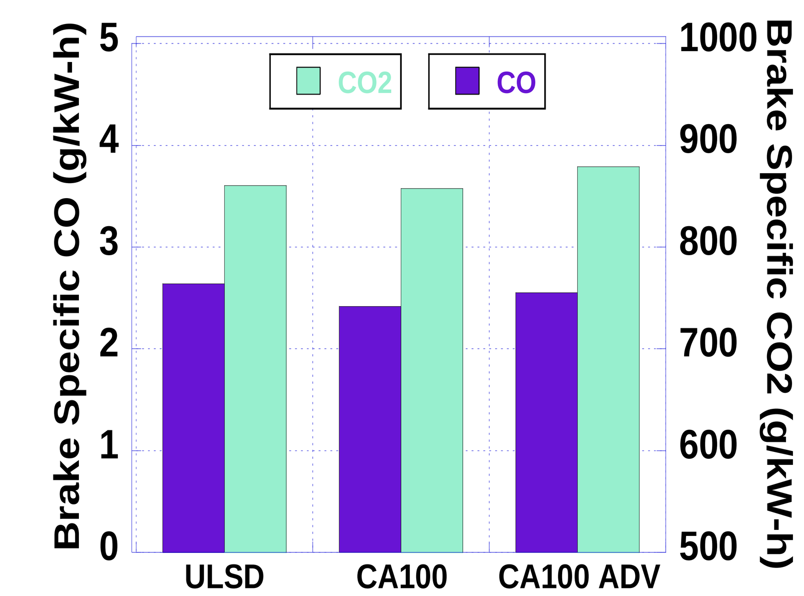

FIGURE 9: Carbon dioxide and Carbon monoxide emissions

Conclusions

- The combustion and emissions of diesel (ULSD) and Brassica Carinata biodiesel (Ca100) were investigated in a modern direct injection engine by calculating the liquid and vapor state properties for biodiesel and obtaining the exhaust emissions using an engine simulation tool, GT-Power.
- Using the determined properties, an improved combustion model for a common direct injection automobile engine was developed.
- Injection timing and pressure were varied in order to regulate the predicted engine efficiency and emissions. Emissions for NOx and soot were notably reduced compared to conventional diesel while still maintaining mechanical efficiency.
- Brassica Carinata biodiesel is a suitable renewable fuel for diesel engines and advantageous as a non-edible feedstock, which enables it to be also used for other industrial purposes due to its high concentration of erucic acid.
- Future work will comprise the possible implementation of turbocharging and Exhaust Gas Recirculation.