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Educating Engineers on the Use of Renewable Ethanol Fuel as a Drop-in Replacement for Gasoline in Small Engines

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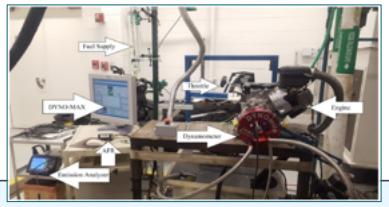
Introduction

Small off-road engines are currently widespread. It is estimated that nearly 121 million small gasoline engines are in use for lawn and garden equipment in the United States alone. Examples of this usage range from small chainsaw engines to lawn tractors. These engines generally produce much higher levels of exhaust emissions per unit power than comparable on-road engines.

Additionally, these engines most often use a carburetor for fuel control. A carburetor, while relatively inexpensive to produce, provides only limited control over the fuel-air mixture. Since this type of fuel control has not been used in the on-road sector for some time, students have little to no familiarity with them.



Objective

Because these engines are inexpensive, a low cost way to **improve emissions** was studied.

Students explored the possibility of reducing emissions by replacing the base gasoline fuel with one based on biomass derived ethanol.

A high ethanol blend was chosen for testing.

This blend represented a compromise between a "summer-blend E85" (85% ethanol) and a "winter-blend E85" (70% ethanol).

Methodology

For this study, a **Baja SAE competition engine** was used. Students were tasked, in the laboratory, to study the use of high-blend ethanol fuel as a drop-in replacement for gasoline.

Since ethanol is an oxygenated fuel, it can provide lower emissions of unburned hydrocarbons and carbon monoxide.

In addition, it is a renewable fuel derived from biomass, which lowers overall life-cycle carbon emissions.

Conclusions

Students were able to investigate small engine operation when using a high-blend ethanol fuel compared to that observed when using gasoline.

Also, measure reductions in the exhaust emissions of some harmful species due to the use of the renewable fuel. Some species of emissions actually increased, leading students to consider the challenges or impacts that need to be overcome when using a renewable fuel.

Results & Analysis

During testing, students first found a large increase in NOx emissions when using the high-blend ethanol fuel in place of gasoline (**Figure 1**).
This is an important limitation often encountered when using an oxygenated blend as a substitute fuel. The use of a larger diameter jet improved the situation, but high emissions of NOx were still noted.This indicates the need for an even larger diameter jet. As shown, the unburned hydrocarbons decrease, which is good for the environment.
Figure 2 demonstrates the large decrease in in carbon monoxide (good for the environment). However, the exhaust carbon dioxide increases slightly. This is due to the additional renewable fuel that must be burned to produce the same output power as during operation on gasoline (E10). The life-cycle CO2 emissions are still reduced.

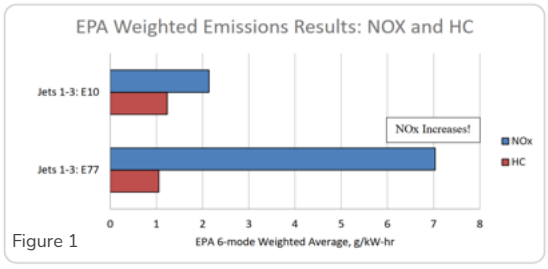


Figure 1

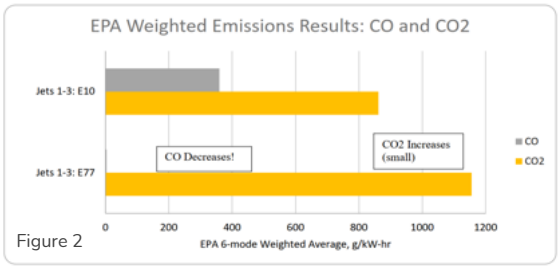


Figure 2

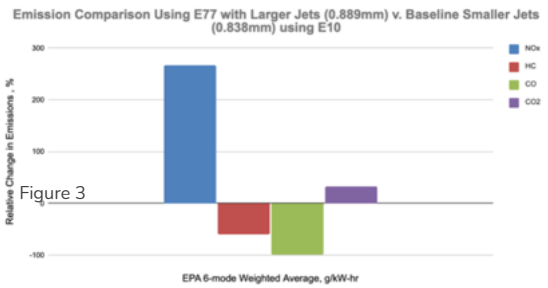


Figure 3

The final cycle weighted average exhaust emission species found, when using high-blend ethanol and the larger jet diameter, are compared to those found when using gasoline and the original size jet. These results are shown in **Figure 3**.

As shown, the students found a substantial improvement in the emissions of carbon monoxide and unburned hydrocarbons. These are some of the benefits of using the high-blend ethanol fuel.

Students also noted a slight increase in the exhaust emissions of carbon dioxide. This increase is smaller with the larger jet size due to air-fuel mixtures which were less lean. Further, since the ethanol is renewably derived, the life-cycle emissions of carbon monoxide will be reduced compared to operation on gasoline (E10).

NOx emissions were still dramatically increased indicating a need to substitute even larger diameter fuel jets to decrease the leanness of the air-fuel mixture.

Finally, student testing found that there was a large variation in results due to manufacturing tolerances and defects inherently present in the low-cost carburetors.

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