The Effect of Oxygenated Fuel Additives on the CO Emissions of a Lawn Mower

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Problem

- Every year, incomplete combustion in internal combustion engines produces the harmful gas, Carbon Monoxide. This is reduced by the ECU and catalytic converter, both of make the engine more efficient. According to the EPA, 5 percent of the nation’s air pollution, including CO, comes from garden engine emissions. This is because engines like those on lawn mowers have no ECUs or converters. Adding oxygenates should decrease the CO emissions by creating more complete combustion.

- **Can oxygenated fuel additives decrease small engine CO emissions?**
  - Which ones decrease emissions the most?
Problem Explained

Car

1. Engine combusts fuel
2. Engine Control Unit analyzes exhaust mixture and adjusts fuel mixture in injectors
3. Catalytic converter finishes the combustion reaction

Mower

1. Engine combusts fuel
2. Exhaust leaves mower

The engine does not adjust to accommodate conditions. The mixture made by the carburetor is always the same.
Hypothesis

- My hypothesis was that oxygenated fuel additives will decrease the CO emissions of a lawn mower.
  - My secondary hypothesis is that butanol will decrease it the most. This is because butanol is the most similar to/compatible with gasoline. It has a lower vapor pressure and higher density. This leads to less charge cooling and less enleanment than ethanol or methanol. The engine is only calibrated to use gasoline, so Butanol’s similarity to it will allow it to use the extra oxygen it has.
About Carbon Monoxide

- Carbon Monoxide (CO) is a chief ingredient in smog, an unwelcome tenant of many American cities.
- It can cause serious health problems in humans. It reduces the flow of oxygen to the heart and brain and causes decreased motor function. At a high enough concentration or a long enough exposure, the individual can even die from CO poisoning.
Combustion

- When fuel is burned, a combustion reaction occurs.
  \[ C_xH_y + O_2 \rightarrow H_2O + CO_2 \]

- However, fuel combusts incompletely and reacts with the other elements in the air, forming other products as well, such as CO, which is harmful.
  \[ C_xH_y + O_2 \rightarrow H_2O + CO_2 + CO + HC \]

- Fuels with their own oxygen require less air to combust and can create cleaner combustion as well.
Emission Machine Design

- Commercial instruments are thousands of dollars.
- I had to make my own from an affordable household detector (Kidde KN-COPP-3)
  - Electrochemical sensor (uses CO to produce a voltage)
  - Detector max = 1000 ppm
  - Exhaust must be diluted in a constant manner to use
- Must be airtight
- Air must be able to flow through detector
- There should be an electrical connection
- There must be an exhaust connection to the mower
- The results must be reliable and constant.
Emission Machine Design

CO reading in ppm

Duct Fan

Kidde Detector

Surrounding fresh air

Exhaust From mower
Emission Machine Operation

Emission Machine

Copper Pipe

Garage Door

Troy-Bilt with 5.5hp, GC160 Honda engine

Mower
Test Samples

- Pure gasoline (only hydrocarbons)
  - Control
- Pump gasoline (87 octane from Bucks County)
- 5%, 10%, 15% ethanol + pure gas
- 5%, 10%, 15% methanol + pure gas
- 5%, 10%, 15% butanol + pure gas
Procedure

- Prepare 400mL of fuel and add to tank
- Run for 5-10 min as a warmup
- Record pre-test measurements
- Start recording and take data every minute for 15 minutes
- Shut off and drain tank, lines, and bowl.
- Repeat for each fuel
Raw Data

[Line graph showing the CO measurements over time for various samples, including Pump Gas, Pump Gas 2, Pure Gas, 5% Ethanol, 10% Ethanol, 15% Ethanol, 5% Methanol, 10% Methanol, 15% Methanol, 15% Methanol 2, 5% Butanol, 10% Butanol, 15% Butanol 2, and 5% Butanol.]
Kidde Results

Comparison to Pure Gas

Additive: Pump Gas, Pure Gas, 5% Ethanol, 10% Ethanol, 15% Ethanol, 5% Methanol, 10% Methanol, 15% Methanol, 5% Butanol, 10% Butanol, 15% Butanol

Comparison values: 1.0, 1.5, 2.0, 2.5, 3.0, 3.5
The Heathkit C1-1080 is a portable exhaust gas analyzer. It uses thermisters to detect the cooling caused by the exhaust gases. I took data with this at the end of warmups, just before I used my own device.
The ESP System 1 is a larger, high-end instrument used for automotive emissions testing. I traveled to a local service station to use it. It uses an infrared sensor that shines infrared light on the exhaust and measures how much light was absorbed. These tests consisted of 5-10 minute warmups and then readings.
ESP System 1 Results

Comparison to Pure Gas

Additive

Pump Gas, Pure Gas, 5% Ethanol, 10% Ethanol, 15% Ethanol, 5% Methanol, 10% Methanol, 15% Methanol, 5% Butanol, 10% Butanol, 15% Butanol
Comparison of Testing Devices
Other Measurements

• The ESP System 1 measured more than one emission component
• Additives may also have affected other emissions
  – $\text{NO}_x$
  – $\text{O}_2$
  – $\text{CO}_2$
  – Hydrocarbons
Graphs of Other Measurements

**NO\textsubscript{x}**

- Ethanol
- Methanol
- Butanol
- Pump Gas
- Pure Gas

**H\textsubscript{x}C\textsubscript{y}**

- Ethanol
- Methanol
- Butanol
- Pump Gas
- Pure Gas

**CO\textsubscript{2}**

- Ethanol
- Methanol
- Butanol
- Pump Gas
- Pure Gas

**O\textsubscript{2}**

- Ethanol
- Methanol
- Butanol
- Pump Gas
- Pure Gas
Overall Conclusions

- By looking at the comparison graph, it can be drawn that butanol is the additive that reduces emissions the most.
- The averages of the Heathkit and ESP System 1 show an average 31 percent and 55 percent decrease in emissions over pure gas, respectively. Following are ethanol, pump gas, and methanol.
- This is because the incompatibility of methanol with the fueling system counteracted its oxygen content.
- I also learned that my testing device had serious error.
Error Analysis

- Icing in pipe
- Mixing of methanol
- Airflow issues
- Irregular engine
- Pipe position in tailpipe
- Leakage (pipe or device)
- Mixing of fresh air and exhaust
- Improper use of sensor
Possible Error Sources During Testing

- Wind
- Inside temperature
- Warmup time
- Block temperature
Graphs of Error Sources

Wind

Warmup

Block Temperature

Inside Temperature
Extensions and Applications

- If I chose to continue this experiment, I could test more additives, like MTBE and possibly some unverified claims made by fuel pills.
- These results can provide environmentally-friendly homeowners with an additive that is proven to decrease emissions.