SSA 1

RPC-list and fuel research

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Goal

- Make an RPC-list
- do research for the fuel

Conclusion

- An RPC-list is made.
- The fuel comparison is not finished yet but already a lot of usefull information is found.

Problems

- Didn't succeed in calculating the fuel consumption.

Follow up Steps

- Finish the Fuel comparison

Work Division

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Overleaf Link

1 RPC-list

Requirements

- The engine has to have a minimum thermal efficiency of 15 %.
- The engine's CO2 emissions should be equal to or lower than the emissions when ran on gasoline.

Preferences

- All sub-questions should be answered in the report.
- The model has to be structured and understandable, so that the final product can be easily adapted by external software engineers after it has been delivered to the client.
- The engine parts should not wear out quicker (as a result of ethanol damage) than when ran on pure gasoline, so that the gen-set requires no more maintenance than usual.

Constraints

- Honda specific four-stroke gen-set is the subject of research and analysis.
- The final product consists of a numerical model which simulates the engine's thermodynamics cycle, as well as a report with an extensive analysis of the engine performance and the ecological impact when used with different fuels, with lastly an advice on what fuel blend to use.

2 Fuel comparison

In order to give the best advice on eco-friendly fuel mixtures, the difference between the fuels needs to be clear. The two fuels, and some different mixtures (E5, E10 and E15), are compared. This comparison is made using specific factors, which are usefull for forming an advice . These factors include: the total carbon footprint (including the production of the fuel), the effects of ethanol on the engine, fuel consumption, thermal efficiency and fuel price.

2.1 Production of gasoline and ethanol

2.1.1 Gasoline

Gasoline is manufactured by refining crude oil through distillation. After refining the crude oil, oil companies add compounds that reduce emissions and increase mileage. To distinguish themselves from the rest oil companies and to increase the performance of the gasoline, they often incorporate different additives.[1]

2.1.2 Ethanol

To produce ethanol, multiple processes are used, differing per region. For example, the USA, which produces 40% of bio-ethanol, uses mainly corn as its source for the fuel. In total, about 40% comes from sugar plants and 60% from starch. In spite of the fact that there are different ways ethanol fuel can be created, the most common way is through aging (also know as fermentation). The essential steps for large-scale production of ethanol are: fermentation of sugars, distillation, dehydration, and denaturing (optional). Nowadays many ethanol plants incorporate new methods of dehydrating which skips the distillation step entirely saving energy up to 840 kJ/L. Some prospects exist for sequestering CO_2 during the fermentation procedure.[2]

2.2 Ethanol effect on the engine

Adding ethanol to the fuel mixture has multiple effects. First of all, due to the high octane-number in ethanol the chance of self ignite due to the pressure in the cylinder reduced. In compression ignition engines this means that the fuel compression can increase so it does more work and the thermal efficiency rises. In spark ignition engines like the one used in this case, self ignition would be premature and is unwanted. Here the benefit is that with added ethanol the premature self ignition called 'knocking' is less prone to take place.

On the contrary, ethanol has some negative effects as well. Ethanol is a component based on water, meaning that it naturally doesn't blend well with oil, such as gasoline. As soon as too much water has entered the tank due to for example condensation and the saturation point is reached, the ethanol will 'disconnect' with the gasoline. This means that when the ethanol-gasoline blend is left untouched for too long, phase separate will take place, meaning that the ethanol will go to the bottom of the tank. The gasoline on top of the engine loses a lot of RON points and a few additives, making the gasoline far less efficient and more damaging than at first. Ethanol also erodes materials quicker, which can damage the engine. However nowadays engines are designed so that they're better resistant for these negative corrosive effects of ethanol.

Unfortunately, there is no source about how long it takes for an engine to stop working/break down due to ethanol, probably this is because the fact that an break down can happen randomly and the lifetime of the engine differs greatly per engine.

An additional effect of blending ethanol into the fuel is an increase in fuel consumption. Because the lower heating value of ethanol is smaller than that of gasoline it produces less energy, so more fuel is needed to produce the same amount of work.

2.3 Fuel consumption

This difference in fuel consumption can be calculated using the stoichiometric air/fuel ratio, as done in Appendix A.1 The results can be seen in the table below

Table 1: Fuel consumption for different fuel mixtures.

Fuel	**E0**	**E5**	**E10**	**E15**
A/F-ratio	15	14.7	14.4	14.1
Fuel consumption [L/Km]				

2.4 Otto efficiency

The Otto cycle is the name of the cycle used in spark-ignition internal combustion engines such as gasoline and hydrogen fuelled automobile engines. The ideal thermal efficiency (Otto efficiency) depends on the compression ratio r of the engine and the specific heat ratio γ of the gas in the combustion chamber. The Otto efficiency can be calculated using Equation 1.

$$\eta_{Otto} = 1 - (1/r_c)^{\gamma-1} \tag{1}$$

Thus, the thermal efficiency increases when the compression ratio increases. The compression ratio of Otto cycle engines is limited by the need to prevent uncontrolled combustion, known as knocking. Modern engines typically have compression ratios in the range of 6 to 12[3]. The compression ratio of this engine is 8.5. The heat capacity ratio for gasoline at atmospheric pressure and ambient temperature is equal to 1.28, whereas that of ethanol is equal to 1.18. In the ideal case, γ is assumed to be constant. Calculating the Otto efficiency using Equation 1, results in a value of 0.451 for gasoline, and 0.320 for ethanol. Therefore, adding more ethanol to the fuel mixture will reduce the thermal efficiency.

2.5 Fuel prices

References

[1] https://www.aaa.com/autorepair/articles/where-does-gasoline-come-from

[2] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6233010//

[3] https://en.wikipedia.org/wiki/Thermal_efficiency

[4]

[5]

[6]

Appendices

A Appendix 1

A.1 Fuel consumption calculations

The stoichiometric air/fuel ratio is the air/fuel ratio needed for a complete combustion. The spark ignition engine uses a carburettor to keep the fuel mixture stoichiometric.

The complete combustion of gasoline can be described by:

$$2C_8H_{18} + 25O_2 = 16CO_2 + 18H_2O \tag{2}$$

And the complete combustion of ethanol can be described by:

$$C_2H_5OH + 3O_2 = 2CO_2 + 3H_2O \tag{3}$$

The stoichiometric air/fuel ratio is described by:

$$AF_{stoic} = \frac{m_{air}}{m_{fuel}} \quad \text{[-]} \tag{4}$$

In Equation 2 it can be seen that 25 mol of oxygen dioxide reacts to 2 mol of gasoline. Using this makes it possible to calculate the molecular mass of the air in the cylinder. Air is comprised of 78.09% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide, and small amounts of other gases. Neglecting the small amounts of other gases the molecular mass of these components are relatively 28.0134 u, 31.998 u, 39.948 u and 44.01 u. Taking this composition into consideration the molecular mass of air needed for a stoichiometric combustion becomes:

$$m_{air,gasoline} = \frac{25 * 78.09}{20.95} * 28.0134 + 25 * 31.998 + \frac{25 * 0.93}{20.95} * 39.948 + \frac{25 * 0.04}{20.95} * 44.01 = 3456.8u \tag{5}$$

For $m_{gasoline}$ it is as simple as adding all molecular masses of the elements in the fuel.

$$m_{gasoline} = 2 * (8 * 12.001 + 18 * 1.0079) = 228.3u \tag{6}$$

Using Equation 4 to calculate the stoichiometric air/fuel ratio:

$$AF_{stoic,gasoline} = \frac{m_{air,gasoline}}{m_{gasoline}} \approx 15.1 \tag{7}$$

For ethanol the caluclations stay the same except the amount of mol oxygen reacting is different. In case of ethanol Equation 3 is used to get the correct mol ratios, here 3 mol of oxygen reacts.

$$m_{air,ethanol} = \frac{3 * 78.09}{20.95} * 28.0134 + 3 * 31.998 + \frac{3 * 0.93}{20.95} * 39.948 + \frac{3 * 0.04}{20.95} * 44.01 = 414.8u \tag{8}$$

$$m_{ethanol} = 2 * 12.001 + 6 * 1.0079 + 15.999 = 46.0u \tag{9}$$

$$AF_{stoic,ethanol} = \frac{m_{air,ethanol}}{m_{ethanol}} \approx 9.0 \tag{10}$$

In the case of E5, E10 and E15, the fuel is composed out of both gasoline and ethanol. Here the values for the stoichiometric air/fuel ratio can be calculated using the aforementioned ratio's of both pure gasoline and pure ethanol:

$$\%\text{gasoline in mixture} * A/F - ratio_{gasoline} + \%\text{ethanol in mixture} * A/F - ratio_{ethanol} \tag{11}$$

Using Equation 11 the stoichiometric ratios of the different blends can be determined. With these ratios can be determined how much more mol fuel, thus how much more fuel is used per mixture.

Table 2: Fuel consumption for different fuel mixtures.

Fuel	**E0**	**E5**	**E10**	**E15**
A/F-ratio	15	14.7	14.4	14.1
Fuel consumption [L/Km]				