SSA 2

Research fuel

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Goal

- The goal of this SSA is to research more into the fuel. The starting point is the previous SSA of Lars and I continued the research he did.

Conclusion

- The way to calculate the fuel consumption is the one presented in subsection 1.2, where the calculation can be done empirically by measuring the the torque and rotational speed at different loads. However, section 1.1 provides many insides into the mixture fuel research and most of the findings can be used in the future.

Problems

- I spend a lot of time in researching an inaccessible way to calculate the fuel consumption (in subsection 1.1), and therefore I could not look more into the method presented in subsection 1.2.

Follow up Steps

- Finishing up the fuel consumption research. The starting point for further research can be the Internal Combustion book [3].

Work Division

- The action of doing the research and writing this SSA was done by me.

Time Division

- Researching into the fuel: 4hrs
- Making the SSA: 1 hr

Overleaf Link

1 Fuel Research

I based my researched from different sources. In the following document I will present the main findings from each source. Apart from the ones mentioned below, I also googled ways to calculate fuel efficiency, but I did no important findings.

It is important to mention that the fuel consumption (FC) is the amount of fuel that the engine uses in order to travel a certain distance (usually 100 km). There are two types of fuel consumption described in [1]: volumetric fuel consumption [l/km] (liter/kilometer) and a mass fuel consumption [g/km] (grams/kilometer). However, in the Handbook (Link) it is mentioned a specific fuel consumption (sFC) with the units [mg/J or g/kJ] (milligrams/Joule or grams/kilo Joules).

1.1 The paper 'Gasoline - ethanol blends Literature Overview by Concawe'

The paper[1] can be found on Canvas.

In this paper is presenting the impact on fuel consumption on mixing gasoline with ethanol.

It is worth mentioning that this paper also covers the effects of gasoline-ethanol mixture on the latent heat of vaporization, on airflow and throttling, and on latent heat.

1.1.1 General estimation for FC

Here are some key proprieties of ethanol that the group might need in the future:

Table 1 Key physical properties of gasoline (Unleaded Gasoline 95RON) and ethanol

Parameter	Unleaded Gasoline (95RON)	Ethanol	% change from gasoline to ethanol	% change from ethanol to gasoline
Density (kg/litre)	0.745	0.794	6.6%	-6.2%
Research Octane Number (RON)	95	>100	==	==
Lower Heating Value (MJ/kg)	43.2	26.8	-38.0%	61.2%
Lower Heating Value (MJ/litre)	32.2	21.3	-33.9%	51.2%
Carbon weight fraction	0.864	0.522	==	==
Hydrogen weight fraction	0.136	0.130	==	==
Oxygen weight fraction	0.0	0.348	==	==
Stoichiometric Air-Fuel (A/F) ratio (AFR)	14.57	8.94	-38.6%	63.0%
Carbon emissions (gCO_2/MJ)	73.3	71.4	-2.6%	2.7%
Mean Molecular Weight	88.6	46.1	==	==
Latent Heat of vaporisation (MJ/kg)	306	855	==	==

Figure 1: Basic proprieties gasoline and ethanol

Gasoline, ethanol and air have the following typical properties:

Table 2 Key properties of gasoline (Unleaded Gasoline 95RON), ethanol, and air

	Gasoline	Ethanol	Air
H_c lower heating value (MJ/kg)	43.2	26.8	
A/F stoichiometric air/fuel ratio (AFR)	14.57	8.94	
h_{vap} vaporization latent heat (kJ/kg)	306 (1)	855 (1)	
c_p specific heat at constant pressure (kJ/kg-K)	2.05 (2)	2.47	1.004
M molecular mass (g/mol)	88.6	46.1	28.97

(1) From Bromberg, Cohn and Heywood 2006 [6]
(2) Calculated for a typical gasoline

Figure 2: Basic proprieties gasoline, ethanol and air

Based on the lower value of the lower heating value of ethanol compared to gasoline (Figure 1), the following changes in FC are mentioned:

- For E10 (10% ethanol, 90% gasoline) the volumetric FC should increase by 3.5% and the mass FC should increase by 4.2%
- For E5, the volumetric FC should increase by 1.7% and the mass FC should increase by 2.1%.

1.1.2 Impact of ethanol on CO_2 emissions

As there is more ethanol added into the mixture, the FC will increase. However, the total carbon emissions [g/MJ] are slightly lower for ethanol, because it has the C/H ratio (carbon/ hydrogen) lower than conventional gasoline. This results in the following estimations: for a fuel with 100% ethanol, the CO_2 emissions are 2.6% lower than for only gasoline mixture (in the conditions that the same energy efficiency is in both cases, so the energy efficiency is maintained). It has also been estimated in the paper that for E10 and E5, the Co_2 emissions will be with 0.18%, respectively 0.09% lower comparing to only gasoline mixture (Figure 3).

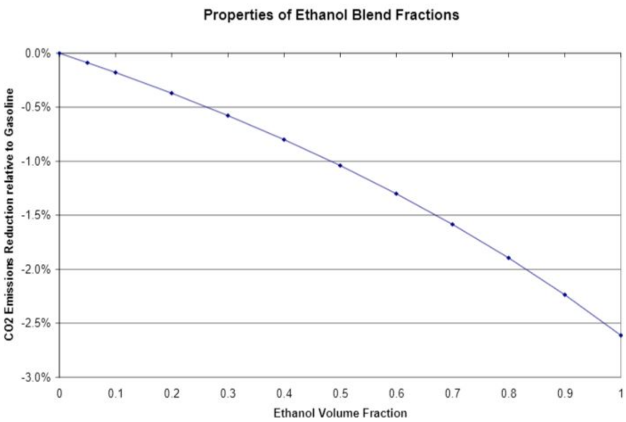

Figure 3: CO_2 emission reduction w.r.t. ethanol volume fraction

1.1.3 Calculation of FC

The paper also showed the method it was used in order to calculate FC. Firstly, it is calculated the mass FC and using that value the volumetric FC can be computed as well. The formulas are:

$$FC_m = \frac{CWF_{exh} \cdot HC + 0.429 \cdot CO + 0.273 \cdot CO_2}{CWF_{Fuel}} [g/km]$$

$$FC_v = \frac{FC_m}{SG_{fuel} \cdot 1000} [l/km]$$

Where:

- FC_m is the calculated mass fuel consumption in g/km
- CWF_{Fuel} is the carbon weight (mass) fraction of the fuel
- CWF_{exh} is the carbon weight (mass) fraction of the exhaust hydrocarbons
- 0.429 is the carbon weight (mass) fraction of CO
- 0.273 is the carbon weight (mass) fraction of CO2
- HC is the calculated HC emissions for the test in g/km
- CO is the calculated CO emissions for the test in g/km
- CO_2 is the calculated CO_2 emissions for the test in g/km
- FC_v is the calculated volumetric fuel consumption in litres/km

- SG_{fuel} is the density (specific gravity) of the fuel in kg/litre

In the process of trying to calculate using these formulas FC, the stochiometric equation for the ethanol - gasoline mixture was also computed. This will be important also for future research.

Chemical mixture of gasoline (C_8H_18) and ethanol (C_2H_5OH) [4].

$$C_8H_18 + C_2H_5OH = C_{10}H_{23}OH$$

Stochiometric equation of the combustion of the ethanol - gasoline mixture [5].

$$2C_{10}H_{23}OH + 31 \cdot O_2 = 20 \cdot CO_2 + 24 \cdot H_2O$$

One big drawback into continuing using these formulas are the factors HC, CO and CO_2, as they are the calculated emissions, they should be measured during the experiments. Unfortunately, it is not possible to calculate any emissions during the experiments as mentioned in one of the documents on Canvas (Link to the PDF).

Figure 4: Slide 3 - Engine Experiments extra info

1.2 Internal Combustion book [3] & Handbook [2]

This book is referenced in the Handbook [2], which can be found on Canvas. It is also mentioned that it will be necessarily to calculate the specific fuel consumption. It is presented that it will be possible to calculate FC by two methods: *analytically*, by assuming various losses such as the variation in heat-loss to the walls and mechanical losses, and *empirically*.

In the Internal Combustion book [3], it is mentioned the following formula for FC (page 51):

$$sFC = \frac{\dot{m_f}}{P}$$

Where:

- $\dot{m_f}$ is the mass flow of the fuel mixture
- P is the power generated by the engine

The way the power P is calculated in the book is by using the following (page 46):

$$P = 2\pi NT$$

Where:

- N is the crankshaft rotational speed
- T is the torque exerted by the engine

References

[1] https://canvas.tue.nl/courses/14094/files/2986579

[2] https://canvas.tue.nl/courses/14094/files/2986578?module_item_id=253237

[3] https://gctbooks.files.wordpress.com/2016/02/internal-combustion-engine-fundamentals-by-j-b-heywood.pdf

[4] https://en.intl.chemicalaid.com/tools/equationbalancer.php?equation=C2H5OH+%2B+C8H18+%3D+C10H23OH

[5] https://en.intl.chemicalaid.com/tools/equationbalancer.php?equation=C10H23OH+%2B+O2+%3D+CO2+%2B+H2O