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EFFECTS OF RENEWABLE ENERGY SOURCES ON AIR-FUEL RATIO

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Abstract

Environmental emission of road transport is a key problem. Periodic environmental test are designed to ensure minimum emission. Periodic checks are based on measurements. In this emission measurements fuel type plays an important role. The Brettschneider equation is a method used to compare the idealized and actual air fuel ratio. Brettschneider established a method to calculate ratio of oxygen to fuel by comparing the ratio of oxygen molecules to carbon and hydrogen molecules in the exhaust. In this article, authors have investigated blended ethanol effect on idealized and actual air fuel ratio based on Brettschneider equation. The main result of the article that blended ethanol has insignificant effect on air-fuel ratio. The article presents inter alia difference in stoichiometric air fuel ratios in case of different fuels, changes in λ due to blending ethanol and comparison of influence of emissions of different types of transport. In the article authors focus particularly on periodic checks and gasoline driven cars. The main research question was if ethanol blends have effect on idealized and actual air fuel ratio based on Brettschneider equation.

Keywords: *air-fuel ratio, lambda, gasoline, ethanol, combustion engines, air pollution, environmental protection*

1. Introduction

A properly maintained and fully functioning vehicle is less likely to over polluting the environment. Roadworthiness checks not only make sure that engine is working properly, but they are also important for ensuring fair competition in the transport sector. There are 2 types of assessment: on-the-spot roadside inspections and periodic checks, where owners have to take the vehicle to a specialist centre. In this article, authors are more focusing on periodic checks and gasoline driven cars. While environmental tests are made basically the exhaust gas is investigated based on Brettschneider's method.

The Brettschneider equation is used to calculate the normalized air-fuel ratio. It is taken from a article written by Brettschneider [1], at Robert Bosch in 1979 and published in "Bosch technische Berichte". In the article, Brettschneider described a method to calculate air-fuel ratio by comparing the ratio of oxygen molecules to carbon and hydrogen molecules in the exhaust. In this article, authors have investigated blended ethanol with gasoline. The main research question was if ethanol blends have effect on idealized and actual air fuel ratio based on Brettschneider equation. The article is structured as follows – first part is introduction, second part is methodology, where Brettschneider equation is described, third part describes the main findings and finally the conclusion can be found.

2. Methodology

In this section Brettschneinder, equation is described. Brettschneider established a method to calculate balance of oxygen to fuel by comparing the ratio of oxygen molecules to carbon and hydrogen molecules in the exhaust.

Work done by Brett C. Singer and Robert A. Harley published in 1998 [2] indicates an error in the conventionally accepted equation, in that Brettschneider assumed that (since gasoline vapours are measured as 'equivalent hexane' – he could simply multiply HC by 6 in order to account for the carbon atoms. Singer and Harley discovered that the used measurement techniques missed about 50% of the car bon in the exhaust gas [3]. Therefore, they suggested modifying Brettschneider equation by a factor of 12 instead of 6. Further on the modified equation were used (1):

$$\lambda = \frac{[CO_2] + \left[\frac{CO}{2}\right] + [O_2] + \left[\frac{NO}{2}\right] + \left(\left(\frac{H_{CV}}{4} \times \frac{3.5}{3.5 + \frac{[CO]}{[CO_2]}}\right) - \frac{O_{CV}}{2}\right) \times ([CO_2] + [CO])}{\left(1 + \frac{H_{CV}}{4} - \frac{O_{CV}}{2}\right) \times \left([CO_2] + [CO] + (n \times [HC])\right)}, \quad (1)$$

where

[XX] – gas concentration in V/V%,

H_{CV} – atomic ratio of hydrogen to carbon in fuel,

O_{CV} – atomic ratio of oxygen to carbon in fuel,

n = 12 for gasoline [2], n = 3 for propane LPG, n = 1 for methane (CNG).

The formula compares all of the available oxygen with the oxygen demand of combustion. At ideal case, in the stoichiometric point, $\lambda = 1.000$. The air-fuel ratio is the most common reference term used for mixtures in internal combustion engines (2):

$$\lambda = \frac{AFR}{AFR_{stochiometric}}, \quad (2)$$

λ (Lambda) is the ratio of actual AFR to stoichiometry for a given mixture. $\lambda = 1.0$ is at stoichiometry [4]. If Lambda value of 1.050 is about 5.0% lean and a Lambda value 0.950 is about 5.0% rich [5]. Once Lambda is calculated, air fuel ratio can be easily determined by simply multiplying Lambda times the stoichiometric air fuel ratio the selected fuel (2).

Different fuels have different stoichiometric air fuel ratios [6] (Fig. 1).

Ethanol production is a key issue; therefore, three-sustainability indicator is introduced. The sustainability value of resource replacement (SV_{rep}), the sustainability value of the fate of waste (SV_{waste}), and the sustainability indicator (SUS_{ind}), were defined for biomass-based carbon chemicals by using the ethanol equivalent (EE) as a common currency (3)-(5):

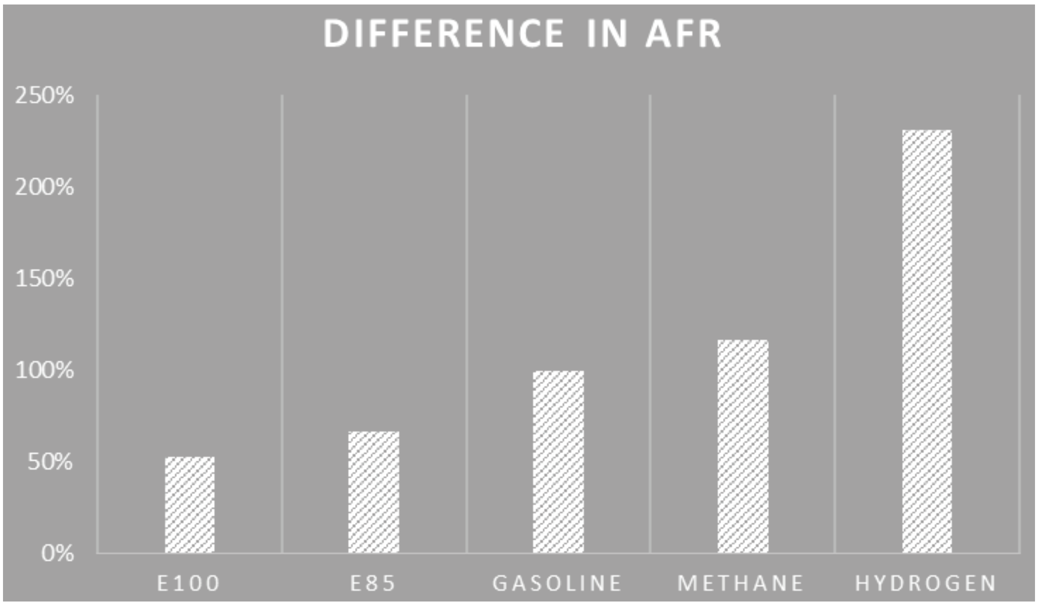

Fig. 1. Difference in stoichiometric air fuel ratios in case of different fuels

$$SV_{rep} = \frac{\dfrac{0.7\,EE_{available\ resource} + EE_{secondary\ resource}}{t_{replacement}}}{\dfrac{EE_{necessary\ resource}}{t_{consumption}}} \cdot \frac{ERoE}{2.3}, \quad (3)$$

$$SV_{waste} = \frac{\dfrac{EE_{treated\ waste} + EE_{untreated\ waste}}{t_{waste\ treatment} + t_{waste\ natural\ decomposition}}}{\dfrac{EE_{generated\ waste}}{t_{waste\ generation}}}, \quad (4)$$

$$SUS_{ind} = \frac{SV_{rep} \cdot SV_{waste}}{SV_{rep} + SV_{waste}}. \quad (5)$$

The corn-ethanol production and the cellulosic (second-generation) ethanol were increasing between 2008 and 2014 in the USA, as indicated in the table. Based on the above mentioned sustainability metrics, we have calculated the SV_{rep}, SV_{waste} values of the fuel ethanol consumption, and the sustainability index accordingly

3. Results

Preliminary results of theoretical investigation could be concluded as ethanol blending into gasoline has insignificant effect on lambda, because ethanol contains a very small amount of oxygen [7, 8], which is released as the fuel is combusted (Fig. 2):

Based on the theoretical investigation of authors there is a significant difference between air fuel ratios of different fuels (Fig. 1.). Further on it can be stated that as Hcv and Ocv parameters are changing with fuel type (gasoline and ethanol) but nearly lambda nearly independent (Fig. 2.). It can be stated that the different chemical structure and different lower heating value slightly decrease lambda. This result is verified by Lukács and Bereczky [9] as they conclude that increased blending volume could cause increase in fuel consumption and released heat when lambda kept constant.

It can be seen from Tab. 1 that SV_{rep} approaches to the sustainable value (i.e. 1).

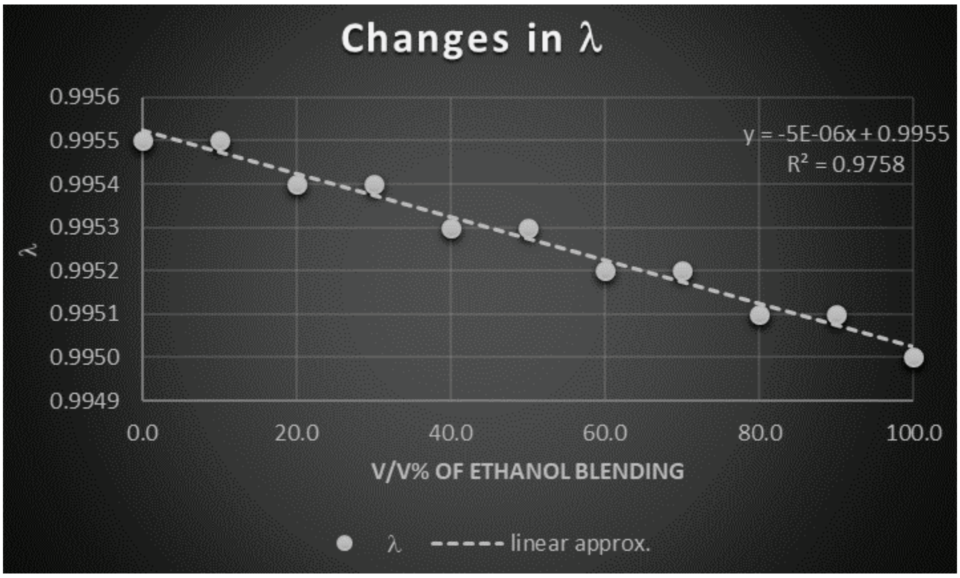

Fig. 2. Changes in λ due to blending ethanol

Tab. 1. Comparison of influence of emissions of different types of transport

	corn ethanol production	cellulosic ethanol production	Conventional renewable fuel	Conventional renewable fuel	In case of ethanol production from corn grain there is NO WASTE: all by-products are utilized	
	$EE_{available}$ resource [mt]	$EE_{secondary}$ resource [mt]	EErequired resource [mt]	SV_{rep}	SV_{waste}	SUS_{ind}
2008	27.8	0	26.88	0.724	1	0.42
2009	32.7	0	31.36	0.73	1	0.422
2010	39.7	0.3	35.84	0.778	1	0.438
2011	41.6	0.75	37.63	0.78	1	0.438
2012	39.5	1.49	39.42	0.714	1	0.417
2013	39.8	2.99	41.22	0.7	1	0.412
2014	42.8	5.23	43.01	0.737	1	0.424

In spite of the increasing ethanol production, there is not enough to cover all the fuel ethanol demands, because in a sustainable world renewable energy such as ethanol shall cover the required energy input for the ethanol production.

4. Conclusion

Analysis of result shows that increasing the blending amount of ethanol has insignificant effect on λ parameter. Ethanol could play an important role in transport industry as a fuel or a fuel-blending component. Noteworthy, the side products on ethanol production can be used in animal feeding. The calculated sustainability values of ethanol approaches to the sustainable value of 0.5 [10].

Acknowledgement

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