THE IMPACT ANALYSIS OF HYDROXIDE MIXTURE ADDITION ON THE COMBUSTION PROCESS IN THE DIESEL ENGINE.

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Abstract: *This paper presents the analysis which is based on the parameters of the real device for producing a mixture of hydroxyl (HHO) and similar parameters to the real 2.0 SDI VW Golf MK V engine. Theoretical analysis has been made to principles of cooperation the engine with HHO's generator. The effects of the gas on the engine and operating economy were established. The analysis was divided into quantitative and qualitative. Quantitative analysis was contained the theoretical and economic calculation of the thermodynamic cycle taking into account the HHO gas. Qualitative analysis was concerned to the quality of combustion in the engine and the impact generator HHO to the quality of the combustion.*

KEY WORDS: DIESEL ENGINE, COMBUSTION PROCESS, HYDROXIDE MIXTURE

1. Introduction

High costs of fuel are essential stimulus for working not only over new fuels or engine constructions but also they are the urge for working over the modification of the combustion process by adding or changing the participation of air components in the working load of diesel engine. One of such solutions is adding of hydroxide mixtures produced in the electrolysis method. The present study is the introduction for breaking research carried out in Zakład Pojazdów Samochodowychi i Silników Spalinowych (Cars and Internal Combustion Engines Plant) and it is also a theoretical consideration of this technology, which takes into account thermodynamics rules as well as economic issues.

1.1 HHO technology

The HHO technology is understood as a system connected to the sparking ignition or diesel engine where the stoichiometric hydroxide mixture called HHO gas is supplied into the suction collector.

HHO generator, which means water electrolysis cell, works on the basis of the following reaction:

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \text{ (cathode)} \qquad (1.1a)\ [1]$$

$$2OH^- \rightarrow H_2O + \frac{1}{2}O_2 + 2e^- \text{ (anode)} \qquad (1.1b)$$

$$H_2O + 286KJ \rightarrow H_2 + \frac{1}{2}O_2 \text{ (total)} \qquad (1.1c)$$

This is the endothermic reaction in which electric energy is added in order to create oxygen and hydrogen. In the electrolytic cell, hydrogen is produced by cathode whereas oxygen by anode. Taking into account the characteristics of hydrogen, oxygen and water and assuming that the energy comes from electric energy, the process goes adiabatically :

$$V_{ad} = -\frac{\Delta H^o}{n \cdot F} = 1{,}48V \qquad (1.2)$$

Thus the potential necessary for adiabatic process of the above mentioned reaction is followed by the pattern (1.2). Smaller potential than this will prevent the reaction process while bigger potential will cause heat production which results as a process loss. Therefore it follows that in HHO generator powered by car installations (V= 12V) there may occur quite intensive electrolyte heating which may cause exploitation problems and may cause significant losses so it is not beneficial in the area of thermodynamics.

2. Theoretical analysis

In order to analyze theoretical basics of engine with HHO generator operations as well as to estimate the impact of HHO gas on the engine work and profitability of exploitation the theoretic analysis was made. This analysis has been divided into quantity and quality one. The quantity analysis included theoretic calculations of the thermodynamic circle considering HHO gas and economic calculations. The quality analysis has described combustion in the diesel engines and, what is more, it tried to estimate the impact of HHO gas generator onto this combustion.

2.1 Analysis of thermodynamic circle

The analysis of thermodynamic circle has been made on exemplary slow suction diesel engine. Such an engine had similar parameters to SDI 2.0 engine in VW Golf MK V car working on the highest power, which performance without HHO system were known and could be compared to obtained results. The analysis has been made to check whether the introduction of HHO improves the thermodynamic efficiency of the circle without consideration of improving the quality of combustion. Especially there was investigated if HHO, as neutral gas in the combustion chamber, which supplies certain amount of heat, has an impact on the thermodynamic circle.

The thermodynamic analysis was carried out by the use of patterns form [4] modified for consideration of the HHO impact as well as patterns based on one's own thoughts.

General assumptions

Sabath's Circle

The maximum pressure of combustion is the same with or without HHO.

HHO does not cause the growth of used heat factor.

HHO gas does not need extra oxygen for combustion.

Adding of HHO into the intake air causes the dilution of the intake air (more air is needed for combustion of 1kg of diesel oil) and it supplies additional thermal energy because of combustion itself.

In the consideration of the engine working cycle, it has been assumed that the whole volume of engine is in one cylinder. Thus at the end it was not necessary to multiply obtained values by the number of cylinders. The results together with used patterns are presented in the following table.

Table 2.1: The results of calculations and equations used for calculating the thermodynamic circle.

	Symbol	Equation	Value without HHO	Value with HHO
Density of sucked air	ρ_{pow}	$\rho_{pow} = \frac{1}{v_a}$	1,05kg/m^3	1,05 kg/m^3
Density of HHO	ρ_{HHO}	$\rho_{HHO} = \frac{P_1}{R_{HHO} T_s}$	0,33 kg/m^3	0,33 kg/m^3
Computational saltatory volume up to 1kg of diesel oil	V_s	$V_s = \frac{1}{1-\%HHO} \cdot \frac{\lambda L_t' v_a}{\eta_v}$	26,13m^3	26,39m^3
Fuel value of HHO	W_{HHO}	$W_{HHO} = W_{H2} \frac{2,02}{18,02}$	13,45 MJ/Kg	13,45MJ/Kg
Fuel value of fuel considering HHO	W	$W = W_{ON} + \%HHO \cdot \rho_{HHO} \cdot (V_c + V_s) \cdot W_{HHO}$	41,90 MJ/Kg	43,13MJ/Kg
Work of one cycle	Work	$Work = -\int_{V1}^{V2} Pdv + \int_{V2}^{V4} Pdv$	1696 J	1726 J
Heat provided in one cycle	Q	$Q = (W\xi \frac{V_2}{V_c})$	2566J	2614J
Efficiency of the thermodynamic circle		$\frac{Work}{Q}$	0,6614	0,6604
Work of one cycle for producing HHO	$Work_{HHO}$	$Work_{HHO} = V_1 \rho_{HHO} \%HHO \cdot W_{HHO} / \varepsilon_{HHO}$	0J	154,50J
Work of one cycle with considering HHO generator	$Work_{net}$	$Work_{net} = Work - Work_{HHO}$	1696J	1572J
Efficiency of the circle with considering HHO Generator		$\frac{Work_{net}}{Q_{ON}}$ Q_{ON} is the heat from combustion of oil	0,66	0,61
The use of fuel	$\dot{m}_{ON}$	$\dot{m}_{ON} = \frac{(Q_{ON}) \cdot 60n/2}{W_{ON}}$	7,72kg/hour	7,60kg/hour
Engine power	Power	$Power = Work_{net} \cdot \frac{n}{2 \cdot 60}$	59,39KW	55,02KW
Unit use of fuel	g_e	$g_e = \frac{\dot{m}_{ON}}{Power}$	0,130Kg /KW hour	0,139Kg /KW hour

3. Conclusions

The abovementioned calculations leads to several important conclusions.

Firstly, the theoretical result of power, 59.37 KW is pretty close to the actual 2.0 SDI engine power in VW Golf MK V car, which is 55 KW [6]. The fact that theoretical calculations show higher power is caused by the resistance and loses in the actual engine. However, the theoretical and actual convergence of the power confirms the assumptions of those calculations.

The most significant conclusion from those calculations is the fact that the adding of HHO gas does not improve the efficiency of the thermodynamic cycle in the diesel engine. Even without considering the energy necessary for producing HHO gas (which equals 0.6604), the efficiency of the thermodynamic circle is lower than the efficiency of the circle without HHO (0.6614). Considering the power needed for producing HHO the efficiency of the engine with HHO (0.57) is much lower than the efficiency without HHO

(0.66). The engine power is about 8KW lower and the unit use of fuel increases by about 6%. The increase of HHO amount does not cause any improvements of the efficiency of engine fed by HHO, while the decrease of HHO amount makes the performance of engines fed or not by HHO convergent. From what has been said it follows that adding of HHO has a negative effect on the thermodynamic circle since the HHO generation consumes profusion of power. Thus any improvements of engine performances must come from increasing of the heat use factor, which means the improvements of combustion quality of fuel-air mixture.

It must be noticed that in the present analysis HHO gas plays similar role to the fumes in the engines with EGR insulation as HHO is neutral gas which does not take part in combustion, except from providing heat. Nevertheless, in the case of ERG installation the neutral fume gasses work as cooling factor in order to reduce nitrogen oxides emission form fumes. Adding HHO gas, on the other hand, probably will increase the temperature of combustion.

4. Literature:

[1]Lewandowski, Witold. M. *Proekologiczne odnawialne źródła energii*. Warszawa : Wydawnictwa Naukowo-Techniczne, 2012.

[2] Tsiplakides, Dimitrios. *PEM Water Electrolysis Fundamentals. http://research.ncl.ac.uk/sushgen/docs/summerschool_2012/PEM_water_electrolysis-Fundamentals_Prof._Tsiplakides.pdf. Pobrane 22 Marca 2013.*

[3] Website of HHO Plus Alternative Technologies Ltd. Company http://www.hho-plus.com/. Downloaded 13.03.2013

[4] Wajand, Jan.A. *Silniki o zapłonie samoczynnym. Warszawa*. Wydawnictwa Naukowo-Techniczne, 1988.