STUDY OF HHO GAS INFLUENCE ON OPERATING PARAMETERS IN CI ENGINE

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Abstract
Over the last decade, we have seen sustained growth in oil consumption. This has an adverse environmental impact. From a global point of view, there is a problematic increase in CO_2 production. Locally the increase in oil consumption manifests itself most often by environmental pollution by particulate matters or nitrogen oxides. In the European Union, individual car traffic accounts for about 20% of CO_2 production and continues to grow. The result is social and political pressure to reduce harmful emissions.
This study deals with an alternative way to reduce harmful emissions with HHO gas. That is generated by electrolysis. The resulting gas is mixed in the intake of the vehicle with ambient air. The presence of additional hydrogen and oxygen during combusting should affect the emissions produced without impact of power. A decrease in performance was observed during measurement, while CO_2 and NO_X emissions increased.

Key words: *CO_2; NO_X; power; torque; emission.*

INTRODUCTION

HHO is a mixture of oxygen and hydrogen produced by electrolysis of water. This mixture is colorless, odorless but extremely flammable. The main problem of HHO gas production is its energy intensity. This is changing due to material developments. Today's HHO generators have much higher efficiency than before *(Laurie Donaldson, 2016)*. This made it possible to reduce the size of the generator and thereby allow installation into the vehicle. HHO is a promising alternative fuel in this this time. Many scientists have conducted many researches and experiments about diesel or biodiesel and hydrogen usage *(Usta, Öztürk, Can, Conkur, Nas, Çon, Can & Topcu, 2005; Al-Baghdadi & Al-Janabi, 2000)*. Hydrogen presents properties that are unique from those of hydrocarbon fuels like a addition, this type of fuel does not contain carbon *(Rimkus, Matijošius, Bogdevičius, Bereczky, Török, 2018; White, Steeper, Lutz, 2006)*. The use of HHO gas in a combustion chamber is expected to increase performance *(Bari, Mohammad Esmaeil, 2010; Kumar & Rao, 2013)*. Furthermore, CO_2 and NO_X emissions are expected to decline *(Baltacioglu, Arat, Özcanli & Aydin, 2016)*.
The aim of this study was to determine the impact of using HHO gas on diesel engine operating parameters. The gas generator was additionally added to the internal combustion engine and used electricity from the onboard network. Electrolysis of the water yielded HHO gas, which was subsequently blended into the intake air. The monitored parameters were engine power and torque. CO_2 and NO_X were monitored for emissions.

MATERIALS AND METHODS

The Škoda Roomster was used for the experiment. It is a three-cylinder turbocharged CI engine. Manufacturer's specifications are in the Tab. 1.

Tab. 1 Škoda Roomster specifications

Parameter	Unit	Value
Engine volume	dm^3	1.422
Max. power (speed)	kW (rpm)	59 (4000)
Max. torque	Nm (rpm)	195 (2200)
European emission standards		EURO 4
Fuel consumption	dm^3 per 100km	5.2
Emission CO_2	$g\cdot km^{-1}$	135

The chassis dynamometer Schenk 3604 was used for vehicle testing under laboratory simulated driving cycle and for power measuring. The driving cycle tested was WLTP in Fig.1. The Worldwide Harmonized Light Vehicles Test Procedure (WLTP) is a worldwide unified procedure for measuring emissions and consumption of passenger cars and light commercial vehicles. To increase the measurement accuracy, each cycle was repeated 3 times.

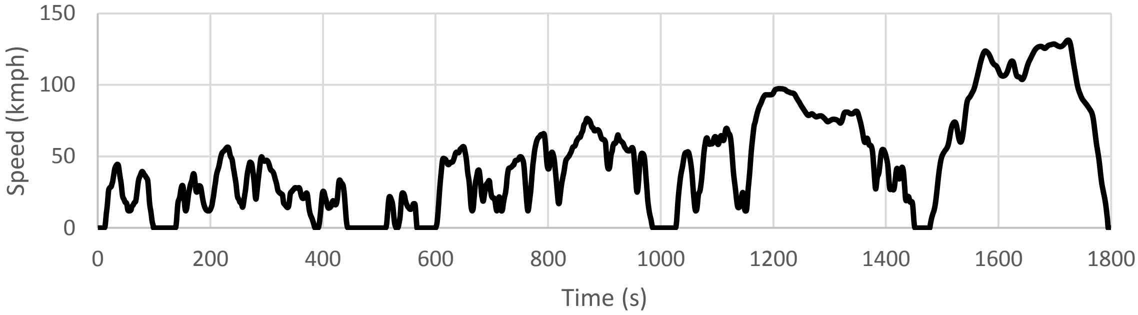

Fig. 1 WLTP driving cycle

The HHO gas generator was a commercially available DCT212 model manufactured by Atthero s.r.o. The main generator parameter is the amount of gas generated. According to the manufacturer, the DCT212 produces 180 $dm^3 \cdot h^{-1}$ at a current of 30A. During the experiment, the current to 20A was reduced due to generator overheating. This caused a reduction in the amount of gas generated to 105 $dm^3 \cdot h^{-1}$.
Exhaust gas components were measured using a Matrix MG-5 analyzer by Bruker. Exhaust gas solids using the EEPS 3090 by TSI analyzer.

RESULTS AND DISCUSSION

An ordinary driver will be concerned if the fuel, air, and HHO mixture will affect engine performance. Engine power measurement was the first step in this study. Fig. 2 shows the results of motor power and torque measurements. The results show that the use of HHO gas has led to a reduction in performance. The maximum power of 64kW was achieved when measuring on diesel. When HHO gas is used, power drops to 60kW. The way in which performance is distributed is more important for drivers. It can be seen from Fig. 2 that there has been a significant distortion of the torque course using HHO gas. This leads to worse engine performance. These results are consistent with the values found by Adrian Birtas *(Birtas & Chiriac, 2011)*.
However, there are many studies whose results are exactly the opposite. In 2013, Le Anh carried out a measurement of both power and torque in percent *(Le Anh, Nguyen Duc, Tran Thi Thu & Cao Van, 2013)*. Increases brake power by 13%, brake torque by 9% and reduces Brake Specific Fuel Conception (BSFC) by 10% on average compared to diesel *(Bahng, Woong, Dongsoon, Youngtae & Misoo, 2016)*.

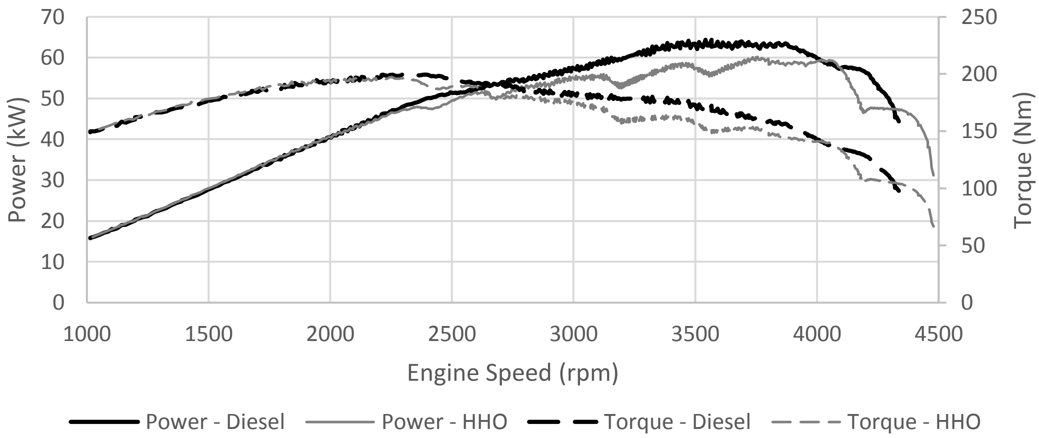

Fig. 2 Brake power output and torque versus engine speed

The production of gaseous emissions was solved as the average mass production per 1 km cycle according to the WLTP measurement methodology. Tab. 2 shows the emission measurement results. The results are converted to total concentration. The results show that with HHO gas production of CO_2 increased by 7%. This will lead to an increase in fuel consumption.
In these studies was reduces CO_2 by 12% or more on average compared to diesel *(Le Anh, Nguyen Duc, Tran Thi Thu & Cao Van, 2013; Bahng, Woong, Dongsoon, Youngtae & Misoo, 2016).*

Tab. 2 Emission CO_2

	Diesel ($g\cdot km^{-1}$)	HHO ($g\cdot km^{-1}$)	Different (%)
WLTP #1	141,3	146,9	
WLTP #2	135,7	149,9	
WLTP #3	138,6	148,5	
Average	138,5	148,4	7% increase

N_2O, NO_2 and NO gases are the most common nitrogen oxide emissions. For the purposes of this study, the results of individual gas measurements are summed and represented as NO_X. The measurement results are shown in Tab 3. During the measurement, the use of HHO in the internal combustion engine has been shown to result in a significant increase in NO_X production by up to 34%.
A subtle result was also achieved in this study where NO_X emissions increased from 345 ppm to 406 ppm *(Birtas & Chiriac, 2011)*. The decrease in NO_X emissions by up to 34% was in study in 2016 *(El-Kassaby, Eldrainy, Khidr & Khidr, 2016).*

Tab. 3 Emission NOX

	Diesel ($mg\cdot km^{-1}$)	HHO ($mg\cdot km^{-1}$)	Different (%)
WLTP #1	164	172	
WLTP #2	108	182	
WLTP #3	121	174	
Average	131	176	34% increase

CONCLUSIONS

The results show that it is not appropriate for the user to use HHO gas in the fuel-air mixture. When HHO gas was used, the power dropped by 6.25%. A change in the composition of the air / fuel mixture leads to engine control instability. The presence of hydrogen gas in the combustion chamber increases the burning rate of the fuel, resulting in harder engine running.
Reducing engine power forces the engine control unit to call this deficit. This leads to increased fuel consumption and thus higher CO_2 production. During the measurement, CO_2 production increased by 7%.
Furthermore, there was another lack of hydrogen combustion in the measurement. It burns at a very high temperature, up to 2 500 °C. At this high temperature, the nitrogen is oxidized in the combustion chamber. This leads to a significant increase in NO_X production. This was well documented during this study because NO_X production increased by 34%.
In conclusion, the retrofitting of the HHO generator to the vehicle is not recommended. From a practical point of view, this is not an easy matter. There is a risk of permanent engine damage during installation. The expected benefits of this technology have not been confirmed during the measurement. On the contrary, during the measurement it turned out that the engine is running in a non-standard mode, its operation is much harder. This makes it difficult to control, which is not user-friendly.

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