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Hydrogen Addition Influence for the Efficient and Ecological Parameters of Heavy-Duty Natural Gas Si Engine

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Abstract

The paper presents the experimental research results of heavy-duty vehicle (public transport bus), fuelled with natural gas and hydrogen fuel mixtures. Spark ignition six cylinder engine tested with different hydrogen additions (from 5% up to 20% according to volume) in the natural gas fuel. The tests were performed on heavy-duty vehicle's dyno test stand in company "SG dujos Auto" research laboratory. The tests were carried out at three load points and one engine speed. Engine had originally a port fuel injection and exhaust gas recirculation system. Experiments showed that engine fuelled with hydrogen addition was able to achieve lower fuel consumption and brake specific fuel consumption. It was also possible to achieve small increase of engine efficiency. The exhaust gas measurements showed that hydrogen addition in natural gas reduced the CO, CO_2 and HC emissions because of the H/C atom ratio change in fuel mixture and improved combustion process. The NO_x emission level was decreasing, although bigger amounts of hydrogen were used in natural gas fuel.

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Keywords: natural gas, hydrogen, heavy-duty engine, efficient and ecological parameters

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1. Introduction

Nomenclature

NGV	Natural gas vehicle	EGR	Exhaust gas recirculation
ICE	Internal combustion engine	SI	Spark ignition
RON	Researched octane number	PFI	Port fuel injection
CNG	Compressed natural gas	Rpm	Revolutions per minute
A/F	Air and fuel ratio		

Upcoming humanity's strategic objectives is to reduce significantly the fossil fuels (oil) consumption, as a radical reduction way of the greenhouse gases, especially carbon dioxide (CO_2). European Commission states that there is no single fuel solution for the future transport because the availability and cost of alternative fuels differ between the transportation modes [1]. Sudden transition to a global use of electric vehicles and alternative fuel sources is not possible, so one of the most acceptable alternatives to the "transition period" is a wider use of simple molecular structure fuel – natural gas of which resources will be sufficient for few hundred years. The increasing amount of the NGVs force to search for the new and innovative ICE technologies and new alternative fuel types, which can improve the fuel economy and reduce exhaust gas emissions [2].

The main benefit of the methane gas is that it has much higher octane number (RON > 130) as compared to petrol (RON 86) and this enables substantially higher compression ratios without knock problems. Such fuel property is more suitable for SI engines. The relationship of compression ratio and thermal efficiency of Otto cycle engine is shown below [2, 3]:

$$\eta = 1 - \frac{2}{\varepsilon^{(y-1)}}, \eta = 1 - \frac{1}{\varepsilon^{(y-1)}}, \tag{1}$$

where ε – compression ratio; γ – adiabatic index.

As CNG engines can operate with higher compression ratio, it is possible to achieve higher thermal efficiency, though some modifications have to be done [4, 5]. Hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO_2), nitrous oxide (NO_x) and particulate matter (PM) are significantly lower with natural gas fuel than with diesel fuel in compression ignition engines or sometimes even with petrol fuel in SI engines [6]. It was noted, that PM emissions are significantly reduced with natural gas fuels because it does not have aromatic and polyaromatic compounds and contains less sulfur compounds comparing with the liquid fuels [7]. Methane stoichiometric combustion balance can be shown as following [2, 8]:

$$CH_4 + \left(0_2 + \frac{79}{21} N_2\right) \rightarrow CO_2 + H_2O + N_2 . \tag{2}$$

The results of the studies showed that the fuel features have direct impact on NGVs emissions and fuel economy. Depending on gas composition, A/F ratio varied also. For this reason, engines are designed so that they will compensate the variations of the fuel composition [7, 9].

To expand alternative fuel range, it is attractive to use energetically potential and clean fuel – hydrogen (H_2). One of the way to apply H_2 is to use natural gas and hydrogen fuel mixtures. In [10] investigation presented, where it was claimed, that hydrogen as additive in natural gas can improve such characteristics like power, efficiency and emissions, when engine was working on lean mixtures [10]. In [11] claims that heavy duty vehicles fueled with hydrogen and natural gas fuel mixtures decrease such pollutants like CO, CO_2 and HC.

Company "SG Dujos Auto" has been researching natural gas and hydrogen fuel mixtures for the wide variety of the vehicles since 2013. Heavy duty (city buses, commercial transport), light vehicles were investigated with different H_2 additions in CNG. Series of experiments showed that one of the promising fuel mixtures is 2% H_2 addition in CNG. The "H2NG" trademark for the natural gas and hydrogen fuel mixtures was registered and