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Experimental study of the effects of Dual-Fuel on the output power and environmental pollution of a spark-ignition (SI) engine in stoichiometric equivalence ratio

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1. ABSTRACT

In the present research work, a research engine with the required measurement system along with laboratory equipment, experimental results of normal combustion (without knocking) at a compression ratio of 11, at two different engine speeds and stoichiometric equivalence ratio at different advances (selection of the optimal advance from at least 6 advances) were extracted for the conditions of G100 (100% gasoline), G87.5 (87.5% gasoline remaining natural gas), G75 (75% gasoline remaining natural gas) and G62.5 (62.5% gasoline remaining natural gas). To ensure the experimental data, information was obtained and stored from 350 consecutive cycles. After analyzing, the information was converted from raw results to usable results by a computer code. The experimental results were used to analyze the combustion, emissions, and performance of the gasoline and natural gas blend. In summary, the $IMEP_{AV}$ (average indicated mean effective pressure) and torque output of the gaseous fuel blend were comparable to the gasoline-burning state, while the levels of CO, HC, and NO pollutants were greatly reduced with increasing natural gas and engine speed.

Keywords: Dual Fuel, Internal Combustion engine, Engine Speed, Combustion, Torque, Pollutant.

2. INTRODUCTION

The main problem of internal combustion engines (SI) is urban pollution and the shortage of hydrocarbon resources. Researchers are introducing solutions to solve these problems by introducing suitable alternative fuels with good ability to reduce pollutants instead of gasoline fuel. In recent years, most of the theoretical and experimental research conducted on spark ignition engines has been in the field of alternative fuels, increasing efficiency and reducing engine emissions. The number of vehicles using natural gas fuel in the world has reached approximately 23 million vehicles, and our country, Iran, has the largest gas-fired fleet in the world [1]. Gas-fired engines have their advantages and disadvantages, including lower knock and torque compared to fossil fuels, the possibility of increasing the compression ratio of the internal combustion engine, easy mixing of fuel with air, reducing engine pollutants, and economic efficiency in Iran [2]. Therefore, researchers in the field of combustion engines presented the concept of simultaneous dual-fuel combustion inside the combustion chamber, and this theory was proposed as a promising plan to solve the existing problem [3]. Yakani et al. [4-5], by examining the mixed-burning fuel in the internal combustion engine, investigated the effect of changing the compression ratio on the amount of environmental pollutants, and in another study, they were able to report the effect of dual lean fuels on environmental pollution.

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3. MATERIALS AND METHODS

In the present study, since it was conducted experimentally using laboratory equipment, all equipment and consumables are explained separately as follows:

3.1. Test rig

The existing test rig is made by the German company Günt (model CT300) with a single-cylinder SI spark ignition research engine. This single-cylinder engine is coupled to an asynchronous dynamometer that has the advantage of speed control. In line with serial research, the fuel supply and spark plug advance system has been upgraded from a carburetor and manual mode to an injector with the ability to spray two fuels simultaneously (gasoline and gas) and electronic with he ability to control the fuel injection length and advance by the user. This has made it possible to test mixed fuel in the laboratory setting. Which is presented in Figure 1.

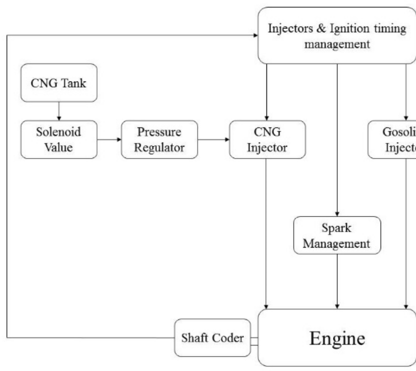

Figure 1. Diagram of equipment used in the laboratory

The research engine in the present study was a single-cylinder spark-ignition model 29C produced at the Freeman Diesel factory and was approved by the German company Günt and added variable speed capability.

3.2. Method of Conducting the Experiments

To achieve the test conditions at a compression ratio of 11, the engine was started and its speed was increased to 1800 rpm until the engine warmed up and reached a steady state. Then, the necessary mass percentages for the fuel mixture were commanded by the engine management system. Considering the accuracy of 1 degree in the crankshaft, 350 consecutive cycles were recorded in each advance. The recorded cycle information, including the crankshaft angle, dynamic and static internal pressure, and top dead center, was collected through a data logger and recorded in the analog-to-digital converter software in the management system. The raw data was separated into separate cycles by Fortran code so that the changes in P-θ (in-cylinder pressure in terms of crank angle) and imep of each cycle and the average of the cycles could be estimated. Also, the speed, torque, temperature of the mixture entering the engine, the amounts of exhaust pollutant species (NO, HC, and CO), and the temperature of the exhaust gases were measured. Then, using the maximum engine output torque and the IMEP obtained from the in-cylinder pressure, the optimal spark advance (selected from at least 6 spark advances) was determined in the defined non-knock range (without harmful knock based on MAPO). Next, the engine operating conditions were changed to full load with 3 other mass compositions of two fuels with a mass step of 12.5% by the engine management system to 87.5%, 75%, and 62.5% gasoline and the rest natural gas (G87.5, G75, G62.5), and all data collection measures were performed in the same way for all compositions.

4. RESULTS AND DISCUSSION

The results of experimental tests on the CT300 single-cylinder engine in different conditions of 100% gasoline, 87.5% gasoline, 75% gasoline and 62.5% gasoline and the rest natural gas in the conditions of stoichiometric equivalence ratio at a compression ratio of 11 and engine speeds of 1500 rpm and 1800 rpm at different spark advances with a crankshaft angular pitch of 1 degree were carried out for 350 consecutive cycles and with the help of the highest IMEP and torque obtained in non-knock conditions, the optimal spark advance for each condition was determined.

Considering that the amounts of fuel and air entering the engine, heat transfer from the cylinder wall, ignition conditions at the spark plug head, and the formation of the initial flame in consecutive engine work cycles with constant conditions applied to the engine management system, are not completely the same, therefore, changes in IMEP and the pressure graph in the cylinder with crankshaft angular pitch are possible. Therefore, to obtain more accurate information, 350 consecutive cycles were sampled for each test as shown in Figure 2, and the average was used in the calculations.

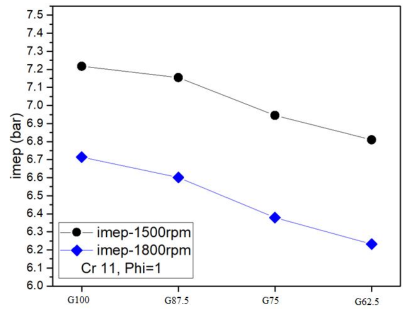

Figure 2. IMEP changes at speeds of 1800 rpm and 1500 rpm in different dual fuel mixture modes

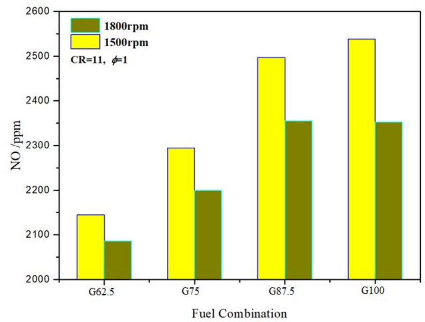

Figure 3. Changes in NO pollutant production in different combinations of gasoline and natural gas fuels

5. CONCLUSION

The results of experimental tests on the CT300 single-cylinder engine in different mixtures of 100% gasoline, 87.5% gasoline, 75% gasoline, and 62.5% gasoline and the rest natural gas in the conditions of stoichiometric equivalence ratio in compression ratio 11 and engine speed rpm1500 and rpm1800 in different spark advances with 1 degree crankshaft angular step for 350 consecutive cycles and with the help of the highest imep and torque obtained in non-knock conditions, the optimal spark advance of each mode has been determined. Then, the performance and emission parameters of the different modes have been compared and examined. The results of the tests and experiments are summarized as follows:

• By adding natural gas to the fuel mixture, the torque and imep values have decreased and also the values of the parameters expressed at engine speed rpm1800 have been obtained lower than those at engine speed rpm1500.

• The standard deviation and coefficient of variation decreased with the addition of natural gas to the two-fuel mixture, which may be due to the reduction of cyclic variations with the addition of natural gas in the two-fuel mixture in consecutive engine operating cycles.

• The amount of CO produced by adding natural gas to the two-fuel mixture decreased. Also, the amount of CO produced at an engine speed of 1800 rpm was lower than that at an engine speed of 1500 rpm.

• The amount of HC produced by adding natural gas to the two-fuel mixture decreased. Also, the amount of HC produced at an engine speed of 1800 rpm was reported to be lower than that at an engine speed of 1500 rpm.

• The amount of NO produced by adding natural gas to the two-fuel mixture decreased. On the other hand, the amount of NO produced at an engine speed of 1800 rpm was reported to be lower than that at an engine speed of 1500 rpm.

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