The effect of some operational and design parameters on the emitted CO pollutant from a spark ignition engine

Jafaar A. Kadhem, Khalid S. Reza, Wahab K. Ahmed

Abstract—Liquefied petroleum gases (LPG) and natural gas (NG) were used as a fuel for a spark ignition type (Prodit). The effect of some design and operation variables on the emitted CO emissions from a spark ignition engine was investigated. The studied parameters were compression ratio, the equivalence ratio, engine speed and spark timing variation. The emitted CO was studied at an engine higher useful compression ratio, which was for gasoline 8:1. The results were compared to the engine output when it was run at the higher useful compression ratio for LPG and NG. The study results indicate that the CO emissions maximum values lay always on the rich side equivalence ratios and its concentrations become low at lean operation. CO concentrations were lower than emitted emissions from gasoline engine. The most significant effective parameter on the CO concentrations is the equivalence ratio.

Keywords: Spark ignition engine, exhaust gas, CO, compression ratio, equivalence ratio, spark timing, engine speed

I. INTRODUCTION

Internal combustion engines have become important in the lives of individuals and society for the urgent need to facilitate mobility and transport of goods [1]. Spark ignition engines are used widely everywhere around the world due to its efficient operation [2]. However, the emitted pollutants from this type of engine began to cause a head ache for the world. One of the most dangerous emitted pollutants is carbon monoxide (CO) resulting from partial oxidation of the carbon in the fuel [3]. Many researchers worked on variable methods to put solutions that reduce this pollutant [4-7]. The use of new alternative fuels is considered as one of these solutions [8-10]. Liquefied petroleum gases (LPG) and natural gas (NG) are known from decades as a good alternatives for use in the spark ignition engines (SIE) [11-14]. Natural gas produces from reservoirs laid underground (dry natural gas), or accompanying with crude oil [15]. LPG is oil product in refineries as it comes from it having low carbon atoms don't exceed five atoms. The low carbon atoms number of the two gasses makes their combustion products have lower exhaust pollutants [16-20]. Europe and America have experienced successfully the use of these two gases as a SIE fuel for decades. The use of gasses fuel in SIE has spread in the last years in India, Iran, and Egypt [21].

Although Iraq is burning millions cubic meters of natural gas in air every day, the use of gaseous fuels was so limited to some experiments on a small number of governmental vehicles [22, 23]. The researchers [24-26] manifests that CO concentrations are very low in weak equivalence ratios (Ω) and increased steadily after passing the stoichiometric ratio to the rich side. These CO concentrations are decreased by decreasing the operational equivalence ratios [27]. CO is not affected greatly by the spark timing [28-31]. The increase of compression ratio (CR) causes a reduction in CO levels on the lean and rich mixtures, due to the temperature inside the combustion chamber increase [32-36].

CO levels are high at low engine speeds because of the low temperature of maximum cycle due to the increase in burning interval and the dilution increasing [37]. At medium speeds, CO concentrations increased because of the use of higher equivalence ratios [38]. At high speeds, these concentrations increase due to the use of higher quantities of fuel, the short time required to interact of Oxygen with carbon, and the increase in the chemical dissociation because of the temperature of the maximum cycle raise highly [39].

The emitted CO pollutants from a CNG and LPG engine were measured and compared to that emitted from gasoline by Ref. [40]. The author revealed that CO levels increased with the equivalent ratio increase especially after stoichiometric equivalence ratio.

The main objective of this paper is to evaluate the levels of the emitted CO from a SIE when it is fuelled by NG and LPG. The study aims to evaluate the possibilities of fuelling alternative fuels to gasoline as LPG and NG in Iraqi cars. This work is a part of the continuous effort of Energy and Renewable Energies Technology Centre in University of Technology, Baghdad, Iraq to wide spread the use of alternative and environment friend fuels [41-83].

II. EXPERIMENTAL SETUP

2.1. Used devices

In this experimental work the engine used was Prodit (Italy). This engine is single cylinder, four strokes, and has the ability of changing its compression ratio form 5:1 to15:1. Also, it can control the variation in air fuel ratio, engine speed, and spark timing. The engine connects to a hydraulic dynamometer mounted on a steel base designed for this purpose.

The gasoline supplying system consists of a primary tank of 6 litres and a secondary tank of one litre and a number of valves control the flow of fuel. The LPG supplying system consists of a fuel tank (80 kg), fuel filter to prevent solid particles from entering the combustion chamber. It also consists of an electromagnetic valve, orifice type flow meter, and an adaptor works as gas evaporator. IN addition,
the system has as a damping box and a gas feeder. The NG supplying system consists of a pressurized gas cylinder, pressure regulator, a system of chocked nozzles to measure its flow and works as a flame trap as well, and gas feeder. The engine average air flow was measured by viscous fluidity cubit device where the pressure of the device is measured and compared using an inclined water manometer. The ignition system has an evacuation conductance type where the spark time varied manually from 0° BTDC to 60°BTDC. CO levels were measured employing Multigas model 4880 emissions analyser that was calibrated in the Central Organization for Standardization and Quality Control, Baghdad-Iraq.

2.2. Used fuels
The used gasoline was produced from Al-Doura Refinery with Octane No. 82. Iraqi gasoline characterized by its low octane number and high sulphur content that is about 500 ppm, as well as a high lead content. The used LPG was produced from Al-Taji Company-Iraq that is consist of 0.08% Ethane, 48.38% Propane, 18.37% isobutene, 3.245% n. butane. The used NG was produced from North Gas Company (Kirkuk-Iraq) consists of 84.32% Methane, 13.27% Ethane, 2.15% Propane, 0.015% isobutene, 0.017% n. butane, 0.03% Pentane.

2.3. Tests procedure
The experiments firstly conducted to evaluate the highest useful compression ratio (HUCR) for a wide range of equivalence ratios at optimum spark timing for each fuel alone. At the resulted HUCR, the equivalence ratio, spark timing, and engine speed impacts were studied on the resulted CO levels.

III. RESULTS AND DISCUSSION

Fig. 1 shows that using gasoline, LPG, and NG as a fuel at the HUCR =8:1(HUCR of gasoline). The CO concentrations were increased in the exhausted gas with equivalence ratio increasing in the rich mixture side for the three tested fuels. The reasons for this increase are: the lack of oxygen in this side (rich side) and increasing the dissociation separation of carbon dioxide to carbon monoxide by the increasing burning temperatures on this side.

At the weak mixture the effect of compression ratio was limited as there was a plenty of oxygen and due to the reduction of exhaust gas temperature as a result to lack of fuel quantity. The figure manifests that CO levels when gasoline was used at this compression ratio emitted higher levels of CO than LPG and NG. This result was expected because of the atomic structure of gasoline which consists of more carbon atoms than LPG and NG.

Fig. 2 shows the emitted levels of CO when the engine was operated at higher useful compression ratios for each fuel. The gasoline engine emitted higher concentrations of CO compared with the LPG and NG engines. The high CO levels that emitted from the gasoline engine is because of the increasing burning temperature that leads to increase the chemical dissociation of CO₂ molecules to CO. The emitted CO in the gasoline engine was higher than that emitted using the other two fuels due to the atomic structure of gasoline.

The CO concentrations were very low in the lean side as Figures 1 and 2 shows. The availability of the oxygen required for interaction. This is clearly seen for equivalence ratios less than Ø =0.96. The resulted concentrations on this side which is less than 15% of volume considered within the standard specification for the accepted pollutants in Europe and America according to the 2003 specifications [2]. CO concentration increased by enriching the fuel mixture by fuel, because lack of oxygen required for interaction and increasing of dissociation by increasing the temperature inside the combustion chamber as mentioned before. In addition, the CO levels for gasoline are higher than that of natural gas and LPG due to lower carbon atoms to hydrogen atoms for the both gasses. The least value for these concentrations is when using natural gas and that is for two reasons: reduction of temperature value for natural gas compared to LPG and gasoline, the slow flame speed of NG compared to the other two fuels which led to reduction of maximum temperature inside the combustion chamber. No effect was noticed for the spark timing on the CO concentrations.

Figures 3 & 4 declare that CO concentrations increased by increasing engine speed at stoichiometric equivalence ratios (Ø = 1.0) or greater, because of lack of the required oxygen and increasing of chemical dissociation resulted from rising
maximum cycle temperature and the short time required to complete the reaction operation.

IV. CONCLUSIONS

Single cylinder, Prodit engine was used in this paper to evaluate the effect of some design and operation parameters on the emitted CO pollutants. CO concentrations were increased by increasing the compression ratio. These emitted concentrations from gasoline are higher than LPG and NG when the engine was run at 8:1 compression ratio, or at the HUCR for each fuel. Increasing engine led to increase CO concentration in the exhausted gas. Spark timing has no effect on the emitted CO concentrations.

![Fig. 3 The relation between equivalence ratio and CO levels at engine speed = 1200 rpm for each tested fuel.](image)

![Fig. 4 The relation between equivalence ratio and CO levels at engine speed = 1800 rpm for each tested fuel.](image)

REFERENCES


