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Experimental and Numerical studying the effect of ethanol and methanol blend with gasoline on engine emissions

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ABSTRACT

According to the global air pollution Crisis, it seems necessary to finding a way for cars pollutions. The Combination of alcoholic fuels with gasoline is one of the methods to reduce pollutions. For optimizing engine performance, fuel availability, toxicity and political advantage, a blend of ethanol, methanol and gasoline is likely to be preferable to using any of these individual substances alone. So the purpose of this paper is studying methanol, ethanol and gasoline blend effect on engine emissions at different engine speed. The simulated model was validated in different RPMs of gasoline engine at full load condition. The effect of combined fuel injection in the simulated model was investigated and compared with the experimental results. The results of simulation have good agreement with experiments. The results show that by ethanol and methanol with gasoline blend CO and HC emissions are lower than gasoline mode, but the NOx and CO2 pollutants increases.

1. INTRODUCTION

Manufacturing B3 engine product line has been started in 1993 in SAIPA Company in Iran. Now it's a strategic and inexpensive engine that is produced in the company. This Engine is used in Pride group products. The main challenge facing this engine and other useful engines is to replace gasoline with other clean fuels for lower pollution and fuel consumption. Ethanol and methanol combustion temperatures are higher than gasoline then it increases NO_X and CO_2 and decreases CO and HC pollutants, because combustion of these fuels is more complete. By injecting combination of ethanol or methanol with gasoline fuels, can use the advantages of both fuels and reduce the disadvantages of each of the fuels significantly. More simulation results in comparison to experimental data's can be very helpful in properly analyzing the results. Increasing simulation results to experimental data's can be very helpful in properly analyzing the results. The industries can widespread use of results. Also the data obtained can be generalized to the different fuel conditions.

2. History of research

In 2012, Farkade and his colleagues investigated emissions of methanol, ethanol and butanol fuels, in a spark-ignition engine which were mixed with different proportions of gasoline. This research results show that alcoholic fuels have lower carbon monoxide and hydrocarbon content in

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comparison to pure gasoline [1]. In 2013, Canakci and his colleagues worked on a four-cylinder multi-point injection engine and found that nitrogen oxide was reduced by increasing ethanol content in gasoline [2]. In 2009, Malikarjon and his colleagues studied emissions and performance of a four-cylinder spark ignition engine fueled with methanol. They added methanol from 0 to 15 percent of gasoline and their results shown an increase in the octane rate of gasoline, as well as a decrease in engine hit (self ignition) [3]. Robert and his colleagues fulfilled sprinkle Plan of 3 types of fuel including gasoline, ethanol and natural gas on the vehicle and in addition to increased power, they were able to decrease the cost of fuel economically in 1 year [4]. Pishgui used variable valve timing system in simulated Peugeot XU7 engine using GT-Power software and his results shows less brake specific fuel consumption for engine[5]. Kasraie used GT-POWER software for the simulation of XU7 internal combustion engine [6]. Riahi used GT-POWER software for the simulation of B3 internal combustion engine [7]. Kakaei used GT-POWER software for simulation and Optimization of the Input runner in XU7 engine [8].Tibaquira and his colleagues used ethanol-gasoline blends on In-use vehicles [9]. Mirmohammadi and his colleagues used GT-Power software to study the effect of turbocharger system using on the performance and emission of an internal combustion engine in the variable compression ratio mode [10]. Mirmohammadi and his colleagues used GT-Power software to study the effect of natural gas-gasoline blends using on the performance and emission of an internal combustion engine [11]. Scala and his colleagues have been analyzed the behavior of a downsized spark-ignition engine firing with alcohol/gasoline blends [12]. Trimbake and his colleagues studied to extend predictive fractal combustion model for ethanol/gasoline blends and assess the influence of ethanol addition to gasoline in a Port Fuel Injection (PFI) engine [13]. Hao Yuan and his colleagues presents a numerical study of trace knocking combustion of ethanol/gasoline blends in a modern, single cylinder SI engine [14]. Trimbake and his colleagues present the numerical study of PDI strategy using a single cylinder SI Ricardo E6 research engine [15]. Jaiswal and his colleagues investigated that EGR has been used on hydrogen boosted SI engine running on gasoline-methanol and ethanol-gasoline blends to determine the additional advantages of the same compared to pure gasoline operation and gasoline-methanol and ethanol-gasoline blends without EGR [16].

The purpose of this research is studying different ethanol and methanol and gasoline mass fraction effect on exhaust emission of B3 engine by experimental test and GT-POWER software.

3. Modeling

The following equation is fuel injected model. Injection time is between 180 to 210 degrees of crankshaft rotation lasts.

$$M_{delivery} = \eta_v N_{rpm} V_d (F/A) \frac{6}{(\#CVL)(Plusewidth)} \quad (1)$$

Weib function is used for combustion modeling [12]. For this purpose, two parameters are needed:

1. Crank angle between the TDC and 50% combustion completion, this parameter is generally 5 to 12 degrees.

2. Crank angle between 50% and 90% combustion completion, this parameter is generally 25 to 35 degrees.

Combustion model is two-zone temperature and other properties for both burned and unburned zone is calculated independently.

Heat transfer rate in the cylinder is calculated using woschni model. Heat transfer coefficient calculated using the following equation as a woschni function:

$$h_g = 3.2 B^{-0.2} P_r^{\,0.8} T_r^{\,0.53} V_c^{\,0.8} \quad (2)$$

That :

$$V_c = C_1 V_m + C_2 \frac{V_d T_{r1}}{P_{r1} V_{r1}} (P_r - P_{mot}) \quad (3)$$

In the above equation in the intake and exhaust strokes:

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$$C_1 = 6.18 + 0.417(\frac{V_s}{V_m}) \quad (4)$$

And the compression and expansion strokes:

$$C_1 = 2.28 + 0..308(\frac{V_s}{V_m}) \quad (5)$$

Also dalton model was used to combine the two fuels [17].

4. Engine simulation

In this study, two zone models is used. The mixture of fuel and air inside the cylinder is divided into two burned and unburned areas.

Table 1 and Table 2 shows engine and fuels specifications respectively.In this study, the percentage of gasoline and methanol or ethanol blend was varied 0%, 10% and30% of methanol and ethanol to gasoline. This blend fuels effect on emissions are evaluated and compared with pure gasoline fueling.

Table 1. General specification of test engine

parametr	value
No. of cylinder	4
Type of engine	In line
Bore	71 (mm)
Stroke	83.6 (mm)
Ignition order	1 – 3 – 4 – 2
Engine volume	1323(cc)
Compression ratio	9.7:1
fuel	gasoline
Max power in gasoline mode	47(Kw)@5250
Max torque in gasoline mode	108(N-m)@2750
No. of valve	8
Fuel system	MPFI

Table 2. Compositions of fuel

Fuel name	G	E10	E30	M10	M30
Fuel	Gasoline	90%Gasoline+10%ethanol	70%Gasoline+30%ethanol	90%Gasoline+10%methanol	70% Gasoline+30%methanol
Combustion heat (MJ/KG)	44.13	42.74	38.67	41.61	36.24
Density (Kg/l)	0.767	0.776	0.779	0.769	0.773

5. Experiment structure

5.1 Fueling system structure

The laboratory engine schematic is shown in figure 1.The percentage of gasoline and methanol or ethanol blend was varied 0%,10% and 30%.More simulation results in comparison to experimental data's can be very helpful in properly analyzing the results of methanol and ethanol blend in gasoline. Fuels have been combined before filling the tank.

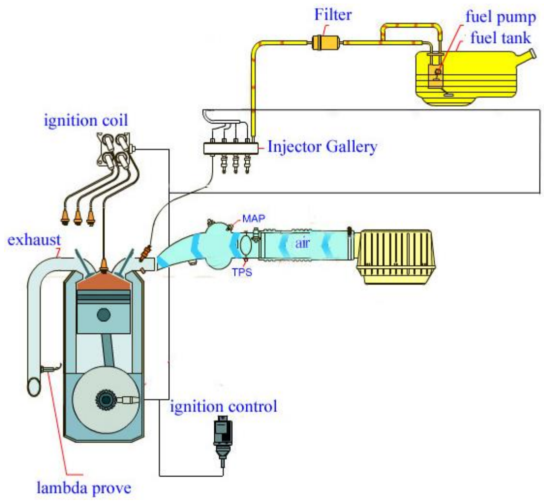

Figure1. Laboratory Engine shematics

5.2 Emissions analyzer

The 4-gases emission measuring device used to analyze the exhaust gases. Figure 2 shows an overview of this device.

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Figure 2. 4-gas analyze device

6. Simulation verification

To investigate the effect of ethanol, methanol and gasoline blend in engine research is needed to build a reliable model. In this study, the engine model was created in GT-POWER software. To verify the results of the simulation, gasoline fuel injected into the engine and the results were compared with experimental results. To ensure the accuracy of simulation model results, gasoline injection in full load mode were compared with experimental results. Experimental data's was provided in engine test cell in mega Motors Company[13]. The base engine is a gasoline B3 engine and its data's are used to verify model at full load in pure gasoline injection mode.

6.1 Simulation results validation

Figure 3 shows the power and Figure 4 shows the torque simulation results in comparison with experimental results from reference. We see that the maximum difference is about9%. The reason for this difference is to ignore the Leakage of combustion gases into crankcase and some experimental constants in models.

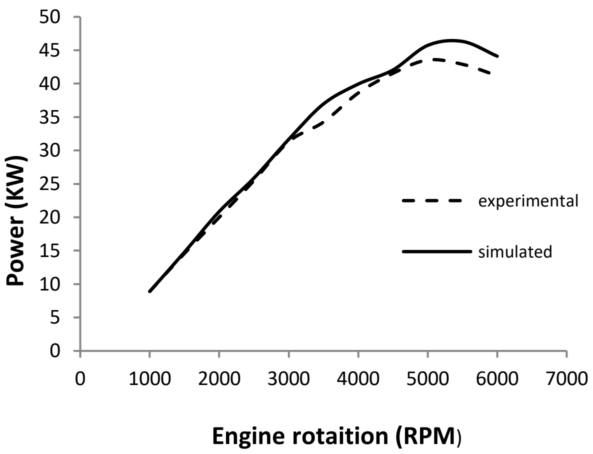

Figure 3. Engine power per RPM

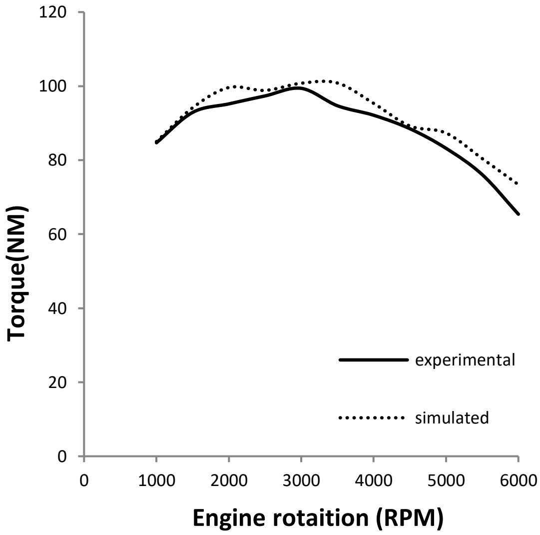

Figure 4. Engine torque per RPM

7. Simulation results

7.1 Comparison of simulation results with experimental results

NO_X emissions from the engine exhaust gas have been shown in figure5 and figure 6. By adding ethanol and methanol into gasoline, NO_X pollutant are increased, because the vaporization temperature of the ethanol and methanol is lower than that of gasoline, the temperature inside the cylinder increases, or there is a side effect in their molecular structure of the oxygen atom, which increases the production of this pollutant. In other words, the presence of an additional oxygen atom in the reaction in combination with high temperatures is a major factor in increasing this pollutant. As can be seen, due to the presence of more oxygen atoms in the structure of ethanol, the production of this pollutant is mainly greater than methanol. The maximum increase in NO_X production in different periods is 98 percent's, which occurs at around 1000 RPM's.

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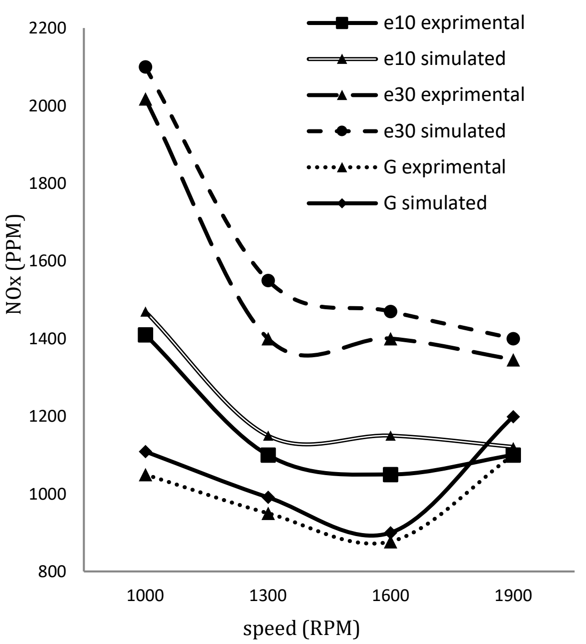

Figure 5. NO_x emission changes in engine speed at different percentages of ethanol

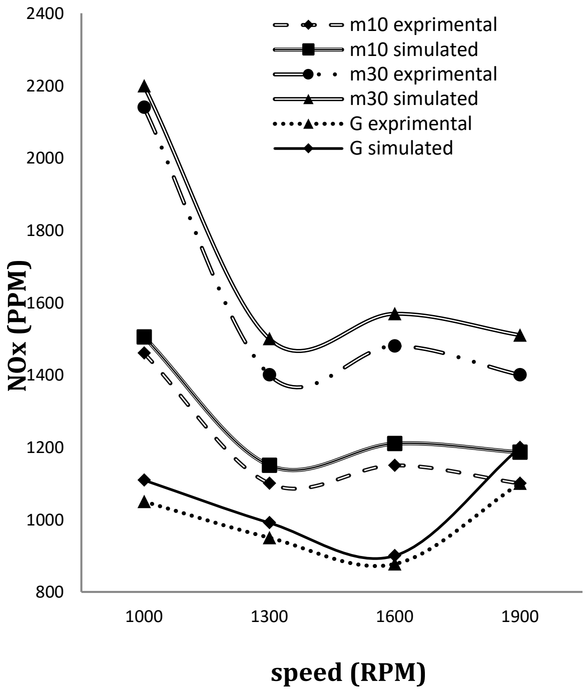

Figure 6. NO_x emission changes in engine speed at different percentages of methanol

Figure 7 show NOX emission in ethanol and methanol percentages in engine full load mode. We see that increasing ethanol in gasoline increase NOx to about 20% after this point it decrease NOx production. For methanol it is different and adding methanol increase NOx for all percent's.

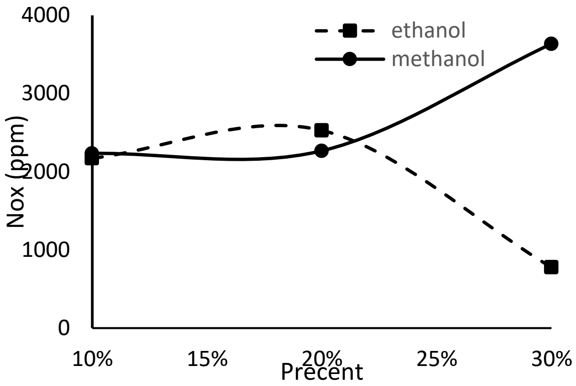

Figure 7. NO_x emission changes in engine full load at different percentages of ethanol and methanol

HC emission in different mass percentages of ethanol and methanol have been shown in figure 8 and figure 9.This pollutant is the result of incomplete combustion of hydrocarbons during the combustion process, which is largely due to lack of oxygen. It has been seen that HC is reduced with increasing ethanol and methanol because the addition of ethanol and methanol increase the amount of oxygen involved in the chemicalreaction and reduce the unburned hydrocarbons in the engine exhaust gases. Another reason for reducing unburned hydrocarbons is to reduce the ratio of hydrogen to carbon to the fuel atomic structure.As can be seen, with ethanol, the production of this pollutant is lower than that of methanol in the same percentages, which is due to the fact that there is more oxygen in the chemical structure of ethanol than the oxygen that it's burning is more fuel efficient and therefore less HC emission. The maximum reduce in HC production in different periods is 24 percent's, which occurs at around 1000 RPM's.

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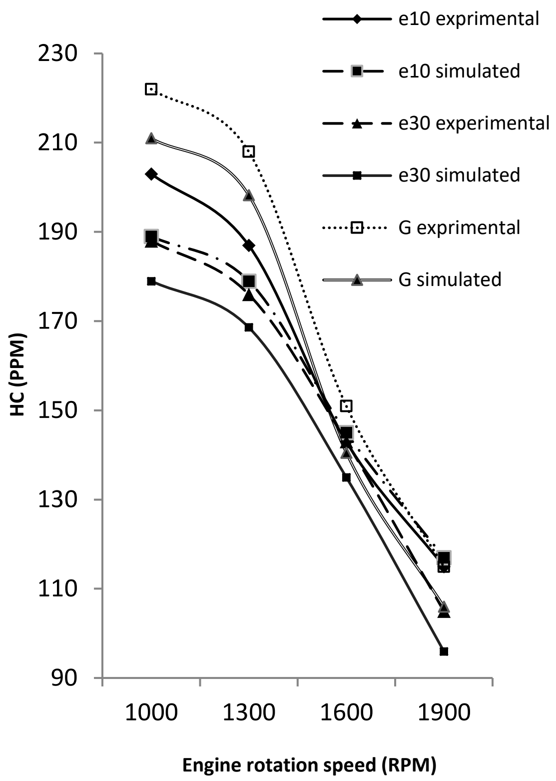

Figure 8. Changes of HC emissions in engine speed at different percentages of ethanol

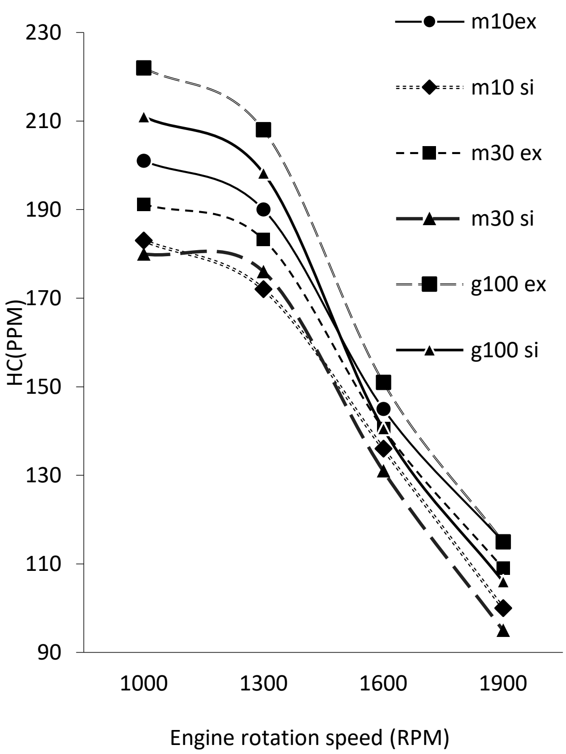

Figure 9. Changes of HC emissions in engine speed at different percentages of methanol

Figure 10 show simulation result for HC emissions in ethanol and methanol percentages in full load mode.By increasing the percentage of ethanol and methanol, the amount of this pollutant does not change much, but for methanol it increase a little more.

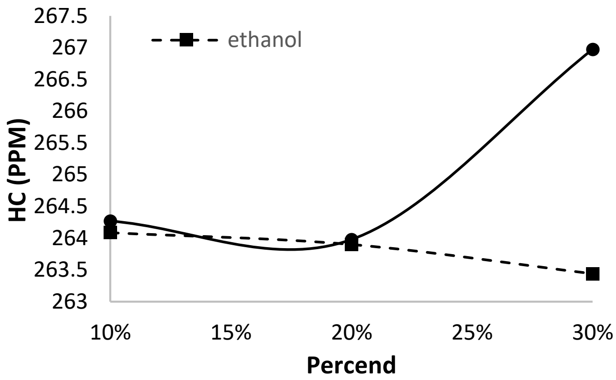

Figure 10. HC emission Changes in engine full load at different percentages of ethanol and methanol

CO emission in different mass percentages of ethanol and methanol has been shown in figure 11 and figure 12.This pollutant is because ofhydrocarbons incomplete combustionwhich is largely due to lack of oxygen. It is seen that CO is reduced with increasing ethanol and methanol,because the addition of ethanol and methanol increases the oxygen atomsparticipating in the chemical reaction of combustion. Also it can be seen, with the ethanol, production of CO pollutant is lower than that of the methanol with the same percentages. As mentioned earlier this is due to the fact that there is more oxygen in the chemical structure of ethanol, then itsburnings is more fuel efficient and less CO emission. The maximum reduce in carbon monoxide production in different periods is 200 percent's, which occurs at around 1000 RPM's.

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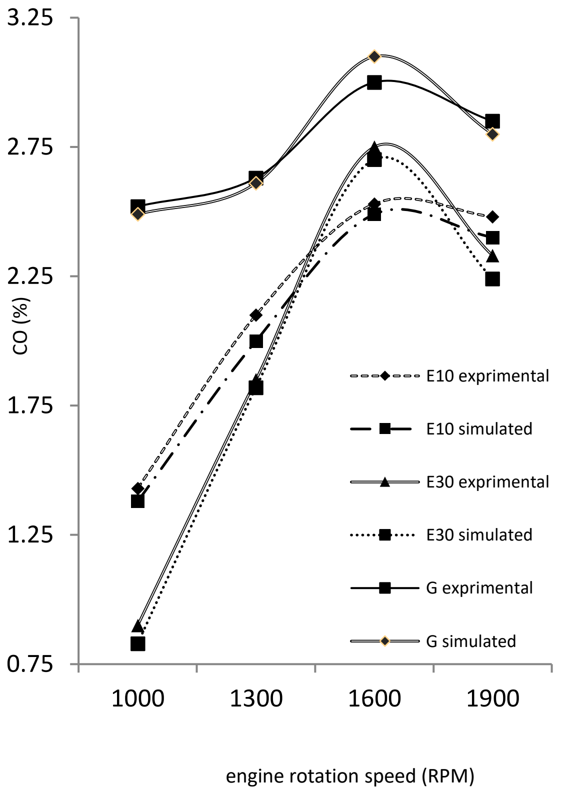

Figure 11. CO emissionsChanges in engine speed at different percentages of ethanol

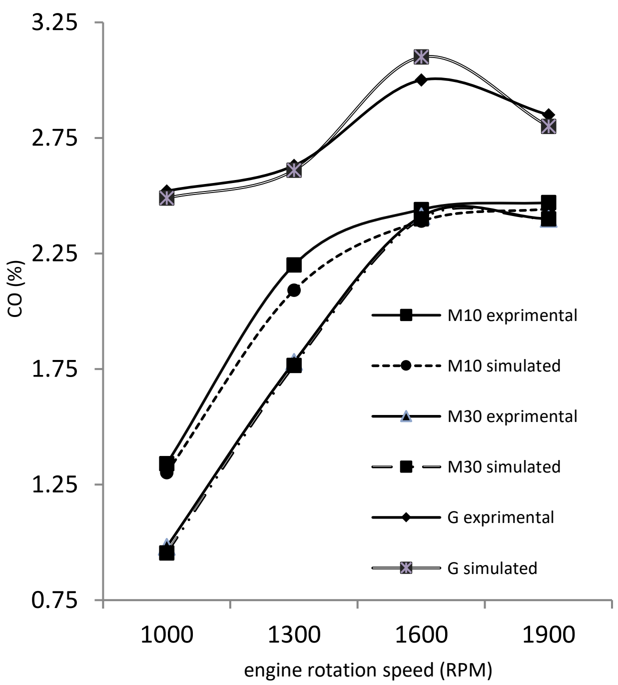

Figure 12. CO emissions Changes in engine speed at different percentages of methanol

Figure 13 show CO emissions in ethanol and methanol percentages in full load mode.By increasing the percentage of ethanol and methanol, the amount of this pollutant is reduced and approaches zero. In this case too ethanol is more efficient.

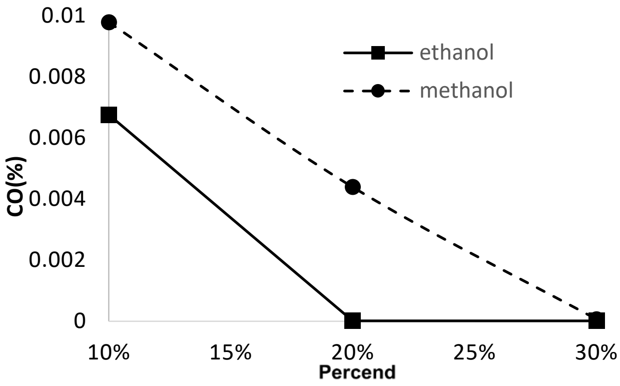

Figure 13.CO emission Changes in engine full load at different percentages of ethanol and methanol

CO_2 emission in different mass percentages ethanol and methanol has been shown in figure 14 and figure 15.This pollutant is the result of complete combustion of hydrocarbons during the combustion process, which is due to the presence of sufficient oxygen. The production of CO_2 pollutants shows an increasingtrend. It means that hydrocarbons have been burnt more thoroughly and increase CO_2production.The maximum increase in carbon dioxide production in different periods is 16 percent’s, which occurs at around 1300 RPM’s.

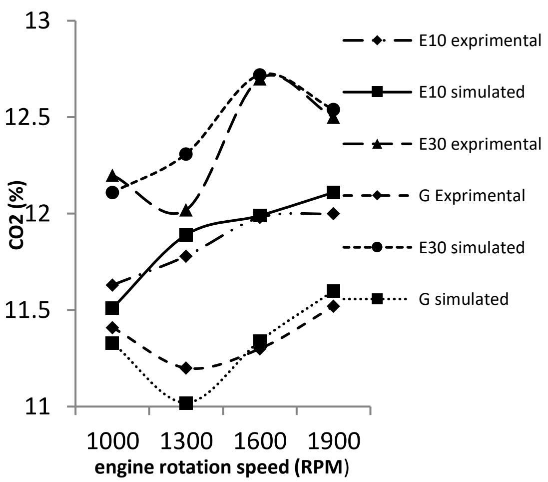

Figure 14. CO_2 emissions Changes in engine speed at different percentages of ethanol

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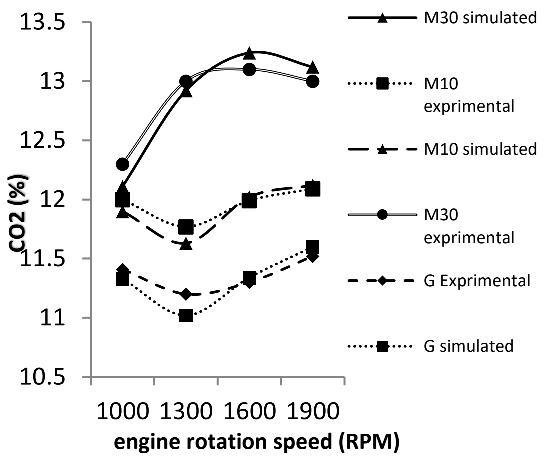

Figure 15. CO_2 emissions Changes in engine speed at different percentages of methanol

Figure 16 show CO_2 emissions in ethanol and methanol percentages in full load mode. By increasing the percentage of ethanol and methanol, the amount of this pollutant first increases slightly and then approaches the initial level. In this case ethanol CO_2 production is more than methanol.

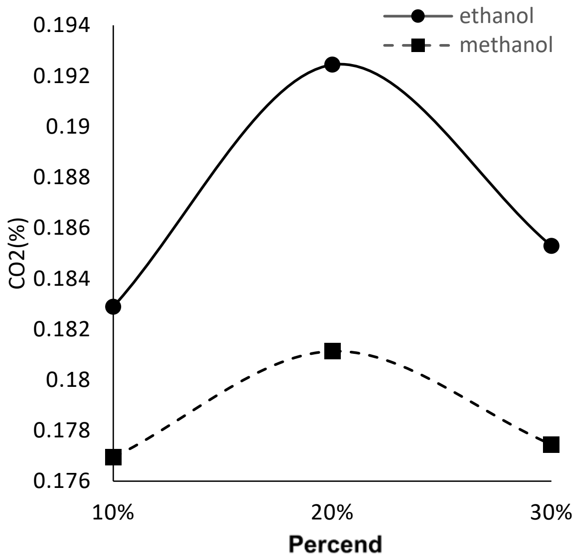

Figure 16. CO_2 emissions in ethanol and methanol percentages in full load mode

4. Conclusions

Fuel crisis and air pollution are one of the most serious issues of today. There are several ways to deal with this crisis. One of these is the use of fuels blends. The combination of fuels makes it possible to take advantage of both fuels and reduce fuel costs to some extent.

The results of this paper shown that, use of alcoholic fuel blend in gasoline in the B3 engine has these advantages:

- Reduce carbon monoxide production, maximum about 200 percent's. after use different percent's blended fuels which occurs at around 1300 RPM's.
- Reduce unburned hydrocarbons production, maximum about 24percent's after use different percent's blended fuels which occur at around 1000 RPM's.
- Increase carbon dioxide production, maximum about 16percent's after use different percent's blended fuels which occurs at around 1000 RPM's.
- Utilize more fuel benefits by changing the percentage of fuels mixed.

But this method has some disadvantages:

- Increase in NOx production about 260 percent's.
- In full load, the production of pollutants does not change much; only carbon monoxide is reduced to zero.

Considering the advantages and disadvantages of combining fuel in conventional combustion engines, this method can be considered as one of the most practical ways to reduce emissions of these engines.

There are currently different ways to reduce the pollution caused by intrinsic combustion engines, the use of combined fuels can be the best and least costly of these methods.

List of symbols

CO : Carbon monoxide emissions (mass fraction)

CO_2: Carbon dioxide emissions (mass fraction)

HC: Emissions of unburned hydrocarbons (mass fraction)

NO_X : Nitrogen oxides emissions (PPM)

V_s : The linear velocity of the piston (m/s)

P_{mot} : Cylinder pressure in the engine case handling (kpa)

N : Engine Rotate Speed (RPM)

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V_s : The linear velocity of the piston (m/s)

$M_{delivery}$: Relivered mass (kg)

T_r : Reference temperature (0ºc)

Vr,1: Volume when Inlet valve close (m^3)

P_{mot}: Cylinder pressure in the engine case handling (kpa)

Tr,1: Temperature when Inlet valve close (ºk)

Pr,1: Pressure when Inlet valve close (kpa)

P_r: Reference pressure (1bar)

E: Experimental

S: Simulated

Greek Symbols

η_v : Volumetric efficiency (m3/s)

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