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A Simulation Study on Performance and Emission Characteristics of a Gasoline Fuelled Motorcycle FI Engine using the Different Mixtures of Gasoline-Ethanol

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Abstract: Using ethanol as an alternative fuel is a good solution to solve crude oil depletion problem because it has several physical and chemical properties similar to pure gasoline. The most common way to use ethanol in SI engine is blend it with gasoline. In this study, the effects of ethanol-gasoline fuel blends (with different blend ratios, E0, E10, E20, E30 and E50) on performance characteristics of a gasoline fuelled motorcycle FI engine were investigated. AVL Boost was used as a computational fluid dynamics simulation tool not only to analyse the performance but also the emissions characteristics for different blends of ethanol and gasoline.

Keywords: *Alternative fuels, Ethanol-gasoline, Motorcycle engine, Simulation study*

Introduction:

Today, finding for alternative fuels to replace gasoline is a necessity because of petroleum depletion, if this issue is not resolved it could lead to an energy crisis in many country. Ethanol is one of the best candidates to be an alternative fuel. The reasons are ethanol not only has high octane number, good antiknock characteristic, but also its auto-ignition temperature and flash point are higher than gasoline, which make it safer for transportation and storage. Another feature of ethanol is that it can be used directly without requiring any major changes in the structure of the engine. Last but not least, it could renewable from natural products or waste materials.

Although having these advantages, ethanol still could not be used extensively because of some drawback could happen with use pure ethanol in the internal combustion engine, therefore the easiest way to use ethanol in internal combustion engine is blend ethanol with gasoline. The heating value of ethanol is lower than that of the gasoline. Therefore, we need 1.6 times more alcohol fuel to achieve the same energy output. The stoichiometric AFR (air–fuel ratio) of ethanol is about 2/3 that of the gasoline, so the required amount of air for complete combustion is lesser than pure gasoline [1].

There are a lot of scientific papers study about blends of ethanol and gasoline. Palmer [2] studied the effect of using various blend rates of ethanol-gasoline fuels in engine test and results indicated that 10% ethanol addition increases the engine power output by 5%. The results also indicated that with 10% of ethanol addition to gasoline could reduce the concentration of CO emissions. The reduction of CO emissions are apparently caused by the wide flammability and oxygenated characteristic of ethanol.

The gasoline engine performance theory to link together with computer modelling of the engine thermodynamics in engine simulations are a great challenge. Engine modelling is a very large subject because of the range of engine configurations possible and the variety of alternative analytical techniques.

Nowadays, engine simulation is becoming an increasingly important engineering tool for time and cost efficiency in the development process of internal combustion engines. By using high speed computers and advances in computational methods has made it possible for the researchers to simulate and analyse complex processes happen inside the engine. The large number of results that are obtained by simulation are rather very difficult to be obtained experimentally.

Many processes in the engines are complicated so the researchers need to use 3D (three-dimensional) simulation to describe them exactly, but it requires greater knowledge and large computational time. Thus simplified 1D simulation is often used. This paper aims to develop the 1D combustion model of four-stroke gasoline port fuel injection motorcycle engine for predicting the effect of ethanol–gasoline fuel blends with different ratio by volume (E0, E10, E20, E30 and E50) on the performance characteristics of the engine.

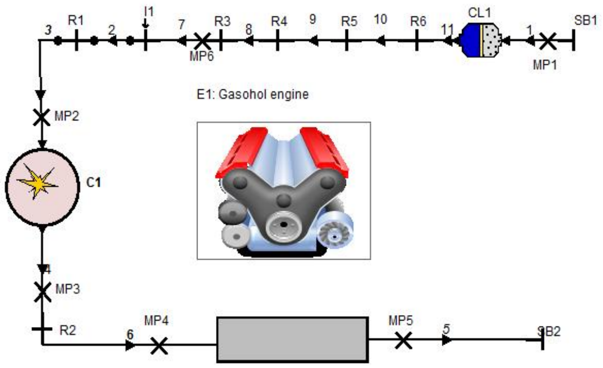

Figure 1: Simulation model of a gasoline fuelled motorcycle FI engine.

Simulation model:

Engine simulation model built on AVL BOOST software. It will study on the characteristics of power and emissions in SI engine when using gasoline-ethanol blended.

Engine in this simulation model had 4 stroke, one cylinder spark ignition with port fuel injection. The Engine Specifications is given in Table 1.

Table 1: Test Engine Specification

S. No	Type	
1	Bore (mm)	53.5
2	Stroke (mm)	55.2
3	Compression ratio	9.6
4	Connecting rod length (mm)	110
5	Maximum power (KW)	6.9
6	Maximum torque (N.m)	9.2

The model can be designed by placing the elements in the working area first and the connecting them with the pipes. The Figure 1 displays the created model. The model consists of the following elements: 2 System Boundaries (SB), 1 Air Cleaner (CL1), 1 Cylinder (C1), 1 injector (I1), 1 Plenums (PL1), 6 Restrictions (R), 6 Measuring points and 11 Pipes (Numbers).

Emission formation model:

The NOx formation model implemented in BOOST is based on Pattas and Häfner [7]. The following reactions (based on the well-known Zeldovich mechanism) are taken into account (Table 2):

$$r_{NO} = C_{PostProcMult} . C_{KineticMult} . 2.(1-\alpha^2). \frac{r_1}{1+AK_2} . \frac{r_4}{1+AK_4} \qquad (1)$$

$$\alpha = \frac{c_{NO,act}}{c_{NO,equ}} . \frac{1}{c_{PostproMult}} . AK_2 = \frac{r_1}{r_2+r_2} . AK_4 = \frac{r_4}{r_5+r_6} \qquad (2)$$

Where

$C_{PostProcMult}$: Denotes Post Processing Multiplier

$C_{KineticMult}$: Denotes Kinetic Multiplier

c : Denotes molar concentration in equilibrium

ri : Denotes reactions rates of Zeldovich mechanism

The CO formation model implemented in BOOST is based on Onorati *et al.* (2001). The final rate of CO production/destruction in [mole/ cm3s] is calculated as:

$$r_{CO} = C_{Const} .(r_1 + r_2).(1-\alpha) \qquad (3)$$

$$\alpha = \frac{c_{NO,act}}{c_{NO,equ}} \qquad (4)$$

Where

c : Denotes molar concentration in equilibrium

ri : Denotes reactions rates based on the model

The process of formation of unburned hydrocarbons in the crevices is described by assuming that, the pressure in the cylinder and in the crevices is the same and that the temperature of the mass in the crevice volumes is equal to the piston temperature. The mass in the crevices at any time period is given by Equation (5):

$$m_{crevice} = \frac{p.V_{crevice}.M}{R.T_{piston}} \qquad (5)$$

$m_{crevice}$: Denotes mass of unburned charge in the crevices [kg]

p : Denotes cylinder pressure [Pa]

$V_{crevice}$: Denotes total crevice volume [m 3]

M : Denotes unburned molecular weight [kg/kmol]

R : Denotes gas constant [J/(kmol K)]

T_{piston} : Denotes piston temperature [K]

Table 2: Six Reactions Based on Zeldovich Mechanism

	Stoichiometry	Rate $k_i = k_{0,i}.T^a . e^{(-TAi/T)}$	K_0[cm^3,mol,s]	a[-]	T_A[K]
R1	$N_2 + O = NO + N$	$r_1 = k_1 . c_{N2} . c_O$	4.93E 13	0.0472	38048.01
R2	$O_2 + N = NO + O$	$r_2 = k_2 . c_{O2} . c_N$	1.48E 08	1.5	2859.01
R3	$N + OH = NO + H$	$r_3 = k_3 . c_{OH} . c_N$	4.22E 13	0	0
R4	$N_2O + O = NO + NO$	$r_4 = k_4 . c_{N2O} . c_O$	4.58E 13	0	12130.6
R5	$O_2 + N_2 = N_2O + O$	$r_5 = k_5 . c_{O2} . c_{N2}$	2.25E 10	0.825	50569.7
R6	$OH + N_2 = N_2O + H$	$r_6 = k_6 . c_{OH} . c_{N2}$	9.14E 07	1.148	36190.66

Results and Discussion:

This simulation study concentrated on the performance characteristics and emission of the ethanol-gasoline blends. Different concentrations of the blends 0% Ethanol (E0), 10% Ethanol (E10), 20% Ethanol (E20), 30% Ethanol (E30) and 50% Ethanol (E50) by volume were analysed using AVL BOOST at full load conditions for the speeds ranging from 1000 - 9000 rpm in the steps of 1000 rpm. The results are divided into different subsections based on the parameter analysed.

Engine performance characteristics

The results of engine power, torque, and specific fuel consumption for ethanol gasoline blended fuels at different engine speeds are shown here.

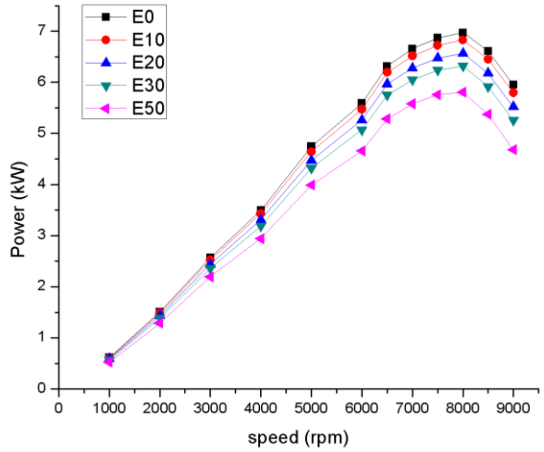

Figure 2: Influence of ethanol gasoline blended fuels on engine brake power.

Figure 2 shows the influence of ethanol gasoline blended fuels on engine brake power. The brake power is one of the most important factors that determine the performance of an engine. The variation of brake power with speed was obtained at full load conditions for ethanol-gasoline blended with different ratio from E0 (0% Ethanol) to E50 (50% Ethanol). The engine brake power decreased for all engine speeds as the volume percentage of ethanol increased in the mixture. The maximum brake power of the engine drop down from 6.97 kW with E0 to 5.81 kW with E50 at 8000 rpm, it also mean that the engine maximum brake power drop down 16.64% when use E50 to replace pure gasoline. The reason of this result is adding ethanol to blended fuel can lead to better combustion but the heating value of ethanol is lower than gasoline and it can be neutralize the positive effects. As a result, a lower power output is obtained.

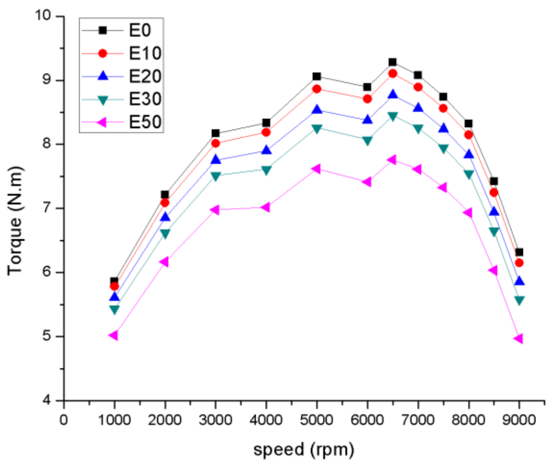

Figure 3: Influence of ethanol gasoline blended fuels on engine torque.

Figure 3 shows the influence of ethanol gasoline blended fuels on engine torque. Similar to the result of engine brake power, engine torque also decreased for all engine speeds when the ethanol content in the blended fuel was increased. The brake torque of pure gasoline (E0) was the highest one. Because of the existence of oxygen in the ethanol chemical component and the increase of ethanol, lean mixtures are produced that decrease equivalence air-fuel ratio to a lower value.

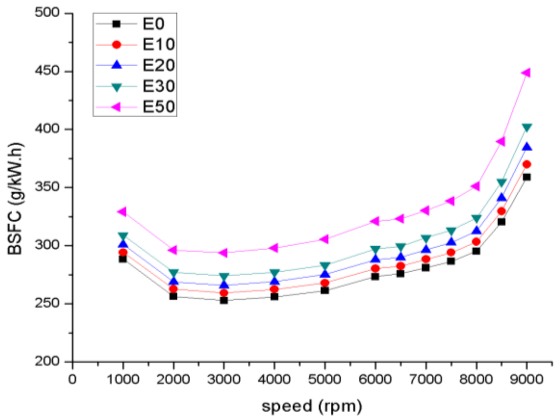

Figure 4: Influence of ethanol gasoline blended fuels on brake specific fuel consumption.

Figure 4 shows the variations of the BSFC for ethanol gasoline blended fuels under various engine speeds. As shown in figure 4 the BSFC increased as the ethanol percentage increased. This behaviour is attributed to the heat value per unit mass of ethanol, which distinctly lower than that of the gasoline fuel and stoichiometric air-fuel ratio are the smallest for these two fuels, which means that for specific air-fuel equivalence ratio, more fuel is needed. The highest specific fuel consumption is obtained at E50.

Emissions characteristics

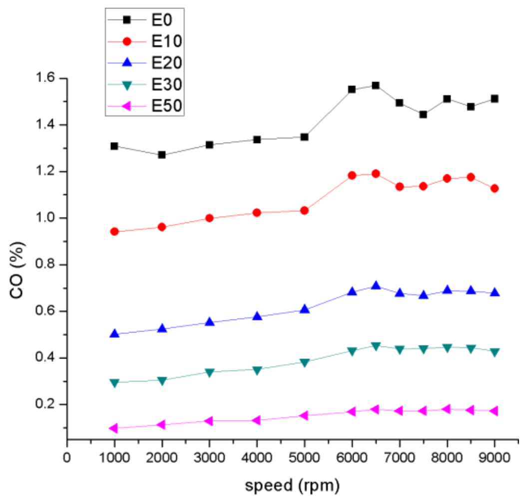

Figure 5: Influence of ethanol gasoline blended fuels on CO emissions.

Figure 5 indicates the effect of ethanol gasoline blended fuels on CO emissions for different engine speeds. It's easy to realize that when the ethanol percentage increase, the CO concentration decreases. This can be explained by the enrichment of oxygen owing to the ethanol, it can provide more oxygen for the combustion process which will promote the further oxidation of CO during the engine exhaust process. Another reason for this reduction is that ethanol (C_2H_5OH) has less carbon than gasoline (C_8H_{18})

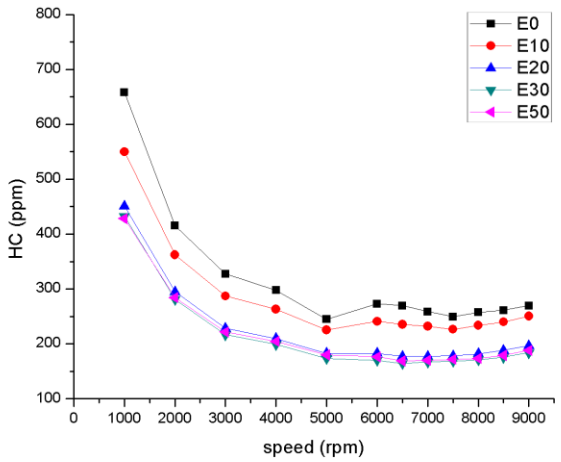

Figure 6: Influence of ethanol gasoline blended fuels on HC emissions.

The effect of the ethanol gasoline blends on HC emissions for different engine speeds is shown in Fig. 6. It can be seen that the HC concentration decreases as the percentage of ethanol increases. The reason for the decrease of HC concentration is similar to that of CO concentration already described above.

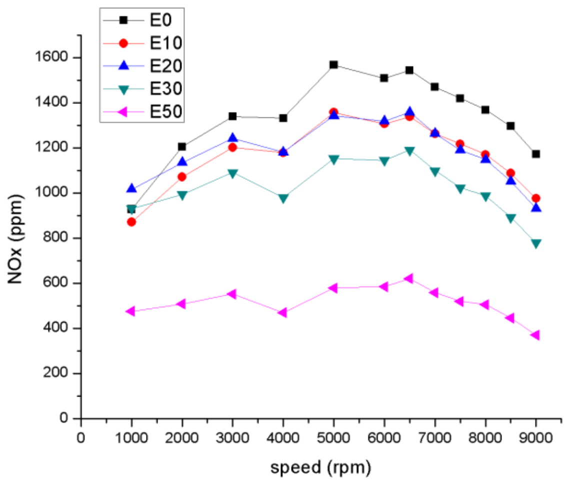

Figure 7: Influence of ethanol gasoline blended fuels on NOx emissions.

Figure 7 shows the effect of ethanol-gasoline blending fuels on NO_x emissions for different engine speeds. It can be seen that when percentage of ethanol increases, the NO_x concentration increases. The cause of this issue is closer to stoichiometric, the temperature of flame inside the combustion chamber increases, and therefore, the NO_x emissions are increased.

Conclusion:

This simulation study demonstrates the influences of ethanol gasoline blended fuels on a gasoline fuelled motorcycle single cylinder FI engine performance and emission characteristics. Ethanol gasoline blended fuels give lower engine brake power and brake torque and higher BSFC than those of pure gasoline.

For the emission characteristics, CO and HC concentration decreases as the volume percentage of ethanol is increased in the mixture, whereas the NO_x emission increases with the increases of ethanol percentage.

Acknowledgement

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