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Effects of high ethanol content blended fuels on performance and emissions of a conventional SI engine

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Abstract

The use of biofuels is not only a potential solution for satisfying the fuel demand but also for reducing emissions from vehicles which cause environmental pollution and adverse health effect. As many countries in the world, Vietnam has been considering ethanol and ethanol-gasoline blends as fuels for vehicles, and the road map for E5 and E10 utilization has been approved recently. In order to increase the ability to substitute ethanol for conventional gasoline, this study aims to experimentally investigate the engine performance and emissions of a conventional SI engine using E0, E30, E50, E85 without engine modification. Results show that at the same throttle valve opening the higher ethanol content in blends, the lower engine torque and the higher fuel consumption. For emissions, blends with high ethanol content reduce significantly CO and HC but increase NO_x; however NO_x emissions reduce with E85.

***Keywords**:* Ethanol-gasoline blends, engine performance, exhaust gas emissions, combustion characteristics.

1. Introduction

The use of biofuels is not only a potential solution for satisfying the fuel demand but also for reducing emissions from vehicles which cause environmental pollution and adverse health effect. There are many kinds of biofuels in which bioethanol seem to be the most popular one. Bioethanol may be produced from various feedstocks such as sugar cane, corn, cassava, molasses, cellulose…by fermentation. So far many studies have been carried out to investigate the effect of ethanol-gasoline blends on performance and emissions of spark ignition engines. It was noted that engine performance and emissions were improved and engines did not need any modification with up to 10% of ethanol in blend [1-4]. However, with higher ethanol content such as E20 and over, some engine modification may be necessary in order to improve thermal efficiency, to maintain engine power as well as material compatibility of engine components [2,5-7].

As many countries in the world, Vietnam has been considering ethanol and ethanol-gasoline blends as fuels for vehicles, and the road map for E5 and E10 utilization has been approved recently. According to the road map, E5 will be mandatory used from 2015 and E10 from 2017.

In order to increase the ability to substitute ethanol for conventional gasoline, this study aims to experimentally investigate the engine performance and emissions of a conventional SI engine using E0, E30, E50, E85 without engine modification.

2. Experimental

2.1. Experimental apparatus

The experimental set up consisted of an engine, engine test bed and exhaust measurement system as shown in Fig. 1. The test engine was Toyota 1NZ-FE engine which is a 4 cylinder, 1.5 liter, multi point injection spark-ignition engine. It has compression ratio of 10.5:1, and rated power is 79kW at 6000rpm. The engine was coupled to an electrical dynamometer which provided brake load. The consumptions of fuel and air were measured by an AVL fuel balance and air flow meter. The cylinder pressure was also detected by a piezoelectric pressure sensor.

For emissions analysis, an AVL Combustion Emission Bench (CEB II) was installed and sampled the raw exhaust gas at the tail pipe. The CEB II comprises analysers for HC, CO and NO_x emission measurements. CO emission was analyzed by using Non Dispersive Infrared (NDIR) analyzers. HC emission was analysed by a Flame Ionization Detector (FID) and NO_x by a Chemiluminescence detector (CLD). Each analyser has 4 measurement ranges that can be adjusted automatically to consist with measured values in order to increase the accuracy.

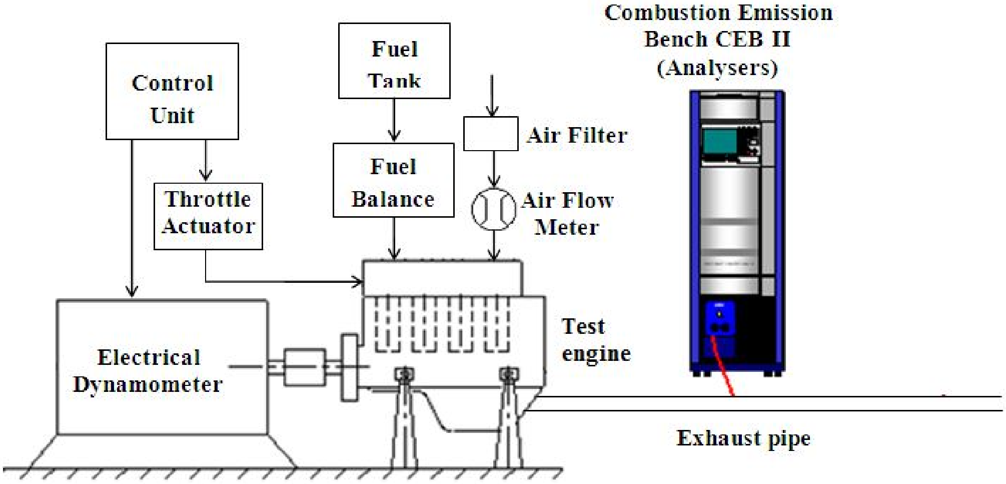

Fig. 1 Experimental setup

2.2. Test cases examined

The experiments were conducted at six different engine speeds ranging from 1000 rpm to 3500 rpm with the increment by 500 rpm, and at two positions of throttle valve: 40% throttle valve opening (40%OT) and wide throttle valve opening (WOT). At each of these engine speeds, the different blends of ethanol and gasoline were tested without any engine modification. Two selected positions of throttle valve were representative of middle load and full load conditions. Before measuring with a new fuel blend, the engine was run for sufficient time to consume the remaining fuel from the previous experiment.

2.3. Test fuels

Test fuels included unleaded gasoline RON92 (E0), blends of ethanol and gasoline which are E30, E50 and E85. Some main specifications of E0 and original ethanol E100 which were specified by our side for this study are listed in Table 1.

Table. 1 Test gasoline and original E100 specifications

Fuel property	E0	E100
Heating value (MJ/kg)	42.6	26.9
Octane number (RON)	92.4	113.3
Density at 15°C (kg/m^3)	730	789
Vapor pressure Reid (kPa at 37.8^{0}C)	60.4	15.7
Sulfur content (ppm)	213	12
Water content (%)	N/A	0.09
Oxygen content (%w/w)	1.6	34.7

3. Results and discussion

3.1 Effects of ethanol-gasoline blends on engine performance

Fig. 2 shows the engine torque of the test engine using E0, E30, E50, E85 at 40% and 100% throttle valve opening (40%OT and WOT). However, the engine could not run with E85 at WOT due to too lean intake mixture, so that the torque output at this throttle valve position is not displayed. In general at the same throttle valve opening, engine torque of gasoline is higher than that of the blends. On average, the torque with E30 just slightly reduces by about 2% whereas it reduces by 11% with E50 and up to 34.4% with E85 at both position of throttle valve as compared to E0. That is mainly due to the lower heating value of ethanol that leads to lower heating value of the blends. Fig. 3 shows the specific fuel consumption (SFC) of engine with different blends. As a result of the lower heating value, SFC with blends is higher than that with gasoline. At 40% throttle valve opening, the SFC increases by 4.4%, 19.1% and 58.9% with E30, E50 and E85 fueling, respectively. And at WOT, the value is 3.0% and 15.3% with E30 and E50. Normally, engine operates at fuel-rich condition at WOT to achieve rated power, and in this case the oxygen content in blends helps to enhance the complete combustion. So that the increase in SFC at WOT is a bit lower than that at 40% throttle valve opening.

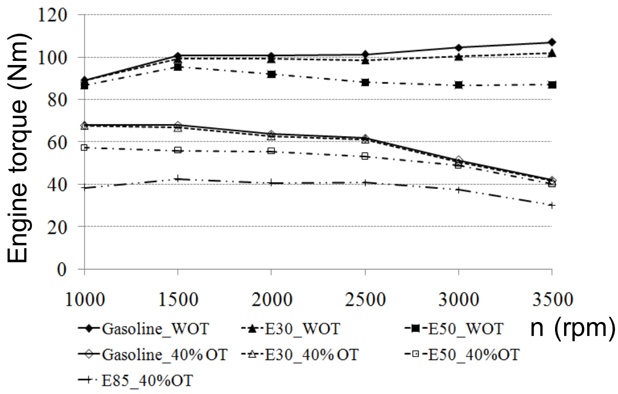

Fig. 2 The effect of blends on engine torque

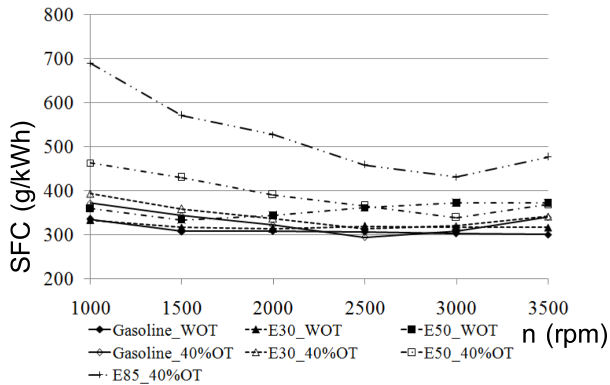

Fig. 3 The effect of blends on SFC

Fig 4 presents the cylinder pressure at 40%OT and WOT. At 40% OT, the peak pressure reduces consistent with lower heating value of blends. The crank angle at which the peak pressure occurs tends to increase when increases the ethanol percentage that means the combustion duration is prolonged. The prolonged combustion can be seen more clearly at WOT. Normally, at WOT the ignition timing is retarded by electronic control unit (ECU) because of more fuel injected and easier combustion. However with the blends, the prolonged combustion causes the peak pressure appears too late, even at the time when piston goes down and the cylinder volume increases. Therefore, the peak pressure is low, even lower than peak pressure of compression process as with E50.

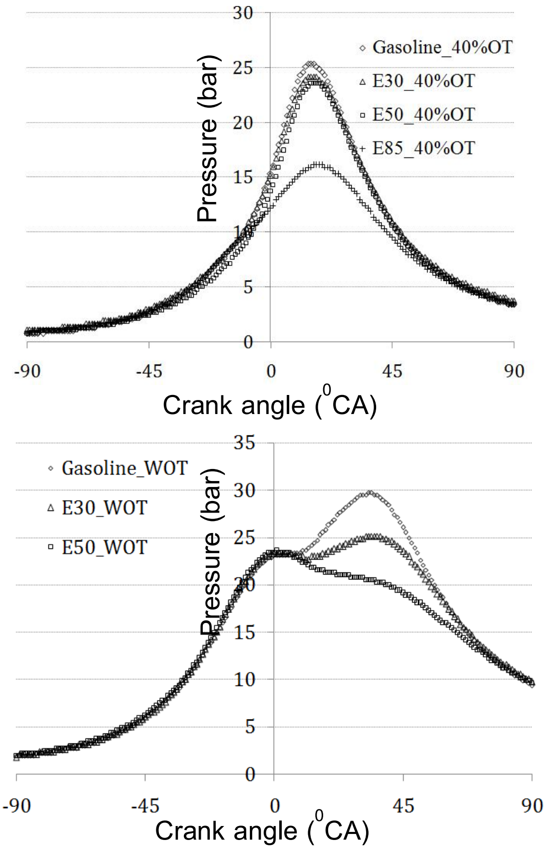

Fig. 4 The effect of blends on cylinder pressure

3.2 Effects of ethanol-gasoline blends on exhaust gas emissions

Figs. 5-6 show the influence of blends on CO and HC emissions. These emissions reduce significantly at all speed range and position of throttle valve, especially for CO, when engine fueled by the blends. It can be seen that the higher ethanol content in blends, the lower CO and HC emissions in exhaust gas. As compared to gasoline on average over speed range, CO emission reduces by 79.3%, 95.5% and 96.2% with E30, E50 and E85 at 40%OT and 86.1% and 96.0% with E30 and E50 at WOT, respectively. Similarly but lower drop, HC emission reduces by 26.5%, 54.0% and 55.6% with E30, E50 and E85 at 40%OT and 12.2% and 43.0% with E30 and E50 at WOT. This result is caused by the oxygen content in blends which may reduce the rich fuel region in combustion chamber and provide proper combustion. The result is also consistent with some previous studies [5,7].

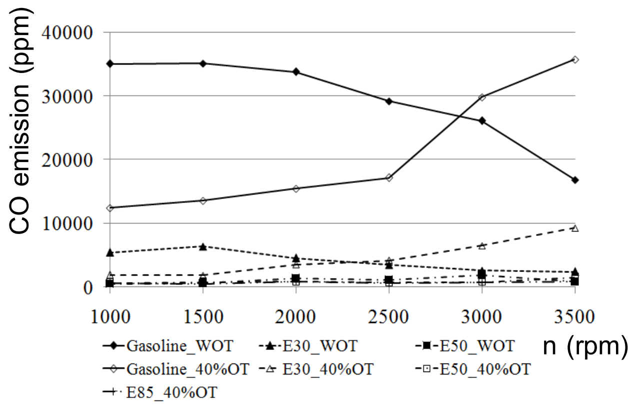

Fig. 5 The effect of blends on CO emission

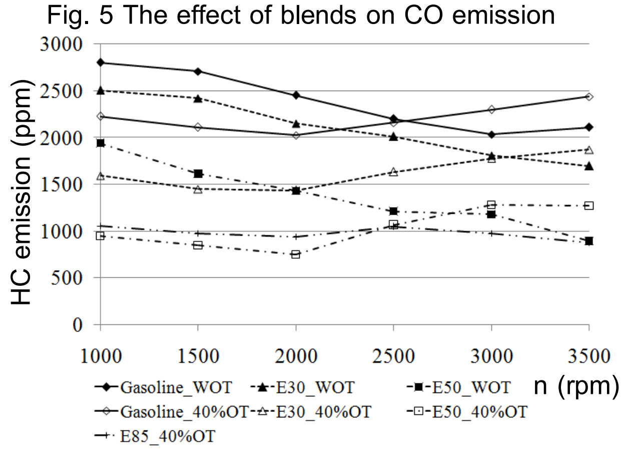

Fig. 6 The effect of blends on HC emission

Other significant emissions are nitric oxides. While nitric oxide (NO) and nitrogen dioxide (NO_2) are usually grouped together as NO_x emissions, NO is the predominant oxide of nitrogen produced inside the engine cylinder. NO_x emission formation is highly dependent on combustion temperature, along with the concentration of oxygen present in combustion products. The effect of ethanol-gasoline blends on NO_x

emissions at 40%OT and WOT is displayed in Fig.7. With the high oxygen content, it is observed that the blends, but except for E85, produce much higher NO_x as compared to gasoline, especially at WOT. On average over speed range at WOT, NO_x emissions increase by 213.2% and 184.8% with E30 and E50. These values at 40%OT are 114.7% and 48.1% with E30 and E50. However at this position of throttle valve, NO_x reduces by 80% with E85 that may be caused by lower peak combustion temperature.

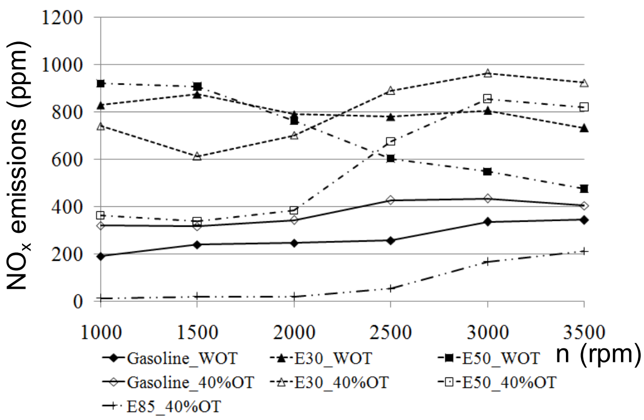

Fig. 7 The effect of blends on NO_x emissions

4. Conclusions

The effects of ethanol-gasoline blends including E30, E50, E85 on performance and emissions of SI engine without any engine modification are studied at different positions of throttle valve. The results show that up to E30, there is not much difference in engine performance. With E50 and E85, the engine torque decreases and fuel consumption increases. These changes can be compensated by supplying more fuel per cycle and advancing the ignition timing. For emissions, high ethanol content blends reduce significantly CO and HC emissions whereas increase quite clearly NO_x emissions, except for E85 with which NO_x emissions reduce, as compared to gasoline.

5. References

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