Effects of Ethanol-Gasoline Blends on Exhaust and Noise Emissions from 4-Stroke S.I.Engine

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Abstract

Considering pollution problems and energy crisis today, investigations have been concentrated on lowering the concentration of toxic components in combustion products and decreasing fuel consumption by using renewable alternative fuels. In the present work, the effect of ethanol addition to gasoline on the exhaust emissions and noise level has been experimentally investigated at various engine loads.

Results of the engine test indicated that using ethanol-gasoline blended fuels increases the power output of the engine dramatically (up to 50 %). While the CO and HC emissions decrease as a result of the leaning effect caused by the ethanol addition; and the CO_2 emission increases because of the improvement of combustion. Also, it was noted that the noise level emission increases slightly with the increase of ethanol content. Finally, the results showed that ethanol can be used as a supplementary fuel to gasoline in modern spark ignition engines without major changes, and it can help to save our environment from toxic pollutants and to save a considerable part of the available oil.

Keywords: **N**oise; **P**ollution; **E**thanol Fuel; **E**nvironmental protection; **F**uel economy

تأثير مزج الايثانول مع الكازولين على الملوثات و الضوضاء لمحرك رباعي الأشواط يعمل بالشرارة

الخلاصة

بسبب مشاكل تلوث البيئة و تحديات نضوب المصادر التقليدية للطاقة, تم إجراء الكثير من البحوث للتقليل من تراكيز المواد السامة في نواتج الاحتراق و للتقليل من استهلاك الوقود باستخدام أنواع متجددة من الوقود كبديل أو مضاف للوقود التقليدي المستخلص من النفط الخام.

في هذا البحث تم دراسة تأثير إضافة الايثانول إلى الكازولين تجريبيا على عوادم محرك رباعي الأشواط يعمل بالشرارة و على الضوضاء المتولدة منه و على أداءه عند أحمال مختلفة.

نتائج البحث بينت إمكانية زيادة قدرة المحرك بصورة كبيرة تصل إلى 50 % و تقليل غازات أول اوكسيد الكاربون و الهايدروكاربونات غير المحترقة و زيادة غازات ثاني اوكسيد الكاربون لتحسن عملية الاحتراق بإضافة الايثانول إلى الكازولين. كما و لوحظ من التجارب زيادة طفيفة في ضوضاء المحرك بزيادة نسبة الايثانول المضاف. أخيرا, النتائج تبين إمكانية استخدام الايثانول كوقود مساند للكازولين في محركات الاحتراق الداخلي لحماية بيئتنا من الملوثات السامة و الضارة و لزيادة عمر مصادرنا التقليدية للطاقة.

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1- Introduction

Considering pollution problems today, investigations have been concentrated on lowering the concentration of toxic components in combustion products. In many areas of the world, there has been tremendous progress in reducing and eliminating the use of lead and methyl tertiary butyl ether (MTBE) in gasoline [1-4]. There is now virtually universal acceptance of the need to eliminate lead and MTBE from gasoline. Numerous researchers [5] in many countries have definitively established its adverse neurological effects, especially on children. When lead is phased out of gasoline, the population's exposure to lead drops in a predictable manner [6]. Even the manufacturer of gasoline lead additives now agrees that their product needs to be phased out [7].

Tetraethyl lead is added to gasoline to provide high octane number. The replacements for lead must therefore have good octane characteristics. ''Octane'' is a measure of the tendency of the air/fuel mixture to resist self-ignition as it is heated during the compression stroke in the engine cylinder. This pre-ignition, or ''knock'', decreases the efficiency of the engine and increases engine wear. The high temperatures and pressures during the compression stroke in the cylinder cause fuel molecules to break down into free radicals (highly reactive molecules with an unpaired electron). Tetraethyl lead scavenges the free radicals, reacting with them before they can build up the chain reaction that causes the pre-ignition. Instead of adding tetraethyl lead, one way to increase the octane value of a gasoline is to change its composition so that it is less likely to generate the free radicals that lead to knock. Molecules with stronger bonds are less likely to break down; strongly bonded hydrocarbons include low bond order hydrocarbons such as ethanol and methyl tertiary butyl ether (MTBE), and hydrocarbons with branched or ring structures [8,9].

The MTBE can present in the exhaust gas when MTBE-containing gasoline is used. The fate of MTBE in the environment is of great concern because a lot of complaints related to irritation effects of MTBE on eyes or lungs were reported in regions using MTBE as gasoline additive [10]. The addition of MTBE into gasoline resulted in a decrease in CO and HC emissions only at high engine loading. During low engine power, MTBE, HC and CO emissions increased with MTBE addition into fuel, and the unburned MTBE constitutes a great percentage of emitted hydrocarbons [10].

However, MTBE is highly soluble in water. Low levels of its concentration make drinking water unpalatable due to its low taste and odor threshold. Moreover, MTBE is much more difficult to be degraded than other gasoline components. Therefore, it has been detected in surface water and ground water because of its widespread use. Beside, MTBE itself is found in exhaust gas and it has irritation effects on eyes or lungs [10,11]. When research animals inhale high levels of MTBE, they will develop cancers or experience other non-cancerous diseases. MTBE even poses a potential for carcinogenicity to humans at high doses [11]. Therefore, it is time to find alternative oxygenates that has no such disadvantages.

Ethanol (C_2H_5OH) is a pure substance. It contains an oxygen atom, which can be viewed as partially oxidized hydrocarbon. Gasoline–ethanol mixtures may be prepared by the addition of a certain percentage of ethanol to the gasoline. Gasoline–ethanol mixtures, which contain up to 20% ethanol by volume, can be safely used without causing any damage to engine parts [11-14]. In this system, depending on the ratio of ethanol, gasoline and water components, it is possible to distinguish the limits of a homogeneous and stable phase. A phase separation is observed in gasoline–ethanol mixtures when the amount of water present in the mixture is over a certain limit. At the phase separation, gasoline, which contains less than 20% ethanol by volume and is also aromatic in character, is said to be more stables [11-15]. As pointed out, in order to be able to use gasoline–ethanol mixtures as a motor fuel, the mixture must be stable and a separation of phases should not occur. In gasoline–ethanol–water systems, the phase separation depends on the ethanol and water content of the blend, the environmental temperature, and the composition of gasoline. In order to reduce the phase separation temperature, higher aliphatic alcohols are usually added to the gasoline–alcohol blends [14,15].

Sustaining a clean environment is an important issue in an industrialized society. The air pollution caused by automobiles and motorcycles is one of the most important environmental problems to be tackled. Since using ethanol–gasoline blended fuels can ease off the air pollution and the depletion of the petroleum fuels simultaneously, much research has been devoted to study the effect of these alternative fuels on the performance and pollutant emission of an engine [11-17].

Alcohol fuels can be produced from renewable resources like locally grown crops and even waste products such as waste paper or grass and tree trimmings [18]. Ethanol is a likely alternative automotive fuel in that it has properties, which would allow its use in present engines with minor modifications [17, 18].

As a fuel for spark-ignition engines, ethanol has some advantages over gasoline, such as better anti-knock characteristics and reduction of CO and UHC emissions. It has a high octane number than gasoline. A fuel with a higher-octane level can endure a higher compression ratio before exploding, giving the engine the ability of delivering more power and thus being more powerful and economical. Ethanol fuels burn cleaner than regular gasoline and produce less carbon monoxide and unburned hydrocarbon. Carbon monoxide is a direct human health hazard, as well as an ozone precursor. Ethanol fuel has high heat of vaporization; therefore, it reduces the peak temperature inside the cylinder and hence reduces the NOx emissions and increases the engine power [11-17].

Some of the combustion characteristics of ethanol such as the auto-ignition temperature and flash point are higher than those of gasoline, which make it safer for transportation and storage. The latent heat of evaporation of ethanol is about 2.5 times higher than that of gasoline, and this reduces the temperature of the intake manifold, and increases the volumetric efficiency. The heating value of ethanol is also lower than that of gasoline. Therefore, about 1.6 times more ethanol fuel needs to achieve the same energy output. Moreover, the stoichiometric air–fuel ratio (AFR) of ethanol is about 2/3 that of gasoline, hence the required amount of air for complete combustion is lesser for ethanol [11-17].

The using of ethanol–gasoline blended fuels increases the emission of formaldehyde, acetaldehyde and acetone up to 5.12–13.8 times than those from gasoline. Although the emission of aldehyde will be increased when ethanol is used as a fuel, the damage to the environment caused by the emitted aldehyde is far less than that caused by the poly-nuclear aromatics emitted from burning gasoline. Therefore, the percentage of ethanol in blended fuel can make the air quality better in comparison to gasoline [11, 16 and 17].

2- Experimental work

The experimental tests started with pure gasoline, which was provided by Al-Khour Refinery (Basra City, Iraq), to set a database level for comparison purposes. Gasoline fuel, the base fuel was mixed with different percentages of ethanol (99.9% purity). Various blend ratios of ethanol-gasoline fuels, (20, 40, 60, 80, and 100% of ethanol in gasoline), have been prepared and then sent to the fuel laboratory of the Al-Khour Refinery for standard properties analysis (Table 1). Some of the combustion-related properties have been summarized in Table 1. The “E” designates ethanol and the number next to E designates the volume percentage of ethanol. The E20 means that 20% ethanol (99.9% purity) was blended with 80% pure gasoline by volume.

The engine performance and pollutants emission tests were carried out at the University of Kufa- college of engineering laboratory, Najaf, Iraq. T85D carbureted single cylinder four-stroke research SI engine with cylinder bore of 70 mm, stroke of 66 mm, displacement of 254 cm^3 and engine speed of 1500 rpm has been used in this research. The engine power has been measured using an electrical dynamometer. The exhaust gas was analyzed for CO and CO_2 by non-dispersive infrared analyzer NDIR, for HC by flame ionization detector FID, Prodit equipment's (model FLUX 2000). A microphone is connected to a PC with sound card and sound recorder and analyzer software, Syntrillium Software Corporation USA ver. 2.1. The engine was operated for a period of 10 minutes to reach steady state operation conditions. Engine temperature was kept under the control during the engine performance test. The tests were conducted two times for each of the test fuels and average of the results was taken. The microphone was fixed close to the combustion chamber wall. For each test, we are waiting for three minutes to let the microphone’s reading reach a steady state conditions (it is indicated by the wave shape and frequency that is measured by software). Figure 1 shows the experimental setup used for the engine test.

3- Results and discussion

Figure 2 shows the effect of the ethanol fuel blending on the air-fuel ratio. It is noted that the air-fuel ratio decreases as the ethanol content increases up to E40. Then, it will increase as the ethanol content increases. Ethanol contains an oxygen atom in its basic form; it therefore can be treated as a partially oxidized hydrocarbon. When ethanol is added to the blended fuel, it can provide more oxygen for the combustion process and leads to the so-called "leaning effect". This indicates that the engine tends to operate in leaner conditions, closer to stochiometric burning as the ethanol content is increased. Its final result is that better combustion can be achieved.

CO is toxic gas that is the result of incomplete combustion. When ethanol containing oxygen is mixed with gasoline, the combustion of the engine becomes better and therefore, CO emission is reduced. The combustion process is more complete when it is closer to stochiometric burning; therefore, the concentration of CO and HC emission decreases. Figures 3 and 4 show the effect of the ethanol fuel blending on the HC and CO emissions. The concentration of HC and CO are decreased as the volume percentage of ethanol fuel is increased in the fuel mixture. This is due to the reduction in carbon atoms concentration in the blended fuel and the high molecular diffusivity and high flammability limits which improve mixing process and hence combustion efficiency (Table 1).

The stoichiometric air–fuel ratio of ethanol is about 2/3 that of gasoline, hence the required amount of air for complete combustion is lesser for ethanol (Table 1). When the engine condition goes leaner, the combustion process is more complete and the concentration of CO_2 emission gets higher (Figure 5).

Figure 6 shows the effect of the ethanol fuel blending on the specific fuel consumption (s.f.c). The s.f.c is slightly increased as the volume percentage of ethanol fuel is increased in the mixture. This is due to the lower heating value of ethanol compared with gasoline (Table 1).

Figures 7 shows the effect of the ethanol fuel blending on the break power. As the ethanol content in the blend fuel increases, power also dramatically increases. The heat of evaporation of ethanol is higher than that of gasoline. High heat of evaporation can provide cooling for fuel–air charge, hence its density increases. Thus higher power output is obtained to some extent. However, power increase starts to decrease when ethanol content is raised to more than 40%. This is due to the lower heating value of ethanol compared with gasoline (Table 1).

Figure 8 shows the effect of the ethanol fuel blending on the volumetric efficiency. The volumetric efficiency is increased as the volume percentage of ethanol fuel is increased in the mixture. The heat of evaporation of ethanol is about 2.75 times higher than that of gasoline (Table 1), and this reduces the temperature of the intake manifold, and increases the volumetric efficiency. However, the volumetric efficiency starts to decrease when ethanol content is raised to more than 40%.

Figure 9 shows the effect of the ethanol fuel blending on the thermal efficiency. The thermal efficiency is increased as the volume percentage of ethanol fuel is increased in the mixture.

The engine noise level was studied at various blend ratios of ethanol-gasoline fuels with different engine loads. Figure 10 shows the measurements of the effect of ethanol blending on the noise level. Each value of noise is made dimensionless by relating it to its value for the gasoline fuel only. It is noted that the noise level emission depends on the engine operating condition rather than the ethanol content. Also, it is seen that there is a slightly increase in the total noise level with the increase in engine load and ethanol content. This is due to the increase in flame speed and hence, the increase in the rate of mass burning due to high burning speed of ethanol-air mixture, which is higher than that of the gasoline-air mixture. Ethanol blending also improves combustion efficiency and therefore the point of maximum rate of heat release is increased due to faster flame front propagation. Therefore the noise level of the ethanol fuel blending was higher than gasoline fuel. This result is clearly explained and approved by Figure 3. Where explain that the fuel combustion process is more complete with ethanol blending fuel.

According to the results of the experiments, it was determined that the most suitable fuel was E40 in terms of power(the increase in output power is about 50%). HC and CO were low with E100 fuel. But power decreased and s.f.c increased extremely with E100 fuel. The noise level of the engine was low with E0 fuel.

4- Conclusion

The engine noise, pollutant emission, and performance of a research SI engine have been investigated by using ethanol-gasoline blended fuels. Experimental results indicated that using ethanol-gasoline blended fuels, the power output, fuel consumption, thermal and volumetric efficiency of the engine increase; CO and HC emissions decrease dramatically as a result of the leaning effect caused by the ethanol addition; and CO_2 emission increases because of the improvement of combustion. It was noted also that the noise level emission depends on the engine operating condition rather than the ethanol content. It is seen that there is a slightly increase in the sound amplitude with the increase in engine load and ethanol content. As well as, the intensity of wave is increased slightly. Finally, the results showed that ethanol can be used as a supplementary fuel to gasoline in modern spark ignition engines without major changes, and it can help to save our environment from toxic pollutants and to save a considerable part of the available oil.

5- Acknowledgments

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Table 1. The properties of gasoline and ethanol

Fuel property	Gasoline	Ethanol
Formula	C8H18	C2H5OH
Molar C/H ratio	0.445	0.333
Molecular weight (kg/kmol)	114.18	46.07
Latent heating value (MJ/kg)	44	26.9
Stoichiometric air/fuel ratio	14.6	9
Auto-ignition temperature (C)	257	425
Heat of vaporization (kJ/kg)	305	840
Density (kg/m^3)	765	785

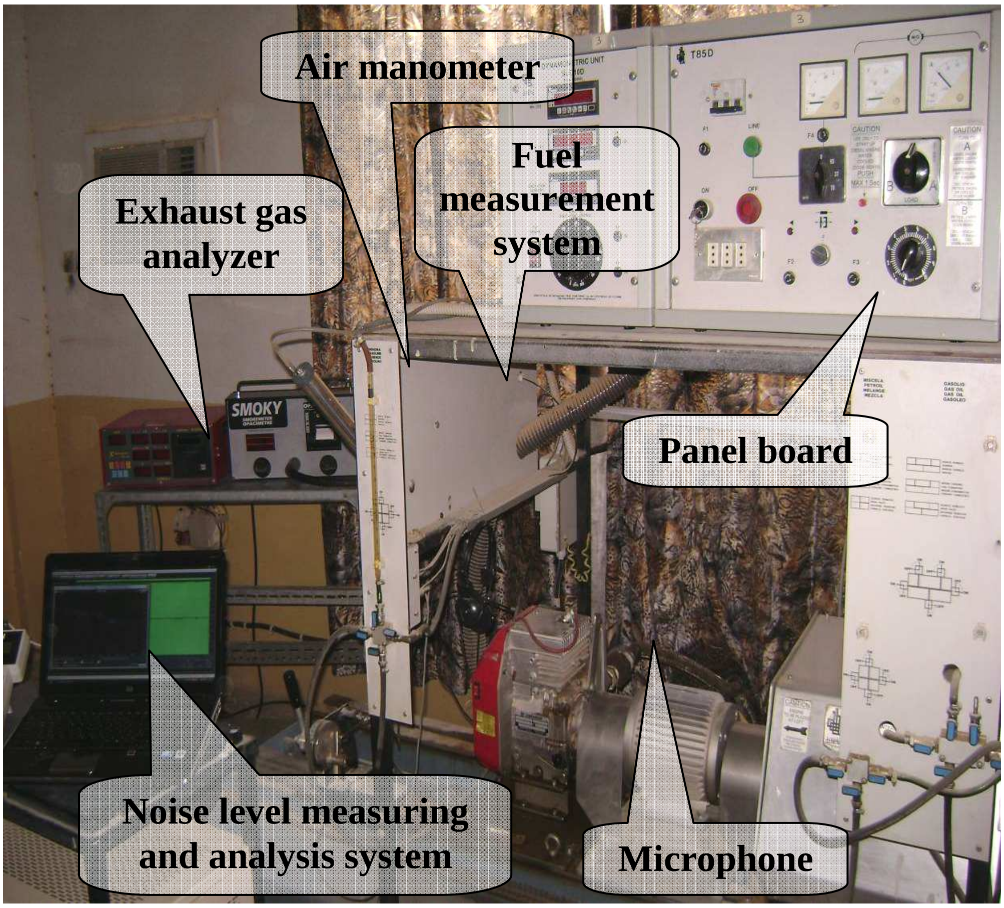

Figure 1. The experimental setup used for the engine test.

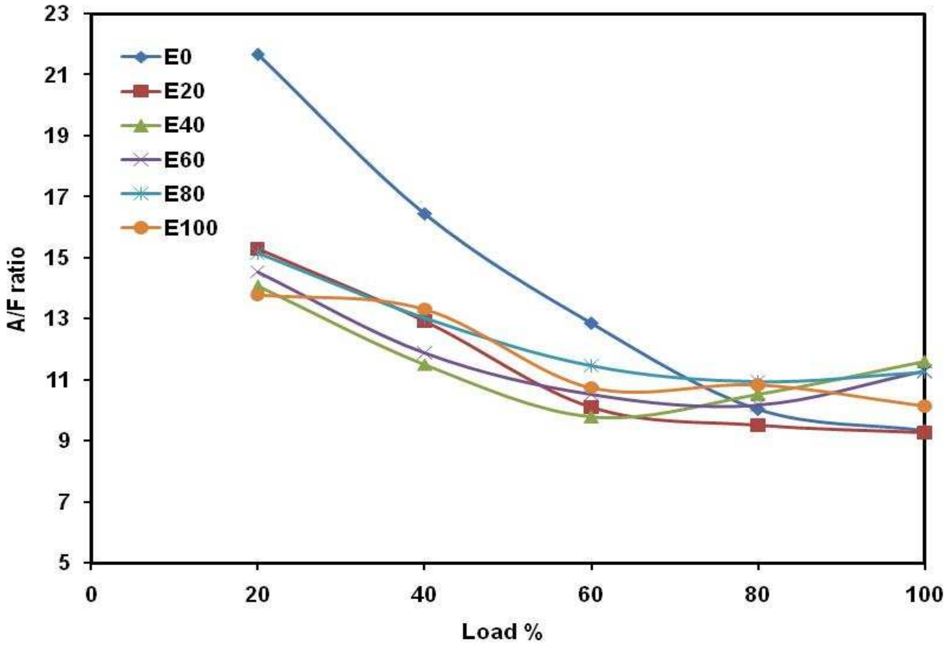

Figure 2. Effect of ethanol blending on the air-fuel ratio at different engine loads.

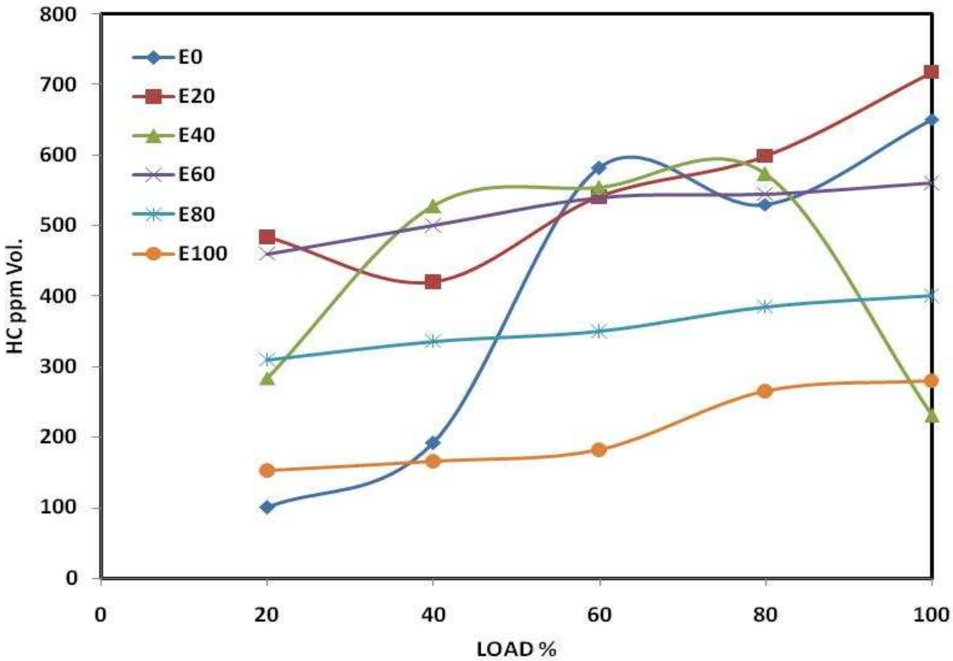

Figure 3. Effect of ethanol blending on the HC emissions at different engine loads.

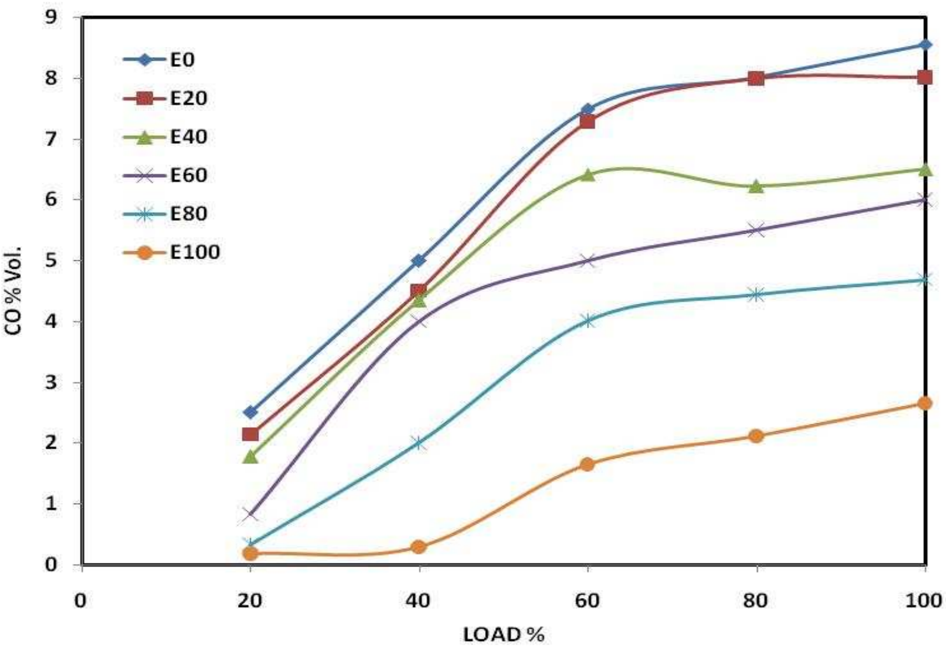

Figure 4. Effect of ethanol blending on the CO emissions at different engine loads.

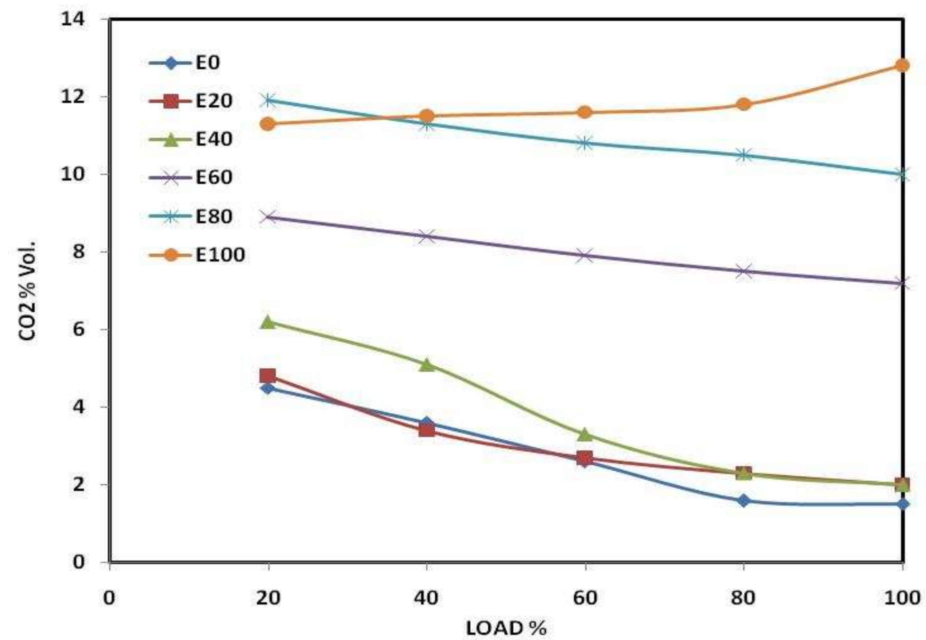

Figure 5. Effect of ethanol blending on the CO_2 emissions at different engine loads.

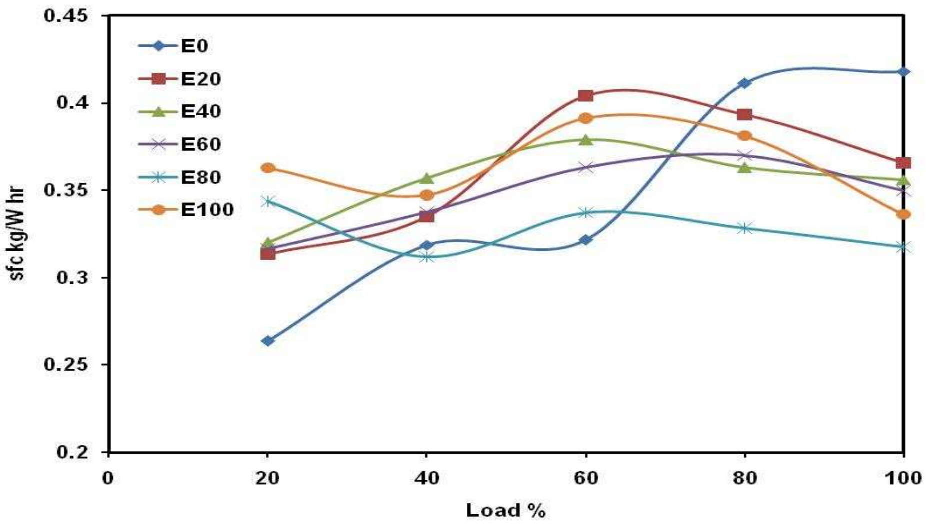

Figure 6. Effect of ethanol blending on the specific fuel consumption at different engine loads.

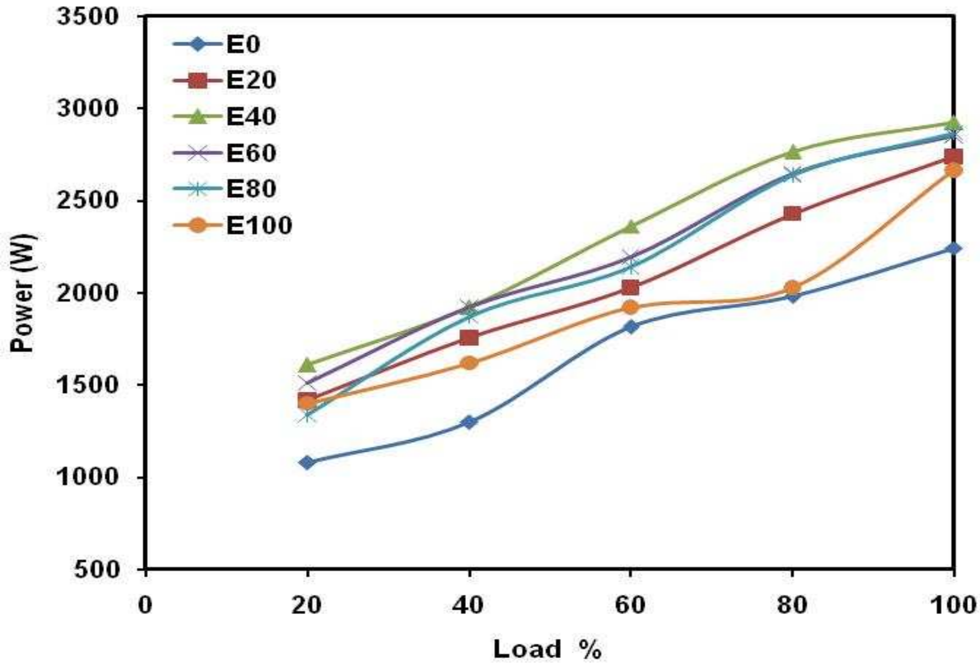

Figure 7. Effect of ethanol blending on the engine power at different engine loads.

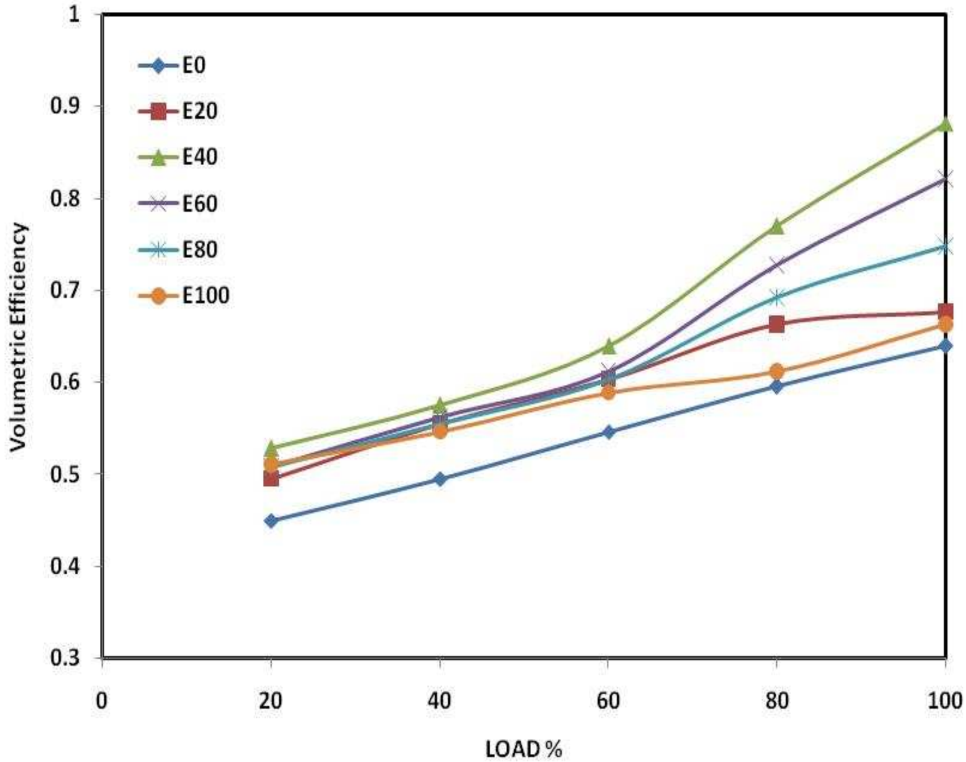

Figure 8. Effect of ethanol blending on the volumetric efficiency at different engine loads.

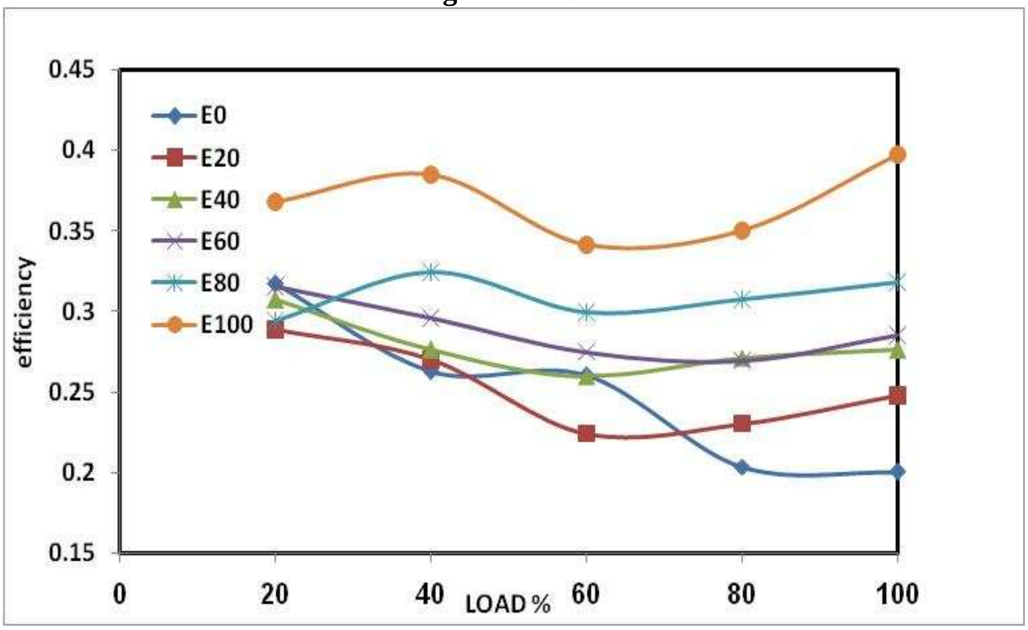

Figure 9. Effect of ethanol blending on the thermal efficiency at different engine loads.

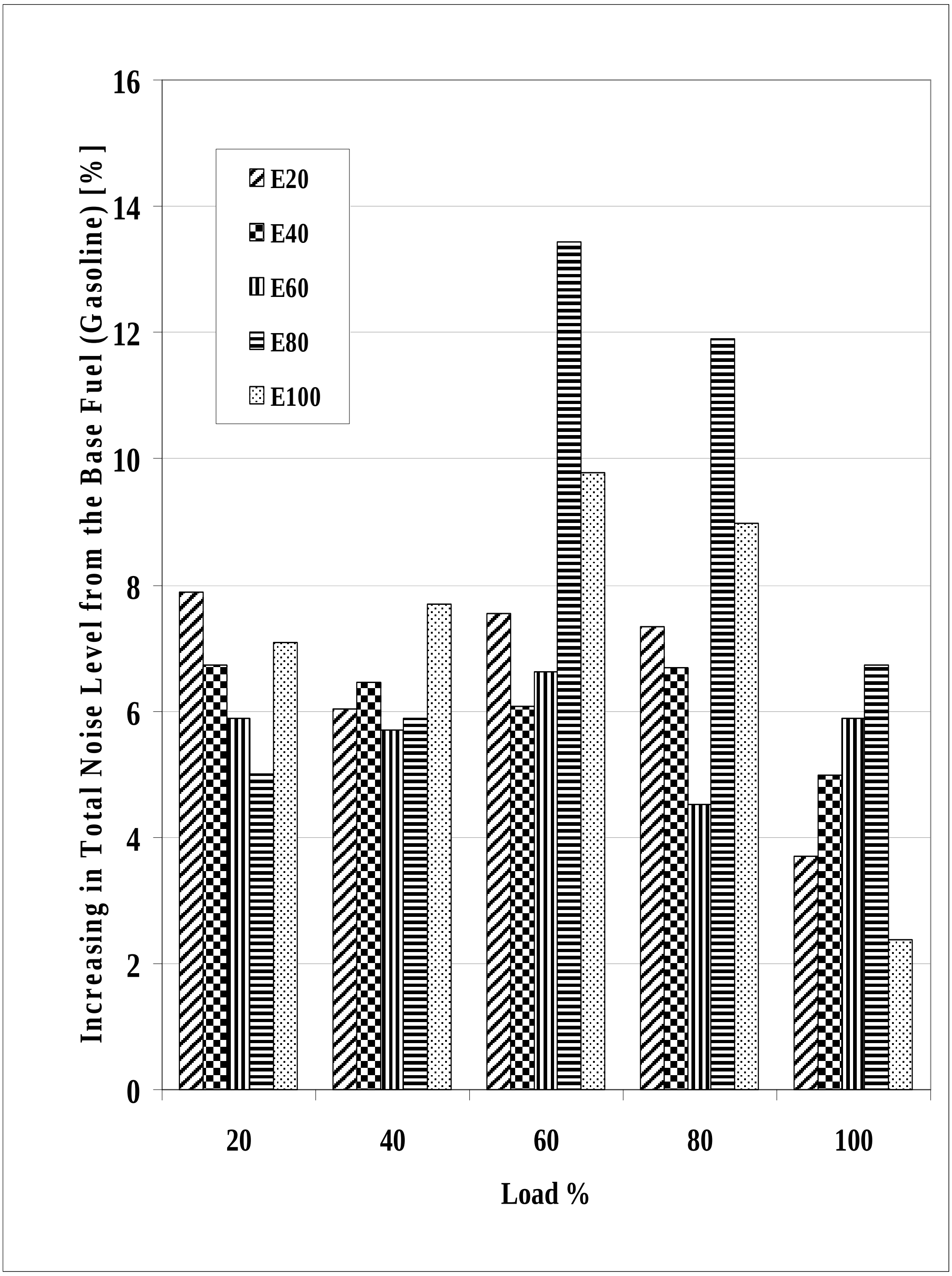

Figure 10. Effect of ethanol blending on the noise level at different engine loads.