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Original Research Article

Investigation of some of the properties of fossil fuels and biofuels blends to use in SI engines

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Abstract

In this research work, gasoline fuel was considered as the base fuel. Bioethanol, biodiesel and diesel fuel were added to gasoline as additives. The fuel blends were first prepared on different volume basis and then, some important properties of the blends including density, dynamic viscosity, kinematic viscosity and water and sediment were evaluated by following ASTM test methods. The obtained data were analyzed and the results showed that increasing the volume percentage of bioethanol, biodiesel and diesel in fuel blends affect the fuel blends properties, these properties helped to identify the effected blended fuels to utilize at SI engine. At second step, 3 optimized blended fuels were selected based on the fuels properties (E20= 20% ethanol and 80% gasoline- GS1=10% ethanol, 2.5% biodiesel, 2.5% diesel and 85% gasoline- GS2= 18.1% ethanol, 4.31% biodiesel, 4.31% diesel and 73.28% gasoline). These optimized blended fuels were utilized in SI engine and the performance and emission parameters were analyzed.

Keywords: Gasoline, Biodiesel, Bioethanol, Diesel, Dynamic viscosity, Kinematic viscosity, Density.

Nomenclature

W	Water and sediment (%V)	E	Bioethanol
DV (μ)	Dynamic viscosity (MPa.s)	B	Biodiesel
KV (ν)	Kinematic viscosity (mm^2/s)	D	Diesel
De (ρ)	Density (g/cm^3)	G	Gasoline

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1. INTRODUCTION

Energy is one of the most vital human asset and a challenging topic in the world. Fossil fuels have provided the largest part of world energy so far. Continuation of using fossil fuels means that the world will encounter many much problems about environment and lack of primal materials. The fuels obtained from sources rather than oil are called alternative fuels. Renewability, lower air pollutant and more economic profits are the advantages of the alternative fuels compare to fossil fuels. Natural gas, propane, ethanol, methanol, hydrogen and biodiesel are the most prevalent alternative fuels [1]. Hitherto, many methods have been used to reduce the environmental pollutant such as engine exhaust emissions. Adding oxygenate components to fossil fuels is one of the most important methods. Among the elements that are used for this purpose, the types of alcohol, biodiesel and ether have high ability to reduce engine exhaust pollutants. For high number of cetane, their ability to reduce pollutions due to lack of sulfur and presence of oxygen are major advantage of these fuels compared to conventional fuels [2, 3]. Ether has a significant effect on quality of exhaust emissions, but its use has been limited because of its negative impacts on environment. Compared to ether, biodiesel produced from vegetable or animal substances and bioethanol produced from plant materials have lower production costs and are environmentally friendly.

In relation to spark ignition (SI) engines, this work is carried out through a combination of alcohol with gasoline. The use of ethanol and gasoline blending fuels in SI engines is studied by many investigators. For ethanol to be mixed with gasoline and ignite in engine, it is necessary to have fuel purity above 95% [4]. There are various methods to reduce the exhaust pollutions of compression ignition engines. These methods can be divided into four techniques: (i) The diesel-biodiesel fuel blend [5-8]; (ii) The diesel-alcohol fuel blend (ethanol or methanol) [9]; (iii) The biodiesel-alcohol fuel blend (ethanol or methanol) [10]; (iv) The diesel-biodiesel-alcohol fuel blend [11-14].

The biodiesel is defined as mono-alkyl esters of fatty acids with long chain that is produced from vegetable oils or animal fats [15]. The biodiesel properties are very similar to diesel fuel and it is used in diesel engines. The bioethanol is the second member of aliphatic-1 alcohols that is produced from plant sugars [15] and has properties similar to gasoline. The bioethanol is generally blended with gasoline and used in gasoline type engines.

In a research work, an experimental investigation was conducted to evaluate the effects of methanol as additive to biodiesel-diesel blends on the direct injection diesel engine performance, emissions and combustion characteristics under variable operating conditions. BD50 (50% biodiesel and 50% diesel in vol) was prepared as the base fuel. The methanol was added to BD50 by volume percent of 5% and 10% (denoted as BDM5 and BDM10). The results indicated that the power and torque outputs for BDM5 and BDM10 were slightly lower than those of BD50. There was a dramatic reduction of smoke emissions with BDM5 and BDM10, but CO, NO_x and HC were almost similar to those of BD50 [11]. In another study it was aimed at evaluation of the spray characteristics and atomization performance of gasoline fuel (G100), bioethanol fuel (E100), and bioethanol blended gasoline (E85) in a gasoline engine. The fuel properties including density, kinematic viscosity, and surface tension for E85 increased as the blending ratio of bioethanol [16]. An experimental investigation was conducted for characterization of the key fuel properties of diesel, methyl ester and their blends. In this study, the methyl esters were produced from five kinds of vegetable oils and blended with diesel fuel by various volume percents. The results indicated that the fuel properties such as density, viscosity, clouding point, distillation temperatures and flash point were very close to those of diesel fuel [17, 5]. In an study, the key fuel properties of diesel-methyl esters blends were measured by following ASTM test methods. The methyl esters were produced from six different vegetable oils and then the blends were prepared on a volume basis. It was found that density and viscosity were increased as the blending ratio of methyl ester [6]. An experimental study was also conducted for characterization of some key fuel properties of diesel-biodiesel-bioethanol blends to evaluate their effects on diesel engine performance. As a result, a new fuel blend called “Diesterol” was developed and used as an alternative fuel [12].

In this research, gasoline fuel was considered as the base fuel. The bioethanol, biodiesel and diesel fuels were added to gasoline as additives. The fuel blends were prepared on different volume basis. Afterwards, some of the important properties of fuel blends including density, dynamic viscosity, kinematic viscosity and water and sediment were evaluated by following ASTM test methods.

2. MATERIALS AND METHODS

2.1. Materials

The biodiesel fuel used in this study was produced from the transesterification of waste cooking oil with methanol (CH_3OH), catalyzed by potassium hydroxide (KOH). The important properties of biodiesel were found out and compared with ASTM D6751 standard. The used gasoline and diesel fuels were the conventional fuels in Iran, purchased from gas station. The bioethanol was also purchased from Bidestan Firm (Iranian firm). The purity of bioethanol was 99.6%. Considering the gasoline as the base fuel, the fuel mixtures were selected as follow:

- According to the results of researches conducted in line with use of bioethanol in gasoline engine, mixing bioethanol with gasoline up to 20% volume does not create a problem in engine and does not need to modify the engine construction [18,19].
- Similarly, mixing biodiesel with diesel fuel up to 20% of volume it is not necessary to modify the diesel engine construction and does not exhibit bad impact on engine performance [7,20].

Therefore, biodiesel and bioethanol were considered from 5-20 volume percent. Accordingly, the volume of the diesel fuel was chosen to be 5-20 percents. So, the volume percentage of gasoline fuel was determined as factorial. After evaluating the properties of gasoline, diesel, bioethanol and biodiesel and comparing their properties with international standards, the fuel blends were provided by the ratios presented in Figure 1.

Fig. 1. The samples of the test fuel blends.

2.2. Methods

In this study, four fuel important properties were measured by ASTM test methods. Each test was carried out in three frequencies by complete random model. The fuel properties measured are water and sediment, dynamic viscosity, kinematic viscosity and density. The density, dynamic viscosity and, kinematic viscosity were measured at 40 ˚C. The ambient temperature was 29-34 ˚C.

The kinematic viscosity is defined as follows:

$\nu = \mu / \rho$ (1)

In this equation,

ν = is kinematic viscosity (mm^2/s)

μ = is dynamic viscosity (MPa.s) and
ρ = is density (g/cm^3).

2.2.1. Density, dynamic and kinematic viscosity

The device used for measuring density, dynamic viscosity and kinematic viscosity is Anton Paar stabinger viscometer model SVM-3000 under ASTM D445 and ASTM D7042-04 standards. This device is able to calculate and display density, dynamic viscosity and kinematic viscosity simultaneously.

2.2.2. Water and sediment

The device that was used for measuring water and sediment is Metrohm Karl Fischer model 794 Basic Titrino under ASTM D2709 standard.
Finally, experimental data were analyzed by means of Excel and Matlab software. So, each fuel blend was denoted by a symbol. Indexes beside each letter represent the volume percentage of fuel mixture. In this case we have a general form including $E_xB_yD_z$.

3. RESULTS AND DISCUSSION

3.1. Results analysis

The experimental data were entered into excel software and their charts were drawn. The charts for each treatments, water and sediment, dynamic viscosity, kinematic viscosity and density, were drawn based on volume percentage of biodiesel and constant volume percentage of diesel fuel. The gasoline values are given in the zero point in all charts. Nomenclature of each of curves in each graph is given according to the chart drawn based on volume percentage of biodiesel and due to constant volume of diesel. For example, Naming $E_{15}D_{10}$ refers to fuels that have 15% volume of bioethanol and 10% volume of diesel. The amount of biodiesel in varies from 5 to 20 percent volume. Next, the analysis of each optional tested parameter is described.

3.1.1. Water and sediment

The curves related to water and sediment versus volume percentage of biodiesel is shown in figs.2 &3.

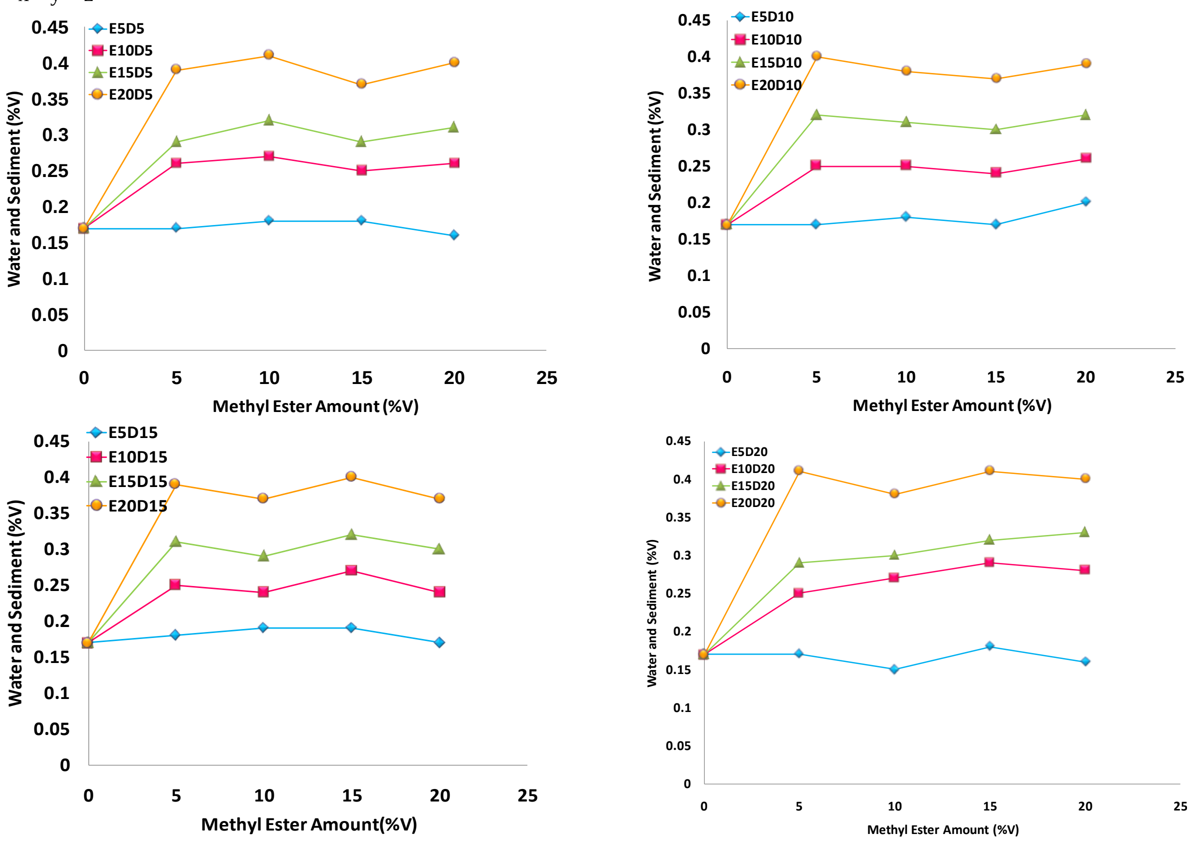

Fig.2. Water and sediment variations of blends with various volume percentages of diesel versus biodiesel volume

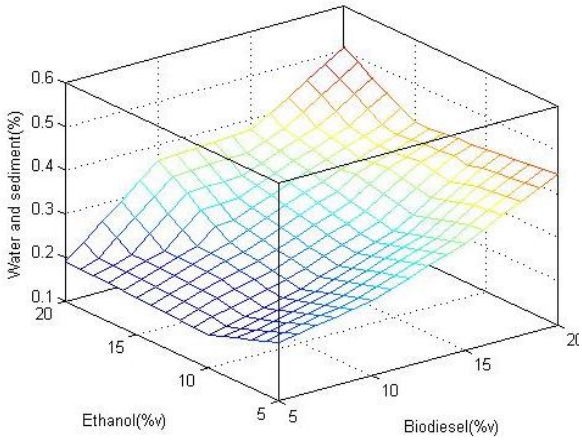

Fig.3. Variations of water and sediment of the blends with various volume percentages of biodiesel and ethanol

Figures 2 and 3 show that with increasing the volume percentage of biodiesel, the amount of water and sediment remains approximately constant. Water and sediment were 0.19% for biodiesel fuel which is a small amount. The changes in water and sediment are constant, because the amount of water and sediment is small for biodiesel fuel and thus it is ineffective on blending of fuels. In addition, in constant volume of biodiesel, with increasing in volume percentage of bioethanol the water and sediment are increased. This rising trend is justified due to the high water and sediment of bioethanol compared to gasoline, biodiesel and diesel fuel. The changes of apparent behavior and curves trend show that a range of water and sediment changes stays constant with increasing the volume of diesel fuel. Little amount of water and sediment of this fuel frustrates its effect on water and sediment changes.

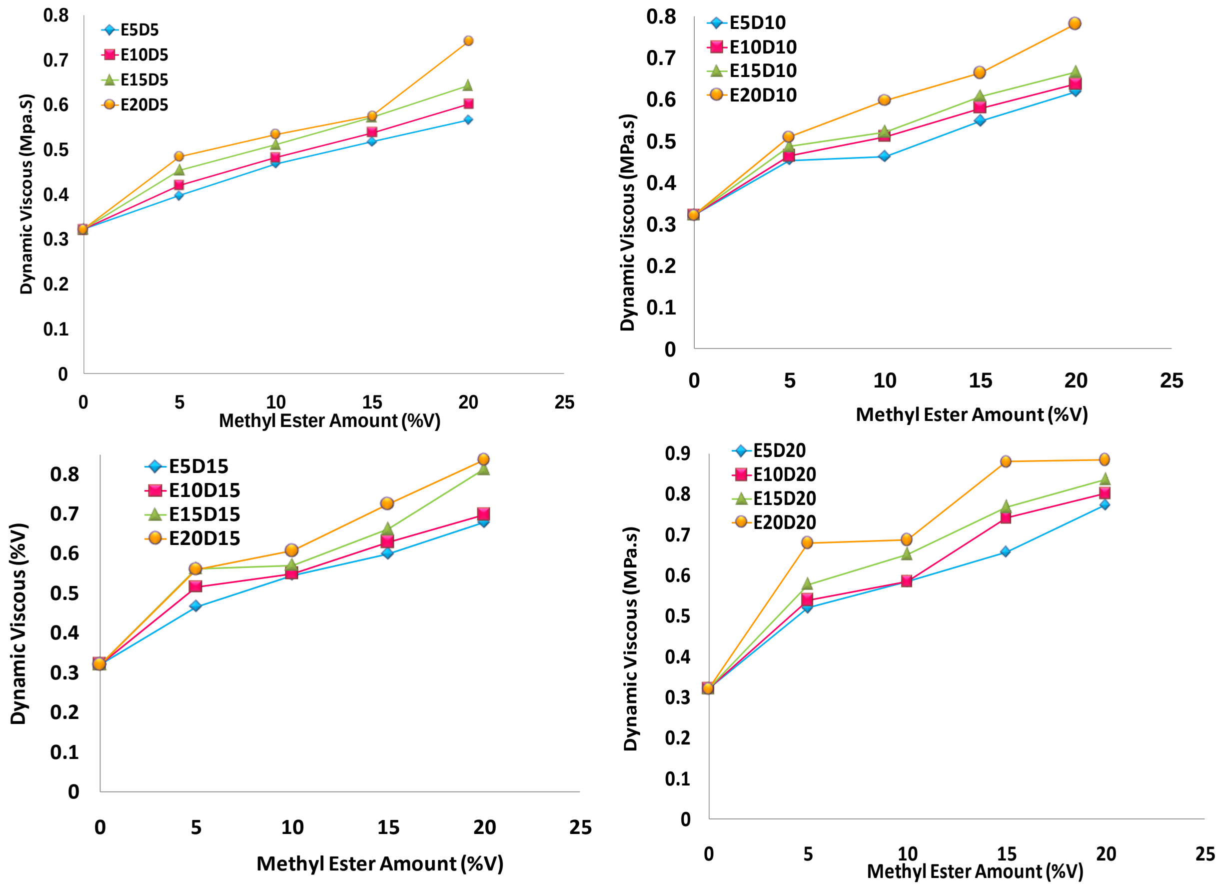

Fig.4. Dynamic viscosity variations of blends with various volume percentages of diesel versus biodiesel volume

3.1.2. Dynamic viscosity

The curves related to dynamic viscosity versus volume percentage of biodiesel is shown in figs.4 and 5. Figure 4 show that with increasing the volume percentage of biodiesel, the amount of dynamic viscosity has a linear rising trend. This could be due to biodiesel with 3.8445 MPa.s has the highest dynamic viscosity in the three other fuels. Pasqualino et al have also in their investigation concluded that with increasing the proportion of biodiesel in the mixture with gasoline, the dynamic viscosity increased [21]. In addition, in constant volume of biodiesel, with increasing the volume percentage of bioethanol the dynamic viscosity increase slightly. This rising trend is justified due to the high dynamic viscosity of bioethanol compared to gasoline fuel.

However, in an experiment on diesel-bioethanol blends, the dynamic viscosity was decreased with increasing in proportion of bioethanol [22]. Its reason was lower dynamic viscosity of diesel compared to bioethanol. The changes of apparent behavior and curves trend show that the range of dynamic viscosity changes increases with increasing in volume of diesel fuel. Their average changes are from 0.5302 to 0.6985 MPa.s.

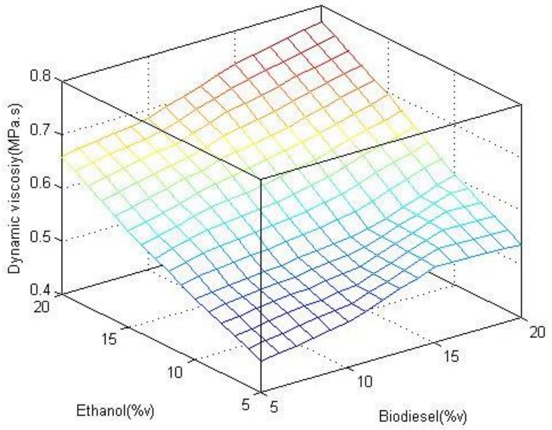

Fig.5. Dynamic viscosity variations of blends with various volume percentages of biodiesel and ethanol

3.1.3. Kinematic viscosity

The curves related to kinematic viscosity versus volume percentage of biodiesel are shown in figs.6 and 7.

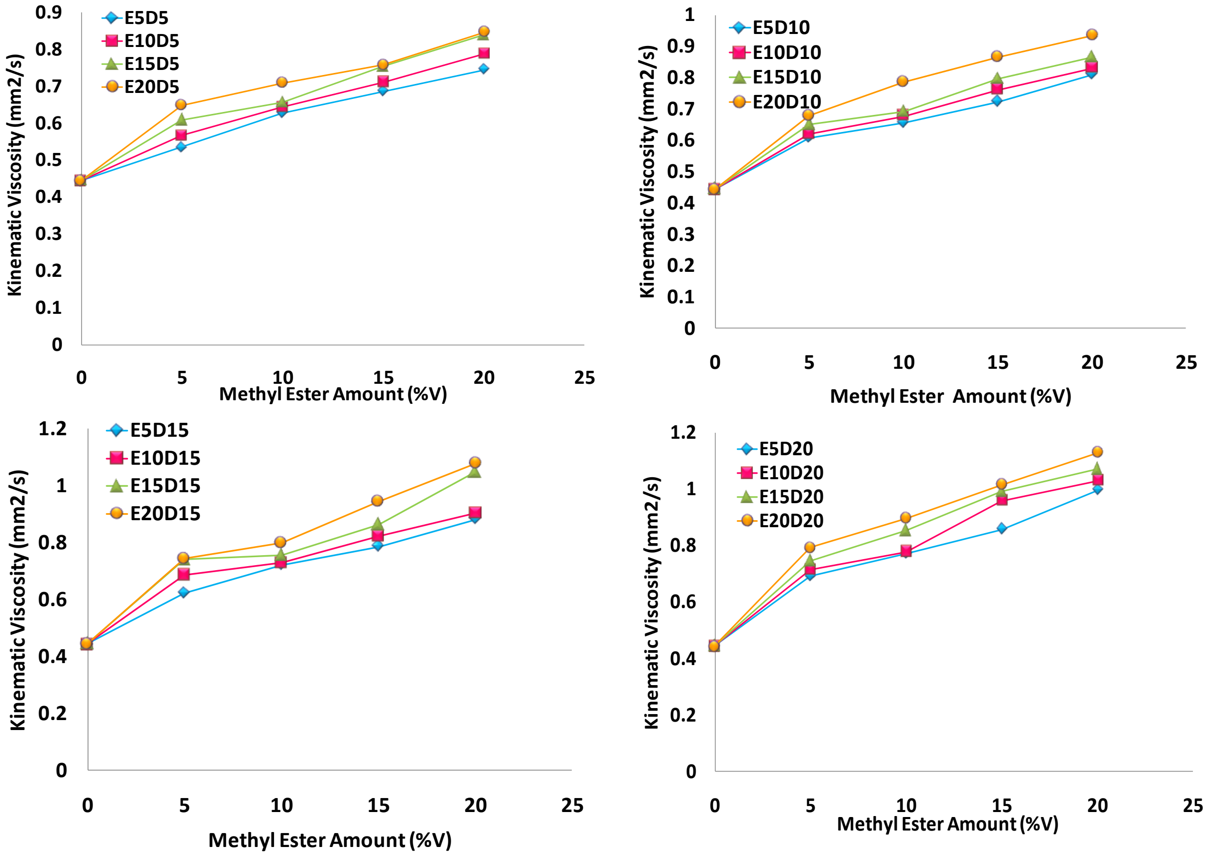

Fig.6. Kinematic viscosity variations of blends with various volume percentages of diesel versus biodiesel volume

Figure 7 show that with increasing the volume percentage of biodiesel, the amount of kinematic viscosity has a linear rising trend. However, as described in dynamic viscosity and according to relation between dynamic and kinematic viscosity (equation.1), most likely the reason for this rising trend is that, the biodiesel with 4.45963 mm^2/s has the highest kinematic viscosity for the three other fuels. The studies conducted by the other investigators, showed the same trend that had been repeated except that they had used diesel-biodiesel fuel blends [5 & 6]. In addition, in constant volume of biodiesel, with increasing the volume percentage of bioethanol the kinematic viscosity slightly increased. This rising trend is justified due to the high kinematic viscosity of bioethanol compared to gasoline fuel. The changes of apparent behavior and curves trend show that the range of kinematic viscosity changes increased with increasing the volume of diesel fuel. Their average changes ranged from 0.6945 to 0.8929 mm^2/s.

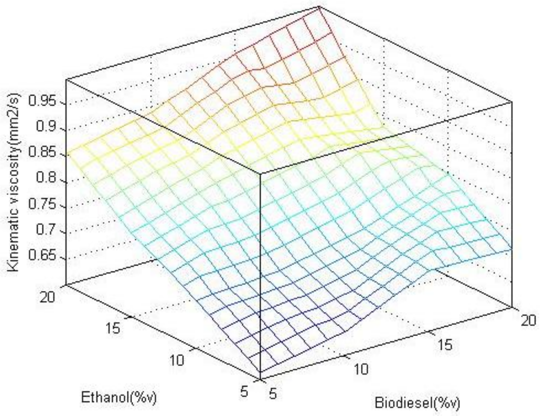

Fig.7. Kinematic viscosity variations of blends with various volume percentages of biodiesel and ethanol

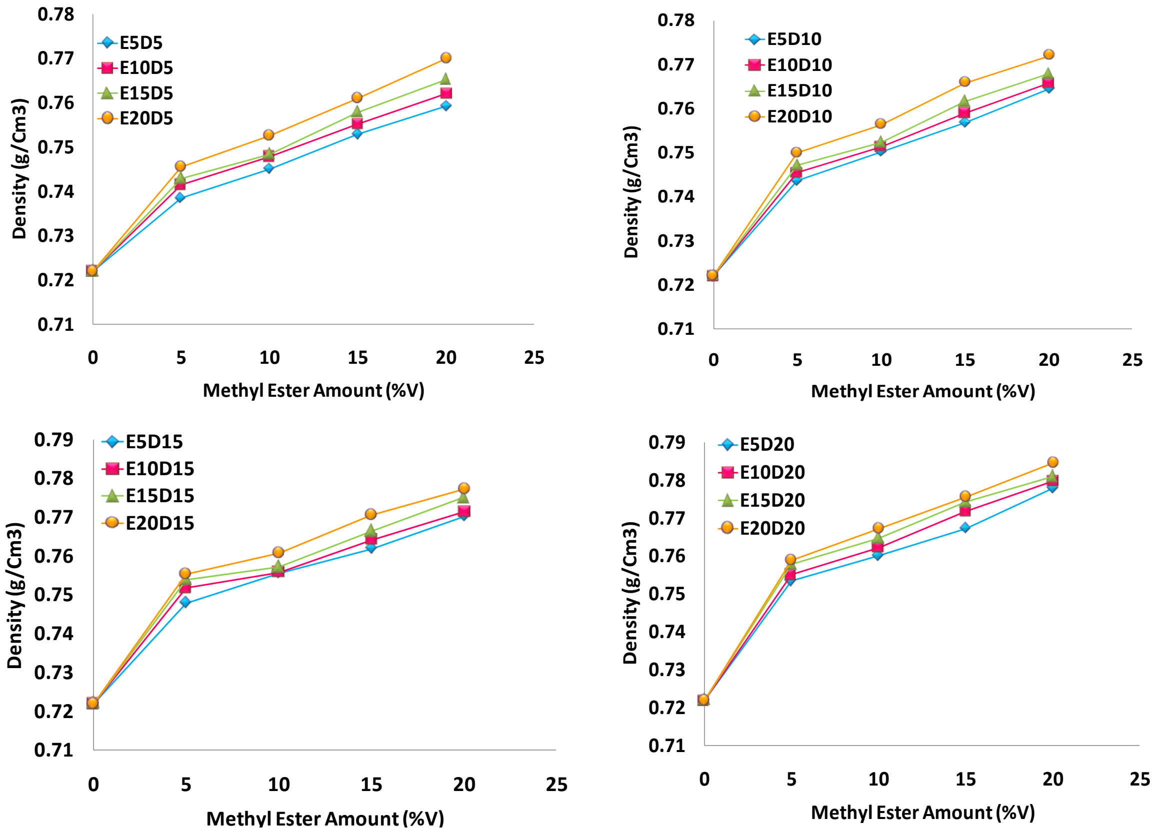

Fig.8. Density variations of blends with various volume percentages of diesel versus biodiesel volume

3.1.4. Density

The curves related to kinematic viscosity versus volume percentage of biodiesel is shown in figs. 8 and 9. Due to apparent trend of curves in fig. 8, with increasing in volume percentage of biodiesel in fuel mixtures, the amount of density has a linear and rising trend. In fact, this increase is insignificant and negligible. However, the other investigators who blended diesel and biodiesel fuel concluded that density increased with increasing in volume percentage of biodiesel in fuel mixture. They had explained the reason that the density of biodiesel is higher than that of diesel [5, 6, 21]. In the other investigations which used diesel-biodiesel-bioethanol blends, it was concluded that the density of all mixtures were below the standard range of diesel fuel [13]. Also, in constant volume of biodiesel, with increasing in volume percentage of bioethanol, the density almost remains constant. The reason for these trends is that the density of biodiesel, bioethanol, diesel and gasoline is almost the same. So, the reason for these trends is that the density of biodiesel, bioethanol, diesel and gasoline is almost the same. Though, in experiment conducted on diesel-bioethanol fuel blend, it was concluded that the density decreased with ethanol increasing [22]. From the changes of apparent behavior and curves trend, it is observable that the range of density remains constant with increasing in proportion of diesel fuel. Their average changes varied from 0.7529 to 0.7682 g/cm^3.

3.2. Engine performance and emission's parameters

Performance and exhaust emissions of XU7JP/L3 spark ignition (SI) engine (figure 10) were measured and evaluated. The experimental results showed that the power and torque of engine decreased 6% and 1% for the mixtures of fossil fuel and biofuel blends respectively, fuel consumption increased by 36%. The tests results also showed that the UHC and CO emissions reduced 8% and 47% but CO_2 emission increased. Experimental results of power, torque, and specific fuel consumption at different fuel blends (G100= net gasoline, E20= 20% ethanol and 80% gasoline- GS1=10% ethanol, 2.5% biodiesel, 2.5% diesel and 85% gasoline- GS2= 18.1% ethanol, 4.31% biodiesel, 4.31% diesel and 73.28% gasoline) and engine speeds have been indicated at figure 11.

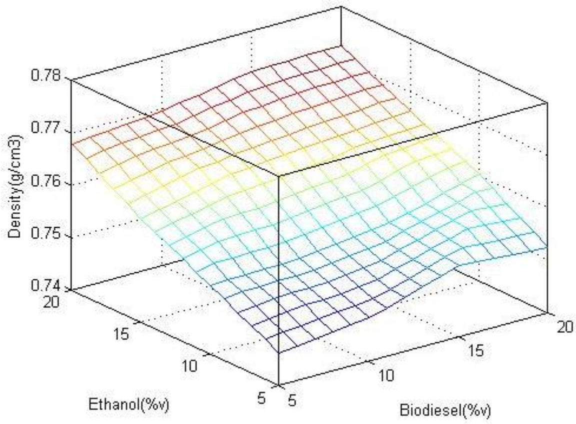

Fig.9. Density variations of blends with various volume percentages of diesel versus biodiesel and ethanol

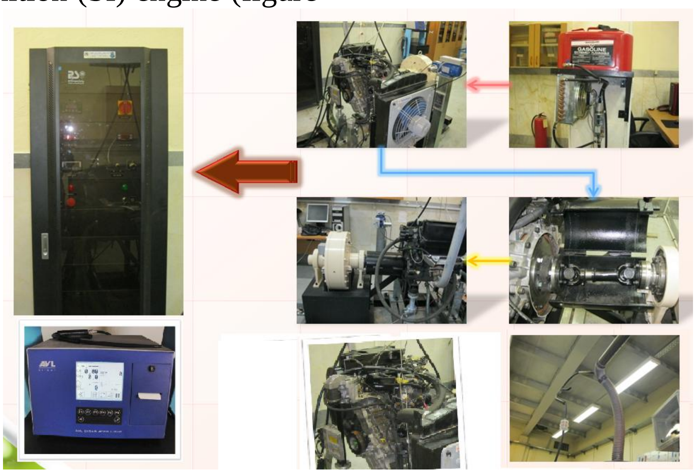

Fig.10. Experimental test set-up

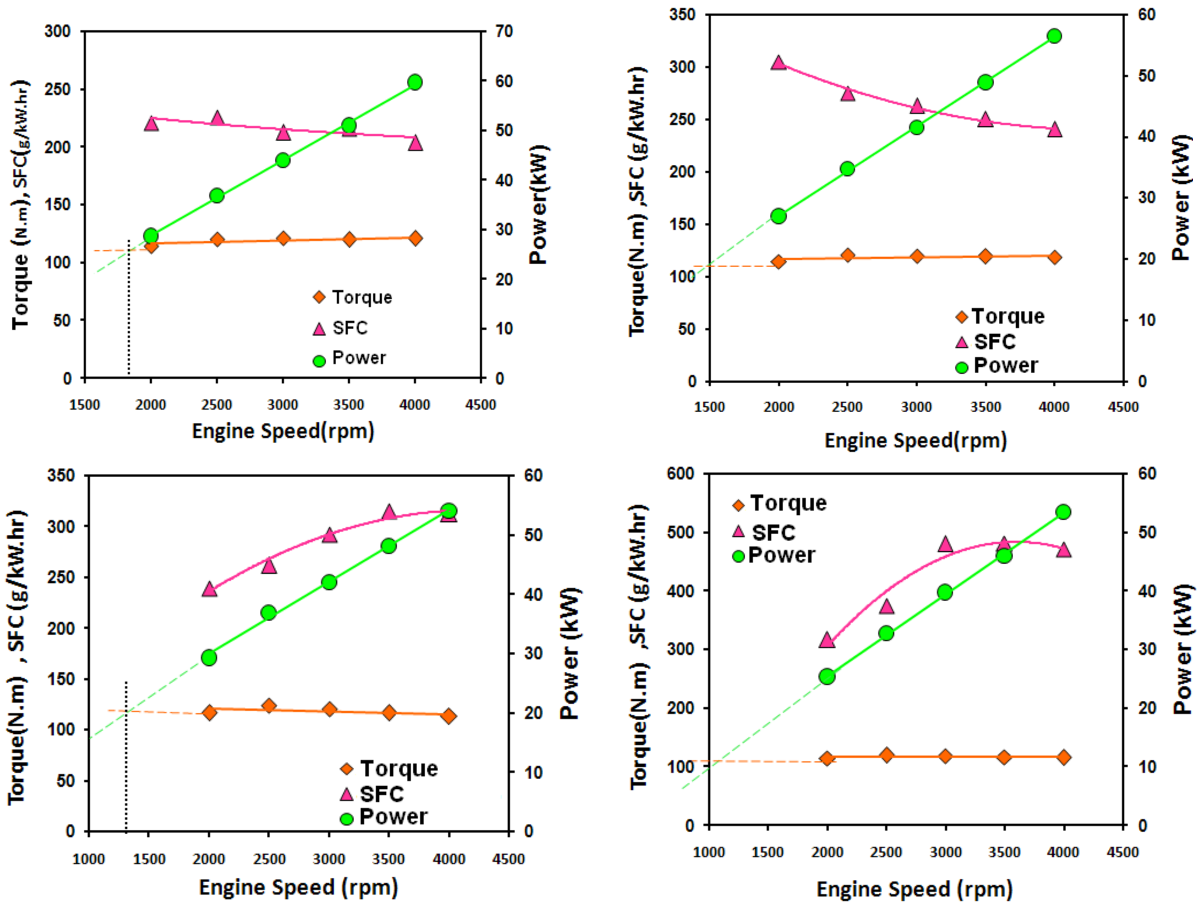

Fig.11. Experimental results of power, torque, and specific fuel consumption at different fuel blends and engine speeds

Experimental results for variation of power, torque, fuel consumption and specific fuel consumption at different fuel blends and engine speeds compared to net gasoline and diesel fuels have been indicated at figure 12.
Experimental results for variation of CO, CO_2, UHC emissions and exhaust gas temperature at different fuel blends and engine speeds compared to net gasoline and diesel fuels have been indicated at figure 13.

4. CONCLUSION

This study can be summarized as follows:

1. In mixtures with different volume percentage of diesel fuel, the amount of water and sediment remains constant with increasing the volume percentage of biodiesel.
2. In constant volume of biodiesel, with increasing the volume percentage of bioethanol, the amount of water and sediment increased.
3. The range of water and sediment changes remains constant with increasing the proportion of diesel fuel.
4. With increasing the volume percentage of biodiesel, the amounts of dynamic viscosity and kinematic viscosity have a linear rising trend. In addition, in constant volume of biodiesel, with increasing the volume percentage of bioethanol, the dynamic viscosity and kinematic viscosity increased slightly.
5. The range of dynamic viscosity and kinematic viscosity changes increased with increasing the proportion of diesel fuel.
6. With increasing the volume percentage of biodiesel, the amount of density remains constant. Also, in constant volume of biodiesel, with increasing the volume percentage of bioethanol, the amount of density remains constant too.

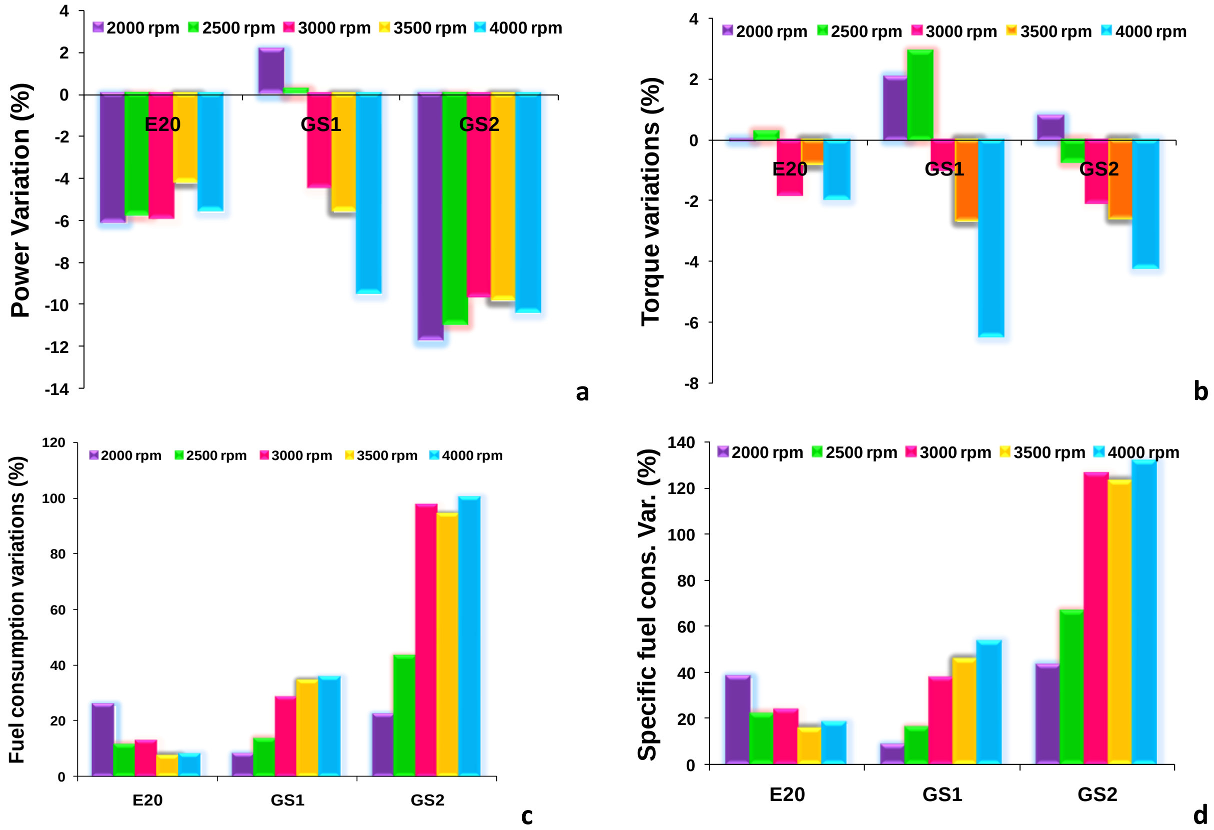

Fig.12. Experimental results for variation of (a) power, (b) torque, (c) fuel consumption and (d) specific fuel consumption at different fuel blends and engine speeds

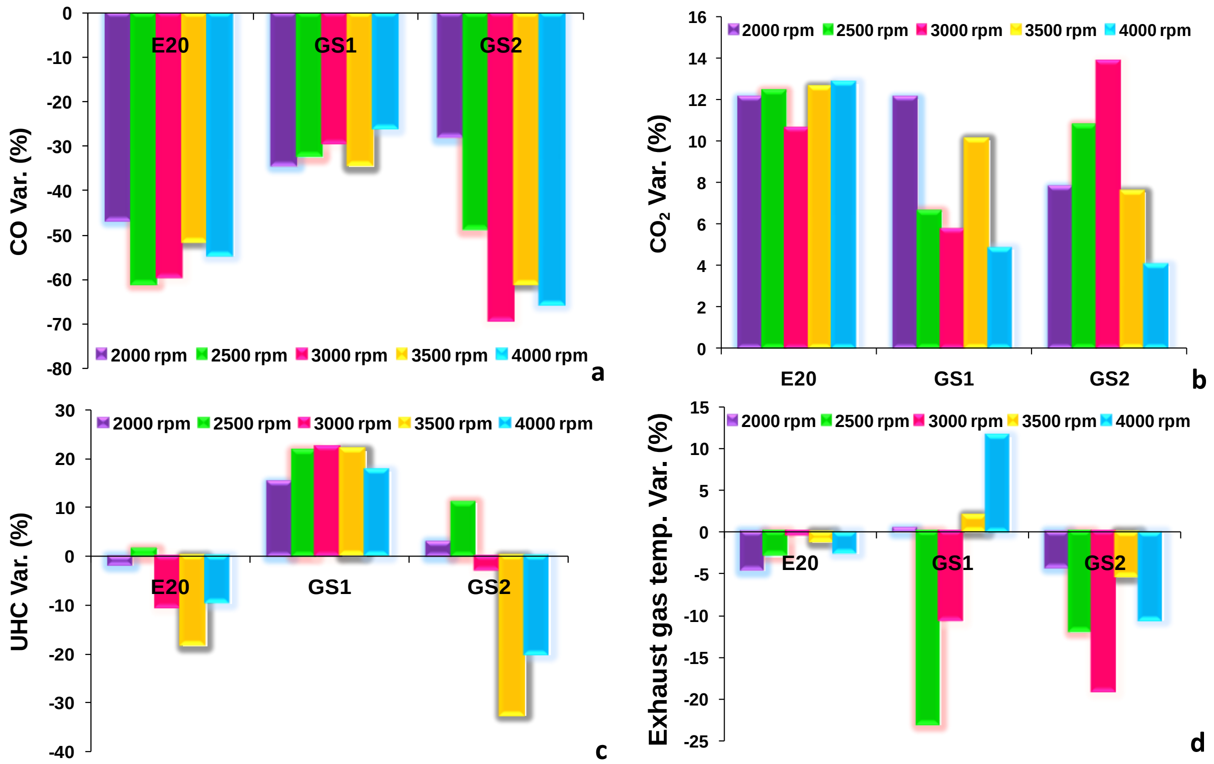

Fig.13. Experimental results for variation of (a)CO, (b) CO_2, (c) UHC and (d) exhaust gas temperature at different fuel blends and engine speeds

7. The range of density changes remains constant with increasing the proportion of diesel fuel.

8. The power and torque of engine decreased 6% and 1% for the mixtures of fossil fuel and biofuel blends respectively, fuel consumption increased by 36%. The tests results also showed that the UHC and CO emissions reduced 8% and 47% but CO_2 emission increased.

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