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Experimental investigation of exhaust temperature and delivery ratio effect on emissions and performance of a gasoline–ethanol two-stroke engine ☆

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ABSTRACT

In this study, the effects of ethanol additives (5%, 10% and 15% in volume) on the performance and emissions (HCs, CO, CO_2 and NOx) of a SI two stroke engine is investigated in different loads and speeds. Also, the effect of exhaust temperature and delivery ratio on emissions and engine performance is discussed. Results show that in most test cases, when alcoholic fuel is used, scavenging efficiency and delivery ratio increased due to rapid evaporation of ethanol and outcomes of scavenging and trapping efficiencies are in more accordance with the perfect mixing model. The most outstanding result of using ethanol additives is significant reduction in pollutions emitted from engine of which CO with 35% reduction has the most reduction percentage among other pollutants. Although most emissions are increased by increasing the exhaust temperature, but hydrocarbons (HCs) on an average decreased by 30% on increasing the exhaust temperature.

1. Introduction

Alternative fuels, as defined by the Energy Policy Act in 1992 (EPACT, US), include ethanol, natural gas, hydrogen, biodiesel, electricity, methanol and so on. These fuels are being used in a variety of vehicle applications. Among alternative fuels, ethanol is one of the fuels employed most widely. Some of its reasons are introduced in the following. First, it can be produced from "cellulosic biomass", such as trees and grasses and is called bio-ethanol. Secondly, ethanol (CH_3CH_2OH) is made up of a group of chemical compounds whose molecules contain a hydroxyl group, OH, bonded to a carbon atom. So, the oxygen content of this fuel favors the further combustion of gasoline. In addition, ethanol is commonly used to increase gasoline's octane number. It can be concluded that using ethanol–gasoline blended fuels can ease off the air pollution and the depletion of petroleum fuels simultaneously. Some works on ethanol as an alternative or additive fuel is presented below.

Hsieha et al. [1] tested the properties of ethanol–gasoline blended fuels with various blended rates (0, 5, 10, 20 and 30%) by volume. Their results show that by increasing the ethanol content, the heating value of the blended fuels is decreased, while the octane number of the blended fuels increases. Hasan [2] showed that using an ethanol–unleaded gasoline blend leads to a

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significant reduction in exhaust emissions to about 46.5 and 24.3% of the mean average values of CO and THC emissions, respectively, for all engine speeds. The addition of methanol to ethanol fuel does not cause visible effects (difficult detection during inspection) and does not generate mechanical engine problems, but can create serious health problems for users and especially for gas station attendants [2]. Hansen et al. [3] observed that increasing the ethanol concentration in diesel oil reduces the fuel cetane number. Ethanol cetane number was estimated to be between 5 and 15, while diesel oil cetane number is around 50. This characteristic is critical for the use of high concentrations of ethanol blended with diesel oil or biodiesel, being a major cause for increased ignition delay [4]. Chen et al. [5] tested fuel blends with up to 30% of ethanol and 10% of soybean biodiesel in diesel oil. They found that engine torque is reduced and BSFC is increased with ethanol addition in the fuel, but smoke and PM emissions are significantly reduced. More studies in this field can be found in Refs. [6–10].

A new and simple strategy for the simultaneous determination of ethanol and methanol in ethanol fuel using cyclic voltammetery on a gold electrode is reported by Pereira et al. [11]. The effects of the using of ethanol as an additive to diesel oil–soybean biodiesel blends on fuel consumption was investigated by Randazzo and Sodre [12]. They found that the cold start time increased by increasing ethanol content in the fuel blend but specific fuel consumption was not affected by increasing biodiesel concentration in the blend or by the use of 2% of ethanol as an additive. However, the use of 5% of ethanol concentration in a B20 blend results an increase in specific fuel consumption. Bo et al. [13] focused on decreasing brake specific fuel consumption (bsfc) of diesel engine by introducing dimethyl ether (DME) or ethanol into intake air and emulsified fuel to diesel engine. Boretti [14] observed a better fuel conversion efficiency for a dual fuel ethanol–diesel than the diesel fuel over the full range of speeds and loads with all the advantages of the renewable ethanol in terms of environment and energy security. Emission characteristics from a four-stroke motorcycle engine using 10% ethanol–gasoline blended fuel (E10) were investigated by Jia et al. [15]. Their results indicate that CO and HCs emissions in the engine exhaust are lower with the operation of E10 as compared to the use of unleaded gasoline. According to He et al. [16], using ethanol as an additive to diesel fuel can reduce particulate matter (PM) emission and increase the flexibility of NOx emissions control under different engine operating conditions. Increased fuel consumption and low ignition quality are pointed out as the main barriers for ethanol application in diesel engines.

Because ethanol or ethylic alcohol (C_2H_5OH) can be produced from herbaceous seeds, beets and potatoes, it can be a suitable alternative fuel for oil categories fuels [17,18]. Ethanol has been blended to gasoline for increasing octane number and its non-detonation properties. Eyidogan et al. [19] investigated the effect of ethanol–gasoline (E5, E10) and methanol–gasoline (M5, M10) fuel blends on the performance and combustion characteristics of a SI engine. They showed using ethanol lead to an increase in bsfc and octane number. These results were expected because the heating values of the alcohols are 37–53% lower than that of pure gasoline. Li et al. [20] used ethanol fuel, which benefits from a low cetane number, in a two stroke diesel engine with exhaust gas recirculation (EGR). They showed that ethanol makes lower soot and NOx, and also causes 2–3% increase in thermal efficiency. The effects of ethanol addition (10% and 15% in volume) on the performance and emissions of a four cylinder turbocharged indirect injection diesel engine having different fuel injection pressures (150, 200 and 250 bar) at full load were investigated by Can et al. [21]. Their results showed that the ethanol addition reduces CO, soot and SO_2 emissions, but it caused an increase in NOx emission and approximately 12.5% (for 10% ethanol addition) and 20% (for 15% ethanol addition) power reductions. Recently, ethanol was widely used as a fuel additive in different engines, some of these recent works are introduced in [22–24].

In this study, the ethanol–gasoline blend fuel is used to determine the effects of exhaust temperature on the performance and emissions (CO, HCs, CO_2, NOx) of a two stroke SI engine running at different speeds and loads. All the experiments were performed without any modification on the engine at 25%, 50% and 75% of full load. Effect of exhaust temperature and delivery ratio on emissions and engine performance are discussed.

2. Mathematical formulation of operating parameters

In this section, all the required equations and operating parameters for a two stroke engine are presented [25].

2.1. Delivery ratio

Delivery ratio is a parameter for describing the scavenging process in two stroke engines. It can be defined as Eq. (1) for experimental purposes,

$$\Lambda = \frac{\text{mass of delivered mixture per cycle}}{\text{refrence mass}} = \frac{\text{mass of delivered mixture per cycle}}{\text{displacement} \times \text{ambient density}} \tag{1}$$

2.2. Scavenging efficiency

Scavenging efficiency indicates to what extent the residual gases in the cylinder has been replaced with fresh air as Eq. (2),

$$\eta_{Sc} = \frac{\text{mass of delivered mixture retained}}{\text{mass of trapped cylinder charge}} \tag{2}$$

a useful and applicable equation for experimental purposes for scavenging efficiency is presented by Ganesan [26].

$$\eta_{sc} = \frac{\dot{m}_a(kg/\,\min)}{N(rpm) \times \rho_{sc} \times V_{total}} = \frac{\dot{m}_a(kg/\,\min)}{N(rpm) \times (p_{exh}/287 \times T_0) \times V_d \times (r/r-1)} \tag{3}$$

2.3. Trapping efficiency

Trapping efficiency indicates what fraction of the mixture supplied to the cylinder is retained in the cylinder.

$$\eta_{tr} = \frac{\text{mass of delivered mixture retained}}{\text{mass of delivered mixture}} \tag{4}$$

By using exhaust gas analyze, trapping efficiency can be calculated by following equation [25].

$$\eta_{tr} = 1 - \frac{[O_2]_{exh}}{[O_2]_{atm}} \tag{5}$$

2.4. Perfect displacement theory

Perfect displacement theory is a limiting idea model for scavenging process which occurs if the burned gases were pushed out by the fresh gases without any mixing. For perfect displacement with m_{tr} as the reference mass in the delivery ratio,

$$\begin{aligned} &\eta_{sc} = \Lambda \quad \text{and} \quad \eta_{tr} = 1 \quad for \quad \Lambda \le 1 \\ &\eta_{sc} = 1 \quad \text{and} \quad \eta_{tr} = \Lambda^{-1} \quad for \quad \Lambda > 1 \end{aligned} \tag{6}$$

2.5. Complete mixing theory

Complete mixing theory is another limiting idea model which occurs when entering fresh mixture mixes instantaneously and uniformly with the cylinder content. For complete mixing model

$$\begin{aligned} &\eta_{sc} = 1 - e^{-\Lambda} \\ &\eta_{sc} = \frac{1}{\Lambda}(1 - e^{-\Lambda}) \end{aligned} \tag{7}$$

3. Experimental apparatus

3.1. Experiment setup

The experimental setup consists of a two stroke and one cylinder SI engine, an engine test bed and an exhaust gas analyzer. The complete test bed has overall dimensions of 84 cm × 92 cm × 104 cm, weighs 90 kg and, in its standard form, requires no external supplies other than 24-volt dc. The engine is provided with a flexible exhaust pipe which may be taken to a window or other suitable opening. A view of test bed in shown in Fig. 1(a) and the exhaust gas analyzer is shown in Fig. 1(b). The engine model is JAP-J34 and the cooling fluid is water. Specifications of the engine are given in Table 1. The generator, a separately excited direct current machine is mounted on bearings and a torque arm and spring balance makes it possible to observe the torque developed by engine. The engine speed is noted, and the useful or brake horsepower may be calculated. The generator functions as a motor to start the engine. For measuring the fuel consumption, the time of 1 cc fuel consumption was measured with a digital chronometer with a definition rate of ±0.01 s. The exhaust temperatures were measured with PT100 sensors whose values were shown on a screen.

3.2. Exhaust gas analyzer

As described above, an exhaust gas analyzer is used in this experiment. The DELTA 1600S analyzer (Fig. 1(b)) is used to measure exhaust gases. It is a small and lightweight (800 g) analyzer. Its response time is 15 s and flow rate approximate 1.2 l/min. This analyzer can measure Carbon monoxide (CO), Carbon dioxide (CO_2), Hydrocarbons (HCs), Oxygen (O_2) and Nitric oxide (NO). Complete information about its resolution is shown in Table 2. The excess air (lambda) calculated from Brettschneider formula can also be determined by this analyzer. Using lambda and stoichiometric air to fuel ratio, we are able to calculate the actual air to fuel ratio.

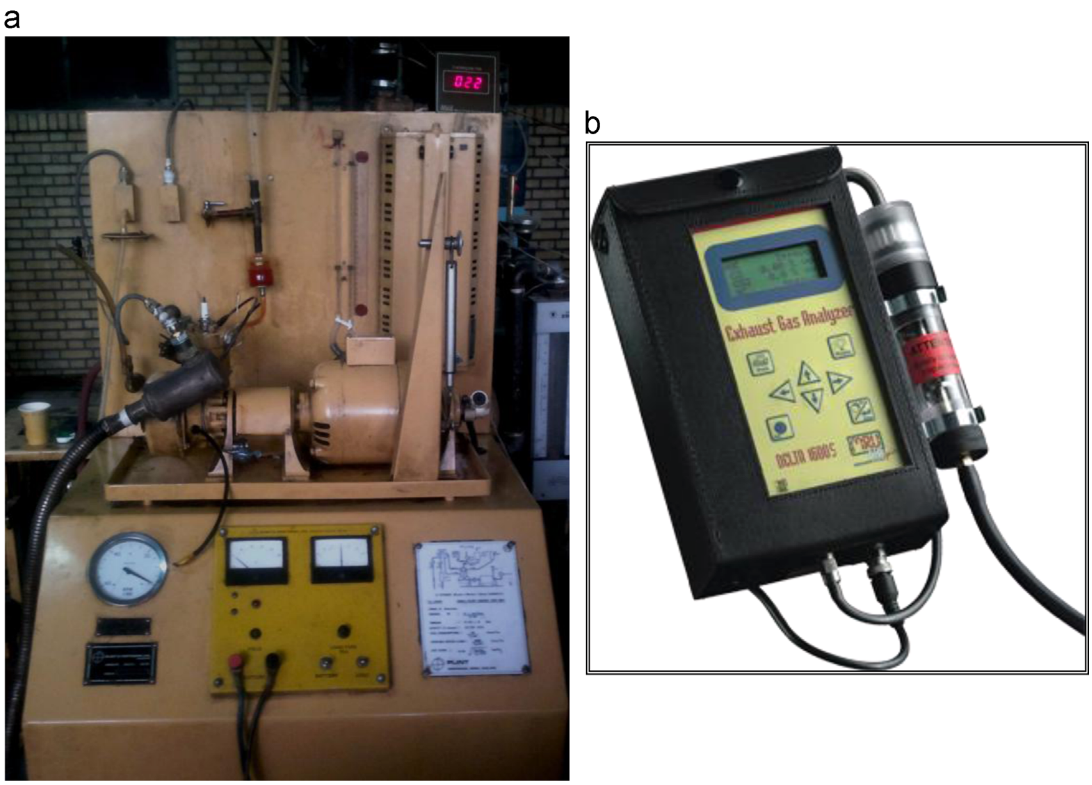

Fig. 1. (a) Experimental setup. (b) Exhaust gas analyzer.

Table 1
Specifications of the test engine.

Engine model	2-stroke JAP-J34
Bore	35 mm
Number of cylinders	1
Stroke	35 mm
Displacement volume	34 ml
Compression ratio	6
Nominal output Power	0.5 kW 4000 rev/min
Maximum speed	6000 rev/min
Corporation	Plint & Partners LTD

4. Tests procedure

For obtaining the performance map, the engine is started with gasoline, and the engine was stabilized awhile to reach a stable state. In this state, the engine is set in full throttle and maximum power is applied to it. We have done these for 2500, 3000, 3500 and 4500 rpm and recorded 1 cc fuel consumption time. Experiments were performed with four different fuels at 25%, 50% and 75% of full load whose fuels were pure gasoline, 95% gasoline + 5% ethanol, 90% gasoline + 10% ethanol and 85% gasoline + 15% ethanol, respectively. Some properties of described fuels are presented in Table 3.

The testing procedure is as follows. After obtaining the performance map in full load, Table 4 is calculated for applying the required torque in different conditions. By using this table and after completion of a standard warm up procedure, the engine speed was increased from 2500 to 4500 rpm at different loads. At each point, the engine was stabilized for 2 min., and then, the measurement parameters (temperatures, exhaust gases, water mass flow, fuel consumption time, torque and speed) were recorded. A sample data obtained in the laboratory for pure gasoline is presented in Table 5.

5. Results and discussion

As a renewable energy resource, alcohol fuel has attracted significant attention in many countries, for it can, not only reduce pressure on energy and emissions, but also stabilize agricultural production and enhance employment. However, due to its low cetane number and high latent heat of vaporization, alcohol fuel is poor in ignition, which makes it difficult to use

Table 2
Measurable gases by exhaust gas analyzer and their accuracy.

Measurable gases by Delta 1600-S	Resolution	Error	Measurable range
HCs (C_3H_8)	1 ppm	± 30 ppm	**0–20,000 ppm**
CO	0.01%vol.	± 0.2%	**0–10%**
CO_2	0.1%vol.	± 1%	**0–16%**
O_2	0.01%vol.	± 0.2%	**0–21%**
NOx (NO)	1 ppm	± 10 ppm	**0–5000 ppm**

Table 3
Some properties of the test fuels.

Properties	Gasoline	Ethanol	Gasoline with 5% ethanol	Gasoline with 10% ethanol	Gasoline with 15% ethanol
Typical formula	$C_{7.93}H_{14.83}$	C_2H_5OH	$C_{7.63}H_{14.39}O_{0.05}$	$C_{7.34}H_{13.95}O_{0.1}$	$C_{7.04}H_{13.51}O_{0.15}$
Density (kg/lit)	0.7378	0.7987	0.7408	0.7439	0.7469
Heating value (MJ/kg)	44.4	26.8	43.45	42.51	41.58
Molecular weight	110	46	106.75	103.63	100.39
Stoichiometric air/fuel	14.5	8.97	14.43	14.31	14.17

Table 4
Applied torque (N.m) to engine obtained from performance map.

Speed (rpm)	25% load	50% load	75% load	100% load
2500	0.21	0.43	0.64	**0.85**
3000	0.24	0.49	0.73	**0.97**
3500	0.28	0.51	0.75	**1.005**
4500	0.27	0.37	0.57	**0.75**

Table 5
Sample data obtained in experiment for pure gasoline.

Load	Engine speed (Rpm)	Dynamometer (*N*)	Time for 1 cc fuel consumption (*S*)	Dynam. voltage (*V*)	Dynam. current (*I*)	HCs (ppm)	CO (%)	CO_2 (%)	NOx (ppm)	O_2 (%)	Lambda (λ)	Exhaust temp. (c)
25%	2500	1.4	31.74	19	1.5	5684	0.6	8.1	76	9.02	2.605	155
50%	2500	2.9	25.23	15	3.5	5010	0.51	8.5	68	8.58	1.232	183
75%	2500	4.3	21.98	12	1.2	4626	0.2	9	89	8.28	1.247	205
25%	3000	1.6	22.37	20	1.5	5280	0.72	8.3	92	8.87	1.24	199
50%	3000	3.3	20.66	19	4.5	4920	0.29	8.5	118	8.69	1.25	218
75%	3000	4.9	15.59	15	8	4610	0.18	8.6	119	8.62	1.275	243
25%	3500	1.9	29.6	25	2	4680	0.84	8.5	48	7.81	1.175	234
50%	3500	3.4	27.18	22	4.5	4225	0.5	8.9	53	7.93	1.243	261
75%	3500	5	25.29	19.9	8	4158	0.45	9.5	62	7.04	1.18	292
25%	4500	1.8	13.68	32	2.5	4426	1.38	8.9	69	6.58	1.099	278
50%	4500	2.5	15.92	32	3	4140	1.49	9	53	6.48	1.096	282
75%	4500	3.8	17.56	29	5	3957	1.24	9.5	71	6.19	1.111	305

effectively in engines (especially diesel engines). To solve this problem, many approaches related to either fuel or engine development have been proposed and a lot of research was carried out of which some of them are presented in Section 1. In this study, the effect of ethanol combustion on the performance and emissions of a two-stroke SI engine is investigated. As described in Section 4, calculating the stoichiometric air to fuel ratio for obtained fuel formula in Table 3 is necessary. Combustion formulation of a C_xH_y fuel is

$$C_xH_y+(x+y/4)\times(O_2+3.76N_2)\rightarrow x\times CO_2+y/2H_2O+3.76(x+y/4)N_2 \tag{8}$$

For pure gasoline,

$$C_{7.93}H_{14.83}+11.63(O_2+3.76N_2)\rightarrow 7.93CO_2+7.42H_2O+43.73N_2 \tag{9}$$

$$Stoichiometric\ \ A/F = 4.76 \times 11.63 \times 28.9/110 = 14.5$$

Combustion for a $C_xH_yO_z$ fuel,

$$C_xH_yO_z + (x + y/4 - z/2) \times (O_2 + 3.76N_2) \rightarrow xCO_2 + y/2H_2O + 3.76(x + y/4 - z/2)N_2 \tag{10}$$

For example, for gasoline with 5% ethanol we have,

$$C_{7.63}H_{14.39}O_{0.05} + 11.2(O_2 + 3.76N_2) \rightarrow 7.93CO_2 + 7.19H_2O + 42.12N_2 \tag{11}$$

$$Stoichiometric\ A/F = 4.76 \times 11.2 \times 28.9/106.75 = 14.43$$

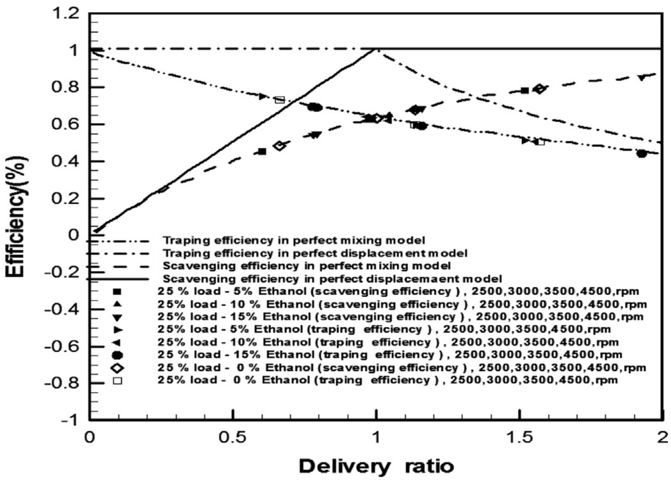

Fig. 2. Comparison of trapping and scavenging efficiencies calculated from experiment data, with perfect mixing and perfect displacement models in 50% full load.

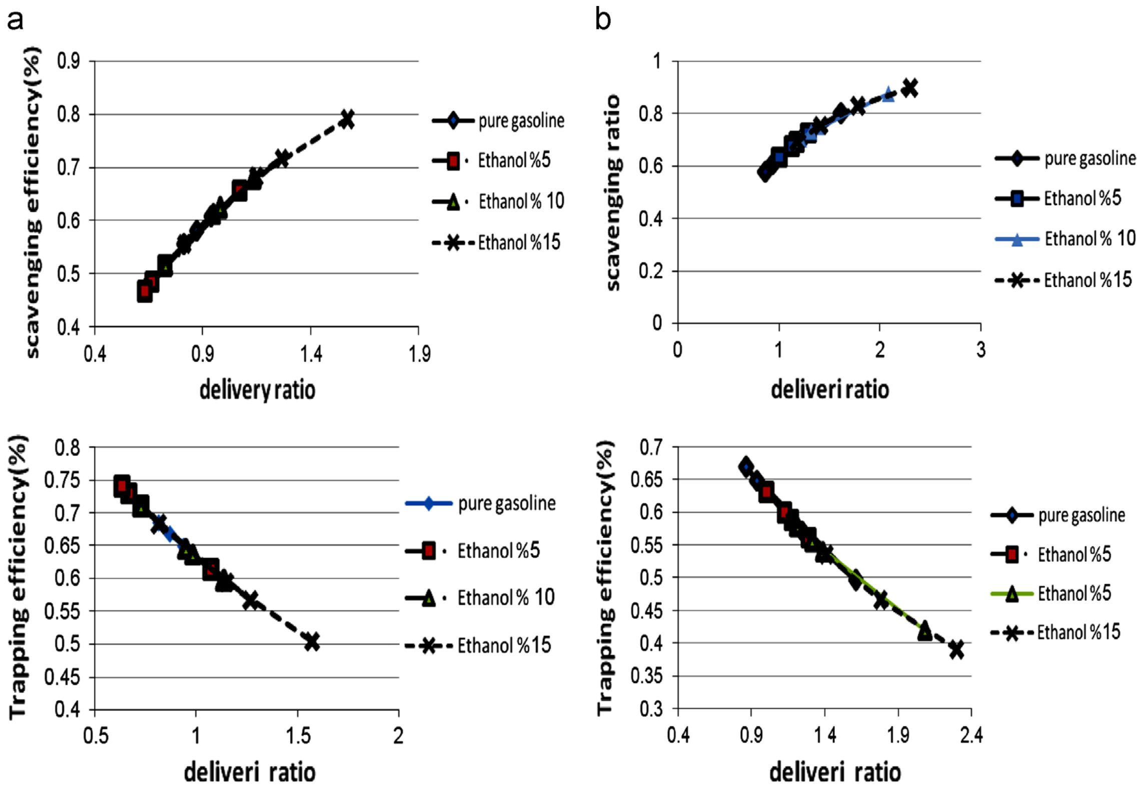

Fig. 3. Effect of delivery ratio and ethanol additives on scavenging efficiency and trapping efficiency (a) 50% full load and (b) 75% full load.

Fig. 2 compares the results obtained from the experiment with the two theory perfect mixing and perfect displacement which were introduced in Section 2. As seen in this figure (50% full load), results are more in accordance with the perfect mixing model. This is due to the rapid evaporation of ethanol in the enterance to cylinder and makes a better mixing. Effect of delivery ratio and ethanol additives on scavenging efficiency and trapping efficiency are presented in Fig. 3 in different loads. As seen in this figure, by increasing the delivery ratio, scavenging efficiency increases due to increase in the inlet mass. But in a constant delivery ratio, no significant effect on efficiency apperared by increasing the ethanol percentage. Also, Fig. 3 shows effect of these two parameters on trapping efficiency. It can be concluded from these two figures that increasing the delivery ratio reduces the trapping efficincy.

Effect of exhaust temperature on carbon monoxide (CO) emissions in different loads and ethanol percentages are depicted in Fig. 4. CO will be produced from the partial oxidation of carbon-containing compounds; it forms when there is not enough oxygen to produce carbon dioxide (CO_2). In the presence of oxygen, carbon monoxide burns and produce carbon dioxide. It is obvious that when engine speed increases, exhaust temperature increases consequently and the required time for combustion decreased, so CO will be increased.

When ethanol or extra oxygen appears in gasoline fuel, due to rapid evaporation and better mixing between air and fuel and consequently excellent combustion, carbon dioxide's intensity (CO_2), like other emissions, will decrease. Fig. 4 confirms that by increasing the exhaust temperature, CO_2 emissions increased significantly. This increase is higher for 15% ethanol than other percentage which is approximately a 30% increase in 50% full load. When the engine speed increases, fuel/air ratio decreases, so oxygen in the mixture increases and consequently hydrocarbons (HCs) decrease by increase in exhaust temperature. This fact is shown in Fig. 5 which is 30% on an average. Also, in piston engines some of the fuel–air mixture "hides" from the flame in the crevices provided by the piston ring grooves. Also, some regions of the combustion chamber may have a very weak flame and low combustion temperature. Thus, when unburned fuel is emitted from a combustor, HCs are formed. HCs emitted from the test engines in different exhaust temperatures, loads and ethanol percentages are presented in Fig. 5. These figures confirm that using ethanol reduces the HCs level in all cases and for each 5% ethanol, HCs decreased by approximately 6%. Nitric oxide (NOx) will be produced from the reaction of nitrogen and oxygen gases in the air during combustion, especially at high temperatures. As seen in Fig. 5 the ethanol additives have most influence on NOx emissions and it can be the biggest advantage of ethanol because it reduces NOx by about 83% when it is used in high percentages (15%) and high speed engines and also it reduces by 38% on average. Because the ethanol chemical formula contains an oxygen molecule, when it is added to gasoline a better combustion occurred and NOx amount reduced. Furthermore, ethanol makes a lower combustion temperature than gasoline and NOx mostly forms in high temperature.

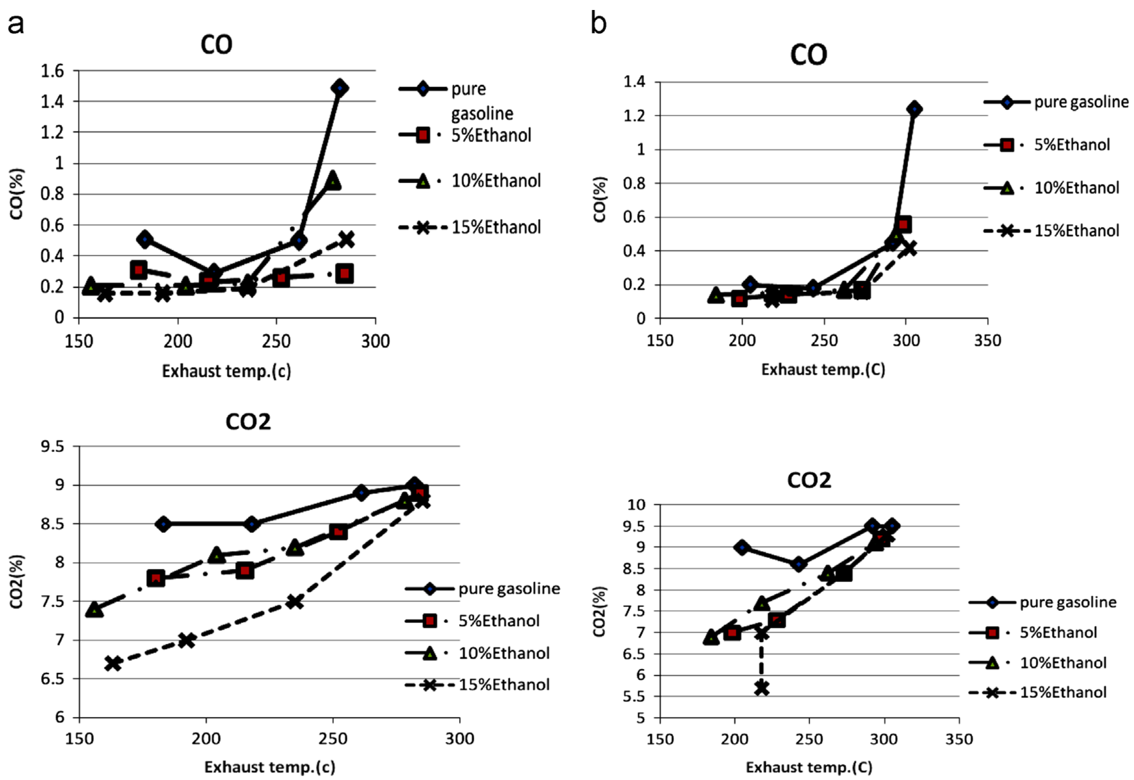

Fig. 4. Effect of exhaust temperature and ethanol additives on CO and CO_2 emissions for (a) 50% full load and (b) 75% full load.

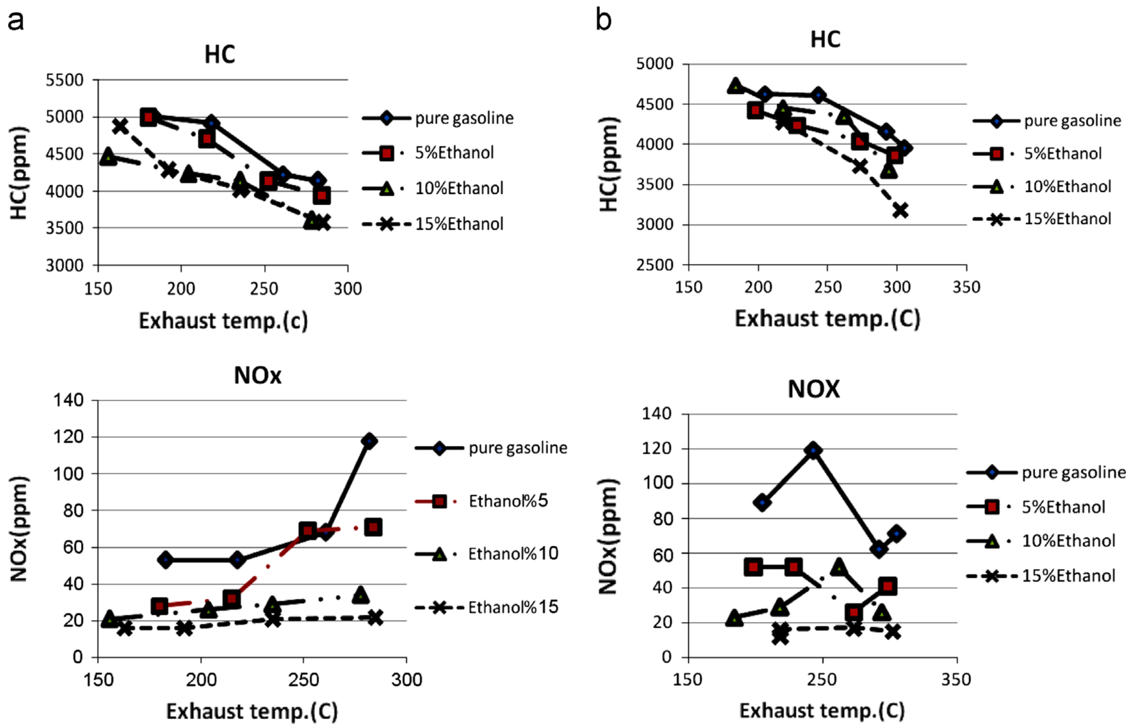

Fig. 5. Effect of exhaust temperature and ethanol additives on CO and NOx emissions for (a) 50% full load and (b) 75% full load.

6. Conclusion

In this study, the effect of exhaust temperature and delivery ratio on performance and emissions of a two stroke SI engine are investigated experimentally. The tests were performed on a chassis dynamometer while running the vehicle at four different vehicle speeds (2500, 3000, 3500 and 4500 (rpm)), and four different loads (25%, 50%, 75% and full load). The results obtained from the use of alcohol–gasoline fuel blends were compared to those of gasoline fuel. The following conclusions can be drawn from the present study:

I. Results of scavenging and trapping efficiencies are more in accordance with the perfect mixing model. This is due to rapid evaporation of ethanol in the enterance to cylinder and makes better mixing.
II. By increasing the delivery ratio, the scavenging efficiency increases due to increase in the inlet mass, but increasing the delivery ratio reduces the trapping efficiency.
III. Due to ethanol evaporation in 10% and 15% ethanol addition, an increase in delivery ratio and subsequently scavenging efficiency (approximately 40%) is observed. But trapping efficiency has been decreased by about 15%.
IV. When the engine speed increases, fuel/air ratio decreases, so oxygen in the mixture increases and consequently hydrocarbons (HCs) decreased by 30% on average with increase in exhaust temperature.
V. When engine speed increases, exhaust temperature increases consequently and the required time for combustion decreased, so CO increases. Generally for different speeds and loads, CO decreased on an average by 35% and on each 5% increase in ethanol content to the fuel, CO_2 decreased about 6.3%.
VI. The biggest advantage of ethanol additives is the NOx reduction which is reduced by about 83% when it is used in high percentages of ethanol (15%) and on an average of 38% in other cases.

References

[1] Hsieha WD, Chen RH, Wu TL, Lin TH. Engine performance and pollutant emission of an SI engine using ethanol–gasoline blended fuels. Atmos Environ 2002;36:403–10.
[2] Hasan MA. Effect of ethanol–unleaded gasoline blends on engine performance and exhaust emission. Energy Convers Manage 2003;24:1547–61.
[3] Hansen AC, Zhang Q, Lyne PWL. Ethanol–diesel fuel blends—a review. Bioresour Technol 2005;96:277–85.
[4] He B, Shuai S, Wang J, He H. The effect of ethanol blended diesel fuels on emissions from a diesel engine. Atmos Environ 2003;37:4965–71.
[5] Chen H, Wang J, Shuai S, Chen W. Study of oxygenated biomass fuel blends on a diesel engine. Fuel 2008;87:3462–8.
[6] Lapuerta M, Armas O, Herreros JM. Emissions from a diesel–bioethanol blend in an automotive diesel engine. Fuel 2008;87:25–31.
[7] Yüksel F, Yüksel B. The use of ethanol–gasoline blend as a fuel in an SI engine. Renew Energy 2004;29:1181–91.

[8] Ghazikhani Mohsen, Hatami Mohammad, Safari Behrouz, Domiri Ganji Davood. Experimental investigation of performance improving and emissions reducing in a two stroke SI engine by using ethanol additives. Propuls Power Res 2013;2(4):276–83.
[9] Mohsen Ghazikhani, Mohammad Hatami, Behrouz Safari. The Effect of alcoholic fuel additives on exergy parameters and emissions in a two stroke gasoline engine. Arabian journal for science and engineering, http://dx.doi.org/10.1007/s13369-013-0738-3.
[10] Ghazikhani Mohsen, Hatami Mohammad, Domiri Ganji Davood, Gorji-Bandpy Mofid, Behravan Ali, Shahi Gholamreza. Exergy recovery from the exhaust cooling in a DI diesel engine for BSFC reduction purposes. Energy 2014;. http://dx.doi.org/10.1016/j.energy.2013.12.004.
[11] Pereira PF, Sousa RMF, Munoz RAA, Richter EM. Simultaneous determination of ethanol and methanol in fuel ethanol using cyclic voltammetry. Fuel 2013;107:725–9.
[12] Randazzo ML, Sodre J. Cold start and fuel consumption of a vehicle fuelled with blends of diesel oil–soybean biodiesel–ethanol. Fuel 2011;90:3291–4.
[13] Bo Z, Weibiao F, Jingsong G. Study of fuel consumption when introducing DME or ethanol into diesel engine. Fuel 2006;85:778–82.
[14] Boretti A. Advantages of converting diesel engines to run as dual fuel ethanol–diesel. Appl Therm Eng 2012;47:1–9.
[15] Jia LW, Shen MQ, Wang J, Lin MQ. Influence of ethanol–gasoline blended fuel on emission characteristics from a four-stroke motorcycle engine. J Hazard Mater A 2005;123:29–34.
[16] He B, Shuai S, Wang J, He H. The effect of ethanol blended diesel fuels on emissions from a diesel engine. Atmos Environ 2003;37:4965–71.
[17] Demirbas A. A realistic fuel alternative for diesel engines. London: Springer; 2008.
[18] Michaelides EE. Alternative energy sources. London, New York: Springer; 2012.
[19] Eyidogan M, Ozsezen AN, Canakci M, Turkcan A. Impact of alcohol–gasoline fuel blends on the performance and combustion characteristics of an SI engine. Fuel 2010;89:2713–20.
[20] Li X, Qiao X, Zhang L, Fang J, Huang Z, Xia H. Combustion and emission characteristics of a two-stroke diesel engine operating on alcohol. Renew Energy 2005;30:2075–84.
[21] Can O, Celikten I, Usta N. Effects of ethanol addition on performance and emissions of a turbocharged indirect injection diesel engine running at different injection pressures. Energy Convers Manage 2004;45:2429–40.
[22] Yang HH, Liu TC, Chang CF, Lee E. Effects of ethanol-blended gasoline on emissions of regulated air pollutants and carbonyls from motorcycles. Appl Energy 2012;89:281–6.
[23] Lei J, Shen L, Bi Y, Chen H. A novel emulsifier for ethanol–diesel blends and its effect on performance and emissions of diesel engine. Fuel 2012;93:305–11.
[24] Karavalakis G, Durbin TD, Shrivastava M, Zh Zheng, Villela M, Jung H. Impacts of ethanol fuel level on emissions of regulated and unregulated pollutants from a fleet of gasoline light-duty vehicles. Fuel 2012;93:549–58.
[25] Heywood JB, Sher E. The two-stroke cycle engine. Philadelphia: Taylor & Francis; 1999.
[26] Ganesan V. Internal combustion engine. Third editionMcGraw-Hill Education; 2008.