ORIGINAL ARTICLE

Experimental investigation on combustion behaviour, performance and emission of fusel oil-gasoline blends using turbocharged SI engine

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ABSTRACT – Because of rising energy demand and pollution concerns in the transportation and industrial sectors, alternative fuel development is critical. The fusel oil, which is a by-product of ethanol distillation molasses, is receiving a lot of interest. The combustion characteristics, performance, and emissions of a 1.8L turbocharged four-cylinder, port injection, spark-ignition engine will be used to compare fusel oil blends with gasoline in this study. The experiment was carried out at a constant engine speed of 2000 rpm with a throttle load of 10-40%. Four samples with various ratios of gasoline combined with fusel oil were tested (100% gasoline, 10%, 20%, and 30% are referred to as F0, F10, F20, and F30 respectively). As a result, compared to gasoline, fusel oil blends increase Brake Specific Fuel Consumption (BSFC) by 5-22%. In comparison to gasoline, the combustion behaviour of in-cylinder pressure, Rate of Heat Release (ROHR), Rate Of Pressure Rise (ROPR), and Mass Fraction Burn (MFB) shows an early 2-3 Degree Crank Angle (CAD). Due to differences in attributes and oxygen content, the Brake Thermal Efficiency (BTE) of combustion utilising fusel oil blends suffers a modest drop of 13-16%. When compared to gasoline, fusel oil blends emit 3-4% less hydrocarbon (HC), 7.5-24.5% less carbon monoxide (CO), and 18-36% less nitrogen oxide (NOx). To summarise, fusel oil blends without water extraction blended with gasoline have a substantial impact on turbocharger engine functioning.

INTRODUCTION

Concerns about crude oil's negative environmental effects have grown in recent decades. Fossil fuels are the world's principal source of energy, with demand rising every year. However, the harmful emissions produced by fossil fuel combustion have exacerbated the environmental crisis. According to Olhoff et al. [1] the carbon dioxide (CO_2) equivalent has increased to 53.5 gigatonnes. They estimated an annual average of 1.5 gigatonnes of CO_2 from 2010 to 2017. According to Majumdar and Deutch [2] the CO_2 in the atmosphere is roughly 3200 gigatons. CO_2 emissions are expected to climb by 92% in 2020, according to the International Energy Agency (IEA). From 2020 to 2035, the IEA estimates that nine billion metric tonnes of CO_2 will be released [3]. In order to address these issues and alleviate environmental concerns, it is critical to conduct research into alternate or sustainable energy sources.

Alternative fuels consistently deliver excellent results and contribute to environmental quality in all areas [4]. These fuels minimised harmful health effects while also reducing reliance on fossil fuels. Some of fuel has been used as an internal engine additive in recent years [5]. The fusel oil on a homogeneous charged compression ignition (HCCI) engine was explored by Calam [6]. N-heptane was utilised as a control in the study, and fusel oil blends of 20% (F20), 40% (F40), and 60% (F60) by volume were used. The intake temperature, lambda, and engine rpm were all kept under strict supervision. He claimed that F40 has a substantial advantage in terms of thermal efficiency, while F60 has a greater CO and HC at 2.5 lambda. Furthermore, utilising fusel oil has a negative impact on performance and emissions. RSM was used by Ardebili et al. [7] to optimise gasoline and fusel oil mixtures (0 percent , 25 percent , 50 percent ,75 percent and 100 percent). They tested engine load at 20 percent, 40 percent, 60 percent, 80 percent, and 100 percent, using a 2500 rpm fixed engine speed. As a result of the optimization, their engine is suited for a 25 percent fusel oil blend and a 47 percent engine load. In terms of emissions, NOx levels are falling, whereas UHC and CO levels are rising.

Abulut et al. [8] investigated the effects of fusel oil mixes with diesel (F0), 10% (F10), 15% (F15), and 20% (F20) blends on combustion, performance, and emission characteristics in a single cylinder diesel engine. The engine was tested at varying loads of 2.5, 5, 7.5, and 10 Nm, with a constant engine speed of 2000 rpm. CO and NOx emissions are greatly reduced as a result. However, as fusel oil mixes grow, HC levels rise. For F0, the BSFC decreases and the BTE rises (diesel). They also noted an increase in ignition latency due to the fusel oil's lower cetane number. Due to the prolonged ignition delay and oxygen in fusel oil, the maximum in-cylinder pressure and HRR rose. Fusel oil mixes with gasoline engines utilising Gasoline (F0), 10% blend fusel oil (F10), 20% blend fusel oil (F20), and 30% blend fusel oil (F30), according to Rosdia et al. [9]. They experimented with 10-40 percent load and a fixed 3000 rpm engine speed to optimise

ignition and injection timing. As a result, BMEP, VE, BSFC, HC, and CO levels greatly rise, while NOx levels plummet. [10] investigated fusel oil, which contains a significant amount of isoamyl alcohol. They were carried out on a spark ignition engine with a variety of compression ratios (8.0:1, 8.5:1, and 9.0:1) and speeds (2600, 2800, 3000 and 3200 rpm). A0 (100 percent gasoline), A10 (10 percent isoamyl+90 percent gasoline), A20 (20 percent isoamyl+80 percent gasoline), and A30 (30 percent isoamyl+70 percent gasoline) were used in the engine. According to the findings, utilising isoamyl at various compression ratios reduced emission. The engine's efficiency improves as the compression ratio is increased.

In the past, in-cylindrical pressure was used to investigate engine combustion. Among the analyses that employ (for example, mass fraction burn (MFB), rate of heat release (ROHR), rate of pressure increase (ROPR), in-cylinder temperature, and so on). MFB is a function of the total amount of energy generated by the heat of the fuel. MFB's profile reveals that he is of the S personality type. Then there's a normalised measure with a scale of 0-1 percent in each each cycle. The start of combustion (SOC), duration of combustion (DOC), and end of combustion (EC) are all critical parameters for MFB (EOC). Furthermore, the Wiebe function [11] can be used to estimate MFB. Rassweiler-Withrow is the best model for producing MFB results, according to Song et al. [12]. The highest rate of heat release is represented by a progress of 50% MFB. According to Duan et al. [13], the zone with the highest combustion efficiency is 50 percent of MFB. It happens a lot after top dead centre, according to them (TDC).

ROHR is defined by Liu et al. [14] as the rate of chemical energy released by the combustion process. They stated that ROHR was influenced by the heating value, oxygen content, density, and other factors. The combustion process is typically divided into two stages: the main combustion stage and the post-oxidation stage. The main stage of MFB computation is for low-temperature combustion at a slow rate, whereas the post-oxidation is for high-temperature combustion at a fast rate. Furthermore, Wei et al. [15] described the decrease in excess air coefficient as a result of increased engine load. It will result in a higher fuel density and a richer fuel mixture. As a result, it promotes faster flame propagation and reduces heat transfer loss throughout the combustion process. As a result, increased temperatures, peak in-cylinder pressure, NOx production, and ROHR are produced. During the engine cycle, the ROPR indicates ROHR. It's also a sign that the engine is knocking. Rough engine operation is caused by a higher ROPR through combustion [16]. Peak pressure rise and consequent engine noise have limited the viability of advanced technology (e.g., programmable ECU, turbocharger, variable valve control, variable compression, etc.). According to Jamrozik [17], the ROPR should not exceed 3-8 Bar/CA to maintain smooth engine performance. Furthermore, if the engine operation hits or surpasses the 10 Bar/CA barrier, the engine work becomes difficult, noisy, and even damaging.

Furthermore, the use of alternate fuel in internal combustion engines has resulted in complete combustion activities. Because of the higher oxygen content, it produces less carbon monoxide (CO), hydrocarbon (HC), and promises to finish burning, increasing combustion efficiency [18]. Indeed, Nwufo et al.[19] shown that with alternate fuel mixtures, combustion becomes complete due to increased oxygen. The temperature of combustion inside the cylinder is lowered by higher heat of vaporisation of fuel, resulting in decrease NOx emissions. The reaction of nitrogen and oxygen content of air received into the cylinder produces NOx, which is most noticeable above 1500-1800ºC [20]. Table 1 illustrates a comparison of several fusel oil blends used in engines.

Table 1. The effect of condition engine using fusel oil blend

Engine	Test condition (load)	Fusel oil blends	Performance	Emission	Ref.
SI 4C	60% load 4500 rpm WOT	F10,F20	Bp ↓, BSFC↑	NOx↓, HC↓, CO↓	[20]
SI 1C	1000W -8000W	F10-F50	Bt↑, BSFC↑	NOx↓, HC↓, CO↓	[21]
SI 4C	10-40% load at 3000 rpm	F10, F20, F30	BMEP↑,VE↑,BSFC↑	CO↑,HC↑, NOx↓	[9]
SI 1C	20%-100% load at 2500 rpm	F0-F100	BTE↓,Bt↓, BSFC↑	NOx↓, CO↑,UHC↑	[7]
SI 4C	60% WOT, 4500 rpm	F10,F20 water sep.	Bp↑,BSFC↑,BTE↑,COV↓	-	[22]
SI 4C	25-100% load, 1500-5000 rpm	F10,F20 F30	BSFC↑,	CO↑,HC↑, NOx↓	[23]
SI 4C	10-26 ADV timing 3500 rpm	F0-F50	Bt↑, BSFC↑,	NOx↑	[18]
SI 4C	15-60% load, 1500-4500 rpm	F10,F20	BTE↑, BSFC↓,	NOx↑,HC↓, CO↓	[24]
CI 1C	3.75-18.75 Nm, 1800-3000 rpm	F0, F5, F10	BSFC↑, MFB↓, HRR↓, COV↓	NOx↓, CO↓	[25]
CI 1C	2.5-10 Nm, 2000 rpm	F0,F10,F15, F20			[8]

The current study's goal is to determine whether engine combustion acceleration behaviour utilising fusel oil differs significantly from that of gasoline. There are still few trials employing waste products, particularly fusel oil, in turbocharged gasoline engines. Then, for alternative fuel, analyses of engine combustion, performance, and emissions are

required. Furthermore, there is still a scarcity of data on the performance and emissions of this fuel in four-cylinder turbocharged engines with a low percentage. In this case, gasoline blends fusel oil have been blended at proportions of 10%, 20%, and 30%, respectively, and are designated as F10, F20, and F30. As a baseline, the gasoline (RON95) from a gas station was used. The tests were conducted with a 10-40% throttle load and a set engine speed of 2000 rpm. In-cylinder pressure, ROPR, ROHR, MFB, BSFC, and BTE were evaluated as performance parameters. To establish the benefits of fusel oil blends, researchers look at NOx, HC, and CO emissions from engines.

METHODS AND MATERIALS

A 1.8L turbocharged spark-ignition (SI), four-stroke, and four-cylinder engine was used in the study. The turbocharged engine's technical specs are listed in Table 2. The compression ratio was set at 9.5:1 by the engine manufacturer. The diameter and stroke of the cylinder block are 81mm and 89mm, respectively. The engine's power and torque were 118kW@6000rpm and 220Nm@3000rpm at the time. The schematic diagram of the engine arrangement is shown in Figure 1. A 100 kW eddy current dynamometer (Dynalec Controls, India) was directly attached to the turbocharged engine via a coupling shaft.

Table 2. Specifications of the engine

Type	SOHC 16 V MPI
Number of cylinders	4
Combustion Chambers	Pentroof Type
Total displacement	1.8 (L)
Piston stroke	89 (mm)
Cylinder bore	81 (mm)
Compression ratio	9.5:1
Max output	118 (kW) @6000 rpm
Max torque	220 (Nm) @ 3000 rpm
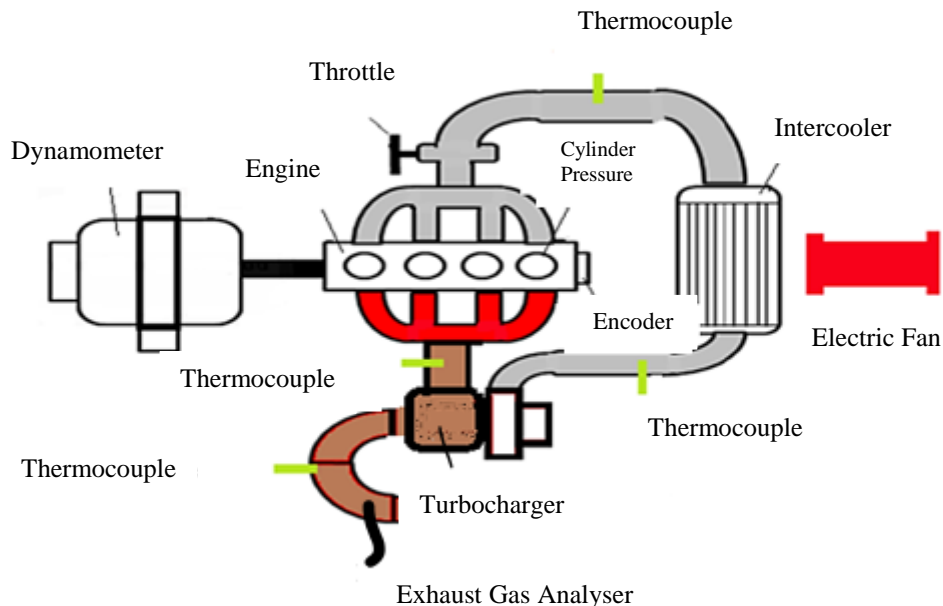
Figure 1. Schematic layout turbocharged gasoline engine and dynamometer

RESULTS

Combustion Analysis Method

For tracking the combustion process with the crank angle, a fiber-optic based direct in-cylindrical pressure sensor and magnetic encoder were used. The TFX combustion analyzer software captured the pressure variations. It has a size range of 0–200 bar and a sensitivity of 1.12 mV-psi. At 200 successive cycles, the average data was acquired. ROHR was calculated using the first rule of thermodynamics. The heat released was calculated by calculating the heat transfer from the cylinder to the wall. Eq. (1) was used to compute the rate of heat loss based on the crank angle degree.

$$\frac{dQ}{d\theta} = \frac{k}{k-1}\rho\frac{dV}{d\theta} + \frac{1}{k-1}V\frac{dP}{d\theta} + \frac{dQ_{heat}}{d\theta} \tag{1}$$

Where, Q is heat release during combustion, θ is crank angle degree, k is specific heat ratio and V is instantaneous volume during combustion. ROHR defined as the rate of chemical energy released by the combustion process. The ROPR was calculated by using Eq (2).

$$\frac{dp}{d\theta} = \frac{p_{i+1} - p_{i-1}}{\theta_{i+1} - \theta_{i-1}} \tag{2}$$

Where, θ is crank angle and p is cylinder pressure. MFB defined as a function of cumulative of percentage energy released by the heat of fuel. It also can be defined as progress of the combustion. The MFB was estimated by using Eq.(3).

$$MFB = 1 - exp\left[-a\left(\frac{\theta - \theta_0}{\Delta\theta}\right)\right]^{m+1} \tag{3}$$

Where θ is crank angle, $\theta0$ is combustion starting angle, $\Delta\theta$ is the total combustion duration (MFB=0 to MFB=1), a and m are adjustable weibe parameter.

Fuel Preparation

Before data collection, the fusel oil and gasoline were blended with an electrical stirrer for 5 minutes. The parameters of the gasoline and fusel oil that were used in the experiment are listed in Table 3. The parameters of gasoline-fusel oil mixtures are shown in Table 4 below. The density of the mixture was measured using an ASTM D4052 technique and a portable specific gravity metre. The octane number, on the other hand, was computed using the weight of a mole of molecule. The research octane number (RON) was determined by using an ASTM D2699-compliant portable octane number device. The heating value of the fuel was tested with an ASTM D240 calorimeter bomb.

Table 3. Properties of gasoline and fusel oil

	Gasoline	Fusel Oil
Boiling Temperature, °C	27-225	122-138 [26]
Latent Heat of Vaporization, kJ/kg	349	501-874 [26]
Lower Heating Value, MJ/Kg	44	29 [27]
Flash Point, °C	-45	41[21]
Auto Ignition Temperature, °C	257	41.6
Stoichiometry	14.7	12.5
Density, kg/m^3	737	847
Viscosity, mm^2/s	0.5-0.6	0.61
Research Octane Number	95	106.8[6]

Table 4. The properties of fusel oil blends

Properties	Test Standard	Fusel 10% Blend (F10)	Fusel 20% Blend (F20)	Fusel 30% Blend (F30)
Density (kg/m^3)	ASTM D4052	776	783	794
Stoichiometry (weight)	Mole Calculation	12.8	13.2	13.8
Octane Number	ASTM D2699	96.1	97.2	98.6
Heating value (MJ/kg)	ASTM D240	42.6	41.6	39.4

The fuel usage was measured using an AIC-1204 HR 2000 model fuel flow metre with 0.01s sensitivity. To deliver gasoline and keep the pressure at 35 psi, a 12V inline fuel pump is used. Eq. (4) was used to calculate the BSFC.

$$BSFC = \frac{\dot{m}_f}{p_e} \tag{4}$$

Where $\dot{m}_f$ is fuel flow and p_e is engine power.

Instrument Preparation

A Kane Auto-plus 5-2 gas analyzer was used to record the exhaust emission components and relative air-fuel ratio. The air-fuel ratio, as well as exhaust gas emissions such as NOx, CO, and HC, are measured. A Benetech GM8903 hot-wire anemometer with an air speed resolution of 0.001m/s was used to monitor the intake air flow rate. Air intake flow can be used to determine the fuel ratio in stoichiometry, or vice versa. The temperatures of the engine oil, suction air, and exhaust gas were then measured with K-type thermocouples and data recorders (Picolog TC-08). To keep the temperature between 85 and 90 degrees Celsius, the engine was cooled by flowing water from an external water tank.

DISCUSSION

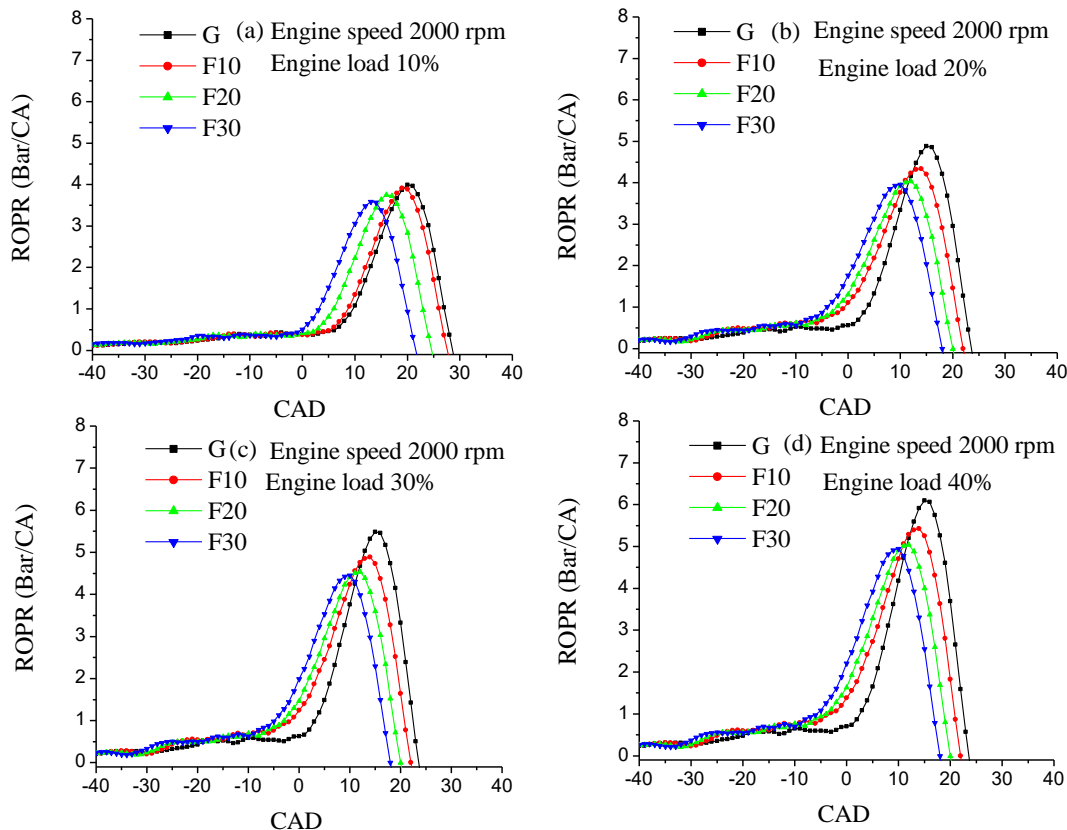### Combustion - In-Cylinder Pressure

For engine speeds of 2000 rpm, Figure 2 shows comparisons of in-cylinder pressure versus crank angle degree (CAD). In-cylinder pressure is shown in Figures. 2(a) to 2(d) for a throttle load of 10% to 40%. Before taking the in-cylinder pressure data, the driving pressure was utilised to calibrate the TFX software and tallied with hand calibration. During engine running, the maximum in-cylinder pressure rises by 3-5 MPa, and peak pressure gasoline fuel is higher than other fuel blends. According to studies, as engine load increases, so does in-cylinder pressure. In comparison to fusel oil, the higher in-cylinder pressure caused by gasoline fuel has a larger heating value [7]. The increase in cylinder pressure comes as a result of the charge flow volumetric efficiency into the engine cylinder. Fusel oil mixtures, on the other hand, burned at a faster pace than gasoline. When compared to gasoline, the fusel oil blends produced peak pressure 2-3 CAD earlier. Not only did the peak pressure drop, but so did the rate of pressure rise. When compared to gasoline, it has a higher vaporisation rate and a faster laminar flame velocity, which helps to shorten the time it takes for flame kernels to form and develop [26]. Fusel oil blends in gasoline were increased, which improved cylinder charge cooling, resulting in lower combustion and temperature [28].
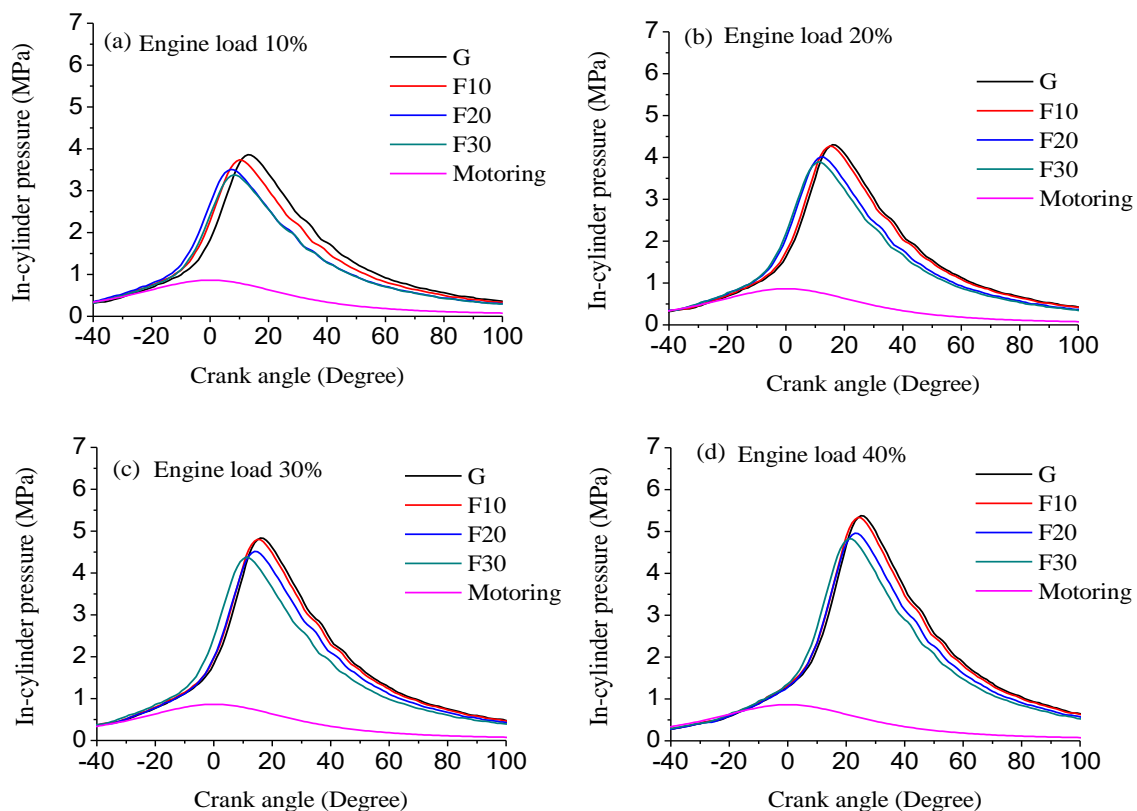
Figure 2. In-cylinder pressure for gasoline and fusel oil blends

Rate of Pressure Rise

The Rate of Pressure Rise (ROPR) was observed at 2000 rpm and 10-40% engine load in Figure 3. Its values were calculated using the first derivative of in-cylinder pressure. It also reflects the heat release rate [29]. As can be seen in the graph, ROPR increases as engine load increases. It has increased as charge density and volumetric efficiency in engine cylinders have increased. For 10-40% engine load, the maximum ROPR is 3.5-6.5 Bar/CA. When fusel oil mixtures are increased, however, ROPR decreases. Combustion pressure was reduced compared to gasoline by a lower premixed burning rate due to higher water content and a shorter ignition delay of fuel blends. The burning velocity of increased combustion has a significant impact on ROPR [30]. When comparing fusel oil blends to gasoline, it can be seen that peak ROPR occurs slightly earlier and has a shorter duration. At high engine loads, this tendency became more noticeable. The molecular structure and reaction kinetic characteristics of alcohol fuel were characterised by Chen et al. [31]. The hydroxyl moiety in fusel oil is linked to the hydrocarbon chain. At low temperatures, the presence of the hydroxyl moiety weakens the C-H bond, allowing hydrogen abstraction processes to dominate [32].
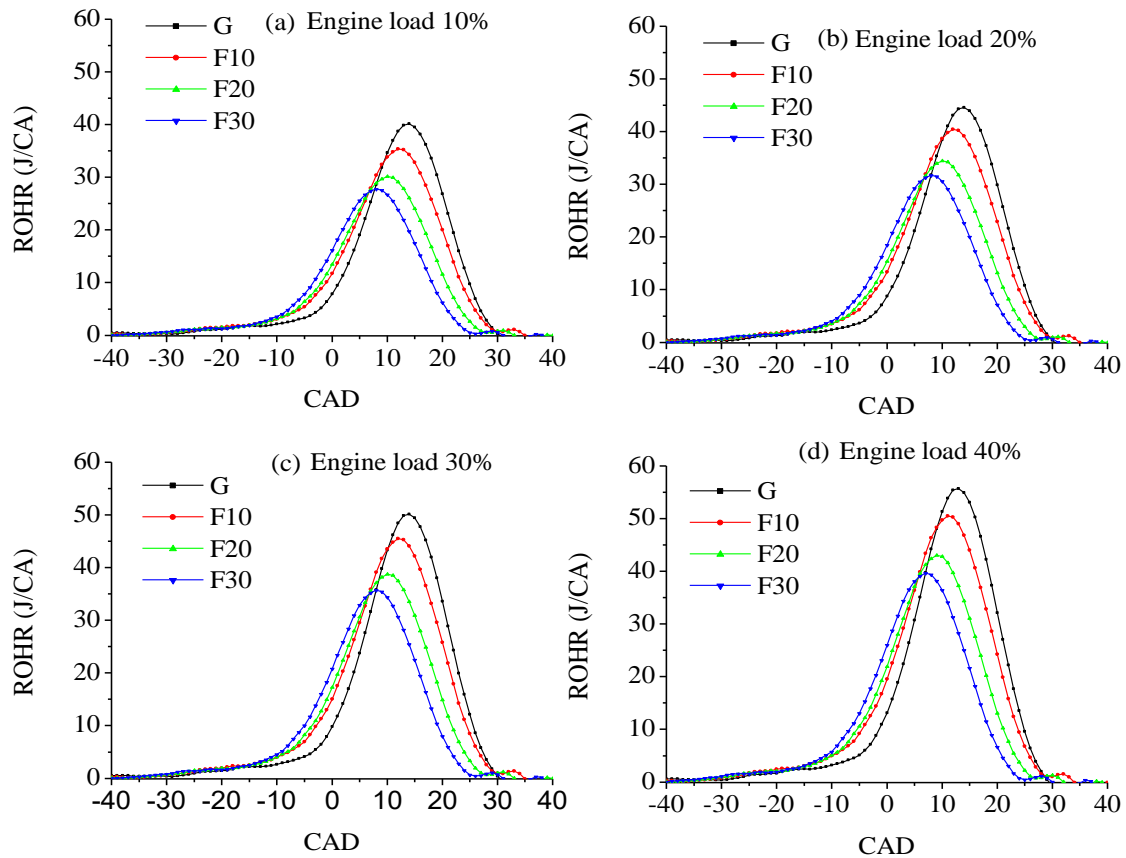

Figure 3. ROPR for gasoline and fusel oil blends

Rate of Heat Release

Figure 4 displays the Rate of Heat Release (ROHR) with an engine load of 10-40% and a speed of 2000 rpm. The ROHR values were derived from the in-cylinder pressure. The rate at which chemical energy from a fuel is released by the combustion process is known as ROHR [33]. It indicates that as engine load increases, so does the peak of ROHR. It rises as the in-cylinder pressure rises as the throttle is opened to increase the volumetric charge in the engine. Then, when comparing fusel oil blends to gasoline, the peak of ROHR occurred slightly sooner for fusel oil blends. Godwin et al. [34] stated that earlier of ROHR was due to increased flame propagation and combustion flame speeds. They also stated that the peak of ROHR is dependent on the amount of fuel used by the participant, whether it is a rich or lean mixture. Because of free radical propagation and the faster laminar flame speed associated with the location of the OH group, oxygenate fuel blends ignited earlier than gasoline. However, when compared to gasoline, the peak of ROHR for fusel oil blends is modest. The reduced heating value and water content of fusel oil blends, which worsen combustion when compared to gasoline, result in a lower peak ROHR [35]. As a result, it contributes to a lower combustion cylinder temperature and reduced NOx emissions.

Figure 4. ROHR for gasoline and fusel oil blends

Mass Fraction Burn

The Mass Fraction Burn (MFB) curve may be used to illustrate flame structure very well. Figure 5 depicts the progress of MFB combustion with a 10-40% engine load at 2000 rpm. It demonstrates that the progress of fusel oil mixes has switched in the direction of gasoline. MFB for blended fuels shifts due to greater flame speed during combustion flame propagation. Due to the higher oxygen content in fusel oil, the flame speed of combustion is faster. It happens 1-2 degrees earlier than the other fuels. Furthermore, due to the higher oxygen concentration, the start of combustion (SOC) of fusel oil blends (0-10%) occurs slightly earlier. Then, due to faster combustion, the duration of combustion (DOC) is reduced at 10-90 percent MFB [36]. During 40 percent engine load, it was shown to be shorter at 30 CAD for fusel oil mixes compared to 38 CAD for gasoline. When comparing fusel oil blends to gasoline, the end of combustion (EOC) at 90-100 percent MFB is 2 degrees earlier for fusel oil blends. Elfasakhany [37] found a similar finding, stating that complete combustion occurs when the reactivity of the fuel is high, as a result of a shorter ignition delay and greater flame speed combustion.
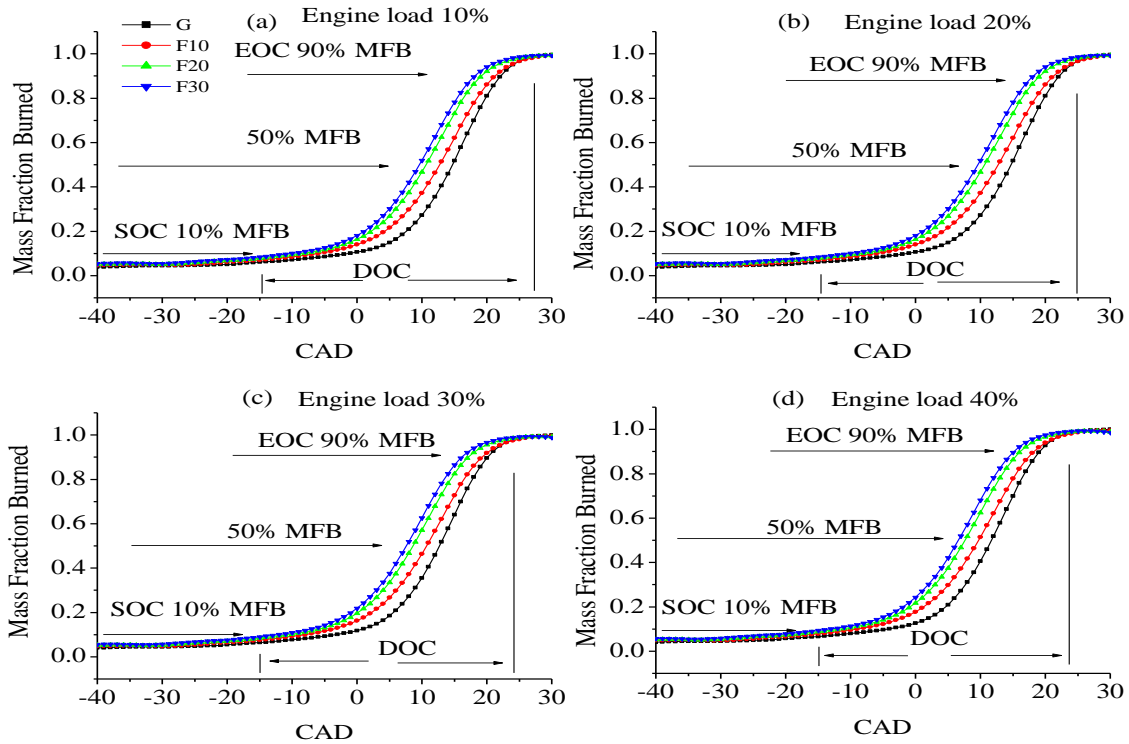
Figure 5. MFB for gasoline and fusel oil blends

Brake Specific Fuel Consumption

The effect of employing gasoline and fusel oil mixes on the Brake Specific Fuel Consumption (BSFC) for an engine speed of 2000 rpm with a 10-40% throttle position is shown in Figure. 6. When fusel oil mixes were increased in the same engine load, BSFC rose 5-22 percent on average compared to gasoline. Increased BSFC occurs in fusel oil blends compared to gasoline due to the high density of fusel oil. Calam et al. [18] found that because fusel oil has a higher density than gasoline, the amount of mass fuel taken into the engine cylinder increases. Then, Thangavelu et al. [38] said that the BSFC increased due to the alternative fuel's reduced heating value of over 30% when compared to gasoline. Fusel oil's poor heating value makes it difficult to improve engine performance [27]. Furthermore, the increase in BSFC is dependent on the proportion of blended fuel. For all test fuels, however, the BSFC increased as engine load rose. Due to higher engine brake heat, greater engine load causes an increase in BSFC [39].
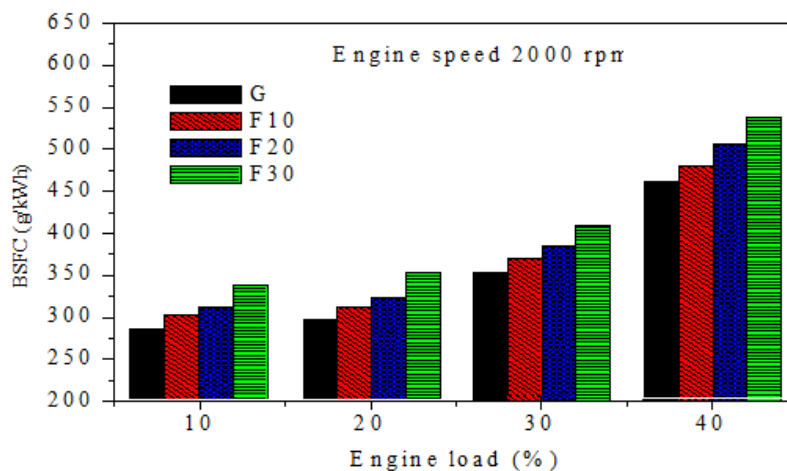

Figure 6. BSFC for gasoline and fusel oil blends

Brake Thermal Efficiency

Brake Thermal Efficiency (BTE) is shown in Figure 7 with an engine speed of 2000 rpm and a load of 10-40%. It is the quantity of fuel used for each unit of power or work performed per hour. When the engine load is raised, BTE increases. It rises as the density of the air/fuel charge in the engine cylinder rises as the throttle is opened. According to

Bendu et al. [40], BTE rises as the maximum gas temperature rises with increased engine load. Furthermore, the earlier onset of combustion results in a greater gas temperature and, most likely, a higher combustion efficiency. When fusel oil mixtures are increased, BTE decreases. When compared to gasoline, BTE decreases by 13-16% for all engine loads. Fusel oil has a reduced heating value, which helps to reduce BTE. Deng et al. [41] obtained a similar finding, stating that the BTE is lower due to heat loss passed to the cylinder wall. BTE was reduced due to alcohol-gasoline blends contributing to an increase in effort lost in the compression process, according to Li et al. [36].
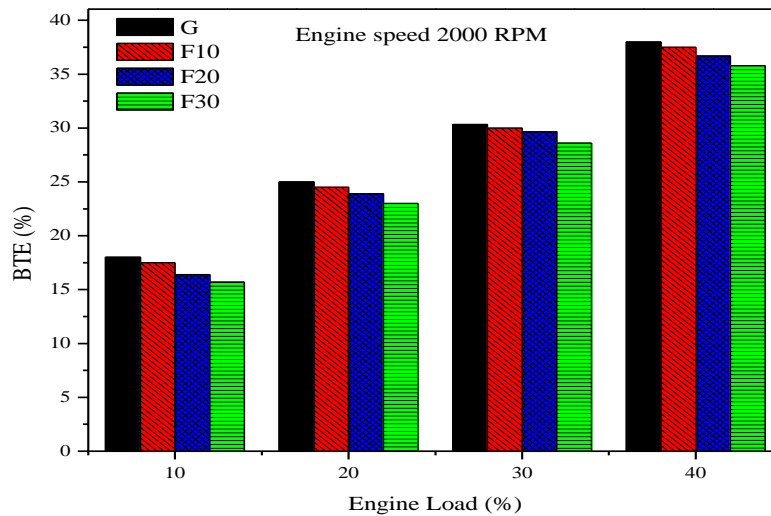

Figure 7. BTE for fusel oil-gasoline blends

Emission Analysis - Oxides of Nitrogen

Figure 8 depicts NOx emissions at 10-40 percent load and 2000 rpm. NOx generation is influenced by in-cylinder temperature, ignition time, and oxygen content in the fuel, according to Wan et al. [42]. The rise in NOx caused by increased in-cylinder pressure and temperature [43]. Shameer & Ramesh [44] discovered that increased NOx emissions are caused by a greater combustion temperature, which leads to an intensified nitrogen-oxygen interaction.
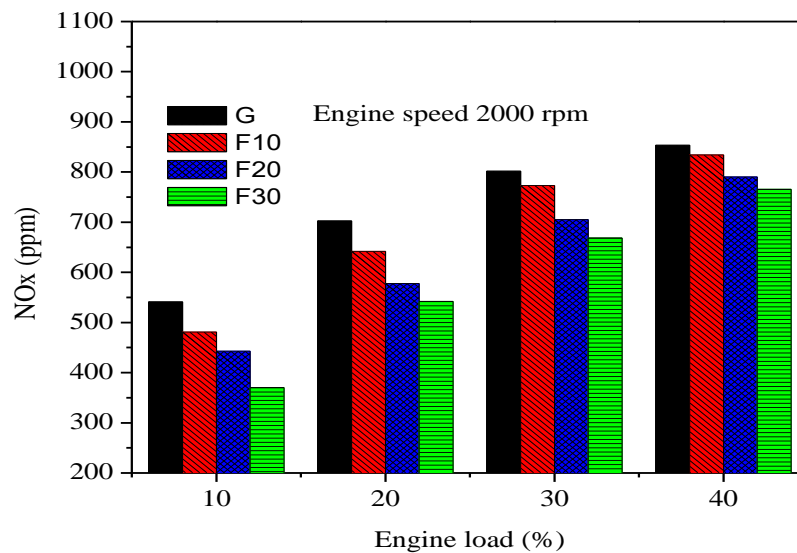

Figure 8. NOx for fusel oil-gasoline blends

By opening the throttle position, the in-cylinder pressure is increased due to the increased density of the air/fuel combination. When fusel oil mixes were increased, however, NOx decreased by 18% to 36%. Every engine test load showed the same pattern. When compared to gasoline, NOx levels are lower due to lower in-cylinder pressure. When alcohol fuel was used, NOx emissions were reduced due to lower in-cylinder temperatures [44]. Because alternative fuel has a lower heating value and a larger latent heat of vaporisation, the maximum in-cylinder temperature was reduced when it was mixed with gasoline, according to Turner et al. [45].

Hydrocarbon

The element hydrocarbon (HC) is made up primarily of carbon and hydrogen. It is a result of incomplete combustion caused by a lack of oxygen, a high temperature, and a long combustion period [8]. Figure 9 shows the HC emission trend at a 2000 rpm engine speed and a 10-40% throttle setting. When the engine load is increased, the HC emissions drop. During engine cycles, HC levels drop due to complete combustion. Masum et al. [46] came to a similar conclusion. During complete combustion, they mentioned an increase in NOx and in-cylinder temperature. According to Hossain and Davies [47], HC emissions from gasoline are higher than those from alternative fuels due to a higher temperature response in the in-cylinder engine during combustion. The full combustion of alternative fuels, which has a higher oxygen content, led to the reduction in HC emissions described by [19]. When fusel oil mixes are increased in gasoline, HC levels drop when compared to gasoline. In comparison to gasoline, HC is reduced by 3-4 percent on average. The use of alternative fuel in internal combustion engines reduces HC because it mostly contains oxygen, according to Jaliliantabar et al. [48]. Prbakaran & Viswanathan [49] described a decrease in HC emissions due to higher combustion temperature with higher engine load.
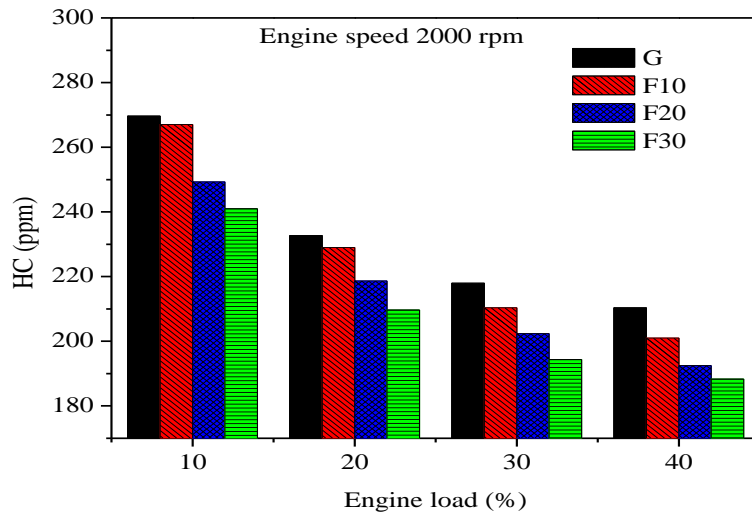

Figure 9. HC for gasoline-fusel oil blends

Carbon Monoxide

Figure 10 shows the carbon monoxide (CO) emissions for various fuel blends at a 2000 rpm engine speed. CO emissions are the result of incomplete combustion caused by a shortage of temperature and oxygen. CO emissions are slightly higher at low load than at higher load. When fuel blends were increased at the same engine load, CO emissions decreased by 7.5 percent -24.5 percent. In cylinder combustion, the reduction of CO for fusel oil blends is well flammability properties occurred [27]. When the engine load is increased, CO emissions drop. According to Iodice et al. [50], a decrease in CO emissions might be induced by a quicker flame speed of oxygen concentration in alcohol fuel, which improves combustion efficiency. Calam et al. [23] determined that higher engine cylinder homogeneity contributes to better combustion and CO reduction. CO emissions for alcohol fuel are lower than for gasoline, according to Ilhak et al. [51], because to a higher lamina flame speed, which lowers the temperature inside the engine cylinder.
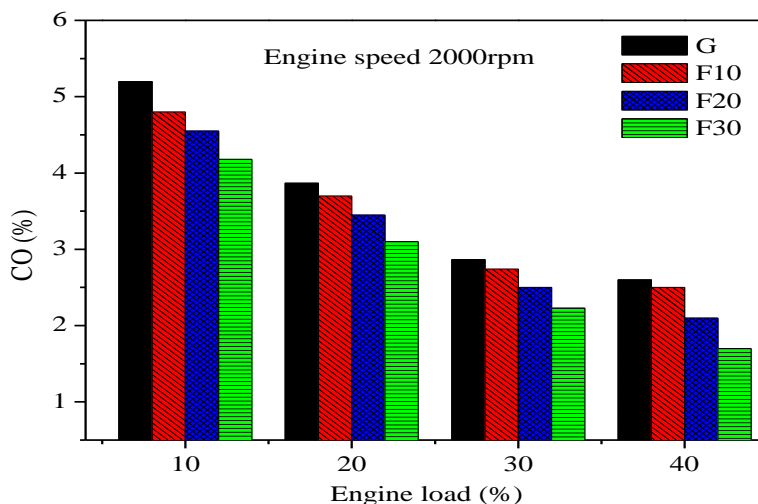

Figure 10. CO emission for gasoline-fusel oil blends

CONCLUSIONS

At an engine speed of 2000 rpm and varied throttle loads of 10-40 percent, the performance and engine emission characteristics of the 1.8L Turbocharged engine fuelled with gasoline and fusel oil mixes are tested. The experimental study yielded the following conclusions:

1) Fusel oil mixes with lower heating values contributed to reduce in-cylinder pressure, ROHR, and ROPR peaks. Then, in comparison to gasoline, MFB progressed by 2-3 degrees. It was discovered that the oxygen presence in fusel oil causes a quicker flame speed of fuel mixture oxidation.

2) A loss in engine performance is caused by a decrease in in-cylinder pressure. As previously stated, the presence of water slowed the rate of combustion. Then, when compared to gasoline, BTE for fusel oil blends was revealed to be 13-16% lower.

3) Engine performance suffers as a result of the lower energy level of fusel oil. The higher the density and heat of vaporisation of fusel oil compared to gasoline, the greater the rise in BSFC fusel oil at 5-22%.

4) Increased engine load and fusel oil mixes lowered HC and CO by 3-4 percent and 7.5-24.5 percent, respectively. They are reduced as a result of complete combustion. Due to the presence of oxygen in fusel oil, combustion is completed. When fuel mixtures are increased, NOx levels drop by 18-36 percent. In a cylinder engine, combustion was completed quickly.

ACKNOWLEDGMENTS

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