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Performance, Combustion Characteristics and Emission Tests of Single Cylinder Engine Running on Fusel Oil - Diesel Blended (F20) Fuel

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ABSTRACT:

Alcohols produced from a renewable source are amongst the important alternative fuels for internal combustion engines. Investigations on alternative fuels for compression ignition engines regarded as one of the major research areas. This paper details an experimental examination of the performance and emissions in single cylinder compression ignition engines operating with fusel oil F20 and pure diesel F0 at five engine speeds and 50% engine load. The test results indicated that the engine power and torque slightly decrease with the F20 at low speeds compared with pure diesel. Further, the in-cylinder pressure was decreased at all engine speed for F20 in comparison with pure diesel. The volumetric efficiency and fuel consumption were increased for F20 due the low heating value of fusel oil. The results showed that CO_2 and CO emissions were increased because of the water content, low heating value and low cetane number for fusel oil. The maximum reduction in NO_x emissions was 18% for F20 at 1500 rpm.

KEYWORDS:

Fusel oil; NO_x emissions; Single cylinder engine; Alternative fuels; Engine performance

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1. Introduction

The attention to utilizing renewable and alternative fuels in internal combustion has been accelerated recently. This is due to rapid decrease in crude oil reserves, growth in the costs of the fossil oil fuels and restrictions on exhaust emissions from internal combustion (IC) engines triggered by environmental concerns [1]. Currently, several countries are substituting their conventional energy sources with green and renewable ones to some extent [2]. The alcohols as pure, blended and additive can be utilized in compression-ignition (CI) engines with diesel [3-5]. Significant research achieved with methanol-diesel and ethanol-diesel blends on the performance and emission of diesel engines. Jincheng et al [6] achieved the experimental work on various amount of ethanol blending with diesel, and they studied the performance and emission of a diesel engine. As a result, the torque and power and thermal efficiencies were decreased and the NO_x emission was also decreased. While the CO and HC was increased compared with diesel. Due to the low heating value of ethanol, the specific fuel consumption was increased.

NO_x emissions from the ignition combustion engine related for many reasons such as engine operating conditions and fuel properties. The thermal NO_x emissions are linked to higher in-cylinder temperature and prompt NO_x with CH of fuels. The idea of using alcohols as a means of producing cleaner diesel engines was introduced over 50 years ago. Ajav et al [7] tested different proportions of ethanol-diesel fuel blends in a constant speed diesel engine. They detected that 9% increase in the specific fuel consumption (SFC) when the blend was 20% as compared with pure diesel, and the increment was with CO and NO_x accrued. Özer et al [8] performed study on a four-cylinder diesel engine with ethanol-diesel fuel emulsion. The effects of ethanol addition on the performance and emissions (CO, soot, SO_2, NO_x) were investigated. They found that the increase in NO_x emission was around 12.5% and a reduction CO, smoke and SO_2 emission was also noted.

Fusel oil is a by-product of alcohol production with fermentation through the distillation process [9-11]. Fusel oil has the appearance of an alternative fuel for use in a spark ignition engine. The structure and quantity of the fusel oil depend on the kind of carbon utilized in the alcohol production, fermentation process, preparation method, and decomposition method of the fusel oil in the mixture [12]. The use of fusel oil as an alternative fuel may be accepted as a new energy source in diesel engines. However, the study of using fusel oil with diesel is not found in literature. There are limited studies achieved with gasoline in spark ignition engine. In this study, a single-cylinder diesel engine with five different speeds with 50% load was used to determine the influence of the blends of fusel oil-diesel on engine performance and emission in comparison with pure diesel. The effects of test fuels on engine power, torque, SFC, in-cylinder pressure, exhaust temperature and volumetric efficiency were studied.

2. Experimental set-up

This study was performed using single cylinder YANMAR TF120 diesel engine with 0.63L capacity and 17.7 compression ratio with Hydrome HGP-3A-F23 dynamometer. The exhaust gas analyzer was also included in the engine test bed. The schematic diagram of the engine test bed is shown in Fig. 1. The data was collected by TFX Engineering. The in-cylinder pressure sensor and crank angle sensor were used to collect the data during engine testing. The outputs were engine power, torque, in-cylinder pressure, exhaust temperature and maximum combustion temperature. The temperature was measured by a K-type thermocouple [13-14]. The temperature readings were displayed via data logger. By using this device, the intake temperature, exhaust temperature, and ambient temperature can be measured simultaneously. The experiment was conducted with five speeds ranging from 1200rpm to 2400rpm with intervals of 300rpm with 50% engine load. The test achieved with pure diesel F0 and fusel oil diesel blend F20 (20% of fusel oil and 80% diesel by volume). The properties of pure diesel, fusel oil and F20 (20% fusel oil blend) are given in Table 1. The test engine specifications were provided in Table 2.

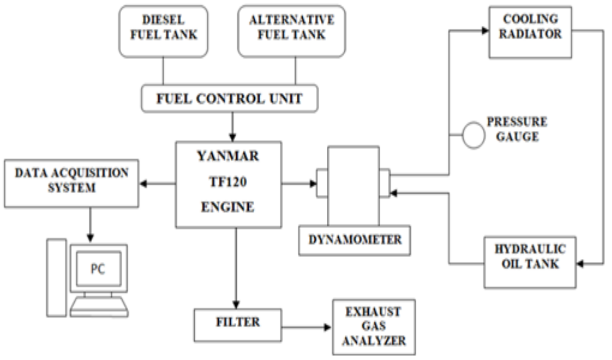

Fig. 1: Schematic view of Yanmar TF 120

Table 1: Properties of test fuels

Fuel properties	Diesel	Fusel oil	F20
Density [kg/m^3]	746	847	761
Higher heating value [MJ/kg]	47.5	29,536	42,12
Cetane Number	46	-	38
Water content %	-	13.5	0.88
Boling point [°C]	-	98	201

Table 2: YANMAR TF120 engine specifications

Description	Specification
Bore dia. × Stroke [mm]	92 x 96
Displacement [L]	0.638
Injection timing	17° BTDC
Compression ratio	17.7

3. Results and discussion

The test was performed under steady state conditions. The engine was tested with pure diesel first to get the base data of the engine, followed by F20 blend fuel. The engine power, engine torque, fuel consumption, exhaust temperature and emissions (CO_2, CO, and NO_x) were measured during the test. The engine performance and emissions in particular thermal NO_x are affected by the in-cylinder pressure. Fig. 2 shows the test results of in-cylinder pressure for 10 cycles. The in-cylinder pressure of diesel is slightly higher than F20. The increasing in-cylinder pressure with pure diesel was due the higher heating value and Cetane number for diesel higher water content of fusel oil. Figs. 3 and 4 show the results of engine torque and power. The engine power and torque have increased at all engine speeds. Despite the low heating value of F20 proportion to diesel, it has seen that the torque and power have slightly decreased with pure diesel (F0) at low engine speed. Water content, being one of the reasons, has restricted the combustion and increased the heat loss. This has lead to a decrease in the power and torque at low speeds [15]. Similar results of reduced power and torque were evidenced by using bio-diesel [16-17] and ethanol [18]. At high speeds (2100 and 2400 rpm), the engine power and torque were increased slightly. The maximum engine power and torques measured at 2400 rpm for F20 were 5.3kW and 21.5Nm respectively. The more amount of fuel was driven into cylinder at high speeds. When the engine speed increases, the energy driven into the cylinder increases. The oxygen content of fusel oil represents one of the main reasons to improve the in-cylinder combustion reactions, despite the higher water content (13.5%) of fusel oil and lower heating value.

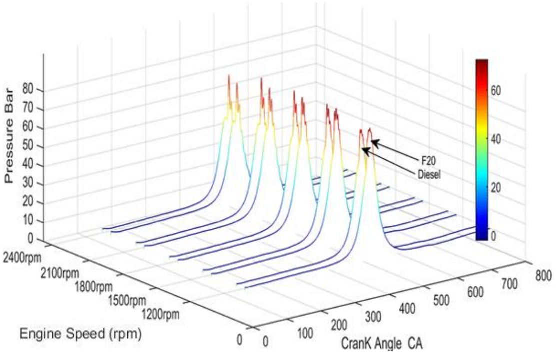

Fig. 2: Comparison of in-cylinder pressure for diesel and F20

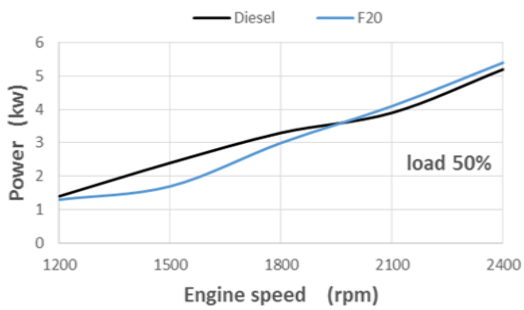

Fig. 3: Comparison of engine power for diesel and F20

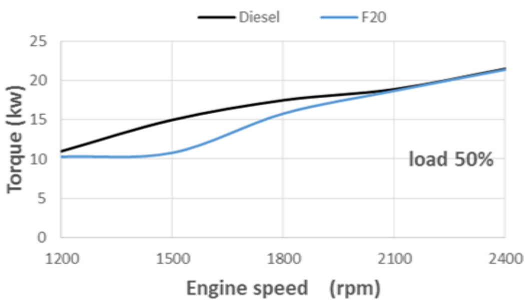

Fig. 4: Comparison of engine torque for diesel and F20

The low heating value of fusel oil (29.536 MJ/kg) compared to pure diesel (47.5 MJ/kg) led to decrease in the heating value of F20. The comparisons of volumetric efficiency and fuel consumption of F20 and pure diesel are shown in Fig. 5 and Fig. 6 respectively. At all speeds, the volumetric efficiency of F20 is higher than diesel thereby the fuel consumption of F20 was also increased. The latent heat of evaporation of alcohol based fuels is higher than diesel that permits lower manifold temperatures and higher volumetric efficiency [16-17]. The variation of in-cylinder temperature with different engine speeds for F20 and diesel is presented in Fig. 7. The temperature of diesel is slightly higher than F20. The maximum temperatures measured at 2400 rpm, which were 1273°C for diesel and 1234°C for F20. The high oxygen content of fusel oil led to the higher in-cylinder temperature in the combustion chamber according to its higher latent heat of evaporation.

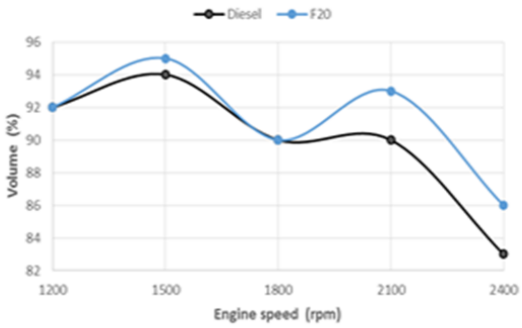

Fig. 5: Comparison of volumetric efficiency for diesel and F20

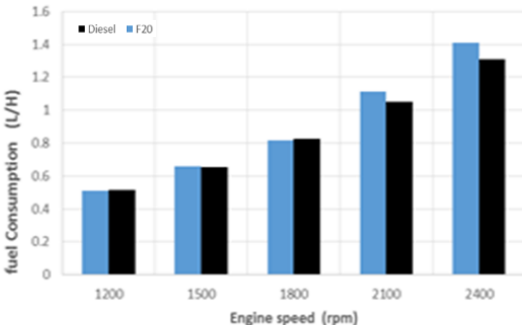

Fig. 6: Comparison of fuel consumption for diesel and F20

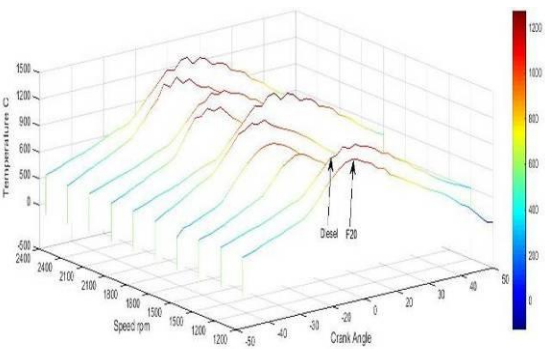

Fig. 7: Comparison of in-cylinder temperature for diesel and F20

The influence of fusel oil on emissions is related with engine operating conditions. NO_x is the greatest harmful gaseous emission from a CI engine. NO_x formation happens at temperatures above 1500°C. The rate of NO_x formation increases quickly with increasing temperature above 1500°C. Fig. 8 shows the comparison of NO_x emission results. The oxygen content in the fusel oil and alcohols led to a more complete and cleaner combustion [18]. Higher oxygen content in the mixture promotes the NO_x formation [17,19]. The water content of fusel oil played a significant role in reducing the NO_x emission by reducing the in-cylinder temperature. As result the NO_x decreased with F20 compared with pure diesel at all speeds. The maximum reduction in NO_x emission was 18% for F20 at 1500rpm. Figs. 9 and 10 show the comparison of CO_2 and CO emissions. With F20 fuel, the CO_2 emissions increased at high speed while the CO increased at all engine speeds.The significant increase was with CO emission which may be due to higher average carbon content per energy of the fusel oil when compared to pure diesel fuel. The CO emission increases when the carbon and hydrogen ratio (C/H) of fuel increases. Another reason for the high CO_2 and CO emission for F20 was due to high oxygen content in the fusel oil.

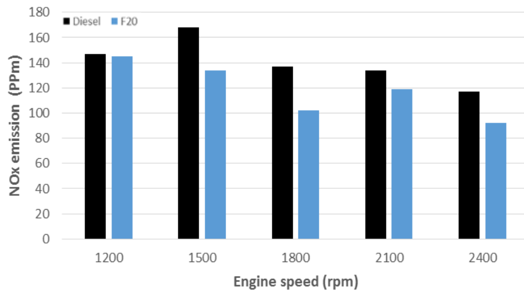

Fig. 8: Comparison of NOx emission for diesel and F20

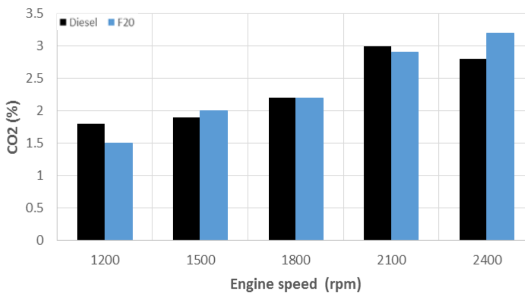

Fig. 9: Comparison of CO_2 emission for diesel and F20

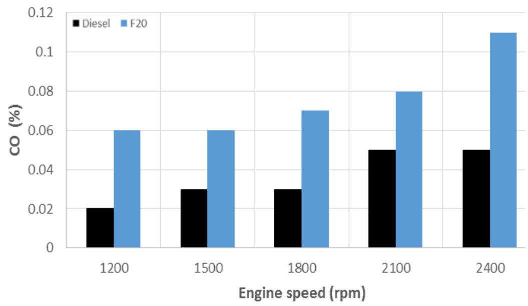

Fig. 10: Comparison of CO emission for diesel and F20

4. Conclusion

In this paper the impact of fusel oil blended diesel fuel (F20) on the engine performance and emissions were examined. The tests were conducted on a single-cylinder diesel engine at 50% engine load and five speeds from 1200 to 2400rpm with intervals of 300rpm. The engine torque and power slightly were decreased due to lower in-cylinder pressure for F20. The volumetric efficiency and fuel consumption were increased with F20 due to the low heating value and higher latent heat of evaporation of fusel oil. The in-cylinder temperature was slightly decreased with F20 due to its high water content. As compared to pure diesel, F20 showed a drastic reduction in NOx emission. The CO_2 and CO emissions were increased for F20 compared with pure diesel. The water content of fusel oil should be extracted before utilising in the CI engine. Thereby, the engine performance of the fusel oil blended diesel (F20) may be enhanced.

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