Influence of Fuel Injection Timing on the Performance and Emission Characteristics of a Diesel Engine Fueled with Jatropha Methyl Ester-Tyre Pyrolysis Oil Blend

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Abstract: Early investigation on utilization of Jatropha methyl ester (JME) tyre pyrolysis oil (TPO) blends in a single cylinder, constant speed, direct injection diesel engine revealed that a blend of 80% JME and 20% TPO referred to as JMETPO20 blend give a better performance and lower emissions compared to other Jatropha methyl ester tyre pyrolysis oil (JMETPO) blends. In this study, for further improvement on performance and emission, and also to find optimum injection timing for blend, experiments have been carried out with varying the injection timings. Tests have been conducted under two advanced and two reratarded injection timings in addition to the original injection timing of 23 ˚CA bTDC. The experimental test results showed that for the JMETPO20 blend at advanced injection timing of of 24.5 ˚CA the brake thermal efficiency (BTE) increased by about 2.21%, compared the results of original injection timing at full load. For the JMETPO20 blend at advanced injection timing of 24.5 ˚CA the nitric oxide (NO) and carbon dioxide (CO_2) emission increased by about 4.56% and 11.91% respectively at full load, and the carbon monoxide (CO) emission decreased by about 11.21%, compared to that of original injection timing.

Keywords: diesel engine, Jatropha methyl ester, tyre pyrolysis oil, injection timing

1. Introduction

As the population increases exponentially, the number of automotive vehicles increase every year. It is estimated that about 2-3 billion ton waste automobile tyres are disposed annually in the world [1]. The waste automobile tyres are majorly disposed from the USA, Europium countries, Australia, Japan, China and India. The accumulation of waste automobile tyres causes a severe environmental problem and, also contaminates the soil and reduces the fertility. The waste tyre is composed of rubber, chemicals, steel wire, fabrics and cotton. The anthropogenic gases raise from the disposal area is one of the reasons for the green house gase (GHG). The burning of automobile tyres is toxic and harmful to the human being and therefore it is illegal in most of the countries in the world [2]. Therefore, it is very much essential to dispose the waste tyres in an efficient way. Pyrolysis process is one of the methods to recycle the waste automobile tyres in to useful energy. It is a simple technique to convert scrap tyres in to value added products. In the pyrolysis process, long chain polymers are thermally broken down into smaller hydrocarbon in the oxygen free environment. The process yields three principal products, viz., tyre pyrolysis oil (TPO), pyro gas and carbon black. The TPO consists of C, H, O, N and S containing organic compounds and water. The organic compounds range from C_5 to C_{20}. The TPO contains fractions of volatility consistent with gasoline, kerosene and diesel [3]. As a result, the TPO was tried as an alternative fuel in both spark ignition (SI) engines and compression ignition (CI) engines. The solid carbon black can be used in industrial application such as re-treading, coating of insulation and industrial filters.

The main drawback of TPO is lower cetane number, which is in the range of 25-30. Recently a research work was carried out to study the effect of blending TPO with a fuel, whose cetane number is greater than diesel. For this purpose Jatropha methyl ester (JME), whose cetane number has marginally higher than diesel was blended at different proportions with TPO. One advantage of JME is oxygen bound fuel. In that study, TPO was blended at different proportions from 10 to 50% with a step of 10% on volume basis, with JME. The blend was denoted as JMETPO10, JMETPO20

JMETPO30 JMETPO40 and JMETPO50, where the numeric value indicates the percentage value of TPO in the JMETPO blend. Experiments were conducted in a single cylinder, four stroke, air cooled, DI diesel engine, with a developing power of 4.4 kW at 1500 rpm to study the combustion, performance and emission characteristics using the JMETPO blends. From the results, it was concluded that the JMETPO20 blend was optimum blend, that gave a better performance and lower emissions compared to other JMETPO blends [4]. The engine behaviour is predominately affected by the fuel and air mixture supplied in the diesel engine. The fuel quantity is governed by fuel injection rate, injection timing and nozzle geometry. Several researchers have documented the research results pertaining to the effect of injection timing on engine performance and emission of diesel engines [5-8]. The present study is aimed to study the effect of injection timing on performance and emission characteristics of a diesel engine fueled with the JMETPO20 blend.

2. Experimental

Experiments were conducted in a single cylinder, four stroke, air cooled, direct injection, diesel engine, with a developing power of 4.4 kW at 1500 rpm. Fig. 1 illustrates the schematic diagram of the experimental set up. The blend was measured on volume basis and, was kept for an observation for thirty days to check its stability. It was observed, that the TPO is miscible with the JME and, the blend was stable during the period of observation.

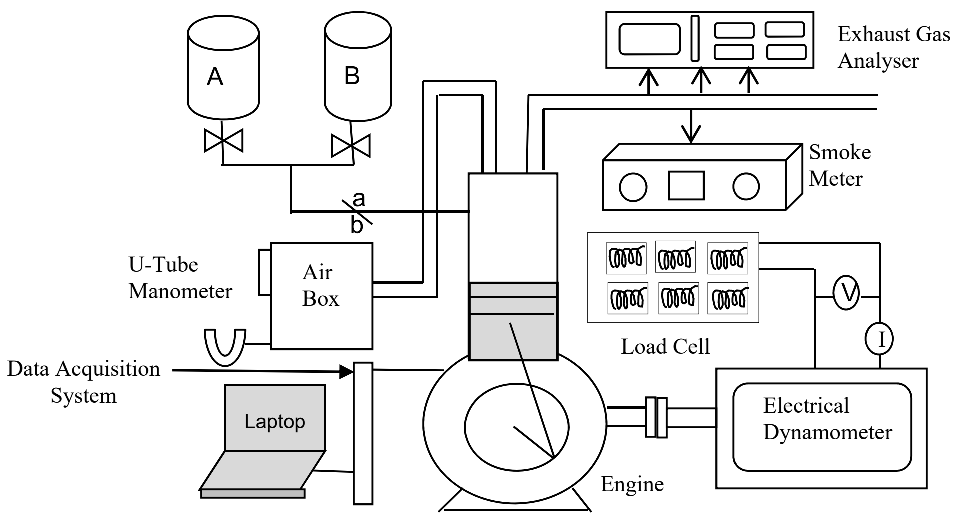

Fig. 1 Schematic Diagram of the Experimental Setup

Experiments were initially started with diesel and after the engine's warm up condition, it was switched over to JME, and then the JMETPO20 blend at the original injection timing of 23 ˚CA bTDC (as set by the engine manufacturer) for obtaining the reference data. Further, the experiments were conducted at different injection timings for the JMETPO20 blend. The original injection timing was altered by adjusting the number of shims fitted under the plunger in the pump, by the addition or removal of shims. For changing the injection timing, the shims fitted under the plunger in the pump was varied by the adding or removing of shims. Every single shim of thickness 0.25 mm shifts the injection timing by about 1.5 ˚CA. The experiments were carriedout with the JMETPO20 blend at four injection timings; two advanced 26, 24.5 and two retarded timings 21.5 and 20 ˚CA bTDC. For the original injection timing of 23 ˚CA bTDC, three shims were used in the fuel pump. The study was carried out with 1.5 and 3 ˚CA advancement, and 1.5 and 3 ˚CA retarded injection timing for the JMETPO20 blend, and the results were compared with those of diesel, JME, and the JMETPO20 blend at the original injection timing.The exhaust emissions of the engine were measured by an AVL

DiGas444 exhaust gas analyser. For each load, the engine was run for 30 minutes. Once the experiment was complete, then the test fuel was drained from the fuel line. The engine was further run with diesel for 30 minutes to remove the strains of the JMETPO20 blend.

3. Results and discussion

3.1 Performance parameters

3.1.1 Brake thermal efficiency

The brake thermal efficiency **(**BTE) reflects quality of combustion and provides comparable of assessing how efficient the energy in the fuel was converted to mechanical output [9]. Fig.2 shows the comparison of the BTE with brake power for diesel, JME, and the JMETPO20 at different injection timings. The BTE of JME is found to be lower than that of diesel at original injection timing, due to high density and lower calorific value of the JME. At original injection timing, the BTE for diesel, JME, and the JMETPO20 blend are found to be 29.89%, 28.61% and 29.88% respectively at full load. It can be observed from the figure, that the JMETPO20 at the advanced injection timing of 26 ˚CA bTDC and 24.5 ˚CA bTDC, the engine delivered the BTE of 29.11% and 30.52% respectively at full load. At retarded injection timing of 21.5 and 20 ˚CA bTDC, the BTE is found to be 29.05% and 28.07% respectively at full load. It can also be observed, that advancing the injection timing by 1.5 ˚CA increased the BTE, however additional advancement is not thus helpful at full load.

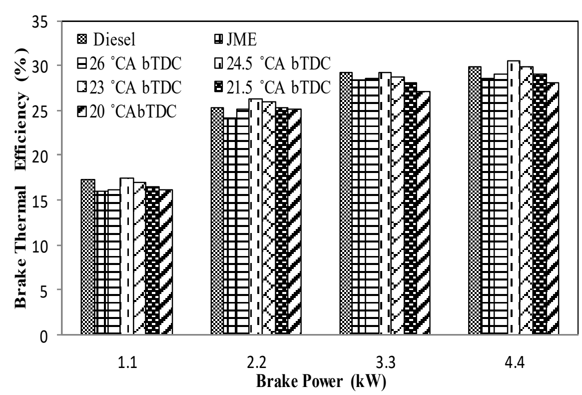

Fig. 2 Variation of the brake thermal efficiency at different injection timings

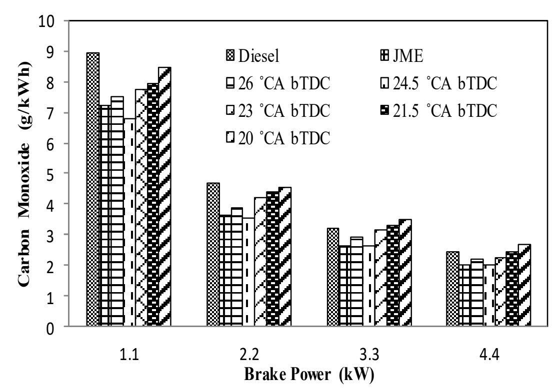

Fig. 3 Variation of the carbon monoxide emission at different injection timings

With the advanced injection timing of 24.5 ˚CA bTDC, the BTE is increased by about 2.06% and 6.25% than that of diesel and the JME respectively at full load. This is as a result of at advanced injection timing leads to better air-fuel mixing which results in improved combustion resulting the maximum BTE. But, with the retarded injection timings, the BTE is decreased owing to incomplete combustion, resulting in a lowered power output and increased brake specific energy consumption (BSEC).

3.2 Emission parameters

3.2.1 Carbon monoxide emission

Fig.4 represents the variation of carbon monoxide (CO) emission with brake power for all the test fuels at different injection timings in this study. It was observed for the JMETPO20 blend that the CO emission decreases at advanced injection timings, whereas increases with retarded injection timings compared to original injection timing. This may be due to at advanced injection timing leads to complete combustion because of early start of ignition [10]. Retarded injection timing exhibits late burning and incomplete combustion caused by the increased ignition delay. It is found for the

JMETPO20 that with the advanced injection timing of 24.5 ˚CA bTDC the CO emission lowered by about 11.16% compared to original injection timing at full load.

3.2.2 Carbon dioxide emission

The carbon dioxide (CO_2) emission is produced by complete combustion of fuel. The CO_2 is important components in global warming [11].The CO_2 emission results were given in Fig.5 for diesel, JME and the JMETPO20 blend at different injection timings. It is clear from the figure that the CO_2 emission increased with the increasing load due to more fuel injection with increasing load. In this study, for the JMETPO20 blend the CO_2 emissions increased by about 11.91% at the advanced injection timing of 24.5 ˚CA bTDC compared to the original injection timing because at advanced injection timing more time is available for the oxidization process which provides better air-fuel mixture leading to improved combustion and caused higher combustion temperature. Also decreased CO_2 emission with retarded injection timings could have noticed due to incomplete combustion of the air-fuel mixture.

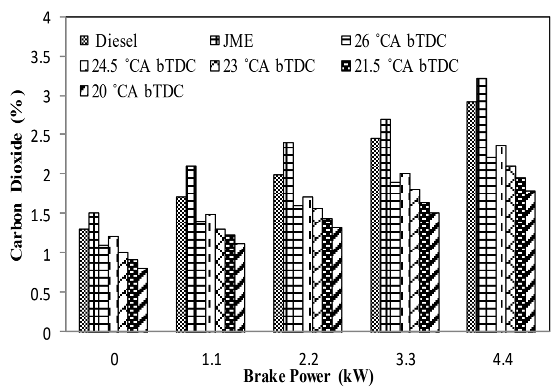

Fig. 4 Variation of the carbon dioxide emission at different injection timings

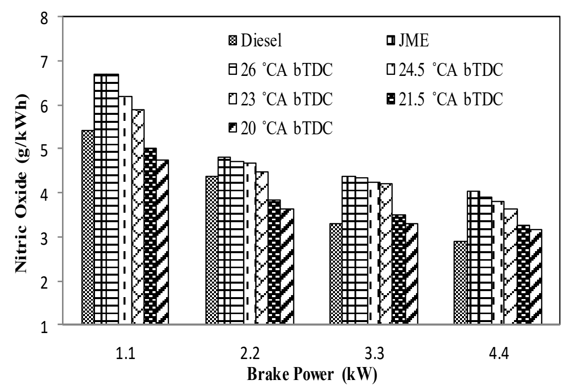

Fig. 5 Variation of the nitric oxide emission at different injection timings

3.2.3 Nitric oxide emission

Fig.6 shows the effect of varying the injection timings on the nitric oxide (NO) emission with diesel, JME and the JMETPO20. The NO emissions are increased at high loads due to enhanced combustion temperature. The NO emission is higher with the JME operation compared to that of diesel and JMETPO20 blend at all injection timings when engine is operating from no load to full load. The oxygen present in the JME is an important factor for the high NO formation [12]. Figure shows for the JMETPO20 blend that when the injection timing is advanced the NO emission increases as a result of higher combustion temperature due to improved combustion in premixed combustion phase. On the other hand retardation of injection timing resulted in reduced NO emission. For the JMETPO20 blend the NO emission at 26 and 24.5 ˚CA bTDC is found to be higher by about 6.94% and 4.56% than that of the original injection timing of 23 ˚CA bTDC at full load, while at the retarded injection timing of 21.5 and 20 ˚CA bTDC, the JMETPO20 blend resulted in a lower NO emission by about 10.04% and 12.74%, compared to that of the original injection timing at full load.

4. Conclusion

In the present study, the effects of fuel injection timing on the performance and emission characteristics of a single cylinder, 4 stroke, air cooled, DI diesel engine were experimentally investigated, when the engine was fueled with the JMETPO20 blend. Advancing the injection timing with 1.5 ˚CA bTDC results in a reduction in the CO emission, and increase in the BTE, the CO_2 and NO emission with the JMETPO20 operation compared to original and retarded injection timings. But, further advancement of 3˚CA bTDC was not beneficial. Retarding the injection timing by 3 ˚CA bTDC for JMETPO20, gave a lower value of the NO emission compared to that of with other injection timings. Overall, it can be concluded that with a little compromise of the NO emission, advanced injection timing of 24.5 ˚CA bTDC was found to be optimum, where the BTE was found to be higher by about 2.21% and the CO emission were found to be lower by about 11.21%, compared to other injection timings at full load.

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