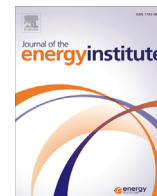




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Effect of injection timing on a DI diesel engine fuelled with a synthetic fuel blend

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ABSTRACT

Carbon black (CB) is one of the products obtained from the pyrolysis of waste automobile tyres. It possesses a considerable amount of heat energy in it. In this research work, the effect of varying injection timing on the combustion, performance and emissions of a single cylinder, air cooled, four-stroke, direct injection (DI) diesel engine was experimentally investigated, by using a synthetic fuel blend. The synthetic fuel blend was composed of 10% CB and 90% diesel on a volume basis and was denoted as Carbodiesel10. Investigations were carried out with Carbodiesel10 at different injection timings, viz; original (23°CA bTDC), two advanced (26°CA bTDC and 24.5°CA bTDC) and retarded (21.5°CA bTDC and 20°CA bTDC) injection timings. With the advanced injection timing of 26°CA bTDC, the brake thermal efficiency was found to be higher by about 6.4% while the fuel consumption was found to be lower by about 11.9% than those of the original injection timing. The NO emission was noticed to be higher by about 23% and the smoke was lower by about 13.5% at 26°CA bTDC than that of the original injection timing.

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1. Introduction

The world research community is trying hard to introduce new and renewable alternative fuels from biomass sources, and the waste organic substances which are available in industries, agriculture and municipal area to meet the energy demand cheaper. Many researchers have documented their research works on the utilisation of solid wastes such as coal, charcoal, carbon-diesel fuel and biomass powder in the form of slurry, or blending with conventional diesel fuel in CI engines [1–5]. In an investigation, charcoal slurry was prepared by mixing it with palm oil which was heated to 50 °C. Few researchers have reported from the investigation that the charcoal emulsion had relatively low sulphur and wax content, underwent the water gas shift reaction during combustion. They also reported that, the presence of surfactants in the emulsion fuels acts as an inhibitor of the corrosion activity of the water and fuel oil [6–8].

The use of coal water slurries (CWS) is an attractive approach to use coal as a fuel in internal-combustion (IC) engines, since fuel handling problems are simpler than that of using it in a powder form [9]. The effect of direct coal liquefaction (DCL) on the combustion and emissions characterization was studied in a diesel engine with the exhaust gas recirculation (EGR). The engine used in this investigation developing power of 246 kW. The trade-off relationship between the NO and soot emissions were reported to be better, when the diesel engine was fuelled with DCL than that of diesel at full load. The experimental results also inferred that with the 19%–50% increase of EGR, the maximum in-cylinder pressure and the brake thermal efficiency (BTE) first increased marginally, and then decreased [10]. In another study, the CWS with 30 micron size coal particles exhibited a better ignition quality and resulted in higher thermal efficiency better than those of the slurries with particle sizes larger than 30 micron [11].

Zhang Qiang et al. [12], have investigated the utilization of CWS in a four stroke, four cylinder, direct injection (DI) diesel engine. The results indicated that, the brake specific fuel consumption (bsfc) decreased, while efficiency increased when fuel injection timing was advanced from 17°CA to 18°CA. The combustion duration was found to be the shortest at the injection timing of 18°CA. Increasing the fuel injection timing, the smoke and CO emissions decreased, while the NO emission increased at full load. The investigation also revealed that the higher needle lift pressures led to shorter ignition delays for the CWS fuel, and the ignition delay for the advanced injection timing was marginally

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Nomenclature

DI	direct injection
CB	carbon black
CWS	coal water slurry
BP	brake power
aTDC	aftertop dead centre
bTDC	before top dead centre
CA	crank angle
HC	hydrocarbon
NO	nitric oxide

longer from that of the retarded fuel injection timing due to a poor atomization. The mixing of the slurry with water can significantly affect the combustion processes and ease of fuel handling [13]. In this investigation, diesel was used as a pilot fuel while CWS was used as a main fuel. It was reported that, the ignition delay was reduced by increasing the nozzle opening pressure and the combustion pattern changed from a fully premixed combustion for a high flow nozzle, to a premixed and diffusion stage for lower flow nozzles, while the diesel pilot had to be increased at low load up to 20% [14]. In an author investigation, fuel break up time and penetration of CWS were compared with diesel spray. For this study the researcher used an injection system that included an injection jerk pump driven by an electric motor, a specially designed diaphragm to separate the abrasive coal from the pump, and a single hole fuel nozzle. It was reported that, the break up time was 0.58 ms for the CWS, and 0.50 for diesel fuel. It was also reported that the spray tip penetration as a function of time was similar for the three fluids of coal water slurry, diesel fuel, and water [15].

Carbon black (CB) is a solid organic waste obtained from the pyrolysis process of waste tyres. CB contains a considerable amount of carbon and heating value in it [16]. A preliminary investigation was carried out on the production of a synthetic fuel adopting by a sequential process using different percentages of CB and diesel. The synthetic fuel was referred to as Carbdiesel. Four different Carbdiesel namely Carbdiesel5, Carbdiesel10, Carbdiesel15 and Carbdiesel20 were tested as alternative fuels in a single cylinder, four stroke air cooled DI diesel developing a power of 4.4 kW at a rated speed of 1500 rpm. The numeric value follows after Carbdiesel indicates the percentage of carbon in it. From the comparison of the performance and emission parameters of all the Carbdiesels with diesel, Carbdiesel10 was selected for a further investigation. The engine combustion is predominantly affected by the fuel quality, injection timing, nozzle opening pressure, compression ratio and combustion chamber geometry etc. In the present work, Carbdiesel10 was tested in the diesel engine at different injection timings, by two advancing and two retarding, in addition to the original injection timing of 23° bTDC, which was set by the manufacturer.

2. Materials and methods

2.1. Preparation and characterisation of synthetic fuel

2.1.1. Conversion process

In the present research work, Carbdiesel was prepared adopting a sequence of processes. A block diagram of the general procedure for the process involved in the preparation of Carbdiesel is shown in Fig. 1. The CB obtained from a pyrolysis plant was dried in direct sunlight for one day to remove the moisture in it. The CB was then crushed manually by hammering to get it in the form of powder. Then, the powder was further classified by a sieve to get a fine powder size of 40 μ . This was done because, the nozzle size of the fuel injector of a diesel engine considered in this investigation was 40 μ . The CB was taken at 10% by volume. The CB powder was mixed with 90% diesel at 80 °C and continuously stirred to get a slurry, with a 0.15 kWh unit electricity consumption. Finally, the slurry was cooled and filtered to get Carbdiesel10. The residues were removed after filtration.

2.1.2. Ultimate analysis and fuel properties of Carbdiesel10

The physical properties and chemical composition of Carbdiesel10 is compared with that of diesel and are given in Table 1. The permissible range of parameters are also given in according with ASTM standards are also given in the table.

2.2. Experimental setup and procedure

Fig. 2 illustrates the schematic representation of the experimental set up. The test engine used in this investigation was a single cylinder, four stroke, DI, diesel engine. With a bore of 87.5 mm and stroke of 10 mm the engine had a maximum power output of 4.4 kW and 1500 rpm. The original injection timing of the engine was set at 23°bTDC, and the fuel nozzle opening pressure was 200 bar.

The engine (1) was coupled to an electrical dynamometer (2), to provide an engine load cell (3). Diesel fuel and Carbdiesel10 were stored in two different fuel tanks (4) and (5) respectively. A valve (6) was located in the fuel line between the tanks (4) and (5) to allow the fuel from any one of these two tanks. The fuel consumption was measured with the help of a fuel sensor (7), which was fixed in the fuel line. The Carbdiesel was injected by the existing injector (8) of the system. An air box (9) was provided on the suction side of the air. A U-tube manometer (10) was mounted on the air box. The two limbs of the U-tube manometer were connected at the inlet and outlet of the air box. The difference in the two air level limbs was used to calculate the head of air. The air consumption was calculated with the help of the head of air. An AVL 444 exhaust gas analyser (11) was used to measure the carbon monoxide (CO), unburnt hydrocarbon (HC), and nitric oxide (NO) emissions in the engine exhaust. The probe of the analysis was inserted in the exhaust, whenever the measurement was taken. An

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