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Research Paper

Synthetic lubrication oil influences on performance and emission characteristic of coated diesel engine fuelled by biodiesel blends

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HIGHLIGHTS

- Synthetic lubricant provides the maximum performance benefits.
- Synthetic lubricant is capable of retaining satisfactory viscosity.
- Synthetic lubricant is to increase the life of the engine.
- Improvement in efficiency of the coated engine with synthetic lubrication.
- No significant changes in the coated engine emission with synthetic lubricants.

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ABSTRACT

In this study, the effects of using synthetic lubricating oil on the performance and exhaust emissions in a low heat rejection diesel engine running on Pongamia methyl ester blends and diesel have been investigated experimentally compared to those obtained from a conventional diesel engine with SAE 40 lubrication oil fuelled by diesel. For this purpose, direct injection diesel engine was converted to Yttria-stabilized zirconia (YSZ) coated engine. The results showed 5–9% increase in engine efficiency and 8–17% decrease in specific fuel consumption, as well as significant improvements in exhaust gas emissions (except NO_X) for all tested fuels (pure diesel, B10 and B20) used in coated engine with synthetic lubricants compared to that of the uncoated engine with SAE 40 lubricant running on diesel fuel.

1. Introduction

Energy demand around the world is increasing rapidly as a result of ongoing trends in modernization and industrialization. Most of the developing countries import fossil fuels to satisfy their energy demand [1]. In the current situation, the main considerations are the decrease in availability of fossil fuels and environmental pollution [2]. The internal combustion engines are affected severely by these considerations. Therefore, it is necessary to develop low emission alternative fuels for diesel engines. As a result, vegetable oils are an important alternative fuel source for diesel engines. However, high viscosity and low evaporation of vegetable oil-based fuels make their use as a fuel more difficult. Direct use of raw vegetable oils without modification in diesel engines causes some damage to the engine parts and also the performance is negatively affected [3]. A couple of methods are available for modifying vegetable oils to make them suitable for engine use. Transesterification has shown good potential for reducing engine problems associated with vegetable oils [4]. Transesterification is a process in which the vegetable oil is added to a monohydric alcohol (ethanol, methanol) with a catalyst to produce an ester and glycerol. This process decreases viscosity and improves the cetane number and heating value of the fuel [5]. These monoesters are known as biodiesel. Biodiesel is a fuel, which can be used directly in a diesel engine without any modification or with a small modification. Biodiesel fuel improves exhaust emission values due to higher oxygen content [6]. Although the fuel characteristics of biodiesels have been made similar to those of diesel fuel by transesterification, the viscosity values of biodiesels are still higher than that of diesel fuel [7]. To eliminate this negative effect, the viscosity of the biodiesel has to be reduced further or some modifications in the engine have to be incorporated to improve the performance. Among the various methods, which have the potential to improve the performance of biodiesel, low heat rejection (LHR) diesel engine is believed to be a better technique [8]. From the reported literatures [9–18] it was observed that ceramic materials like zirconia oxide, NiCrB, MgO-ZrO_2, yttria stabilized zirconia (YSZ), par-

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tially stabilized zirconia (PSZ) and ceramic material of sintered silicon nitride (SSN) were used as thermal barrier materials for a LHR engine. The coatings of insulation materials used in the LHR engine should have high temperature strength, high expansion coefficient, low friction characteristics, good thermal shock resistance, light weight, low thermal conductivity and durability. Yttria-stabilized zirconia (YSZ) was chosen in this study on combustion chamber coating in LHR engine concept. The higher temperatures of the combustion chamber surfaces of LHR engine deteriorate the properties of lubricating oil. Hence one of the main directions of the research in adiabatic engines should be development of lubricating oils capable of retaining satisfactory viscosity at higher temperatures encountered in the engine [19,20]. The viscosity of lubricating oil is decreased in LHR engine due to high in-cylinder temperature resulting in increased friction power of the engine, thereby decreasing brake power of the engine. This drawback can be minimised by using synthetic lubrication oil. The technical advantages of synthetic motor oils include: better low- and high-temperature viscosity performance at service temperature extremes; better (higher) viscosity index; better chemical and shear stability; decreased evaporative loss; possibility to extended drain intervals, with the environmental benefit of less used oil waste generated; improved fuel economy in certain engine configurations; better lubrication when extreme cold weather starts; possibly a longer engine life; and increased horsepower and torque due to less initial drag on the engine [21]. This paper discusses the benefit of using synthetic lubricants for lubrication of coated engines, and an experiment was carried out to characterise the performance and emission of the coated engine fuelled by Pongamia methyl ester blends with diesel, and then the results were compared to uncoated engine that used SAE 40 lubrication oil running on diesel fuel. Engine was operated on three different conditions, viz. (a) coated condition with SAE40 lubricant, (b) uncoated condition with SAE 40 lubricant and (c) coated condition with synthetic lubricant.

2. Materials and methods

2.1. Biodiesel production

The raw Pongamia oil was obtained from the local market. Free fatty acid (FFA) value of the oil was found to be 3.15%. As the FFA value was higher than 1%, the oil underwent into a two step transesterification process. First the raw Pongamia oil was filtered and heated to a temperature of 110 °C to remove the impurities and water content and then fed to the acid esterification process with 45% methanol by volume and 0.5% concentrated H_2SO_4 at 50 °C reaction temperature followed by catalyst esterification with 30% of methanol by volume and 1% of KOH by weight at 55 °C reaction temperature. In both processes continuous stirring was done by a magnetic stirrer at one hour reaction time and then left to settle for 24 hours to form the two distinct layers. The upper layer was the biodiesel and the bottom layer was glycerine. The upper layer of ester was separated out. The separated ester was washed with warm distilled water to remove the catalyst and excess glycerine present in the ester and then heated to 110 °C to remove the moisture. The properties of the prepared biodiesel were tested as per ASTM and were listed in Table 1.

2.2. Plasma spray coating of combustion chamber parts

Cylinder head, piston crown, exhaust and inlet valve of the diesel engine were coated with a 200 μm thick YSZ material by plasma spray coating method. Before coating micro machining was carried on piston crown surface in order to maintain the compression ratio of the engine at is equal to 17.

Table 1
Physiochemical properties of diesel, raw Pongamia oil, ester and their blends.

Properties	Diesel	Raw Pongamia oil	Ester	Blend 1 (B10)	Blend 2 (B20)
Density (g/cc)	0.785	0.912	0.837	0.789	0.789
Viscosity (Cst) at 40 °C	2.74	42.88	5.88	3.362	4.418
Flash point (°C)	46	240	150	49	51
Fire point (°C)	51	251	178	57	62
Calorific value (kJ/kg)	42,144	39,707	41,881	41,874	41,383
Cetane number	49	–	53	–	–

2.3. Experimental setup

The single cylinder, four stroke, direct injection and water cooled diesel engine was used for this study. The engine was coupled to drum and rope type dynamometer for load measurement. The photographic view of the experimental setup is shown in Fig. 1 and the detailed specifications are given in Table 2. Chromel-Alumel (k-type) thermo-couples were installed in the exit pipe to measure exhaust gas temperature. The fuel flow was measured by using a 50 cc graduated burette and stopwatch. Nitrogen oxides (NO_X), carbon monoxide (CO), hydrocarbon (HC) and carbon dioxide (CO_2) were measured by a gas analyser. Then the fuel consumption, exhaust gas temperature, lubrication oil temperature and exhaust emissions were measured and recorded for different loads. The engine was first started by manual cranking with diesel as a fuel and was allowed to reach its steady state (for about 30 min). The tested fuels used during this study were diesel fuel and blend of 10 and 20 percent biodiesel by volume in the diesel fuel. Tests were performed on the uncoated engine with SAE40 lubricant and then repeated on the coated engine with SAE40 and synthetic lubricant oil for all tested fuels.

Fig. 1. Photographic view of the experimental setup.

Table 2
Engine specifications.

Engine type	Single cylinder 4-stroke diesel engine
Rated power	2.6 kW/3.5 HP
Rated speed	1500 rpm
Compression ratio	17
Injection type	Direct injection
Type of cooling	Water
Loading	Rope brake dynamometer