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ORIGINAL ARTICLE

Investigation of palm methyl-ester bio-diesel with additive on performance and emission characteristics of a diesel engine under 8-mode testing cycle

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Optimum blend

Abstract Biodiesel is receiving increasing attention each passing day because of its same diesel-like fuel properties and compatibility with petroleum-based diesel fueled engines. Therefore, in this paper the prospects and opportunities of using various blends of methyl esters of palm oil as fuel in an engine with and without the effect of multi-functional fuel additive (MFA), Multi DM 32 are studied to arrive at an optimum blend of bio-diesel best suited for low emissions and minimal power drop. Experimental tests were conducted on a four stroke, three cylinder and naturally aspirated D.I. Diesel engine with diesel and various blend percentages of 20%, 40%, 45%, and 50% under the 8 mode testing cycle. The effect of fuel additive was tested out on the optimum blend ratio of the bio-diesel so as to achieve further reduced emissions. Comparison of results shows that, 73% reduction in hydrocarbon emission, 46% reduction in carbon monoxide emission, and around 1% reduction in carbon dioxide emission characteristics. So it is observed that the blend ratio of 40% bio-diesel with MFA fuel additive creates reduced emission and minimal power drop due to effective combustion even when the calorific value is comparatively lower due to its higher cetane number.

1. Introduction

The fossil fuels namely oil, coal and natural gas are the primary energy sources that have powered modern industrial civilisation. The equivalent global consumption of these resources was over 9 billion tonnes of crude oil in 2005, as reported in [1]. Also, according to the International Energy Outlook of 2011 published by the U.S Energy Information Administration [2] shows that the world use of liquid fuels will increase from 85.7 million barrels per day in 2008 to 112.2 million barrels per day in 2035. The demand for these resources is set to increase even further given the dramatic economic expansion occurring in developing countries mainly in BRICS region. However, the trend of dependence on fossil fuels is not sustainable as fossil fuels, by their very nature

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are finite, non-renewable and in the case of oil, we are rapidly approaching the point at which this resource is being consumed faster than it can be recovered from the ground.

The most promising alternates available for compression ignition engines are biodiesels which are essentially fatty acids of vegetable or non-edible oils. Other alternates include compressed natural gas, hythane, E-Diesel (Ethanol based), Biomass to Liquid (BTL) [3]. Bio-Diesel can also be extracted from various sources of oils ranging from edible sources(palm oil, vegetable oil, rapeseed, rice bran oil) to non-edible sources (Jatropha, Pongamia, Karanjia seeds) [4].

Bio-diesel consists of no petroleum products and it can be used in 100% pure form or blended with petroleum diesel Bio-diesel can be used in compression ignition engine directly with/without any engine modificatios because bio-diesel has properties similar to petro-diesel fuels. Biodiesel is said to be clean fuel since it has almost no sulphur, no aromatics and has about 10% built in oxygen [1], which helps it to burn fully. Ignition quality blended bio-diesel is better compared with pure diesel due to its higher cetane number.

Palash et al. [5] studied the performance and emissions of a multi-cylinder diesel engine with Jatropha biodiesel blends as fuel and N, N-diphenyl-1, 4-phenylenediamine (DPPD) antioxidant as an additive. They found that the additive of DPPD reduces the NO_x level and the exhaust gas temperature significantly. There have been various studies conducted using biodiesel fuels [6–11] and their results revealed that biodiesel fuels have good emission characteristics, i.e., reduced HC, CO and smoke levels and increased NO_x emissions as compared to diesel fuelled engine. Several authors have shown different mechanisms responsible for an adverse effect on NO_x emission. The NO_x emission was attributed to the thermal and prompt mechanisms [12–17].

Varatharajan [12] in another work used additives such as DPPD, NPPD, p-phenylenediamine (PPD), ethylenediamine (EDA), α-Tocopherol acetate, BHT and L-ascorbic acid with two combinations of biodiesel 20% and 100% and found that the optimum concentration of DPPD is 0.15%(m). McCormick et al. [18] found that higher NO_x formation was due to the dominant prompt NO_x mechanism and gave suggestions to reduce NO_x by adding antioxidants to fuel. Varatharajan et al. [19] performed an experimental study on a single cylinder diesel engine with soybean biodiesel mixed with DPPD and N-phenyl-1, 4-phenylenediamine (NPPD) additives. They found NO_x reduction by 9.35% and 28.36% for 20% and 100%, respectively.

Literature has shown that palm oil to be the most oil producing crop per acre [20,21] than many of the other oils and also found to be best suited for trophical climate thus making it an ideal crop to be grown in a country like India as it also attractive to profit-driven investors.

2. Palm methyl ester based bio-diesel

Crude palm oil extracted from palm seeds usually exhibit high viscosity values making them unsuitable to be used as a fuel for continuous running. Therefore, a process called trans-esterification [22] is performed so as to reduce the viscosity by treating the crude oil with alcohols (commonly ethanol or methanol) wherein a by-product is obtained in the form of glycerol which has to be separated. Trans-esterification reaction is a stage of converting oil or fat into methyl esters of fatty acid. The general reaction for obtaining biodiesel through trans-esterification [1].

$$\text{Oil or Fat} + \text{Methanol} \rightarrow \text{Methyl Ester} + \text{Glycerol}$$

Trans-esterified Palm methyl ester was bought from Rasha Petroleum Limited & the diesel fuel used as standard was purchased from a Bharat Petroleum petrol station in Chennai, India. The various physical and chemical properties of palm ethyl ester are compared to that of conventional petro-diesel and the observations of palm methyl ester's properties are noted below in Table 1.

The palm methyl ester bio-diesel was blended with conventional petro-diesel at room temperature as both the liquids are having viscosity values closer to each other. The blended bio-diesels were done at different ratios to arrive at an optimum ratio which would not sacrifice power at cost of emissions. The properties of blended bio-diesel namely density, viscosity were inferred from various journals who had done extensive tests on the same palm oil methyl ester bio-diesel [25,26].

This power loss in palm methyl ester bio-diesel is mainly attributed to the lower calorific value inherited naturally. Better emissions are partly due to the higher cetane number value. Cetane number indicates the ignition lag time (time between the first fuel injected into the chamber and ignition start time). Palm methyl ester has higher cetane value (65) compared to diesel fuel (51), thereby resulting in better combustion quality leading to reduced emissions.

3. Experimental test setup and procedure

A four stroke, three cylinder water cooled naturally aspirated diesel engine was used for experimental investigation. Detailed engine specifications were provided in Table 2. The diesel engine was fuelled by the alternate fuel by a separate fuel tank setup which was routed to a fuel filter before feeding it to the engine. The engine was run at various speeds for full load and no load conditions along with the ISO 8178 8-mode test cycle governed by emission laws [27]. The readings such as engine speed, torque, brake power, engine inlet & exhaust temperatures, engine lubrication oil temperature, engine water inlet & outlet temperatures are recorded by using EDACS (Engine Data Acquisition and Control System) developed by ARAI, from various sensors mounted on the engine through the integrated circuit established between sensor junction box and data acquisition system.

The engine load was given through Eddy current dry gap dynamometer (150 kW, 500 Nm) as shown in Fig. 1, by through Digital Dyno Controller in the E-DACS. The Engine throttle was controlled by through Digital Throttle Controller in the E-DACS system. The fuel consumption of the engine is measured by using SAJ Gravimetric Fuel Consumption Metre and the engine exhaust emission measurements are measured by using AVL DI Gas 444 four gas analyzer. The mass flow rate of air inlet is measured using u-tube manometer for the calculation purpose. A schematic diagram of the engine test cell is shown in Fig. 2 for clear picture of the various components and connections of engine test bed facility used for the present study.