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Experimental investigation of evaporation rate and exhaust emissions of diesel engine fuelled with cotton seed methyl ester and its blend with petro-diesel

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ABSTRACT

An experimental study to measure the evaporation rates, engine performance and emission characteristics of cotton seed biodiesel (cotton seed oil methyl ester) and its blends in different volumetric proportions with diesel is presented. The thermo-physical properties of all the fuel blends have been measured and presented. Evaporation rates of neat cotton seed biodiesel, neat diesel and their bends have been measured under slow convective environment of air flowing with a constant temperature. Evaporation constants have been determined by using the droplet regression rate data. The neat fuels and fuel blends have been utilized in a test engine with different load conditions to evaluate the performance, combustion and emission characteristics of the fuels. The specific fuel consumption values of the two blends, viz. B25 and B75 are found to be same. At the highest load, B0 records the lowest CO volume followed by B100. From the observed evaporation, performance and emissions characteristics, it is suggested that a blend of B50 and B75 can be optimally used in standard diesel engine settings.

1. Introduction

In the face of the twin crises arising from fossil fuel depletion and environmental degradation, it has become imperative to invent newer technologies to improve fuel efficiency and reduce pollution in the automobile sector. This clearly indicates that vehicles have a predominant role in regulated and unregulated pollution and the tail pipe emission contributes significantly to climate changes. Diesel engines are a major and widely used power source for in-sea and on-land transportation because of its simple mechanism, excellent performance, easy maintenance, low fuel oil cost, high compression ratio, high power/weight ratio, high thermal efficiency and durability. Diesel engines are the most fuel-efficient combustion engines in human history. The diesel engine emission causes depletion of ozone layer, greenhouse effect and acid rain productions which leads to many human diseases and the degradation of the environment. As fuel is the life-line of transportation sector, factors like fossil fuel depletion, environmental degradation have driven the automobile industries to invest heavily in research works to find alternative fuels and to invent newer technology to improve fuel efficiency, economy and reduce pollution from the existing fuels. This scenario has led to a renewed interest in the use of vegetable oils for making biodiesel because of their bio degradable, non-toxic, less polluting and renewable nature. Worldwide biodiesel is produced mainly

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from edible oils, but in India, non-edible oil seeds are available in abundance such as cotton seed (*Gossypium* spp.), Pongamia (*Pongamia pinnata*), Jatropha (*Jatropha curcas*), Mahua (*Madhuca indica*), Neem (*Azadirachta indica*), and Rubber seed (*Hevea brasiliensis*) oil, which can be tapped for biodiesel production.

In a typical cotton seed farm in South India, there are around 50–70 trees per acre of land. Approximately 50 kg of oil seeds are extracted every 4–6 months from each tree. The yield is about 400 liters of oil per acre. The cost of one liter of oil will be around INR 45. Cotton plants are also cultivated in other parts of India. It has large potential for extracting the oil and used as alternate fuel for engines. Hence cotton seed oil is considered for this study. Basha et al. (2009) have stated that vegetable oil are suitable alternate fuel for compression ignition engine in its pure form or blended with petroleum diesel. Moreover biodiesel is better than diesel based on some of its physical properties like sulfur content, flash point, aerometric content and biodegradability. Ramadhas et al. (2004) have reviewed that the very high viscosity and low volatility of the vegetable oils causes poor atomization, incomplete combustion and fouling due to carbon deposition. There are different classes of reducing the viscosity of vegetable oil i.e., vegetable oil blends with diesel and conversion of biodiesel. Transesterification process is method of converting vegetable oil into biodiesel and the properties of the biodiesel are similar to that of fossil diesel. The biodiesel preparation with its emission characteristics of diesel engine are discussed by Puhan et al. (2004). The performance of diesel engine was conducted with mahua biodiesel in naturally aspirated DI diesel engines. They used neat diesel and neat biodiesel. Emissions were measured by Puhan et al. (2005). Murugesan et al. (2012) have conducted test on a single cylinder diesel engine fuelled with methyl-ethyl esters of pongamia and neem oils blended with diesel, up to B40 blend gives similar brake thermal efficiency. The mahua biodiesel blended with fossil diesel is used as a fuel and the engine performance obtained by blends is discussed extensively with different volumetric ratios. They concluded that biodiesel 20% by volume with 80% diesel formed an optimum mixture for their engine parameters Raheman and Ghadge (2007). There was no significant variation in brake power whereas exhaust gas temperature of all preheated biodiesel cotton seed oil methyl ester is high and break specific energy consumption required to preheat cotton seed oil methyl ester is high as compared to neat diesel. However, the optimum conditions for biodiesel production are suggested (Ranganathan et al., 2012). The performance and emissions test was carried using neat orange oil by Purushothaman and Nagarajan (2004) and found that there was a considerable hike in heat release rate, thermal efficiency and NO_x than that of fossil diesel. Jaichandar and Tamilporai (2003) have reviewed that on a diesel engine one third of the heat energy is converted into useful work, one third is wasted through exhaust gas and remaining wasted through heat carried out to the coolant. As per second law of thermodynamics, thermal efficiency could be increased by reducing heat rejection to the coolant. In this effort, to achieve low heat rejection of the engine, the combustion chamber walls are insulated by ceramic coatings. Wong (1995) has reported that coating thickness for the better thermal efficiency will be in the range of 0.25–0.5 μm. The diesel engine was operated fuelled with biodiesel and LPG with exhaust gas temperature. In general the oxides of nitrogen of diesel engine were higher fuelled with biodiesel without EGR. Hence, the oxides of nitrogen could be reduced fuelled with biodiesel and LPG with EGR. Recirculation of exhaust gases into the engine decreases the combustion chamber temperatures and marginal improvement in thermal efficiency was observed with EGR. However, reduction in air flow into the engine slightly increases carbon monoxide and hydrocarbon emissions. The exhaust gas temperature of dual fuel engine with EGR is lower than that of engine without EGR (Ramadhas et al., 2010). Assanis et al. (1991) test was conducted on a supercharged DI diesel engine with PSZ coating thickness of 0.5–1 μm by use of plasma spraying machine and compared the results with standard engine, in their study insulating the piston crown with a thin (0.5 μm) coated engine gave better engine performance and reduced emissions. Kamo et al. (1989) reported that thin thermal barrier coatings of engine combustion chamber will increase the volumetric efficiency of the engine. Biodiesel can be used as more efficient fuel in the low heat rejection engines, because of the high temperature of the thermal barrier coated combustion chamber. Corn oil methyl ester was utilized by Hazar and Ozturk (2010) as a fuel in an Al_2O_3-TiO_2 coated engine. The performance was compared to that of uncoated diesel engine and found that there was a decrease in CO, NOx and SFC along with an increase of 11.3% in exhaust gas temperature for all the biodiesel blends in the coated engine. The performance parameter enhancement of turbocharged diesel engine coated with yttria stabilized zirconia ($Y_2O_3ZrO_2$) and NiCrAl using sunflower oil methyl ester was found by Hasimoglu et al. (2008). A blend of B20 (20% cotton seed oil biodiesel and 80% neat diesel) gives optimum performance and lower emissions as compared to neat diesel (Dilip Kumar and Ravindra Kumar, 2012).

From the above literature review, it is clear that several studies have been carried out with biodiesel as an alternative fuel in engines. In this paper, engine studies on pure cotton seed biodiesel and its blends with petro-diesel in various volumetric proportions, evaporations studies are discussed. For any liquid fuel, an important parameter is the rate at which it can vaporize at ambient conditions. To carry out evaporation studies, a suspended droplet experiment has been setup and evaporation rate constants for pure and blended cotton seed biodiesel have been estimated. This suspended droplet evaporation study will not provide direct vaporization characteristics inside an actual engine. However, it will be useful for fuel characterization study as it gives different evaporation features of several blends. Evaporation characteristics of multi-component fuels and vegetable oils have been reported in literature (Daif et al., 1998; Morin et al., 2000).

2. Experimental setup and procedure

2.1. Evaporation studies

Suspended droplet experiments are carried out to estimate the evaporation rates of pure cotton seed oil and its blends with diesel in various volumetric proportions. Fig. 1 shows the schematic of the experimental setup. Heated air at a given