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Improving the performance and emission characteristics of a single cylinder diesel engine having reentrant combustion chamber using diesel and Jatropha methyl esters

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ABSTRACT

The emissions from the Compression ignition (CI) engines introduce toxicity to the atmosphere. The undesirable carbon deposits from these engines are realized in the nearby static or dynamic systems such as vehicles, inhabitants, etc. The objective of this research work is to improve the performance and emission characteristics of a diesel engine in the modified re-entrant combustion chamber using a diesel and Jatropha methyl ester blend (J20) at three different injection pressures. From the literature, it is revealed that the shape of the combustion chamber and the fuel injection pressure have an impact on the performance and emission parameters of the CI engine. In this work, a re-entrant combustion chamber with three different fuel injection pressures (200, 220 and 240 bars) has been used in the place of the conventional hemispherical combustion chamber for diesel and J20. From the experimental results, it is found that the re-entrant chamber improves the brake thermal efficiency of diesel and J20 in all the tested conditions. It is also found that the 20% blend of Jatropha methyl ester showed 4% improvement in the brake thermal efficiency in the re-entrant chamber at the maximum injection pressure. Environmental safety directly relates to the reduction in the undesirable effects on both living and non-living things. Currently environmental pollution is of major concern. Even with the stringent emission norms new methods are required to reduce the harmful effects from automobiles. The toxicity of carbon monoxide (CO) is well known. In the re-entrant combustion chamber, the amount of CO emission is reduced by 26% when compared with the conventional fuel operation of the engine. Moreover, the amount of smoke is reduced by 24% and hydrocarbons (HC) emission by 24%. Thus, the modified re-entrant combustion chamber reduces harmful pollutants such as unburned HC and CO as well as toxic smoke emissions.

1. Introduction

Pollution levels are increased in the vicinity. Automobile manufacturers are trying to improve the performance and efficiency of the engine while keeping compliance with the stringent emission norms (Saroop et al., 2013). The availability of fossil fuels has been decreasing day by day at one hand and on the other the demand for fossil fuels is increasing every day. Countries like India Diesel demand is much higher than Petrol. To meet the demand, bio-diesel comes into the picture. Biodiesel, which is a relatively clean-burning, renewable fuel produced from fresh and used vegetable oil, could be used to replace at least a portion of the diesel fuel consumed in this country. To avoid food crisis and high price rise non-edible oil seeds need to be used for commercial production of biodiesel. Many researchers have initiated to work on the use of low cost non-edible oils as an alternative feedstock for biodiesel production. Among non-edible oil feedstock, seeds of castor and jatropha, and microalgae oil are proved to be one of the highly promising reliable source having high seed oil content (Sruthi et al., 2013). Biodiesel can be used in almost any normal internal combustion diesel engine, with a few special modifications, and it can be stored and transported using the existing infrastructure and equipment for regular petroleum diesel. When injection pressure is increased, fuel particle diameters will become smaller because formation of mixing fuel to air becomes better through injection period, smoke opacity will be less (Bhusnoor et al., 2007). Smaller engines are more sensitive to intake air conditions fluctuations of air movement in the intake system occurrence, high swirl number reduces smoke and soot emissions as turbulence is high (Sayin et al., 2012). CO and HC mass emissions

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Nomenclature

ppm	parts per million
CI	compression ignition
J20	Jatropha methyl ester blend 20%
JOME	Jatropha methyl esters
TDC	top dead center
B.T.E	brake thermal efficiency
CO_2	carbon dioxide
DPM	diesel particulate matter
Bmep	brake mean effective pressure
UBHC	unburned hydrocarbon
CO	carbon monoxide
mm	milli meters
NO*x*	oxides of nitrogen
SEC	specific energy consumption
DPF	diesel particulate filter
PAH	poly aromatic hydrocarbons
PM	particulate matter
EGR	exhaust gas recirculation

decreased with increasing Fuel injection pressure due to superior fuel–air mixing in the combustion chamber (Achari et al., 2013). To improve the performance of biodiesel in the CI engine research work has also been focused on various combustion chamber geometries to improve the air motion. Increase in swirl always improves the combustion (Pandhare and Padalkar, 2013). Reduction in emissions is achieved by matching of piston bowl with injection and turbocharger systems (Srinivas et al., 2005). The reduction of harmful emissions such as HC (18%), CO (12%) and Smoke density (20%) is achieved in the toroidal shape combustion chamber when compared with the conventional chamber for a single cylinder diesel engine (Annamalai and Jaichander, 2012).

The present research work focuses on the effective mixing of fuel and air by having a modified re-entrant chamber and reduction in the emissions for biodiesel blends, along with the appropriate injection pressure was found by analyzing the various parameters.

1.1. Materials and methods

1.1.1. Re-entrant combustion chamber

It is a type of combustion chamber designed and fabricated to improve the air motion inside the cylinder. This increases the rotational flow of air (swirl and tumble) and promotes fuel and air mixing throughout the combustion chamber. Enhancing the in cylinder flow of air could lead to better fuel distribution and mixture formation. Figs. 1 and 2 shows the conventional and re-entrant chambers.

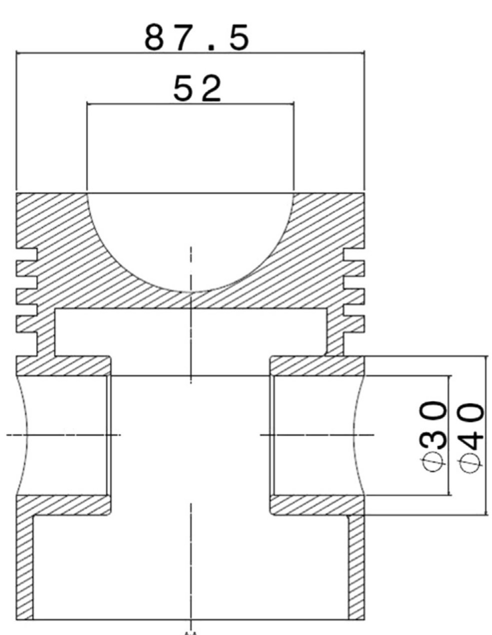

Fig. 1. Conventional Chamber (mm).

1.1.2. Engine set up

The diesel engine is a constant speed, four stroke and vertical air-cooled type, coupled with an electrical dynamometer with rheostat loading. The specifications are given in the Table 1. An AVL pressure transducer (piezo electrical type) is used to measure the pressure developed in the engine cylinder. AVL angle encoder is used to indicate the position of the crank shaft with time. The output of the pressure transducer and the angle encoder is processed in the AVL data acquisition system, and various combustion parameters are obtained for the tested fuels. AVL five gas analyzer is used to measure the exhaust gasses like CO, HC, CO_2, O_2, and Lambda. AVL smoke meter (437C) is used to measure the smoke in terms of opacity (%). Fig. 3 shows the complete Layout of engine set up.

1.1.3. Properties of Jatropha methyl esters

Methyl esters of jatropha oil are one of the best alternative fuels used in diesel engines for research purposes. The cetane number of Jatropha oil is close to that of diesel. This makes it an ideal alternative fuel compared to other vegetable oils. The flash point of Jatropha methyl ester (JOME) is 140 °C, compared to 50 °C for diesel. Due to its higher flash point, Jatropha oil has certain advantages over petroleum crude, like greater safety during storage, handling and transport has been reported (Mallikarjun et al., 2013). It contains various acids such as palmitic, stearic, oleic, linolic and other acids. It is decided to conduct the experimental work using jatropha methyl esters and its blend. It can be burned in neat form (100% bio-diesel) or it can be mixed with regular petroleum diesel in any concentrations, such as 2% (J2), 5% (J5) and 20% (J20). Important properties of the diesel and the biodiesel are given in Table 2.

1.2. Results and discussion

The experimental work was done for two different types of combustion chambers, The experiment were conducted from no load to full load on a single cylinder DI four stroke diesel engine coupled with an electrical dynamometer with all the necessary accessories. For a compression ignition engine injection pressure is one of the most important parameter which influences the performance, emission and combustion characteristics of the engine. The list of instruments and their capacity are shown in Table 3.

In view of that, this work concentrates on the effects of combustion chamber shape on emission reduction (conventional chamber and the modified re-entrant chamber), fuel type (diesel and J20.) and the injection pressures (200, 220 and 240 bar) were studied.

1.2.1. Brake thermal efficiency

Fig. 4 shows the variation of brake thermal efficiency with brake mean effective pressure for diesel with the re-entrant combustion chamber at three different injection pressures (200,