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Experimental analysis of exhaust gas after treatment system using water scrubbing in a single cylinder diesel engine for diesel and biofuel blends

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ABSTRACT

A low-cost exhaust gas after treatment system called water-scrubbing is attempted in this paper. An emission treatment setup is fabricated, which is installed in the exhaust of the engine. This takes the exhaust gas and sprays water in the exhaust and passes it through the chamber containing silica gel. An attempt is made to investigate experimentally the performance and emission characteristics of a direct injection (DI) diesel engine, with and without water injection at the exhaust using diesel fuel (DF), diesel-Karanja oil blend (DKB) and diesel-Jatropha oil blend (DJB). The exhaust gas after treatment system helps to reduce NOx, CO and Particulate matter. The performance of the engine has also been monitored to determine whether the engine has any decrease in performance when the setup is used and it is found that there is no change in the engine performance.

1. Introduction

Diesel engines are widely used in a variety of applications ranging from automobiles to power generation due to their good fuel efficiency and durability. But diesel engine emissions are harmful to health and to the environment (Li et al., 2008). Emission control regulations have been introduced in all countries in order to reduce the emissions of vehicles. The emissions that are considered by emission regulations are hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx) and particulate matter (PM). The limits of these emissions are very much stringent from Euro I to Euro IV (Alkemade and Schumann, 2006). For petrol powered vehicles, the factors considered for emission reduction are engine design, combustion chamber design, compression ratio, valve timing, manifold designs, charge stratification, warm-up time, exhaust gas recirculation, ignition system, thermal after-burning, catalytic converters and closed loop lambda control. For Diesel powered vehicles, the factors considered for emission reduction are exhaust gas recirculation, intake air temperature, catalytic converter and filters (Denton, 2004).

The qualms of world energy demands are the price of straight fossil fuels and increase in global Carbon dioxide (CO_2) level. The scarcity and depletion of straight fossil fuels are the remaining fears and encouraged worldwide into alternative energy sources for automobiles. The reasons for search of fuels are to make sure that when the deficit in crude oil occurs, there can be a smooth transition to other fuels, to provide long-standing safety of supply, to improve air excellence and

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Nomenclature

DI	direct injection
DF	diesel fuel
DKB	diesel-Karanja oil blend
DJB	diesel-Jatropha oil blend
HC	hydrocarbon
CO	carbon monoxide
NOx	oxides of nitrogen
PM	particulate matter
CO_2	Carbon dioxide
IC	Internal Combustion
NO	nitric oxide
NO_2	nitrogen dioxide
H_2	hydrogen
NG	natural gas
CFD	computational fluid dynamics
RTWI	real time water injection
PAH	polycyclic aromatic hydrocarbons
SO_2	sulfur dioxide
CAD	Computer Aided Drafting

to conquer the lack of the native crude oil supply. The selection criteria of alternative fuels are it must be cheap and should be available everywhere, it must burn and produce less emission, it must have high calorific value, it must be easy and cheaper to produce, it should need less modification in existing Internal Combustion (IC) engines, it should increase the engine life, it should require less engine maintenance, and it should be easy for handling and storage.

2. Literature survey

The literature survey has been performed with reference to problems of pollution and emission reduction techniques.

With the increase in the number of engine vehicles, air pollution is also increasing quickly; and with the increase in air pollution, all living conditions are affected in a negative way (Barbella et al., 1988). Traditional diesel engines produce high emissions of particulate matter (PM) and oxides of nitrogen (NOx), which consist of nitric oxide (NO) and nitrogen dioxide (NO_2) (Liu et al., 2012). It is proved that the emissions from diesel engines consist of a complex mixture of gaseous and particulate fractions (Roegner et al., 2002). The composition of the mixture varies greatly with fuel and engine type, load cycle, maintenance, tuning, and exhaust gas treatment.

The effects of in-cylinder water injection on a direct injection (DI) diesel engine were studied using a computational fluid dynamics (CFD) program (Bedford et al., 2000). The method of introducing water with fuel or directly into the combustion chamber of reciprocating engines was practiced (Prasad et al., 2015). A study was conducted (Melton et al., 1975) to find the feasibility of total cooling of a single-cylinder diesel engine by direct water injection of water into the combustion chamber. A system for injection of diesel fuel and water with real-time control, or real –time water injection (RTWI) was developed and applied on heavy duty diesel engines (Chadwell and Dingle, 2008).

The major problem of using neat Karanja oil as a fuel in a compression ignition engine arises due to its very high viscosity (Baiju et al., 2009). The exhaust emissions of alcohols were almost identical. Specially designed heat exchanger which utilizes waste heat from exhaust gases can be used for fuel preheating of Karanja oil and its blends (Agarwal and Rajamanoharan, 2009). The preheating and non-preheating were used for lower blends of Karanja oil. While operating the engine on Karanja oil (preheated and blends), performance was found to be very close to mineral diesel for lower blend concentrations (Acharya et al., 2009). The preheated oil's performance was slightly inferior in efficiency due to low heating value. It can perform well in the unmodified engine for a long period of operation without any ignition problems. Results are presented based on tests on a single cylinder direct-injection engine operating on diesel fuel, Jatropha oil and blends of diesel/Jatropha oil in proportions of 97.24%/2.6%; 80%/20% and 50%/50% by volume. (Forson et al., 2004) The results covered a range of operating loads on the engine. Carbon dioxide emissions were similar for all fuels, the 97.24% diesel/2.6% Jatropha fuel blend was observed to be the lower net contributor to the atmospheric level. The test showed that Jatropha oil could be conveniently used as a diesel substitute in a diesel engine. A single cylinder, constant speed direct injection diesel engine was operated on neat Jatropha oil (Narayana Reddy and Ramesh, 2006). From the collected particulate mass, emitted directly from the exhaust of diesel engines burning diesel and biodiesel fuels from the field as well as in the laboratory, emit mass of particles and polycyclic aromatic hydrocarbons (PAH) (Valle-Hernandez et al., 2013).

Heat and mass transfer during silica gel-moisture interactions were studied (Sun and Besant, 2005). Initially dry granular silica gel bed is subject to a sudden uniform air flow at a selected temperature and humidity. A lab scale physi-sorption based