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Emission control strategy by adding alumina and cerium oxide nano particle in biodiesel

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ABSTRACT

In order to evaluate the effect of nano particles such as Alumina (Al_2O_3) and Cerium oxide (CeO_2) as additives in Jatropha biodiesel, an experimental investigation is carried out to study the performance and emission characteristics in a single cylinder, four stroke DI diesel engine. Alumina and Cerium oxide nano particles are added with Jatropha biodiesel at mixed proportions forming 10, 30 and 60 parts per million. Significant improvement in the brake thermal efficiency near to that of neat diesel is observed for the nano particle blended test fuels along with the reduction of nitric oxide, carbon monoxide, unburned hydrocarbon and smoke emission by 13%, 60%, 33% and 32% respectively.

1. Introduction

Biodiesel is considered as the main alternative fuels for compression ignition engines, because of their properties such as rich oxygen content, higher kinematic viscosity, reduced smoke emission and diluted level of pollutants from the engine exhaust (Smoke, Carbon monoxide, particulate matter and unburned hydrocarbons). Biodiesel containing 10% oxygen content helps in better combustion of the fuel [1]; on the other hand, it results in the formation of high local temperatures inducing more NOx emissions during combustion. When compared to petrol and diesel, a 12% hike in NOx emission is observed for biodiesel fuel [2]. To control such NOx emissions many strategies have been followed by researchers around the countries such as biodiesel blends, engine modification, exhaust gas reduction techniques and alteration in fuel formulations. Among them, fuel formulation techniques are considered as the most beneficial way of controlling the level of pollutants at the engine exhaust. In continuation of such techniques, the addition of nano particles in biodiesel results in reducing the level of pollutants at the engine exhaust and enhancing the engine performance substantially. Nano particle blended test fuels show better thermal properties, due to the higher surface area to volume ratio of the nano particle [3], resulting in increased oxidation of hydrocarbons and acting as oxygen buffer against NO [4]. A few experiments were conducted with nano particles as additives in both diesel and biodiesel fuels with significant reduction of exhaust emission and improved brake specific fuel consumption. An experimental investigation with cerium oxide nano particle as addition (at 20, 40 and 60 ppm (parts per million)) in Jatropha biodiesel fuel had shown significant NO reduction by 30% and hydrocarbon emissions by 40%, besides increased brake thermal efficiency by 1.5% [4]. Experimental investigation conducted in a single-cylinder four stroke direct injection variable compression ratio diesel engine using diesel-biodiesel-ethanol blends blended with cerium oxide nanoparticle at 25 ppm, resulted in drastic reduction of exhaust emissions such as hydrocarbon, nitric oxide and carbon monoxide [5]. The addition of aluminium nano particle in diesel along with 3–6 % volume of water addition as fuel in a diesel engine shows reduced concentration of smoke and nitrous oxide with significant improvement in brake thermal efficiency [6]. Basha and anand [7], drew attention of blending two nano particles namely alumina and CNT (dosing ratio of 25 and 50 ppm) in Jatropha biodiesel and found maximum reduction of NO by 23% for alumina and CNT blended Jatropha biodiesel. In continuation with significant NO

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Table 1
Specification of Nanoparticles.

Item	Specification	
Manufacturer	M/s. Alfa Aesar, USA	M/s. Sigma Aldrich, USA
Chemical name	Alumina (Al_2O_3)	Cerium Oxide (CeO_2)
CAS no	1344-28-1	1306-38-3
Molecular weight	101.96	172.11
Average particle size diameter	51 nm	32 nm
Specific surface area	32 m^2/g	30 m^2/g
Appearance	White	Yellow

reduction, the brake thermal efficiency of engine increases for alumina and cerium oxide blended Jatropha biodiesel along with smoke opacity reduction by 1.5%.

From the literatures, the blending of two nano particles in biodiesel shows the most promising results for the performance and emission characteristics of the engine in particular NO emission compared to the individual addition of a nano particle. So, in this present experimental investigation, two nano particles are blended in various parts per million (ppm) with Jatropha biodiesel and the performance and emission characteristics of the test fuels are investigated in comparison with neat diesel and neat biodiesel as base fuels.

2. Experimental section

2.1. Nano particle characterisation & test fuels

Alumina and Cerium oxide nano particles are procured from Alfa Aesar and Sigma Aldrich Company respectively and its specifications are given in Table 1. The morphology of the alumina and cerium oxide nano particles are determined by Scanning Electron Microscope (Model: VEGA3 TESCAN, Czech Republic) as shown in Figs. 1 and 2 respectively and the crystalline phase of nanoparticles are determined by X-ray Diffraction (Model: Rigaku, Ultima IV, Japan) and the intensities are compared with the data from the Joint Committee on Powder Diffraction Standards (JCPDS) as shown in Figs. 3 and 4 respectively. Three types of test fuels are prepared by equally dispersing Al_2O_3 and CeO_2 nano particles in mass fraction forming 10, 30 and 60 ppm with Jatropha biodiesel. To prepare the JBD5A5C test fuel, nano particles Al_2O_3 and CeO_2 of 5 ppm each, are added to the Jatropha biodiesel and dispersed using an apparatus called Ultrasonicator. An Ultrasonicator is used for equally dispersing Al_2O_3 and CeO_2 nano particles in Jatropha biodiesel for nearly 1–2 h before the start of the experiment. The stability characteristic tests are carried out for the test fuels in graduated test tubes and found stable for 2 days. The same procedure is carried out for the preparation of other test fuels JBD15A15C and JBD30A30C respectively and the properties of the test fuels are shown in Table 2.

2.2. Engine setup

Fig. 5 shows the schematic view of the experimental setup and Table 3 shows the engine specification utilized for the present study. The experimental setup consists of a single cylinder, four-stroke air cooled diesel engine running at a constant speed of 1500 rpm with a rated

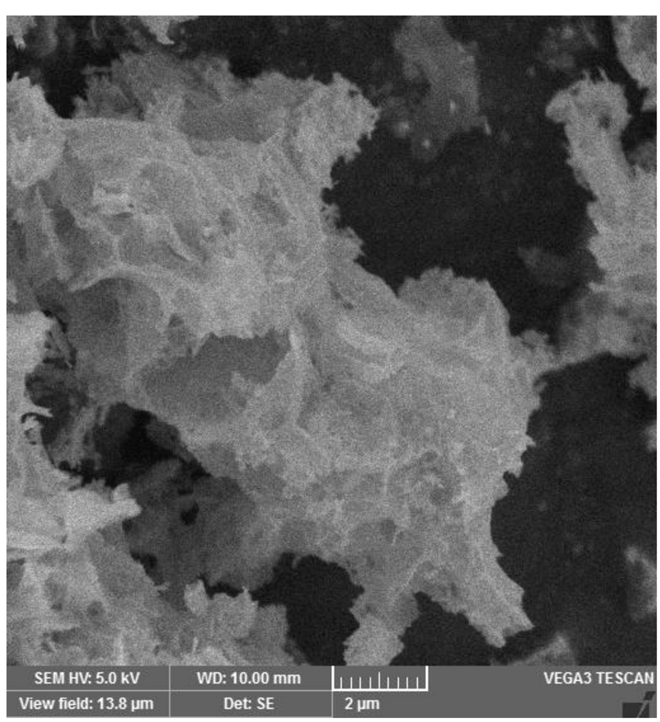

Fig. 1. SEM image of Al_2O_3.