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Full Length Article

Experimental investigation on effect of MgO nanoparticles on cold flow properties, performance, emission and combustion characteristics of waste cooking oil biodiesel

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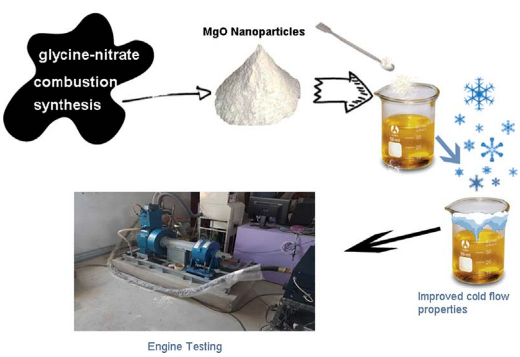
GRAPHICAL ABSTRACT



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ABSTRACT

Commercialization and effective use of biodiesel is still unattained due to its poor cold storage property. Biodiesel produced from waste cooking oil (WCO) using methanol was blended with 0%, 80% and 90% petroleum-based diesel (PBD) fuel and 20 ppm, 30 ppm, 40 ppm and 50 ppm of magnesium oxide (MgO) nanoparticles. The test fuels quality was found to be within limits of the ASTM standards. 30 ppm concentration of MgO nanoparticles showed improvement in cloud point (CP), cold filter plugging point (CFPP) and pour point (PP) of the test fuels. The results showed that the brake specific fuel consumption (BSFC) of B100W30A, B20W30A and B10W30A fuels were 28.2%, 9.48%, and 2.45% higher than the B100, B20 and B10 fuel respectively. PBD showed lower BSFC but higher brake power (BP) and brake thermal efficiency (BTE) when compared to the other test fuels. The BTE and BP of the B100W30A, B20W30A and B10W30A fuels were 4.57% and 1.17% on an average higher than those of B100, B20 and B10 respectively. In general, MgO nanoparticles blended fuel released relatively lesser emissions than B100, B20, B10 and PBD. Combustion analysis of nanoparticles blended fuel was better than other test fuels and comparable with PBD.

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Nomenclature

P_{max}	Maximum cylinder pressure
$°CA_{Pmax}$	Crank angle at maximum cylinder pressure
HRR_{max}	Maximum heat release rate
$°CA_{HRRmax}$	Crank angle at maximum heat release rate
B100	100% WCO biodiesel
B20	20% WCO biodiesel and 80% PBD
B10	10% WCO biodiesel and 90% PBD
B100W30A	100% WCO biodiesel blended with 30 ppm MgO nanoparticles
B20W30A	20% WCO biodiesel and 80% PBD + 30 ppm MgO nanoparticles
B10W30A	10% WCO biodiesel and 90% PBD + 30 ppm MgO nanoparticles
XRD	X-ray powder diffraction
MC	Moisture content

1. Introduction

The need for transportation is increasing and PBD being a very important fuel is in great demand. Reports from experts say that the existing fossil fuel reserve will last no longer than a decade [1]. Moreover, harmful vehicular emissions like CO, HC and SO_x, leads to the need for an alternative fuel, which is safer and should be more economical than PBD [2]. In this specific circumstance, biodiesel can be a promising solution because of its practically identical properties to PBD fuel. Biodiesel will play an important role in achieving a significant reduction in emissions [3].

Biodiesel fuel is produced from biomass. Biodiesel is perceived to be non-toxic, non-flammable, sustainable giving less ozone-harming substance outflow and security of supply. Biofuels have several beneficial properties [4]. They emit very less carbon dioxide and carbon monoxide when compared to PBD [1]. Biofuels helps in reduction of carbon dioxide depletion since the biomass burnt releases carbon dioxide, which is in turn taken in by plants for its growth. Because of the excess oxygen molecules in the biodiesel, the emission of carbon monoxide is almost zero [5].

Biodiesel contains a high amount of saturated fatty acid esters, which are prone to form wax/crystals at low temperatures [4]. Wax/crystal formation arrests the free flow of fuel along pipes and filters, thus influencing the operation of engines, in this way, the poor cold flow properties significantly restrain the utilization of biodiesel in cold climate [6]. There are numerous methods to enhance the cold flow properties of biodiesel, like the application of branched chain alcohol for transesterification, alteration of fatty acid profiles of biodiesel, winterization, mixing petroleum-based diesel with biodiesel and adding additives [7]. In general, mixing PBD with biodiesel shows an improvement in the essential fuel properties of biodiesel, specifically to its low-temperature performance [8]. Chemical additives referred as cold flow improvers when blended with biodiesel improve the biodiesel property. These chemical additives added additionally to biodiesel improves the performance of the engine, combustion characteristics and reduce emission [2,9,10].

Different researchers have investigated the potential of cold flow improvers to enhance the cold flow properties of biodiesel. To the best of our knowledge, very limited researchers have worked on the use of MgO nanoparticles to improve the cold flow property of biodiesel produced from WCO. The CP of madhuca biodiesel was reduced by 10 °C and 13 °C by the addition of 20 (vol.%) ethanol and kerosene respectively, but Lubrizol had no impact on the cloud point [11]. Ethyl acetoacetate was explored as a potential bio-based diluent for enhancing the cold flow properties of biodiesel from WCO [12]. Blends of ethylene vinyl acetate and naphthenic distillates were used for enhancing cold flow properties of Soybean biodiesel [13]. Diesel-biodiesel blend with a cold flow improver Wintron Synergy was explored and was found to bring down CP of the fuel blends [14]. The mixtures of ethyl acetoacetate, iso-decyl methacrylate and iso-octyl methacrylate in various concentrations are used for the study to enhance the cold flow properties of WCO biodiesel [8]. Different cold flow improvers like Poly-alpha-olefin [15]surfactants, including sugar esters, silicone oil, polyglycerol ester and diesel conditioner were explored [16]. PP of the rapeseed methyl ester was slightly increased with the addition of SiO_2 and MgO nanoparticles [17]. A literature reported that use of MnO_2 or MgO additive has enhanced the properties (viscosity, flash point, CP and PP) of diesel fuel [18]. In general, there is less work given on the utilization of metal-based additive to enhance cold flow properties of waste cooking oil biodiesel.

Oxygenates have been reported to vary the physicochemical properties, performance and reduced emissions when used as additives in a biodiesel, especially in nanoparticles form, with increased surface area to volume ratio. Numbers of literature have investigated the role of various metal additives in engine performance and emission. Metals additives like barium, cerium, iron, manganese, copper, magnesium, calcium and platinum have catalytic activity and is employed for blending with biodiesel to improve combustion, the performance of the engine and reduce emissions [16,19–21]. Some researcher have reported the application of manganese oxide and copper oxide as additives to improve diesel fuel properties (like flash point, fire point and viscosity) and performance of the fuel in internal combustion (IC) engine [22]. The investigation of SiO_2 and MgO nanoparticles as an additive in rapeseed methyl ester showed that emission of NO_x and CO was reduced and the performance of engine increased marginally. However, there is no literature available on the use of MgO nanoparticles for enhancing WCO biodiesel-PBD blends performance, emission, combustion and cold flow property.

The effect of MgO nanoparticles on cold flow property, engine performance, emission and combustion for WCO biodiesel blends is yet to be reported. The aim of this study is to investigate the effects of MgO nanoparticles additive at different concentration (20 ppm, 30 ppm, 40 ppm and 50 ppm) on the improvement of cold flow properties of WCO biodiesel blends. The study also aims to investigate the impact of the MgO nanoparticles addition in the WCO biodiesel blends for improvement of the performance, emissions and combustion characteristics in a IC engine. The nanoparticles addition proved efficient in the present study is lesser in concentration than that has been reported earlier with other additives. This process is an easy and good alternative for the modification of biodiesel cold flow property.

2. Materials and methods

2.1. Chemicals

Methanol (assay 99.0%, HPLC grade), glycine (assay ≥99.7%), NaOH (assay 98.0%, GR grade) and magnesium nitrate hexahydrate (assay 99.0%, GR grade) were purchased from Central Drug House Private Limited, Chennai. PBD used in the current work was purchased from Hindustan Petroleum.

2.2. Production of biodiesel from WCO

WCO was obtained from the kitchen of Sathyabama Institute of Science and Technology, Chennai, Tamil Nadu, India. Methanol to WCO (6:1 Molar ratio), NaOH (0.5 wt% of WCO) and the reaction time of 90 min. were maintained in the transesterification process [23]. A batch reactor of 0.5 L capacity comprising of a three-necked round bottom