Fuel 236 (2019) 365–372

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Experimental analysis of nanofuel additives with magnetic fuel conditioning for diesel engine performance and emissions

Rashmi Rekha Sahoo*, Animesh Jain

Department of Mechanical Engineering, Indian Institute of Technology (BHU), Varanasi 221005, India

ARTICLE INFO

Keywords:
Engine
Magnetic field
Nanoadditive
Diesel
Performance
Emission

ABSTRACT

This paper presents an experimental work for the realization of the concept including nanofuel application to a single cylinder diesel engine, with and without magnetic fuel conditioning at various locations on fuel line. With the effect of magnetic field, ionization takes place and declustering the hydrocarbon fuel molecules for better atomization of the fuel and mixing the fuel-air mixture to enhance the combustion, which improves the fuel economy. CuO nanofuel was prepared by 0.5% CuO (wt./wt.) mass fraction nanoparticles blended with diesel fuel by means of a mechanical homogenizer and an ultrasonicator. Physicochemical properties of CuO nanofuel were measured and compared with neat diesel fuel. Their stability characteristics were analyzed under static conditions. The effects of the CuO nanoparticles on the engine performance and emissions were also investigated with permanent magnet of field strength 3000 Gauss. Mounting permanent magnets in fuel line enhanced fuel properties such as it aligned and oriented hydrocarbon moleculesfor better atomization of fuel, which results better emission of engine.

The experimental analysis revealed that CuO nanofuel has improved performance and emission characteristics. The engine test results with magnetic fuel conditioning showed that, the CuO nanofuel has better mechanical efficiency of 7%, reduction in BSFC by 6% and reduction in 13% and 19% for CO_2 and NO_x emissions respectively, compared to diesel fuel. As a whole, CuO nanofuel with magnetic fuel conditioning have pronounced effect on enhancing the brake thermal efficiency and reducing the harmful pollutants of the compression ignition engine.

1. Introduction

Today, diesel engines are used worldwide for transportation, manufacturing, power generation, construction, and farming [1]. Most fuels for internal combustion engine are liquid, fuels do not combust until they are vaporized and mixed with air. Generally a fuel for internal combustion engine is compound of molecules and each molecule consists of a number of atoms made up of number of nucleus and electrons, which orbit their nucleus. Magnetic movements already exist in their molecules and they therefore, already have positive and negative electrical charges. However, these molecules have not been realigned due to which the fuel is not actively interlocked with oxygen during combustion. Thus, the fuel molecule or hydrocarbon chains must be ionized and realigned. The ionization and realignment is achieved through the application of magnetic field [2]. The hydrocarbon fuels leave a natural deposit of carbon residue that clogs carburetor, fuel injector, leading to reduced efficiency and wasted fuel. Pinging, stalling, loss of horsepower and greatly decreased mileage on cars are very noticeable.

Many of experimental studies, which present evidences for the benefits of magnetic treatment were occurred. For motor vehicles and industrial boilers, much fuel economy and noticeable soot suppressions could be approached when the magnetic treatment was introduced [3]. Generally, electrons having ability to store up energy within itself similar to flywheel called spin. When it provides with small amount of magnetic field, it absorb the energy and the properties will change which is based on the theories i.e. Chemistry theory – Covalent bond, Physics theory – Barnett effect, Math's theory – Quantum mechanics [4]. Magnetic fuel treatment works on the principle of magnetic field interaction with hydrocarbon molecules of fuel and oxygen molecules. Liquid fuel is a mixture of organic chemical compounds consisted predominantly of carbon and hydrogen atoms – hydrocarbons. Due to various physical attraction forces, they form densely packed structures called pseudo compounds which can further organize into clusters or associations [5]. These structures are relatively stable and during air/fuel mixing process, oxygen atoms cannot penetrate into their interior.

* Corresponding author.
E-mail address: rrsahoo.mec@itbhu.ac.in (R.R. Sahoo).

https://doi.org/10.1016/j.fuel.2018.09.027
Received 17 July 2017; Received in revised form 2 May 2018; Accepted 6 September 2018
0016-2361/

Nomenclature

MFC	magnetic fuel conditioning
BP	brake power
BSFC	brake specific fuel consumption
BTE	brake thermal efficiency
CuO	copper oxide
CI	compression ignition
DGM	digital gauss meter

The access of appropriate quantities of oxygen to the interior of these molecular groups (associations) is thus hindered. This result in the incomplete combustion of fuel in the interior of such associations and causes the formation of carbon particles and carbon monoxide as well as increased quantities of hydrocarbons emitted into the environment [6]. It is now well accepted that a hydrocarbon fuel can be polarized by exposure to external force such as magnetism. The effect of such magnetism is the production of a moment created by the movement of the outer electrons of a hydrocarbon chain moving the electrons into states of higher principal quantum number. This state effectively breaks down the fixed valance electrons that partake in the bonding process of the fuel compounds. These states create the condition for freer association of fuel particulars. In so doing, the hydrocarbon fuel becomes directionalized or aligned which does not necessarily create new hydrocarbon chains but more explainable aligns the conduced magnetic moment into a dipole relationship within itself. The clusters of hydrocarbons changed with the influence of magnetic field and they are more dispersed as shown in Fig. 1. This magnetic alignment then permits rapid bonding with the respective oxidizing media. The result of which is, of course, more complete and rapid burning of the hydrocarbon fuel [7,8]. Hayder [9] used the energy of permanent magnets in the research for the treatment of vehicle fuel (Iraqi gasoline) to reduce consumption and found that the overall performance tests showed a good result and the percentages of exhaust gas components (CO, HC) were decreased by 30%, 40% respectively. Deshmukh [10] investigated a new way of fuel conditioner called as Magnetic Fuel Conditioner (MFC), where ferrite magnets were used as MFC to improve the efficiency and emission. Mounting permanent magnets in fuel line enhanced fuel properties such as it aligned and oriented thehydrocarbon molecules for better atomization of fuel which results better emission of vehicle. Chaware [11] investigated the effect of the fuel magnetization reduces the viscosity of hydrocarbon fuel due to declustering of the hydrocarbon fuel molecules which results in better atomization of the fuel and efficient combustion of air fuel mixture for enhanced thermal efficiency and improves the fuel economy of engine. Some experimental investigations [4,12] reveled that, the strength of magnet depends on engine size. The magnetic flux density to be imparted to fuel widely varies depending upon fuel, air or stream, combustion equipment and its condition. In general, the preferred range of magnetic flux density is from 1000 to 3000 Gauss for multicylinder engines and the magnetic field strength is a function of engine size, based on fuel consumption. Their experimental results with the application of MFC reveled the considerable reduction in exhaust gas emissions such as CO, CO_2, HC and NO_X, increase in thermal efficiency and break thermal efficiency [13–15].

Many studies concerning nanofuel have been published especially in the past 10 years [16]. Metallic based and oxygen containing compounds, such as aluminum oxide (Al_2O_3), titanium oxide (TiO_2) and copper oxide (CuO), which act as a combustion catalyst for hydrocarbon fuels. The stability or agglomeration of nanoparticles in the base fluid is an important issue to the scientists concern. The effects of CeO_2, MnO, ZnO and CuO as nanoadditives in diesel fuel have been investigated experimentally, on the basis of physicochemical properties of diesel as well as the engine performance and emissions. Nanoparticles increases the evaporation rates with early ignition compared to diesel and ZnO nanoparticle created a negative effect of producing more NO_x than that of neat diesel. It is concluded that the additives caused a marginal increase in performance and significant decrease in levels of pollutants emission [17–20]. Microexplosion mechanism of nanoadditives in diesel, results a sudden catastrophic break-up of the droplets and rapture accompanies the formation of daughter droplets that pinch off from the parent droplet and further undergo microexplosion for improvement in fuel consumption [21–23]. Many researchers found that the combustion behaviour of diesel with the addition of nanosize energetic materials as an additive improves the combustion and engine performance of diesel engines. In addition, due to the small size of nanoparticles, the stability of fuel suspensions should be noticeably improved [24–31]. The potential characteristics of nano-additives which has improved the fuel properties (like enhanced cetane number, rapid ignition characteristics and higher surface area/volume ratio). These facts have motivated for further study on nanofuel with new system for better engine performance.

In this study, focus has been laid on understanding of the magnetic action modes which have lead to the fuel economy for nanofuel and reducing exhaust emissions in engine applications. Experimental investigation on CuO nanofuel preparation and its application to diesel engine with and without magnetic fuel conditioning at various locations on fuel line have been presented in this work. Effects on magnetic positions, engine performance parameters (brake specific fuel consumption, mechanical efficiency and brake thermal efficiency) and emissions with the application MFC for CuO nanofuel have been discussed and the results were compared with neat diesel.

2. Experimental analysis

The experimental investigations have been carried out in three stages. In first stage, the selection of permanent magnet and the magnetic field strength at different positions on the fuel pipe line have been investigated. In second stage, preparation of CuO nanofuel, influence of the addition of dispersants on stability of nanofuel and various physicochemical properties of neat diesel and CuO nanofuel were measured. Then, in the third stage the performance and emission tests were conducted on a diesel engine with constant speed, using nanofuel sample and compared with those of the neat diesel, with and without application of magnetic field.

2.1. Selection of magnet and its application at different positions

The energy required for generating the magnetic field was more than the fuel energy saved due to magnetic fuel conditioning. These reasons suggested for using permanent magnets instead of electromagnets. A fixture which can hold magnets of different sizes in different orientations was designed. The permanent magnet also known as Neo magnet, which is most widely used type of rare earth magnet and in bright silver color. A permanent magnet which made from alloy of neodymium, iron and boron and this magnet considered to be the

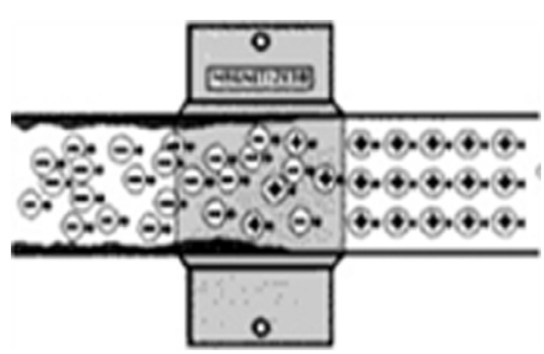

Fig. 1. Magnetizer Action in fuel line.