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An overview on comparative engine performance and emission characteristics of different techniques involved in diesel engine as dual-fuel engine operation

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ABSTRACT

Abatement of pollutant emissions from transport sector is one of the major concerns throughout the globe. One of the main technical challenges for transportation sector is to reduce pollutant emissions from diesel engine and to meet satisfactory engine performance, simultaneously. Different technical changes have been introduced in diesel engine to apply alternative biofuels to reduce pollutant emissions. Blend, fumigation, and emulsion are three different dual fuel engine operation techniques, which have been introduced in diesel engine for biofuel application. In the blend mode, biofuel and diesel are mixed in desired proportions before injecting into cylinder, whereas in fumigation mode, biofuel is injected into intake manifold to mix with the intake fresh air. Emulsion is a process wherein two immiscible substances are mixed together. This study provides a comprehensive review on these three techniques of biofuel injection and their comparative effects on the engine performance and emissions. From these studies, it is found that the effects on engine performance and emission mostly depend on biofuel properties. Increase in break specific fuel consumption (BSFC) is common in each method due to the lower calorific value of biofuels. Brake thermal efficiency (BTE) decreases in blend and fumigation modes, but increases in emulsion mode. Nitrogen oxides (NO_x) emissions decrease in fumigation and emulsion modes, but increase in blend mode. Carbon monoxide (CO) and Hydro carbon (HC) emissions increase in fumigation and emulsion modes, but decrease in blend mode. Particulate Matter (PM) emission decreases in all three modes.

Contents

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1. Introduction

Nowadays, environment pollution is one of the major concerns throughout the world. The global transportation sector is one of the main contributors to environment pollution, since this sector is the major source of NO_x, HC, CO, CO_2 and PM emissions and accountable for 26% greenhouse gas emissions [1]. These emissions have extremely deleterious effects on human health. Several researchers have reported that the exhaust emissions from vehicles are responsible for respiratory and cardiovascular health problems, and neurodegenerative disorders [2–4]. Moreover, global warming as a consequence of greenhouse gas has an adverse effect on climate change. Global warming becomes menace to the biological system of the earth. Global warming increases the temperature over Iceland and melts snow. As a result, the sea level is increased and the new area of habitant is being deluged. The awareness for environment protection throughout the world is mounting and more stringent emission regulations are being legislated. Due to the above situation, researchers have launched intensive researches to find out substitute alternatives of diesel fuel and their appropriate implementation techniques in diesel engine.

Currently, three application techniques of alternative biofuel for example, blending, fumigation and emulsion have been implemented in diesel engine to reduce pollutant emissions. In blend mode, bio-diesel and diesel are premixed with desired proportion before injecting into cylinder. In fumigation mode, biofuel is injected into intake manifold to mix with intake fresh air by spraying or carbureting. Emulsion is a process of mixing two immiscible substances e.g. water and fuel are not suitable to be blended, by applying two different phases in the mixture, the dispersed phase and the continuous phase. Studies have proved that each application technique has significant effects on engine performance and emission characteristics.

In this literature review, a large number of research articles have been investigated to study the technical effects of blend, fumigation and emulsion on the engine performance and emission characteristics and to compare the results.

2. Blend, fumigation and emulsion as dual fuel operation in diesel engine

2.1. Blend

Blend method is mostly used as a dual fuel technique in CI engine to apply the biofuel as substitute fuel. In blend mode, biofuel and diesel are mixed with desired proportion. In case of blending, no additional equipment is required to apply bio-fuel [5] because biofuel is pre-mixed with diesel at desired proportion inside one fuel tank and then the mixture is injected into the engine cylinder through the fuel injector without any modification of fuel injection system. In this system, large amount of biofuel supply is limited due to having poor miscibility of biofuel with diesel. Since, in blend mode, two liquids having different psychochemical properties are mixed together, there is a possibility of instability and separation problem during the engine operation. For this reason, different sorts of additives like co-solvents or dodecananals or mixers are added in biofuel–diesel blending to ensure the miscibility of blend and to overcome the phase separation problem, which eventually minimizes the supply of fuel to the engine [6,7]. Due to this, blending mode may need 25% less amount of fuel consumption on energy basis compared to the fumigation mode [8]. Moreover, the psychochemical properties of biofuel and diesel are not similar and blending of such two fuels may lead to changes in key fuel properties like viscosity, density and cetane number.

2.2. Fumigation

Fumigation mode is mostly used to apply alcohol into CI engine. A schematic diagram of alcohol fumigation is provided in Fig. 1. In fumigation mode, biofuel is injected into intake manifold to mix with intake fresh air by spraying or carbureting. [9–14]. In fumigation mode, some additional instrument such as carburetor, vaporizer or injector, along with a separate fuel tank line and controls is required to inject bio-fuel into intake manifold [15].

The use of discrete fuel tank provides opportunity to revert the engine operation to neat diesel operation, if any problem arises during the biofuel combustion [16]. In fumigation mode, biofuel is injected into intake manifold, then mixed with intake upstream fresh air, which abates the mixture temperature and increases its density. Thus, large amount of air can be delivered and greater amounts of power can be achieved if right proportion of fuel is added [15]. Since, bio-fuel is premixed with upstream intake air, it is not required to add any additives in fumigation mode to ensure the miscibility of bio-fuel and diesel fuel. Due to this advantage, bio-fuel can substitute up to 50% diesel supply in fumigation mode [16]. Albeit, fumigation mode may increase weight of the vehicle body, but this system gives the opportunity to supply more energy to engine compared to the other modes.

2.3. Emulsion

Emulsion is a process of mixing two immiscible substances (water and fuel are not suitable to be blended), which are mixed together by applying two different phases in the mixtures, the dispersed phase and the continuous phase. In emulsion mode, one substance i.e. the dispersed phase is uniformly distributed throughout the second substance i.e. the continuous phase [17]. Usually, emulsion is classified based on the polarity of the dispersant phase compared to that of the dispersed one. In all emulsion applications, one of the fluids is water. On the other hand, another one is characterized by a lower dielectric constant indicated as oil. For this reason, emulsions are usually categorized as dispersions of water droplets in oil (water-in-oil emulsions, W/O) or oil droplets in water (oil-in-water emulsions, O/W) as shown in Fig. 2 [18].

In W/O emulsion mode, oil is for the continuous phase and water droplets are for the disperse phase. The psychochemical properties of emulsion mode such as density viscosity etc. rely on the droplet's size and size distribution. Therefore, the size of water droplets in emulsion actually controls the engine performance and emission. In emulsion mode, if the size of water droplets is smaller,