Review on effects of performance, emission and combustion characteristics of emulsified fuel in bifuel engine

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Abstract: The emission norms of diesel engines are turned more stringent due to continuous increasing of environmental pollutants. Thus, global researchers explore to reduce emissions from diesel engines by fulfilling the performance parameters. The major emissions in the diesel engines are the NOx emissions due to the higher combustion temperatures. Generally, dual fuel engines play a vital role in regulating both emission and performance parameters. Diesel engines are converted to dual fuel mode by using the various techniques such as blend, fumigation, and emulsion. Among these, water-diesel emulsion (WiDE) also can lessen the emissions of NOx and other pollutants promptly. It is observed that the combination of emulsified fuel and the gaseous fuels showed a simultaneous improvement in the thermal efficiency and reduction of NOx emissions. Various emulsion preparation techniques and effects of different gaseous fuels used with emulsified fuels in bifuel engines have been reviewed in this paper.

Keywords: bifuel; blend; emissions; emulsion; performance.


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1 Introduction

Diesel engines offer good fuel rate, flexible and more durability (Nagaraja et al., 2016). So it plays a dominant role in the transportation, industrial and farming sectors (Abedin et al., 2016). But, diesel engines contribute major environmental pollutants like NOx, PM, SOx, and CO emissions (Seifi et al., 2016). These emissions have been affecting the human health and environmental cycle. Generally, the exhaust emissions vary on different parameters (Nagaraja et al., 2013); they are the types of the engine, operating parameters, type of fuel, and availability of emission control system for that engine (Hasannuddin et al., 2016). In recent years, researchers are facing a major problem with NOx emissions (Nagaraja et al., 2012), NOx is formed due to the higher combustion temperature in the cylinder (Barik and Murugan, 2014). Typically, NOx emissions from the engine was controlled by using the water in various techniques such as

- Fumigation method
- direct water injection
- emulsified method (Khan et al., 2017; Yahaya Khan et al., 2014; Scarpete, 2013; Mingrui et al., 2017).

The three techniques mentioned above have considerable effects on engine performance and emission characteristics. First two need the additional retrofitting and also causes the corrosion problem due to water. But the third method does not require any additional engine retrofitting and also it gives the better reduction in NOx (Kadota and Yamasaki, 2002). The water diesel emulsion was prepared by using the various methods (Leong et al., 2017). The water and diesel are two immiscible liquids so they need a surfactant for mixing (Shinjo et al., 2014). Water diesel emulsion combustion exhibits microexplosion phenomenon, it helps for proper utilisation of energy (Sahoo et al., 2009). The water diesel has various volatility properties and they lead to the micro explosion in the emulsion.

Most of the investigations are carried out on the diesel engine for blend, fumigation, and emulsion on the engine performance and emission characteristics. Researchers around the world are trying on the possibilities to reduce peak combustion temperature, without declining the engine performance and reduce NOx emissions. The present review paper covers the various research papers on the emulsified fuel in the diesel engine.
1.1 Features of blends

The blend is the combination of oils. Diesel was mixed with the various bio fuels in a required proportion depends on the physicochemical properties (Nagaraja et al., 2015). The additives are added to the blends for improving the stability and proper ignition. Generally, various additives are used such as ferrocene (Kasper et al., 1999; Jung et al., 2005) and etc., are added to blends to ensure the miscibility.

1.2 Features of fumigation

A gaseous fuel is sent through the inlet manifold for improving the octane percentage for proper combustion. Generally, the gaseous fuel is injected by using the spray technique or carburetion to a compression ignition engine. The gaseous mixer burns and becomes the contributor to the power producing (Ma et al., 2010). Various gaseous fuels such as biogas (Bora and Saha, 2015), LPG (Lata et al., 2012), natural gas (Song, 1984), and hydrogen (Adnan et al., 2012; Premkartikkumar et al., 2013, 2015) are used as fuels for diesel engine, to maintain the combustion temperature high and to decrease the smoke emission.

1.3 Features of emulsion

Emulsion does not show a static internal structure (El-Din et al., 2013). It is a process of integration with two immiscible substances, in this mode, it forms two layers i.e., one is the dispersed phase and second one is the continuous phase. Small amount of surfactant is used for the preparation of emulsion (Khan et al., 2017). Surfactant reduces the interfacial tension between the immiscible liquids (Sai et al., 2018). The stability of emulsion plays a vital role in the applications of emulsion. Mostly, stability depends on the droplet size and phases of emulsion.

2 Materials and methods

Diesel engines are widely used for the power generation in industrial and agricultural applications (Abedin et al., 2016). Due to imposed environmental regulations, controlling of exhaust gas emissions from the diesel engine is essential. WiDE plays a key role in the control of emissions from the diesel engine.

2.1 Emulsion preparation techniques

Emulsion was prepared by using the various surfactants. Hydrophilic-Lipophilic Balance number (HLB) of a surfactant plays a vital role in the emulsion preparation. For WiDE preparation, the surfactants required the HLB number of below 10 (Al-Sabagh et al., 2011). These types of surfactants are called as lipid soluble. In this diesel is continuous phase and water as dispersed phase. Califano et al. prepared WiDE by using the magnetic stirrer and span 80 as surfactant (Califano et al., 2014). Emberson et al. (2016) prepared the emulsion by using the ultrasonic generator, span 80 and tween 80 as surfactants. Most of the researchers used the following equipments for the preparation of emulsions such as horn type piezoelectric transducer (Zolfaghari et al., 2016), ultra-turrax machine (Ogunkoya et al., 2015), and electrical blender (Abu-Zaid, 2004).
2.2 Bifuel engines

Bifuel engines are run on the combination of various fuels. Generally, for bifuel engines, gaseous fuel was directly injected into the inlet manifold (Premkartikkumar, 2016). The flow of the gas was controlled by the suitable gas flow meter along with air stream of engines own suction.

Bora and Saha (2015) work on the diesel engine by using the biogas as secondary fuel. Biogas was sent through inlet manifold and diesel was supplied under dual fuel mode (DFM). Korakianitis et al. (2010) operated the dual fuel engine using emulsion and natural gas. Kumar and Jaikumar (2014) tested engine performance and emissions by bifuel method. Here, they sent the \( H_2 \) from inlet manifold and waste cooking oil as pilot fuel.

3 Performance and emission analysis

3.1 Emulsion

Armas et al. (2005) conducted the experiments by using the water diesel emulsion as fuel for the diesel engine. They found the micro explosion phenomenon and a significant reduction in NOx emissions due to reduction of peak temperature in the combustion chamber. Some of the researchers work on the numerical study of WiDE combustion process and they found the effect of ignition delay due to chemical kinetics (Samec et al., 2002). The water content in the WiDE shows the reduction of thermal efficiency due to a low heating value of water (Badrana et al., 2011). The WiDE causes the ignition delay; it can be overcome by addition of 2-Ethylhexyl nitrate (Ghojel et al., 2006).

Premkartikkumar et al. (2015) investigated the diesel engine fuelled with WiDE and they conclude that 15% water content WiDE gives better efficiency and greater control of the emissions.

3.2 Fumigation

Arat et al. (2016) investigated on diesel and CNG. In their experiment, CNG was enriched with HHO with enriched with HHO. They found that the average improvement of brake power, HHO with Pilot diesel was 3.4% and 25HHOCNG with Pilot diesel was 6.28% when compared with the neat diesel. Dhole et al. (2014) worked on dual fuel engine with a different substitution of \( H_2 \), Producer gas (PG) and the mixture of PG and \( H_2 \) respectively. They found that brake thermal efficiency (BTE) was improved by 7% when 20% hydrogen was used as secondary fuel and 8% BTE got decreased by using 30% PG is as secondary fuel. A mixture of PG and \( H_2 \) (in the ratio 60:40) reduced 3% of BTE. Lata et al. (2012) investigated on dual fuel engine with the combination of hydrogen and LPG as secondary fuels. They conclude that, when 30% hydrogen was used as secondary fuel, 17% of BTE got enhanced. They also observed that when using 40% LPG was used as secondary fuel, the BTE got increased by 6%. HC and CO were reduced in both cases and observed slight decrease of NOx and smoke. A mixture of hydrogen and LPG showed 27% improvement in BTE and 68% reduction in HC emission. Selvi Rajaram et al. (2014) studied the effect of oxygen enriched hydrogen-HHO and their results showed an improvement of BTE by 11.06%, reduction in carbon
monoxide and unburned hydrocarbon by 15.38% and 18.18% respectively. But there was an increase of carbon dioxide by 6.06% and NOx emissions by 11.19%. Premkartikkumar et al. (2015) worked on the diesel engine with enriched hydrogen fuel and reduced injection timing. From the studies, they found the reduction of break specific energy consumption and NOx emissions as compared to the neat diesel operation.

3.3 Emulsified bifuel engine

Korakianitis et al. (2010) operated the dual fuel engine with rapeseed methyl ester (RME) emulsion and gaseous hydrogen. From that they found that the thermal efficiency was more for emulsified fuels than the neat RME, due to the micro explosion phenomenon. Hydrogen dual-fuel operation exhibited the lower power output because of gaseous fuel injection. This also result a stable engine operation and reduction knocking. On the other hand, it increased NOx emission at higher loads. Chintala and Subramanian (2014) worked on dual fuel engine, in this work they studied how the energy share of H2 could be improved with reduction in NOx. Kumar and Jaikumar (2014) worked on compression ignition engine using waste cooking oil (WCO) emulsion as pilot fuel and hydrogen as primary fuel, it shows 30.3% improvement in BTE when 10.5% hydrogen energy share at full load condition and HC emissions are also reduced by 50% when compare with the neat WCO, but they observed a slightly higher NOx emissions.

4 Conclusions

The exponential increase of environmental pollutants and stringent emission norms of the diesel engine, create the motivation for finding eco-friendly fuel.

Based on the comprehensive review carried out on the using of diesel/biodiesel in various modes of operation, the following conclusions are drawn. When biodiesel blends are used as fuel in a compression ignition engine, it increases the brake specific fuel consumption around 10%. At the same time, it also decreases BTE due to poorer atomisation and combustion. In emission analysis, biodiesel blends show nearly 50% lower CO and HC emissions and around 30% increase in NOx emissions compared with neat diesel fuel. This is due to its higher combustion temperature with fuel bound oxygen content. The biodiesel when it is used as an emulsion, NOx emissions get reduced by 30% to 70% when the water content is around 10–30% in the emulsified fuel. An emulsified fuels offer the microexplosion phenomenon and this leads to improvement in the combustion efficiency, and reduction in the PM emissions of about 16–40%. Most of the researchers suggested the optimum water content as 30% by volume for getting the better combustion. The current diesel engines can be converted into dual fuel mode without major modifications. Emulsion with fumigation technique gives better efficiency compared to single fuel mode. Dual fuel engines offered less volumetric efficiency when the gaseous fuel was inducted from the inlet manifold. The in-cylinder injection of gaseous fuel does not affect the volumetric efficiency and it leads to the improvement of the power output of the engine. It also enhances the performance and significant reduction of exhaust emissions except for NOx emissions when compared with neat diesel engine operation. When the diesel engine is operated in a dual fuel mode with an emulsified fuel and a small quantity of hydrogen, it shows the significant increase in the performance and an appreciable amount of reduction in all engine emissions including...
NOx and smoke. This research area can be extended by optimising the design of combustion chamber, geometry of fuel injector nozzle, and analysis of the chemical kinetics of the emulsified fuels.

References


