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Application of nano emulsion method in a methanol powered diesel engine

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ABSTRACT

Demand of methanol-blended diesel fuel is increasing to compensate the use of diesel fuel in transportation purpose despite of their own drawbacks of emission like other petroleum fuels. One of the major drawbacks is high NO_x emission. The nitrogen oxides (NO_x) emission from methanol-blended diesel engine is not only harmful for the environment, but also affects the life of world population slowly. Present research is to reduce NO_x emission from a methanol-blended diesel engine. The methanol-blended diesel engine was used in the experiments. In the investigation, diesel fuel is used with three blends of methanol-blended diesel fuel in the proportion of 0%, 10%, 20% and 30% respectively, viz, diesel, D + M10, D + M20 and D + M30. Results indicated that, D + M30 blend produced lower emissions than other blends, but NO_x emission was still higher. Therefore, it was selected as an optimum blend. To bring this under control, water nano emulsion method was applied to the optimum blend. The optimum blend was treated by WNE method in the percentage of 5%, 10% and 15% while keeping the optimum blend ratio constant. The results revealed that, NO_x emission was reduced significantly by the use of 15% water nano emulsified blend, whereas other emission were increased marginally.

1. Introduction

The quest for more sustainable alternative fuel seems deepening and far more revealing than ever with side effects of global warming being felt across the globe. According to the referenced research articles, the energy resource is available for countable generations only. The coal is available for 218 years and natural gas is for 63 years. . Amongst various natural resources, the most apocalyptic data are available for the crude oil and it is expected to available only for less than half century [1–5]. The rapid depletion of fossil fuel, unsustainable industrialization and prolific use of energy in transport sector are primarily contributing to the already worsening energy crisis and subsequently raising concerns amongst the scientific fraternity across the world. These issues are portrayed as a major challenge to elite technical brains. To some extent, these issues have been resolved by the researchers, who working actively to find an alternative of conventional petroleum fuel. Over the years of exhaustive research, biofuel has emerged as most viable alternative to the conventional fossil fuel, thus, increase in demand of biofuel is quite natural. Some of the promising biofuels are biogas, biodiesel and alcohols. The researchers are attracted towards alcohols due to its accessibility, easy storage and manipulation. The leakage of biogas in automobiles caused by high pressure is an inescapable problem [6]. The edible oil cannot be employed as alternative fuel anymore because it may cause food crisis. The non-edible oil can be used as biodiesel to find an alternative of diesel fuel in transportation purpose, but the difficulty of large scale cultivation may arise and which can indirectly enhance food crisis [6]. Thus, the focus is moved on alcohols like methanol and ethanol in terms of non-conventional energy resources [7,8].

Alcohols have become cynosure of discussion for diesel engines because they are renewable and oxygenated fuels. Ethanol has achieved the reputation of primary fuel in Brazil from the last 35 years [9,10]. Whereas, methanol was used as a fuel in the oil crisis of 1970. Importantly, methanol has been blended with gasoline in Europe since 1980. Presently, ethanol and methanol are widely used as an alternative of fuels either by blending with fuel or in the form of base fuel in diesel engines [11,12].

Diesel fuel is a combination of hydrocarbon chains. However, methanol is a neat fluid. The property of hydrocarbons in diesel fuel makes it suitable for diesel engine. Methanol has proved as a promising fuel for diesel engines. Methanol is capable to reduce emissions from diesel engine used either as a partial alternative of diesel fuel or as an additive. Use of methanol-blended diesel fuel

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Nomenclature

BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
CA	Crank angle
CO	Carbon monoxide
HC	Hydrocarbon
HRR	Heat release rate
NO_x	Nitrogen oxides
PPM	Particulate per million
FSN	Filter smoke number
TDC	Top dead center
BTDC	Before top dead center
WNE	Water nano emulsion (water + emulsifier)
WNEB	Water nano emulsion blend (water nano emulsion + optimum blend)

typically reduces smoke, CO and HC emission owing to complete combustion; however, higher in cylinder temperature can cause greater NO_x emission. Methanol reduces smoke formation due to high H/C ratio, high stoichiometric fuel ratio and high oxygen content. A methanol powered diesel engine requires more fuel than diesel fueled engine to maintain the same amount of power. It is because of lower energy content of methanol than diesel fuel. The presence of oxygen atom in methanol enhances combustion process. Methanol absorbs more heat to vaporize than diesel fuel due to high latent heat of vaporization. Therefore, it may lead to heat sinking effect or cooling effect inside the combustion chamber. The low viscosity of methanol helps to easily inject, atomize and mix with air compared to diesel fuel.

On the other hand, high ignition temperature, high latent heat of vaporization and low cetane number of methanol produces a weak ignition behavior and the ignition delay period tends to increase. The high auto ignition temperature of methanol than diesel fuel makes it safe for transportation purpose and storage, while the much lower flash point is a disadvantage for safety [13–16].

The diesel engine requires some physical adjustment in case of the fumigation mode. Methanol fumigated diesel engine may require a separate fuel injector. Whereas, a high pressure and a low pressure fuel injector are used to inject diesel and methanol respectively. To spray methanol, diesel engine should have a separate fuel tank, supply channel and their control valves [17,18], but it involves large quantity of methanol without any additive and can destabilize the solution during the combustion process and proceeds to poor mixing of the fuels [18,19].

The blending method is defined as the mixing of two fuels before injection of fuel in the combustion chamber. The combustion of the diesel alcohol blend is possible in a diesel engine without any physical modification, and it is supposed to be a simple and attractive approach [20]. The methanol has poor miscibility with diesel fuel. Although, methanol has to be used in limited quantity in blending method. The choice of additive is important with regard to the constancy of the blends [21,22]. The blend method is more effective with respect to exhaust emissions from diesel engine, while comparison has carried out between blend and fumigation modes of methanol injection inside the combustion chamber [23].

According to a detailed study of the effect of methanol in diesel engine, the soot, CO and HC emission is low; but NO_x emission has not shown any general trend. The NO_x emission is very harmful for the human being. When, the methanol is blended with diesel fuel in the percentage of 0–15%, NO_x emission is increased and soot, CO and HC emission is decreased accordingly [24,25]. Though, methanol can be used as an additive in the diesel - biodiesel blend and can reduce CO and soot emission successfully, still, NO_x emission is high at full load condition and at varying speeds for all blends [26,27]. The same trend is observed with Reactivity Controlled Compression Ignition engine (RCCI), when it is treated by methanol - diesel blend and has not shown any significant reduction in NO_x emission [28].

Adversely, NO_x emission increased from low load to full load operating condition while fraction of 5% methanol is used in the blend [29]. Moreover, it increased at partial load, full load operating condition and different brake mean effective pressure [26,30and31].

Water nano emulsion method was better than EGR (Exhaust gas recirculation) method and initial swirl method to reduce NO_x emission from the methanol-blended diesel engine, when the blend injected through fumigation mode at high and low load operating conditions [32,33]. The introduction of water through the separate fuel injector is used to reduce NO_x and soot emission simultaneously [34]; however, the mixture of water and air can inject through carburetor also. The use of carburetor is an effective way to reduce NO_x and soot emission without any major influence on performance parameters [35]. It has been proved that, the performance parameters are not affected by the use of carburetor, but some studies have shown improvement in engine torque, brake thermal efficiency and power output at high water diesel blend ratio in diesel engine [36,37].

Two different methods of water addition, such as blending and fumigation in diesel engine are compared experimentally, whereas blending method with 15% water seems to be more effective than the fumigation method in terms of percentage of emission reduction [38]. With the application of water in diesel fuel, a micro explosion phenomena activates accordingly. The improvement in spray characteristics is observed due to micro explosion phenomena, which leads to enhance the pace of combustion process and achieve low emissions. Moreover, simultaneous reduction of NO_x and soot emission can be achieved by variation in water diesel blend ratio and oxygen concentration at constant operating parameters [39].

The above survey of literature is primarily related to emission reduction from methanol-blended diesel engines. It is evident that, researchers are trying to reduce NO_x emission from methanol-blended diesel engines. Such studies clearly show that, NO_x emission increases irrespective of load, speed and brake mean effective pressure, as a result of increase in methanol in methanol-diesel blend [24–31]. Further, the dual fuel mode RCCI (reactivity controlled compression ignition) engines have been used essentially to reduce NO_x and soot emissions, to reduce heat transfer losses, to increase fuel efficiency and to remove the need of costly after-treatment systems. Yet, such endeavors have not resulted in any significant reduction in NO_x emission while methanol-blended diesel fuel was used in RCCI engine [28]. For that reason, there is greater need than ever to bring NO_x emission from methanol-blended diesel engines to the extent of safer and healthier environment. Thus, methanol blended diesel fuel should be treated by a suitable emission reduction method, which can reduce NO_x emission effectively without any major influence on soot emission, CO emission, HC emission and performance parameters. The methanol-blended diesel engine becomes center of attraction for the energy researchers, inspite of major drawback of NO_x emission. However, exhaust gas recirculation (EGR) and swirl method have tendency to reduce NO_x emission from the methanol-blended diesel engine. Yet, these are less suitable than WNEB method due to requirement of major modifications in the engine; additionally, it increases overall cost of the system.

The aim of the present paper is to reduce NO_x emission from