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Computational Combustion and Emission Analysis of Soybean Methyl Ester–Diesel Blends

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Summary : As global petroleum demand continues to increase, alternative fuel vehicles are becoming the focus of increasing attention. Biodiesel has emerged as an attractive alternative fuel option due to its domestic availability from renewable sources. This paper discusses the effect of blending soybean methyl ester with diesel in different proportions on combustion and emissions of a single cylinder, 4-stroke diesel engine. Percentage of soybean methyl ester (SME) substitution varied 0% to 100%, simultaneously. Multizone combustion analysis was carried out using Diesel-rk software. Based on some of the computed results, it's observed that all blending of SME produce significant reduction in the Bosch smoke number (BSN) and particulate matter (PM) concentrations compared with pure diesel fuel. A multiparametric optimization technique using Rosenbrok method has been performed which gives 15.06 % reduction in the air pollutant emissions (SE) and 2.65 % reduction in the S.F.C.

Keywords : Soybean methyl ester; diesel; combustion; emission

Introduction

In recent times, biodiesel has received significant attention both as a possible renewable alternative fuel and as an additive to the existing petroleum-based fuels. It has the major advantages of having high biodegradability, excellent lubricity and no sulfur content [1]. Many researchers have shown that particulate matter (PM),unburned hydrocarbons (UHC), CO, and sulfur levels are significantly less in the exhaust gas while using biodiesel as fuel. However, an increase in the levels of oxides of nitrogen is reported with biodiesel. There are also several combustion-related disadvantages by using biodiesel in modern diesel engines. Biodiesel has a calorific value of approximately 12% lower than diesel, meaning that biodiesel has a lower energy density. This manifests itself in a larger biodiesel fuel requirement in order to achieve the same power level as diesel [2,3]. These performance and emissions related differences occur as a result of fuel property differences between biodiesel and diesel including molecular composition and structure, cetane number, higher and lower heating values, and heat of vaporization.

Diesel-rk computational model

In the multizone combustion model, the spray is split into seven characteristic zones, as shown in Fig. (1). In each zone specific evaporation and burning conditions are specified in the model. The spray evolution passes through three stages:1. Initial formation of dense axial flow 2. Main stage of cumulative spray evolution 3. Period of spray interaction with the combustion chamber walls and fuel distribution on the walls. The border between the initial and main stages of spray evolution corresponds to the moment when the axial flow close to the spray tip starts to deform and break up, forming a condensed mushroom-shaped forward front.

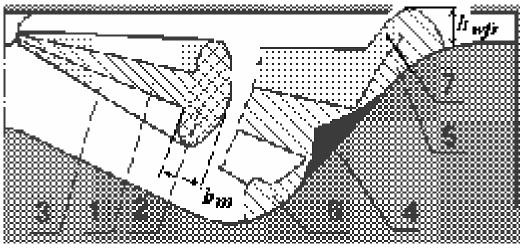

Fig.(1) Characteristic zones of the diesel spray

As the spray moves on, constant breakup of the spray forward part takes place and the front is renewed by new flying fuel portions. The delayed droplets move from the breaking front to the environment. The moving spray carries the surrounding gas with it. The gas velocity in the environment being rather low. Meanwhile gas in the axial core is rapidly accelerated to the velocity close to that of droplets. The core diameter in the cross section is about 0.3 of the spray outside diameter. The current position and the velocity of an Elementary Fuel Mass (EFM) injected during small time-step and moving from the injector to the spray tip are related as:

$$\left(\frac{U}{U_o}\right)^{3/2} = 1 - \frac{l}{l_m}$$

where: *l* is the current distance between the injector's nozzle and the EFM; U is the current velocity of the EFM; is the travel time for the EFM to reach a distance *l* from the injector's nozzle; U_o is the initial velocity of the EFM at the nozzle of the injector and l_m is the EFM's penetration distance. As an illustration, Fig. 2 presents the variation of spray evolution parameters as functions of time.

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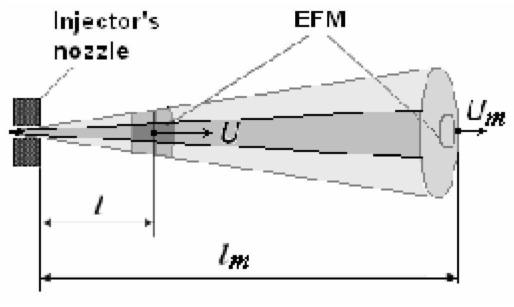

Fig.(2) Variation of spray evolution with time.

The general principle evaporating equations, heat release and emissions are mentioned in [4,5]

Results

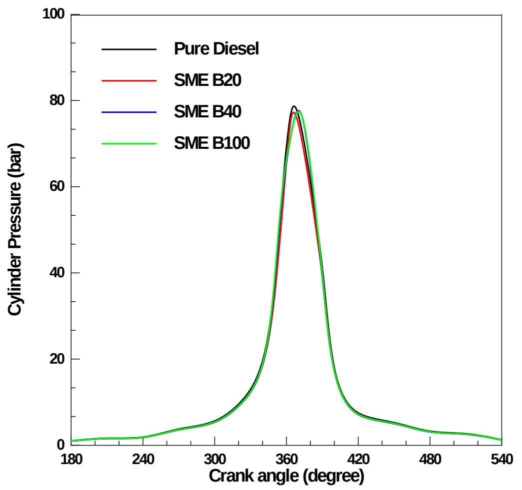

Fig. (3) Variation of Cylinder Pressure and with crank angle for diesel fuel and different SME blends

Figure (3) presents the results of the effect of SME blending on the cylinder pressure of a diesel engine. The engine was run on 100 percent of diesel oil, (pure diesel operation), and 20 %, 40 % and 100 % SME biofuel blends. It can be seen the predicted cylinder pressure for both diesel and SME biofuels are in close agreement especially in the region of peak values (i.e.) the global behavior for these figures is the same.

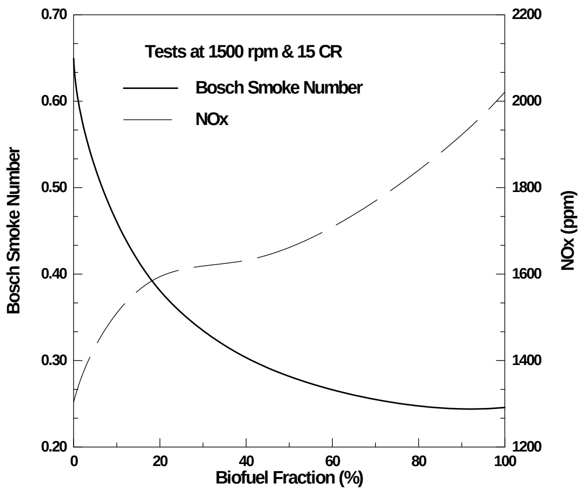

Fig.(4) Effect of SME blending on the Bosch smoke number & NOx emissions

Figure (4) discusses the relation between Bosch smoke number and NOx emissions with different percentages of SME blending. The smoke levels for all SME blends are lower than that of pure diesel. The average smoke level for B20 %, B40 %, and B100 % were less than that of diesel fuel by 41.3 %, 53.2 %, and 62.6 % respectively. This is because smoke decreases with high oxygen content in the biofuel that contributes to complete fuel oxidation even in locally rich zones, so the oxygen within the fuel decrease the tendency of a fuel to produce soot. The NOx emission for B20 % is higher than that of base line diesel fuel by 22 % and this result comes in agreement with results obtain by [6]. This is associated with the oxygen content in the biodiesel hence the fuel oxygen may provide additional oxygen for NOx formation.

Conclusions

A good reduction in the BSN, and PM emission for all blends of SME relative to that of diesel fuel. For all blends of SME, the computed NOx was higher than that of pure diesel oil. It is observed from all tested fuel blends, that B20 % SME was the best one which had same performance results with good reduction in the emissions as compared to base line diesel fuel, also less increase in the NOx emissions was noticed in B20 % SME as compared with B40 % & B100 % SME biodiesel respectively. The Rosenbrok method of optimization has been performed which gives 15.06 % reduction in the SE emissions and 2.65 % reduction in the S.F.C.

Acknowledgements

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