NUMERICAL SIMULATION OF CI ENGINE CHARACTERISTICS FUELED WITH SOYABEAN BIODIESEL AND ITS BLENDS

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Abstract: In this paper the combustion, performance and emission characteristics of a Compression Ignition (CI) engine fuelled with diesel, methyl soyate and its various blends with diesel fuel-SME20, SME40 and SME60 have been simulated and compared. The simulated results show an increase in the brake specific fuel consumption (BSFC) and a decrease in the brake thermal efficiency (BTE) with an increase in the biodiesel share in the blends, the highest BTE and the lowest BSFC being for pure diesel, whereas, the lowest BTE and the highest BSFC was observed for pure methyl soyate (SME100). In case of combustion, it was observed that with the increase in the methyl soyate share in the blends, the in-cylinder peak pressure increased and the ignition delay period decreased. From emission point of view, with the increase in the share of biodiesel in the blends, NO_x, increased and PM and smoke emissions decreased with the increase in the biodiesel share in the blends.

Keywords: Simulation, CI engine characteristics, Methyl Soyate, Blends.

Introduction: The rapid increase in the requirement of the constantly depleting, non-renewable fossil fuels; apart from the global warming and environmental pollution caused due to the burning of these fuels; has lead to an urgent search for a suitable alternative to these fuels. Facing the challenges of limited fossil fuel reserves and stringent environmental constraints, the issue of finding substitutes for fossil fuels has become a major work for researchers studying internal combustion (IC) engines [1]. In this quest for a green alternative, many researchers have tried and are still working to find the compatibility of biofuels and diesel ethanol blends with a conventional diesel engine with minor or almost no modification in the engine. However, the experimental efforts are not always economical from the perspective of time and money, when compared to numerical simulations.

Combustion in a CI engine being a very complex process, numerical models can be divided into two major groups, viz. thermodynamic models and fluid dynamic models. In addition to that, several softwares based on the above models, are commercially available that can be used for the simulation of compression engines. In the work presented in this paper, a commercially available software DIESEL-RK has been used to simulate the performance, combustion and emission characteristics of a Compression Ignition (CI) engine using pure diesel (B0), methyl soyate (SME100) and its various blends with diesel, viz. SME20, SME40 and SME60 and make a comparison of the same.

Effect of biodiesels on engine characteristics: In its composition biodiesel is a fatty acid methyl ester produced from vegetable oils or animal fats [2]. Thus, this difference in the composition and properties of biodiesel from pure diesel will result in difference in the engine performance, combustion and emissions. Engine power will decrease with the increase of content of biodiesel [3]. The use of biodiesel will lead to loss in engine power mainly due to the reduction in heating value of biodiesel compared to diesel [4]. The same reason can be accounted for the increase in the brake specific fuel consumption. In case of combustion parameters, use of biodiesel increases the in cylinder pressure. This is attributed to the higher cetane number and the reduced ignition delay for the biodiesels [5]. Another reason for this may be due to the higher oxygen content in biodiesels leading to improved combustion [6-7]. The ignition lag or ignition delay is defined as the time or crank angle between the start of fuel injection into the combustion chamber and the start of combustion [8].

The use of biodiesel decreases the ignition delay compared to pure diesel. Biodiesel and its blend have larger cetane number than that of diesel, resulting in earlier combustion [9]. In case of emissions, the use of biodiesel increases the content of NO_x in the combustion products [10-11]. Higher NO_x content in the combustion products can be explained by high oxygen content in biodiesel [12].

Properties of fuels used and methodology: Some of the important fuel properties of methyl soyate and conventional petro-diesel are presented for ready reference in Table I for comparison.
The engine used in this work has the specification shown in Table II.

TABLE I. PROPERTIES OF DIESEL AND METHYL SOYATE

Property	Diesel	Methyl Soyate
Cetane No.	48	51.3
Calorific Value ($MJkg^{-1}$)	42.5	36.22
Composition (Mass fraction)		
C	0.87	7731
H	0.126	1188
O	0.004	1081
Molecular Mass	190	292.2
Specific Vaporization Heat ($KJkg^{-1}$)	250	325
Density (kgm^{-3})	830	885
Flash Point (°C)	63	168

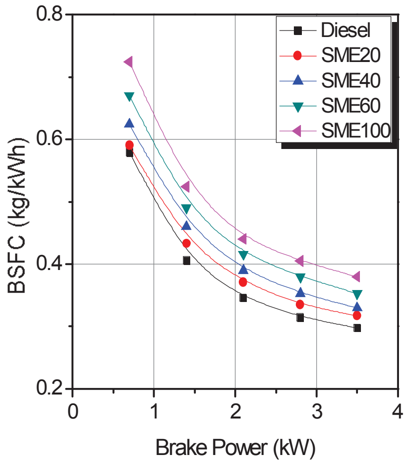
TABLE II. ENGINE SPECIFICATIONS

Manufacturer	Kirloskar Oil Engines Ltd.
Model	TV 1
Type	Four Stroke, Water Cooled
No. of cylinder	One
Rated Power	3.5 kW @ 1500 RPM
Compression Ratio	18
Bore	87.5 mm
Stroke	110 mm
Connecting rod length	234 mm

Results and Discussions: Various performance, combustion and emission characteristics which have been numerically simulated are shown and discussed in this section. The predicted results have been validated with the experimental results for the base fuel (diesel fuel) and it shows a reasonably good agreement in terms of performance, combustion and emissions parameters.

4.1Brake Specific Fuel Consumption: The variation of brake specific fuel consumption with brake power for the different fuels has been shown in figure 1. The figure shows an increase in the BSFC with the increase in the biodiesel percentage in the blends, the lowest being for pure diesel (B0) and the highest being for pure methyl soyate (SME100). The heating value of methyl soyate is lower compared to pure diesel. Thus, more fuel will be required in case of methyl soyate to produce the same power as that produced using pure diesel, increasing the BSFC.

Fig. 1. Variation of BSFC with brake power



Brake Thermal Efficiency: Figure 2 shows the variation of brake thermal efficiency with brake power for the different fuels. It can be seen from the figure that the graph shows exactly the opposite trend compared to the BSFC graph. Increase in biodiesel percentage in the blends decreases the BTE. Again the lower heating value of methyl soyate can be stated as primary reason for this trend.

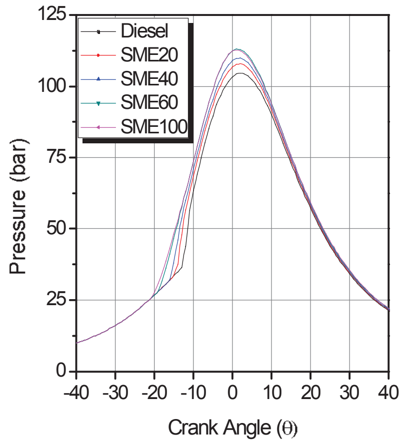


Fig. 2. Variation of BTE with brake power

Peak Pressure Rise: Figure 3 depicts the peak pressure rise with respect to the crank angle for the different fuels at full load condition. It can be seen that the peak pressure rise increases and delay period decreases with the increase in biodiesel share in the blends. This may be because of the higher cetane number of methyl soyate. Also the reduced ignition delay and the higher oxygen content of methyl soyate results in an improved combustion, eventually, increasing the peak pressure.

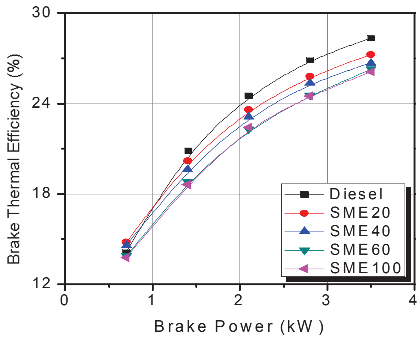


Fig. 3. Variation of in-cylinder peak pressure with crank angle at full load.

Ignition Delay: Methyl soyate differs from diesel in its cetane number value. The higher cetane number of methyl soyate and its blends results in an earlier combustion as compared to that of diesel. Hence, the ignition delay period decreases with increase in methyl soyate share in the blends.

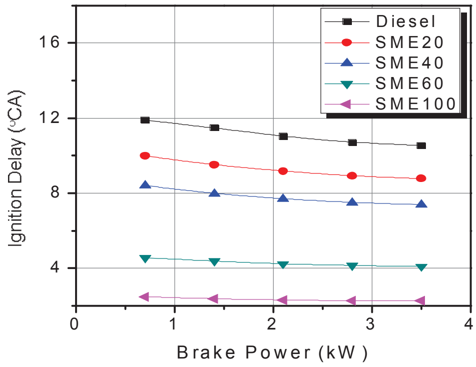


Fig. 4. Variation of ignition delay with brake power

NO_x emission: From figure 5 it can be observed that the use of methyl soyate increases the NO_x emission as compared to pure diesel. Biodiesel contains higher amount of oxygen than pure diesel, leading to a complete combustion. This results in a higher temperature, causing the formation of valance oxygen form dissociation, which eventually increases the NO_x.

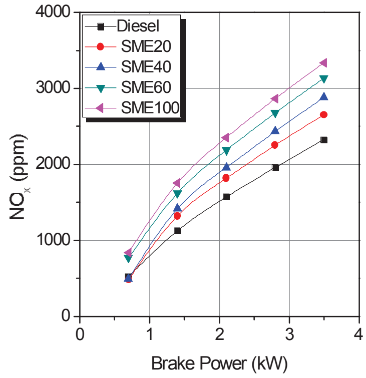


Fig. 5. Variation of NO_x emission with brake power

Specific PM and Smoke emissions: Figure 6 and figure 7 show a decrease in PM and smoke emissions respectively, with the increase in the biodiesel share in the blends. The primary reason for PM and smoke emissions are the incomplete combustion of fuel mixture and combustion of heavy lubricating oil.

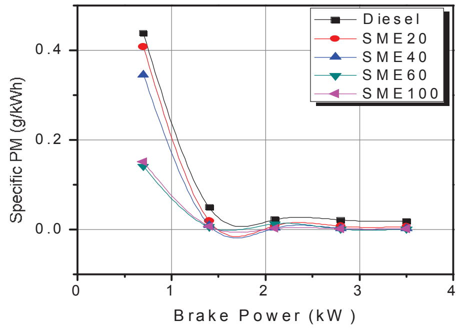


Fig. 6. Variation of specific PM with brake power

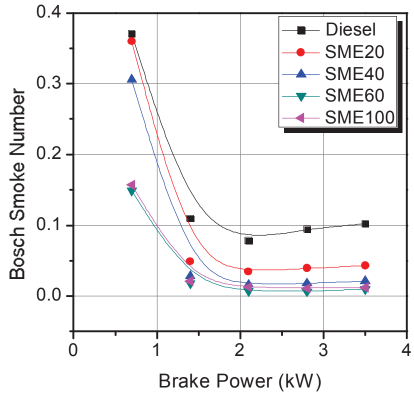


Fig. 7. Variation of smoke emission with brake power

As such the complete combustion of biodiesel owing to the higher oxygen content in it tends to reduce the PM and smoke emissions at the tailpipe.

Conclusion: From the present work it is evident that methyl soyate and its blends with diesel can be considered to be a suitable alternative to diesel fuel. The minor drawback is the slight reduction in performance and an increase in NO_x emission, which can be considered when the situation strictly demands for an alternate and renewable fuel. In addition to that, use of methyl soyate gives a considerable reduction in the PM and smoke emissions. When the combustion characteristics are considered it is found that the use of methyl soyate increases the in-cylinder pressure and decreases the ignition delay period compared to pure diesel.

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