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2.1 INTRODUCTION

In power generation and transportation a lot of efforts are being taken worldwide, to reduce the dependency on petroleum products. In the last few decades vegetable oils and biomass derived fuels have received much attention. In agriculture-based country like India these fuels have been found to be potential in large quantities. Biomass is a renewable and eco-friendly fuel available in large quantities. Though India is the second largest producers of ethanol in the world, its use in the power generation and transportation sector is not as in the case of other countries like Brazil and U.S. Hence, bio-derived fuels have a wide scope for use in place of diesel.

2.2 NEED FOR ALTERNATIVE FUELS

Increased in environmental pollution are caused due to transportation and agricultural, and it can be replaced by bio fuels. Biodiesel and bio ethanol are the two main bio fuels considered around the globe. Biodiesel can be produced from vegetable oils such as edible or non edible oil and from animal fats by undergoing esterification process to remove glycerol content and it can be used as a fuel in diesel engines [1, 2, 3]. Due to its low heating value and high viscosity and increase in oxygen concentration can burn effectively than diesel fuel. Several suggestions have been given by different scientists by doing several blends of biofuels when undergoing different compression ratios and injection pressures. Normally biodiesel are free from sulphur so it can reduce acid rain formation and particulate emissions can be reduced.

Unregulated emissions in biodiesel are reduced due to the formation of aromatic hydrocarbon. Even though methyl esters are having oxygen concentration in its content, it
emits pollutions such as carbon monoxide, unburned hydrocarbons, nitric oxide, smoke and soot particles at the engine exhaust \[4, 5, 6\]. More number of researches has been conducted by several personalities on direct injection diesel engines with pure vegetable oil and methyl esters of vegetable oil and it is compared with the diesel fuel. By seeing the test results we can come to a conclusion that hydrocarbon emissions are lower in the case of biodiesel when compared with the diesel fuel. This is also due to oxygenated nature of biodiesel where more oxygen is available for burning and reducing hydrocarbon emissions in the exhaust \[7, 8\].

2.3 ENGINE PERFORMANCE AND EMISSION

Ramadhas et al. \[9\] had conducted experiments on the utilization of rubber seed oil Methyl esters on A four stroke, direct injection, naturally aspirated single cylinder diesel engine. It is reported that Rubber seed oil extracted from the rubber seeds is having high free fatty acid content so it must undergo esterification process to bring the properties closer to diesel. The experiments are carried out by using different blends of methyl esters of rubber seed oil and using diesel as a fuel the combustion and emission characteristics are carried out in a single cylinder direct ignition diesel engine, when the engine is running at a constant speed of 1500 rpm. The results reveals that for a blend of B10 the brake thermal efficiency is recorded as 28\% and for diesel fuel the thermal efficiency achieved is about 25\% which is lower than B10. When the concentration of blend is increased the decrease in efficiency is achieved and it is recorded as 26\%, 25\% and 24\% for B50, B75 and B100 respectively. It may be due to lubricating properties of biodiesel. The biodiesel molecules of (i.e. methyl esters of the oil) contain some amount of oxygen, which under goes in the combustion process. When the percentage content in
the biodiesel increases, due to its high viscosity, the engine won’t find time to undergo complete combustion, which in turn leads to reduction in efficiency. Pure biodiesel gives lower brake thermal efficiency than diesel, may be due to the reduction in calorific value and increase in fuel consumption as compared to diesel. When the engine is fuelled with raw rubber seed oil, the efficiency reduced drastically and the specific fuel consumption gets increases. In case of B80 & B100, the brake specific fuel consumption is found to be higher than that of diesel. During maximum load condition, the specific fuel consumption of pure biodiesel is more than 14% than that of diesel. The reason may be due to low calorific value of biodiesel than diesel. Increase in concentration of blend increases the exhaust gas temperature and which leads to increase in smoke emission. Increase in exhaust gas temperature leads to increase in NO\textsubscript{X} emission because temperature and NO\textsubscript{X} are proportional with each other. The results conclude that diesel engine can run successfully without any engine modification and can give better efficiency than diesel and helps in pollution reduction.

Edwin Geo et al. [10] have carried out investigations to study the performance, combustion and exhaust emission characteristics of Rubber seed oil Methyl ester in a single cylinder direct injection, four-stroke diesel engine. The properties of the rubber seed oil methyl ester were observed and it is similar to that of diesel and they were miscible with diesel without any phase separation. He utilized three different types of fuel for his experimental investigation such as Diesel, Rubber seed oil methyl ester and pure Rubber seed oil. Results indicated that the maximum brake thermal efficiency obtained for the engine operating on RSOME and RSO is 27.89 % and 26.56 % respectively at full load. The RSOME has a lower viscosity, which results in better atomization of the fuel as
compared to RSO. However, the brake thermal efficiency is higher with diesel (29.93%) at full load. The brake specific energy consumption of the engine with RSO operation at full load is 13.55 MJ/kWh which is higher compared to 12.90 MJ/kWh of RSOME operation. This is because of the lower heating value, higher viscosity and density of RSO. Lower heating value of RSO consumes more amount of fuel to generate the required amount of energy depending upon the load. The peak pressure in case of RSO is about 72 bar and for RSOME it is 74.3 bar at maximum power. However, with diesel it is 75.5 bar.

The rate of pressure rise with diesel, RSOME and RSO is 4.5, 4 and 3.6 bar°CA at full load conditions. The maximum exhaust gas temperature is recorded as 231°C at a load of 25% and for full load it is noted as 410°C for raw rubber seed oil and for rubber seed oil methyl ester it is 210°C for 25% loading and at maximum load it attains a maximum temperature of 406°C, for diesel fuel it is recorded as 180°C for 25% loading and at peak load it gives a maximum of 380°C. The high viscosity and poor volatilities of RSO lead to higher HC and CO emission than RSOME. At maximum output, the HC emissions are 0.72 and 0.62 g/kWh respectively for RSO and RSOME. NOx emission for the RSO operation are 6.9 g/kWh and 9.6 g/kWh with RSOME at full load. NOx emissions are higher with RSOME than RSO because of higher combustion temperature. Reduced ignition delay and combustion duration were noticed with RSOME and diesel compared to RSO, due to the low viscosity of fuels. The ignition delay at full load is 7°CA with RSOME and 8°CA with RSO. Peak pressure is shifted with RSO than RSOME due to longer ignition delay.
Ramadhas et al. [11] worked on Characterization and effect of using rubber seed oil as fuel in compression ignition engine. He carried out different experimental studies on a single cylinder diesel engine when it is running at a constant speed of 1500rpm. He conducted tests on diesel fuel as well as rubber seed oil and makes the comparative statement between two fuels. The rubber seed oil is blended with diesel to reduce its before injecting it in to the engine cylinder. Different load conditions have used for all the blends. The exhaust emissions and smoke densities have been measured with the standard equipments. By his observations he found out that the biodiesel blend containing twenty percentage rubber seed oil and eighty percentage diesel gives better efficiencies and it makes close to the diesel fuel. By seeing the specific fuel consumption, the fuel consumed during combustion for different loading is higher when compared with the diesel because of its high viscosity in the blends. The exhaust gas temperature has been reduced gradually because of complete combustion in the biodiesel blend. Even though biodiesel is an oxygen content fuel complete combustion can be achieved

Edwin Geo et al. [12] carried out experimental studies to improve the performance of rubber seed oil by exhaust gas preheating. Tests were carried out on a Kirloskar TAF-1 single cylinder air-cooled; direct injection, four-stroke diesel engine. He used the three variables like diesel, raw rubber seed oil and preheated rubber seed oil. No esterification technique is utilized in this work. He achieved the thermal efficiency as 29.93%, 26.56% and 27.89% for diesel, raw oil and preheated oil. The efficiency is lower than the diesel fuel due to its high viscosity of the oil. The specific fuel consumption values achieved are 296.71, 329.06 and 316.17 g/kWh. The specific fuel consumption is reduced when comparing the raw oil with preheated oil, this may occur due to the
improved atomization property. The obtained exhaust gas temperatures are 364°C for diesel fuel and 410°C for rubber seed oil. The low volatility of the rubber seed oil generates high temperature in the engine exhaust. By considering the emission analysis increased in smoke emission is achieved in the engine exhaust for raw oil due to its incomplete combustion, but for diesel fuel it is very low about 3.4BSU at maximum load and for raw oil it 6.1BSU and for preheated oil it is 5.8BSU.

The carbon monoxide emission is analyzed and it has been concluded that at maximum load condition the carbon monoxide emission values are 33% higher than the diesel fuel. When the raw oil is preheated to 155°C, it has been reduced to about 15%. The nitric oxide emissions achieved are 6.9g/KWh for the raw rubber seed oil and 10.69g/KWh for diesel fuel and 8.3g/KWh for preheated rubber seed oil. Nitric oxide emissions are lower for rubber seed oil due to the low intensity of premixed combustion. Finally it can be concluded that exhaust gas preheating is most effective to utilize as a fuel without any engine modification.

Edwin Geo et al. [13] had done experiments on two fuels such as rubber seed methyl esters with hydrogen. He selected a constant speed compression ignition engine which can generate a power of about 4.4KW. He achieved the results when the engine is loaded with twenty five percentage, fifty percentage, seventy five percentage and for hundred percentage. The thermal efficiency has been increased for about 2.4% in the single fuel operation. When hydrogen is mixed with rubber seed oil methyl ester in dual fuel operation, the peak efficiencies are 28.12%, 29.26% and 31.62% with rubber seed oil, rubber seed oil methyl ester, diesel and for hydrogen. While analyzing the emissions a small reduction in emission can be achieved for carbon monoxide and hydrocarbons,
but Nitric oxide emissions shoots up due to its increase in temperature when it undergoes combustion. Even though hydrogen is a gaseous fuel it can burn within a short period of time which increases the temperature which leads to increase of Nitric oxide emission.

Jindal et al. [14] studied the performance and emission characteristics on an variable compression ratio diesel engine by varying the compression ratio and injection pressure. He selected the vegetable oil named jatropha for his experimental work, which is non edible oil.

Result shows the relationship between the variables such as compression ratio and injection pressure. Initially the methyl ester utilized as a fuel in diesel engine is prepared in the chemistry laboratory using esterification process. He selected jatropha oil for his study in diesel engine. Due to its high viscosity and high acid number, it cannot be used directly in diesel engines. Acid and alkaline esterification is done to reduce its free fatty content present in the raw oil. The yield obtained after esterification is purified by undergoing water washing and finally it is dried by using silica gel.

The experiment is designed to run the engine from no load to full load conditions by keeping the engine at standard compression ratios at about 17.5 and the injection pressure is varied for about 150, 200 & 250 bar. The increase in thermal efficiency can be achieved when the engine is allowed to run at higher injection pressures and it is to be around 8.5%. The emission aspects are analyzed in detail, when the compression ratio is increased the exhaust gas temperature and hydrocarbon increases at the engine exhaust. Reduction in smoke and carbon monoxide is seen. The Nitric oxide emission did not find any change with higher compression ratios. On comparing the overall performance of the
engine a small reduction in emission can be seen and the thermal efficiency increases drastically.

Raheman et al. [15] had conducted experiments on Ricardo E6 engine using a vegetable oil named Mahua which is non edible, and he under goes esterification process to produce biodiesel from raw oil, and it is blended with diesel with certain percentage and the diesel engine is made to run at different compression ratios and injection timings. The results reveal that when the compression ratio has been increased the efficiency of the engine increases and proportional to each other. We can achieve good performance of the engine at higher compression ratios, because the ignition delay period is reduced. Normally methyl esters of vegetable oil are having low volatility when comparing with the diesel fuel, which make the combustion in a faster manner due to release of high temperature.

The efficiency of the engine can also be increased by varying the injection timing of the engine. When the piston reaches the top dead centre the injection timing can be advanced from $35^\circ$ to $40^\circ$ an improvement in thermal efficiency is seen. Similarly the exhaust temperature increases with the increase in blends of methyl ester; this can also be reduced when the engine is allowed to run at higher compression ratios. Even though biodiesel is safe to use in diesel engines and it can be blended with diesel fuel to any percentage at any compression ratios to reduce the emission and increasing the efficiency of the engine.

2.4 SUMMARY OF REVIEW

From the literature review, it was observed that Methyl esters has low heating value than the diesel fuel, due to the presence of oxygen content, but at the same time it
has a higher relative density (3 to 5% more than diesel) so overall impact is approximately 7% lower energy content per unit volume. Research work was carried out with various bio-fuels. A few research works was conducted using Rubber seed oil methyl esters blended with diesel in a single cylinder diesel engine. The methyl esters of rubber seed oil is extracted from the raw rubber seed oil by esterification process. The pilot experiments are conducted with different composition of acid and alkaline to optimize the yield. In the present investigation the process optimization was done based on the percentage yield calculated by the use of gas chromatograph. In the current study experiments were done on a constant speed, variable compression ratio DI diesel engine running with blends of bio-diesel and Diesel as solution with different compression ratios to evaluate the performance, emission and combustion parameter along with the standard settings specified by manufacturer.

2.5 FORMULATION OF PROBLEM

Several experimental studies on diesel engine fuelled with hundred percent Rubber seed oil biodiesel report lower engine performance and considerable variation in exhaust gas emissions at different operating conditions. Inefficient and incomplete combustion of bio-diesel due to the existing fuel injection system design and operating conditions are main causes for this. Thus there is a need to study the influence on engine operating parameters in order to optimize the combustion and emission characteristics of diesel engine by using Rubber seed oil methyl ester as fuel in different compression ratios. This investigation has been carried out with the following objectives.

i. Optimization technique using design of experiment for biodiesel extraction
ii. Various blends of biodiesel-diesel are used as fuel in a Variable Compression Ignition Engine.

iii. Effect of injection pressure at different nozzle opening conditions.

iv. Improved engine performance and emission reduction when the piston is coated with Copper, Magnesium oxide and Nickel.

The experimental results such as brake specific fuel consumption, brake thermal efficiency and emissions (CO, HC, NOx and smoke) are also used to optimize the engine with different fuels at different operating conditions. Findings from this study also contribute to make settings in engine parameters for replacing the diesel with alternative fuel (Rubber seed oil bio-diesel) in practice.