Combustion Analysis of Cottonseed Biodiesel With Cerium Oxide Nanoparticles

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Abstract- *With the development of nanotechnology, nano-fuels have been developed and tested widely along with many fuels. Nano-fuels have shown great improvement in combustion, emission and performance characteristics of CI engines. The current research is focusing on the effect of cotton seed oil biodiesel with cerium oxide nanoparticles used along with diesel in various concentrations of B6 up to B36 and 35ppm of nanoparticles in each of them. The experiment was carried out on a single cylinder variable compression ratio diesel engine for compression ratios of 16 and 18. Combustion characteristics were found to be improved by adding cerium oxide nanoparticles. For B30 blend, maximum cylinder pressure was recorded as 44.89 bar at CR-16 and 56.48 bar at CR18, except the pressure of 63.06 bar in case of B12 blend at CR-16 which was because of knocking.*

Keywords- cottonseed biodiesel, combustion, cerium oxide, cylinder pressure.

I. INTRODUCTION

For any country, transportation plays the key role in development of economy. Currently, the issue for worldwide transportation sector is the energy supply, which is mostly fulfilled by fossils fuels majorly. Globally, an average consumption of energy in transport sector is increased by 1.1% per year due to the development in automobile industry. It has been reported that out of the total global liquid fuel consumption from year 2010-2040, only the transportation sector has a share of 63%. In India, transportation consumes close to 70% of total diesel supply, 66% of which is used by passenger and commercial vehicles. [1] India is already the fifth largest greenhouse gas emitter in the world and is estimated to go to the third position in upcoming 2-3 years. Transport sector considerable contribution in greenhouse emission especially in developing and developed countries. The maximum amount of greenhouse gases added to the atmosphere are from electricity and transportation whose contribution is 34% and 27% respectively. [2] Also, the population is increasing day by day and especially in India, the growth rate of automotive sector is
one of the largest in the world.

According to Demirbas, a peak in global oil production may occur between 2015 and 2030. After that the production process will highly decelerate. India is the world's fourth largest petroleum consumer after United States, China and Japan which makes India dependent upon the oil exporting countries for meeting its own energy demand. Improvement in the performance of diesel engines is an important challenge to be addressed, in the current era due to the fast depletion of fossil fuel resources as well as due to the harmful hydrocarbon and nitrogen oxide emissions. In this regard, various studies have been done on addition of catalytic particles along with fuel blends in engines so as to reduce such emissions. Commonly used additives are titanium oxide, aluminium oxide, cerium oxide, copper particles etc. These particles, when added in nano-sized phase, improve the performance of fuel blends further, reduce the NOx emissions and soot formation.

India's biofuel production accounts for only 1% of the global production. This includes 380 million litres of fuel ethanol and 45 million litres of biodiesel. India is not self-sufficient in edible oil production and depends upon large quantities of import of palm oil and other vegetable oils to meet the domestic demand.By calculating the production rate of biodiesel and for mixing 20% with diesel the demand for biodiesel in the year 2017 is around 20 billion litres. By looking at the demand and production capacity there is 150 times lacking of biodiesel production in India.

The biofuel policy of India aims at accelerated development and promotion of the cultivation, production and use of biofuels to increasingly substitute petrol and diesel for transport and be used in stationary and other applications, while contributing to energy security, climate change mitigation, apart from creating new employment opportunities and leading to environmentally sustainable development.

Pankaj Shelke found that ignition delay and maximum rate of pressure rise were found to be decreased with biodiesel as compared to diesel. For diesel, the ignition delay was 11 0 CA; while for B20, it was found to be 6.50 CA.The rate of pressure rise is reduced with all biodiesel blends as compared to diesel. [3] As per the research by Basavraj, at 75% load, diesel had a peak pressure of 61.42 bar while that for CSO biodiesel was 59.27 bar.[6]

II. EXPERIMENTATION

Cottonseed biodiesel was prepared by transesterification method and cerium oxide nanoparticles were added to it through ultrasonication method. In this process, the particles are suspended uniformly throughout the mixture by stirring it at higher frequency with the help of stirrer. The blends used in this experiment are- B6, B12, B18, B24, B30 and B36 with CeO2 quantity of 35 ppm in each case. The Basic properties of these blends are enlisted below:

Table **Error! No text of specified style in document.** Physical and chemical properties of cottonseed biodiesel

Blend	Density (kg/m³)	Calorific Value (kJ/kg)
B00	830	42.05
B06	832	42.00
B12	835	41.90
B18	837	41.66
B24	840	41.5
B30	842	41.09
B36	845	40.96

The setup consists of single cylinder, four stroke, Multi-fuel, research engine connected to eddy current type dynamometer for loading. The test was carried out on Variable Compression Ratio engine setup. Set up is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle measurements. These signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements.

The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance and combustion analysis.Engine Performance Analysis was carried out with the use of engine analysis software.

The testing is carried out for compression ratios 16 and 18 with load increasing from 0.5 up to 12 kg gradually. The nanoparticle concentration is kept constant throughout the research at 35 ppm

Figure 1: Actual setup of VCR diesel engine for testing

Table 2Engine Specifications

Make	Kirloskar
Type of Engine	Single cylinder, 4 stroke Diesel Engine
Stroke	110 mm
Bore	87.5 mm
Capacity	661 cc
Power	3.5 kW at 1500 rpm
Compression Ratio range	12:1 to 18:1

III. RESULTS AND DISCUSSION

A. Cylinder Pressure

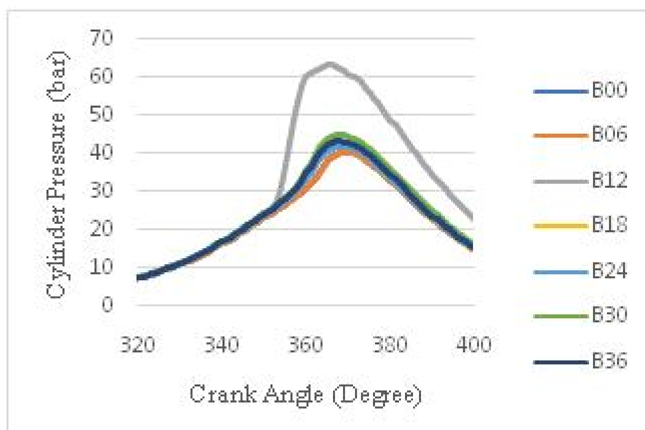

Figure 2: Cylinder pressure Vs. Crank angle at CR-16

The in-cylinder pressure versus crank angle (P-θ) data for diesel and biodiesel blends is shown in fig.15 and fig.16. The peak cylinder pressure is increased from 40.35 bar with diesel to 44.89 bar for B30. This is due to higher cetane number of biodiesel tends to lower ignition delay period of biodiesel blends than base diesel. Also, the enhanced surface area to volume ratio due to addition of cerium oxide nanoparticles adds in increasing the peak cylinder pressure. The in-cylinder pressure versus crank angle data plays very important role in engine design and smooth engine running operation.

At CR-16, a sudden pressure rise is observed with blend B12 wherein a peak pressure of 63.06 bar is observed. This is the condition of knocking. Except this condition, B30 has maximum pressure of 44.89 bar at CR-16 and 56.48 bar at CR-18.

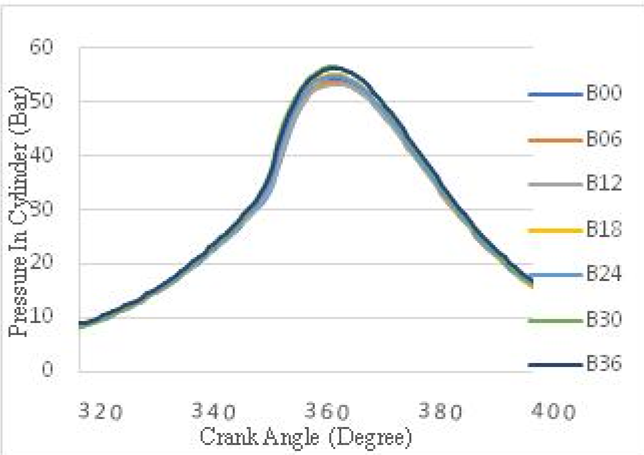

Figure 3: Cylinder pressure Vs. Crank angle at CR-16

B. Net Heat Release Rate

Fig.4&5 show the net heat release for all fuel at CR-16 and CR-18 respectively. It is observed that the graph initially goes in negative values because of the endothermic reactions that take place. The net heat release gets positive when combustion starts. B30 has maximum heat release rate of 21.22 J/Degree at CR-16, while, at CR-18, B18 has maximum heat release rate of 30.61 J/Degree.

The heat release rate goes on reducing with addition of biodiesel as it has less calorific value than diesel, but, the addition of cerium oxide nanoparticles has a significant effect for increasing this heat release rate because of rapid combustion in premixed phase and longer ignition delay. Also, it is observed that heat release rate is much increased as compression ratio is increased from 16 to 18.

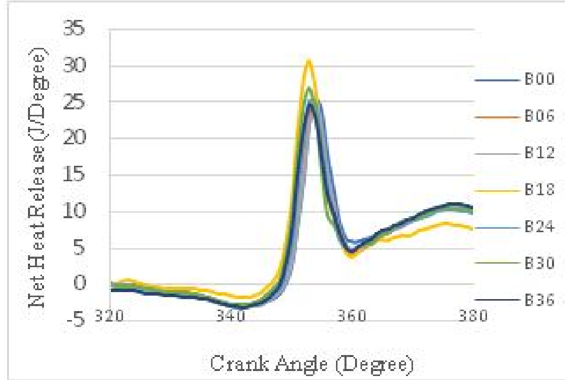

Figure5: Net heat release Vs. Crank angle at CR-18

C. Rate of pressure rise

The rate of pressure rise is plotted against crank angle for all blends at CR-16 and CR-18 as shown in fig.6 and fig.7. It is observed that the maximum rate of pressure rise at CR-16 is obtained for B30 with a value 2.16 bar/degree while the same blend B30 gives maximum value at CR-18 also with 3.66 bar/degree.

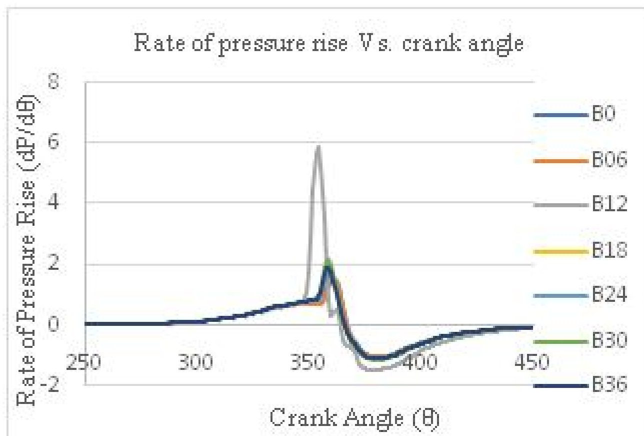

Figure 6: Rate of pressure rise Vs. Crank angle at CR-16

It is also observed from the readings that the addition of cerium oxide nanoparticles and biodiesel has a significant effect on rate of pressure rise as it goes on increasing from B00 with biodiesel concentration. It is also observed that this rate increases with increase in compression ratio. The rate graph suddenly goes towards peak reading when pre-mixing and combustion starts which is around 17 ^{0} crank angle advance TDC. At CR-16, due to knocking, a sudden hike in graph is observed with peak value of 5.88 bar/degree for B12 blend.

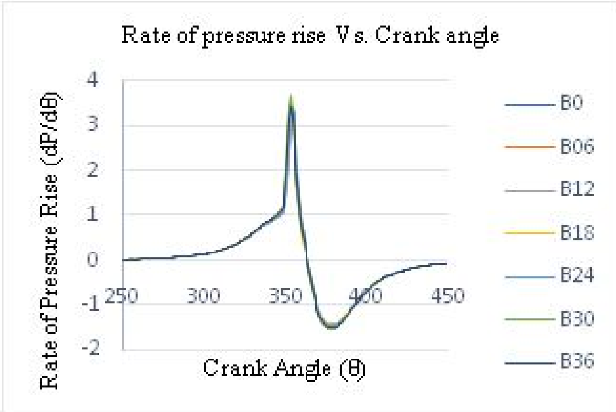

Figure 7: Rate of pressure rise Vs. Crank angle at CR-18

IV. RESULT VALIDATION

A. Cylinder Pressure

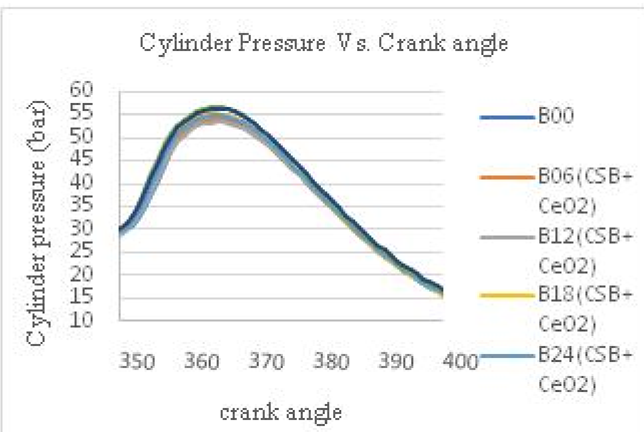

Figure 8: Results of Cylinder Pressure Vs. Crank angle for research

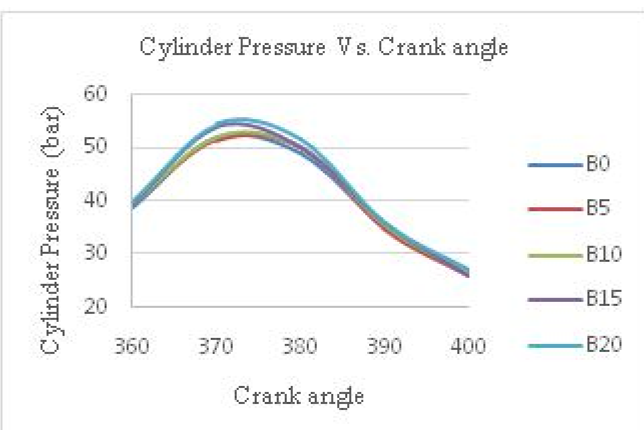

Figure 9: Results of Cylinder Pressure Vs. Crank angle for research with cotton seed biodiesel [3]

The cylinder pressure Vs. crank angle graphs of both research works show that the cylinder pressure increases with increase in cottonseed biodiesel percentage. Also, in both research, the addition of biodiesel has advanced the Start of Combustion as compared with base diesel fuel. The Maximum peak pressure is 56.48 bar with B30 in this research while that for the other research is 54.5 bar for B20.

B. Rate of Pressure Rise

The rate of pressure rise Vs. crank angle graphs of both research works show that the cylinder pressure increases with increase in cottonseed biodiesel percentage. The research conducted by Shelke has obtained the pressure rise rate of maximum value for diesel and low concentration blends during actual combustion while present study has found that heat release rate if more with biodiesel than neat diesel. The maximum value of pressure rise is found to be maximum for B30 which is 3.66 bar/degree. The trend of variation for both graphs is different because of the presence of nanoparticles. The addition of them increases the density, viscosity.

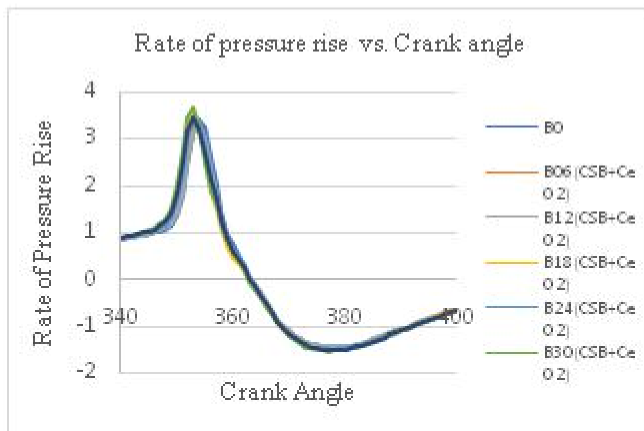

Figure 10: Results of rate of pressure rise Vs. Crank angle for research

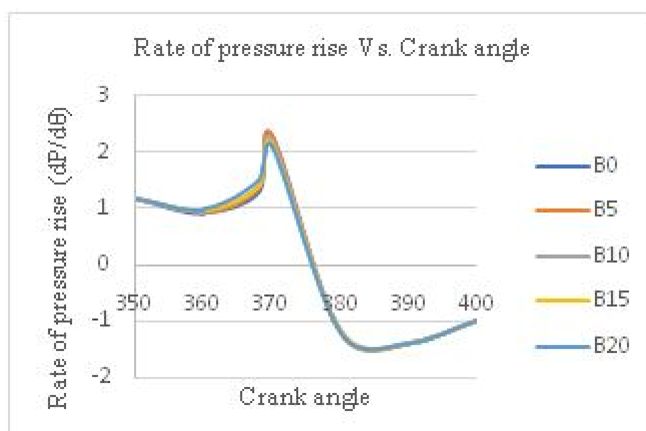

Figure 11: Results of Rate of pressure rise Vs. Crank angle for research with cotton seed biodiesel [3]

V. CONCLUSION

The engine test was carried out with cottonseed oil biodiesel with cerium oxide nanoparticles in 35 ppm concentration. The test was carried out with compression ratio 16 & 18. After the experimentation and analysis, it can be concluded that-

1. Catton seed biodiesel can be used along with cerium oxide nanoparticles in single cylinder VCR engine without any change in the setup.
2. The peak cylinder pressure was observed to be increased with increase in biodiesel concentration. The maximum value of cylinder pressure obtained is 56.48 bar for B30 at CR-18. Also, with addition of biodiesel and nanoparticles, the combustion was advanced in all blends compared with neat diesel.
3. Net heat release was maximum for B-18 at CR-18 followed by B30.
4. Knocking was observed at CR-16 for the blend B12, which resulted in sudden rise in cylinder pressure, heat release and rate of pressure rise.
5. B30 can be considered as the optimum blend among all with 28.86% efficiency at full load. It gives less emissions than diesel. It has higher cylinder pressure than other blends. In future, it can be considered as a good option as an alternative fuel.

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