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CONCLUSIONS AND SCOPE FOR FUTURE WORK

7.1 Conclusions

Finally, the following conclusions have been drawn based on CI engine experimental, computational, and energy-economic analysis of different biodiesel.

7.1.1 Experimental

The experimental analysis has been conducted on Kirloskar made a VCR engine fuelled with diesel and blends (B10, B20, B30, and B50) of Neem, Linseed, Mahua, and Castor biodiesel at varying compression ratio (15, 16, 17 and 18). These are the following conclusions drawn from the experimental results.

- For all the fuel, brake power increased with increasing the compression ratio from 15 to 18, and its maximum value (3.47 kW) obtained for pure diesel when the engine runs at an 18 compression ratio. Neem biodiesel identified as a higher brake power (3.46 kW) in compare to Linseed, Mahua, and Castor biodiesel blends and its B20 blend is more comparable with diesel.
- The value of brake specific fuel consumption (BSFC) was decreased for all the selected fuels with the variation of compression ratio from 15 to 18. Lower BSFC recognized to diesel fuel as compared to Linseed, Castor, Mahua, and Neem biodiesel and its blends. Minimum (0.23 kg/kWh) and maximum (0.34 kg/kWh) value of BSFC respectively for diesel and Linseed biodiesel blend B50, respectively. The value of BSFC was lower (0.25 kg/kWh) for Neem biodiesel

blends (B10 and B20) in comparison to Linseed, Mahua, and Castor biodiesel blends.

- The formation of CO was decreased with increasing compression ratio from 15 to 18. The higher value CO emission observed for diesel fuel in comparison to all biodiesel blends. The CO formation was decreased with the increased proportion of biodiesel in blends. A lower value of CO was obtained for Linseed biodiesel in compared to Neem, Castor, and Mahua biodiesel blends.
- The formation of NOx was increased with increasing the compression ratio for diesel and all the selected biodiesel; however, its value decreased with increasing the percentage of biodiesel in blends. Lower NOx formation was observed for diesel (145 ppm) fuel as compared to all the biodiesel blends. A lower value of NOx obtained for Linseed biodiesel (150 ppm) in compared to Neem, Castor, and Mahua biodiesel blends.

From the above comparative investigation of engine performance and emission characteristics of diesel with biodiesels (Castor, Linseed, Mahua, and Neem) blends, and considering power and emission balanced, Neem and Mahua biodiesel blends of B20 have been recognized as a better fuel for unmodified CI engine at full load and 1500 rpm speed.

7.1.2 Computational

The empirical correlation has been proposed for the evaluation of burning duration in the CI engine, and it comprises the effects of engine speed, compression ratio, fuel injection timing, equivalence ratio, and calorific value of the fuel. The correlation was validated, and by using this improves the accuracy of the computational result and reasonably agrees with experimental results. The following conclusions were drawn based on the mathematical modeling and computational program (FORTRAN code) for diesel engines with the variation of biodiesel blendings, injection timing, and stroke/bore ratios at different compression ratios and engine speed.

(a) Biodiesel blending

- Due to the lower calorific value of biodiesel, the brake power, indicated power BMEP and IMEP were decreased by 2.30 %, 1.94 %, 2.30 %, and 1.94 %, while the BSFC and ISFC increased by 8.67 and 9.03 % with increasing biodiesel blends from B00 to B50.
- The value of brake power, indicated power, BMEP, and IMEP increased while decreased the BSFC and ISFC with increasing the compression ratio for all the blends.
- The average value of peak cylinder pressures and NOx were decreased by 2.86 % and 10.10 %, respectively, with increasing the proportion of biodiesel in the blends (from B00 to B50); on the other hand, its values increased with compression ratio.

(b) Injection timing

- The average value of brake power, indicated power, brake mean effective pressure (BMEP) and indicated mean effective pressure (IMEP) were decreased by 0.97 %, 0.71 %, 1.18 % and 0.92 % with retarded injection timing from 43^o bTDC to 7^o aTDC. Brake power, indicated power, and IMEP were increased with engine speed from 1500 to 4000 rpm for all fuel injection timing. On the other hand, reverse trends are followed for BMEP.
- Both brake specific fuel consumption (BSFC) and indicated specific fuel consumption (ISFC) were increased by 1.273 % and 0.981 % with retarded

injection timing from 43^{o} bTDC to 7^{o} aTDC. While increased brake specific fuel consumption, on the contrary, decreased ISFC was with an engine speed for all injection timing.

- The average value of peak cylinder pressure and nitric oxide (NO) were decreased by 5.26 % and 13. 67 % with retarded the injection timing from 43^{o} bTDC to 7^{o} aTDC. And under the other operating condition, with increasing the engine speed (from 1500 to 4000 rpm), its value decreased.

(c) Stroke/Bore ratios

(i) At different engine speed

- The average value of brake power, indicated power, BMEP, and IMEP were increased by 27.52 %, 27.43 %, 0.89 %, and 0.71 % with the increase of stroke/bore ratios from 0.5 to 2.0. While increased brake power, indicated power, and BMEP with increasing the speed from 1500 to 4000 rpm; on the contrary, the opposite trend follows for IMEP.

- Both brake specific fuel consumption (BSFC) and indicated specific fuel consumption (ISFC) were decreased by 0.48 % and 0.33 % with increasing the S/B ratios at all speed ranges. The BSFC of the engine increased with speed, and reverse trends follow for ISFC.

- The average value of peak cylinder pressure and formation of NO were decreased by 0.16 % and 0.66 % with increasing the S/B ratios at all engine speed. The value of the peak cylinder pressure was increased, while decreased NO formation with an engine speed for all S/B ratios.

Higher percentage improvement in all the results has been observed during the initial increment of the stroke bore ratio (0.5 to 1).

(ii) At different compression ratio

- The average value of brake power, indicated power, BSFC, and ISFC were increased by 26.18%, 26.24%, 0.81, and 0.74%, with the increase of stroke/bore ratios from 0.5 to 2.0. The average value of BMEP and IMEP was decreased by 0.37 % and 0.32 % when changing the stroke/bore ratio from 0.5 to 2.0.
- Both brake power and indicated power were increased with increasing the compression ratios from 15 to 18 while reverse trends follow for BSFC and ISFC.
- The average value of BMEP and IMEP was decreased by 0.37 % and 0.32 %, with increasing the S/B ratio from 0.5 to 2.0. On the contrary, its value increased with increasing the compression ratio from 15 to 18 for all S/B ratios.
- The value peak cylinder pressure and formation of NO were decreased by 4.87 % and 5.98%, with increasing the stroke/bore ratios from 0.50 to 2.0 for all compression ratios. On the other hand, Both Pmax and NO formation were increased with increasing the compression ratio for all S/B ratios.

From the discussion and conclusions of the above results, it has found that the higher percentage improvement of all results during the initial increments in S/B ratios (0.5 to 1).

7.1.3 Energy and Economic

- During the cultivation of biodiesel plants, minimum input energy was observed for Neem (0.77464 MJ/kg).

- Maximum energy output (102.32 MJ/kg) and minimum energy input (18.548 MJ/kg) obtained for Neem as compared to other selected plants in the production of biodiesel.
- The highest energy ratio obtained for Neem (5.5164) and lowest for Palm (1.9908).
- Neem (0.0567 $KgMJ^{-1}$) and Mahua (0.0533 $KgMJ^{-1}$) produced higher unit (kg) of biodiesel production per unit (MJ) of energy consumption in comparison to other remaining biodiesel plants.
- The net energy is positives for all the plants, but its maximum value was obtained (83.77 MJ kg^{-1}) for Neem.
- According to economic results, higher gross production values obtained for Neem (222.27 Rs kg^{-1}) and Karanja (206.07 Rs kg^{-1}) as compared to other biodiesel plants. And the lower value of total production cost for Neem (78.14 Rs kg^{-1}) and Palm (76.12 Rs kg^{-1}).
- The higher value of gross return value (168.70 Rs kg^{-1}), net returns (144.13 Rs kg^{-1}) and, of benefit to cost ratios (2.84) were obtained for Neem biodiesel plants in comparison to others.
- The average value of productivity is higher for Neem (0.0122 Kg Rs^{-1}) and Palm (0.0118 Kg Rs^{-1}) than that of other remaining biodiesel plants. It means that 12.20 and 11.8 gram of biodiesel produces with expenses of one rupee respectively for Neem and Palm.

According to the results of energy and economic analysis, the plantation of Neem is very economical for biodiesel production.

7.2 Scope for Future Work

- Multi-dimentional appraoach for combustion analysis and performance study of Compression Ingnition engine with using different biodiesel blends as a fuel.
- This study is first step for giving the direction energy life cycle assessment of biodiesel, but does not consider environmental and social aspects and these can be considered in future.
- Circular economy or recycle of waste material obtained during the production of biodiesel.
- Glycerol purification for healty economic.
- Combustion analysis through Engine Indoscope using different biodiesel.