

Chapter 5 Conclusion and Scope of Future Work

5.1 Conclusion

The current research work aims to mitigate the NO_x emissions of the CI engine fueled with diesel-biodiesel fuel blends. The *Madhuca longifolia* biodiesel was prepared by the transesterification process. Three diesel-biodiesel fuel blends were prepared. The experimental work was carried out on single cylinder, four stroke, variable compression engine. The whole research work was divided in two phases. In first phase the NO_x emission has been quantify for the four various compression ratios, four fuel injection pressures, at different load conditions. The effect of compression ratio and injection pressure on NO_x emission also studied in the second phase of experimentation, the water was injected in the downstream of the engine to investigate the effect of water on NO_x emissions as well as on the other emission parameters.

5.1.1 Phase -I Experimentation

1. B20 blend emits higher NO_x of 1953 ppm at CR 18 and IP 600 bar under 75% load and emits least NO_x of 46 ppm at CR 15 and IP 600 bar under 25% load condition.
2. At lower load conditions, biodiesel blends have lower NO_x emission as compared to diesel fuel due to biodiesel having a higher viscosity and poor mixing while at higher loads, it contains more oxygen resulting in higher in-cylinder temperature producing higher NO_x emission.
3. Carbon monoxide emissions exhibit an initial decrease followed by an increase as the load increases. The compression ratio has a more significant effect on CO emissions compared to injection pressure and blend content. Among all the tested fuels, the B30 blend releases the most amount of CO emissions, at a maximum of 0.4% vol., when tested at a compression ratio of 18 and an injection pressure of 600 bar under full load. On the other hand, diesel fuel emits the lowest amount of CO emissions, at 0.07% vol., when tested at a CR of 18 and an IP of 400 bar under 25% load.
4. The highest level of UHC emissions, reaching 360 ppm, was observed for diesel fuel with a compression ratio of 18 and an injection pressure of 600 bar under full load conditions. Conversely, the lowest level of UHC

emissions, measuring 18 ppm, was found for a B30 blend with a CR of 16 and an IP of 500 bar under a partial load of 25%. With the exception of CR 15, all biodiesel blends exhibited lower UHC emissions than diesel fuel across all injection pressures and compression ratios.

5. The smoke opacity rose in accordance to the increase in the percentage of load. As the level of IP rises, the smoke opacity of all biodiesel blends falls.

5.1.2 Phase -II Experimentation

The phase I experimental results showed that the maximum NO_x emissions, across all fuel injection pressures and compression ratios, occurred at 600 bar. The engine load conditions were 75% and 100%. These operating parameters were carried forward for the phase II experimentation. The water injected downstream of the engine and the effect of water on NO_x emissions as well as on other exhaust emission parameters were studied.

1. As the rate of water injection increased, there was a corresponding drop in NO_x emissions, showing a nearly linear relationship. For all the blends (B10, B20, and B30), CR (15, 16, 17, 18), and both loading circumstances (75% and 100%). It has been observed that NO_x emissions decrease by a maximum of 130.4 cc/min flow rate and then stabilize. This could potentially be attributable to the attainment of the maximum reaction rate between H₂O and NO_x.
2. The overall average reduction in NO_x emissions obtained for water injection flow rates of 38.7 cc/min, 82.7 cc/min, 130.4 cc/min, and 166.7 cc/min is 7.87%, 12.26%, 17.72%, and 17.42%, respectively, across all instances.
3. As the water injection flow rate increases, CO emissions decrease. By observing the trend, it seems to be following some empirical relation rather than following linearity. Average reduction of the CO emissions for water injection flow rate of 38.7 cc/min, 82.7 cc/min, 130.4 cc/min, and 166.7 cc/min are 17.14%, 32.77%, 42.68% and 42.51% respectively.
4. In a limited number of cases, there was a minimal decrease in HC emissions observed. In addition, the levels of HC emissions stay unchanged during most of the test sessions.

5. As the injection water flow rate increases, the smoke emissions decrease. The average reduction in smoke emissions for injection flow rates of 38.7 cc/min, 82.7 cc/min, 130.4 cc/min, and 166.7 cc/min is recorded as 34.72%, 66.51%, 69.36%, and 67.68% respectively.

The practical importance of the results include compliance with emission limits.

NOx Emission:

For compression ratios 15 and 16, NO_x emissions were recorded below the BS VI limit for all blends at a 25% loading condition; but in all other cases, NO_x emissions surpassed the BS VI standard limit. On the other hand, we are able to achieve the reduction of excessive NO_x emission by 18.36% to 24.97% with respect to BS VI standard for all the cases by water injection at exhaust manifold.

CO Emission:

The test conducted using CR 17 and a B20 fuel mix at a 75% loading condition, along with 166.7 cc/min water injection, has satisfied the BS VI standards. No other test run has achieved CO emissions beneath the BS VI threshold. Although the surplus CO emission has reduced by 28.57% to 85.71% with respect to BS VI norms in various cases by injecting water at exhaust manifold.

Smoke Emission:

The smoke emission of all the cases are below the BS VI norms limit.

5.2 Summary of Conclusion

The objective of the study was to reduce the NO_x emissions of the compression ignition engine fueled by a blend of diesel and biodiesel. By injecting water downstream of the engine at a flow rate of 130.4 cc/min, we have successfully achieved an average reduction of 17.72% in NO_x emissions. We introduced the water during the post-combustion phase, taking care to ensure that it had no effect on the engine's performance or combustion parameters. In addition to the decrease in NO_x emissions, we observed a 42.04% reduction in CO emissions and a 69.36% reduction in smoke emissions.

5.3 Scope of Future Work

- The decrease in NO_x emissions has been limited at 17.72%, maybe because the maximum rate of reaction between H₂O and NO_x has been reached. The research can be extended to increase the reaction rate.

- The result of the reaction between NO_x emissions and H₂O is the formation of HNO₃ and HNO₂, both of which are inherently acidic. It is possible to expand the scope of the project to create an exhaust system that is resistant to corrosion.
- The study can be expanded to assess the impact of steam injection.