Chapter 6

Concluding Remarks

The experimental study is conducted on a four stroke, variable compression ratio diesel engine using Karanja biodiesel and its blends with diesel. The thermal performance and emissions characteristics are evaluated by running the engine at different combinations of preset CRs of 14, 15, 16, 17, 17.5 and 18, IPs of 150 bar, 200 bar and 250 bar, and varying loads from 0kg to 12 kg in steps of 3kg. The thermal performance parameters evaluated are BTHE, BSFC, BMEP, Volumetric Efficiency, HBP, HGas and EGT while the emission constituents measured are CO, HC, NO_X, CO_2, O_2 and SO_X. Along with emission constituents, the smoke intensity is also measured in terms of HSU. A detailed combustion analysis of the engine running on pure diesel and Karanja biodiesel at different preset compression ratios of 14, 16 and 18 and full load is also conducted. The combustion parameters analysed are cylinder pressure, net heat release rate, mass fraction burnt, mean gas temperature, rate of pressure rise, pressure volume plot, cumulative rate of heat release and injection pressure. Thus, the output parameters are BTHE, BSFC, BMEP, Volumetric Efficiency, HBP, HGas and EGT for thermal performance and CO, HC, NO_X, CO_2, O_2 and SO_X for emission constituents. Further, for optimization genetic algorithm (GA) analysis is carried out selecting only BTHE, BSFC and EGT as thermal performance parameters since other parameters directly influence the already selected once and CO, HC, NO_X, CO_2 and O_2 as emissions constituents. SO_X is not included as one of the output parameters in emission constituents as it is negligible in case of engine operated with Karanja biodiesel.

It should be noted that the three different studies conducted on thermal performance, emission constituents and combustion analysis leads to prediction of each of them in isolation, although a unification of thermal performance and emission constituents with combustion analysis is a possibility. However, it is difficult to strike an optimum combination of the possible maximum thermal performance and minimum emission constituents with respect to a combination of CR, IP, bio-diesel blend when the engine operates at a preset load (Say at full load) using only the experimental data. Hence, a suitable technique of optimization along with a modeling is to be chosen to strike an optimum balance between the chosen four input parameters to predict the output parameters.

Thus, a computational study consisting of multi-objective optimization of thermal performance and emission characteristics using GA technique and modeling using ANN for the engine is carried out. The combination of optimization and modeling is intended to find the optimum combination of the four input parameters, viz, CR, IP, load and blend and subsequently to predict the output parameters, viz. BTHE, BSFC and EGT for thermal performance and CO, HC, NO_x, CO_2 and O_2 for emission constituents for the optimum combination of input parameters. The GA toolbox of MATLAB is used for the purpose of optimization. The ANN is modeled by using the selected results of the experimental study using EASYNN-PLUS software. The accuracy with which this neural network works is judged by comparing the outputs from the network with the experimental data. The output parameters can be determined from the optimized input parameters.

Based on the experimental and computational studies, following are the important observations made and the conclusions drawn thereon.

1. A single cylinder, four stroke, variable compression ratio (VCR) CI engine originally designed to operate on diesel as fuel may be operated on pure Karanja biodiesel without any system hardware modifications.
2. Based on the experimental study, it can be concluded that with the increase in CR, the performance of diesel engine operated using Karanja biodiesel and its blends approach to that operated using Diesel oil. And at a higher CR and IP of 18 and 250 bar respectively, the thermal performance of Karanja biodiesel is closest to that of Diesel oil compared to that operated at other CRs of 14, 15, 16, 17 and 17.5. Higher IP of 250bar is preferable for Karanja biodiesel due to its higher viscosity. Thus, the best combination of input parameters in terms CR and IP will be 18 and 250 bar respectively when the engine is operated at full load. The experiments, however, can not specify any optimum Karanja biodiesel blend that will simultaneously maximize thermal performance and minimize emission constituents.
3. The thermal performance evaluation, in isolation, indicates that the blend B20 operates closest to that of Diesel oil whereas, the engine operated with any higher CR ranging from 16 to 18, the emission constituents of CO, HC, CO_2, O_2 and SO_x are the least and remains constant in the CR range of 16 to 18. Both the

above observations are made when the engine is operated with IP at 200 bar and full load at 12 kg.

4. On the basis of comparison made with earlier investigations with similar input parameters of CR, IP and load of 18, 200 bar and 12 kg (full load) respectively, the thermal performance of the engine operated with Karanja biodiesel is found to be superior in comparison with that operated using Jatropha and Mahua biodiesels. BTHE of the engine operated using Jatropha and Mahua biodiesels are found to be lesser by 12% and 17% respectively than that operated using Karanja biodiesel. BSFC is found to be 9% and 56% more respectively for Jatropha and Mahua biodiesels operated engines as compared to that of Karanja biodiesel used in the present study.
5. Karanja biodiesel (B100) gives minimum harmful emissions as compared to all other blends. Further, at a higher CR of 18 and IP of 250bar, the fairly reduced exhaust emissions are observed irrespective of the fuel blend used. Therefore, operating the diesel engine with Karanja biodiesel at a CR of 18 and IP of 250 bar results in minimum emissions but for NO_x emissions. If NO_x is also to be minimised, then the engine should be operated at CR of 16, which will result in a decrease in BTHE of about 13% and an increase in BSFC of 14% which are not affordable just for the sake of reduced NO_x emissions. A comparison of present study made with earlier investigations revealed that NO_x emission at a CR of 18 are found to be higher by 32% for Jatropha biodiesel as compared to that of Karanja biodiesel used in the present study
6. Although, B20 blend gives better thermal performance compared higher blends of Karanja, it is not recommended as it poses problems of higher levels of exhaust emissions.
7. It is inferred from the combustion analysis that as CR increases from 14 to 18 at full load and IP of 200bar, the difference in performance between Karanja biodiesel and Diesel oil reduces which results in almost the same level of thermal performance for the engine when fuelled with Karanja biodiesel as compared to that fuelled with Diesel oil. The combustion characteristics of diesel engine using Karanja biodiesel is similar to that using pure Diesel oil at higher CR of 18 which is very promising as far as Karanja biodiesel as an alternative fuel in diesel engines is concerned.

8. From the large number of experimental data for thermal performance and emission constituents obtained for various input parameters such as load, CR, IP and blend, picking up an optimum combination of the input parameters manually is not possible. The effects of blend proportion, load, compression ratio (CI) and injection pressure (IP) on thermal performance and emission constituents create a multi-objective scenario. Therefore, there is a need to find optimum conditions considering both thermal performance and emission constituents. GA is one optimizing technique that can help tackle the multi-objective scenario. Using GA as the optimization tool, it is concluded that the optimum values of CR, IP, and blend proportion are 18, 228 bar, and B70 respectively when the engine is operated at full load which results in maximizing the thermal performance by maximizing BTHE and minimizing BSFC and EGT and minimizing all other emission constituents including NO_x except O_2.
9. As the optimum values of input parameters, viz., CR, IP, and blend proportion are found to be 18, 228 bar, and B70 while operating the engine at full load using GA and the combination of these input parameters are not readily available through the hardware experiments conducted, it is necessary to use a modeling tool to predict the output parameters of thermal performance and emission constituents with an acceptable error limit. For this purpose, a multi layer feed forward ANN model with 80-20 rule for training the network is selected. From the comparison of a selected set of readings obtained from experimental study with that from ANN, it can be concluded that models developed for prediction of thermal performance and exhaust emission constituents have an acceptable error and hence can be used for obtaining the output parameters correspond to optimized input parameters. Further, if the engine is operated using B70 blend, the BTHE, BSFC and EGT have to be compromised by about 6%, 6% and 1.4% respectively compared to Diesel oil and the emission constituents namely CO, HC, CO_2, O_2 and NO_x by 20%, 50%, 5%, 0.6% and 3.6% respectively compared to Karanja biodiesel.