Chapter – 5

Conclusions

The experimental and theoretical (modeling and optimization) studies are conducted on the thermal performance and pollutant emissions constituents using an indirect, four stroke, multi cylinder (four cylinder), naturally aspirated, water cooling, compression ignition engine developing 26.7kW at the test speed of 4000 rpm with diesel oil alone, dual fuel mode of hydrogen gas-diesel combination and diesel/DMM blend with hydrogen gas. Hydrogen gas is supplemented through continuous induction in to the air inlet manifold with varying rates of 1 to 18 l/min. Further studies are carried out to recoup the shortage of the air displacement from inlet manifold due to hydrogen induction through an oxygenation of diesel oil fuel by substituting 10% (by volume) of DMM blended with diesel. The effect of induction of hydrogen in inlet manifold with and without DMM is thus, experimentally carried out. On the theoretical front, artificial neural network (ANN) technique is used for modeling. The experimental data is used to learn and verify two ANN models, viz., thermal performance model to predict the brake power with diesel fuel consumption and exhaust emission constituents' model to predict the CO, CO_2, HC, SO_2 and NO_X for diesel engine operated by hydrogen-diesel as a duel fuel. Genetic Algorithm (GA) is used as optimization technique to find the optimum operation condition for diesel engine operated by hydrogen-diesel blend as fuel. Single objective optimization as well as multi objective optimization ~~is~~ are carried out to maximize the power and minimize the diesel fuel consumption, CO, CO2, HC, SO_2 and NO_X. to individually and collectively optimize thermal performance and exhaust gas constituents. Based on the above studies, following conclusions are drawn:

1- A multi cylinder compression ignition engine originally designed to operate using diesel oil as fuel may be operated under a hydrogen-diesel dual fuel mode without any system hardware modifications.

2- Hydrogen induction in the inlet air manifold up to 18 l/min poses no difficulties in engine operation for the system under consideration. It should be noted that few problems such as back fire, knocking tendency etc are found to occur when high hydrogen induction rates of the order of 20 l/min and more are considered. This is due to shortage of the air/oxygen ratio inside the combustion chamber due the displacement of intake air with inducted hydrogen.

3- A continuous hydrogen induction in the inlet manifold significantly reduces the consumption of diesel oil. The decrease in diesel fuel consumption rate and brake specific fuel consumption rate are of the orders of 20 to 25 % and 16% to 18 % respectively with hydrogen induction rate of 18 l/min irrespective of the load and speed conditions.16% and 23 % reductions in volumetric efficiency are observed with hydrogen induction rate of 18 l/min under no load and full load operation of the engine running at 1000 rpm. However, when the speed is increased to 2000 rpm, the decrease in volumetric efficiency is only about 3.5%. One can conclude that indirect manifold induction of hydrogen is beneficial and suitable at operating conditions of higher load and speed. The highest possible hydrogen induction rate of the order of about 18 l/min is preferable when thermal performance alone is the criterion.

4- Exhaust gas constituents like CO, HC and SO_2 significantly increase with hydrogen induction at the intake manifold beyond a rate of about 7 l/min to 8 l/min for all the operating conditions of load and speed. However, NO_x emissions are found to decrease with higher hydrogen induction rates. Therefore, it can be concluded that the hydrogen induction rate must be restricted to about 7 to 8 l/min so as to control the level of pollutants in the exhaust even though higher induction rates are beneficial for better thermal performance.

5- The shortage of the availability of oxygen due to hydrogen induction can be addressed effectively by oxygenation of diesel oil through blending with suitable blend. Thus 10% DMM/diesel blending is used to study its effect on thermal performance and exhaust gas constituents with and without hydrogen induction. The improvement in thermal performance parameters, when DMM/diesel blend is used instead of diesel oil alone, like brake thermal efficiency (increased by 7%), and brake specific energy consumption (decreased by 5%) are notable. Further, there is marginal decrease in exhaust gas constituents such as CO, CO_2, HC, and SO_2. There is a marked effect of DMM/diesel blend with hydrogen induction on the reduction in CO_2 content in exhaust as compared to that with diesel alone without hydrogen induction. Oxygenated diesel with hydrogen induction is therefore beneficial in limiting the pollutant generation.

6- Over the last few decades of the development of compression ignition engines, experimental investigations were vital. However, few theoretical modeling, simulation and optimization have helped to supplement the developments in the recent past. ANNs are a modeling technique that can be very useful when experimental data bank is available. A multi layer feed forward ANN model with 80-20 rule for training and pruning the network is selected. From the validation study carried out with a chosen combination of speeds at 1300 rpm and 1800 rpm, it can be concluded that the model is applicable to predict thermal performance and gas emission constituents with a maximum error of 10 % and an average error of 5 %.

7- As is seen during experimental study that there is no one optimum hydrogen induction rate at the intake air manifold with reference to thermal performance and exhaust gas constituents under different operating conditions of the engine. The effect of hydrogen induction rate increase on thermal performance parameters is to increase them monotonically whereas the exhaust gas constituents are found to generally increase with an exception of NOX. Therefore, there is a need to find the optimum hydrogen induction rate considering both the thermal performance parameters and pollution constituents in exhaust. It is essential to work on an optimization technique to find an optimum value of hydrogen intake from point of view of maximizing brake power and minimizing of fuel consumption and proportion of exhaust gas emission constituents that are pollutants. Genetic algorithm is one optimizing technique that can help one to tackle the multi-objective and multimodal scenario.

From the present optimization through GA it can be concluded that the optimum hydrogen induction rate can be between 6 to 8 l/min which is in close agreement with the present experimental results and that of Saravanan and his associates.