Abstract

The present experimental and theoretical studies are aimed at the prediction of the optimum performance of a multi cylinder compression ignition engine using a suitable fuel consisting of a combination of diesel blend with the introduction of hydrogen gas. The optimum performance of the engine is based on the maximization of few chosen thermal performance parameters and minimization of the generation of exhaust emission constituents which are pollutants. For this purpose, an extensive experimental study is undertaken. Amongst the various combinations of the introduction of hydrogen in to a compression ignition engine, the technique of hydrogen induction through the intake air manifold is selected for the present study. This selection is based on an extensive literature survey which indicated that this is a relatively unexplored area with little or no studies reported in open literature on multi cylinder compression ignition engines using separate introduction of partial indirect induction of hydrogen gas and suitably oxygenated diesel oil. Further, the hydrogen induction in intake manifold is the easiest and least expensive and safe technique of hydrogen introduction in to the engine with diesel oil alone or oxygenated diesel oil with suitable blend as primary fuel. Therefore, the present study is confined only to a partial replacement of primary fossil fuel like diesel oil with or without oxygenation and induction of hydrogen gas.

A large number experimental test runs are carried with a number of combinations of operating conditions of the engine like speed , brake load applied beginning with a validation test consisting of conventional performance test using diesel oil alone before moving on to the extensive tests using indirect intake manifold hydrogen gas induction with varying rates from 1 liter per minute (l/min) up to 18 l/min. Experiments on the effect of hydrogen induction are repeated with oxygenated diesel (DMM-diesel blend) as primary fuel. All these experiments are conducted to determine an optimum indirect hydrogen induction rate which may provide better thermal performance along with minimum harmful pollutants emissions. The speed and load are varied stepwise, speed being in steps of 1000, 1250, 1500, 1750 and 2000 rpm while load being in steps of eddy current of 0.5, 1.0, 1.5 and 2.0 Amp applied at the eddy current dynamometer.

In the recent years, many models and simulations have been tried to give a clear view about the diesel engine performance, fuel characteristics, emission etc. under varied conditions of speed, load and other operating parameters. One of these techniques is the artificial neural network (ANN). ANN modeling (neural networks) encompasses very sophisticated techniques

capable of modeling complex functions and processes. The true power and advantage of neural networks lies in their ability to represent both linear and nonlinear relationships as well as having the capability of learning by example. For processes that have non-linear characteristics such as those found in diesel engine performance modeling, traditional linear models are simply inadequate. In comparison to traditional computing methods, neural networks offer a different way to analyze data and to recognize patterns within that data by being generic non-linear approximators. Artificial Intelligence (AI) techniques seem to be best solution for predicting engine emissions since they do not demand any additional sensor installation.

Developing a suitable model for thermal performance and exhaust gas emissions of a compression ignition (CI) engine for evaluating the effect of hydrogen induction poses the problem of absence of widely accepted correlations. Artificial neural networks are found apt in such a scenario to capture the relationship between the response parameters and the control parameters selected as per the design of experiments. A model is desirable to simulate the engine performance and help predict the effect of load, speed and different hydrogen induction rates on the thermal performance and exhaust gas constituents to have a clear idea of benefits of hydrogen induction. Thus, a large number of experimental data acquired during the experimental programme may now be used to predict the performance parameters and exhaust gas emission constituents at any operating condition of the engine. A multi layer feed forward ANN model also termed as a multi layer perceptron (MLP) is selected to predict thermal performance and engine emission constituents using the extensive experimental data compiled during experimentation. ANN approach including the selection of modeling tool and modeling strategy adopted for the thermal performance evaluation and constituents of engine emissions are given. The implementation of the above is made through the use of EasyNN, a commercially available software .

On the theoretical optimization front, no studies appear to have been carried and reported in the open literature regarding the use genetic algorithm (GA) as an optimization tool to optimize a multi cylinder compression ignition engine performance in terms of both thermal performance and gas emission constituents to find the optimum hydrogen induction rate in to the intake manifold . The problem of finding the optimum value of hydrogen induction from the point of view of maximizing brake power and minimizing fuel consumption and proportion of exhaust gas emission constituents poses a multi-objective and multimodal scenario. A correlation relating the output variables namely the brake power, diesel consumption and each of the exhaust gas constituents to the control variables namely speed, load and hydrogen induction rate is required. Feasible region is bonded by practical limit of control variables. These represent maximum and minimum values set in the design of experiment for each of the control variables. The optimization is carried out as single objective optimization treating minimization of exhaust gas constituents such as CO, CO_2, NO_X, SO_2, HC individually and diesel fuel consumption, maximizing the brake power (actually minimizing the inverse of brake power) and a single fitness function to minimize emissions and inverse of brake power. Appropriate software is to be selected for implementing GA. Possibility extends from ready freeware and open source softwares to toolboxes of celebrated platforms like MATLAB and requirement of hand coding where inbuilt facilities of these software do not satisfy peculiarity of the specific problem. The MATLAB Genetic Optimization toolbox is selected as the implementation tool.

From the present study, it can be concluded that the hydrogen induction in to a compression ignition engine along with diesel oil helps not only improvement in thermal performance but decreases pollutant emission gases. Hydrogen induction rate of 7 l/min in to the engine with diesel oil as primary fuel decreases the exhaust gaseous pollutants such as CO, CO_2, SO_2, HC and NO_x . The thermal performance alone by considering the minimisation of diesel oil consumption and maximization of brake power on equal weightage basis shows that the hydrogen induction rate of 6 l/min in to the engine operated on diesel oil is the best option. The combined optimum operation considering 40 % weightage to lower emissions and 60 % weightage to thermal performance with equal weightage to both brake power and diesel oil consumption is possible at lower speed and load with a hydrogen induction rate of 8 l/min. Full load operation of the engine giving less weightage to gas emissions (30%) and more to thermal performance (50% to fuel consumption and 20% to brake power) demands higher speeds with 8 l/min hydrogen induction. In short, the operation of a compression ignition engine with diesel oil as primary fuel when blended with hydrogen by inducting in to the intake manifold at the rate of 6 – 8 l/min results in the optimum operation considering both thermal performance and exhaust gas emission constituents. The results of the optimization through GA agree well with the present experimental results.