Optimization of Performance and Emission Characteristics of Biodiesel Based Diesel Engines: A Review

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Abstract—The optimization techniques help in predicting the performance and emission characteristics at best combination of engine input parameters. The current work related to various research contributions by different researchers for optimizing performance and emission parameters of a compression ignition engines. It is observed that RSM is an effective statistical tool for designing the experiments of engine input parameters and computational tools like GA helps in predicting optimal solutions.

Key words: Optimization techniques, Performance and emission characteristics, RSM, NSGA-II

1. INTRODUCTION

The biodiesels are used by blending them with commercial diesel in CI engines. The engines running on these biodiesels should have optimum performance [Dhingra et al., 2013a; Dhingra et al., 2013b; Dhingra et al., 2014a; Dhingra et al., 2014b; Dhingra et al., 2014c; Dhingra et al., 2014d; Dhingra et al., 2016a; Dhingra et al., 2016b]. The objective is to maximize performance characteristics and minimize emission characteristics in CI engine using biodiesel. The various research works are summarized as below:

Pal et al. (2010) developed thumba (Citrullus colocynthis) biodiesel through hydrodynamic cavitation and suggested an optimum value of 30 % thumba biodiesel in diesel (TB30) running on a four cylinder, direct injection water cooled diesel engine at variable speed. The performance, combustion and emission characteristics were significantly improved at TB30 with a favorable pressure-crank angle (p-θ) diagram as compared to conventional diesel. The results of the experiments revealed that biodiesel production through hydrodynamic cavitation technique was simple, efficient, time saving, eco-friendly and industry viable process. Also thumba biodiesel can be used as an alternative fuel in compression ignition engines by blending with diesel. Valente et al. (2010) checked the performance (fuel consumption and emissions) of castor and soybean biodiesels in a diesel powered generator. The comparison was then analyzed with straight diesel as a fuel in a generator.

Acharya et al. (2011) designed the experiments of karanja oil to study the effect of viscosity with increase in fuel temperature. The combustion performance of the oil was improved at higher temperature due to decrease in the viscosity of oil. A single cylinder direct injection diesel engine of 5 HP was used for evaluating the thermal efficiency and brake specific fuel consumption. Performance of the engine running on karanja (preheated and blends) biodiesel was found to be very close to the engine running on mineral diesel. Also preheated karanja oil performance was slightly lower in efficiency due to lower heating value.

Reddy and Mohan (2011) evaluated optimum output parameters of a CI engine by utilizing sunflower oil-diesel blend through artificial neural network. The output parameters were calculated theoretically by standard formulae and experimental values were used for performing different training functions in the neural model with different hidden layers (nxm).

Berman et al. (2011) suggested that castor oil based biodiesel blend of 10 % (volume ratio of biodiesel and diesel) can be used as a fuel in compression ignition engines. Bunce et al. (2011) analyzed the behavior of performance parameters in a modern diesel engine by the use of 100 % soybean biodiesel. The engine was modified to reduce the NOx emissions, particulate matter (PM) and peak rate of change of in-cylinder pressure. The optimum settings for NOx reduction were achieved through modulation of air-fuel ratio (AFR), exhaust gas recirculation (EGR) fraction and fuel rail pressure. ... Ganapathy et al. (2011) applied response surface methodology for the optimization of performance parameters in a jatropha biodiesel fuelled diesel engine. The input parameters that varied during testing were: injection timing, load torque and engine speed. The optimum conditions for required objectives were: BSFC of 0.2875 kg/kWh, BTE of 30.96 %, Pmax of 65.79 bar, CO of 4.96 vol. %, HC of 0.0076 vol. %, NOx of 5.27 ppm and smoke of 321.69 ppm at injection timing of 342.6 CAD, load torque of 11.4 N-m and engine speed of 1801 rpm.

Macor et al. (2011) experimentally investigated the effects of blended biodiesel (B30) on regulated (CO, HC, NOx and PM) and unregulated (aldehydes and polycyclic aromatic hydrocarbons) pollutant emissions of two Euro 3 commercial trucks. The results of the experiments showed a slight increase in fuel economy, increase in CO and HC emissions, significant reduction in soot fraction along with particulate matter (PM) and particle number while no change in NOx emissions for both engines running on B30 blended biodiesel as compared to mineral diesel. Furthermore, a slight increase in formaldehyde emissions and an ambiguous trend in acetaldehyde emissions were also observed.

Maheshwari et al. (2011) developed non-linear regression models of performance and emission parameters through experimentation on a single cylinder, constant speed (1500 rpm), direct injection diesel engine running on karanja biodiesel-diesel blends (5 %, 10 %, 15 %, 20 %, 50 % and 100 %) at variable injection timing and load. With increase in injection timing of the engine running on neat karanja biodiesel, an improved efficiency and lower HC emissions were observed. The multi-objective optimization was applied in order to evaluate the required performance and emission parameters. The optimum blending ratio of 13 % and injection timing of 24° bTDC were observed when equal weightage was given to efficiency and emissions.
McCarthy et al. (2011) experimentally investigated performance and emissions from an internal combustion engine fuelled with two biodiesels (type A and type B) with various blends of B5, B10, B50 and B100. NOx emissions were found to decrease by 14% for type A biodiesel and increase by 17% for type B biodiesel. CO emissions were reduced by 58% and 27% for both the type A and type B biodiesels respectively. The results also revealed that performance (torque and fuel consumption) and HC & CO emissions from both the biodiesels fuelled engine were in lower side as compared to diesel.

The improved performance and emission parameters of a variable compression ratio diesel engine were experienced by Muralidharan et al. (2011) with the use of waste cooking oil biodiesel blends (20%, 40%, 60% and 80%) in diesel at the expense of nitrogen oxides emissions. Also, the combustion characteristics of all biodiesel-diesel blends were found to be comparable to that of diesel at fixed speed of 1500 rpm and variable load conditions.

Pandian et al. (2011) applied desirability approach for optimization of performance and emission characteristics operating on pongamia-pinnata (karanja) biodiesel-diesel blends on a twin cylinder water cooled naturally aspirated CIDI diesel engine. The experiments were designed (to measure performance and emission parameters) based on response surface methodology (RSM) by considering injection system parameters such as injection timing, injection pressure and nozzle tip protrusion. It was observed that NOx emissions were higher for all the designed experiments for pongamia biodiesel-diesel blend as compared to diesel. Therefore desirability approach was helpful in achieving the required objectives (BSEC, BTE, CO, HC, smoke opacity and NOx) and optimum conditions were found to be at 225 bar injection pressure, 21° bTDC injection timing and 2.5 mm nozzle tip protrusion for pongamia biodiesel-diesel blend in an engine of 7.5 KW at 1500 rpm. The sunflower oil based biodiesel was utilized in a CI engine by Reddy and Mohan (2011) for prediction of optimum parameters using artificial neural network.

Shivakumar et al. (2011) proposed ANN model for the prediction of performance and emission parameters in a single cylinder, four stroke, variable compression ratio diesel engine. The tests were conducted for three injection timings (24°, 27° and 30° bTDC) by adjusting the thickness of advance shim. The inputs to ANN were: Compression ratio, injection timing, bend percentage and load percentage while brake thermal efficiency (BTE), brake specific fuel consumption (BSFC) and exhaust gas temperature (Texh) were used as outputs to the trained network. The results from the trained neural models showed a good correlation between the actual and predicted values of engine output parameters with 8% relative mean square error. Yoon and Lee (2011) considered biogas-biodiesel as a dual fuel in a compression ignition engine and compared its combustion and emission characteristics with straight diesel. Zhu et al. (2013) evaluated particulate and unregulated emissions by considering the effects of ethanol-biodiesel blends and diesel oxidation catalyst. Xue et al. (2011) evaluated the performance of biodiesel in a diesel engine.

Mohamad et al. (2012) created artificial neural network models of engine out responses (CO, CO2, NO, UHC, Pmax, location of Pmax, HRRmax, location of HRRmax and cumulative HRR) for a light duty diesel engine operating on biodiesel-diesel blends. The inputs to the neural model were: Engine speed, output torque, fuel mass flow rate, and biodiesel fuel types and blends. Validation of the results predicted through ANN was performed on parallel engine test bed. The effects of various parameters of ANN such as; type of transfer function, training algorithm, number of neurons and methods of optimization for network settings were also reported. ANN was found to be a reliable tool in achieving the required outputs with less computational time.

II. CONCLUSION

1) Design of experiments using RSM based on CCRD is suitable for the class of the problems in which empirical model (response characteristics as a function of process parameters) has been created and the objective is to optimize the response characteristics. This technique predicts good results as long as the developed regression model is considered valid after performing the confirmatory experiments.

2) The performance of optimization algorithm using GA in multi-objective responses is superior as compared to desirability approach. Furthermore, for simultaneous optimization of conflicting responses, multiple optimum solutions are obtained, where none of the solution is better than other. The pareto optimum sets of solution can be used as guidelines by the end users to select optimum combination of engine output and emission parameters depending upon their own requirements.

REFERENCES


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