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Optimal Performance and Emission Analysis of Diesel Engine Fuelled with Palm Oil Methyl Ester with an Artificial Neural Network

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Abstract: Biofuels or biodiesels are fuels that are in biodegradable and non-toxic. They are manufactured from waste cooking oils, vegetable oils and animal fats or tall oil (a by-product of the pulp and paper industry). These oils undergo a procedure called transesterification whereby they are subjected to a reaction with an alcohol usually ethanol or methanol by means of a catalyst such as sodium hydroxide. This results formation of ethyl or methyl ester called biodiesel and a by-product called glycerin. Pure biodiesel fuel is considerably not as much of flammable than petroleum diesel which burns at 50 degrees Celsius. Biodiesels are frequently used in blend with petroleum diesel and are named as biodiesel blends. These blends will contain a flashpoint and a gel point wherever between the two pure fuels depending on the mixture. Artificial neural networks (ANNs) are recently developed techniques which are in variably used in obtaining exact correlations which involves non-linear data. An ANN can be considered to be consisting of interconnected group of relatively simple processing elements or nodes, called neurons, where the global performance is resolute by the relations between the processing nodes and the network parameters. Neural networks, when trained properly are good at providing very fast, extremely close approximations of the correct output for nonlinear data. This study deals with artificial neural network modeling a diesel engine using palm oil methyl ester to predict brake power, brake thermal efficiency, specific fuel consumption and exhaust emission of engine. This property of biodiesel produced from palm oil was measured and the experimental results reveal that blends of palm oil with diesel fuel provide improved engine performance and improved emission characteristics. Using some of the experimental data for training, an ANN model program for the engine was developed. Different activation functions and several rules were used to assess the percentage error between the desired and predicted values. It was observed that the ANN model can predict the engine performance and exhaust emission quite well.

Keywords: Performance, Emission, Diesel Engine, POME, ANN

1. Introduction

Bio diesels refer to a family of CI engine fuels that are produced from natural sources such as oils of sunflower palm, poongami and jatropha. It is believed that Biodiesels which may be the oils themselves or their esters are the most likely successors to petroleum derived diesel.

It is also more practical that these alternate fuels are introduced gradually as blends with diesel so that the production facilities are able to grow and markets are able to switch from petroleum derived diesel to Bio diesels. Studies have shown that often best results are achieved in blending a Biodiesel with diesel in suitable proportions and the results obtained are better than those of diesel or the pure Biodiesel. Hence it becomes extremely necessary to evaluate these blends of Biodiesels with diesel for their performance and emission characteristics. So far most of the research has been concentrated on the testing of the Biodiesel or some particular ratio of blend. Some studies reveal that the characteristics of these blends do not vary in a linear fashion and there may be certain combinations that might be more advantageous than others from the performance and

emissions point of view. Artificial neural networks have been employed as they can produce accurate correlations for non-linear data.

Artificial neural networks (ANNs) are recently developed techniques which are invariably used in obtaining accurate correlations which involves non-linear data. An ANN can be considered to be consisting of interconnected group of relatively simple processing elements or nodes, called neurons, where the global behavior is determined by the associates between the processing nodes and the network parameters. Neural networks, when trained properly are good at providing very quick, tremendously close approximations of the correct output for nonlinear data. Their applications can be categorized into classification, pattern recognition and detection, assessment, monitoring and control, and forecasting and prediction. Modern neural networks can be educated to solve problems that seem impossible for conventional computers or human beings. The objective of this study is to establish correlations in the form of networks between the percentage of blend in Biodiesel along with the Biodiesel's properties and the performance and emission characteristics of a CI engine and to obtain the optimal blend of Biodiesels with diesel which would result in reduced values of SFC, NO_X and HC. Due to the nonlinear nature of the problem and the number of variables associated mathematical modeling and/or statistical analysis becomes difficult. However the necessary objective might be achieved by implementing ANNs, which have proved to play an significant role in the modeling and prediction of the performance and control of combustion processes and in the prediction of exhaust emissions as a function of fuel properties.

B. Ghobadian et al. (2009) they had studied about the artificial neural network modeling a diesel engine using waste cooking biodiesel fuel to predict the brake power, specific fuel consumption, torque, and exhaust emission of engine. They had concluded that the results were found to be very similar. The maximum power and torque produced using diesel fuel was 18.2kw and 64.2 Nm at 3200 and 2400 rpm. By adding up 20% of waste vegetable oil methyl ester, and the concentration of the CO and HC emissions were considerably decreased when biodiesel was used.

D. Vinay Kumar et al (2013) they had studied about the biodiesel fuel derived from different vegetable oils, animal fat will be prepared by transesterification to be the simplest process to prepare with less infrastructure. A back propagation neural network model with a 3-6-5 configuration was developed to predict SFC, brake thermal efficiency, emissions of CO, HC and NOx of a diesel engine. The results were in concord less than 6.8% average relative error with those obtained experimentally.

P. PaiSrinivas et al. (2010) in this paper they had studied that one of the significant routes to tackle the problem of increasing prices and the pollution problems of the petroleum fuels is by the use of fuels known as biodiesels. Brake thermal efficiencies of biodiesel blends are very close to diesel and 20% blend with diesel, B20 provided the maximum efficiency for biodiesel operation for all compression ratios. Exhaust emissions like CO, HC were reduced for Waste cooking oil biodiesel blends when compared with diesel values for all compression ratios.

M. M. Deshmukh et al. (2014) in this paper they had studied about the best optimization technique for a diesel engine to predict and optimize the BTE, BSFC and Texh of the engine. Using 60% experimental data for training, an ANN model based on back propagation neural network for the engine was developed. Then the performances of the ANN predictions were measured by comparing the predictions with the experimental results which were not used in the training process. It was observed that the ANN model can predict the engine BTE and SFC quite well with correlation coefficients of about 0.96198 and 0.96237 and the mean square error values were within 1.885% which is acceptable.

R. Manjunatha et al (2010) in this paper they studied about the effectiveness of various biodiesel fuel properties an engine operating conditions on diesel engine combustion towards the formation of exhaust emissions. The performance characteristics such as brake power, brake thermal efficiency, brake specific fuel consumption, volumetric efficiency, exhaust gas temperature were measured along with regulated and unregulated exhaust emissions of CO, HC and NOx. An Artificial neural network was developed based on the available experimental data.

Yakup Sekmen et al (2006) in this paper they had studied that the fuel injection pressure is one of the significant operating parameters affects atomization of fuel and mixture development, therefore, it determines the performance and emissions of a diesel engine. Increasing the fuel injection pressure reduce the particle diameter and caused the diesel fuel spray to vaporize quickly. In this study the Artificial neural networks are used to determine the effects of injection pressure on smoke emissions and engine performance in a diesel engine.

2. Performance Analysis

Brake Thermal Efficiency

From the fig. 1, it is observed that the BTE is slightly lower than the diesel for palm oil methyl ester and its blends. The BTE is less for palm methyl ester because of less calorific value.

The brake thermal efficiency is based on BP of the engine. This efficiency gives an idea of the out put generated by the engine with respect to heat supplied in the fuel form. For CI engine brake thermal efficiency steadily increases with increase in BP.

From the fig. 1, it shows that brake thermal efficiency is low at low values of BP and is increasing with rise of BP for all blends of fuel. For a blend of 20% the brake thermal efficiency is high at low BP values when compare with other blends of fuel and is very close to diesel at high values of brake power. Hence at the blend of 20% of methyl ester the performance of the engine is good.

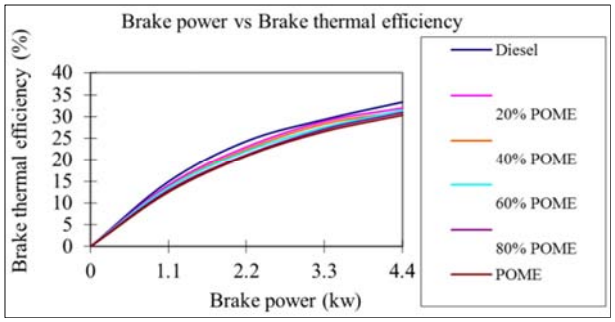

Fig. 1. *Variation of Brake Thermal Efficiency with Brake power.*

3. Emission Analysis

Emission characteristics are improved for biodiesel compared to conventional diesel except oxides of nitrogen, which is slightly higher than diesel. Biodiesel runs in any conventional unmodified diesel engine and yields about equal performance as petroleum diesel. So basically engine just runs like normal except odour. Transesterified vegetable oils have lower viscosities than the parent oils. Accordingly they get better injection process and ensure improved atomization of the fuel in the combustion chamber. Bio-diesel can be blended in any ratio for reduced emissions and the increased lubricity makes for a superior running of vehicle.

Analyzed the emission properties of palm oil methyl esters. Results of the experiments in the form of carbon monoxide (CO), Nitrogen oxides (NOx), Hydrocarbons (HC) and Smoke density for variable load conditions for various blends of palm oil methyl esters compare with the petroleum diesel in the form of graphs.

3.1. CO Emission

From fig. 2, it is observed that CO decreases with rising load for all the blends of palm oil methyl esters. If percentage of blends of palm oil methyl esters increases, CO reduces. The concentration of CO decreases with the rise in percentage of biodiesel in the fuel. This may be credited to the presence of O_2 in biodiesel, which provides sufficient oxygen for the conversion of carbon monoxide (CO) to carbon dioxide (CO_2). It can be observed that blending biodiesel 20% with diesel results in a slight reduction in CO emissions when compared to that of diesel.

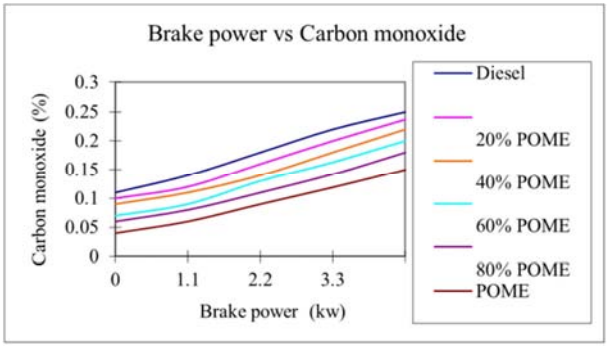

Fig. 2. *Variation of CO emission with Brake power.*

3.2. HC Emission (in PPM)

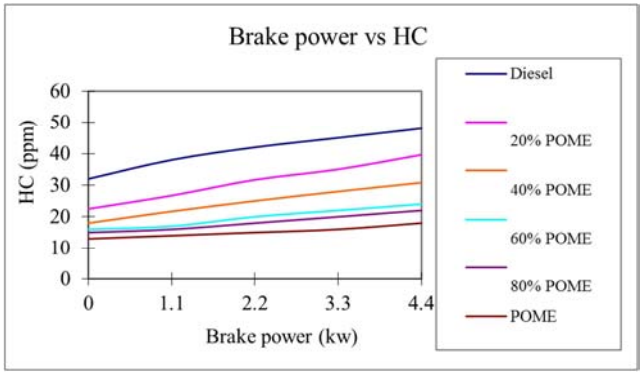

Fig. 3. *Variation of Hydrocarbon Carbon with Brake power.*

From fig. 3 it is observed that hydro carbon (HC) increases with rising load for all the blends of palm oil methyl esters. If percentage of blends of palm oil methyl esters increases, HC reduces. The hydrocarbon emissions are contrariwise proportional to the percentage of methyl ester in the fuel blend. A significant difference between methyl ester and diesel operation can be inferred. The diesel oil operation showed the highest concentrations of HC in the exhaust at all loads. Since methyl ester is an oxygenated fuel, it improves the combustion efficiency and hence reduces the concentration of hydrocarbon emissions (HC) in the engine exhaust. Blending 20% methyl ester with diesel greatly reduces HC emissions especially at rated load condition.

3.3. NOx Emission

From fig. 4, it is observed that NOx increases with rising load for all the blends of palm oil methyl esters. If percentage of blends of palm oil methyl esters increases, NOx increases. It can be seen that NOx emissions increase with increase in percentage of methyl ester in the diesel-methyl ester fuel blend. The NOx increase for methyl ester may be associated with the oxygen content of the methyl ester, since the fuel oxygen may supplement in supplying additional oxygen for NOx formation. Moreover, the higher value of peak cylinder temperature for methyl ester when compared to diesel may be another reason that might explain the increase in NO_X formation.

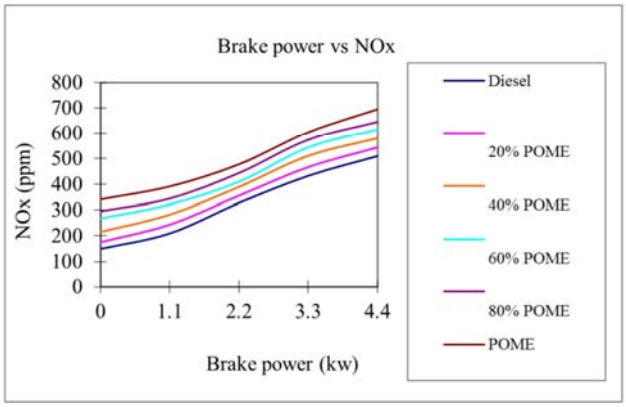

Fig. 4. *Variation of NO_X with Brake power.*

4. Artificial Neural Network (ANN)

4.1. Modeling with the ANN

The ANN technique is a mathematical or computational model based on biological neural networks. This technique is useful particularly when we deal with parameters required time and sophisticated instrument. ANN is a non-linear model and since many phenomena in industry have non-linear identity, the need for such model would be significant. An ANN model for the diesel engine with diesel and biodiesel blended fuels was developed using the 10 data gathered in test runs. In the model, 80% of the data set was randomly assigned as the training set, while the remaining 20% of data are put aside for prediction and validation.

4.2. Mean Square Error

The performance of the network in training is shown in fig. 5. the goal for the training was set to 10^-20. This ensured a suitable response. From all the networks trained, few ones could provide this condition, from which the simplest network was choosen. It is resulting that one can absolutely predict engine brake thermal efficiency and specific fuel consumption independently using the designed network. It is also observed that the ANN can provide the best accuracy in modeling the emission indices. Generally, the artificial neural network offers the advantage of being fast, accurate and reliable in predicting results, particularly when numerical and mathematical methods fail. There is also a significant simplicity in using ANN due to its power to agreement with multivariate and complicated problems. The simulated values by the model were obtained as 0.0009 of mean square error.

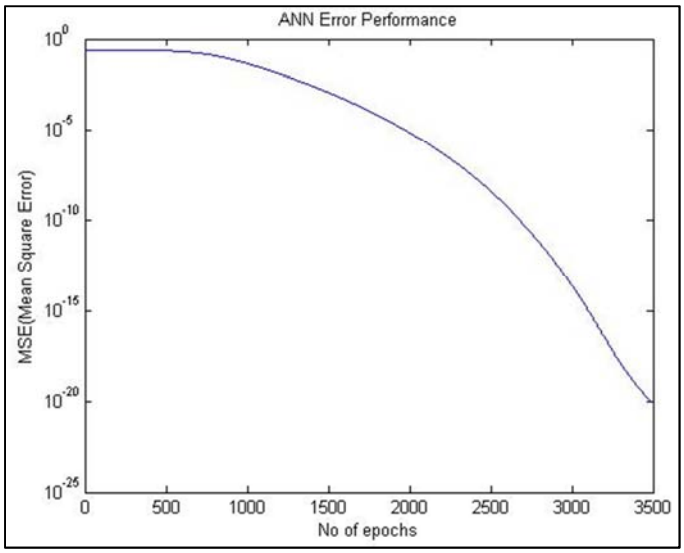

Fig. 5. *Mean Square Error.*

5. Performance Analysis by ANN

Brake Thermal Efficiency

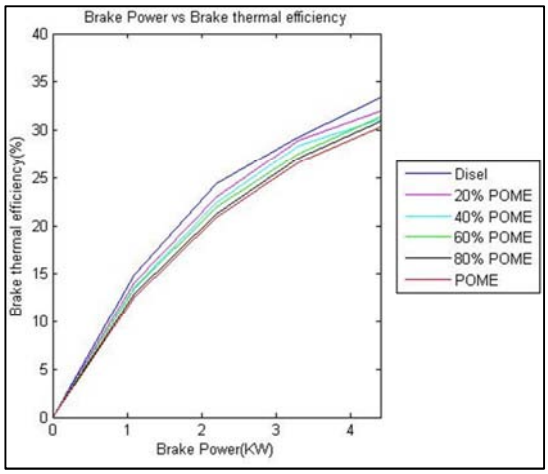

Fig. 6. *Variation of Brake Thermal Efficiency with Brake power by ANN.*

6. Emission Analysis by Ann

6.1. Carbon Monoxide

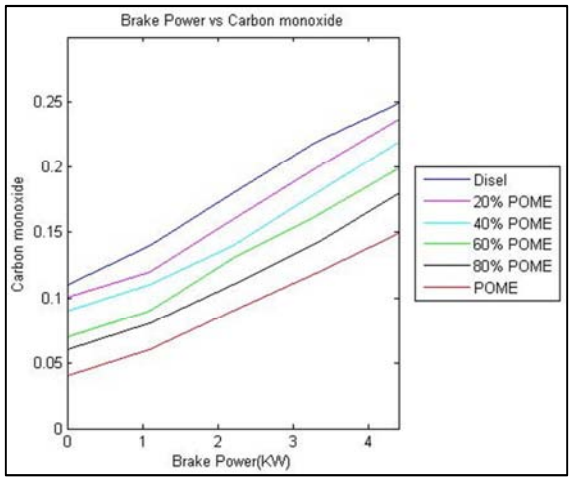

Fig. 7. *Variation of Specific fuel consumption with Brake power by ANN.*

6.2. Hydro Carbon

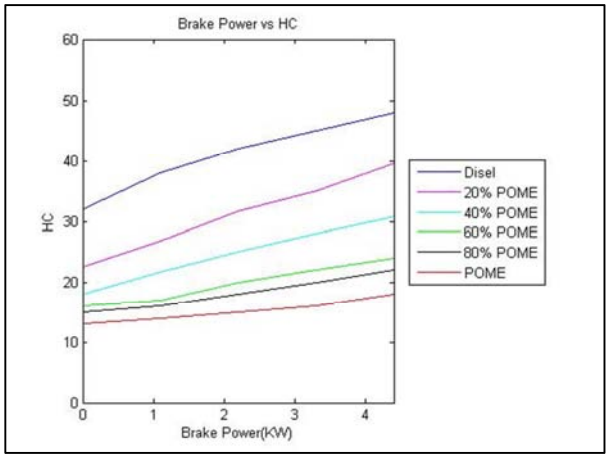

Fig. 8. *Variation of Hydrocarbon with Brake power by ANN.*

6.3. NOx Emission

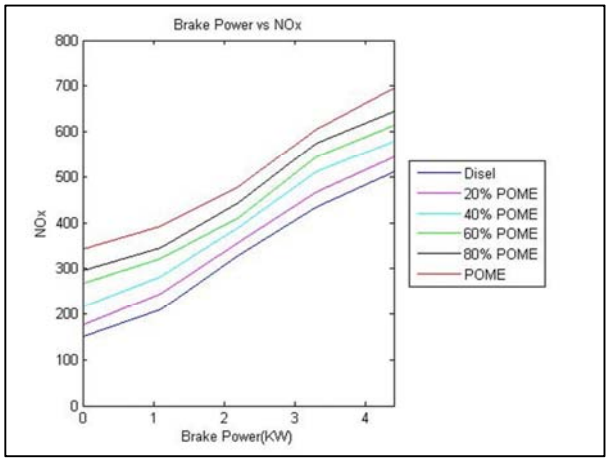

Fig. 9. *Variation of NOx Emissionwith Brake power by ANN.*

7. Conclusion

The engine has been tested under same operating conditions with diesel fuel and palm oil methyl ester fuel blends. The results were found to be comparable. The maximum brake thermal efficiency for the diesel is 33.36 and the 20% biodiesel shows the nearest value to the diesel was 31.96. The concentration of the CO and HC emissions were significantly decreased when biodiesel was used.

An Artificial neural network was developed trained with the collected data of this work. It can be concluded that the performance analysis were predicted quite well with MSE error was 0.0009. Therefore the ANN proved to be a desirable prediction method in the evaluation of engine parameters. The ANN can be used to predict the emission characteristics once the error was known from the performance analysis and it makes the method useful for predicting without any experimental setup. There is also a priority in using artificial neural networks, since other mathematical and numerical algorithms might fail due to the complexity and multivariate nature of the problem. Generally speaking, ANN provided accuracy and simplicity in the analysis of the engine performance.

Nomenclature

ANN: Artificial Neural Network
BTE: Brake Thermal Efficiency
CI: Compression Ignition
CO: Carbon monoxide
HC: Hydrocarbons
NO_X: Nitrous Oxide
POME: Palm Oil Methyl Esters
SFC: Specific Fuel Consumption

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