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Artificial Neural Network Based Modelling for Vibration Characteristics of DI Diesel Engine Using Bio-Diesel

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Abstract— The experimental determination of various properties of diesel-biodiesel mixtures is very time consuming as well as tedious process. The aim of the present work is to model the vibration characteristics of DI diesel engine using neural networks with mahuwa oil as biodiesel. An Artificial neural network (ANN) model based on the Back-Propagation algorithm is developed for vibration analysis. The data obtained during the experimental process is used to develop the ANN model. The experimental data obtained for the better performance combination of 20 % blend of Mahuwa oil (B20) with 15% hot and 20% cooled exhaust gas recirculation (EGR) and without EGR is used for modelling . Multilayer perceptron neural network with suitable architecture was used for nonlinear mapping between input and output parameters of ANN. Brake power, exhaust gas temperature, brake thermal efficiency, specific fuel consumption and cetane value of diesel and B20 blend of 15% hot and 20 % cooled EGR levels were used as input parameters to train the network using suitable activation functions. The output parameters to be predicted are vibration in various engine parts like the head, bottom and crank of the engine. The results showed that training through back propagation was sufficient enough in predicting the engine vibration. It was found that R (Regression Coefficient) values were 0.97, 0.95 and 0.94 for vibration measured in the head, bottom and crank of the engine respectively. The developed model can be used as a tool for estimating the vibration in the head, bottom and crank of the engine using diesel and biodiesel blends under varying operating conditions.

Keywords— Vibration, IC Engine, Biodiesel, Artificial neural network

I. INTRODUCTION

Day by day fast depletion, demand of fossil fuels and increase in the environment pollutions are major problems in the world. Therefore many of the research work have been carried out in the various renewable energy sources in recent years. Vegetable oil is the most important type of renewable energy sources. A rapid auto-ignition of a portion of the fuel mixture in the cylinder generates a local pressure pulse, leading to pressure oscillations, propagating across the cylinder. These oscillations create noise outside the engine, which is called ''knock''. Knocking in the engine has some unfavorable effects such as the vibration of the engine. The vibration results in a decrease in engine efficiency, considerable rise in engine specific fuel consumption, composition of the emission changes with a chance to rise in pollution and may cause structural damage to the engine in the long term.

As such a mixture of diesel and biodiesel in a specified proportion will have different properties than either of pure diesel or biodiesel [1]. It may not always be convenient to make experimentation every time in estimation of the vibration characteristics of Diesel engine using biodiesel blend. The need arises to develop a model to reduce the necessity for elaborate measurement procedures which is expensive and time consuming. An Artificial Neural Network (ANN) approach is used in present work to address the problem [2-5]. In present work, the method of back propagation neural network was examined in order to know its validity to predict the properties of diesel-biodiesel mixtures through curve fitting. Neural network architecture was examined to predict the vibration properties of diesel- biodiesel blends. The selection of a neural network to a specific problem depends upon the network topology like the number of layers, the size of each layer, and the pattern of connections and the assignment of connection strengths to each pair of connected unit sand of threshold to each unit [6-7]. In the present study the biodiesel was prepared in the laboratory and the properties of its blends were experimentally measured. The performance of the neural network was then compared with the experimental result. As modelling the vibration of the Diesel engine is the main focus of this paper, the experimental procedure involved in the data collection used for ANN model is not discussed in detail. The rest of this paper is organized as follows. Subsequent sections describe related work. The 3rd section present brief view about the experimental process involved. The 4th section is for Back-propagation Neural Network. ANN modelling is described in section 5.Performance evaluation is discussed in the 6th section. Conclusions are given in the 6th section. Conclusion is given in 7th section.

II. REVIEW OF LITERATURE

Internal combustion engine noise has always been a research interest in mechanical engineering. Reducing the noise means creating a better environment as well as a good quality engine in terms of the improved combustion process

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improved fuel injection and reduced piston slap, etc. For this purpose, there is a need to measure vibration signals of engines and analyze those Xianhua Liu et al [8].

Ghobadian et.al [9] the use of ANNs of modelling the operation of internal combustion engines is a more recent progress. This approach was used to predict the performance and exhaust emissions of diesel engines and the specific fuel consumption of a diesel engine. Artificial neural network (ANN) based modelling of diesel engine using waste cooking biodiesel fuel was used to predict the brake power, torque, specific fuel consumption and exhaust emissions of the engine [10]. Jatinder Kumar et.al [11] carried out; other tools of determination of properties of diesel-biodiesel blends were tried. A traditional statistical technique of linear regression (principle of least squares) was used to estimate the flash point, fire point, density and viscosity of diesel and biodiesel mixtures. A set of seven neural network architectures, three training algorithms along with ten different sets of weight and biases were examined to choose best Artificial Neural Network (ANN) to predict the above-mentioned properties of diesel biodiesel mixtures. The performance of both of the traditional linear regression and ANN techniques was then compared to check their validity to predict the properties of various mixtures of diesel and biodiesel. Hari Prasad et.al [12] this study deals with artificial neural network (ANN) modelling of a diesel engine to predict the exhaust emissions of the engine. To acquire data for training and testing the proposed ANN, a single cylinder, four-stroke test engine was fuelled with biodiesel blended with diesel and operated at different loads. Using some of the experimental data for training, an ANN model based on a feed forward neural network for the engine was developed. Then, the performance of the ANN predictions was measured by comparing the predictions with the experimental results which were not used in the training process.

From the literature it is clear that no neural network modelling was done to model the vibration characteristics of diesel engine using Mahuwa as biodiesel. Thus the main objective of the work is to model an artificial neural network for predicting the vibration characteristics of diesel engine used in the experimentation.

III. EXPERIMENTAL SETUP

The experimental tests were carried on a single cylinder, four strokes and water cooled, Kirlosker TV 1 diesel engine. It is coupled with an eddy current dynamometer. The dynamometer was interfaced to a control panel. The engine always runs at 1500rpm. Digital Vibration Meter Model: Equinox-VM 6360 is used to measure the vibration. Experimental tests have been carried out to evaluate the performance, and emission characteristics of a diesel engine when fuelled with biodiesel (Mahuwa blends of 20%) and diesel fuel separately. The work is carried out to measure the vibration in diesel and biodiesel at different load (20%, 40%, 60%, 80% and 100%), with 15 % hot EGR and 20% cooled EGR. The experimental test is also carried out without using EGR.

IV. Back-propagation Neural Network (BPN)

In this study, the feed-forward network was employed because of its superior classification ability. Among the feed-forward networks, BPN is the best known networks and it remains one of the most useful ones. This iterative gradient algorithm is designed to minimize the mean square error between the actual output of a multilayer feed forward perceptron and the desired output. The back-propagation algorithm includes a forward pass and a backward pass. The purpose of the forward pass is to obtain the activation value, and the backward pass is to adjust the weights and biases based on the difference between the desired and the actual network outputs. These two passes will continue iteratively until the network converges. The feed-forward network training by back-propagation pseudo-code algorithm can be summarized as follows. While error is too large

Step 1. For each training pattern (presented in random order):
Step 1.1. Apply the inputs to the network.
Step 1.2. Calculate the output for every neuron from the input layer, through the hidden layer(s), to the output layer.
Step 1.3. Calculate the error at the outputs.
Step 1.4. Use the output error to compute error signals for pre-output layers.
Step 1.5. Use the error signals to compute weight adjustments.
Step 1.6. Apply the weight adjustments.
Step 2. Periodically evaluate the network performance.

V. MODELLING WITH THE ANN

In the present study ANN model is built to study the engine behaviour in order to obtain the output parameters of vibration characteristics of DI diesel engine using Biodiesel. An ANN model for the diesel engine with diesel and biodiesel blended fuels was developed using the experimental data. There are 40 data patterns available from the experimental data of diesel engine .The values were measured experimentally using diesel and biodiesel blend with 15% Hot and 20% cooled EGR and without EGR under varying load (20%, 40%, 60%, 80% and 100%). In the model, 70% of the data set was randomly assigned as the training set, 15% of the total data patterns have been used for validation and remaining 15% is used for testing. All the input and target values were normalized to fall in the range of [0, 1]. Back propagation algorithm was chosen as the training algorithm with tansig as the activation function of the hidden layer and output function was chosen as logistic function. The Back propagation training algorithm uses the supervised training technique where the network weights and biases are initialized randomly at the start of the training phase. A network with one hidden layer and 50 neurons was used (Table 1). The six input nodes of the ANN architecture consisted of brake power, exhaust gas temperature, brake thermal efficiency, specific fuel consumption, cetane value and EGR levels (hot/cooled) of diesel and B20 blend. The cetane value is different for biodiesel and diesel. The desired outputs from the

ANN were the vibrations at three different engine positions (head, crank and bottom). Optimization algorithm used for training and testing the data patterns is implemented in Neural Network Toolbox of MATLAB 7.0. This algorithm uses the learning rate , the momentum and a goal of 0.00001 which was reached in 500 epochs were used as model parameters [6-7].

Table 1. Neural Network parameters

Network Type	Feed forward
No.Of Neurons in input layer	6
No.Of Neurons in output layer	3
No.Of Neurons in hidden layer	50
Learning rule	Back propogation
Activation function	tansig function

VI. RESULTS AND DISCUSSION

The model predicted vibrations were compared with those measured experimentally; Fig 1- 9 shows the time plot of predicted and measured vibration at various engine parts such as head, crank and bottom. The vibration of the engine in running condition with diesel as well as biodiesel implementation is measured at three positions with the help of vibration meter. The vibration is measured in terms of acceleration. The predicted vibrations were compared with those measured experimentally. The plot of predicted and measured vibration at various engine parts such as head, crank and bottom is drawn with actual value along x-axis and predicted value along y-axis.

Figure 1-3 shows the comparison of actual vibration and the vibration predicted using ANN without EGR at various load condition with diesel and biodiesel as fuel in head, crank and bottom position of the engine respectively. Figure 4-6 shows the comparison of actual vibration and the vibration predicted using ANN with 15% Hot EGR at various load condition with diesel and biodiesel as fuel in head , crank and bottom position of the engine respectively. Figure 7-9 shows the comparison of actual vibration and the vibration predicted using ANN with 20% Cooled EGR at various load condition with diesel and biodiesel as fuel in head , crank and bottom position of the engine respectively.

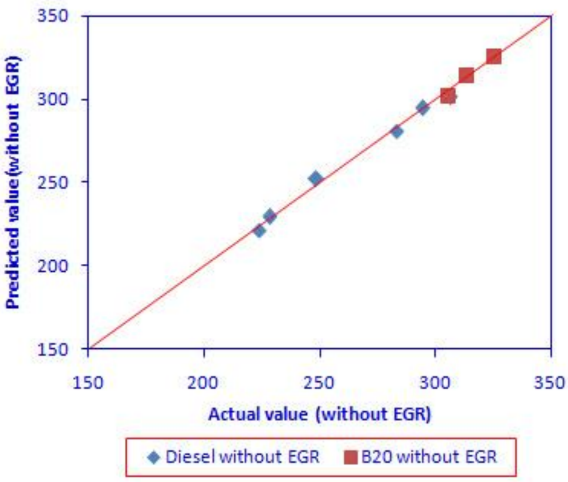

Fig 1. Actual Vs Predicted without EGR in Head position

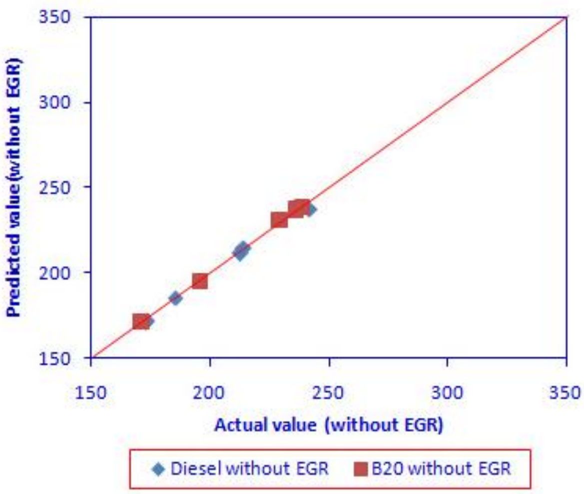

Fig 2. Actual Vs Predicted without EGR in Crank position

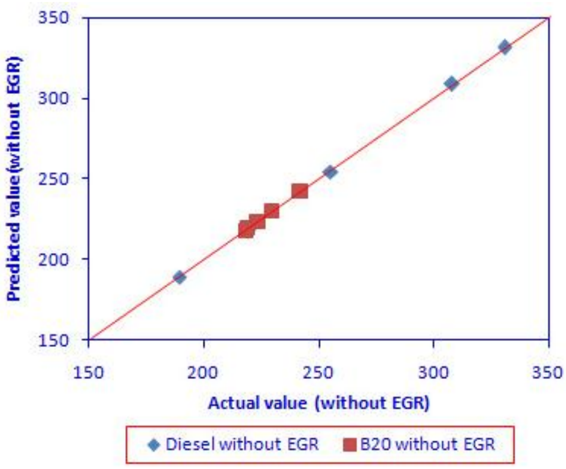

Fig 3. Actual Vs Predicted without EGR in Bottom position

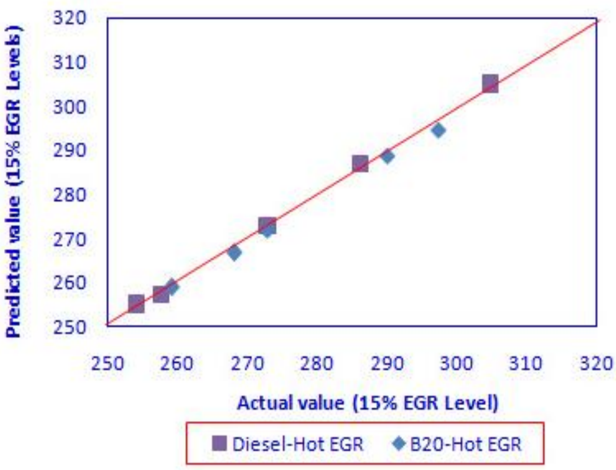

Fig 4. Actual Vs Predicted with 15% hot EGR in Head position

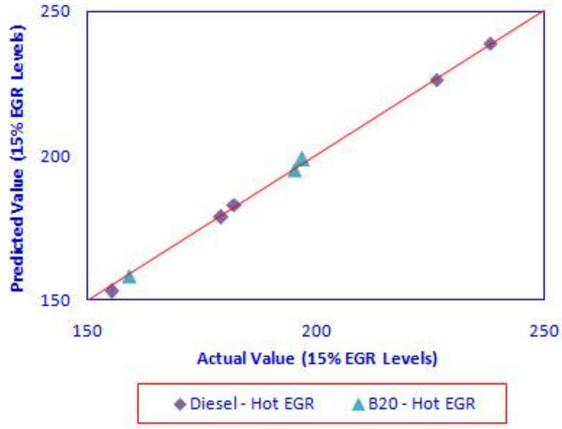

Fig 5. Actual Vs Predicted with 15% hot EGR in crank position

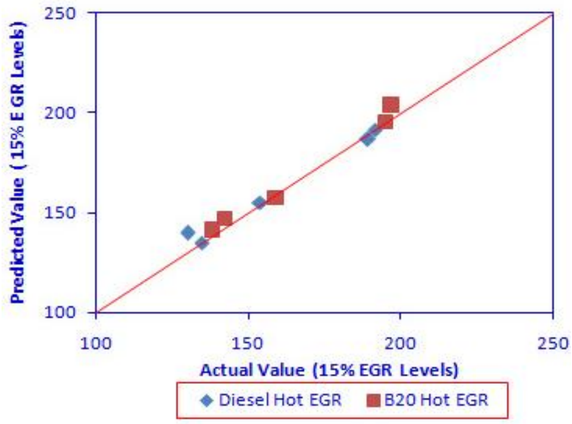

Fig 6. Actual Vs Predicted with 15 % hot EGR in bottom position

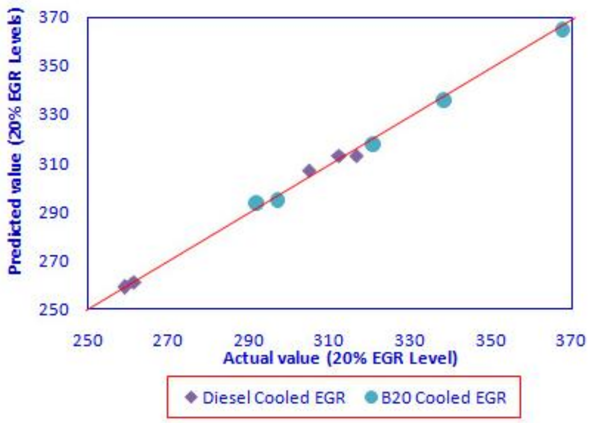

Fig 7. Actual Vs Predicted with 20% cooled EGR in Head position

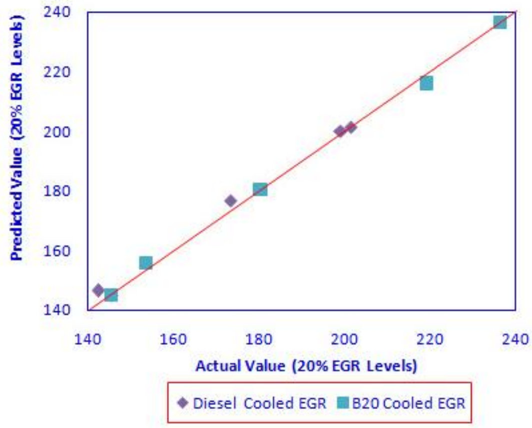

Fig 8. Actual Vs Predicted with 20% cooled EGR in crank position

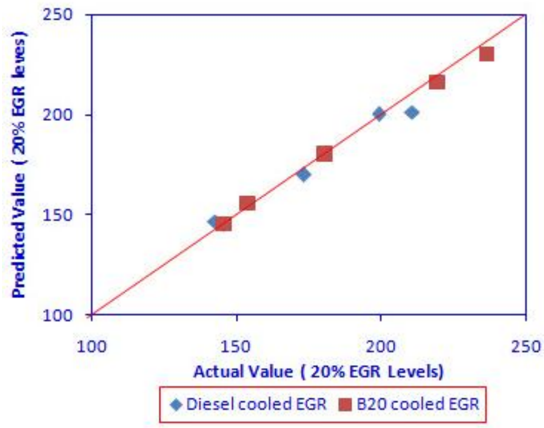

Fig 9. Actual Vs Predicted with 20% cooled EGR in bottom position

Regression statistics output characterizes the goodness of the neural network model adapted as a whole. To have a more precise investigation into the model, a regression analysis of outputs and desired targets was performed.

$$R^2 = 1 - \left[\frac{\sum_j (t_j - o_j)^2}{\sum_j (o_j)^2} \right]$$

Where t is target value, o is output value. To characterize the goodness of the neural network model adapted as a whole the regression statistics output is calculated. A regression analysis of outputs and desired targets is performed to have a more precise investigation into the model. Regression Coefficient (R) is found out to be 0.992, 0.988 and 0.980 at three different engine positions (head, crank and bottom) respectively without using EGR and Regression Coefficient (R) is found out to be 0.983, 0.978 and 0.996 at three different engine positions (head, crank and bottom) respectively with 15% Hot EGR .

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Similarly , the regression coefficient (R) is found out to be 0.955, 0.99 and 0.943 at three different engine positions (head, crank and bottom) respectively with 20% Cooled EGR .The calculated values of regression coefficient indicates the amount of variation of actual and predicted values for vibrations There is a high correlation between the predicted values by the ANN model and the measured values resulted from experimental a test, which implies that the model succeeded in prediction of the engine vibration.

VII. CONCLUSION

In this paper an attempt has been made to model engine vibration parameters using back propagation neural network. Artificial neural networks (ANNs) based models is employed on this data because of their ability to handle nonlinearity and not requiring assumptions on the input data as needed by statistical models. Regression analysis was performed on the predicted and actual vibration values at the head, crank and bottom of the engine position. Regression coefficient values measured showed that the model has succeeded in the prediction of diesel engine vibration. ANN model is thus being used as a flexible computing tool for diagnostic purposes. Thereby avoiding time consuming and costly experiments. The accuracy in terms of regression coefficient can be increased by increasing the number of training samples. In future Hybrid neural networks can be developed for vibration modelling to increase the accuracy.

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