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Validation of Experimental test results with aid of Artificial Neural Network of Palm Oil Methyl Ester-Diesel Blends as Fuel in Diesel Engine

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Abstract

The research work to check the performance of the experimental data with Artificial Neural Network (ANN). The validation of experimentation of Palm Oil Methyl Ester (POME) as fuel over Direct Injection (DI) single cylinder, four stroke diesel engine has been studied in this research. Experiments were conducted at constant speed of 1500 rpm, the load and water flow rate are varied from 0 to 10kg and 60 ml/s to 90 ml/s respectively, and performance data is generated for various fuel blends like B20,B40,B60,B80 and B100 at different compression ratios of 16:1, 17:1, 18:1, 19:1, and 20:1. For better validation, the fuel performances like Specific Fuel Consumption (SFC) and Brake Thermal Efficiency (BTE) of diesel engines are to validate with ANN. The conclusion revealed that for partial load, the specific fuel consumption is lower and brake thermal efficiency is higher at compression ratio 19 was observed for blend 80% Biodiesel and 20% Diesel (B80) when compared to B0. At maximum load the SFC and BTE was optimum at compression ratio 18 with fuel blends of B60.

Key Words:Palm oil methyl ester, compression ratio, specific fuel consumption, brake thermal efficiency, diesel engine, artificial neural network.

1. Introduction

The motto of this study is to find out the replacement of diesel fuel due to energy and environmental crises in India. The alternate fuel is a new solution is to replacement of diesel usage in compression ignition engine. Due to energy demand the need of alternate fuel research is essential in India and World. From previous studies,[1] Lin Lin et al., reviewed the developments of biodiesel in past and present challenges. Also discussed the possible environmental and social impacts of food security, land change and water source.[2] Zhang et al reviewed that the biodiesel produced from waste cooking oil leads cost reduction. By applying acid-catalyzed process using waste cooking oil proved to be technically feasible. [3] Muralidharan and Vasudevan, optimized the performance and emission characteristics of varying compression ratio with waste sunflower oil methyl ester.[4] Amarnath and Prabhakaran, results discussed that at higher compression ratios the engine gives lesser emissions and better performance. Genetic algorithm optimization technique was used to optimize the parameters.[5] Nagaraja et al, Investigate the increasing the engine parameters increases the brake thermal efficiency and reduces brake specific fuel consumption with lower emissions for methyl ester of palm oil as compared to diesel.[6] Yilmaz et al, conduct the experimentation of ethanol concentrations with different blends of biodiesel–diesel–ethanol. With the help of engine load emission characteristics of biodiesel–diesel–ethanol blends were compared diesel.[7] Nagaraja et al, Compared the two type of methyl ester fuel with diesel at different compression ratio and maximum load. The results concluded that methl ester based fuel give best performance than diesel at compression ratio 19.[8] Parlak et al. (2006) studied the ability of an ANN model, using a back propagation learning algorithm, to predict specific fuel consumption and exhaust temperature of a diesel engine for various injection timings. The proposed new model was compared with experimental results. It was concluded that a well-trained neural network model provides fast and consistent results.

The objective of the study was to develop an ANN model to predict the performances of palm oil methyl ester–diesel blends. The literature concluded that most of the researches are carried their work based on the performance studies of different biofuels without ANN models. The evaluating the performance of Palm Oil Methyl Ester (POME) with different compression ratio is very limited using ANN technique. Hence the study of the characteristics of POME on diesel engine with different compression ratio is essential. The research focus on the test results of biodiesel is validating with aid of ANN model. The different blends of POME and diesel fuel are tested and the following validation test are carried out

- The performance characteristics such as SFC and BTE test results are validate with the aid of ANN model with respect to Load (L), Compression Ratio (r), Blends (V), Water flow (W_f).

2. Materials and Methods

Development of Neural Network Model

ANN is one of the most powerful computer modeling techniques based on statistical approach, currently being used in many fields of engineering for modeling complex relationships which are very difficult to describe with physical models. The attraction of neural networks comes from their remarkable information, processing characteristics pertinent mainly to non-linearity, high parallelism, fault and noise tolerance and learning and generalized capability. There has been a continual increase in the research towards the application of artificial neural networks in modeling and monitoring of performance of CI engine (Kiani et al. 2010; Gholamhassan et al.2007).

ANN Model for Performance Characteristics

The four steps used in the development of the ANN model for specific fuel consumption and brake thermal efficiency are as follows (Math Work Inc., 2008)

- Collection of input/output data set
- Preprocessing of input/output data set
- Neural network designing and training
- Testing of the network

3. Results and Discussions

Neural Network Designing and Training

The experimental data were to be separated into training and testing data. There were no general guidelines available which could be followed to measure the ratio between the amount of training and testing samples. As per the recommended ratio of training and testing, this can be given in percentage such as 90%: 10%, 85%: 15%, 80:20% and 70%: 30%. Hence out of 30 experimental data 70% was used for training, 15% for testing and 15% for validation. So the recommended amounts of training, testing and validation samples were 20, 5 and 5 respectively (Shivakumar et al 2010 ;Zurada, 1997). The input and output data for the training, testing and validation samples are shown in Table 10.1.

Table 1: Design Matrixes for an ANN Model with Measured Value and Predicted Value of Performance Parameters

S. No.	Design matrix				Performance of measured values		Performance of Predicted values	
	V	r	L (kg)	wf (ml/s)	SFC (kg/kWhr)	BTE (%)	SFC (kg/kWhr)	BTE (%)
1	40	17	2.5	60	0.497	17.412	0.497	17.021
2	80	17	2.5	80	0.509	18.046	0.53	18.654
3	40	19	2.5	80	0.486	17.818	0.45	20.468
4	80	19	2.5	60	0.486	18.957	0.486	19.269
5	40	17	7.5	80	0.289	29.953	0.289	27.266
6	80	17	7.5	60	0.270	34.061	0.256	34.462
7	40	19	7.5	60	0.249	34.683	0.29	34.286
8	80	19	7.5	80	0.258	35.611	0.256	34.241
9	40	17	2.5	80	0.607	14.265	0.576	16.196
10	80	17	2.5	60	0.505	18.240	0.479	17.502
11	40	19	2.5	60	0.475	18.247	0.451	19.585
12	80	19	2.5	80	0.476	19.365	0.522	20.246
13	40	17	7.5	60	0.258	33.511	0.245	32.867
14	80	17	7.5	80	0.259	35.567	0.246	34.312
15	40	19	7.5	80	0.248	34.849	0.235	34.371
16	80	19	7.5	60	0.246	37.418	0.233	37.484
17	20	18	5	70	0.302	27.869	0.31	26.866
18	100	18	5	70	0.340	28.537	0.323	28.928
19	60	16	5	70	0.347	25.724	0.329	23.695
20	60	20	5	70	0.316	28.219	0.33	25.598
21	60	18	0	70	0	0	0	0
22	60	18	10	70	0.252	35.355	0.239	34.11
23	60	18	5	50	0.296	30.174	0.281	28.602
24	60	18	5	90	0.308	28.948	0.292	29.602
25	60	18	5	70	0.305	29.267	0.36	29.21
26	60	18	5	70	0.303	29.226	0.3	28.98
27	60	18	5	70	0.299	29.257	0.32	29.22
28	60	18	5	70	0.301	29.217	0.31	29.602
29	60	18	5	70	0.304	29.247	0.34	28.56
30	60	18	5	70	0.303	29.257	0.32	28.99

Network Architecture of Performance Characteristics

The next step was to decide the suitable network structure for SFC and BTE. The network structure was usually designed based on trial and error. The process of trial and error was carried out by adjusting the number of nodes of hidden layer of the network structure. Though it was free to check the network with any number of nodes in the hidden layer, however it was subject to the complexity of the mapping, computer memory, computation time and the desired data control effect. If too many nodes were used it may result in waste of computer memory and computation time, while few nodes may not provide the desired data control effect. Hence, the trial and error in this study were limited to one network, which is 4-10-2. The networks were created in MATLAB 7.6. The network architectures are shown as Figure 1 (Sayin et al 2007).

Performance and Error Analysis

Figure 2 shows the performance and error graph of SFC and BTE of network 4-10-2. The network was trained for 174 iterations and the best validation performance was 32.0997. It was obtained at 174 epochs. The error percentage of this network is in the range of -0.45% to 0.50%. This is shown in Figure 3 and 4. (Ganapathy et al 2008; Yusaf et al 2010).

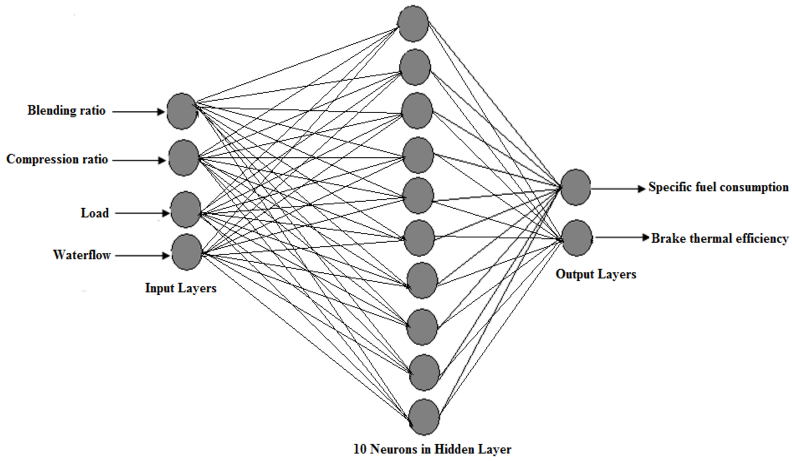

Figure 1: Network Architecture Showing Ten Neurons in the Hidden Layer

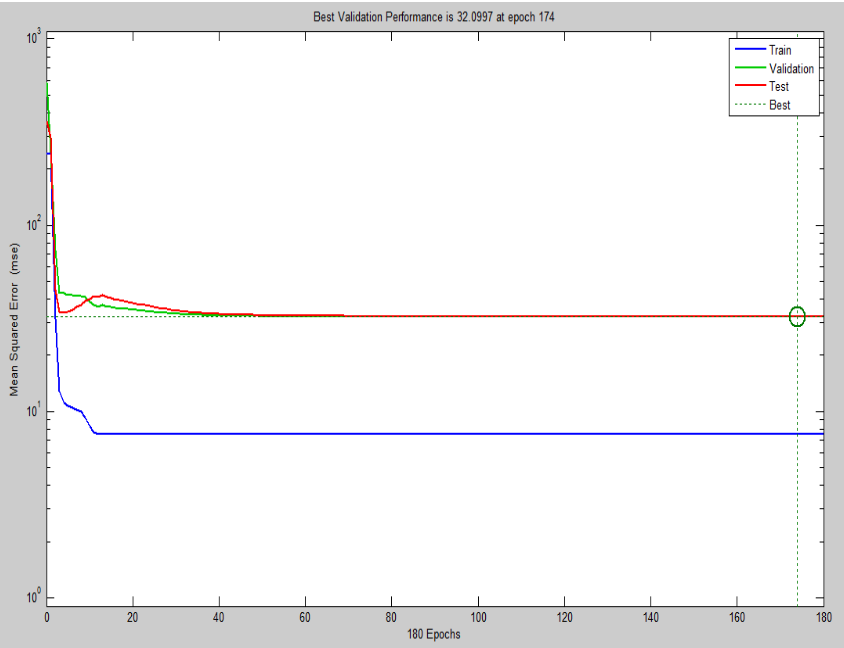

Figure 2: Performance Graph of Network 4-10-2

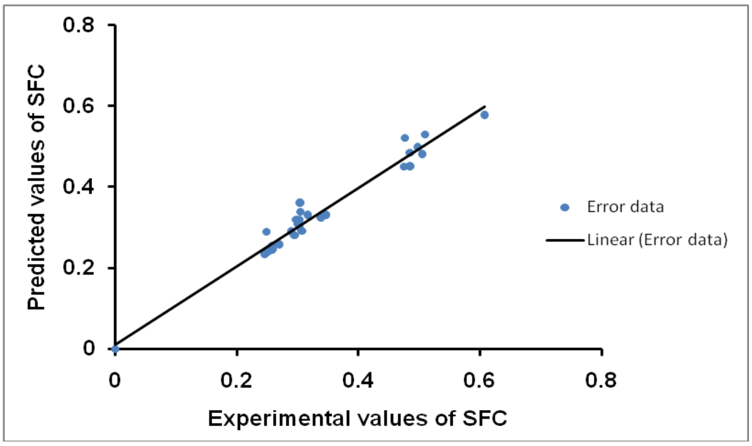

Figure 3: Error Graph of Network 4-10-2

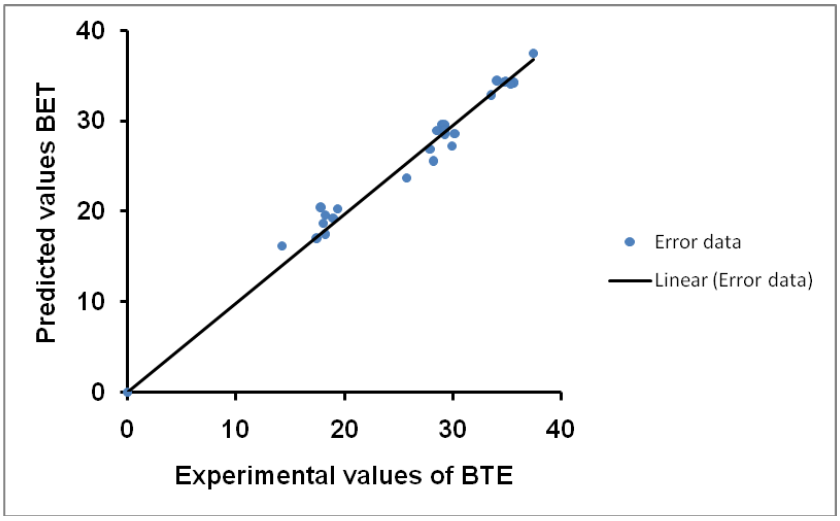

Figure 4: Error Graph of Network 4-10-2

It is observed that a predicted value of specific fuel consumption and brake thermal efficiency was obtained for training, testing, and validation of all the data. The percentage error was within the limits of 0.05%. Hence there exists a close relationship between the experimental and predicted values. This indicates that the network 4-10-2 is suitable for the prediction of engine performance parameters of specific fuel consumption and brake thermal efficiency.

Validation of Results

Confirmatory tests were conducted with the same experimental data and to validate the accuracy of the results obtained. The results of confirmatory tests are presented in Table 2.

Table 2: Results of Confirmatory Tests

Test No	Process Parameters						Specific fuel consumption		Brake thermal efficiency	
	B	***r***	***L***	W_f	Observed Values SFC	Observed Values BTE	predicted value **(ANN model)**	**% Error**	predicted value **(ANN model)**	**% Error**
1	60	18	10	70	0.252	35.35	0.239	0.013	34.11	1.24
2	80	19	7.5	60	0.246	37.41	0.233	0.013	37.48	-0.07
3	40	17	7.5	60	0.258	33.51	0.245	0.013	32.86	0.65
Mean Error								0.013		1.82

From the confirmatory tests, it was found that the ANN model were able to predict the performance parameters with high accuracy.

4. Conclusion

These research focused on the development of the ANN model for predicting performance of diesel engines. It has been found in the analysis of neural networks that the performance of the network highly depends on the number of neurons in the hidden layer. From the analysis, the network which had high accuracy in predicting SFC and BTE was identified.

- The models developed to predict the performance characteristics have high accuracy. This has been validated by conducting confirmatory tests. The direct and interactive effects of the process parameters were presented in graphical form. This helped to understand the behavior of the process parameters on performance characteristics. The algorithm which produced the accurate result was identified. ANN technique was successfully employed to develop neural network model so as to predict specific fuel consumption and brake thermal efficiency.
- Fractional factorial with 30 experimental runs was successfully employed to collect data for developing the ANN model.
- A correlation coefficient of 1 was obtained for training, testing, validation and all other relevant data. Hence, there exists a close relationship between the experimental data and the developed model.
- It has been inferred from the network analysis that by varying the number of neurons in the hidden layer and by using the same training algorithm it is possible to predict different values for SFC and BTE.
- Confirmatory tests were conducted to validate the regression model and ANN models and a mean error of 0.013% and 1.82% were observed for the regression and ANN models, respectively.

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