Comparison of Statistical and Neural Network Techniques in Predicting Physical Properties of Various Mixtures of Diesel and Biodiesel

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Abstract: - The experimental determination of various properties of diesel-biodiesel mixtures is very time consuming as well as tedious process. Any tool helpful in estimation of these properties without experimentation can be of immense utility. In present work, 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 were then compared to check their validity to predict the properties of various mixtures of diesel and biodiesel.

Key Words: - Biodiesel, Artificial Neural Network, Principle of least squares, Diesel, Linear Regression.

I INTRODUCTION

Fossil-diesel is depleting very fast and the biodiesel is quickly picking up the market to bridge the gap. Whereas, the biodiesel has the advantage of being potential renewable source of energy, is also known to be non-toxic, eco-friendly, and easy to store and transport and has better lubricity properties [1]. However, it has the disadvantages of high cost compared to petroleum diesel, reduced cold flow properties, detergent characteristics in fuel tank may block fuel ways in the fuel injection system and high viscosity may affect the atomization process in the engine [2]. Biodiesel is completely miscible with diesel oil, thus allowing blends of diesel and biodiesel in any percentage, which may be used in various applications [3]. The various properties of blends like flash point, fire point, viscosity and density are of immense importance as they affect the transportation, storage, handling, atomization and combustion. As such a mixture of diesel and biodiesel in a specified proportion will have different properties than either of pure diesel or biodiesel [4]. It may not always be convenient to make experimentation every time while switching over from one blend to another. Any tool helpful in estimation of these properties without experimentation can be of immense utility. A traditional linear regression analysis using principle of least squares and an Artificial Neural Network (ANN) approach is used in present work to address the problem [5-8].

In present work, the method of least squares was examined in order to know its validity to predict the properties of diesel-biodiesel mixtures through curve fitting. A set of seven neural network architectures, three training algorithms along with ten different sets of weight and biases were examined to predict the physical properties of diesel-bidiesel blends. It is of practical importance to make a comparison of both the techniques for selection of a better method of estimation of the mixture properties. The selection of a neural network to a specific problem depends upon the network topology -that is, 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 units and of threshold to each unit [9-13].

2 SCOPE OF PRESENT WORK

In the present study the biodiesel was prepared in the laboratory and the properties of its blends were experimentally measured. A linear regression analysis of the obtained data was made to estimate the properties of diesel-biodiesel blends. A set of seven ANNs with different training algorithms, weights and biases were examined to select the ANN to give the best estimation of properties of diesel-bidiesel blends. The performance of the best neural network was then compared with the traditional least squares method.

3 MATERIALS AND METHODS

Biodiesel was prepared from soybean oil by the trans-esterification process, using methanol, in the presence of basic catalyst [14-16]. Different blends were made from the biodiesel and diesel with varying composition. The flash point and fire point were measured using Pensky-Marten Apparatus. The viscosity was measured using Redwood viscometer and calibrated specific gravity bottle was used to measure density. The values of different properties for various blends are shown in Table 1.

Table 1 Experimental value of properties of various blends of diesel and biodiesel.

Mixture		Flash Point (°C)	Fire Point (°C)	Viscosity (cSt)	Density (g/ml)
Biodiesel (% v/v)	Diesel (% v/v)				
00	100	55.4	63.0	5.27	0.8424
10	90	55.6	66.0	6.21	0.8459
20	80	56.0	66.2	7.12	0.8504
30	70	57.2	67.0	7.40	0.8545
40	60	58.0	69.0	7.76	0.8583
50	50	59.0	70.0	8.25	0.8617
60	40	60.1	71.2	8.93	0.8666
65	45	61.7	73.3	9.52	0.8692
70	30	63.2	75.3	10.16	0.8720
75	25	66.4	78.2	10.41	0.8743
80	20	70.0	81.0	10.53	0.8746
85	15	71.2	82.3	10.81	0.8765
90	10	72.0	83.2	11.07	0.8790
95	05	76.2	85.2	11.38	0.8819
100	00	80.0	87.0	11.63	0.8847

The data available in Table 1 was used to draw a scattergram between percentages of biodiesel (in diesel-biodiesel mixtures) and corresponding flash point, fire point density and viscosity respectively. A linear relation was observed in each case. The equation of line which best fits was found using principle of least squares in each case. The linear equations obtained were then used to predict the properties of diesel-biodiesel mixtures.

4 NEURAL NETWORKS: FORMULATION AND SELECTION

Seven numbers of neural networks having different architecture as shown in Table 2 were used. They were trained using three training algorithms i.e. Batch Gradient Descent with Momentum, Levenberg-Marquardt and Scaled Conjugate Gradient. The each algorithm with ten different sets of weights and biases was used to train each neural network for 1000 epochs using experimental values of properties as training data. The goal (Mean Square Error) was used to evaluate the performance of each neural network.

The combination of neural network architectures, training algorithms, weights and biases with minimum goal was selected as the desired neural network. In order to check its validity the blend properties of fresh samples were predicted using selected neural network and compared with the experimental measurements. The selected neural network was further generalized using early stopping technique to enhance its performance and was further used to predict the properties of diesel and biodiesel mixtures.

Table 2 Different Neural Network used

Neural Network	Architecture
NN1	2-1-4
NN2	2-2-4
NN3	2-3-4
NN4	2-4-4
NN5	2-5-4
NN6	2-6-4
NN7	2-7-4

5 RESULTS AND DISCUSSION

Table 3 summarizes the comparison between the experimental (actual) values of the properties and values of properties predicted using method of least squares.

It was found during the study of performance of seven neural networks that the best combination of architecture and training algorithm for the present problem is NN7 (2-7-4) and Levenberg-Marquardt respectively. Table 4 indicates the comparison between the values predicted by best neural network (i.e. NN7 having best combination of neural network architecture, training algorithm, weights and biases) and the actual values found by laboratory experiments for different mixtures. The selected ANN was then generalized with early stopping technique, in order to avoid over fitting for better performance.

Table 3 Comparison between actual properties found by experimentation and properties predicted by using principle of least squares.

Mixture		Flash Point (°C)		Fire Point (°C)		Viscosity (cSt)		Density (g/ml)	
Biodiesel (%v/v)	Diesel (%v/v)	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
25	75	56.5	56.5	66.3	66.7	7.29	7.03	0.8523	0.8523
35	65	57.8	58.8	67.2	69.0	7.57	7.65	0.8563	0.8565
45	55	58.5	61.1	69.4	71.4	8.09	8.28	0.8594	0.8606
55	45	59.5	63.4	70.8	73.81	8.56	8.90	0.8640	0.8648

Table 4 Comparison between actual properties and properties predicted using ANN

Mixture		Flash Point (°C)		Fire Point (°C)		Viscosity (cSt)		Density (g/ml)	
Biodiesel (%v/v)	Diesel (%v/v)	Actual	Predicted	Actual	Predicted	Actual	Predicted	Actual	Predicted
25	75	56.5	56.0	66.3	66.2	7.29	7.12	0.8523	0.8504
35	65	57.8	57.2	67.2	67.0	7.57	7.40	0.8563	0.8545
45	55	58.5	58.0	69.4	68.9	8.09	7.78	0.8594	0.8586
55	45	59.5	61.6	70.8	73.3	8.56	9.53	0.8640	0.8689

Table 5 Mean Square Error after Generalization.

Property	Mean Square Error	
	Least-squares	ANN
Flash point	5.74	0.16
Fire point	4.11	0.74
Viscosity	0.06	0.02
Density	5.3E-07	5.54E-06

Table 5 provides the information about mean square error in prediction of individual properties using principle of least square and generalized neural network. It is clear that individual mean square error is comparatively much less in case of neural network than principle of least squares. Figure 2, 3, 4 & 5 shows the comparison between the experimental values and predicted values of flash point, fire point, viscosity and density respectively in case of ANN as well as principle of least squares.

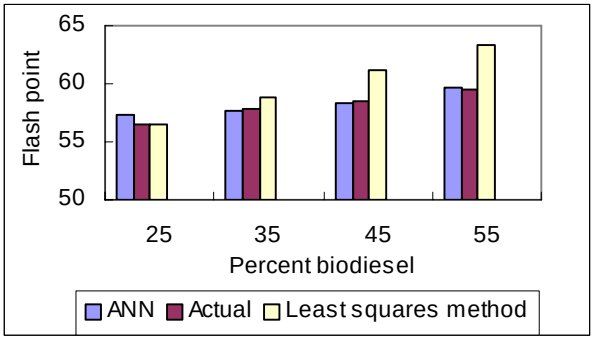

Fig. 2 Parity plot for flash point

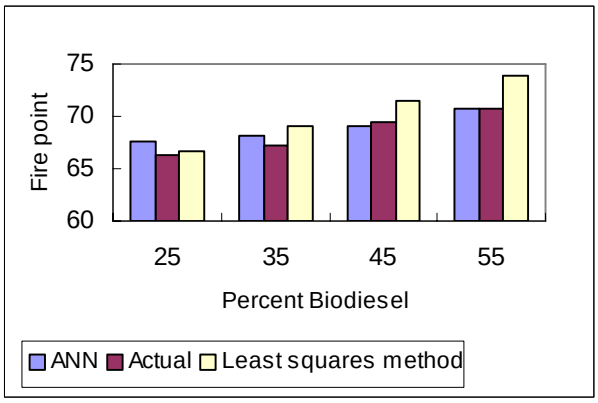

Fig.3 Parity plot for fire point

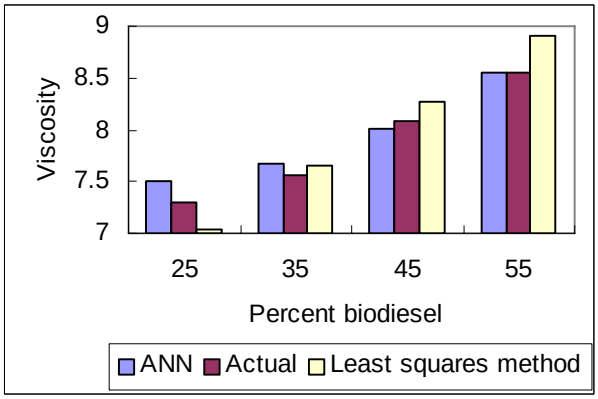

Fig.4 Parity plot for viscosity

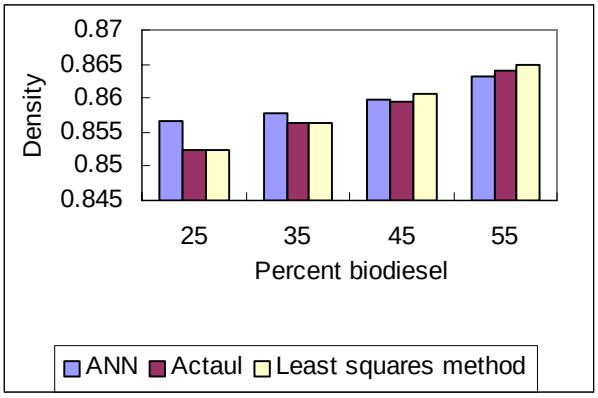

Fig.5 Parity plot for density

6 CONCLUSIONS

The results show that the ANN is a better choice for this particular system. It is clear from figure 2, 3, 4 and 5 that the predicted and experimental values of the properties have negligibly small error in case of artificial neural network and it gives a better estimation of said properties than statistical technique of cure fitting (principle of least squares). It can be inferred that the neural network NN7 (2-7-4) along with Levernberg-Marquardt algorithm can be a better choice over principle of least squares to predict the above-said properties of various mixtures of diesel and biodiesel. The performance of neural network may further be improved by adjusting the other training parameters like goal, epochs, learning rate, magnitude of the gradient etc.

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