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Prediction of biodiesel fuel properties from its fatty acids composition using ANFIS approach

Mostafa Mostafaei

Mechanics of Biosystems Engineering Department, Agricultural Faculty, Razi University, Iran

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ABSTRACT

Biodiesel is renewable fuel, environment-friendly and a potential substitute for petroleum diesel. The biodiesel properties are based on the type of used oil and its structure. The aim of this study is to model and predict biodiesel properties such as kinematic viscosity, iodine value, cloud point and pour point from fatty acids composition using ANFIS approach. The input variables were carbon number (Cn), the number of double bonds (dn), wt% of mono unsaturated fatty acids (MU), wt% of poly unsaturated fatty acids (PU), wt% of saturated fatty acids C0, temperature (T), and molar weight (Mw). The performance of developed ANFIS model was compared using statistical criteria such as coefficient of determination (R^2), root mean square error (RMSE) and mean absolute percent error (MAPE). It was determined that the coefficient of determination, R^2 related to kV, IV, CP, and PP were 0.989, 0.996, 0.938, and 0.981 respectively. The RMSE and MAPE criteria were ranges between 0.28 and 2.15 and 0.25–0.62 in the order already mentioned. Consequently, the results show that developed ANFIS models have a higher accuracy and predictive ability.

1. Introduction

Reduction of conventional fossil fuel reserves, global warming, increasing greenhouse gas emissions and rising costs of fossil fuels, have made the biomass resources more attractive [1]. The increasing energy demand and reducing oil reserves, the liquid biofuels such as biodiesel and bioethanol has stayed at the forefront of alternative fuels. Biodiesel is renewable fuel, environment-friendly and a potential substitute for petroleum diesel, which is produced from the reaction between vegetable oils or animal fats and short chain alcohols such as methanol or ethanol in the presence of alkaline catalysts. The obtained fuel can be used without major changes in the structure of the diesel engines [2,3]. This chemical reaction is called alcoholysis or transesterification. The purpose of the transesterification reaction is to reduce the viscosity of the oil. The physical and chemical properties of the biodiesel are based on the type of used oil and its structure [4]. The properties such as viscosity, iodine value, saponification value, density, cetane number, flash point, cloud point and pour point are some of the important quality parameters of biodiesel.

There are different methods to determine the quality parameters of biodiesel. The experimental procedures are not difficult but require considerable time and expense. As well as, the development of methods aimed at predicting these parameters has increased. A good model provides not only a rapid estimation of fuel properties but helps in the further development and guiding for an ideal biofuel. So a straightforward and accurate model is greatly desirable.

Gopinath et al. developed a multiple linear regression model to predict the iodine value and saponification value of different biodiesels. The prediction errors of their model were less than 3.4% [1]. Phankosol et al. presented an empirical equation for estimation of biodiesel viscosity from its carbon number and number of double bonds at different temperatures. The average absolute deviation (AAD) estimated for biodiesel fuels were 6.95% [5]. Rocabruno-Valdés et al. proposed models based on artificial neural network (ANN) to predict the density, dynamic viscosity, and cetane number of biodiesel, while the mean squared error (MSE) in the validation stage was 1.842 10–3 [6]. Talebi et al. developed a new software package, the Biodiesel Analyzer© Version 1.1, for predicting 16 different properties of biodiesel based on the fatty acid methyl ester profile [7]. Hong et al. used the fatty acid alkyl esters of biodiesels to estimate the fuel properties. The average absolute errors (AAE) of biodiesel characteristics were from 0.14% to 7.5% [8].

Today, the ANFIS procedure is used for modeling phenomena in various sciences, especially in the field of renewable energies, combustion, performance, and emissions of engine etc. [9–14]. Sohpal and Singh used ANFIS approach to predict amount of catalyst and time for reaction through a batch reactor operation [15]. Up to now, the ANFIS-based model has not been provided for predicting biodiesel fuel characteristics [16]. Of course, in our previous works, we have been focusing on the use of ANFIS in the biodiesel production process [17,18].

E-mail addresses: b.mostafaei@razi.ac.ir, bouck58@yahoo.com.

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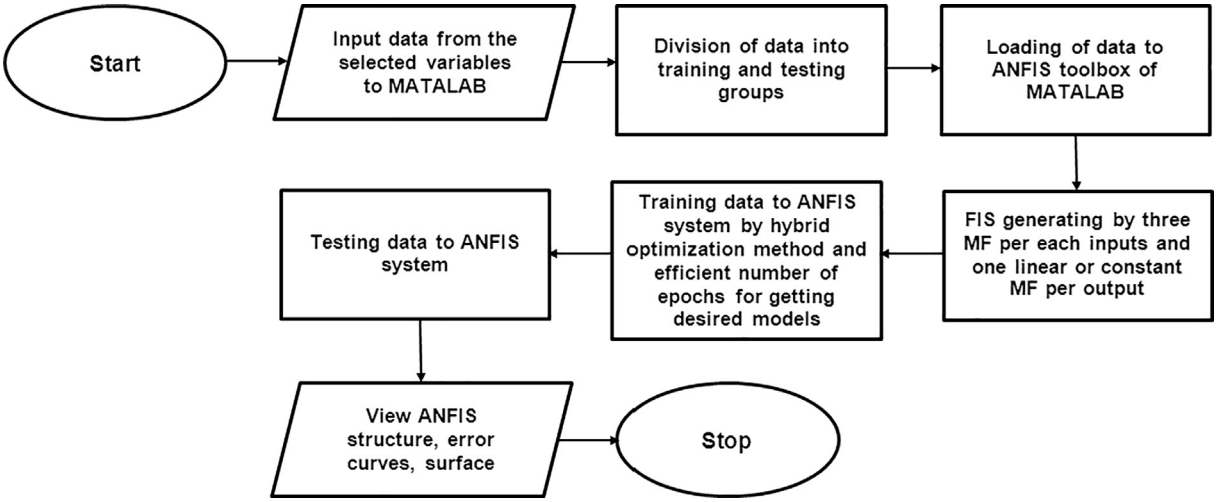

Fig. 1. Flowchart for ANFIS modeling.

Table 1
The experimental data used for predicting the kinematic viscosity of biodiesel.

Ref.	Cn[a]	dn[b]	T[c]	μ (target)	M (this study)	Ref.	Cn[a]	dn[b]	T[c]	μ (target)	μ (this study)
Training data											
[5]	17.82	1.51	293.15	6.45	6.68	[5]	17.68	1.09	333.15	3.26	3.31
[5]	17.82	1.51	313.15	4.10	4.17	[5]	17.68	1.09	343.15	2.81	2.83
[5]	17.82	1.51	333.15	2.87	2.97	[5]	17.68	1.09	353.15	2.58	2.54
[5]	17.82	1.51	353.15	2.15	2.15	[5]	14.10	0.24	313.15	2.87	2.84
[5]	17.82	1.49	293.15	7.07	6.81	[5]	14.10	0.24	333.15	2.05	2.09
[5]	17.82	1.49	313.15	4.41	4.27	[5]	14.10	0.24	353.15	1.55	1.55
[5]	17.82	1.49	333.15	3.05	3.04	[5]	14.10	0.24	373.15	1.22	1.21
[5]	17.82	1.49	353.15	2.24	2.20	[5]	17.96	1.34	313.15	4.47	4.52
[5]	17.96	1.05	293.15	7.95	7.96	[5]	17.96	1.34	333.15	3.00	3.03
[5]	17.96	1.05	313.15	4.87	4.90	[5]	17.96	1.34	353.15	2.16	2.08
[5]	17.96	1.05	333.15	3.33	3.27	[5]	17.96	1.34	373.15	1.63	1.67
[5]	17.96	1.05	353.15	2.45	2.47	[5]	17.49	1.3	313.15	4.23	4.29
[5]	17.86	1.54	293.15	6.83	6.85	[5]	17.49	1.3	333.15	2.93	2.92
[5]	17.86	1.54	313.15	4.29	4.29	[5]	17.49	1.3	353.15	2.18	2.07
[5]	17.86	1.54	333.15	2.98	3.01	[5]	17.49	1.3	373.15	1.69	1.74
[5]	17.86	1.54	353.15	2.21	2.12	[5]	17.80	1.54	313.15	4.63	4.56
[5]	17.17	0.67	313.15	4.92	4.87	[5]	17.80	1.54	333.15	3.20	3.28
[5]	17.17	0.67	323.15	3.79	3.89	[5]	17.80	1.54	353.15	2.37	2.38
[5]	17.17	0.67	333.15	3.23	3.19	[5]	17.80	1.54	373.15	1.84	1.86
[5]	17.17	0.67	343.15	2.77	2.75	[5]	14.58	0.21	313.15	3.19	3.21
[5]	17.17	0.67	353.15	2.56	2.57	[5]	14.58	0.21	333.15	2.25	2.25
[5]	17.68	1.09	313.15	4.96	4.81	[5]	14.58	0.21	353.15	1.69	1.64
[5]	17.68	1.09	323.15	3.82	3.97	[5]	14.58	0.21	373.15	1.32	1.35
Test data											
[19]	17.82	1.51	373.15	1.68	1.72	[19]	17.68	1.09	303.15	6.32	5.84
[19]	17.82	1.49	373.15	1.76	1.77	[19]	14.10	0.24	293.15	4.41	4.11
[19]	17.96	1.05	373.15	1.88	2.49	[19]	17.96	1.34	293.15	7.43	7.33
[19]	17.86	1.54	373.15	1.71	1.63	[19]	17.49	1.30	293.15	6.74	7.04
[19]	17.17	0.67	293.15	7.93	7.94	[19]	17.80	1.54	293.15	7.42	7.14
[19]	17.17	0.67	303.15	6.26	6.11	[19]	14.58	0.21	293.15	5.00	4.80
[19]	17.68	1.09	293.15	8.00	7.72						

[a] Calculated from Eq. (1).
[b] Calculated from Eq. (2).
[c] The absolute temperature, in Kelvin (K).

The purpose of this manuscript is to model and predict biodiesel properties such as kinematic viscosity, iodine value, cloud point and pour point from fatty acid methyl esters mixture. The ANFIS (adaptive network based fuzzy inference system) approach was used for modeling process. The obtained results were compared with the consequences of other methods presented in literature such as [1,5,19–22]. Firstly, the experimental data used in this research were obtained from various literature and after the modeling process, the obtained results were compared to the others model. This comparison and analysis were performed using statistical criteria such as coefficient of determination (R^2), root mean square error (RMSE) and mean absolute percent error (MAPE).

2. Materials and methods

2.1. Experimental database

The kinematic viscosity data was obtained via published literature