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Fuzzy logic model for prediction of cold filter plugging point of biodiesel from various feedstock

Filiz Al-Shanableh[a]*, Ali Evcil[b], Mahmut Ahsen Savaş[c]

[a,b,c]*Mechanical Engineering Department, Near East University, Nicosia, 99138, North Cyprus*

Abstract

The present study investigates the potential of Fuzzy Logic model to predict the cold filter plugging point (CFPP) of biodiesel fuel from its fatty acid (FA) composition. CFPP defines the operability for diesel fuel which is strongly influenced by the FA of feedstock. Prediction of CFPP based on the FA of feedstock can reduce the experimental effort to produce a biodiesel suitable for a regional climate. To generate fuzzy prediction model, data sets containing FA composition and CFPP temperatures of 60 biodiesel samples traced from literature. To check the accuracy of the model developed, waste/refined frying oil (WFO/RFO) and waste/refined canola oil (RCO/WCO) were converted to biodiesel fuel by transesterification then, their CFPP temperatures were determined following the EN and ASTM standards. The CFPP temperatures estimated by the multi input single output (MISO) fuzzy model were in close agreement with the experimental values. The validation results confirm the applicability of the fuzzy model developed here with its high degree of accuracy and minimum time demand can be rapid alternative to the costly and time consuming actual experiments and trails.

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Keywords: biodiesel; cold filter plugging point; fatty acid composition; fuzzy logic

1. Introduction

Biodiesel is one of the most popular alternatives among the liquid fuels due to its suitability for the conventional diesel engines with minimum or no modifications, as well as in blends with petroleum diesel. The usage of biodiesel have beneficial effects on the environmental pollution, dependency to petroleum exporting countries, as well as improvement of domestic industry. Despite its positive effects, biodiesel produced should meet the specifications of

Corresponding author: Filiz Al-Shanableh. Tel.; +90-392-2236624; fax: +90-392- 223 6624.
E-mail address: filiz.shanableh@neu.edu.tr

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ASTM D6751 or EN 14214 standards before being commercialized in the market. One of the major technical obstacles to the practical use of biodiesel fuel is its cold flow properties, which can be critical depending on the climate and seasonal conditions of a region (Hoekman et al., 2012). Crystal formation and agglomeration in cold weather can lead to large crystals that restrict or block flow through fuel lines and filters, leading to fuel starvation and subsequent engine failure. The cold flow properties of biodiesel and all diesel fuels can be described via the cold filter plugging point (CFPP), cloud point (CP), pour point (PP). Among these parameters, the CFPP is direct and reliable indicator for low-temperature engine operability. The CFPP is more commonly used to estimate of the lowest temperature at which a fuel gives trouble-free flow in certain fuel systems (Echim et al. 2012). The CFPP specified in ASTM D6371-05 and EN 116:1998 directly affects the diesel engine performance in winter. It determines the lowest temperature where 20 ml of fuel can be drawn through a 45 micron screen in 60 seconds with 200 mm of water (1.96 kPa) vacuum. Present work concentrates on the influence of the fatty acid (FA) composition of feedstock on the CFPP of biodiesel fuel produced. Biodiesel is a mixture of fatty acid methyl esters (FAME) with each ester component contributing to the properties of the fuel and those are identical to that of its parent oil or fat. Prediction of CFPP of biodiesel based on the FA composition of the feedstock prior to production can lead to a way for a suitable biodiesel for the regional climate conditions. One of the methods that can used to determine the effects of the FA composition on CFPP temperature of biodiesel is the Fuzzy Logic Method or simply fuzzy method. Fuzzy method that can be an alternative to classical statistical or mathematical methods was presented by L.A. Zadeh. Non-random uncertainty does not suit the use of statistical or mathematical methods, and these methods are inadequate for such cases. Such non-random uncertainties are identified and modelled as fuzzy (Ata and Dinçer, 2017). Prediction modelling studies such as multiple regression analysis were proposed to predict the CFPP temperature of biodiesel from different feedstock. Sarin et al. (2009) proposed CFPP prediction model based on palmitic methyl ester content (P_{FAME}) while Su et al. (2011) modelled based on the weighted average number of carbon atoms in FAME (Nc) and total unsaturated FA content (U_{FAME}). Moser (2008), Ramos (2009) and Wang (2011) prediction models was related to the total saturated FA contents (ΣSats). All of these prediction models achieved around 0.90 of coefficient of determination (R^2) however, for a limited number of experimental data. In these models, it is essential for the user specified data points to fit the curve in order to obtain an empirical correlation. Nevertheless, the curve fitting is not necessary in soft computing methods such as fuzzy logic systems or artificial neural networks (ANN). While fuzzy model has not been adapted for CFPP prediction yet, Al-Shanableh et al. (2016) predicted the CFPP temperatures based on the nine FA components using the ANN model and the R^2 value was found as 0.97 and noted that ANN was superior to the other methods. For the prediction of CFPP, experimental data of 60 biodiesel fuel samples were traced from the literature with their corresponding FA compositions of parent feedstock. The values collected were utilized as input and output data for fuzzy logic model. The generated fuzzy model was used to predict CFPP of four different biodiesel samples that were produced in this work, i.e., waste/refined frying oil based biodiesel (WFOME/RFOME) and waste/refined canola oil based biodiesel (RCOME/WCOME).

2. Methods

2.1. Biodiesel Preparation and Determination of CFPP

Four types of feedstock, namely waste frying oil (WFO), refined frying oil (RFO), refined canola oil (RCO) and waste canola oil (WCO) were converted into biodiesel via a base catalyzed transesterification as prescribed by Freedman et al. (1986). Nine FA components (C12:0, C14:0, C16:0, C18:0, C18:1, C18:2, C18:3, C20:0 and C20:1) of those feedstock were determined following the EN ISO 5508 as tabulated in Table 1.

Table 1. FA compositions of biodiesel feedstock used in the current work.

	Fatty Acid Composition (wt %)											
	C12:0	C14:0	C16:0	C18:0	C18:1	C18:2	C18:3	C20:0	C20:1	SFA	MUFA	PUFA
WFO	1.18	0.10	39.29	4.04	40.42	13.84	0.18	0.0	0.0	44.99	40.56	14.02
RFO	1.02	0.08	38.4	3.52	39.2	16.9	1.02	0.0	0.0	43.35	39.28	17.92
RCO	0.08	0.0	5.63	1.57	62.97	21.34	6.99	0.46	1.04	7.74	64.01	28.33
WCO	0.56	0.0	6.02	2.01	63.22	18.08	4.61	0.49	1.12	9.08	64.3	22.69