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BSFC PREDICTION OF A DIESEL ENGINE FUELLED WITH BIODIESEL BY RSM

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Abstract: *The effects of biodiesel (from waste cooking oil) in fuel mixture (biodiesel and diesel fuel No. 2) on brake specific fuel consumption (BSFC) of a diesel engine were investigated by response surface methodology (RSM) in this study. The experiments were conducted on a four cylinder direct-injection diesel engine. The developed mathematical models by RSM were helpful to predict the response parameters and further to identify the significant interactions between the input factors on the response. Results showed that the use of biodiesel BSFC increases 18 to 24% by the using net biodiesel. Also results showed that the reduction in engine load appeared to cause an increase in BSFC which increase up to 15% by reducing the engine load.*

Keywords: BSFC, Biodiesel, Diesel engine, RSM, Engine speed.

1. Introduction

Biodiesel has received wide attention as a replacement for diesel fuel because it is biodegradable, nontoxic and can significantly reduce toxic emissions and overall life cycle emission of CO2 from the engine when burned as a fuel (Xue et al., 2011). If the fuel properties of biodiesel are compared to petroleum diesel fuel, it can be seen that biodiesel has higher viscosity, density, pour point, flash point and cetane number and no sulphur link (Canakci et al., 2009). Many researches compared the blends with different content biodiesel For BSFC. Most of them (Aydin and Bayindir, 2010; Meng et al., 2008; Godiganur et al., 2010; Qi et al., 2010) agreed that the fuel consumption of an engine fueled with biodiesel becomes higher. Some of them (Armas et al., 2010; Zhu et al., 2010; Godiganur et al., 2010; Labeckas and Slavinskas, 2006) believed that, with increasing the content of biodiesel, engine fuel consumption will increase. On the contrary, it was reported in (Ozgünay et al., 2007; Song and Zhang, 2008; Pal et al., 2010) that fuel consumption was decreased for biodiesel compared to diesel. The objective of this research work is to investigate the effects of biodiesel percentage of in fuel mixture (biodiesel and diesel fuel No. 2), engine speed and engine load on changes in brake specific fuel consumption (BSFC) by response surface methodology (RSM).

2. Methods

2.1. Biodiesel preparation, Test engine experimental procedure

Biodiesel from waste vegetable cooking oil is a more economical source of the fuel, so in the present investigation biodiesel was produced from this source.

The engine tests were carried out on a 4-cylinder, four-stroke, turbocharged, water cooled and DI diesel engine (110 hp at 2800 rpm). The engine speed was measured by a digital tachometer with a resolution of 1 rpm. The engine was coupled to an E400 ferromagnetism dynamometer to provide brake load and a system with scale method was used to for determination of consumed fuel. The engine was allowed to run for a few times until the exhaust gas temperature, the cooling water temperature, the lubricating oil temperature, have attained steady-state values and then the data were recorded.

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2.2. Experimental design and statistical analysis

The standard RSM design using central composite design (CCD) was employed to examine the relationship between the response variables and set of quantitative experimental factors. The independent variables were percentage of biodiesel in fuel mixture in fuel mixture (x_1), engine speed (x_2) and engine load (x_3). The response (y) was BSFC. The coefficients of the polynomial were represented according equation (1) by b_0 (constant term); b_1, b_2 and b_3 (linear effects); b_{11}, b_{22} and b_{33} (quadratic effects); and b_{12}, b_{13} and b_{23} (interaction effects):

$$y = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_{11}x_1^2 + b_{22}x_2^2 + b_{33}x_3^3 + b_{12}x_1x_2 + b_{13}x_1x_3 + b_{23}x_2x_3 \quad (1)$$

Minitab software version 15.0 was used to develop the mathematical models and to evaluate the subsequent regression analyses and analyses of variance (ANOVA). Based on these models, the main and interaction effects of the process parameters on BSFC characteristics were computed and plotted in contour plots as shown in Fig. 1.

3. Analysis and Results

3.1. Statistical analysis

The complete 20 numbers of experiments were performed and the experimental data for BSCF of the diesel engine are shown in Tab. 1. The statistical analysis indicates that the proposed model (Eq. (2)) was adequate, possessing no significant lack of fit and with very satisfactory value of the R2 (96.4%) for the response. Fig. 1 shows the interactions between the engine speed and responses in contour plot form. The graphical form plots were obtained by holding the value of engine load at 25%, 50%, 75% and 100% constant level in the related mathematical model.

Tab. 1: The experimental and predicted data for the response.

Experiment number		1	2	3	4	5	6	7	8	9	10
BSFC (gr/(kW.hr)	Experimental data	234	258.6	245.8	288.3	219.5	241.6	238.7	265.9	210.5	261
	Predicted data	230.6	258.7	248.8	288.5	217	236.3	235.2	266	213.1	262.7
Experiment number		11	12	13	14	15	16	17	18	19	20
BSFC (gr/(kW.hr)	Experimental data	237.4	284.3	257	220	238.6	242.8	250.8	236.4	241.2	239.6
	Predicted data	242.7	283	256.4	226	241.2	241.2	241.2	241.2	241.2	241.2

$$BSFC(gr/(kW/hr) = 298.74 + (0.5)x_1 + (-0.088)x_2 + (-0.236)x_3 + (0.0014)x_1^2 + \\ + (2.67x10^{-5})x_2^2 + (-0.00018)x_1x_2 + (-0.00336)x_1x_3 \quad (2)$$

3.2. Brake specific fuel consumption (BSFC)

Fig. 1 shows the effects of biodiesel percentage and engine speed on the predicted BSFC of the engine at various load condition. As the Fig. 1 show, the maximum BSFC is more than 330 (gr/Kw.hr) for fuel blends included more than 95% biodiesel at 25% engine load and engine speed between 2700 to 2800 rpm. Also the minimum BSFC (less than 208 (gr/Kw.hr)) happens at full engine load and engine speed between 1500 to 1700 rpm for fuel blends included less than 10% biodiesel. According to the results, the BSFC initially decreased with increase in speed up to 1300 rpm and then BSFC remains approximately constant between 1300 rpm and 1900 rpm. For the range more than 1900 rpm, the BSFC increased sharply with speed. The predicted values for BSFC increase with the increasing amount of biodiesel in the fuel blend. The heating value of the biodiesel is lower than that of diesel fuel No. 2. Therefore, if the engine was fueled with biodiesel or its blends, the BSFC will increase due to the produced lower brake power caused by the lower energy content of the biodiesel (Aydin and Bayindir, 2010; Ozsezen et al., 2009; Adaileh and AlQdah, 2012; Hossain et al., 2013). At the same time, for the same volume, more

biodiesel fuel based on the mass flow was injected into the combustion chamber than diesel fuel No. 2 due to its higher density. In addition to these parameters, viscosity, the atomization ratio and injection pressure should be considered since they have some effects on the BSFC values (Lin et al., 2009; Song and Zhang, 2008). As the Fig. 1 show with increase in load, the BSFC of biodiesel decreases. One possible explanation for this trend could be the higher percentage of increase in brake power with load as compared to fuel consumption (Godiganur et al., 2010; Qi et al., 2010).

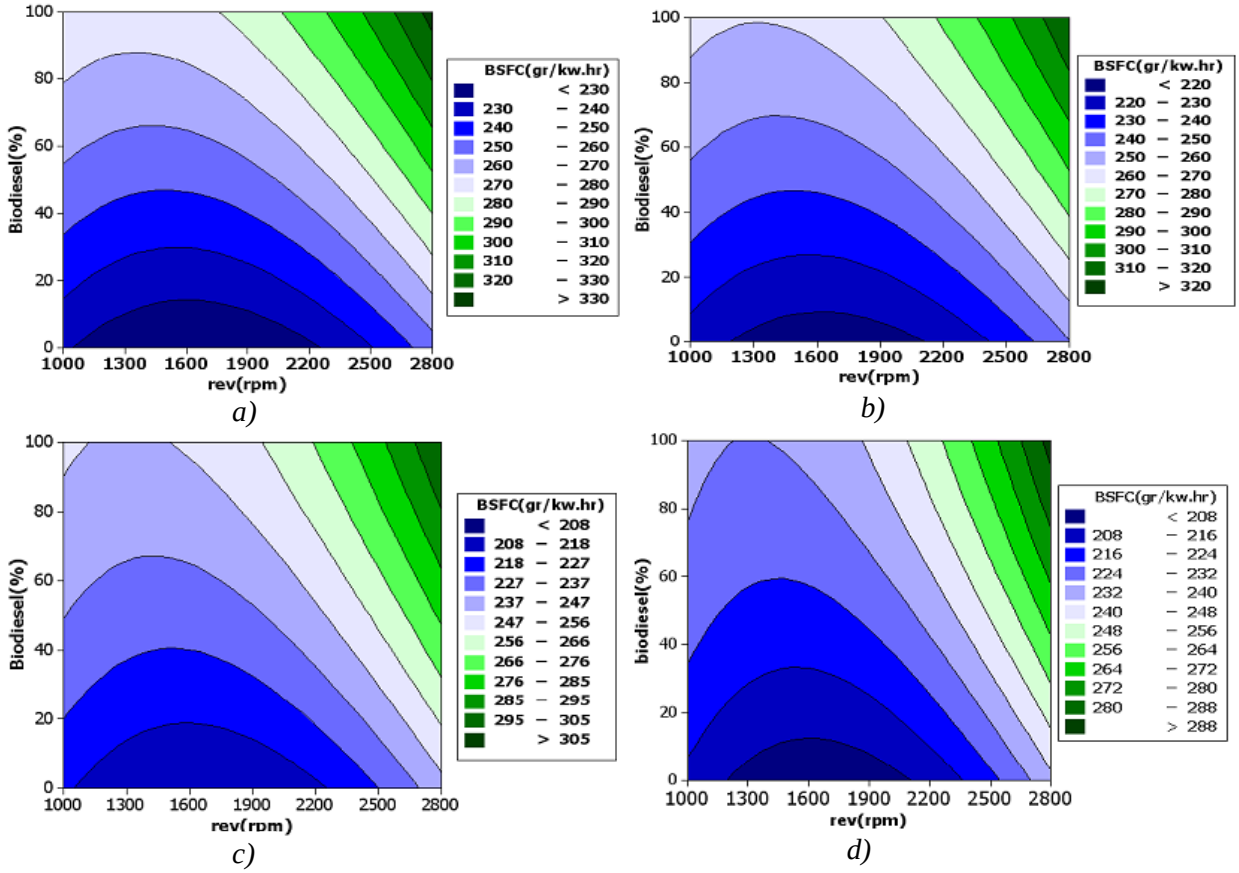

Fig. 1: Effect of percentage of biodiesel in fuel mixture and engine speed on BSFC at: a) 25%; b) 50%; c) 75%; d) 100% (full) engine load.

4. Conclusions

- The statistical models as fitted can be effectively used to predict the engine performance. Also the effect of biodiesel produced from waste cooking oil blends and diesel No. 2 fuel on engine performance was investigated.
- The brake specific fuel consumption increases with the increase of biodiesel in the blends, due to the lower heating value of biodiesel. Results showed that the brake specific fuel consumption of diesel No. 2 fuel is 18 to 24% more than the brake specific fuel consumption of net biodiesel at various engine loads.
- The brake specific fuel consumption at 25% engine load was around 15% more than this characteristic at full engine load for all fuel blends.
- These results are similar to those found in the literature and support that waste cooking oil methyl esters have similar properties with diesel fuel.
- Also the results of the study show that use of biodiesel blends with diesel had not significant change on performance of the diesel engine.

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