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Emission Characteristics of a Diesel Engine fueled with Diesel-biodiesel-JP-4 Blends

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ABSTRACT

The main objective of this research is to study the effects of JP-4-biodiesel-diesel fuel blends and operating parameters on the emission characteristics of a CI engine. The experimental tests were performed on a four-cylinder DI diesel engine. The Mixture-RSM method was used to develop mathematical models based on experimental data. The results showed that with the increase of the biodiesel proportion in the fuel blend, the emission of hydrocarbon and carbon monoxide in the exhaust decreases due to oxygen contents in the molecular structure of biodiesel that leads to effective combustion. According to the results, HC and CO emissions boosted up significantly with the use of jet fuel JP-4 in fuel mixture due to the lower cetane index of jet fuel in comparison with diesel and biodiesel. Results also indicated that the NO_x formation is highly related to biodiesel proportion in fuel mixture due to less compressibility and its higher cetane number. On the other hand, the results indicated that NO_x emissions reduced by using JP-4 as a result of retarded combustion of jet fuel that reduces combustion temperature. According to the results, CO and HC emission decreased at higher engine loads due to a more complete combustion condition. However, the NO_x emission continuously intensifies at the higher levels of engine load due to the arising temperature of combustion gas. Generally, the results indicated that the use of JP4 fuel can improve NO_x emissions of the engine but it does not have a desirable effect on other emission characteristics of the engine.

1) Introduction

Today, fossil fuels are the main resource for energy supply. Petroleum reserves are coming to be finished because of large demand in the world. Also, the use of fossil fuel in the SI and CI engines significantly affects the environment and emission of pollutant gaseous. Therefore, alternative energy and fuel sources have become more prominent these years [1].

Among these alternative fuels, biodiesel is the most important liquid biofuel extracted from animal fat and vegetable oil feedstocks [1-3]. Many studies have been down on the performance and emission parameters of CI engines with biodiesel-diesel mixtures. On the other hand, there are less researches in the literature related to using jet fuels in diesel and other types of engines. For example, the effect of JP-8 on fundamental combustion and spray characteristics of diesel engines JP-8 as an aviation fuel is studied in some studies [4-7].

JP-8 can enhance combustion pressure in comparison with diesel fuel. Moreover, the wider spray angle, shorter spray tip penetration, and faster vaporization than diesel are the combustion properties of JP-8 [4-6]. The idea of using a single military fuel was conceived after the Second World War to simplify the logistic supply chain for petroleum products in the NATO nations. This idea has been called the Single Fuel Concept (SFC). JP-8, which had been used as aviation fuel, was selected for the SFC. This movement resulted in many studies on the effect of aviation fuels when diesel fuel was fully substituted in diesel engines [4]. Therefore, there are some ongoing researches on JP-5 as an alternative of JP-8 fuel along with diesel and biodiesel as an aviation fuel for using in a CI engine [8].

According to the environmental problems and existence of the strict requirements for CI engines, it is necessary to study the application of new alternative fuels and a mixture of them in the engines. Many studies carried out to investigate NO_x, SO_x, HC, and CO as the main regular pollutant gaseous emitted from internal combustion engines fueled with diesel-biodiesel blends [9-12]. Moreover, some researches were performed about using aviation fuels in a diesel engine to evaluate the emission characteristics of the engine:

Korres et al. [8] used JP-5-diesel-biodiesel blends in a diesel engine to study the engine emission parameters. The results indicated that the NO_x and particulate matter emissions decreased by using JP-5 as compared to petroleum diesel fuel due to its lower cetane number. Biodiesel has notable effects in the reduction of particulate emissions but enhanced NO_x emissions as a result of its chemically bound oxygen content.

In another experimental study [4], the exhaust emission of a CI engine fueled with JP-8 and petroleum diesel fuel was investigated. The results showed that the spray angle and spray tip penetration are wider and shorter respectively compared with petroleum diesel fuel when the engine fuelled with JP-8. About the emissions, the results indicated a reduction in smoke by using JP-8 while this fuel emitted larger values of HC and NO_x with JP-8 due to higher volatility and longer ignition delay.

Uyumaz et al. [13] tested the blends of JP-8 and biodiesel produced from sunflower oil in a CI engine by at rated speed and under various loads. They investigated the combustion and emission parameters of the engine. The results indicated that NO_x emissions enhanced with the higher biodiesel percentage in the fuel mixture. Also, CO emissions reduced when the biodiesel amount is higher in fuel blends due to the oxygen content of biodiesel that improves the oxidation reactions. This investigation showed that the mixture of biodiesel and JP-8 can be easily consumed in an engine.

Gowdagiri et al. [14] measured NO and CO emissions in a diesel engine by using petroleum and hydro-processed and Fischer–Tropsch as a diesel and aviation fuels. The results showed that CO emissions were reduced with increasing cetane number because of that there is more time for CO burning and formation CO_2. It is reported that NO emissions decrease with increasing H/C due to the reduction in peak temperature and thermal NO_x formation.

Roy et al. [15] investigated the emissions of an engine with fuel blends included kerosene, biodiesel, diesel and Wintron XC 30 (additive). The tests are carried out to analyze engine parameters by utilizing various blends of biodiesel and kerosene. The results indicated that methyl ester-kerosene blends improved emissions of the engine at higher loads due to more complete combustion conditions. Besides, the NO_x has included a significant proportion of NO_2 at lower loads because of that many cooler regions causes NO_2 formed is quenched and could not be converted back to NO.

Bhowmik et al. [16] studied the effects of applying the ethanol- diesel–kerosene blends on the emission parameters of an indirect injection diesel engine. The researchers implied that the addition of ethanol in the fuel mixture has a positive impact on NO_x, THC, and CO emission of the diesel engine due to higher oxygen content and lower cetane number.

Given that there is not any research on the use of JP-4 blended with the biodiesel-diesel mixture in the diesel engines and this aviation fuel is one of the most important products in Iran by NIOPD Company so the purpose of this study is to investigate the impact of various JP-4-biodiesel-diesel fuel mixture and engine operating parameters (load and speed) on the emission characteristics of a diesel engine. Mixture-Response Surface Methodology (RSM) was applied to develop models to predict the emission (CO, HC, and NO_x) characteristics of the engine.

2) Materials and methods

2-1) Fuel preparation and properties

In this research, waste cooking oil methyl ester (biodiesel) was provided from Tarbiat Modares University (TMU) biofuels laboratory [12]. Moreover, JP-4 was supplied from NIOPD Company. Table 1 shows the properties of biodiesel, JP-4 and conventional diesel that used in this study.

Table1: Properties of the fuels

Property	ASTM	Unit	Bio diesel	Diesel	JP-4
Flash point	D93	°C	175	60	-10
Kinematic viscosity at 40°C	D445	mm^2/s	4.15	4.03	No specification
Density (15ºC)	D4052	kg/m^3	880	840	758
Lower heating value	D240	MJ/kg	38.7	43	42.8
Cetane index	D613	----	62	57	45

2-2) Tests setup

The tests were carried on a direct inject, four-stroke and turbocharged diesel engine model OM364. All test rig components are presented in Figure1. Table 2 shows the engine specifications. The engine was fuelled with various fuel mixtures included biodiesel, JP-4, and diesel fuel according to the design of the experiment matrix (Table 4) and run at the specified loads and speeds. An AVL Gas analyzer was used to measure the emission parameters of the engine. Table 3 also presents the specs of the test instruments. According to the standard the engine was operated for some minutes when the operating parameters (temperature of cooling system water, lubrication oil and exhaust gas) have reached constant levels and then the parameters were recorded.

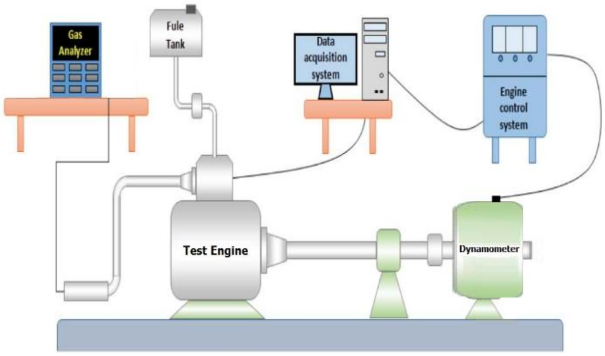


Figure1: The engine test setup

Table2: The test engine specifications

Model	OM364
Number of cylinders	4
Stroke(mm)	133
Bore(mm)	97.5
Compression ratio	17:1
Maximum power	92 kW at 2400 rpm
Maximum Torque	455 N.m at 1450 rpm
Cooling system	Water

Table3: The specifications of testing instruments

Variable	range	Resolution	Accuracy
Speed	-	±1(rpm)	±20 (rpm)
CO	0–10 vol.%	±0.01 (vol. %)	±0.05 (vol. %)
HC	0–20,000 ppm	±1 (ppm)	±3% reading
NO_x	0–5000 ppm	±1 (ppm)	±5% reading

2-3) Design of experiments and analysis

The experimental tests were designed by the application of the design of experiments according to Mixture-RSM. Response surface methodology (RSM) is a compilation of mathematical and statistical methods, helpful for fitting the models and analyzing the problems in which quite a lot of independent parameters control the dependent parameter(s). The empirical mathematical modeling for any performance characteristic is fitted with the correlating parameters [17]. In RSM, the response surface can be viewed as a mathematical model expressed as:

$$Y = f(x_1, x_2, \dots, x_i) \tag{1}$$

where *Y* is the performance characteristic of the system, *f* is the performance function, x_i is the independent parameter i.

The models are extracted to determine the variables (dependent and independent) relationship. The independent variables were the percentage of No.2 diesel (X_1), biodiesel(X_2), JP-4(X_3) in the fuel blend, speed(X_4) and load(X_5). Table 4 shows the experimental designs of actual (X) amounts of the variables. Besides, HC, CO, and NO_x emissions were as dependent variables (Y).

The mathematical models were developed by Design Expert version7 and also analyses of variance (ANOVA) and regression were performed by this software[19]. In this study, the ranges of fuel variables were considered as 0 to 100, 0 to 100 and 0 to 20 for biodiesel, diesel and JP-4 percentage in fuel mixture respectively. Also, the ranges of 20% to 100% and 1200 rpm to 2600 rpm were determined for engine loads and engine speeds respectively. That way the amounts of dependent variables were predicted by developed mathematical models. Based on the models, the effects of the independent variables on engine emissions characteristics were calculated and presented in the plots.

Table 4: The design matrix for experimental tests

Diesel (%)	Biodiesel (%)	JP-4 (%)	load (%)	speed (rpm)
X_1	X_2	X_3	X_4	X_5
0	80	20	100	2600
0	100	0	20	1900
0	80	20	100	1200
62.5	22.5	15	40	2250
100	0	0	60	1200
80	0	20	20	1900
100	0	0	100	1200
0	80	20	20	1200
50	50	0	100	2600
62.5	22.5	15	40	1550
22.5	62.5	15	60	1900
0	100	0	20	1200
100	0	0	100	2600
0	90	10	60	2600
80	0	20	100	1200
0	100	0	20	2600
100	0	0	80	1900
0	100	0	100	2600
80	0	20	20	2600
50	50	0	100	1200
90	0	10	100	2600
50	50	0	60	1200
0	80	20	20	2600
0	100	0	100	1200
0	90	10	100	1900
90	0	10	20	1200
0	80	20	60	1200
90	0	10	20	2600
80	0	20	20	1200
80	0	20	100	2600
80	0	20	60	1200
0	100	0	20	2600
0	100	0	60	1200
0	100	0	100	1200
100	0	0	60	2600
50	50	0	20	2600
0	80	20	100	1200
50	50	0	20	1200
90	0	10	100	1200
100	0	0	20	1200
0	80	20	20	1900
80	0	20	100	1200
50	50	0	20	1900
80	0	20	20	2600
100	0	0	20	1900
100	0	0	20	2600

3) Results and discussion

3-1) Statistical analysis

The complete experimental tests were done according to the designed matrix with three times of repetition. The statistical analysis indicated that the model was sufficient and there is no lack of fit.

Also, the R^2 values are adequate for all the dependent variables. The R^2 values for hydrocarbon, carbon monoxide and NO_x emissions were 92.3%, 93.7%, and 95%, respectively. Moreover, the results showed that all regression models were with significant p-values at 0.001 without a lack-of-fit [18].

The experimental and model data were

compared to validate the mathematical models (Figures 2). It can be seen that the model data are suitable following the experimental data.
The mathematical models for HC, CO, and NO_x emission were defined as Eq. (2) to Eq. (4):

$$\begin{aligned} HC\ = {} & +0.183\ X_1 - 0.125X_2 + 0.38\ X_3 \\ & + 3.189 \times 10^{-3} X_1X_4 \\ & + 1.09 \times 10^{-4} 2X_1X_5 \\ & + 1.152 \times 10^{-3} X_2\ X_4 \\ & - 2.172 \times 10^{-4}\ X_2\ X_5 \\ & - 0.012X_3\ X_4 - 2.089 \\ & \times 10^{-4} X_3\ X_5 + 3.54 \\ & \times 10^{-7} X_1X_4\ X_5 - 1.9 \\ & \times 10^{-8} X_2X_4\ X_5 + 3.63 \\ & \times 10^{-7} X_3X_4X_5 + 1.23 \\ & \times 10^{-5} X_1\ {X_4}^2 - 4.21 \\ & \times 10^{-8} X_1{X_5}^2 - 1.12 \\ & \times 10^{-5} X_2{X_4}^2 - 6.2 \\ & \times 10^{-8} X_2{X_5}^2 + 8.53 \\ & \times 10^{-5} X_3{X_4}^2 - 7.22 \\ & \times 10^{-8} X_3\ {X_5}^2 \end{aligned} \qquad (2)$$

$$\begin{aligned} CO\ = {} & 8.66 \times 10^{-4}\ X_1 + 7.89 \times 10^{-4}\ X_2 \\ & + 5.66 \times 10^{-4}\ X_3 - 6.71 \\ & \times 10^{-6}\ X_1X_4 \\ & - 1.6 \times 10^{-7}\ X_1X_5 - 1.15 \\ & \times 10^{-5} X_2X_4 - 1.88 \\ & \times 10^{-7}\ X_2X_5 + 2.06 \\ & \times 10^{-5} X_3X_4 - 1.53 \\ & \times 10^{-7} X_3X_5 - 4.55 \\ & \times 10^{-12}\ X_1X_4X_5 + 1.01 \\ & \times 10^{-9}\ X_2\ X_4X_5 - 6.29 \\ & \times 10^{-9} X_3\ X_4\ X_5 + 3.81 \\ & \times 10^{-8}\ \ X_1\ {X_4}^2 + 1.87 \\ & \times 10^{-11} X_1{X_5}^2 + 6.74 \\ & \times 10^{-8} X_2{X_4}^2 + 9.72 \\ & \times 10^{-12} X_2{X_5}^2 \\ & - 7.8 \times 10^{-8} X_3{X_4}^2 + 8.76 \\ & \times 10^{-11} X_3{X_5}^2 \end{aligned} \qquad (3)$$

$$\begin{aligned} NOx\ = {} & 1.34\ \ X_1 - 1.11\ X_2 + 7.89\ X_3 \\ & + 0.13\ \ X_1X_4 - 8.58 \\ & \times 10^{-4}\ X_1X_5 + 0.18\ X_2X_4 \\ & + 2.12 \times 10^{-3} X_2X_5 \\ & + 0.34\ X_3X_4 - 0.015\ X_3\ X_5 \\ & + 2.74 \times 10^{-6}\ X_1X_4X_5 \\ & - 3.77 \times 10^{-5} X_3X_4X_5 \\ & - 8.99 \times 10^{-4}\ X_1\ {X_4}^2 - 1.1 \\ & \times 10^{-3} X_2{X_4}^2 \\ & - 8.23 \times 10^{-7}\ X_2{X_5}^2 \\ & - 1.91 \times 10^{-3} X_3{X_4}^2 \\ & + 4.43 \times 10^{-6}\ X_3{X_5}^2 \end{aligned} \qquad (4)$$

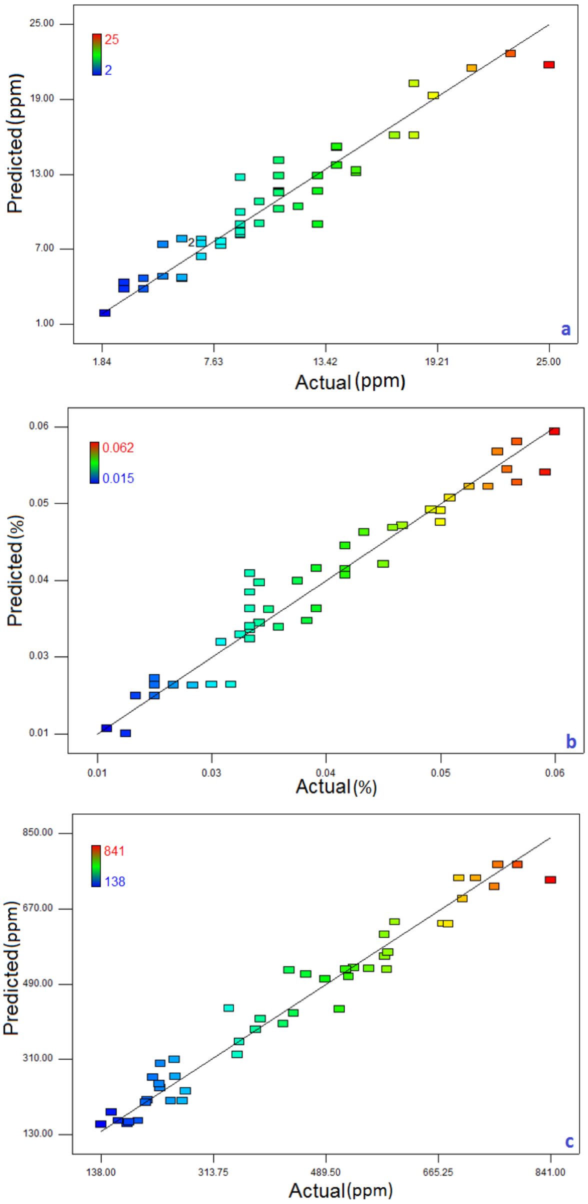


Figure 2: Predicted values versus actual values of a) HC emission b) CO emission c) NO_x emission

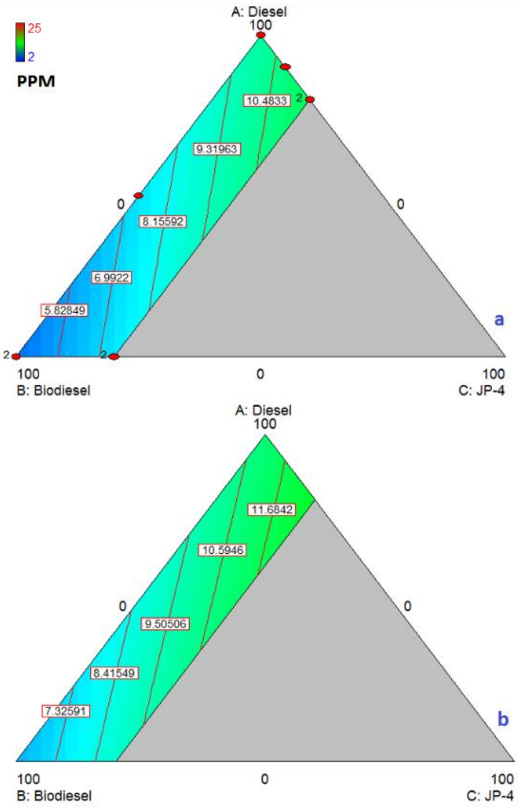
3-2) HC emissions

The predicted HC amounts (ppm) for JP4-biodiesel-diesel fuel blends at full engine are presented in figure 3. The results showed that the maximum (12 ppm) and minimum (2 ppm) HC emissions occurred at an engine speed of 1550 and 2600 rpm under full engine load. The results showed that HC emission decreases when the biodiesel percentage in the mixture increases.
The oxygen molecules in the structure of the cooking oil methyl esters help to provide better combustion conditions. This is could be an important reason for less production of unburned hydrocarbon for biodiesel fuel blends

[9, 12]. Moreover, the cetane number of the fuel blend is improved by the higher proportion of biodiesel in the mixture, and it enhances the efficiency of combustion and then reduces the emission of HC pollutants [19].

However, the HC emissions boosted up at least 12% when JP-4 was added to the fuel mixture. This condition is a result of a lower cetane index of JP-4 compared to diesel and biodiesel which causes retarded combustion phase [6; so the combustion temperature is reduced under JP-4 combustion and then the HC emissions increase [6]. This issue is related to incomplete combustion conditions during the stage of the power stroke. Moreover, the larger diffusion phase with diesel compared to JP-4 causes a reduction in HC emission [4].

As it is shown in the figure 3, HC emissions decrease up to 46% with an increase of engine speed due to better atomization and swirling condition which improves the effect of mixing fuel and air molecules in the cylinder. These conditions can make the fuel mixture more homogeneous and reduce HC emissions [19].



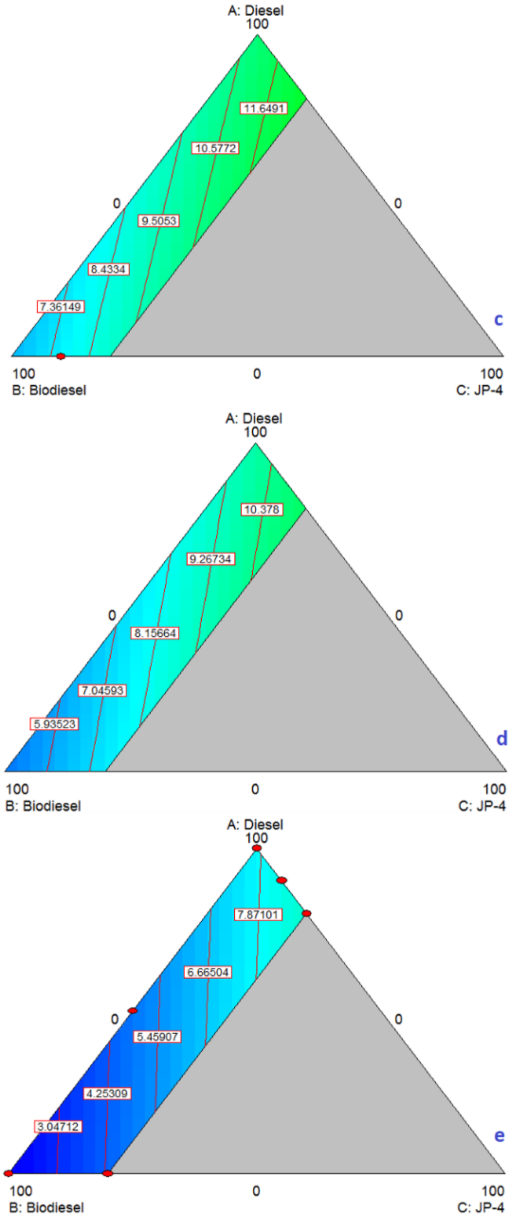


Figure 3: HC emission variations at speed of a) 1200 b) 1550) c) 1900 d) 2250 e) 2600 rpm under full load

According to Figure 4, the HC emissions increased at lower engine loads around 30%. This is because of a lean fuel and air mixture area and poor distribution of fuel in the cylinder. Besides, the higher cylinder temperature condition at higher engine loads provides more complete combustion condition and produces a lower amount of hydrocarbon emissions [9].

Based on this figure, the HC emissions were not changed at medium engine speeds and engine loads more than 65%. However, generally, the HC emissions increased at first and then decreased at higher RPMs by increasing engine speed.

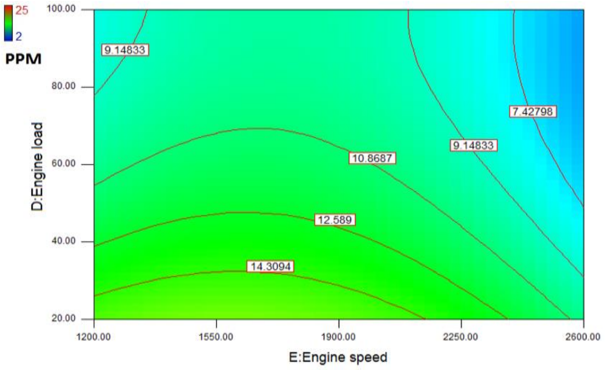


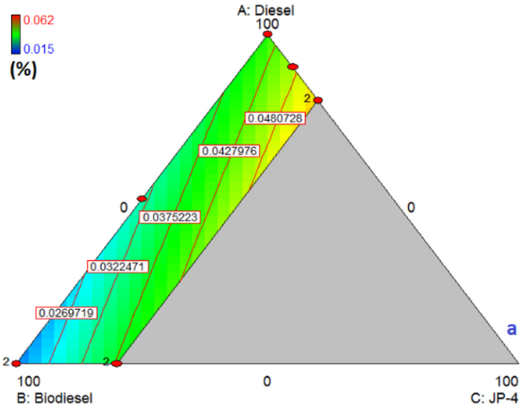
Figure 4: HC emission variations versus engine speed and load for fuel blend D45B45J10

3-3) CO emissions

Figure 5 shows the CO emission (%) for different fuel blends. The results showed that the maximum (0.053%) and minimum (0.014%) CO emissions occurred at an engine speed of 1200 and 2600 rpm under full engine load.

It can be observed that the carbon monoxide emission has a reduction (about 35%) with an increase in speed. This reduction can be attributed to better fuel atomization, better mixing fuel, and air molecules and an increase in air turbulence intensity which happens at higher engine speeds [19]. However, carbon monoxide emissions are higher at the lower engine speeds because of the bad fuel atomization and distribution across the cylinder and low temperature of burned gas which resulted in a lack of oxygen and deficient combustion at lower speeds [20].

Similar to other studies, the oxygen content in the biodiesel can reduce CO emission and leads to complete combustion and higher temperature combustion in the cylinder [12, 20-22]. Biodiesel is less compressible than diesel, it can also affect the CO emission reduction [19].



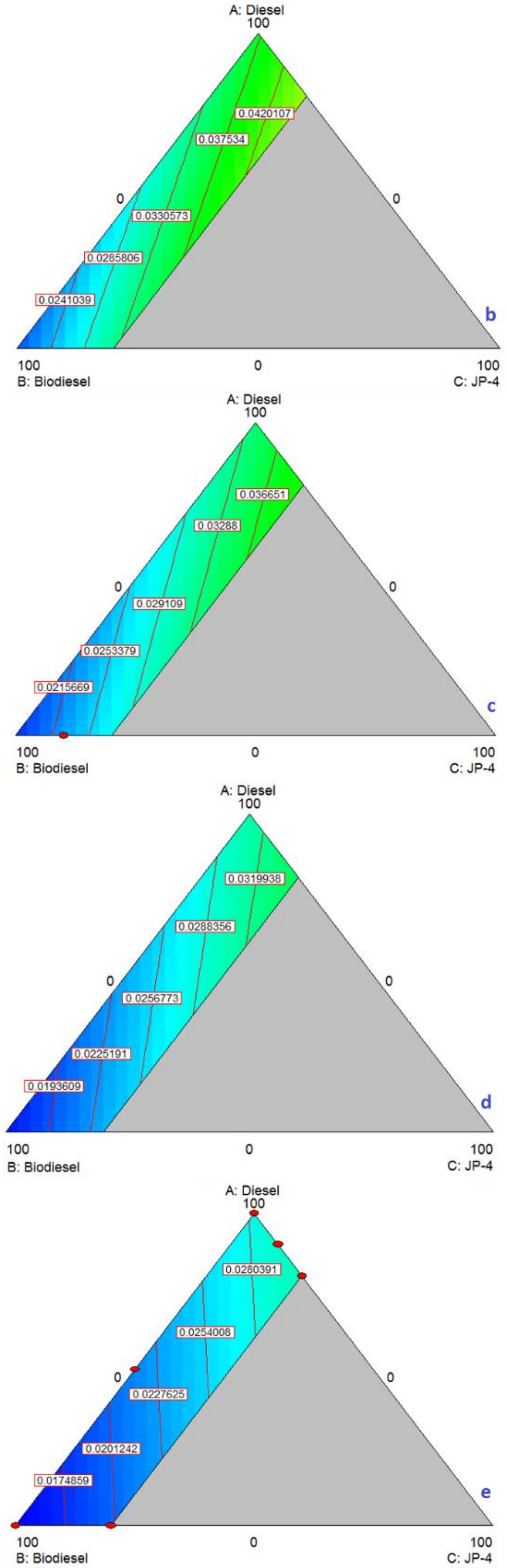


Figure 5: CO emission variations at speed of a) 1200 b) 1550) c) 1900 d) 2250 e) 2600 rpm under full load

According to the results, CO emission will be higher up to 28% when the JP-4 percentage increases in the fuel mixture. This is because of the lower cetane number of JP-4 fuel compared to biodiesel and diesel fuels that cause the small diffusion combustion phase [23, 24]. Therefore, the combustion occurs at the lower and insufficient temperature conditions and consequently forms the higher CO emission from the engine [6, 13].

As figure 6 shows the CO emissions are higher under low engine loads. Local fuel-air equivalence ratio and unstable combustion reactions are two parameters that have an important role in CO production. Therefore, lower temperatures of the combustion chamber and the lean air-fuel ratio at lower loads help to that that CO_2 is not produced perfectly and then CO emission increases [25]. At the higher engine loads, the combustion happens with high efficiency because of higher in-cylinder temperature that provides better combustion conditions. Also, the high cetane number of waste cooking oil methyl ester helps to form a less rich mixture; so the CO emissions decrease around 22% in this condition [9]. However, the CO emission slightly increases in engine loads more than 85% because of that the oxygen molecules decrease in the cylinder at very high engine loads [13].

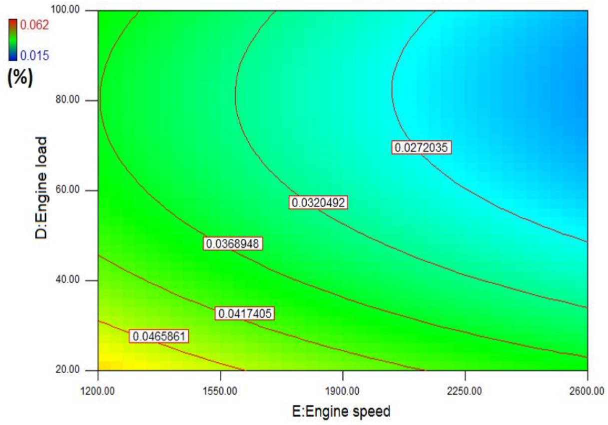


Figure 6: CO emission variations versus engine speed and load for fuel blend D45B45J10

3-4) NO_x emissions

There are some parameters such as residence time of combustion gas with high temperature, the cetane number of fuel blends, excess of oxygen and nitrogen molecules in the reaction zone that control nitrogen oxides emission in the combustion chamber [26]. As it is shown in Figure 7, NO_x emissions (ppm) decrease around 20% with an increase in speed.

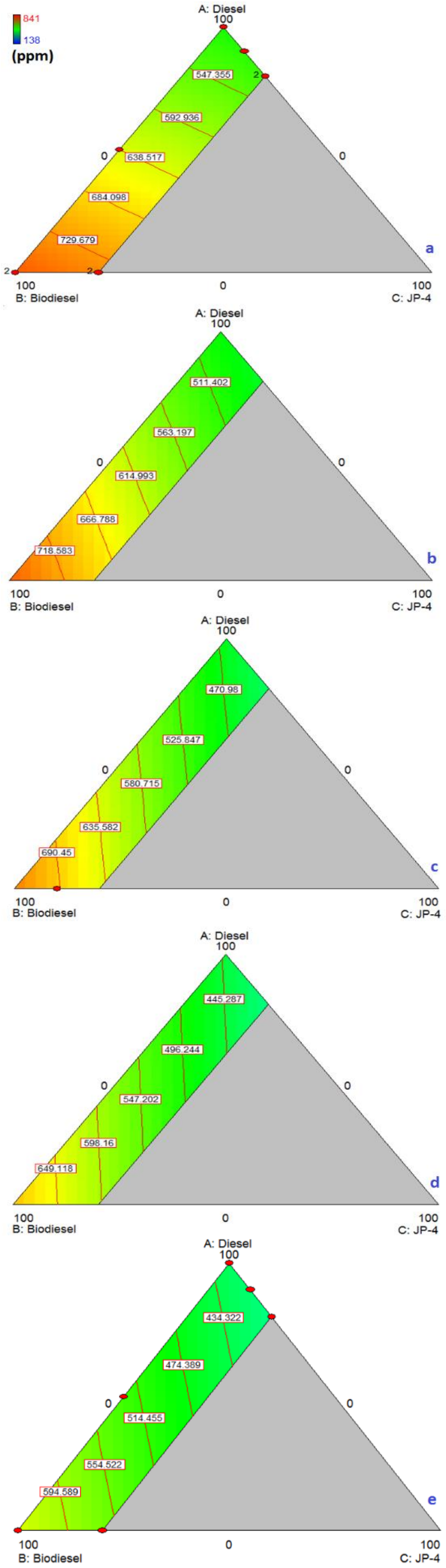


Figure 7: NO_x emission variations at speed of a) 1200 b) 1550) c) 1900 d) 2250 e) 2600 rpm under full load

This is because of that the ignition delay in the meantime decreases at higher engine speeds, and then it tends to reduce the residence time of the combustion gas with high temperature [21, 27]. The results showed that the maximum (775 ppm) and minimum (405 ppm) NO_x emissions occurred at an engine speed of 1200 and 2600 rpm under full engine load. It can be seen, the nitrogen oxides production is highly related to the biodiesel content in the fuel blend [28].

This is related to less compressibility property, higher isentropic bulk modulus and cetane number of biodiesel that cause an advance of injection and ignition for this fuel.

These parameters lead to a higher temperature of the combustion chamber and produce a higher amount of NO_x emissions [27, 29]. Moreover, the NO_x formation was intensified for diesel fuel and JP-4 due to the presence of oxygen molecules in the structure of the cooking oil methyl ester [12, 30].

The results also showed that NO_x formation could be declined by around 9% when the engine fuelled with JP-4. It is as the result of lower combustion temperature with JP-4 due to retarded burning phase that makes the combustion with low temperature during JP-4 combustion and decreases NO_x formation [6]. This could be also due to the mixing of air and jet fuel vapors that causes lower temperature variation in the cylinder [16]. Besides, JP-4 has lower aromatic contents compared with diesel fuel so it produces lower NO_x [24, 31]. Moreover, although higher premixed combustion phase causes to in-cylinder temperature raising, it also resulted in larger heat transfer to the cylinder wall; so that the temperature of the combustion chamber is reduced and then it causes lower NO_x emission [4]. Also, current jet fuel has very low fuel bound nitrogen levels that cause the lower formation of NO_x emission [32].

Figure 8 shows the NO_x emissions versus speed and load for fuel blend D45B45J10. The nitrogen oxides formation continuously increases with the load. The main reason for this behavior is that the temperature of burning gas enhances with an increase in load for each fuel blend [33]. However, the results showed a reduction in NO_x emission at engine loads more than 80% due to the lack of oxygen amount in the cylinder at this condition that causes NO_x deceleration [13].

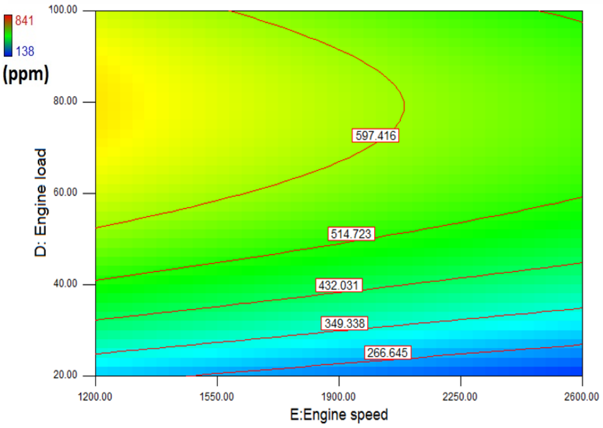


Figure 8: NO_x emission variations versus engine speed and load for fuel blend D45B45J10

4) Conclusions

In this research, Mixture-RSM was employed to develop models and determine the emission characteristics of the diesel engine fuelled with JP-4-biodiesel-diesel blends. It was concluded that:

a) The fitted models can be properly applied to predict the emission characteristics of the engine.
b) With the increase of the biodiesel proportion in the fuel blend, the emission of hydrocarbon and carbon monoxide in the exhaust decreases. The reason is related to oxygen contents in the molecular structure of biodiesel that leads to effective combustion and less HC and CO emissions for biodiesel fuel blends.
c) HC and CO values intensified significantly by using jet fuel JP-4 in the fuel mixture. This is a result of retardation of the combustion phase due to a lower cetane number of JP-4 compared to diesel and biodiesel that makes the decreased combustion temperature.
d) The emission of HC and CO enhances under low engine loads. This could be due to the lean mixture and low-temperature areas of the cylinder at lower loads which lead to less CO into CO_2 reaction. At higher engine loads, the combustion occurs with high-efficiency thanks to higher cylinder temperature that provides more complete combustion condition. However, CO emission slightly increases in engine loads of more than 85% because of the lack of oxygen molecules in the cylinder.
e) The time of the ignition delay reduces in the meantime with an increase in RPM and then contributes to a reduced residence time of the

peak temperature of the combustion gas and NO_x formation.

f) NO_x formation is highly affected by the amount of biodiesel in the mixture because of less compressibility, its higher isentropic bulk modulus, and cetane number. Also, the nitrogen oxides values were enhanced compared with petroleum diesel fuel and JP-4 because of the oxygen content in the structure of waste cooking oil methyl ester.

g) The NO_x formation could be reduced with using JP-4 because of retarding the combustion phase that leads to the lower combustion temperature condition; Besides, JP-4 has lower aromatic contents compared to diesel fuel so it produces lower NO_x.

h) The NO_x emission continuously intensifies at the higher levels of engine load due to the arising temperature of exhaust gas. Although NO_x emission decreases at engine loads more than 80% due to the lack of oxygen amount in the cylinder at this condition that causes NO_x deceleration.

i) According to the results, JP-4 could be useful to reduce the NO_x emission of the engine fueled with the JP-4-biodiesel-diesel blend. However, about HC and CO emissions, it is not suggested a high proportion of this jet fuel in the fuel mixture. Also, the results showed that the HC and CO values changed with the variation of engine speed but the NOx emission was not related to the engine speed, especially at lower loads. However, all emission parameters were depended on engine load variations.

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مشخصه‌های آلایندگی یک موتور دیزل با کاربرد مخلوط‌های سوخت دیزل-بیودیزل-JP-4

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چکیده

هدف اصلی این تحقیق بررسی تاثیر مخلوط‌های JP-4- بیودیزل- دیزل و شرایط کارکردی موتور (سرعت و بار اعمالی) بر روی مشخصه‌های آلایندگی یک موتور دیزل می‌باشد. آزمایش‌های تجربی بر روی یک موتور چهار سیلندر پاشش مستقیم انجام شد. در این تحقیق روش Mixture-RSM جهت توسعه مدل‌های ریاضی بر مبنای داده‌های تجربی به کار داده شد. نتایج تحقیق نشان داد که مدل‌های برازش شده قابلیت پیش‌بینی مشخصه‌های آلایندگی موتور را دارند. نتایج نشان داد که با افزایش مقدار بیودیزل در مخلوط سوخت مقدار انتشار آلاینده‌های HC و CO به علت وجود مولکول‌های اکسیژن در ساختار بیودیزل که سبب احتراق بهتر و کامل‌تر می‌شوند، کاهش می‌یابد. بر اساس نتایج تحقیق، با افزایش مقدار سوخت JP-4 در مخلوط سوخت مقدار انتشار آلاینده‌های HC و CO به علت عدد ستان کمتر و فرصت کمتر احتراق این سوخت در مقایسه با دیزل و بیودیزل به شدت افزایش می‌یابد. همچنین نتایج مشخص کرد که تولید آلاینده NO_x به شدت وابسته به مقدار بیودیزل در مخلوط سوخت می‌باشد که علت آن تراکم ناپذیری کمتر و عدد ستان بیشتر سوخت بیودیزل است. از طرف دیگر نتایج نشان داد که با افزایش مقدار JP-4 در مخلوط سوخت، انتشار آلاینده NO_x به علت تاخیر در احتراق بیشتر این سوخت که سبب کاهش دمای احتراق می‌شود، کاهش می‌یابد. بر اساس نتایج بدست آمده، انتشار آلاینده‌های HC و CO در بارهای بالاتر موتور به علت شرایط بهتر احتراق کاهش می‌یابد. هر چند مقدار انتشار آلاینده NO_x در بارهای اعمالی بالا به موتور به علت دمای زیاد گاز احتراق شدت می‌گیرد. به طور کلی نتایج نشان داد که افزودن سوختJP-4 سبب کاهش آلاینده NO_x می‌شود؛ در حالی که تاثیر مثبتی بر دیگر مشخصه‌های آلایندگی موتور ندارد.

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