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Optimization of Diesel Engine Performance and Emissions Characteristics with Tomato Seed Blends and EGR Using Response Surface Methodology

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Abstract

The impact of load, Tomato Methyl Ester (TME), and Exhaust Gas Recirculation (EGR) enriched diesel on engine performance and exhaust gas emissions was examined in this study using the Response Surface Methodology (RSM) optimization technique. TME blend biodiesel (20, 40, and 60%) and EGR (10, 20 and 30%) were selected to maximize BTE and minimize BSFC, NOx, CO, smoke, and HC. The engine was operated using the RSM technique by load (0–100%). The results showed that the response variables were significantly influenced by load, TME and EGR concentration of engine. The results of the constructed quadratic models' analysis of variance (ANOVA) suggested that each model was an appropriate fit. Additionally, an optimal was found by optimizing the user-defined historical design of an experiment. The responses corresponding to optimal study factors were load 100%, TME Blend 20 % and EGR 10% gives maximum BTE of 32.5%. The fuel consumption 0.2 kg/kW.h is reduced when load 50%, TME Blend 60 % and EGR 10%. Smoke and NOx emissions were decreased by 15.09% and 49.04%, while CO and HC emissions were increased by 27.54% and 21.76%

Keywords: Exhaust gas recirculation; Emission; Optimization; Performance; Tomato methyl ester.

Research Article

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1. Introduction

The reserves of oil are fast decreasing and are unlikely to be enough to meet the constantly expanding demand for power for the remainder of the twentieth century. Energy demand is increasing at a pace never before seen, and available resources are insufficient to meet the demand. In this scenario, the use of diesel as a means of transport has climbed by around 40% over the past decade. The farming sector contributes significantly to diesel consumption since heavy machinery runs on diesel. Furthermore, car diesel engines contribute 26% of total emissions of greenhouse gases into the environment, which is posing an unavoidable risk to the Earth's stability. This has prompted experts to look into alternative fuels, such as EGR for the adaptable dual-fuel vehicle [1].

The EGR approach is an easy, inexpensive, and efficient solution to reduce NOx emissions [2]. The emissions and performance of a single cylinder diesel engine using diesel fuel containing 20–100% WCO biodiesel blend. The most effective option for reducing HC, CO, and smoke emissions was B20 [3]. Although the remaining emissions stayed below acceptable standards, NOx emissions were reduced to an acceptable level with 10% EGR. On DI engines working on straight WCO methyl ester, EGR (at 30%) was tested [4-6]. The results showed that particular UBHC for BSFC, smoke, and brake increased by varied percentages. A 20% reduction in BTE and NOx levels was achieved. Researchers found that as EGR rates increased from 0% to 20% while using pentanol-biodiesel blends, BSFC, CO, HC, and smoke emissions increased [7-9].

The investigation how the NOx reduction devices affected a biodiesel-powered diesel engine's performance. According to reports, the antioxidant additions in biodiesel can increase CO and HC emissions while decreasing NOx emissions by 33.5% [10]. Although it raises BSFC and decreases engine BTE, it can cut NOx emissions by up to 78% when compared to biodiesel and roughly 28% when compared to diesel combustion utilizing EGR. Along with a decrease in smoke and PM emissions, the EGR injection technology also reduces NOx emissions by up to 28% [11-13]. In order to understand the impact of combining biodiesel mix and EGR on the emission characteristics of the diesel engine utilizing various blends in contrast to diesel fuel, the goal of this research is to provide detailed data [14-22].

In the current investigation, several ratios of load, TME blends, and EGR were used. Using the RSM approach, the performance and emission levels of TME blends were examined on a stationary, SI engine at various fuel blended concentrations, loads, and EGR rates. The most effective TME blend at an appropriate EGR rate was found using the RSM. The BTE and BSFC performance were both prioritized when setting the optimization criteria. Using the desired technique, the emission of smoke, NOx, CO, and HC were reduced. An additional test was used to corroborate the results. Additionally, the various analysis of engine performance has been conducted for the ideal value of the input factors.

2. Materials and Methodology

2.1 Tomato Seed Cultivation in India

Waste tomato seeds from the processing of red tomatoes with an average weight were used for the extraction procedure. It is cultivated in India. Major states include Bihar, Karnataka, MP, UP Orissa, AP, and Assam. Tomato seed oil was transesterified for 1 hour at 50 °C using a solution of anhydrous ethanol (1/12 molar concentration of oil: ethanol) and NaOH as a catalyst for the reaction (0.17% weight vs. oil). A vacuum distillation method was used to remove extra ethanol from the reaction mixture before phase separation was used to extract the TME. Seeds are by products of the food industry's production of tomato juice, sauce, ketchup, and food colours like lutein and beta-carotene. By flotation, seeds are recovered from recycled garbage to be utilized [18]. The table 1 below lists the properties of TME and diesel.

Table 1. Properties of fuels

Properties	TME	Diesel
Viscosity (cSt)	28	2.62
Flashpoint (_C)	189	68
Calorific value (MJ/kg)	35.9	42.7
Density (kg/m^3)	915.1	855

2.2 EGR application

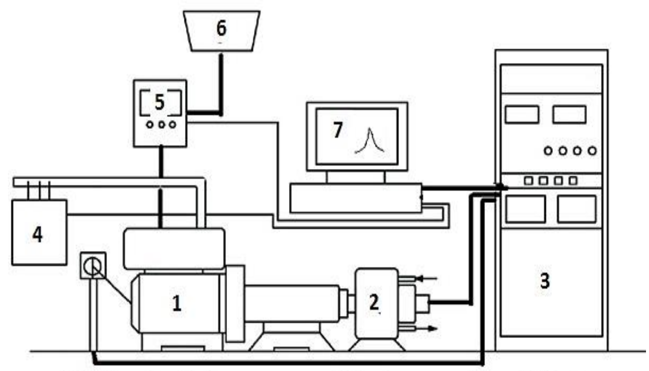
An external EGR system has been included to this experiment in order to perform 10%, 20%, and 30% EGR flow rates. Exhaust gas recirculation involves injecting some exhaust from the engine into an engine's inlet manifold in order that it may combine with fresh air, lowering NoX levels. As the particular heat of the ingredients within the combustion chamber increases, the oxygen level decreases. The total quantity of exhaust gas was measured using an aperture metre. An EGR device was used to modify the EGR rate, and Eq 1 was used to calculate the percentage of the EGR amount.

$$EGR\ (\%) = ((CO_2)_{in}-(CO_2)_{atm})/((CO_2)_{out}-(CO2)_{atm}) \qquad (1)$$

Where $(CO_2)_{in}$ and $(CO_2)_{out}$ are concentration of CO_2 at the inlet and the outlet.

2.3 Experimental test engine

Throughout the experiment, a dynamometer was linked to a single-cylinder Kirloskar diesel engine to simulate braking load. Figure 1 depicts a test engine schematically.



1. Diesel engine 2. Dynamometer 3. Engine control panel 4. Exhaust gas analyzer 5.Fuel gauge 6. Fuel tank 7. Computer

Fig. 1. Test engine is depicted schematically

3. Experimental design

Design-Expert® programme (version 13) has been utilized for trial design, optimization, and validation [19]. Table 2 illustrates the data input factors and their levels. All variables that are entered are calculated numerically. The load (0-100%), TME blend biodiesel (20,40 & 60%), and EGR (10,20 & 30%) were chosen to maximize BTE while minimizing BSFC, NOx, CO, smoke and HC.

Table 2. Factors and levels for TME Blends with EGR

Process parameters	*Levels*		
	1	2	3
A- Load (KG)	0	50	100
B - TME Blend (%)	20	40	60
C - EGR (%)	10	20	30

RSM is an analytical approach used to create quadratic/Box-Behnken models of prediction for input and response variables. RSM assists in determining the impact of input parameters on response variables, minimizing the number of experiments, and optimizing response variables. Table 3 shows the experimental design matrix for Tomato Methyl Ester Blends with EGR.

4. Result and Discussion

The overview of ANOVA (Table 4) and the assessment of the model for performance of BTE and BSFC, the emission characteristics of CO, HC, NoX, and Smoke emissions similarly displayed values of R2, Adj. R2, Pred. R2, and acceptable precise well suited inside the mandate limitations for accuracy and sufficiency of the model for intended responses. Equations 2,3,4,5,6 and 7 in Table 5 give the polynomial regression equations for performance of BTE and BSFC, the emission characteristics of CO, HC, NoX, and Smoke emissions.

Table 3. Experimental design matrix for Tomato Methyl Ester Blends with EGR

Sl.No	Run	*Load (KG)*	*TME Blend (%)*	*EGR (%)*	*BSFC (kg/kW.h)*	*BTE (%)*	*CO (% Vol)*	*HC (ppm)*	*NoX (ppm)*	*Smoke (BSU)*
1	1	100	60	30	0.7	14	0.07	41	725	28
2	17	0	20	30	0.45	21	0.09	43	580	38
3	18	0	20	10	0.33	23	0.14	53	885	49
4	14	50	20	10	0.3	28.5	0.25	73	1000	61
5	5	100	20	10	0.67	15	0.009	128	1235	72
6	19	50	40	20	0.42	22	0.023	48	260	30
7	16	0	60	10	0.32	25	0.035	42	610	39
8	6	50	60	20	0.26	29	0.07	52	900	50
9	3	100	40	20	0.66	19	0.16	72	1030	63
10	13	50	20	20	0.39	28	0.05	126	1270	74
11	12	50	20	30	0.28	31	0.08	47	865	32
12	4	100	20	30	0.23	32.5	0.13	49	725	41
13	20	0	20	10	0.65	30.5	0.24	59	785	52
14	8	50	60	10	0.39	31.5	0.04	79	965	65
15	15	0	60	30	0.3	30	0.12	130	1175	76
16	7	50	60	30	0.25	27	0.23	56	810	50
17	2	100	60	10	0.2	25	0.11	76	1110	62
18	11	50	40	10	0.66	19	0.16	72	1030	63
19	9	50	40	30	0.67	15	0.019	128	1235	72
20	10	50	40	20	0.7	14	0.017	40	825	29

Table 4. ANOVA of prediction responses BSFC, BTE, CO, HC, NoX and Smoke

	BSFC (Kg/Kw.h)	BTE (%)	CO (% vol)	HC (ppm)	NOX (ppm)	SMOKE (BSU)
Std. Dev.	0.1713	5.14	0.0926	25.97	363.27	14.99
Mean	0.3810	25.30	0.11135	72.50	824.50	52.40
C.V. %	44.95	20.33	83.20	35.82	44.06	28.61
R^2	0.4214	0.4998	0.2528	0.6070	0.3697	0.4467
Adjusted R^2	-0.0994	0.497	-0.4197	0.2533	-0.1976	-0.0513
Predicted R^2	-10.9544	-10.5001	-3.5552	-2.0754	-3.4235	-4.1843
Adeq Precision	3.6931	3.1347	2.0822	5.6931	3.9045	4.3443

Table 5. Equations of polynomial models in terms of coded fators for Tomato Methyl Ester Blends

Process Parameters	Equations
BSFC = 0.638909 + -0.0039 * A + 0.00455 * B + -0.0330909 * C + 2e-05 * AB + -1e-05 * AC + 0.0005 * BC + 4.63636e-05 * A^2 + -0.0002125 * B^2 + 0.000431818 * C^2	(2)
BTE = 12.0106 + 0.265 * A + 0.0114583 * B + 0.744356 * C + -0.0024375 * AB + 0.000875 * AC + -0.0134375 * BC + -0.00218242 * A^2 + 0.00495833 * B^2 + -0.00354545 * C^2	(3)
CO = -0.0516909 + -0.00129 * A + 0.01601 * B + -0.0120809 * C + 1.45e-05 * AB + 1.15e-05 * AC + -1.625e-05 * BC + 3.80364e-06 * A^2 + -0.000206 * B^2 + 0.000348318 * C^2	(4)
HC = 122.252 + 2.385 * A + -3.48167 * B + -3.39848 * C + -0.017 * AB + -0.048 * AC + 0.08875 * BC + -0.00650606 * A^2 + 0.0283333 * B^2 + 0.0486364 * C^2	(5)
NoX = 1231.18 + 18.23 * A + -27.1329 * B + -14.7287 * C + -0.093125 * AB + -0.46375 * AC + 0.434375 * BC + -0.0485952 * A^2 + 0.259083 * B^2 + 0.191091 * C^2	(6)
Smoke = 56.1939 + 0.88 * A + -0.972083 * B + -0.143561 * C + -0.006375 * AB + -0.02275 * AC + 0.028125 * BC + -0.00137576 * A^2 + 0.00791667 * B^2 + -0.00454545 * C^2	(7)

4.1 Performance Result

TME Blends with EGR, as illustrated by the contour 2D plot (see Figure 2(a)). High engine BTE at high load concentration is encouraged by the red coloring of the contour region [5]. The colour of the BTE progressively shifted from green to red. The more specific variation of reaction (BTE) is displayed in the 3D surface plot shown in figure 2(b). The 3D surface plot displays the growing BTE curve with positive moments along the load, EGR, and TME Blends. The highest thermal efficiency is seen at 100% engine load. As the amount of TME biodiesel in blends and the EGR frequency increase, the BTE gradually decreases. The dark and light-colored circles located above and below the surface, respectively, reflect the observed and projected values. Specific examinations and graphs may also be used to assess the accuracy of the offered models. In general, efficient model preference little variation between experimental and predicted results. The figure 3 depicts a comparison of expected and actual BTE. The minor differences between the anticipated and actual data sets demonstrate the quadratic regression model's accuracy.

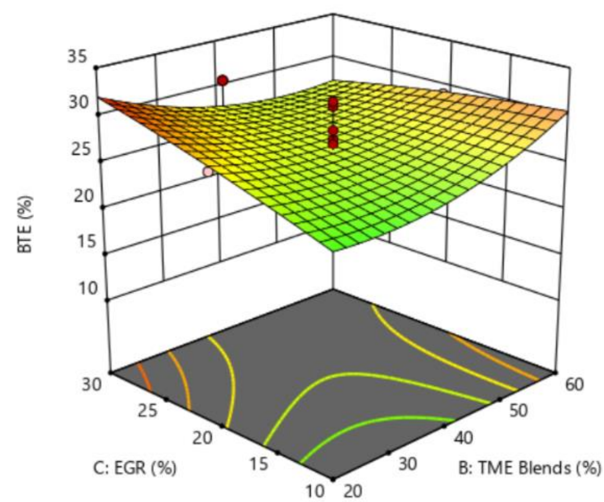


Fig. 2(b). Contour 3D Surface plot with EGR and TME Blends – BTE performance

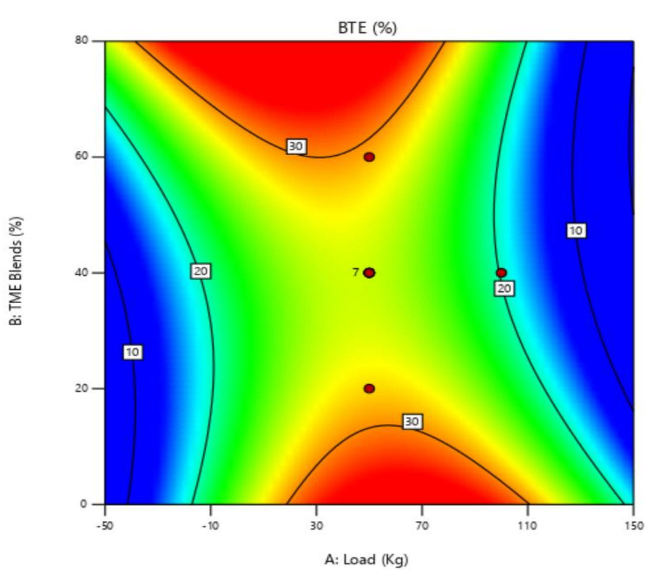


Fig. 2(a). Contour 2D Surface plot with EGR and TME Blends – BTE performance

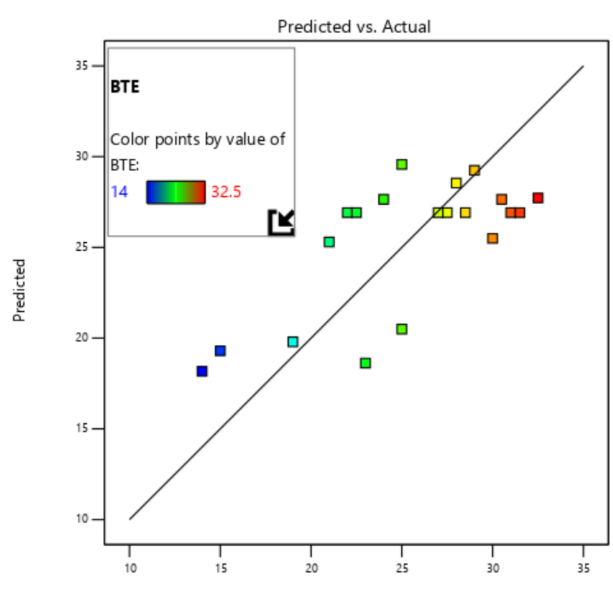


Fig. 3. Actual and predicted values for BTE

The figures 4(a) show the adding of TME with EGR impacts the fuel consumption trend of a 2D surface plot. The contour 2D shows how increasing TME blend mixes one at a time enhanced fuel efficiency. Furthermore, the green colour zone shows that there are more rapid fluctuations in BSFC for the load range of50%-75% than for high loads [7].

The 3D response surface plot in the figure 4(b) demonstrates the BSFC's rising trend with load and TME blend concentration. Because of the high friction resistance, the need for TME blend rises at high load, resulting in a dramatic lift in the curve at the culmination.

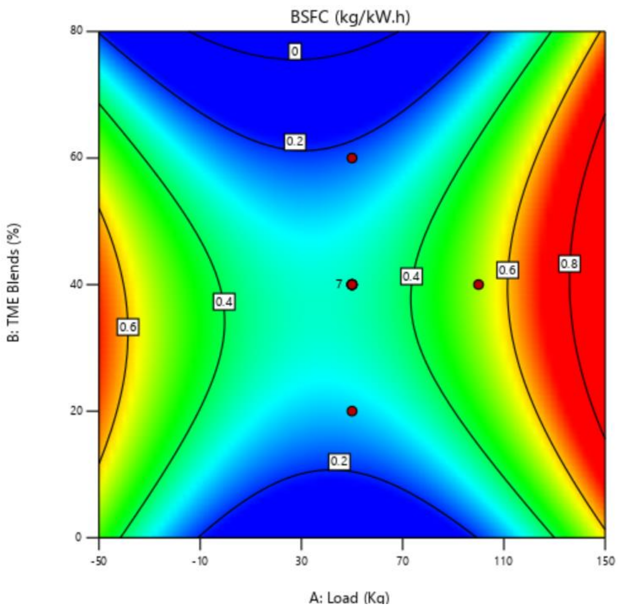


Fig. 4(a). Contour 2D Surface plot with EGR and TME Blends – BSFC performance

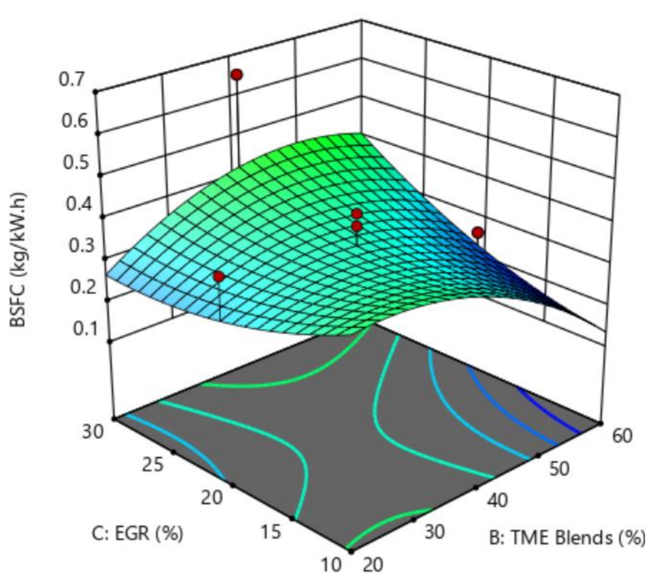


Fig. 4(b). Contour 3D Surface plot with EGR and TME Blends – BSFC performance

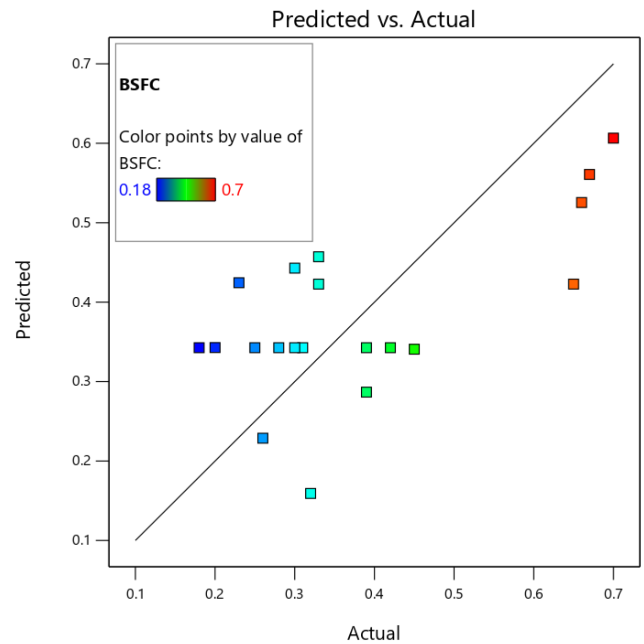


Fig. 5. Actual and predicted values for BSFC

TME blend enriching improves fuel economy mostly due to the higher calorific value of the TME blend. Figure 5 illustrates a bit of disorder data near the regression line in the comparison of anticipated and actual BSFC. The condition is caused by the manual usage of equipment in determining the BSFC. However, the variations are not excessive, and so the model is acceptable.

Table 6. ANOVA table of BSFC and BTE emissions

	BSFC (KG/KW.H)			BTE (%)		
SOURCE	Sum of Squares	F-value	p-value	Sum of Squares	F-value	p-value
MODEL	0.2136	0.8092	0.6198	264.26	1.11	0.4331
A-LOAD	0.0373	1.27	0.2858	23.08	0.8728	0.3722
B-TME BLENDS	0.0084	0.2867	0.6041	1.23	0.0463	0.8339
C-EGR	0.0113	0.3861	0.5483	9.89	0.3739	0.5545
AB	0.0032	0.1091	0.748	47.53	1.8	0.2097
AC	0.0002	0.0068	0.9358	1.53	0.0579	0.8147
BC	0.08	2.73	0.1297	57.78	2.19	0.1701
A^2	0.0227	0.7731	0.3999	50.25	1.9	0.1981
B^2	0.0167	0.5684	0.4683	9.08	0.3433	0.5709
C^2	0.0038	0.1307	0.7252	0.2585	0.0098	0.9232
RESIDUAL	0.2933			0.2644		

The performance of BTE and BSFC shows in table 6 the ANOVA results for the second response variables BTE and BSFC. The model is significant since it shows less than the designated range with a F value of 0.8092 for BTE and 1.11 for BSFC and a p-value of 0.6198 for BTE and 0.4331 for BSFC. The ANOVA results reveal that load, TME blends, and EGR have significant impacts on fuel performance. However, when examined on a model, load variations were found to have a higher impact on an engine with EGR concentration and TME blends were found to have better fuel consumption.

4.2 Emission Result

Figure 6(a) shows the variations in carbon monoxide emissions with load, EGR, and TME blend concentrations. The 2D contour plot (Figure 5) illustrates the basic pattern of CO emission from the engine under varied loads. The emissions are depicted using a multi-color system, with green representing an increase in CO emission at 50 to 60% of load, and blue representing the minimum and green representing the maximum. Figure 6(b) shows a 3D response surface illustrating CO variation with load, EGR, and TME Blends.

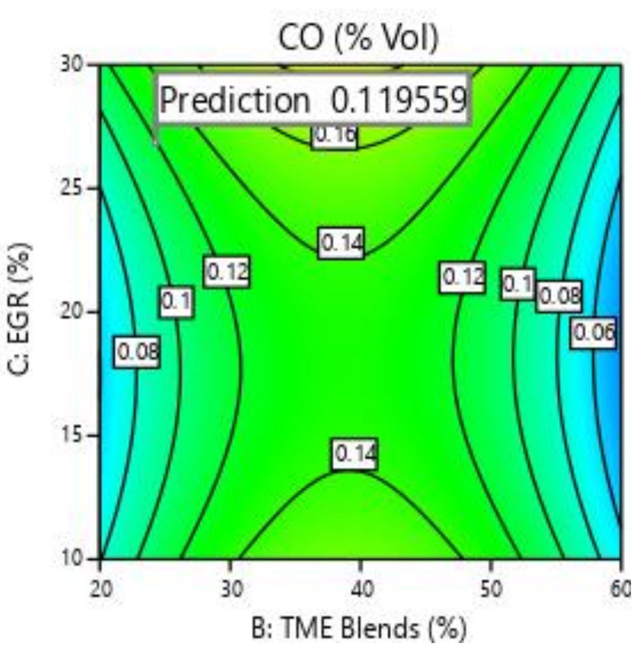


Fig. 6(a). Contour 2D Surface plot with EGR and TME Blends – CO Emission

The incomplete combustion of fuel within the engine is the primary source of carbon monoxide emission. Adding a small amount of EGR setup with hydroxy gas additionally reduces the amount of carbon, but also allows for full burning, lowering emissions. As a result, a decrease in the pattern is observed in the presence of an EGR setup. The analysis of actual and expected CO emissions in Figure 7 indicates that the chosen model is correct. The responses corresponding to optimal study factors were load 0%, TME Blend 40% and EGR 20% gives minimum CO of 0.009 (%vol).

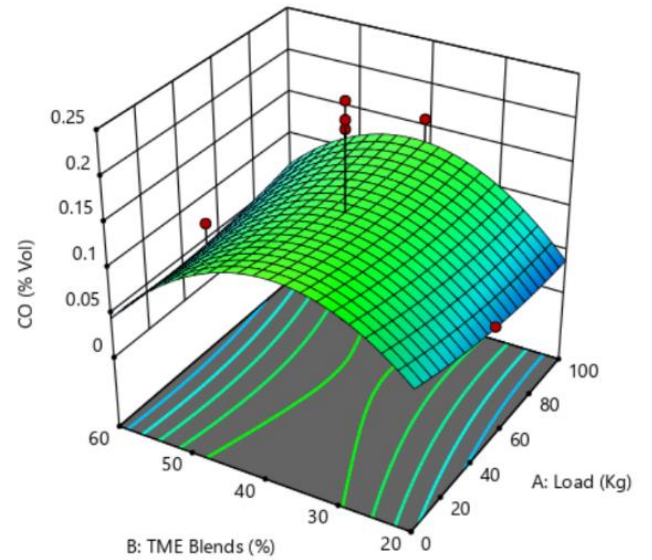


Fig. 6(b). Contour 3D Surface plot with EGR and TME Blends – CO Emission

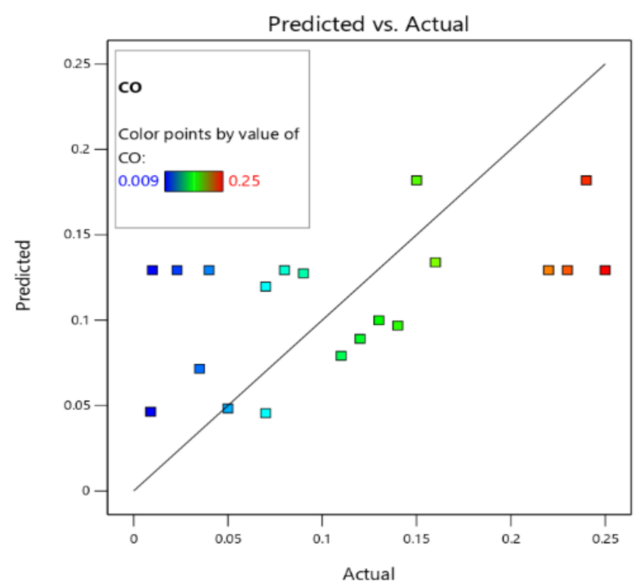


Fig. 7. Actual and predicted values for CO

The figure 8(a) illustrates the precise influence of various parameters on hydrocarbon emissions. The combination of load, EGR, and TME blends reduced all concentrations of HC emissions, and those with the lowest emissions have been found to be at 100% load, as shown in the Figure 8(b) 2D plot. Based on the overall analysis, increasing the load from 0% to 100% has a much smaller effect on HC emissions than on CO emissions.

A similar tendency can be seen on the 3D response surface, where illustrates the emission fluctuations of each fuel combination. While carbon in the oil that lubricates and secondary fuel such as diesel is oxidized by excessive oxygen and an excessive combustion temperature within the cylinder, hydroxy gas reduces HC. Furthermore, the engine's performance in this regard has been improved by a comparatively low quenched range and a wider combustion range in the case of the HC emission.

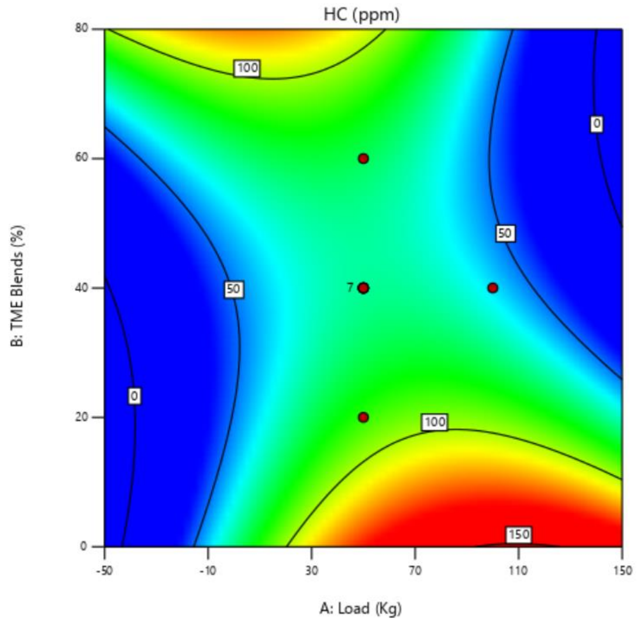


Fig. 8(a). Contour 2D Surface plot with EGR and TME Blends – HC Emission

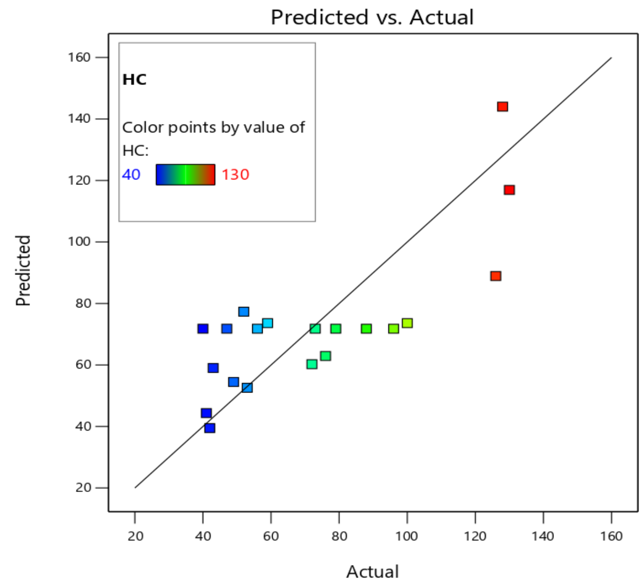


Fig. 9. Actual and predicted values for HC.

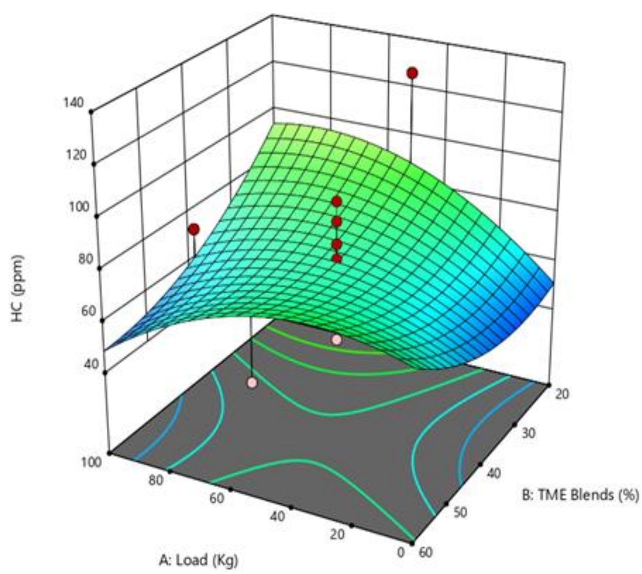


Fig. 8(b). Contour 3D Surface plot with EGR and TME Blends – HC Emission

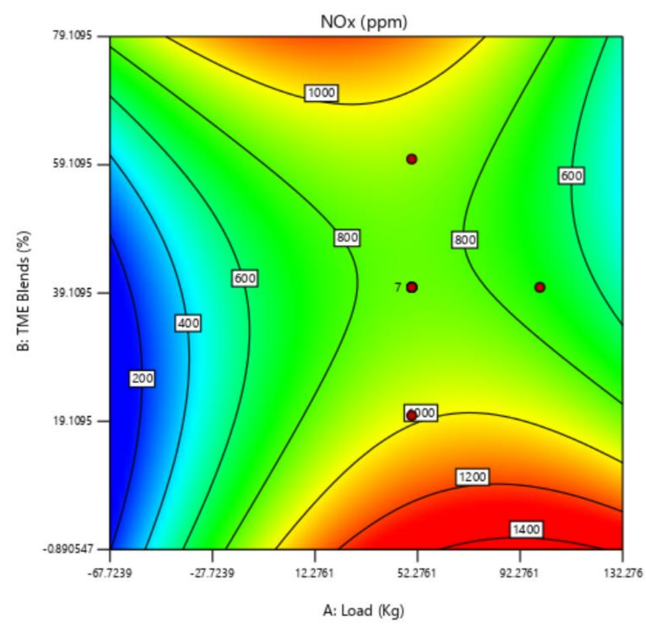


Fig. 10(a). Contour 2D Surface plot with EGR and TME Blends – NoX Emission

The figure 9 depicts a comparison of expected and actual HC emission. The minor differences between the anticipated and actual data sets demonstrate the quadratic regression model's accuracy. The responses corresponding to optimal study factors were load 0%, TME Blend 60% and EGR 30% gives minimum HC of 40 ppm.

The effect of load, EGR, and TME blends on NoX emission can be investigated using the 2d contour plots and 3D response surface illustrated in Figure 10(a). The region of various colours in the figure's top left corner shows how the NoX level increased as EGR was incorporated and is now at its highest at 100% load.

Figure 10(b) where the 3D response surface shows a gradual increase in NoX level, shows the same direction more clearly. The raised NoX level carried on by the addition of hydroxy gas could be attributed to increased thermal efficiency and uncontrolled burned at high temperatures within the chamber. Figure shows that as fuel enrichment and load increase, the opacity falls. According to the 2D contour plot and 3D response surface, a diesel blend with a 100% load generates the least amount of smoke. Increased combustion and temperature of the oxygen burn may be responsible for an engine's increased NoX emissions.

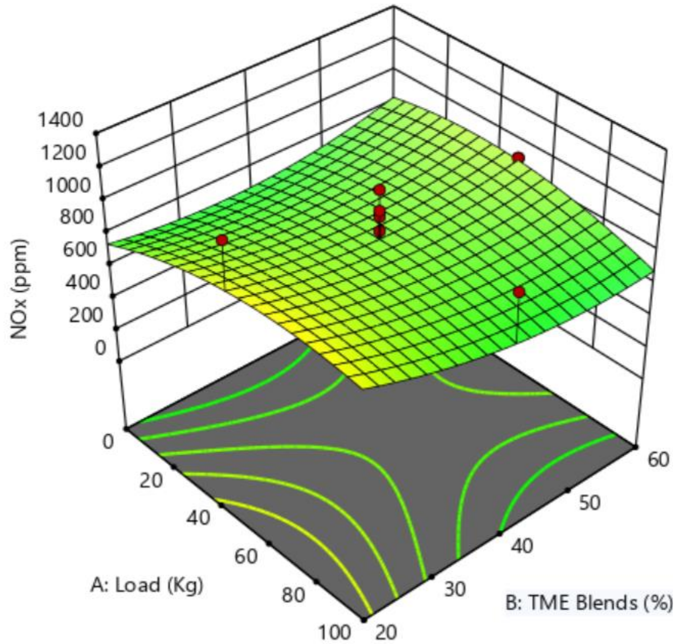


Fig. 10(b). Contour 3D Surface plot with EGR and TME Blends – NoX Emission

The figure 11 depicts a comparison of expected and actual NoX emission. The minor differences between the anticipated and actual data sets demonstrate the quadratic regression model's accuracy. The responses corresponding to optimal study factors were load 50%, TME Blend 40% and EGR 20% gives minimum NoX is 580 ppm.

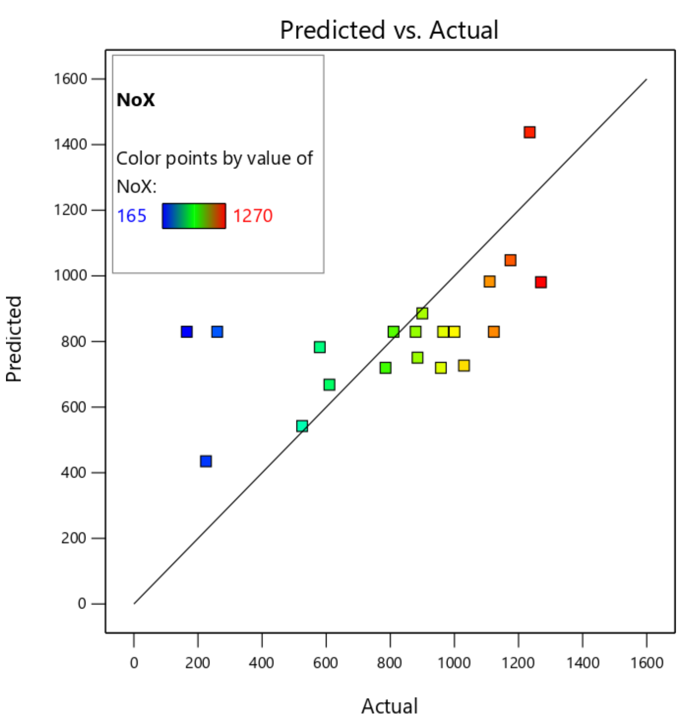


Fig. 11. Actual and predicted values for NoX

The 2D contour plots and 3D response surface shown in Figure 12(a) can be used to examine the effects of load, EGR, and TME blends on smoke emission. The area of different colours in the top left corner of the picture demonstrates how the smoke level climbed when EGR was added and is currently at its peak at 100% load. Figure 12(b), where the 3D response surface depicts an incremental rise in smoke level, more clearly illustrates the same tendency. The increased smoke level caused by the hydroxy gas addition could be attributed to the chamber's enhanced thermal efficiency and uncontrolled burning at high temperatures.

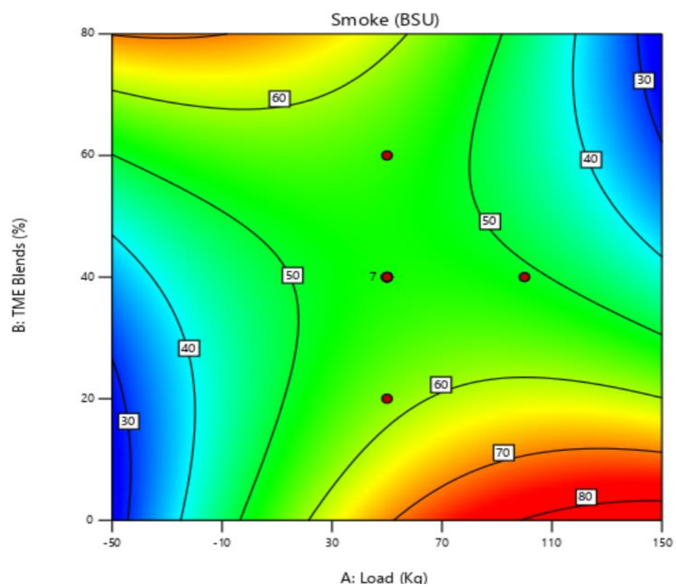


Fig. 12(a). Contour 2D Surface plot with EGR and TME Blends – Smoke Emission

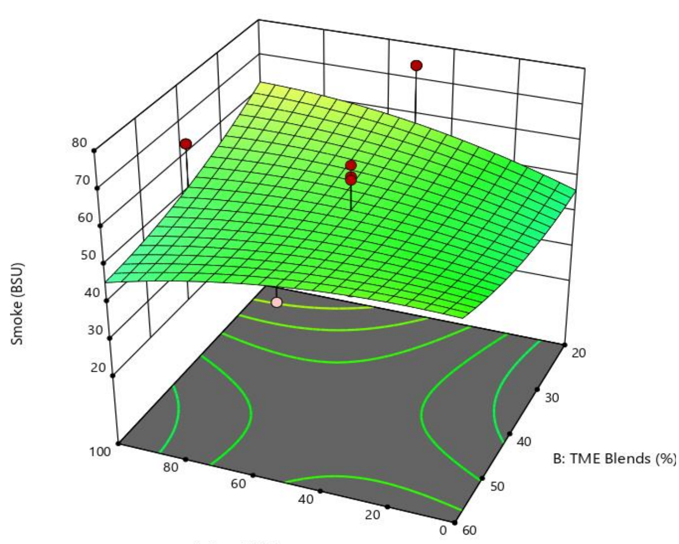


Fig. 12(b). Contour 3D Surface plot with EGR and TME Blends – Smoke Emission

Figure 13 shows how the opacity decreases with increasing fuel enrichment and load. The least amount of smoke is produced by a diesel blend with a 100% load, according to the 2D contour plot and 3D response surface. The increased smoke emissions from an engine may be caused by higher combustion and temperature of the oxygen burn. The comparison of anticipated and actual smoke emission is shown in the figure 12. The correctness of the quadratic regression model is demonstrated by the little variations between the expected and actual data sets. The responses corresponding to optimal study factors were load 100%, TME Blend 40% and EGR 30% gives minimum smoke of 28 BSU.

The emission characteristics of CO, HC, NoX and Smoke shows in table 7 & 8 the ANOVA results for the second response variables, CO, HC, NoX and Smoke. The model is significant since it shows less than the designated range with a F value of 0.3759 for CO, 1.72 for HC, 0.6516 for NoX and 0.897 for smoke. A p-value of 0.9217 for CO, 0.2061 for HC, 0.7343 for NoX and 0.5601 for smoke. The ANOVA results reveal that load, TME blends, and EGR have significant impacts on emission characteristics. However, when examined on a model, the CO and NoX reduced due to increase of EGR setup. The load variations were found to have a higher impact on an engine with EGR concentration and TME blends were found to have better emission control.

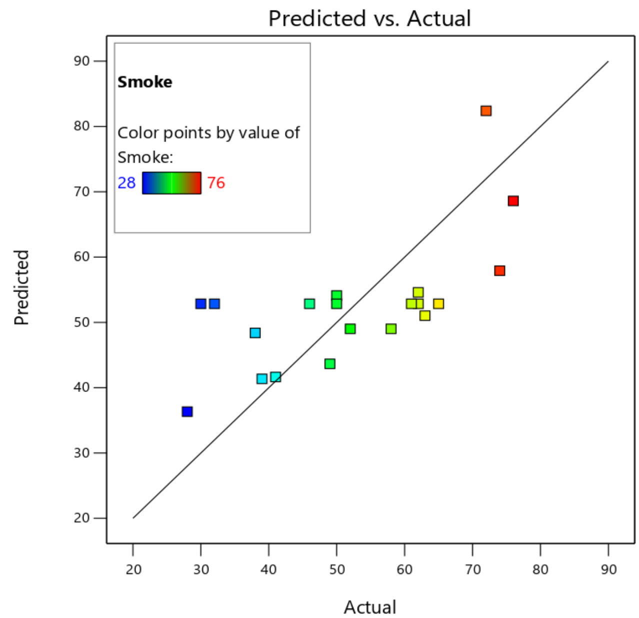


Fig. 13. Actual and predicted values for Smoke

Table 7. ANOVA table of CO and HC emissions

	CO (% VOL)			HC (PPM)		
SOURCE	Sum of Squares	F-value	p-value	Sum of Squares	F-value	p-value
MODEL	0.029	0.3759	0.9217	10415.37	1.72	0.2061
A-LOAD	0.0002	0.0242	0.8796	186.1	0.276	0.6108
B-TME BLENDS	0	0.0023	0.9628	336.4	0.4988	0.4961
C-EGR	0.0026	0.3073	0.5915	76.72	0.1138	0.7429
AB	0.0017	0.196	0.6674	2312	3.43	0.0938
AC	0.0003	0.0308	0.8642	4608	6.83	0.0259
BC	0.0001	0.0098	0.9229	2520.5	3.74	0.082
A^2	0.0002	0.0178	0.8966	446.56	0.6622	0.4347
B^2	0.0157	1.83	0.2064	296.41	0.4395	0.5223
C^2	0.0025	0.2907	0.6016	48.64	0.0721	0.7937
RESIDUAL	0.0858			6743.63		

Table 8. ANOVA table of NoX and Smoke emissions

	NOX (PPM)			SMOKE (BSU)		
SOURCE	Sum of Squares	F-value	p-value	Sum of Squares	F-value	p-value
MODEL	7.74E+05	0.6516	0.7343	1814.79	0.897	0.5601
A-LOAD	2866.8	0.0217	0.8858	21.96	0.0977	0.7611
B-TME BLENDS	22562.5	0.171	0.688	36.1	0.1606	0.697
C-EGR	1.39E+05	1.05	0.329	95.38	0.4243	0.5295
AB	69378.12	0.5257	0.485	325.13	1.45	0.2568
AC	4.30E+05	3.26	0.1012	1035.13	4.6	0.0575
BC	60378.13	0.4575	0.5141	253.13	1.13	0.3136
A^2	24913.4	0.1888	0.6732	19.97	0.0888	0.7718
B^2	24784.31	0.1878	0.6739	23.14	0.1029	0.7549
C^2	750.79	0.0057	0.9414	0.4248	0.0019	0.9662
RESIDUAL	1.32E+06			2248.01		

5. Conclusions

The impact of load, tomato methyl ester (TME), and exhaust gas recirculation (EGR) enriched diesel on engine performance and exhaust gas emissions was concluded in this study using the response surface methodology (RSM) optimization technique.

- The responses corresponding to optimal study factors were load 100%, TME Blend 20% and EGR 10% gives maximum BTE of 32.5%. The fuel consumption 0.2 kg/kWh is reduced when load 50%, TME Blend 60% and EGR 10%.
- The responses corresponding to optimal study factors were load 0%, TME Blend 40% and EGR 20% gives minimum CO of 0.009 (%vol). The responses corresponding to optimal study factors were load 0%, TME Blend 60% and EGR 30% gives minimum HC of 40 ppm. The responses corresponding to optimal study factors were load 50%, TME Blend 40 and EGR 20% gives minimum NoX is 580 ppm. The responses corresponding to optimal study factors were load 100%, TME Blend 40% and EGR 30% gives minimum smoke of 28 BSU.
- The overview of ANOVA (Tables) and the assessment of the model (Table) for performance of BTE and BSFC, the emission characteristics of CO, HC, NoX, and Smoke emissions similarly displayed values of R2, Adj. R2, Pred. R2, and acceptable precise well suited inside the mandate limitations for accuracy and sufficiency of the model for intended responses.

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Nomenclature

EGR	:	Exhaust gas recirculation
DI	:	Diesel engine
CO	:	Carbon monoxide
HC	:	Hydrocarbon
NOx	:	Nitrogen oxide
BTE	:	Brake thermal efficiency
BSFC	:	Brake-specific fuel consumption
TME	:	Tomato Methyl Ester
RSM	:	Response Surface Methodology

Conflict of Interest Statement

The authors declare that there is no conflict of interest in the study.

CRediT Author Statement

P.Kumaran: Conceptualization, Writing-original draft, formal analysis
S.Natarajan: Supervision, Validation, Data curation,

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