Experimental investigations on Cerium Oxide nanoparticles incorporated Diesel + Ethyl acetate alternative fuel

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ABSTRACT

This work attempted to analyze the performance of a compression ignition engine that was fuelled with diesel-ethyl acetate blends and contained Cerium Oxide nanoparticles. The major input process factors considered were the diesel/ethyl acetate ratio, the amount of Cerium Oxide nanoparticles added, and the time required to consume 10 cc of fuel. To improve performance, 20 sets of tests were created with process parameter values from a central composite design model. Based on this, the experiments were carried out, and the results were recorded. The generated model was evaluated for significance using analysis of variance. The response surface methodology was used to optimize the brake thermal efficiency while minimizing unburned hydrocarbon emissions. The model was validated using validation trials, and the error between the experimental and projected values was less than 5%, indicating that the model was designed with a high level of predictability. Interactions and perturbation plots were created to determine which parameters have the most influence on the output response.

Keywords: alternative fuel, diesel, cerium oxide nanoparticles, response surface methodology.

1. INTRODUCTION

The growing concern about environmental pollution and the depletion of fossil fuel reserves has increased the need to investigate sustainable and eco-friendly energy alternatives. Among numerous renewable energy sources, biodiesel has emerged as a promising alternative due to its biodegradability, lower emissions, and potential to lessen dependence on conventional diesel fuels [1, 2]. Biodiesel, which is often made from animal fats, vegetable oils, or recycled oils used for cooking, is a renewable and more sustainable choice that can drastically reduce greenhouse gas emissions and pollution. [3]. The transition to alternate fuels is not just an environmental one, but also an economic one. With the increased volatility of global oil prices and the geopolitical tensions surrounding oil-producing countries, ensuring a steady and affordable energy supply has become crucial [4]. Alternative fuel is an encouraging option since it can be generated domestically, reducing dependency on imported fossil fuels and improving energy security [5]. Blending diesel with ethyl acetate has been found to improve diesel engine performance and emissions. Ethyl acetate, a renewable solvent, improves combustion efficiency and reduces the viscosity of the blend, resulting in higher engine performance and lower emissions [6, 7].

This mix not only optimizes fuel qualities but also helps to achieve sustainability goals by using bio-based additives. Furthermore, the addition of nanoparticles to biodiesel blends has been hailed as a breakthrough in fuel technology. Nanoparticles' high surface area and catalytic characteristics considerably improve the fuel's combustion efficiency and emission profile [8]. Studies have indicated that nanoparticle additions can enhance thermal conductivity, reduce friction, and promote cleaner combustion, therefore enhancing the overall performance of biodiesel engines [9, 10]. Optimizing alternative fuel production and blending procedures is critical for increasing the efficiency and efficacy of these renewable fuels. Advanced optimization approaches, such as machine learning algorithms and multi-objective optimization, are increasingly being used to discover the ideal conditions for biodiesel production and mixing, providing higher output, better fuel characteristics, and less environmental effect [11, 12]. According to the literature review and earlier investigations, no research on the usage of Diesel + ethyl acetate with cerium oxide nanoparticles in a compression ignition engine was identified. Hence, this study attempted to optimize the technological factors involved in the usage of diesel blends containing ethyl acetate and cerium oxide nanoparticles in a compression ignition engine system.

2. MATERIALS AND METHODS

2.1 Experimental Setup and Procedure

An indigenous single-cylinder compression ignition diesel engine test apparatus was used to assess engine performance. The rig works by feeding diesel into the combustion chamber, compressing it to high pressure, and then igniting it with compression. Data from sensors and instruments were utilized to analyze engine efficiency, combustion characteristics, and emission levels in order to improve diesel engine design and operation. Figure 1 shows the compression ignition engine test setup that was used in the studies. The basic ingredients for this study included fuel, ethyl acetate, and 99.9% pure Cerium Oxide nanoparticles. All raw materials were of very high quality. As a result, it was employed immediately in the studies, with no further purification. Table 1 shows the physical and chemical characteristics of diesel and ethyl acetate. Cerium oxide (CeO_2) nanoparticles, with a density of 7.22 g/cm³ and particle sizes typically between 5-50 nm, exhibits a high surface area (>50 m²/g) and a face-centered cubic structure. They have strong catalytic activity, thermal stability, and antioxidant capabilities due to their capacity to flip between +3 and +4 oxidation states, making them ideal as additives in various applications [13].

Figure 1. CI engine test rig

Table 1 – Physicochemical properties of diesel and ethyl acetate

Fuel	Diesel	Ethyl acetate
Density (kg/m^3)	846	903
Specific Gravity	0.84	0.896
Flash Point	51°C	-3.6°C
Fire Point	63°C	7.8°C
Calorific Value (kJ/kg)	43950	22165
Viscosity (cst) at 51°C	3.12	0.43

2.2 Identifying feasible limits

The feasible limits of the technological parameters were determined using prior research [14, 15, 16], which included performance studies of Compression Ignition Engines, as well as trial and error experiments. The three most important technological process parameters that influence the performance characteristics of a Compression Ignition Engine powered by diesel and ethyl acetate and incorporating Cerium Oxide nanoparticles were discovered to be the diesel-to-ethyl acetate ratio, the quantity of Cerium Oxide nanoparticles added, and the time required to consume 10 cc of fuel.

The following results were achieved after conducting trial and error experiments. i) When the studies were carried out with a blend of less than 3% ethyl acetate in diesel, the engine efficiency was found to be low and unacceptable. The CO content of the emissions exceeded tolerable limits.

ii). When the studies were carried out with a blend of more than 12% ethyl acetate in diesel, the overall energy content of the fuel mixture decreased, potentially leading to lower engine performance and fuel economy.

iii) If the time length for consuming 10 cc of fuel was less than 40 seconds, excessive fuel input at a shorter time resulted in fuel waste and a higher concentration of NOx in the exhaust. iv). If the time length for consuming 10 cc of fuel was set to be longer than 65 seconds, the engine's performance would suffer due to a lack of fuel supply at the necessary rate. v). If Cerium Oxide nanoparticles were added to diesel+ethyl acetate blends at a concentration less than 2.5 mg/l, no improvement in engine efficiency was seen.

vi). If Cerium Oxide nanoparticles were added to diesel+ethyl acetate blends at a concentration more than 7.5 mg/l, the percentage of undesired NOx, UBHC, and CO_2 emissions began to rise.

Thus, the performance of the compression ignition diesel engine was achievable with a blend percentage of 3% to 12% ethyl acetate in diesel, a fuel consumption period of 40 to 65 seconds, and the addition of Cerium Oxide nanoparticles ranging from 2.5 mg/l to 7.5 mg/l. Table 2 shows the ranges for the three most essential process parameters. The trials were carried out by varying the technological process parameters. All other process parameters of the compression ignition test equipment remained constant. The experiments were carried out under full load conditions. When the Compression Ignition Diesel Engine was powered by diesel + ethyl acetate and Cerium Oxide nanoparticles at full load, the braking thermal efficiency was identified and the amount of unburned hydrocarbon content in the output gas was determined using exhaust gas analysis.

Table 2 - Feasible range of technological parameters

Parameter	Notation	Levels				
		-1.68	1	0	1	+1.68
Blend percentage of ethyl acetate in Diesel (%)	BEA	3	5	7.5	10	12
Time for consumption of 10 cc of fuel (s)	TC	40	45	52	60	65
Addition of Cerium Oxide nanoparticles (mg/l)	NP	2.5	3.5	5	6.5	7.5

2.3 Designing a central composite design model.

For assessment, a central composite design model was chosen. Because the individual values had a wide range, twenty coded conditions were applied. A five-level central composite design model, comprising six star and centre points, was employed with eight sets of design points. The most positive coded value for the Diesel + ethyl acetate with Cerium Oxide nanoparticles powered test rig conditions was +1.68, while the least negative technological parameters were -1.68. Montogomery DC [17] obtained the values for the intermediate range of process parameters.

$R_i = 1.682[2R – (R_{max} + R_{min})/(R_{max} + R_{min})]$ --- (1)

In the aforementioned equation, the coded variable value for R is R+. R is created to assume any value of the variable based on the values between R_{min} and R_{max}. The coded parameter's lowest and greatest values were denoted as R_{min} and R_{max}, respectively. Table 3 shows the central composite design model produced using twenty various conditions.

Table 3 shows the brake thermal efficiency of the Diesel + ethyl acetate with Cerium Oxide nanoparticles-fueled test rig under varied running conditions. Furthermore, the amount of unburnt hydrocarbon content in ppm discharged in the exhaust was determined using exhaust gas evaluation procedures, and the results are displayed in Table 3. The goal of this experiment was to maximise the BTE while minimising the emission of UBHC.

Table 3 – Range of central composite design model with experimental values

No	Actual factor value			BTE	UBHC
Run	BEA	TC	NP	%	ppm
	%	sec	kgf		
1	7.50	52.50	2.50	28.32	133.104
2	12.00	52.50	5.00	42.66	141.733
3	7.50	52.50	5.00	44.66	129.269
4	10.18	59.93	3.51	34.66	132.864
5	7.50	52.50	5.00	45.32	128.07
6	10.18	45.07	3.51	31.66	138.138

7	7.50	65.00	5.00	40.32	134.542
8	7.50	52.50	5.00	44.32	127.591
9	10.18	59.93	6.49	38	143.411
10	7.50	52.50	5.00	44.66	129.509
11	4.82	45.07	6.49	34.32	138.857
12	4.82	45.07	3.51	18.67	142.452
13	4.82	59.93	6.49	40.32	136.949
14	10.18	45.07	6.49	51.66	142.692
15	7.50	52.50	5.00	43.66	129.029
16	7.50	52.50	5.00	45	128.789
17	4.82	59.93	3.51	42.32	133.583
18	7.50	40.00	5.00	33	139.562
19	7.50	52.50	7.50	43.32	141.494
20	3.00	52.50	5.00	34.66	139.336

3. RESULTS AND DISCUSSION

3.1 Establishing empirical relationships

Relationships between the 'diesel + ethyl acetate with Cerium Oxide nanoparticles powered Compression Ignition Diesel engine' combustion technological process parameter values and responses were developed empirically. The responses were measured in terms of Break Thermal Efficiency (BTE) percentage and unburnt hydrocarbon (UBHC) content in exhaust fumes.

These responses were attributed to the important 'diesel + ethyl acetate with Cerium Oxide nanoparticles fuelled Compression Ignition Diesel engine' combustion technological process parameters such as the diesel-to-ethyl acetate ratio, the quantity of Cerium Oxide nanoparticles addition, and the time required to consume 10 cc of fuel. According to the relationship revealed by Paventhan et al., [18] the equations for brake thermal efficiency and unburned hydrocarbons are given as follows:

BTE = f (BEA, TC, NP) --- (2)

UBHC = f (BEA, TC, NP)----- (3)

A second-order polynomial regression equation has been used to model the response surface K for brake thermal efficiency and unburnt hydrocarbons in the 'diesel + ethyl acetate with Cerium Oxide nanoparticles powered compression ignition diesel engine'.

$K = u_0 + \Sigma u_i x_i + \Sigma u_{i1} x_{i2} + \Sigma u_{ij} x_i x_j$--------(4)

The second order polynomial equation for the ratio of diesel to ethyl acetate (BEA), time taken to consume 10 cc of fuel (TC), and quantity of Cerium Oxide nanoparticles added (NP) is as follows.

$$BTE/UBHC = \{u_0 + u_1 (BEA) + u_2 (TC) + u_3 (NP) + u_{12} [BEA \times TC] + u_{13} [BEA \times NP] + u_{23} [TC \times NP] + u_{11} (BEA)^2 + u_{22} (TC)^2 + u_{33} (L)^2\} \text{ --------- } (5)$$

In the equation above, u_0 represents the average of all responses. The coefficients of the regression equation (u_1, u_2, u_3, and u_{nn}) are determined by the three input components' linear, interaction, and squared terms. The coefficient values were evaluated using design expert software. The significance of individual coefficient values was determined using student t tests and p values.

Table 4 – ANOVA test results for break thermal efficiency model

Source	SS	Df	F - ratio	p-value Prob>F	
Model	1082.4	9	552.85	< 0.0001	Significant
BEA	82.8	1	399.45	< 0.0001	
TC	73.56	1	341.82	< 0.0001	
NP	281.63	1	1369.2	< 0.0001	
BEA x TC	2.7.32	1	969.5	< 0.0001	
BEA x NP	12.73	1	48.62	< 0.0001	
TC x NP	148.32	1	669.35	< 0.0001	
BEA^2	66.84	1	3.9.84	< 0.0001	
TC^2	118.06	1	583.45	< 0.0001	
NP^2	139.59	1	683.21	< 0.0001	
Res	2.12	10			
LOF	0.43	5	0.38	0.8765	No
Std. Dev 0.43		R^2		0.9982	
Mean 42.82		Adj		0.9988	
C.V. % 1.09		Pred		0.9952	
PRESS 5.9		Adeq Pres		100.029	

Tests were performed using analysis of variance (ANOVA) to maximise the break thermal efficiency model and minimise the UBHC content. Table 4 shows the ANOVA test findings for the break thermal efficiency model, whereas Table 5 shows the ANOVA results for the unburned hydrocarbon content minimization model.

Table 4 shows that the Brake Thermal Efficiency maximisation model has a Model F-value of 552.85, indicating that it is significant. This means that there is only a 0.01% probability that a "Model F-Value" this large will arise owing to noise. "Prob > F" values less than 0.0500 suggest that the model terms are significant. In this scenario, relevant model terms include BEA, TC, NP, BEA x TC, BEA x NP, TC x NP, BEA^2, TC^2, and NP^2. Values above 0.1000 imply that the model terms are not significant. The "Lack of Fit F-value" of 0.38 indicates that the lack of fit is not substantial when compared to the pure error. There is an 87.65% likelihood that this significant "Lack of Fit F-value" is caused by noise.

Table 5 - ANOVA test results for un-burnt hydrocarbon content minimization model

Source	SS	Df	F - ratio	p-value Prob>F	
Model	583.62	9	131.32	< 0.0001	Significant
BEA	7.29	1	13.25	< 0.0001	
TC	43.69	1	85.36	< 0.0001	
NP	63.52	1	129.41	< 0.0001	
BEA x TC	3.89	1	8.63	< 0.0001	
BEA x NP	28.54	1	60.33	< 0.0001	
TC x NP	19.83	1	44.74	< 0.0001	
BEA^2	233.45	1	496.41	< 0.0001	
TC^2	122.70	1	254.86	< 0.0001	
NP^2	136.41	1	274.56	< 0.0001	
Res	5.32	10			
LOF	2.39	5	0.83	0.6943	No
Std. Dev 0.73		R^2		0.9941	
Mean 133.54		Adj		0.9932	
C.V. % 0.59		Pred		0.9741	
PRESS 22.52		Adeq Pres		41.85	

The Model F-value of 131.32 indicates that the unburned hydrocarbon content minimization model is noteworthy. There is a 0.01% probability that a "Model F-Value" this large will occur owing to noise. "Prob > F" values less than 0.0500 suggest that the model terms are significant. Values above 0.1000 imply that the model terms are not significant. The "Lack of Fit F-value" of 0.83 indicates that the lack of fit is not significant when compared to the pure error. A "Lack of Fit F-value" of this magnitude is 69.43% likely to be caused by noise. Break thermal efficiency of 'diesel + ethyl acetate with Cerium Oxide nanoparticles powered Compression Ignition Diesel engine' is shown as

$$BTE = \{44.61 + 2.48 (BEA) + 2.29 (TC) + 4.56 (NP) -5.04 [BEA \times TC] + 1.21 [BEA \times NP] - 4.29 [TC \times NP] -2.13 (BEA)^2 -2.84 (TC)^2 -3.13 (L)^2\} \text{ --------- } (6)$$

The un-burnt hydrocarbon emissions of the 'diesel + ethyl acetate with Cerium Oxide nanoparticles powered compression ignition diesel engine' are represented as

$$UBHC = \{128.72 + 0.68 (BEA) – 1.74 (TC) + 2.12 (NP) + 0.78 [BEA \times TC] + 1.92 [BEA \times NP] + 1.62 [TC \times NP] + 4.13 (BEA)^2 + 2.90 (TC)^2 + 2.98 (L)^2\} \text{ --------- } (7)$$

3.2 Empirical relationship assessment.

The developed empirical relationship was evaluated using the ANOVA approach. The results' appropriateness was validated using the created response surface model. R^2 was defined as the determination coefficient. The R^2 value can be utilised to assess the quality of fit of the proposed break thermal efficiency enhancement and unburned hydrocarbon emission reduction model. After evaluating the various values from the results of the ANOVA analysis in Tables 4 and 5, it was determined that only about 5% of the fluctuations were unexplained.

Because the modified R^2 value was high, it was possible to conclude that the constructed model had a high level of significance. The corrected coefficient of determination agreed well with the projected R^2 value. The value of sufficient precision is used to assess the inaccuracy produced during prediction and to compare the anticipated values.

Because the determination coefficient was greater than 0.95, it was possible to conclude that the experimental results were closely related to the expected values of break thermal efficiency and unburnt hydrocarbon emissions. Figure 2 (a) shows the correlation between the projected and actual break thermal efficiencies of a 'diesel + ethyl acetate with Cerium Oxide nanoparticles powered Compression Ignition Diesel engine', while Figure 2 (b) shows the correlation for hydrocarbon emissions.

3.3 Optimization of technological parameters

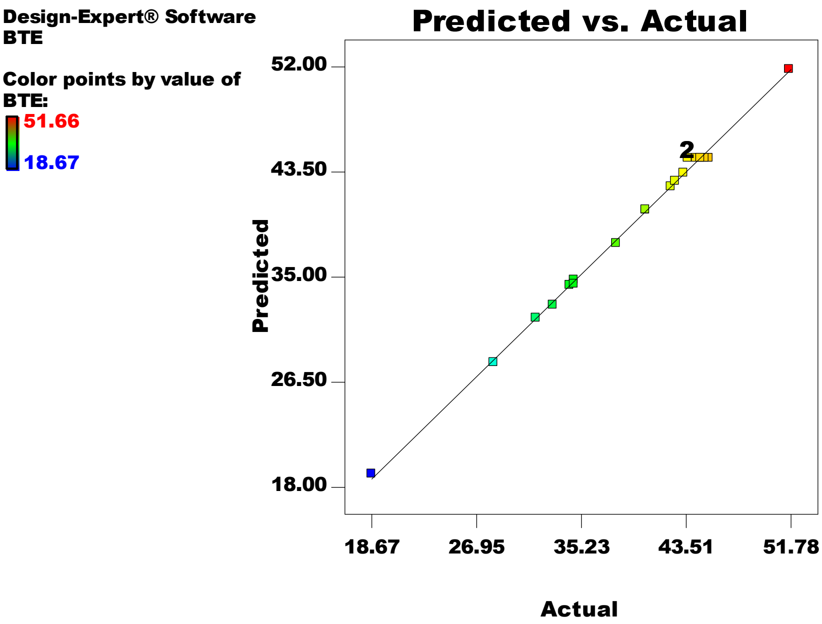
The relationship between the combustion process parameters of the 'diesel + ethyl acetate with Cerium Oxide nanoparticles powered Compression Ignition Diesel engine' and the output responses was found using mathematical and statistical methods. In this study, response surface approach was utilised to optimise the process parameters. As the number of variables increased, such as the diesel-to-ethyl acetate ratio, the quantity of Cerium Oxide nanoparticles added, and the time required to consume 10 cc of fuel, response surface methodology proved to be extremely efficient in optimisation. The response surface methodology was used to assess changes in dependent variables such as break thermal efficiency and unburnt hydrocarbons.

$N = \Phi(e_1, e_2 \ldots e_k) \pm er$ ----- (8)

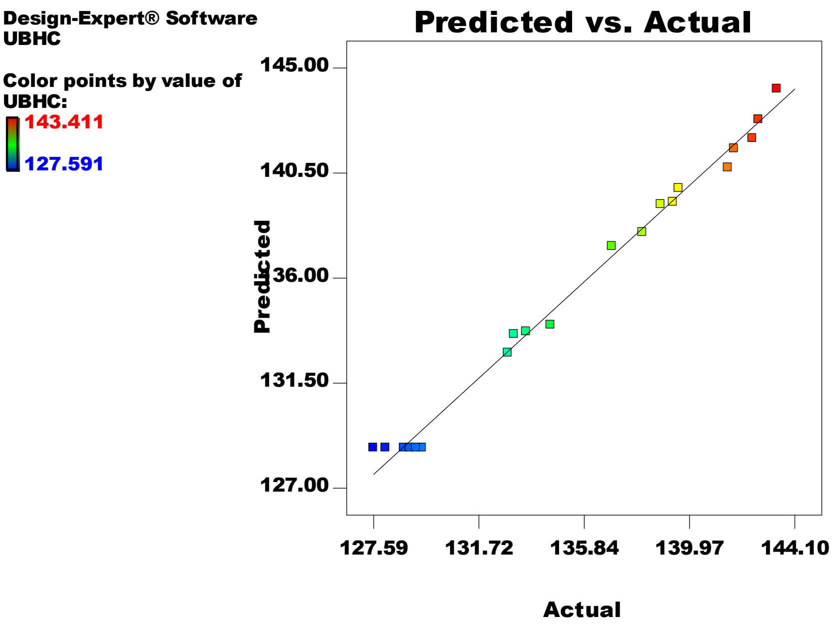
N indicates the response, while e_1, e_2, and e_k represent qualitative characteristics. The residual error (er) indicates experimental errors. The independent variables were represented as a typical surface region.

3.4 Developing 3D surface plots and contours

Using circular shapes, contours were used to show the relationship between important factors such as the ratio of diesel to ethyl acetate, the amount of Cerium Oxide nanoparticles added, and the time required to consume 10 cc of fuel, as well as the responses in the form of brake thermal efficiency and unburnt hydrocarbon emissions. The stationary point is designed to achieve the value of maximum, minimum, or saddle. Characterising the stationary point allows for a response surface investigation and optimisation. Contours were created using software designed by experts. The ideal zone can be accurately determined by evaluating the surface's form.



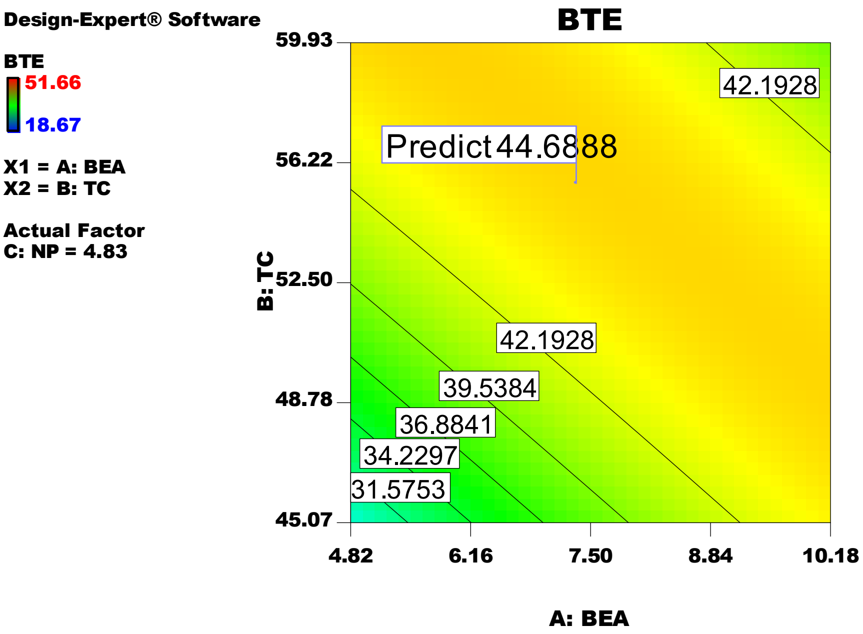
(a) BTE model



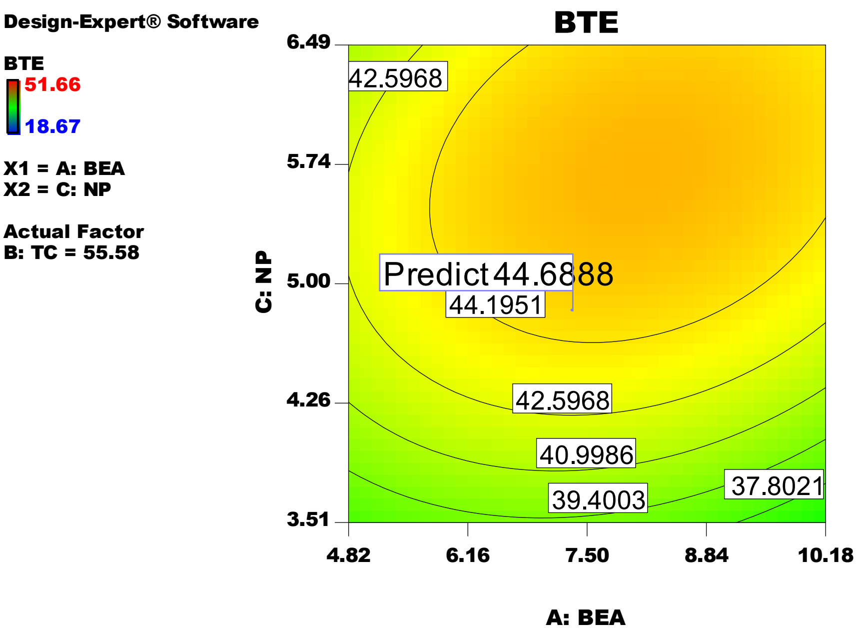
(b) UBHC model

Figure 2 Correlation between predicted and actual values

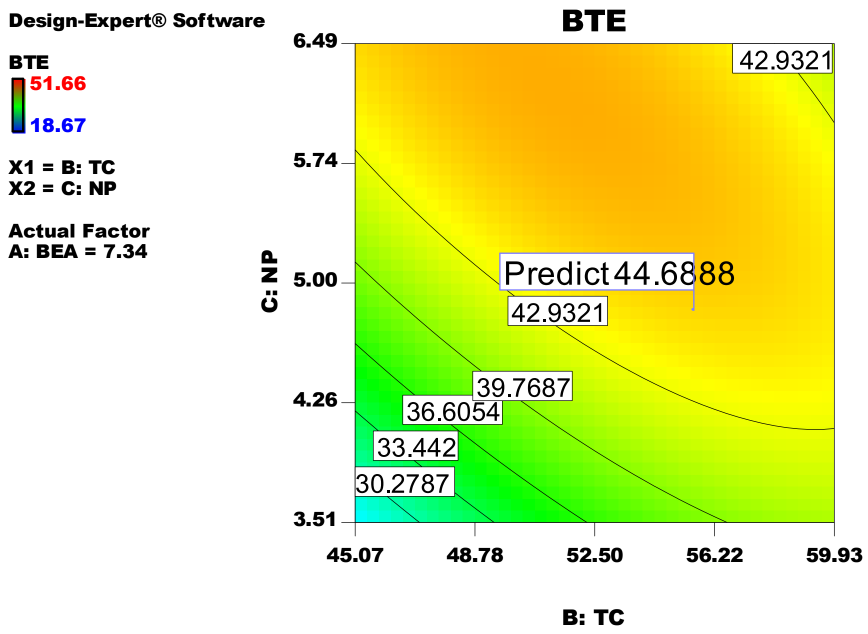
The circular contours indicate the factors' independence. The contours' elliptical forms show that the factors interact. The responses, such as the brake thermal efficiency and emission of unburnt hydrocarbon in the exhaust, were traced in the Z axis by using two of the diesel + ethyl acetate with Cerium Oxide nanoparticles fuelled Compression Ignition Diesel engine's combustion process parameters at the middle range and plotting them in the two-reference axis such as the X and Y axes.



(a) BTE – Contours BEA vs TC

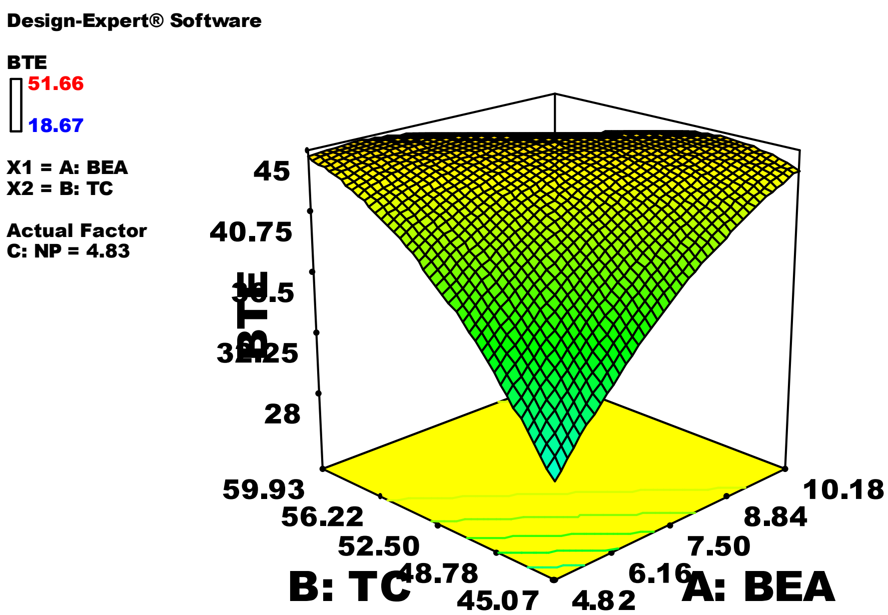


(b) BTE – Contours BEA vs NP

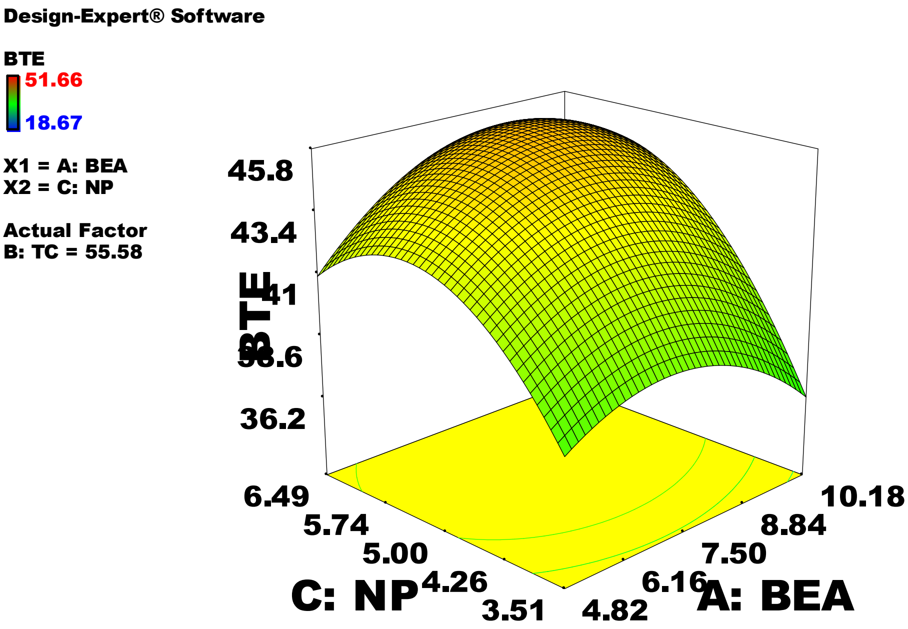


(c) BTE – Contours TC vs NP

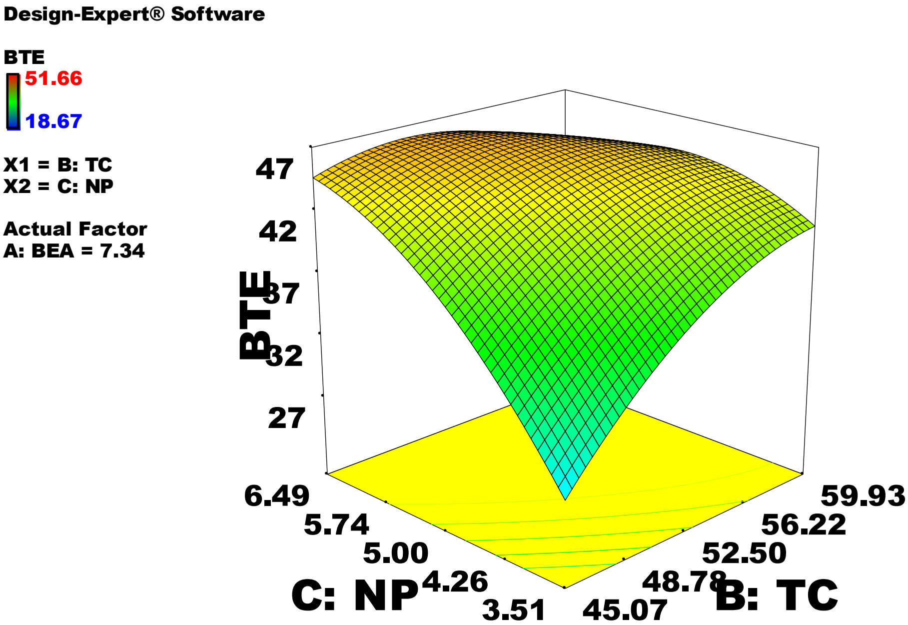
Figure 3 Contours for BTE maximization model



(a) BTE – 3D-surface BEA vs TC

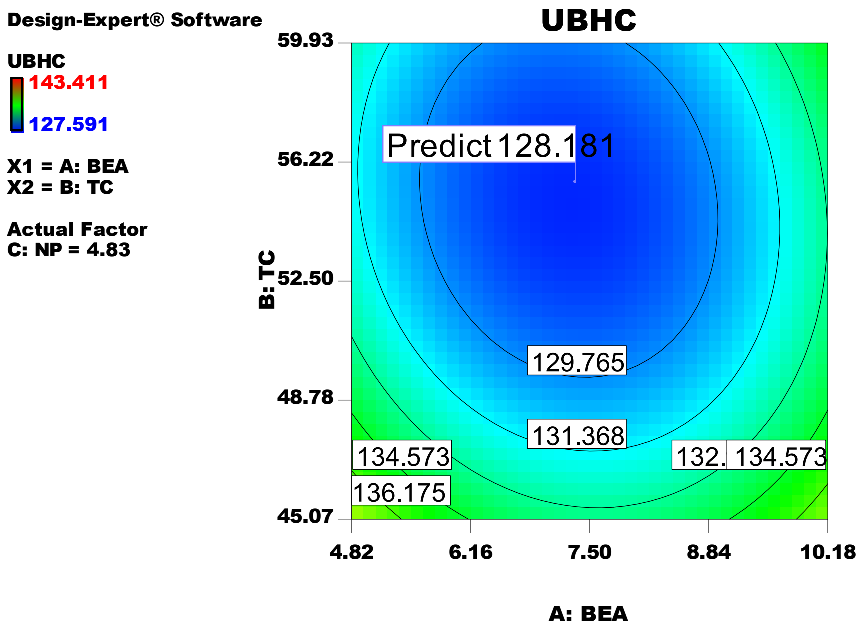


(b) BTE – 3D-surface BEA vs NP

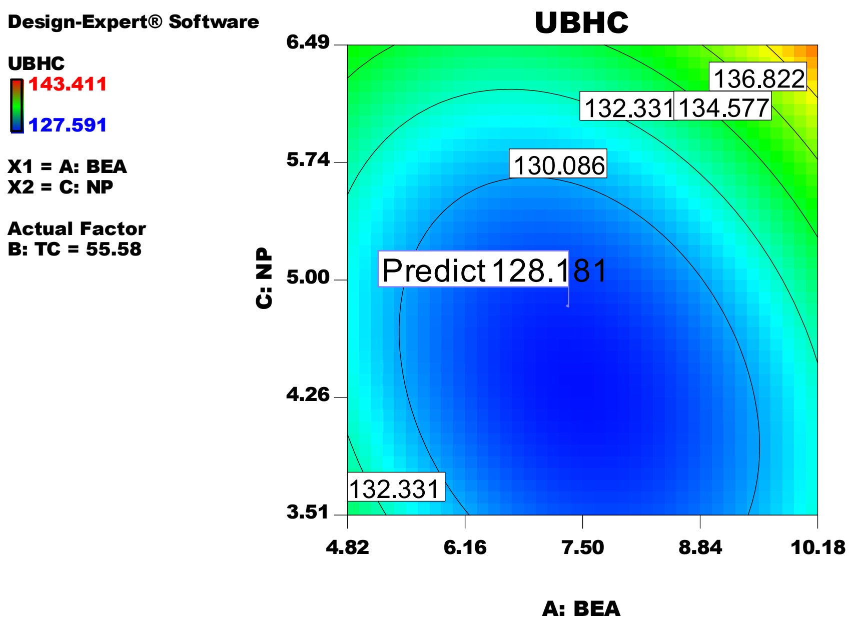


(c) BTE – 3D-surface TC vs NP

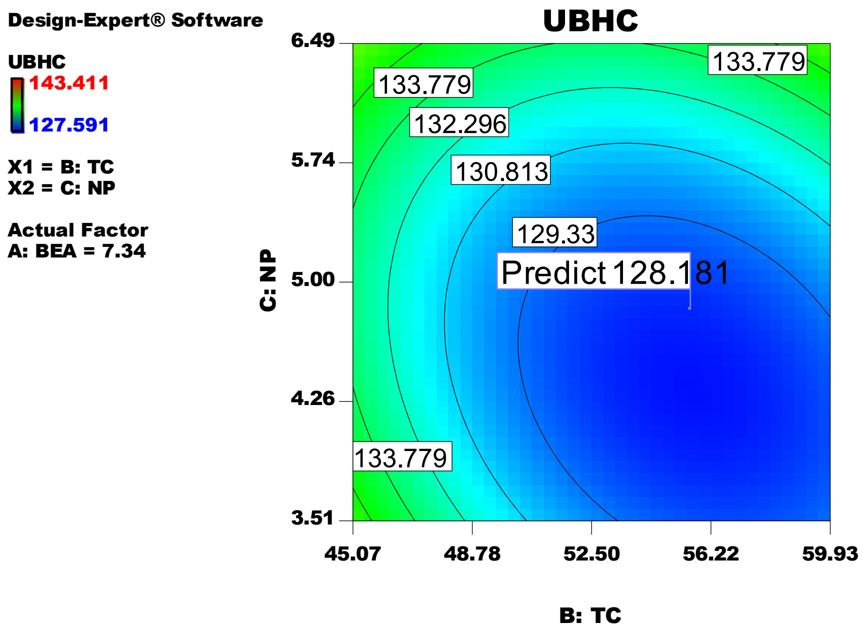
Figure 4 3D-surface plots for BTE maximization model



(a) Contours UBHC – BEA vs TC

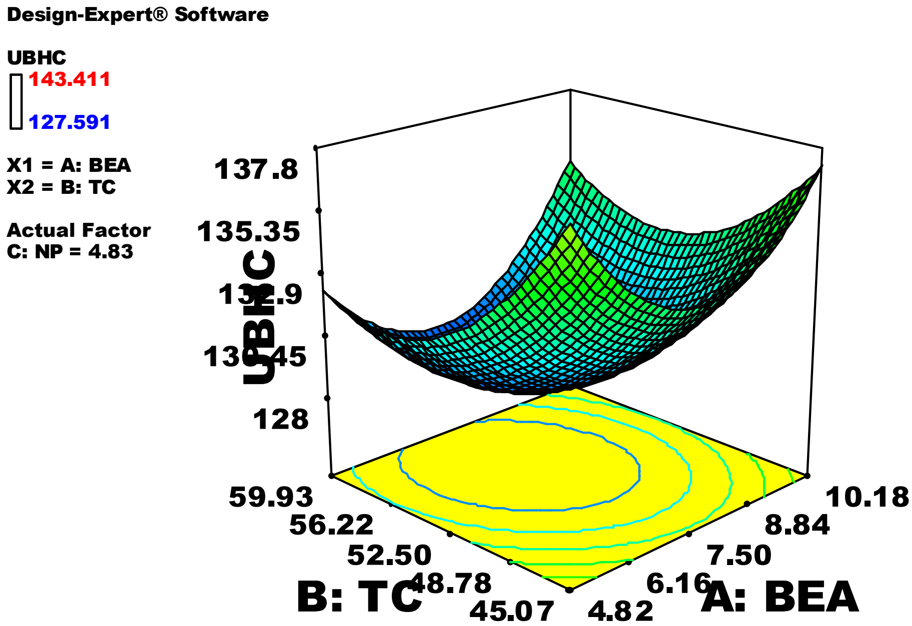


(b) Contours UBHC – BEA vs TC

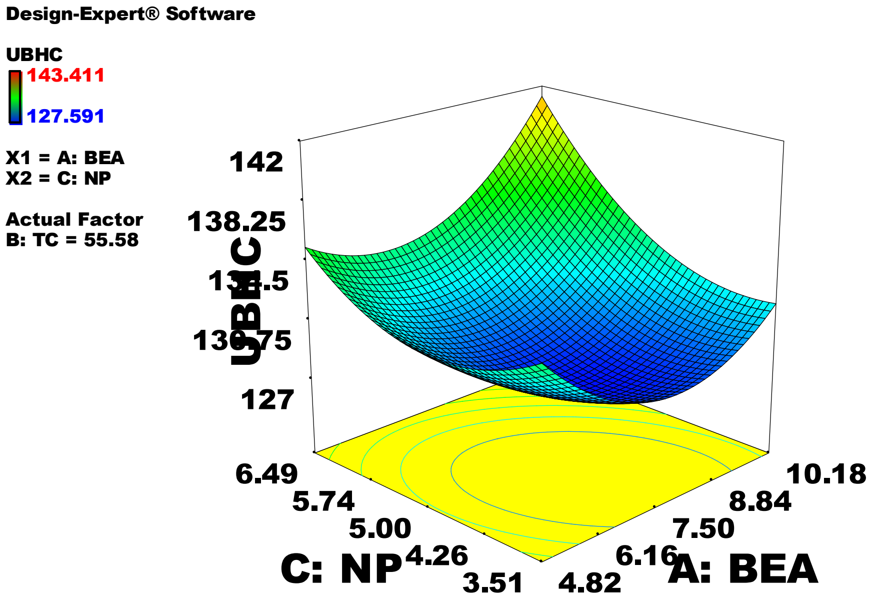


(c) Contours UBHC – TC vs NP

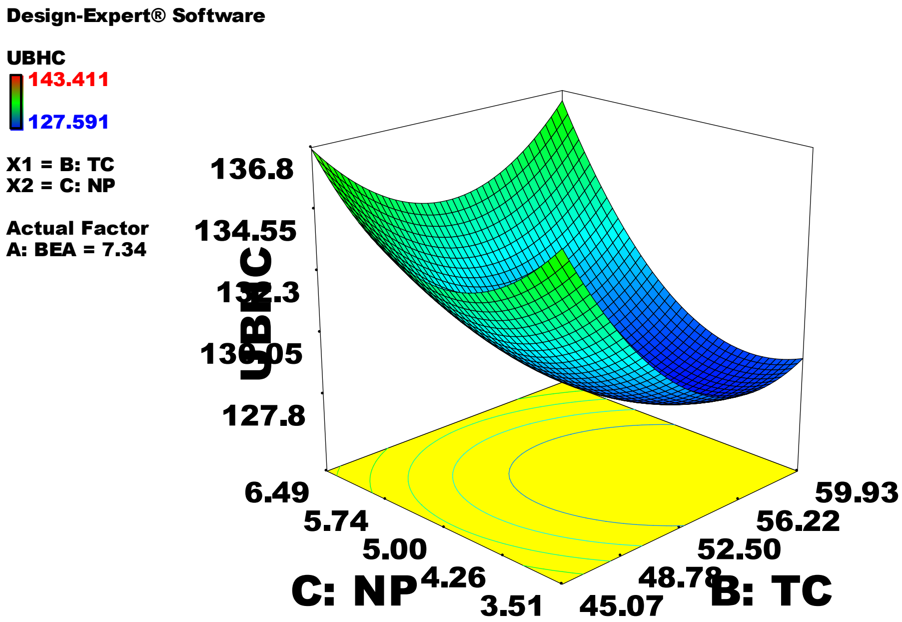
Figure 5 Contour plots for UBHC minimization model



(a) 3D surface UBHC - BEA vs TC



(b) 3D surface UBHC – NP vs BEA



(c) 3D surface UBHC – NP vs TC

Figure 6 3D-surface plots for UBHC minimization model

The point of optimality was reached utilising 3D surface plots of the replies. Figure 3 shows contour graphs for brake thermal efficiency. Figure 3 (a) depicts the contour plots for BEA vs TC. Figure 3 (b) shows the contour plots for BEA vs NP. Figure 3 (c) shows the contour plots for

TC vs NP. Figure 4 shows the 3D surface plots for the BTE enhancement model. Figure 4 (a) shows the surface plots for BEA against TC. Figure 4 (b) depicts the surface plots of BEA vs NP. Figure 4(c) shows the contour plots for TC vs NP. Figure 5 illustrates the contours for the UBHC minimization model. Figure 5 (a) shows the contours of BEA vs TC. Figure 5 (b) shows the contours of BEA vs NP. Figure 5(c) depicts the contours for TC vs NP. Figure 6 shows three-dimensional surface plots for the UBHC minimization model. Figure 6 (a) depicts a surface plot of time for BEA vs TC. Figure 6(b) depicts the surface plot of BEA vs NP. Figure 6 (c) shows the surface plot of TC vs NP. Optimal values could be obtained by studying the contours and surface plots.

3.5 Evaluation of plots and validation

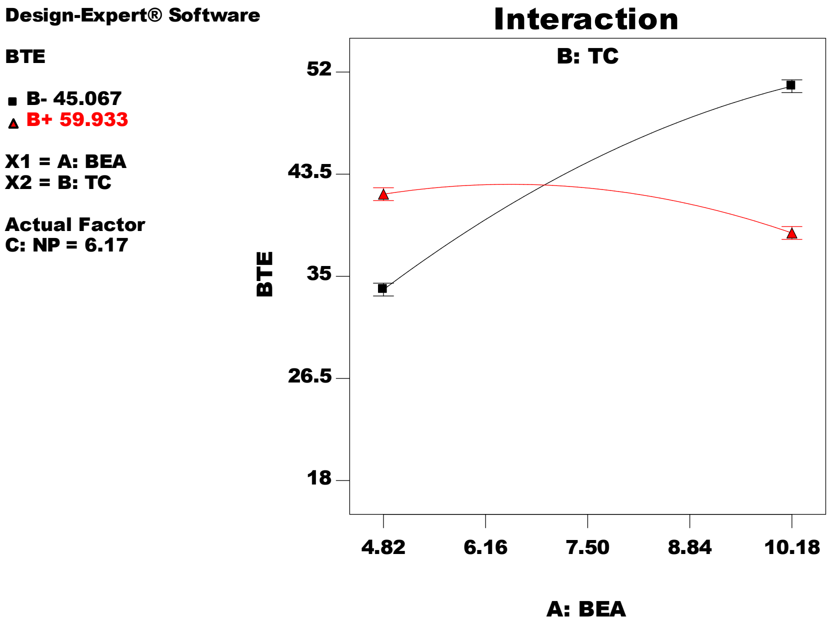
The optimal parameters for (BEA) blend percentage ethyl acetate in diesel were 7.35%, (TC) time for consumption of 10 cc fuel was 55 seconds, and (NP) quantity of Cerium oxide nanoparticles was 4.8 mg/l, as determined by the optimisation technique. In addition, the estimated maximum break thermal efficiency was 44.6%, and the exhaust gases had a minimum of 128.1 ppm of unburnt hydrocarbon. Validation studies were carried out to determine the predictability of the designed break thermal efficiency enhancement with unburnt hydrocarbon exhaust minimization model. Three such experiments were carried out using the optimized values of the technological process parameters, and the results are shown in Table 6. Validation experiments revealed that the error between anticipated and actual values was less than five percent. This demonstrated that the model was designed with a high predictability.

Table 6 – Validation experiments and results

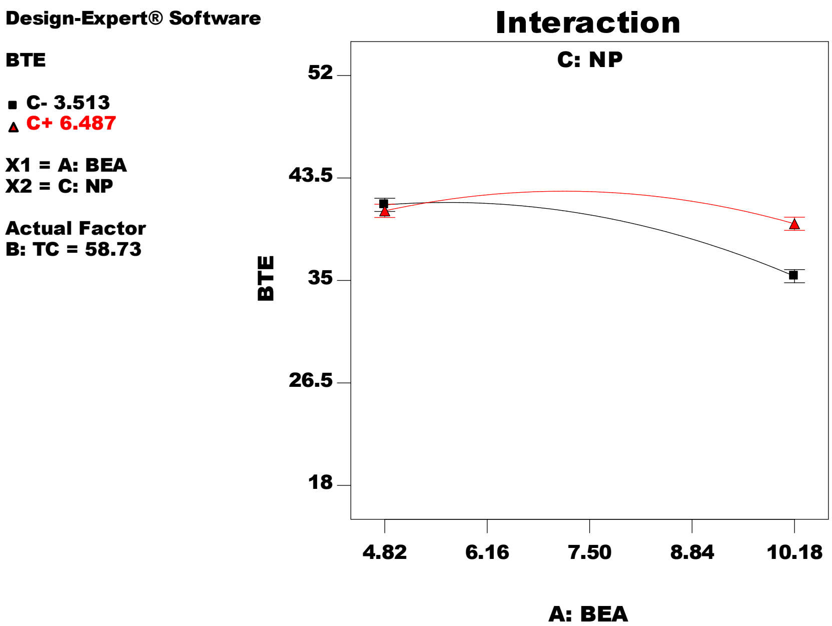
Response	Predicted	Experimental	Error
Brake thermal efficiency	44.6%	42.8%	-4.04%
		43.6%	-2.24%
		44.1%	-1.12%
Un burnt Hydrocarbon emission	128.1 ppm	131.2 ppm	2.42%
		133.6 ppm	4.29 %
		130.4 ppm	1.8 %

3.6 Interaction and perturbation plots

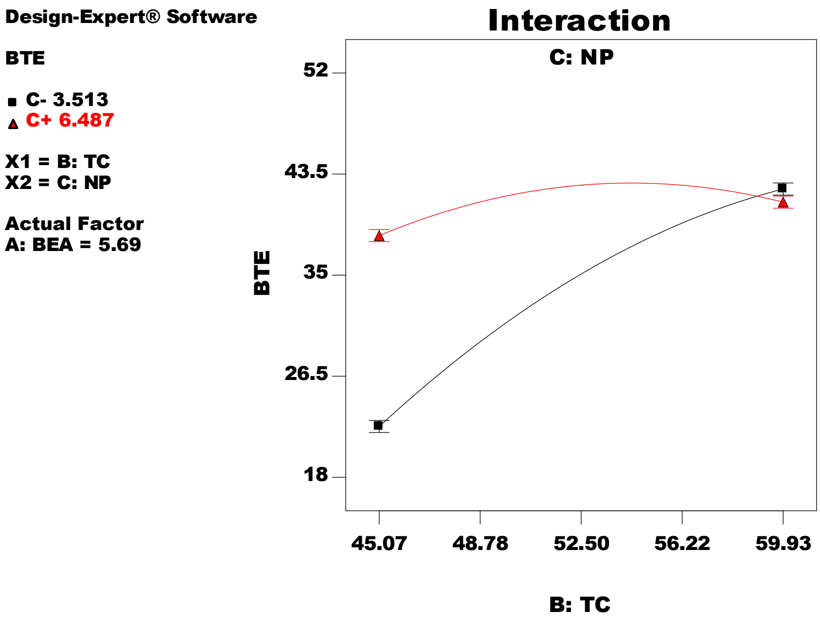
Interaction charts were created to help detect the interactions between process factors. Perturbation plots were created to rank the process parameters that influence the output responses. Figure 7 shows the interaction plots for BTE. Figure 7(a) depicts the interaction between BEA and TC at NP concentrations of 6.17 mg/l. Figure 7(b) depicts the interaction between BEA and NP at a time constant of 58.7 seconds. Figure 7 (c) shows the interaction between TC and NP at a BEA of 5.69%.



(a) BTE interaction – BEA vs TC



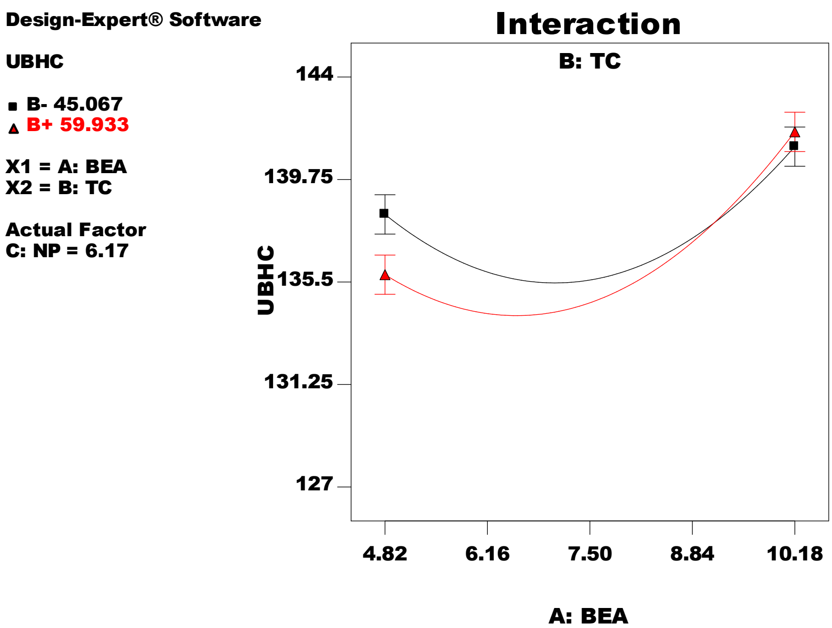
(b) BTE interaction – BEA vs NP



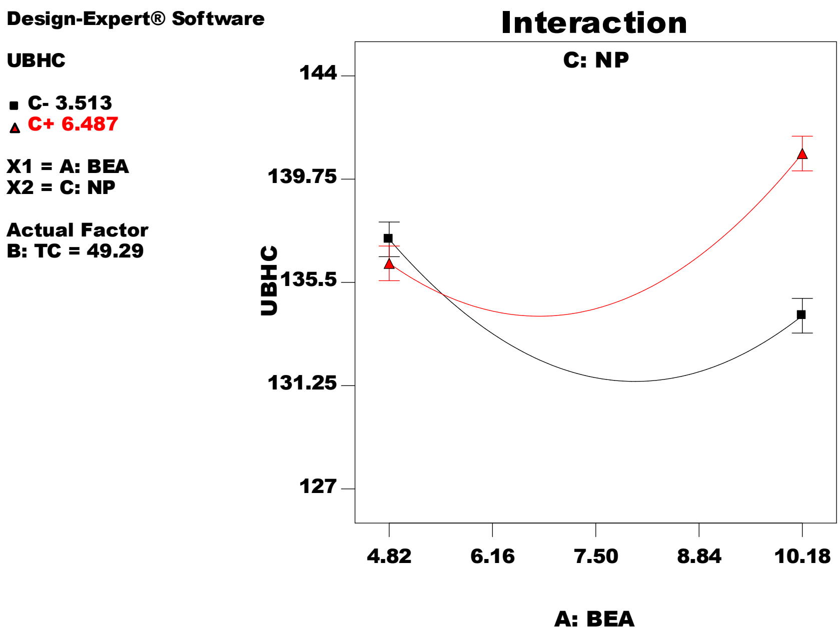
(c) BTE interaction – TC vs NP

Figure 7 Interaction plots for BTE

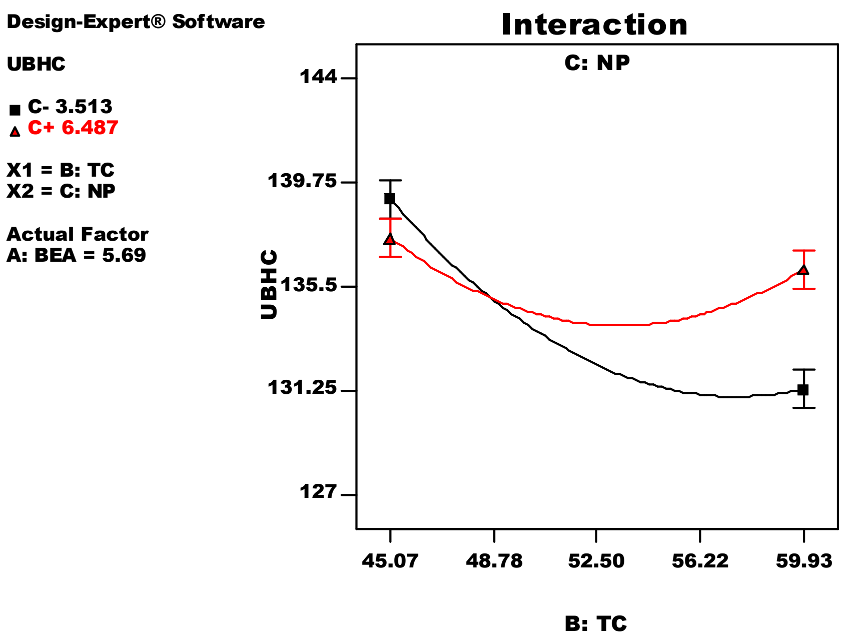
The interaction plots for UBHC are shown in Figure 8. Interaction between BEA & TC at NP of 6.17 mg/l is shown in Figure 8 (a). Interaction between BEA & NP at TC of 49.2 s is shown in Figure 8 (b). Interaction between TC & NP at BEA of 5.69% is shown in Figure 8 (c).



(a) UBHC interaction – BEA vs TC

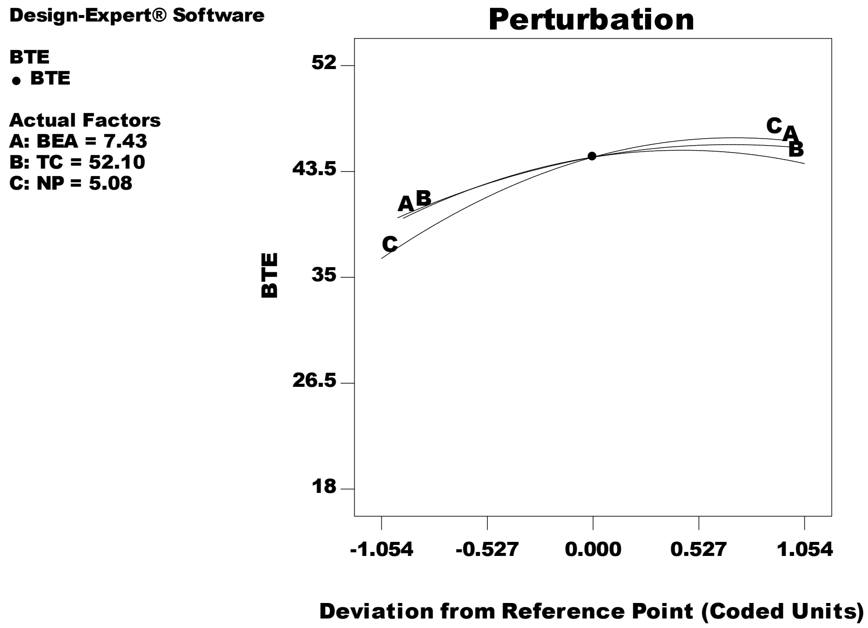


(b) UBHC interaction – BEA vs NP

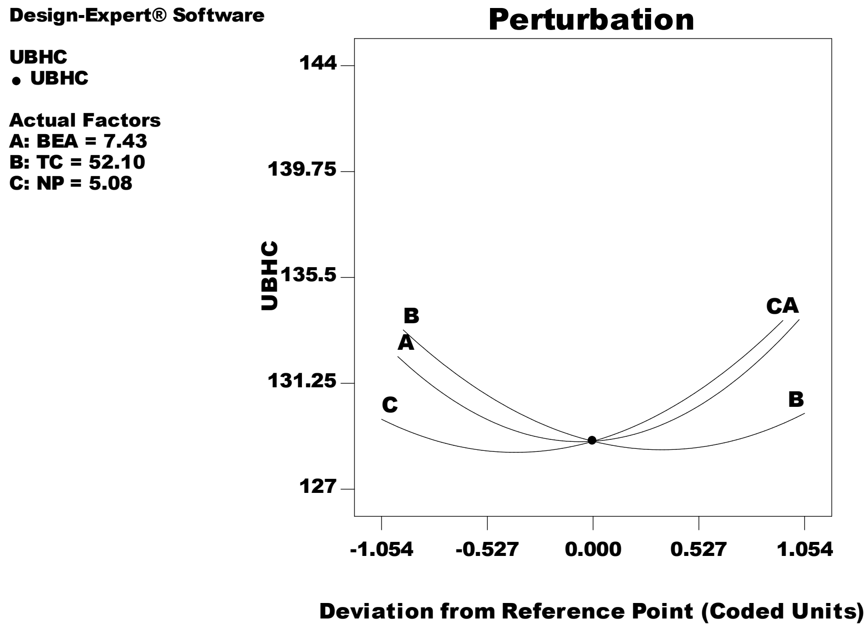


(c) UBHC interaction – TC vs NP

Figure 8 Interaction plot for UBHC



(a) Perturbation - BTE



(b) Perturbation - UBHC

Figure 9 Perturbation plots for BTE & UBHC

From Figure 9 (a) and 9 (b) it was found that the output BTE and UBHC was affected by changes in NP to a greater extent than BEA and TC.

4. Conclusion

The following conclusions were reached from the experimental evaluation of a compression ignition engine powered by diesel + ethyl acetate and using Cerium Oxide nanoparticles. The central composite design model was used to develop empirical relationships between responses such as brake thermal efficiency and unburnt hydrocarbon emissions were formed with the important technological parameters such as the ratio of diesel with ethyl acetate, the quantity of Cerium Oxide nanoparticles addition, and the time taken for consumption of 10 cc of fuel. Using ANOVA analysis, the created model's significance was determined to be greater than 95%. The optimized values for (BEA) blend percentage ethyl acetate in diesel were 7.35%, (TC) time for consumption of 10 cc fuel was 55 seconds, and (NP) quantity of Cerium oxide nanoparticles was 4.8 mg/l, were discovered using an optimisation technique. In addition, the estimated maximum break thermal efficiency was 44.6%, and the exhaust gases had a minimum of 128.1 ppm of unburnt hydrocarbon. This was proven to an extremely high degree of prediction. Interactions and perturbation graphs demonstrated that nanoparticle addition affected the output more than variations in fuel input and mix percentage.

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