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Experimental investigations of Co_3O_4, SiO_2, cotton seed oil additive blends in the diesel engine and optimization by ANN-SVM process

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The demand for alternative fuel replaces the pure utilization of diesel fuel in the engines. Nano additives and the biodiesel are introduced as the additives for reducing the emission characteristics and fulfil the energy requirements. The main objective of this research is to determine the emission characteristics of metal additives and cottonseed added diesel. Three combinations of cobalt oxide contributeto the fuel blend preparation, namely, cobalt oxide + cottonseed oil, Cobalt oxide + silicon oxide and separate cobalt oxide in the diesel fuel. Such combinations are mixed in the diesel fuel by adopting the method of ultrasonic dispersed technique with three different proportions such as 25 ppm, 50 ppm and 100 ppm of Nano additives and B20, B40 and B60 blends of cottonseed oil. The strategy of Artificial Neural Network-Support Vector Machine (ANN-SVM) is applied to optimize and predict the better-reduced emission characteristics of CO, HC and NO_x through the mat lab platform. The testing is carried out with five different load conditions such as 0, 25, 50, 75 and 100 N and a constant compression ratio 17.5. Terminally, the comparison between predicted and experimented values are also presented for determining the better cobalt oxide fuel blend combinations with minimum emission outflow. The combination of both additives such as silicon oxide and the cobalt oxide proceeds better emission characteristics from both the predicted and the experimented outcomes. In which, the predicted outcomes are 64.1% of NO_x, 0.018% of CO and 1.610% of HC.

Key words: Cobalt oxide, Cottonseed oil, Silicon oxide, Additives, ANN-SVM, Brake thermal efficiency.

Introduction

Energy plays a major role in the daily survival of humans and certain sectors of power generation, transportation, and industries. The vast demand for fossil fuels results in the energy crisis due to its depleting and non-renewable behavior. In the application of IC engines, itemits certain harmful gases while burning in the engine [1]. The supreme emission characteristics are achieved on the basis of proper combustion and performance behaviors of the engine [2]. The diesel engine promotes better efficiency than the petrol engine and so, the diesel engine performs as a prime mover application in several engineering fields. The emission from the pure diesel fuel results the global warming disturbed air quality and uncontrolled human health [3]. Carbon monoxide, hydrocarbon and nitrous oxides are the major emission gases, which produced from the diesel engine. Therefore, it is necessary to reduce the effect of such emission rates by means of alternative fuels such as bio and nano fuel [4]. The need for alternative fuels from sustainable sources is increasing and it also acts as a substitute for fossil fuels. The preservation of the environment and sustainable development is achieved by the utilization of an alternative fuel [5]. Many types of research are carried out by the application of alternative fuels such as vegetable oil, certain oil obtained from the seeds on diesel engines. The biodiesel and the nano additives added diesel behaves less toxic and eco-friendly [6]. The biodiesel incorporates complete industrial and commercial interest. It emits a fewer amount of particulate emissions and less quantity of unburnt carbon monoxide, hydrocarbons and sulfur oxides etc. [7]. There are nearly 400 oil-bearing plants are identified as the alternative additive agent for diesel, in which soybean, cottonseed oil, peanut oil, safflower, sunflower, rapeseed etc., are considered as major utilized oil.

The use of pure vegetable oils in the diesel may cause engine problems such as fouling of the injector, incomplete combustion, carbon deposited in the injector and poor atomization of fuel. This is due to its certain worst characteristics such as higher ranges of flash point, pour point, density and viscosity level [8]. Such issues are overcome by the application of certain Nano metal additives. The reduction of pollution range and the enhancement of combustion efficiency are improved by the application of fuel additives. The several metallics based catalytic additive particles that contribute to the

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emission controls are listed as copper, barium, manganese, iron etc. [9]. Nanoparticles are added as the molecular form into the diesel and its contribution todiesel fuel is actingas a most peculiar concept [10]. In the recent advances, many types of research are carried out with the help of nano additives to the diesel, biodiesel and its blends. The clogging action is also prohibited with the help of nanoparticles because of its micron-sized particles [11]. Silicon oxide is commonly used in the several ceramics and the glass industries. It possesses better behavior for minimizing the harmful gases from the emission rates [12]. In addition to this, cobalt oxide plays a significant role inburning activities in the combustion chamber. The nanoparticles of cobalt oxide offer a perfect cycle life and high reversible capacity [13]. From the overall applied combinations, the process of optimization promotes the precise outcome of the emissive characteristics. Taguchi and ANOVA optimization processes are deeply utilized in several industrial types of research [14]. Several algorithms are also contributed toprediction and optimization purposes for different emission characteristics of the fuel blend. ANN process is an enriched utilized algorithm in several emission research applications [15, 16]. In this present work, three varieties of cobalt oxide combinationsare blended in the base diesel fuel with three different proportions for analyzing and minimize the emission characteristics of harmful gases. In addition to this, the obtained experimental emission outcomes are optimized and predicted with the assistance of the ANN-SVM algorithm. Finally, a contrasting behavior is achieved for selecting the optimal fuel additive combinations in between the experimental and the predicted outcomes.

The emission characteristics such as NOX, HC, CO, CO_2 are reduced in the combustion stage of biodiesel after the addition of ZnO nanoparticles. Research work has been performed by Deepti Khatri et al. [17] to reduce the formation of emission in a diesel engine with the help of ZnO nanoparticles. Here, the ZnO nanoparticles are added with diesel fuel at five various weights in between 5 to 25 mg. The emission characteristics of ZnO nanoparticle blend biodiesel were analyzed under six various loads such as 2 kW, 4 kW, 6 kW, 8 kW, 10 kW and 12 kW at 1500 rpm engine speed. Suresh Vellaiyan et al. [18] had performed an investigation to reduce the emission of diesel with the help of ZnO incorporated water emulsified soybean biodiesel. The experimentation was performed under the full load condition of single-cylinder, natural aspirated, and four-stroke diesel engines based on Taguchi L 16 array construction. According to the GRC and S/N ratio, the emission characteristics of the fuel blend were analyzed. After the addition of ZnO incorporated water emulsified soybean biodiesel with diesel, the diesel engine performs well in terms of emission and workload. A waste cooking oil (WCO)-based biodiesel was preferred by Cheruiyot et al. [19] to reduce the emission characteristics of diesel. In which, the preferred biodiesel blended with the diesel under 5 different ratios named as B20, B40, B60, B80 and B100. Up to B60, the reduction rate emission was increased, but after the blend range of B60, the reduction rate of emission was reduced due to the viscosity property.

This research paper is sorted as follows: The existing utilization of bio and Nanofuel from the different research papers are surveyed in section 2. In section 3, the methodology, which proposed in this work, is demonstrated with the flowchart representation. The utilized materials, preparation of additive fuel blends and the methods used for the purpose of optimization and prediction are briefly categorized in section 4. The experimental results obtained from the testing of three proposed additive combinations are provided in section 5. Terminally, section 6 concludes the presented work with the attaining future scope.

The significant contribution of our proposed work is given below:

- To develop an alternative fuel blend toreplace the use of pure diesel and minimize the emission characteristics.
- The ANN-SVM algorithm contributes to identifying the optimal fuel blend and forecasting the optimally selected fuel blends on the basis of emission characteristics.

Contribution of Ceramics in Bio Diesel Emission Analysis

In the above flowchart, Fig. 1 demonstratesthat our proposed fuel blend model. Initially, the diesel fuel is prepared by the mixing of three different combinations of cobalt oxides in diesel fuel, namely, cobalt oxide + silicon oxide, cobalt oxide + cottonseed oil and separate cobalt oxide by using the ultrasonically dispersed strategy. These three combinations are added with three different proportions. Then, in the middle stage, the prepared blends are tested to determine the emission rates, such as CO, HC and NO_x. Finally, the experimental outcomes are optimized and new outcomes are predicted via ANN-SVM algorithms. In addition to this, the predicted gained outcomes are contrasted with the experimental outcomes to assess the better emission ranges.

Test engine and fuel preparation methods

In this paper, the influence of different cobalt oxide combinations in diesel fuel is analyzed byavoiding certain design modifications of the engine. The selection of materials, fuel blend separation and working principles involved in the experiments are categorized by this section.

Materials and machines used

Diesel engine

The Kirloskar TV-1 four-cylinder diesel engine is

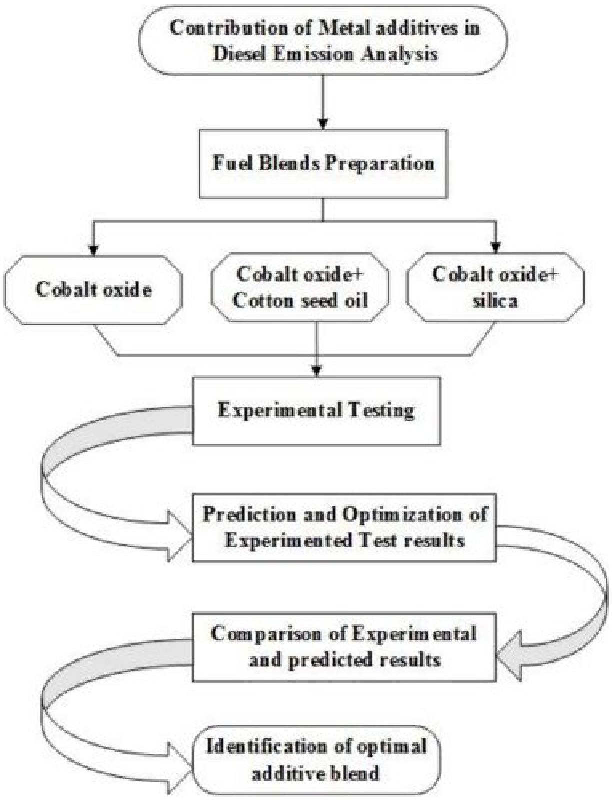


Fig. 1. Fuel blend architecture.

Table 1. Diesel engine specifications.

Engine Model	Kirloskar TV-1
Strokes produced in each cycle	4
Length of Connecting Rod	234 mm
Stroke Length	110 mm
Swept Volume	661.45 cc
Compression Ratio	17.5
Speed	1500 RPM
Power	3.5 KW

utilized to test the prepared fuel blend combinations of diesel additives namely, Co_3O_4+SiO_2, Co_3O_4+cottonseed oil and separate Co_3O_4.

The specifications of the utilized diesel engine are tabulated in Table 1. The facilitation of loading activities and measuring emission behaviors is accomplished by the Eddy current dynamometer and AVL digital 444 analyzer. Both these devices are connected at the end of the diesel engine.

Testing procedures

Thetesting of proposed three different combinations of additive added fuels are carried out with five distinct load conditions like 0, 25, 50, 75, and 100 N and with a constant compression ratio of 17.5. Three different units are comprised of the diesel engine named fuel consumption unit, load, and emission-measuring unit. The working activities, which involved in the Kirloskar Tv-1 diesel engine are signified in Fig. 2. The fuel, which ignited from the engine, is further measured by these mentioned units to determine the emission characteristics.

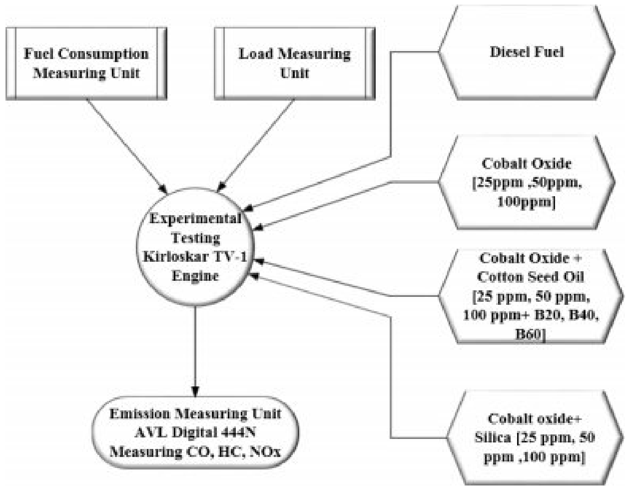


Fig. 2. Design of the experimental system.

Table 2. Thermo physical properties.

Thermophysical Properties	Cotton seed oil	Cobalt oxide	Silica
Density g/cm^3	0.92	6.11	0.919
Viscosity (cSt)	13.6	4.5	15.59
Thermal Conductivityw/mk)	0.175	1.235	0.539

Additives

Cottonseed oil and two different nanoparticles such as cobalt oxide and silica particles are added in the base diesel fuel for enhancing the emission behaviors of the engine. Thecobalt oxide gives a better clean burning and it reduces the emission rate of unburnt hydrocarbon. The oxide content in the Co_3O_4 particles is response and manage the burning behavior and diminishing the NO_x generation. In addition to this, two additional additives namely, cottonseed oil and silicon oxide particles are separately added with the cobalt oxide. The cottonseed oil and the silicon oxide particles achieve the minimum formation of harmful gases when added with the cobalt oxide. Such additives are selected on the basis of its boiling point and the size of the nanoparticles. The preferred nano size of the particles is 6 nm to 8.5 nm. In addition to this, the availability of the additive materials and its satisfied cost are also considered as its major criteria. The thermo physical properties of the utilized cottonseed oil and nano particles are listed in Table 2.

Fuel blend preparation

The additives such as cobalt oxide, silicon oxide, and cottonseed oil are added in the base diesel fuel with three prepared proportion of blends. These entire combinations are leaded by the contribution of cobalt oxide. So, both the nanoparticle (silicon oxide) and the bio agents (cottonseed oil) are utilized with cobalt oxide throughout the paper.

- Cobalt oxide (25 ppm, 50 ppm, 100 ppm)
- Cobalt oxide + Cottonseed oil (25 ppm, 50 ppm, 100 ppm + B20, B40, B60)
- Cobalt oxide + Silicon oxide (25 ppm, 50 ppm, 100 ppm)

ANN-SVM prediction and optimization

The optimization and the prediction of the emission performance of fuel blends are analyzed by using the ANN-SVM strategy. This strategy optimizes and predicts the values based on engine loading conditions and compression ratio. The supreme role of the artificial neural network and support vector machine to optimize the testing conditions and emissionbehaviours of the blends and predict the performances for the optimally selected blends. Several explicit issues are solved by an interlinked processing layer in the model of ANN. In addition to this, SVM supports to supervising the classification and regression techniques. The blend of ANN-SVM strategies quickens the prediction and optimization process by fitting the several regression issues [20, 21]. The decision function of support vector classification (SVC) decision function is,

$$f_c(x) = W^T\varphi(x) + b = \sum_{i=1}^{N} \alpha_i y_i k(x_i, x) + b = \sum_{i \in SV} \alpha_i y_i k(x_i, x) + b \quad (1)$$

Where α_i are the lagrange multipliers which explain only the non-zero values and kernel function is denoted as k.

The regression function of the support vector machine is expressed as,

$$f_r(x) = W^T\varphi(x) + b = \sum_{i=1}^{N} (\alpha_i - \alpha_i^*) k(x_i, x) + b = \sum_{i \in SV} (\alpha_i - \alpha_i^*) k(x_i, x) + b \quad (2)$$

The nonlinear function h_i based ANN regression function f is defined as,

$$f(x) = w_0 + \sum_i w_i h_i(x) \quad (3)$$

Where i^{th} hidden node attains in the hidden layer are denoted as h_i and w_i denotes the weight.

$$h_i(x) = \frac{1}{1 + \exp\left(w_{i,0} + \sum_{j=1}^{p} w_{i,j} x^j\right)} \quad (4)$$

Here, weight is mentioned $w_{i,j}$, and j^{th} the input variable is denoted as x^j. SVM eliminates the noise from the dataset and the dataset is refined by train the ANN. ANN quickly predicts the new data points and the prediction accuracy of both methods is the same. There are two training phases in ANN-SVM and the first phase of SVM trains the dataset.

$$D = \{x_i, y_i\}_{i=1}^{N} \quad (5)$$

Here, x_i it mentions the input feature vector and y_i mentions the target output value. Based on the regression function or the decision of trained SVM, obtains the function values $f(x_i) \in R$ for each data point x_i. The input feature vector and the function values are used to obtain the new refined dataset $D' = \{x_i, f(x_i)\}_{i=1}^{N}$ in the second phase. The fitted function values are taken based on the training set value of ANN. New data points are tested based on the regression function of trained ANN and the classification problems are solved using ANN-SVM methods. The given below table

Table 3. Steps Involved in Classification and Regression of ANN-SVM.

Algorithm for ANN-SVM Classification	
Given a training data set $D = \{X_i, Y_i\}_{i=1}^{N}, Y_i \in \{1,...,c\}$, the ANN-SVM procedures are as follows [23].	
Step 1	The training of both multi-class and binary classification of support vector machine is taking place. In which, binary classification is performed when the value of c equals to 2 and greater than 2 helps to perform the multi-class support vector classification.
Step 2	With the help of the decision function of SVC, the construction of the new data set $D' = \{X_i, \{f_1(X_i), ..., f_c(X_i)\}\}_{i=1}^{N}$ is achieved and computes the values of decision function $f_j(X_i)$ for the original training data set D.
Step 3	The multiple-output of ANN is trained with D'. The ANN j^{th} output node corresponds to the j^{th} decision function f_j.
Step 4	Test results are classified. The multi-class decision functions are approximated by the regression function of ANN.
ANN is integrated with certain multi-class decision functions of support vector classification and the hidden nodes help to control the ANN regression function.	
ANN-SVM Regression	
Step 1	The training process is accomplished for the SVM data set $D = \{X_i, Y_i\}_{i=1}^{N}, Y_i \in R$.
Step 2	By the SVM regression function, the creation of a new training data set $D' = \{X_i, \{f_i(X_i)\}\}_{i=1}^{N}$ takes place.
Step 3	ANN is trained for the newly formed data set D'.
Step 4	The trained ANN from the previous step helps to provide the final regression outcomes.

represents the regression function for the ANN-SVM methods.

The above Table 3 shows the accompanying procedures involved in the optimization and prediction of experimental outcomes. Both the classification and regression problems involved in the experimental results are solved with the assistance of ANN-SVM algorithms. In which, the regression process is integrated with the support vector and ANN classification decision functions to optimize the associated problems.

Experimental Results and Discussion

The emission performance of cobalt oxide combinations in the diesel fuel is tabulated by means of input parameters. The load and compression ratios are acting as the input parameters and the emission outflow of CO, HC, and NO_x are performed as output. In which, the compression ratio is constantly set as 7.5 and the value of load differs from 0 N to 100 N. The ANN – SVM machine learning techniques help to optimize and predict the three cobalt oxide blends in diesel fuel. The MAT lab simulation software is utilized for enlarging the application of ANN-SVM. In addition to this, the comparison of both experimented and predicted results are signified in the final section.

Table 4 signifies the emission rate of both normal and cobalt oxide added diesel fuel adopted with five different load variations such as 0, 25, 50, 75 and 100 N. In which, the emission rates of CO and HC are optimal for the cobalt oxide added diesel and NO_x emission rate is minimum for the pure diesel fuel.

Table 5 displays the performance analysis of both pure diesel and the cobalt oxide added diesel. The performance, such as brake specific fuel consumption and the brake thermal efficiency are measured from the Co_3O_4 added biodiesel and the pure diesel. The table demonstrates that the increase in load conditions increases the brake thermal efficiency and decreases the brake specific fuel consumption.

The emission behavior of cottonseed and cobalt oxide are tabulated in Table 6 with three different proportions. The emission rate of CO and HC is minimized according to the increasing of loads and the NO_x emission rate is increased when the load increases. The emission characteristics of HC and CO are best in the 100 ppm of cobalt oxide and B60 blends of cottonseed oil. The NO_x emission characteristics are optimal for the 25 ppm of cobalt oxide + B40 cottonseed oil blend.

The BSFC and BTE performances of both cobalt oxide and cottonseed oil added diesel are indicated in Table 7. From the two discussed performances, the brake thermal efficiency is directly proportional to the load condition and the brake specific fuel consumption is decreased with the increase of load conditions. The 100 ppm of cobalt oxide with a B60 blend of cottonseedoil yields the optimal range for both performances.

Table 8 shows the emission characteristics of both additives of cobalt oxide and silicon oxide particles added diesel. The 100 ppm of both additives results in less amount of emission characteristics of three different gases, namely CO, HC and NO_x. The load variations increased with the increase of emission rate of all these mentioned emission gases.

The performance rate of both cobalt oxide and silicon oxide in the diesel fuel are tabulated in the above table 9. At the 100 ppm range, both the BSFC and BTE performances are optimal for the Co_3O_4 and SiO_2 added diesel, in which it achieves the 35.3% of brake thermal efficiency and it is greater than the pure diesel fuel, where the brake thermal efficiency of diesel is 21.94%.

Predicted results using ANN-SVM methods

The optimization of experimental data and the prediction of data are achieved with the help of ANN-

Table 4. Emission rate in diesel and Co_3O_4 added diesel.

Emission	Input		Output			
	Load (N)	CR	Diesel	25 ppm	50 ppm	100 ppm
CO (% Vol)	0	17.5	0.21	0.029	0.034	0.04
	25	17.5	0.16	0.029	0.035	0.042
	50	17.5	0.14	0.035	0.039	0.047
	75	17.5	0.1	0.042	0.046	0.047
	100	17.5	0.15	0.043	0.046	0.049
HC (ppm)	0	17.5	57	7	8	5
	25	17.5	49	6	6	3.5
	50	17.5	46	6	6	5
	75	17.5	33	2	2	2
	100	17.5	44	5	3	4.5
NO_x (ppm)	0	17.5	43	55	92	90
	25	17.5	65	73	111	98
	50	17.5	70	81	117	112
	75	17.5	67	94	121	120
	100	17.5	53	101	127	130

Table 5. Performance measure of diesel and Co_3O_4 added diesel.

Performance	Input		Output			
	Load (N)	CR	Diesel	25 ppm	50 ppm	100 ppm
BSFC (kg/kWh)	0	17.5	0.72	11.72	5	9
	25	17.5	0.61	0.79	1.3	1.0
	50	17.5	0.47	0.50	0.9	0.61
	75	17.5	0.41	0.42	078	0.52
	100	17.5	0.38	0.42	0.5	0.55
Brake Thermal Efficiency (%)	0	17.5	0.54	0.83	2.12	1.92
	25	17.5	8.58	13.2	12.1	13.3
	50	17.5	15.28	20	18.3	18.9
	75	17.5	18.6	24.6	21.2	22.22
	100	17.5	21.94	24.3	25.8	26.3

Table 6. Emission in Co_3O_4 and cotton seed oil added diesel.

Emission	Input		Output								
	Load (N)	CR	25 ppm + B20	25 ppm + B40	25 ppm + B60	50 ppm + B20	50 ppm + B40	50 ppm + B60	100 ppm + B20	100 ppm + B40	100 ppm + B60
CO (% Vol)	0	17.5	0.030	0.028	0.025	0.033	0.031	0.029	0.036	0.033	0.01
	25	17.5	0.034	0.031	0.028	0.038	0.036	0.031	0.041	0.038	0.037
	50	17.5	0.039	0.036	0.033	0.042	0.039	0.032	0.044	0.042	0.040
	75	17.5	0.046	0.040	0.037	0.049	0.046	0.040	0.051	0.046	0.042
	100	17.5	0.049	0.041	0.038	0.053	0.049	0.044	0.056	0.053	0.049
HC (ppm)	0	17.5	5	4.7	4.4	6	5.7	5.4	4	3.6	3.4
	25	17.5	45	4.0	3.3	4.5	4.3	4	3	2.7	3.1
	50	17.5	3.8	3.3	2.7	3.8	3.5	3.2	3.3	3.0	2.7
	75	17.5	1.5	1.1	0.5	2	1.7	1.3	2	1.5	1.1
	100	17.5	3.8	3	2.2	3	2	1.9	4	3.6	3.1
NO_x (ppm)	0	17.5	56	54	51	90	85	80	97	92	88
	25	17.5	71	68	63	112	96	89	117	112	108
	50	17.5	78	76	68	119	117	110	118	114	110
	75	17.5	97	93	88	124	119	111	127	122	114
	100	17.5	106	101	93	134	130	123	144	138	131

Table 7. Performance of Co_3O_4 and cotton seed oil added diesel.

Performance	Input		Output								
	Load (N)	CR	25 ppm + B20	25 ppm + B40	25 ppm + B60	50 ppm + B20	50 ppm + B40	50 ppm + B60	100 ppm + B20	100 ppm + B40	100 ppm + B60
BSFC (kg/kWh)	0	17.5	3.1	2.9	2.2	5.5	3.7	2.8	8.18	5.6	4.9
	25	17.5	0.85	0.77	0.62	0.78	0.88	0.56	0.83	0.78	0.53
	50	17.5	0.63	0.5	0.49	0.67	0.62	0.44	0.76	0.49	0.37
	75	17.5	0.52	0.48	0.41	0.51	0.43	0.41	0.58	0.45	0.36
	100	17.5	0.52	0.47	0.39	0.52	0.41	0.39	0.55	0.43	0.28
Brake Thermal Efficiency (%)	0	17.5	3	3.02	2.92	2.7	3.7	3.76	3.21	2.9	2.93
	25	17.5	13.5	14.1	15.88	15.1	16.1	16.39	14.4	15.3	15.8
	50	17.5	21.1	21.9	21.3	20.81	21.99	22.02	20.l2	23.8	22.9
	75	17.5	25.22	26.3	24.9	24.1`	24.32	24.0	25.4	25.5	25.3
	100	17.5	26.8	27.5	25.66	25	24.99	25.07	25.77	26.3	25.9

Table 8. Emission rate of both Co_3O_4 and SiO_2 added diesel.

Emission	Input		Output			
	Load (N)	CR	Diesel	25 ppm	50 ppm	100 ppm
CO (% Vol)	0	17.5	0.21	0.028	0.023	0.019
	25	17.5	0.16	0.029	0.024	0.022
	50	17.5	0.14	0.031	0.027	0.024
	75	17.5	0.1	0.033	0.031	0.026
	100	17.5	0.15	0.036	0.033	0.028
HC (ppm)	0	17.5	57	7	5.5	4.8
	25	17.5	49	8	7.5	5
	50	17.5	46	8	7.7	5.1
	75	17.5	33	9	8	5.8
	100	17.5	44	10	8.5	7
NO_x (ppm)	0	17.5	43	55	48	36
	25	17.5	65	60	54	44
	50	17.5	70	64	61	53
	75	17.5	67	69	68	60
	100	17.5	53	80	75	72

Table 9. Performance of Co_3O_4 and SiO_2 added diesel.

Performance	Input		Output			
	Load (N)	CR	Diesel	25 ppm	50 ppm	100 ppm
BSFC (kg/kWh)	0	17.5	0.72	5.72	8	10
	25	17.5	0.61	0.90	2.5	0.78
	50	17.5	0.47	0.77	1.5	0.42
	75	17.5	0.41	0.56	1.3	0.56
	100	17.5	0.38	0.46	0.9	0.51
Brake Thermal Efficiency (%)	0	17.5	0.54	4.93	2.12	5.1
	25	17.5	8.58	18.2	15.1	19.6
	50	17.5	15.28	22	19.3	24.3
	75	17.5	18.6	24.6	23.2	28.22
	100	17.5	21.94	25.3	28.8	35.3

SVM methods in MAT lab. The three different compression ratios of 17.5, 19.5, and 22.5 and load conditions such as 100, 125 and 150 N are utilized for predicting the emission rates. From the overall testing conditions, load at 150 N and compression ratio of

Table 10. Predicted emission results of engine.

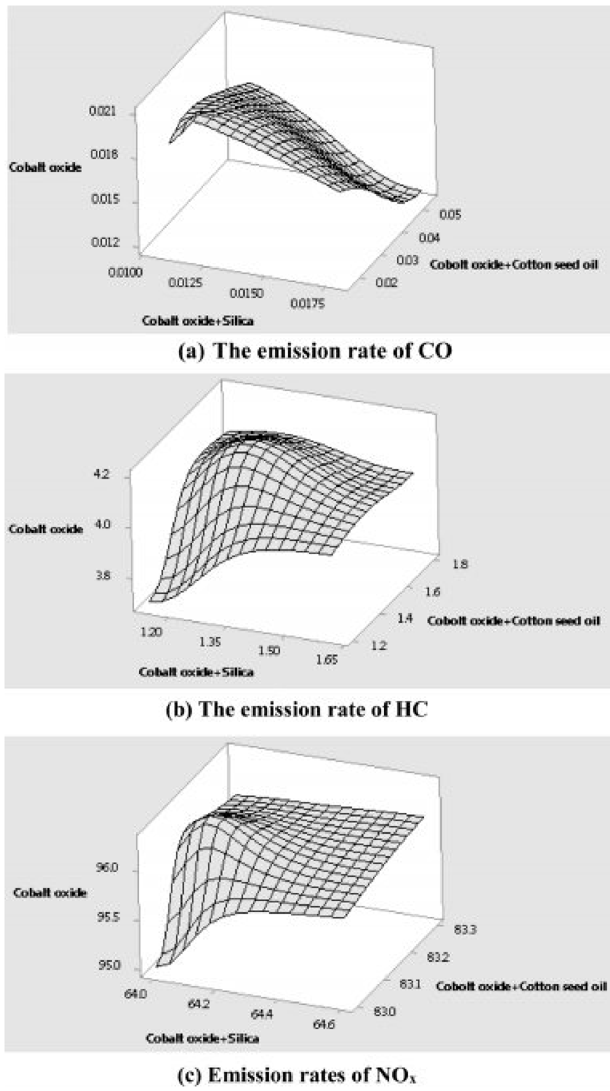
Predicted emission in engine						
Performance	Output					
	Load (N)	CR	Diesel	Co_3O_4 25 ppm	25 ppm + B60 25 ppm	
					Co_3O_4 + Cottonseed	Co_3O_4 + SiO_2
CO (% Vol.)	100	17.5	0.146	0.021	0.018	0.012
	125	19.5	0.144	0.019	0.0165	0.011
	150	22.5	0.141	0.012	0.054	0.018
HC (ppm)	100	17.5	43.6	4.2	1.5	1.30
	125	19.5	43.4	3.7	1.2	1.140
	150	22.5	42	4	1.8	1.610
NOx (ppm)	100	17.5	51	95	83	64
	125	19.5	52.4	96	83.3	64.6
	150	22.5	52.1	96.3	83.1	64.1

22.5 promotes superior emission and performance characteristics. Generally, the engine emits lesser emission rates when using 25 ppm of cobalt oxide and silica combinations in the diesel fuel. The predicted emission characteristics of pure diesel and different additives added diesel are tabulated in the given Table 10.

The forecasted emission outcomes of three combinations of cobalt oxide diesel blends are tabulated in Table 10. The predicted outcomes are achieved by varying the three different load conditions, namely 100, 125 and 150 N and the various compression ratios suchas 17.5, 19.5 and 22.5. From all the additive combinations, the cobalt oxide with silicon oxide blend in the diesel promotes better emission characteristics when compared with the other additive combinations. At the same time, the emission behavior of NO_x is better in the predicted results of pure diesel than the additive added alternative fuel. The emission characteristics of the three proposed combinations of cobalt oxide are shown as wireframe graphical representation in Fig. 3. From all these predicted results, the emission gas of CO is yielded as very less amount and a large quantity of NO_x emission is created, when compared to the other emission gases. However, when compared with the pure diesel fuel all the proposed additive combinations produced a minimum amount of emission rates.

The conclusion is decided from the comparative analysis of both the predicted and the experimented results. The whole proposed combinations of cobalt oxide additives are optimized for the predicted results when contrasted with the experimented values. Such comparative analysis is to be discussed in the portion below.

In Fig. 4, the optimal level of emission outflow obtained from both the experimental and predicted results is depicted in the form of graphical representation. The combinations of diesel additives namely, cobalt oxide, cobalt oxide + cottonseed oil and cobalt oxide + silicon oxide are contrasted in this section. In which, the emission behaviors of three different gases are separately represented in the proceeded graph. In all these mentioned graphs, the predicted values of emission gases show optimal outcomes than the experimental



(a) The emission rate of CO

(b) The emission rate of HC

(c) Emission rates of NO_x

Fig. 3. Wireframe graphical representation for the predicted emission rates.

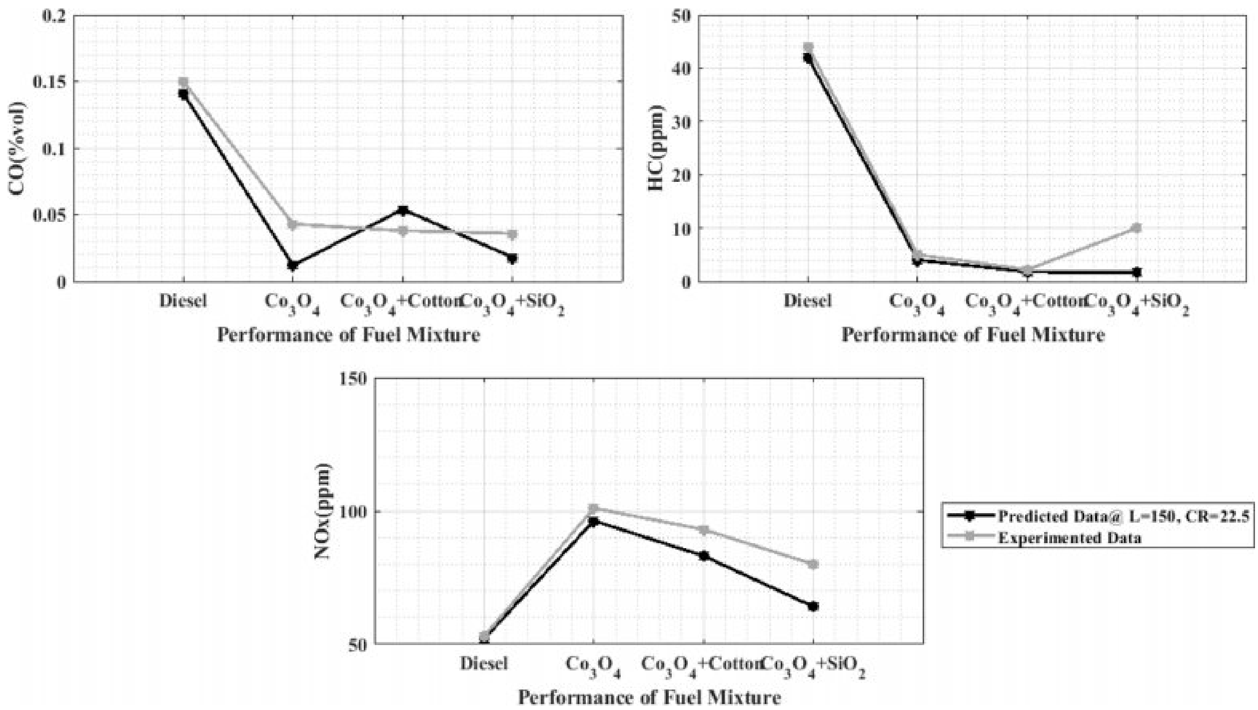


Fig. 4. Comparison of experimental and predicted outcomes of engine emission rate.

values. From the predicted results, the optimal values of HC and CO emission rates are yielded from the blend of 25 ppm of silicon oxide + cobalt oxide in the diesel fuel at the load of 125 N and the compression ratio of 22.5. The predicted emission outcomes are 0.018% of CO, 64.1% of NO_x and 1.610% of HC. In these input conditions, the emission rate of NO_x is minimum for the pure diesel fuel. When using copper oxide nano particles on the bio diesel blend, the emission rates are more when compared to our optimized fuel blend combination [22].

Conclusion

In this paper, the emission rates of diesel fuel are reduced by adding three varieties of nano and bio-additives. The additive mixes utilized in the diesel fuel are cobalt oxide, cobalt oxide + cottonseed oil and cobalt oxide + silicon oxide particles. The emission test is achievedby the use of diesel engine with five different load input conditions such as 0, 25, 50, 75, and 100 N and the constant compression ratio 7.5. The learning algorithm of ANN-SVM is utilized to optimize and forecast the experimental outcomes. From the test results, it proved that the emission of HC and CO are favorable for our proposed blended cobalt oxide combinations. However, the NO_x emission rate is optimal for pure diesel fuel. The supreme yields are obtained from the proportion rate of 25 ppm of cobalt oxide and silicon oxide; and the blend B60 of cottonseed oil. These emission characteristics are predicted for the 25 ppm of cobalt oxide and silicon oxide and B60 blend of cottonseed oil with three different compression ratios such as 17.5, 19.5 and 22.5. Similar to the experimental outcomes, the predicted result reveals that the proposed combinations of cobalt oxide yield favorable CO and HC emissions and the emission rate of NO_x is optimal for diesel fuel. From the predicted results, 25 ppm of Co_3O_4 and SiO_2 and B60 blend of cottonseed oil promotes minimum and optimal emission rates. Generally, at load conditions 150 N and the compression ratio of 22.5, the 25 ppm of Co_3O_4 + SiO_2 in the diesel fuel emits supreme behaviors such as 0.018% of CO, 1.610% of HC and 64.1% of NO_x. In the future, the work is extended by utilizing different combinations of nano additives to the diesel fuel for improving the emission characteristics of diesel engines. In addition to this, various hybrid types of the algorithm are also adopted to optimizing and predict the optimal emission characteristics.

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