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Estimation of a Spark Ignition Engine's Performance Parameters for Ethanol-Gasoline blends using Response Surface Methodology

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Abstract: ***The Internal Combustion(IC) engine design and growth plays an important role in determining engine performance and emission features. The performance and emission properties of the spark ignition (SI) motor are also more influenced by gasoline ethanol blends. In this work, an effort has been made to optimize the operating parameters in order to minimize BSFC, CO, NO_2, CO_2, HC and maximize BTE using Response Surface Methodology (RSM). The engine is operated under constant speed conditions with different working conditions for better mixing and distinct additive composition (iso-octane) in the range of 0.3%, 0.4% and 0.5%. The appropriate RSM was used to reduce the use of petrol, its exhausts and maximize Brake Thermal Efficiency. The experimental and statistical approximation demonstrates the rise in Thermal Brake Efficiency (BTE) and decline in Specific Brake Fuel Consumption (BSFC). In addition, the chosen RSM model demonstrates reduced CO, HC, NO_2 and CO_2 emissions. From the assessment, it is noted that E30 mix with 0.5% additive has better motor efficiency features and reduced emissions at a peak speed of 1800rpm among all test blends with varying proportion of additives.***

Keywords: Gasoline, Spark Ignition Engine, Iso-Octane, Ethanol, Response surface methodology.

I. INTRODUCTION

Exhaustion of fuels (fossil) at a faster rate, environment degradation and stringent environmental regulations [1] are forcing internal combustion engine researchers to anticipate the need to find sustainable, eco-friendly, and renewable fuels to the present standard automotive fuels. Excess use of gasolene ends up in global warming, acid rain, gas depletion, climate change, etc.[2]. The problem of environmental degradation aggravates once non-eco-friendly hydrocarbon boosters are adscititious to the gas like Tetra Ethyl Lead (TEL) [3]. Performance of SI engine is greatly prejudiced by the capacity and category of the fuel. The blend of petrol and TEL was used in early model cars (beginning in 1920) to boost octane ratings [4]. Every gallon of gas contained one gram of TEL boosts amount by ten times [5]. TEL contains 640.6 milligrams of lead per gram in it. However, TEL was slowly less used late 1970's and stopped usage all told on-road vehicles within the U.S. in 1995 as a result of TEL is harmful and poison chemical process converters [6]. Iso-octane is another promising alternative additive for boosting the blended fuel octane rating. Alcohols are emerging as promising octane boosters. Alcohols will either be blended with gasolene and burned in regular automobile, or used straight in modified engines [7].

Though Alcohols are clean burning fuels, it leads to low oxides of the chemical elements, hydrocarbon and carbon dioxide emissions than other biomass fuels [8]. However, the combustion might cause an increase in organic compound emissions, which are undesirable for health reasons [9]. Small modifications to the fuel systems are required, since ethanol damages several plastics and metals of fuel supply system [10]. In addition, use of 100 percent alcohol leads to cold start problems in unqualified gasolene engine [11]. RSM evaluates the relation between several explanatory factors and one or more reaction variables using statistics used in engine performance using DOE [12]. RSM is a significant instrument for optimizing the extraction of biofuel. In order to identify the relationship between biofuel output and the sample variables, a second order model can be effectively developed [13]. Based on the variable gasoline-ethanol blends and speed RSM was used to optimize engine power, torque, and BSFC and emission elements [14]. In this study, RSM is used to optimize the BSFC, BTE, and emission properties for various gasoline-ethanol blends under varying working environments with additives at a steady velocity. The primary goal of this job is to verify RSM's ability to optimize engine performance and exhaust parameters. Here the optimum values were obtained and the engine efficiency was assessed.

II. MATERIALS AND METHODS

A. Engine Test Setup

The testing of performance and emission features was performed on a four-stroke, one-cylinder, computerized SI motor with variable compression ratio. Table.I indicates engine specifications. The engine configuration supplied with gasoline engine, eddy current dynamometer, and multi-fuel tank is shown in Fig.1. It includes a system for data acquisition, a computer, an operating panel and an analyzer for exhaust gas. To measure the pressure of combustion, crank-angle, airflow, fuel flow, temperature and load, the required measurements are provided. The engine operates with programmable Open ECU, Throttle Position Sensor (TPS), fuel pump, ignition spray coil, fuel spray nozzle, trigger sensor, etc. The engine efficiency involves BTE, Mechanical Efficiency, and BSFC measurements. Enginesoft is a software package based on Lab-view, which can serve most of the application testing requirements including surveillance, reporting, data entry and information logging. The computer code is used to evaluate energy, efficiencies, fuel consumption and analysis of combustion. Various graphs are obtained and the results have been tabulated under separate working conditions.

Table I. Engine Specifications

Specifications	Details
Product	Research Engine test setup single cylinder, 4-stroke, Multifuel, VCR.
Engine	Single cylinder, 4-stroke, water cooled, stroke length 110 mm, bore 87.5 mm, 661 cc. Petrol Mode: 4.5 kW@ 1800 rpm, Speed range 1200-1800 rpm, CR range 6-10,
Dynamometer	Type eddy current, water cooled, with loading unit
ECU	PE3 Series ECU, Model PE3-8400P, full build, potted enclosure. Includes
Piezo Sensor	Combustion: Range 350Bar, Diesel line: Range 350 bar,
Crank Angle Sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data Acquisition Device	NI USB-6210, 16 bit, 250kS/s.
Air Flow Transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	"Enginesoft" Engine performance analysis software

Fig.1. Actual system of Computerized SI engine Test Rig with Exhaust Gas Analyzer

B. Experimental Methods

The gasoline–ethanol blends were prepared in the ratio of 1:0.05(E5), 1:0.11(E10), 1:0.176(E15), 1:0.25(E20), 1:0.33(E25), 1:0.428(E30) and 1:0.538(E35). The second set of test samples were prepared by adding 3%, 4% and 5% Iso-octane as an additive to E30 blend. The fuel blends were arranged just before beginning of the investigation, to guarantee that the fuel composition is homogenous and prevent the reaction of ethyl alcohol with water vapour. In this work, Design Expert Software (Version 11) has been used to generate the values of optimization parameters. Three operational factors such as Load, Compression Ratio and Blends have greater effect on performance parameters and emission characteristics of SI engine at maximum speed of 1800rpm; hence these factors have been selected as independent factors. Factor values have been selected based on the specification of the engine [15]. Table II shows the independent factors used in central composite design (CCD) for the optimization technique.

Table II. Independent Parameters used in CCD for constant speed

Operating variable	Units	Low	High	-α	+α
Load	kg	4	10	1.95462	12.0454
Compression Ratio		8	10	7.31821	10.6818
Blend	%	15	30	9.88655	35.1134

C. Optimization of Load, Compression Ratio and Gasoline Ethanol Blends at Constant Speed to minimize BSFC and maximize BTE

Experiments were conducted as shown in Table III to discover minimum BSFC and maximum BTE per experimental matrix. Twenty studies were carried out by varying the ratio of load, compression and blend as shown in Table III. From Table III it is clear that experimental BSFC has its minimum value of 0.58 kg/kW-hr at 7kg load, 10.6818(≈11) Compression Ratio and E22.5 blends. Predicted BSFC has its minimum value of 0.5840 kg/kW-hr at above optimized operational conditions. A difference of 0.68 % in BSFC is observed between experimental and predicted value. From Table III, it is also clear that experimental BTE has its maximum value of 22.2 % at 7kg Load, at a Compression Ratio 9 with 9.88655%(≈E10) blend. Predicted BTE has a maximum value of 21.58 % for optimized operational conditions. An increase of 2.87% in BTE is observed between experimental and predicted values.

D. Optimization of Speed, Compression Ratio and Gasoline Ethanol Blends at Constant speed to minimize CO, HC, NO_2 and CO_2

Table IV represents the optimized values for emission test for CO, HC, NO_2, and CO_2 at constant speed indicates the experimental CO has minimum value of 0.11% at 10kg load, at a Compression Ratio of 8 with 15% (E15) blend. Predicted CO has a minimum value of 0.0810% at above optimized operational conditions. A decrease of 26.36% in CO is observed between experimental and predicted value. It is also clear that experimental HC has a minimum value of 68ppm at1.95462kg (≈ 2kg) load at a Compression Ratio of 9 with Blend of 22.5%. Predicted HC is minimum (66.07ppm) at optimized operational conditions. A decrease of 2.84% in HC is observed between experimental and predicted value. The experimental NO_2 has its minimum value of 10 at 10kg load at a Compression Ratio 8 and 30% (E30) blend. Predicted NO_2 has its minimum value of 9.01at optimized operational conditions. A decrease of 9.9% in NO_2 has been observed between experimental and predicted value. It also shows that experimental CO_2 is minimum value of 4.78% at 12kg load at a Compression Ratio 9 with 22.5% blend. Predicted CO_2 is minimum value of 4.09% at optimized operational conditions. There is a decrease of 14.44% in CO_2 between experimental and predicted value.

E. Optimization of Load, Compression Ratio and Iso-Octane Additive at Constant Speed to minimize BSFC and maximize BTE

In fact, the three operational variables such as Load, Compression Ratio and Additives have a higher impact on SI engine's performance parameters and emission features at Constant speed of 1800rpm. Hence these factors were chosen as distinct variables [16]. Table V shows the independent factors used in CCD for the optimization technique.

Table V. Independent parameters used in CCD for constant speed

Operating variable	Units	Low	High	-α	+α
Load	kg	4	10	1.95462	12.0454
Compression Ratio		8	10	7.31821	10.6818
Additive	%	0.3	0.5	0.231821	0.568179

Experiments were conducted as shown in Table VI to discover minimum BSFC and BTE according to the experimental matrix. The load, compression ratio and additive were varied for twenty experiments. From Table VI it is clear that experimental BSFC is minimum with a value of 0.58 kg/kW-hr at 9kg load at Compression Ratio 7 with 0.231821%(≈ 3ml) of Additive Iso-Octane. Predicted BSFC is minimum at a value of 0.5655 kg/kW-hr at optimized operational conditions. There is a difference of 2.5% in BSFC between experimental and predicted values. Brake Thermal Efficiency (BTE) experimental matrix is obtained after the analysis. Experiments were performed to discover maximum BTE according to the experimental matrix shown in Table VI. From Table VI it is clear that experimental BTE has a maximum value of 26.97% at 8kg Load, at a Compression Ratio 9 with 0.5% additive. Predicted BTE has its maximum value of 26.98% at optimized operational conditions. There is an increase of 1.08% in BTE between experimental and predicted values.

F. Optimization of Speed, Compression Ratio and Gasoline Ethanol Blends at Constant speed to minimize CO, HC, NO_2 and CO_2 with additive iso-octane

Experiments were conducted to discover minimum CO according to the experimental matrix shown in Table VII. From Table VII it is clear that experimental CO is minimum with a value of 0.046% at 9kg load, at a compression ratio of 1.95462 (≈2) with 0.4% of additive. Predicted CO is minimum value of 0.0451% at optimized operational conditions. An increase of 2% in CO is observed between experimental and predicted value. To find minimum HC, from Table VII it is clear that experimental HC is minimum value of 49ppm at 8kg load, Compression Ratio of 10 with additive of 0.5%. Predicted HC is minimum value of 48.31ppm at optimized operational conditions. A decrease of 1.41% in HC is observed between experimental and predicted value. To estimate minimum $NO_{2,}$ Table VII it is clear that experimental NO_x is minimum value of 28 at 9kg load, Compression Ratio 2 with additive of 0.4%. Predicted NO_x is minimum value of 26.50 at optimized operational conditions. A decrease of 5.36% in NO_x is observed between experimental and predicted value. To determine minimum CO_2, from Table VII it is clear that experimental CO_2 is minimum value of 3.68% at 8kg load at Compression Ratio 4 with 0.4% of additive. Predicted CO_2 is minimum value of 3.05% at optimized operational conditions. There is decrease of 17.12% in CO_2 is observed between experimental and predicted value. Data on the proportion of relative conventional errors during engine efficiency and accumulation of information on exhaust emissions were calculated for three repeatable measurements. These findings, based on the proportion of comparative normal error calculations for each performance and exhaust emission type, yielded an error of less than or equal to 5% [16].

III. RESULTS AND DISCUSSION

A. Developed model analysis with surface response methodology

The model assessment is analyzed using the submitted variance analyzes (ANOVA). In this work, around 20 distinct information points were built. The p-value of ANOVA assessment, which is less than 0.05, indicates that the variables have a consequential impact at a confidence level of 95 percent [17]. It is desirable to have an elevated R^2 value, close to 1, and a plausible adj R^2 adjustment is mandatory [18]. The smallest value of r was mandatory to obtain the most suitable kinds of model. The best quadratic fit models for all answers are based on the value of the R^2 and the r proposed by DoE software. Adequate accuracy (AP) measures the signal to noise ratio and it is always desirable to have a value more preponderant than 4. The response values for an AP is more preponderant than 4, is shown to indicate an appropriate signal implicitly insinuating that these models can be used to navigating the design space [19].

B. Interactive Effect of Ethanol Gasoline Blends at Constant speed

- **Brake Specific Fuel Consumption (BSFC)**

Fig. 2 shows the 3-D for the effect of the engine Load and Compression Ratio (CR) on BSFC at constant speed. With increase in Load, BSFC decreases and reaches minimum value at 7kg load and then increases for a given compression ratio. At the same time with increase in compression ratio, BSFC decreases, reaching minimum value of 0.58kg/kW-hr at compression ratio of 10 for a given load. At the same time with increase in compression ratio, BSFC decreases, reaching minimum value at compression ratio of 9 for a given load. The model equation based on coded values for minimum BSFC is shown in Eq. (1).

$$BSFC= (0.9075 – 0.0336\ X_1 – 0.1105\ X_2 + 0.0125\ X_3 – 0.03255\ X_1\ X_2 -0.0425\ X_1\ X_3 – 0.01250\ X_2\ X_3 - 0.1159\ X_1^2 – 0.0487\ X_2^2 + 0.0291\ X_3^2) \qquad (1)$$

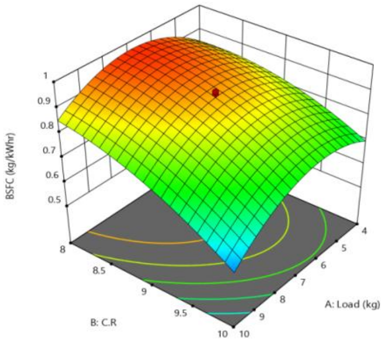

Fig. 2 3-D plot for the effect of BSFC to the Load and compression ratio (CR) at constant speed.

- **Brake Thermal Efficiency(BTE)**

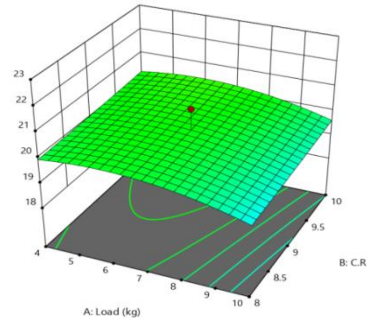

Fig. 3 3-D plot for the effect of BTE to the Load and compression ratio(CR) at constant speed

Fig. 3 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on BTE at constant speed. With increase in Load, BTE increases and reaches maximum value at 7kg load and then decreases for a given compression ratio. At the same time with increase in compression ratio, BTE increases, reaching maximum value of 22.2% at compression ratio of 9 for a given load. The model equation based on coded values for minimum BSFC and its equation is as shown below in Eq. (2).

$$BTE = (20.16 – 0.3384\ X_1 + 0.1663X_2 - 0.0947\ X_3 + 0.0338\ X_1\ X_2 + 0.2588\ X_1\ X_3 – 0.01962X_2\ X_3 – 0.4226\ X_1^2 + 0.0194\ X_2^2 + 0.4436\ X_3^2) \qquad (2)$$

- **Carbon Monoxide (CO)**

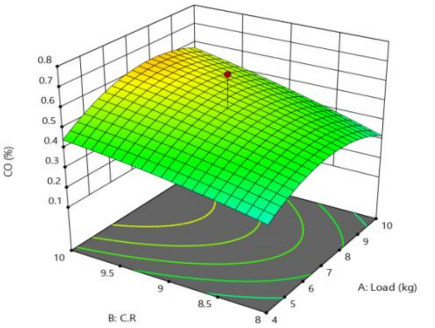

Fig. 4 3-D plot for the effect of CO to the Load and compression ratio(CR) at constant speed.

Fig. 4 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on CO at constant speed. With increase in Load, CO decreases and reaches minimum value at 10kg load and then increases for a given compression ratio. At the same time with the increase in compression ratio, CO increases, reaching maximum value at compression ratio of 9 for a given Load. The model equation based on coded values for minimum CO is shown in Eq. (3).

$$CO= (0.8993 – 0.0435\ X_1 – 0.1353\ X_2 + 0.0344\ X_3 – 0.005\ X_1\ X_2 + 0.0025\ X_1\ X_3 – 0.0150\ X_2\ X_3 -0.1228\ X_1^2 – 0.0698\ X_2^2 -0.0026X_3^2) \qquad (3)$$

- **Corbon Dioxide ($CO_{2)}$**

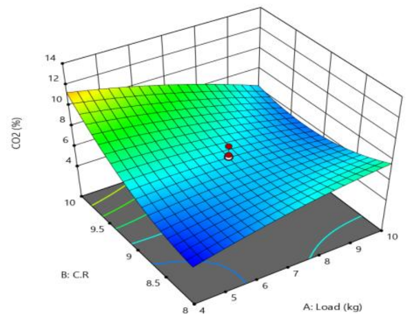

Fig. 5 3-D plot for the effect of CO_2 to the Load and compression ratio(C R) at constant speed.

Fig. 5 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on CO_2 at constant speed. With increase in Load, CO_2 decreases and reaches minimum value at 7kg load and then increases for a given compression ratio. At the same time with the increase in compression ratio, CO_2 increases, reaching maximum value at compression ratio of 9 for a given Load. The model equation based on coded values for minimum CO_2 is shown in Eq. (4).

$$CO_2= (6.62-0.4792X_1+1.32X_2–0.8993X_3-2.02X_1X_2–0.3197X_1X_3+ 0.1838\ X_2\ X_3-0.4014\ X_1^2 + 1.31\ X_2^2+0.9916\ X_3^2) \qquad (4)$$

- **Hydrocarbon(HC)**

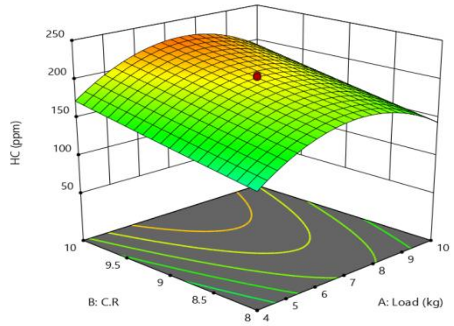

Fig.6 3-D plot for the effect of HC to the Load and compression ratio (CR) at constant speed

From Fig.6 the following conclusion can be drawn that in case of plot representing funnel shape and random scattering indicates that the suggested model for HC emission optimization describes the process appropriately. Fig. 6 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on HC at constant speed. With increase in Load, HC decreases and reaches minimum value at 1.95462kg (≈2) load and then increases for a given compression ratio. At the same time with increase in compression ratio, HC increases, reaching maximum value at compression ratio of 9 for a given Load. The model equation based on coded values for minimum HC is shown in Eq. (5),

$$HC= (202.74 + 9.16\ X_1 + 23.11\ X_2 – 14.99\ X_3 + 1.62\ X_1\ X_2 – 17.13\ X_1X_3 – 4.63\ X_2\ X_3-42.89\ X_1^2 + 0.4244\ X_2^2 -26.27\ X_3^2) \qquad (5)$$

Nitrogen Dioxide (NO_2)

Fig. 7 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on NO_2 at constant speed. With increase in Load, NO_2 decreases and reaches minimum value at 8kg load and then increases for a given compression ratio. At the same time with the increase in compression ratio, NO_2 increases, reaching maximum value at compression ratio of 9 for a given Load. The model equation based on coded values for minimum NO_2 is shown in Eq. (6),

$$NO_x=(14.18–0.3927X_1+1.08X_2–1.22X_3–1.50X_1X_2–2.75X_1X_3+1.5X_2X_3 –0.1661X_1^2+1.25X_2^2–0.1875\ X_3^2) \qquad (6)$$

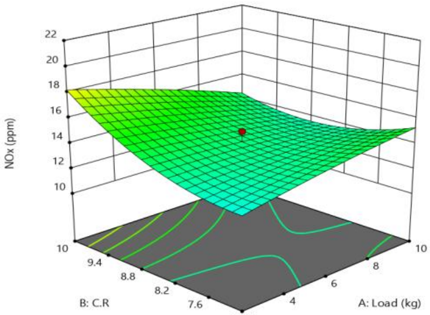

Fig. 7 3-D plot for the effect of NO2 to the Load and compression ratio(CR) at constant speed

B. Interactive Effect of Ethanol-Gasoline Blend with Additive at constant speed

- **Brake specific Fuel consumption(BSFC)**

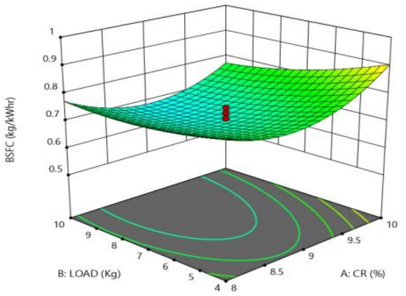

Fig. 8 3-D plot for the effect of BSFC to the Load and compression ratio at constant speed.

Fig. 8 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on BSFC at constant speed. With increase in Load, BSFC decreases and reaches minimum value at 9kg load and then increases for a given compression ratio. At the same time with the increase in compression ratio, BSFC decreases, reaching minimum value at compression ratio of 10 for a given load. At the same time with the increase in compression ratio, BSFC decreases, reaching minimum value at compression ratio of 9 for a given load. The model equation based on coded values for minimum BSFC is shown in Eq. (7).

$$BSFC=(0.7054-0.0240X_1-0.0419X_2+0.0431X_3-0.0238X_1X_2+0.0062X_1X_3 -0.0538X_2X_3+0.0858X_1^2+0.0239X_2^2-0.0238X_3^2) \quad (7)$$

- **Brake Thermal Efficiency (BTE)**

Fig. 9 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on BTE at constant speed. With increase in Load, BTE increases and reaches maximum value at 8kg load and then decreases for a given compression ratio. At the same time with the increase in compression ratio, BTE increases, reaching maximum value at compression ratio of 10 for a given load. The model equation based on coded values for minimum BTE and it is as shown below in Eq. (8).

$$BTE = (81.84-0.0032X_1 + 0.174X_2 - 0.0186X_3 + 0.0012X_1 X_2 - 0.063X_1X_3 - 0.0288X_2 X_3 - 0.0599X_1^2 -0.0317X_2^2 - 0.122 X_3^2) \quad (8)$$

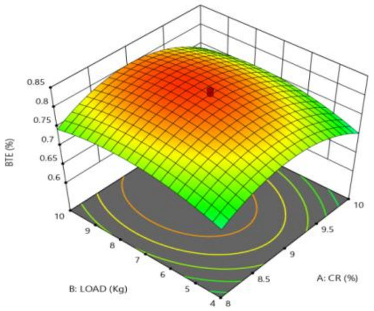

Fig. 9 3-D plot for the effect of BTE to the Load and compression ratio at constant speed.

- **Carbon monoxide (CO)**

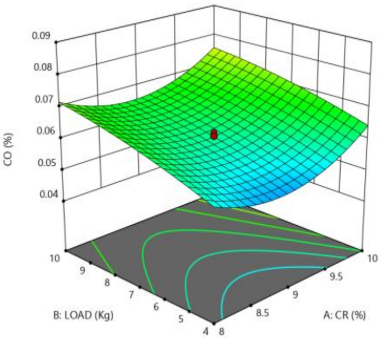

Fig. 10 3-D plot for the effect of CO to the Load and compression ratio (CR) at constant speed

Fig. 10 shows the 3-D plot for the effect of the engine Load and compression ratio(C R) on CO at constant speed. With increase in Load, CO increases and reaches maximum value at 10kg load and then decreases for a given compression ratio. At the same time with the increase in compression ratio, CO decreases, reaching maximum value at compression ratio of 9 for a given Load. The model equation based on coded values for minimum CO is shown in Eq. (9).

$$CO = (0.0608+0.0026X_1- 0.0063X_2 + 0.0010X_3 - 0.0006X_1 X_2 - 0.0031X_1 X_3 - 0.0014X_2 X_3 + 0.0080 X_1^2 - 0.0014 X_2^2 - 0.0016 X_3^2) \quad (9)$$

- **Hydro carbon (HC)**

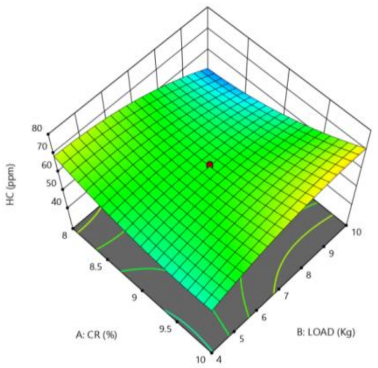

Fig. 11 3-D plot for the effect of HC to the Load and Compression ratio (CR) at constant speed

Fig. 11shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on HC at constant speed. The model equation based on coded values for minimum HC is shown in Eq .12. With increase in Load, HC decreases and reaches minimum value at 8kg load and then increases for a given compression ratio. At the same time with the increase in compression ratio, HC increases, reaching maximum value at compression ratio of 10 for a given Load. The model equation based on coded values for minimum HC is shown in Eq. (10).

$$HC=(62.84+2.13X_1-1.05X_2-14.99X_3+7.63X_1X_2+1.88X_1X_3+2.13X_2X_3 -3.88X_1^2-4.26X_2^2+1.05X_3^2) \quad (10)$$

- **Carbon Dioxide (CO_2)**

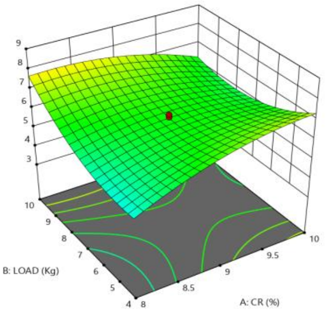

Fig. 12 3-D plot for the effect of CO2 to the Load and compression ratio (CR) at constant speed.

Fig. 12 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on CO_2 at constant speed. With increase in Load, CO_2 decreases and reaches minimum value at 8kg load and then increases for a given compression ratio. At the same time with the increase in compression ratio, CO_2 increases, reaching maximum value at compression ratio of 9 for a given Load. The model equation based on coded values for minimum CO_2 is shown in Eq. (11).

$$CO_2= (6.31 +0.1938X_1 + 0.3634X_2 + 0.4684X_3 - 0.8887X_1 X_2- 0.2762X_1X_3 - 0.3762X_2 X_3-0.4882X_1^2 + 0.7793X_2^2- 0.3786X_3^2) \quad (11)$$

- **Nitrogen Dioxide (NO_2)**

Fig. 13 shows the 3-D plot for the effect of the engine Load and compression ratio (CR) on NO_2 at constant speed. With increase in Load, NO_2 decreases and reaches minimum value at 7kg load and then increases for a given compression ratio. At the same time with the increase in compression ratio, NO_2 increases, reaching maximum value at compression ratio of 9 for a given Load. The model equation based on coded values for minimum CO_2 is shown in Eq. (12).

$$NO_2 = (102.740+4.02X_1+1.3X_2-6.98X_3-1.12X_1X_2+4.63X_1X_3-2.62X_2X_3-7.62X_1^2-26.18X_2^2-0.3755X_3^2) \quad (12)$$

Table- III: Experimental matrix of CCD for BSFC and BTE

Std	Run	Load (Kg)	CR	Blend	BSFC*, kg/kW-hr	BSFC#, kg/kW-hr	BTE*, %	BTE#, %
2	1	10	8	15	0.9100	0.8989	19.45	19.30
20	2	7	9	22.5	0.9300	0.9075	21.00	20.16
3	3	4	10	15	0.6800	0.6852	21.20	21.22
12	4	7	10.6818	22.5	0.5800	0.5840	20.50	20.50
7	5	4	10	30	0.7800	0.7701	19.93	20.12
13	6	7	9	9.88655	0.9600	0.9688	22.20	21.58
6	7	10	8	30	0.8900	0.8639	20.00	20.02
8	8	10	10	30	0.5600	0.5530	20.70	20.03
17	9	7	9	22.5	0.9200	0.9075	19.96	20.16
1	10	4	8	15	0.8300	0.8161	19.85	20.57
10	11	12.0454	9	22.5	0.5000	0.5233	18.20	18.40
15	12	7	9	22.5	0.9000	0.9075	20.00	20.16
9	13	1.95462	9	22.5	0.6300	0.6363	19.80	19.54
19	14	7	9	22.5	0.9000	0.9075	20.00	20.16
18	15	7	9	22.5	0.9000	0.9075	20.00	20.16
4	16	10	10	15	0.6500	0.6380	19.60	20.10
14	17	7	9	35.1134	0.9900	1.01	20.70	21.26
11	18	7	7.31821	22.5	0.9300	0.9556	20.00	19.94
5	19	4	8	30	0.9600	0.9511	20.70	20.25
16	20	7	9	22.5	0.9000	0.9075	20.00	20.16

Note: * Experimental value, **#** Predicted value

Table- IV: Experimental matrix of CCD for emission parameters

Std	Run	Load (Kg)	CR	Blend (%)	CO*, %	$CO^{\#}$, %	HC*, ppm	$HC^{\#}$, ppm	NO_2*, %	$NO_2^{\#}$, %	CO_2*, %	$CO_2^{\#}$, %
2	1	10	8	15	0.1100	0.0810	146.00	145.97	21.00	20.96	10.95	10.74
20	2	7	9	22.5	0.5000	0.5332	204.00	202.78	15.00	14.18	6.89	6.62
3	3	4	10	15	0.4500	0.5781	148.00	148.86	16.00	15.40	12.19	12.13
12	4	7	10.6818	22.5	0.7500	0.6560	246.00	242.84	20.00	19.53	12.83	12.54
7	5	4	10	30	0.1510	0.1780	145.00	143.88	21.00	21.45	12.82	12.53
13	6	7	9	9.88655	0.4700	0.3630	153.00	153.69	17.00	16.77	11.11	10.93
6	7	10	8	30	0.5600	0.4298	94.00	91.00	10.00	9.01	6.69	6.75
8	8	10	10	30	0.5100	0.4700	138.00	131.21	13.00	12.16	5.66	5.71
17	9	7	9	22.5	0.5000	0.5332	206.00	202.78	15.00	14.18	5.26	6.62
1	10	4	8	15	0.1890	0.2269	99.00	96.65	14.00	13.24	5.89	5.84
10	11	12.0454	9	22.5	0.2000	0.2929	99.00	96.89	13.00	13.05	4.78	4.09
15	12	7	9	22.5	0.5000	0.5332	204.00	202.78	15.00	14.18	6.83	6.62
9	13	1.95462	9	22.5	0.2600	0.1700	68.00	66.07	15.00	14.37	6.78	6.29
19	14	7	9	22.5	0.7000	0.5332	203.00	202.78	15.00	14.18	7.76	6.62
18	15	7	9	22.5	0.5000	0.5332	208.00	202.78	15.00	14.18	6.68	6.62
4	16	10	10	15	0.5000	0.5412	206.00	204.68	18.00	17.11	8.69	8.57
14	17	7	9	35.1134	0.2100	0.3199	108.00	103.28	13.00	12.65	7.93	7.91
11	18	7	7.31821	22.5	0.2300	0.3269	166.00	165.12	16.00	15.90	7.83	8.12
5	19	4	8	30	0.2900	0.2467	116.00	110.17	14.00	13.29	5.78	5.50
16	20	7	9	22.5	0.5000	0.5332	206.00	202.78	15.00	14.18	6.98	6.62

Note: * Experimental value, **#** Predicted value

III. OPTIMIZATION

The DoE searches for a blend of factors, that simultaneously satisfy the requisites placed on each of the responses and factors. In desirability approach of predication, many best solutions were obtained. The results with highly desirables are selected. Highly desirable of 0.87 was obtained in the following input system parameters like E30 at the engine speed 1800rpm which can be considered as an optimum parameter. At optimal input parameters, the values of the BSFC, BTE, CO, CO_2, and HC were found to be 0.5840 kg/kW-hr, 21.58%, 0.081%, 4.09% and 66.07ppm respectively. In order to validate the optimized results, the experiments were performed at the optimal condition of engine speed 1800rpm and fuel blends of E30. There was a paramount positive correlation between all the output responses at the optimum conditions, which designates a desirability value of 0.87. A maximum desirability value proximate to 1 represents an ideal response [20]. In this case, the value of 0.87 denotes that there is a good trade-off regions subsisted that satiates the model criteria. A confirmation test was done to validate the model's precision and also for desirability. Confirmatory tribulations are not compulsory to conduct if the RSM models produce a prognostication error of less than 5%.

Table.VI: Experimental matrix of CCD for BSFC and BTE with additive Iso-octane

Std	Run	Load (Kg)	CR	Additive (%)	BSFC*, kg/kW-hr	BSFC#, kg/kW-hr	BTE*, %	BTE#, %
10	1	10.6818	7	0.4	0.9900	0.9883	22.86	22.56
13	2	9	7	0.231821	0.5800	0.5655	21.76	21.16
8	3	10	10	0.5	0.7500	0.7451	25.18	24.98
14	4	9	7	0.568179	0.7100	0.7105	25.99	24.69
9	5	7.31821	7	0.4	0.9200	0.9076	22.94	21.94
19	6	9	7	0.4	0.6600	0.7054	23.96	22.98
17	7	9	7	0.4	0.7300	0.7054	23.98	22.98
16	8	9	7	0.4	0.6900	0.7054	23.97	22.98
20	9	9	7	0.4	0.7100	0.7054	23.99	22.98
15	10	9	7	0.4	0.7500	0.7054	23.98	22.98
6	11	10	4	0.5	0.9800	0.9840	24.67	24.83
5	12	8	4	0.5	0.8600	0.8760	24.78	24.48
11	13	9	1.95462	0.4	0.8700	0.8435	24.68	24.50
7	14	8	10	0.5	0.7400	0.7321	26.97	26.98
12	15	9	12.0454	0.4	0.6900	0.7024	26.44	26.22
1	16	8	4	0.3	0.6800	0.6948	20.94	20.35
4	17	10	10	0.3	0.7600	0.7539	23.84	23.35
2	18	10	4	0.3	0.7600	0.7778	23.88	23.09
18	19	9	7	0.4	0.6900	0.7054	23.97	22.98
3	20	8	10	0.3	0.7600	0.7659	23.92	22.97

Note: * Experimental value, **#** Predicted value

Table.VII: Experimental matrix of CCD for CO, HC, NO2 and CO_2 with additive Iso-octane

Std	Run	Load (Kg)	CR	Additive (%)	CO*, %	CO# , %	HC*, ppm	HC#, ppm	NO2*, %	NO2#, %	CO2*, %	CO2#, %
10	1	10.6818	7	0.4	0.0880	0.0878	77.00	77.39	89.00	87.94	5.15	5.25
13	2	9	7	0.231821	0.0640	0.0636	71.00	71.94	115.00	113.42	4.46	4.45
8	3	10	10	0.5	0.0760	0.0766	72.00	72.57	67.00	67.77	5.85	5.70
14	4	9	7	0.568179	0.0670	0.0671	61.00	59.67	91.00	89.94	5.82	6.02
9	5	7.31821	7	0.4	0.0790	0.0789	71.00	70.22	76.00	74.42	4.51	4.60
19	6	9	7	0.4	0.0610	0.0608	62.00	62.84	104.00	102.74	6.23	6.31
17	7	9	7	0.4	0.0590	0.0608	63.00	62.84	106.00	102.74	6.12	6.31
16	8	9	7	0.4	0.0610	0.0608	64.00	62.84	105.00	102.74	6.34	6.31
20	9	9	7	0.4	0.0610	0.0608	62.00	62.84	103.00	102.74	6.48	6.31
15	10	9	7	0.4	0.0620	0.0608	63.00	62.84	99.00	102.74	6.41	6.31
6	11	10	4	0.5	0.0630	0.0625	55.00	55.17	72.00	72.67	7.59	7.51
5	12	8	4	0.5	0.0620	0.0622	62.00	62.41	53.00	53.14	5.98	5.89
11	13	9	1.95462	0.4	0.0460	0.0451	52.00	52.58	28.00	26.50	7.87	7.90
7	14	8	10	0.5	0.0790	0.0788	49.00	48.31	54.00	52.73	7.78	7.65
12	15	9	12.0454	0.4	0.0680	0.0674	50.00	49.04	32.00	30.86	8.96	9.12
1	16	8	4	0.3	0.0570	0.0566	78.00	77.71	70.00	71.10	3.68	3.05
4	17	10	10	0.3	0.0780	0.0780	72.00	71.86	77.00	77.73	6.12	6.07
2	18	10	4	0.3	0.0690	0.0694	64.00	62.97	71.00	72.14	6.37	6.37
18	19	9	7	0.4	0.0610	0.0608	63.00	62.84	99.00	102.74	5.78	5.50
3	20	8	10	0.3	0.0670	0.0677	56.00	56.10	80.00	81.20	6.98	6.62

Note: * Experimental value, **#** Predicted value

IV. CONCLUSION

According to experiments and results obtained by the above methods, the following findings are summarized. Adding ethanol in gasoline fuel can amend engine performance and reduce CO and HC emissions. But it can cause an incrementation in CO_2 and NO_2 emissions. RSM can be employed to optimize the engine performance and exhaust emissions. For selected criteria's all the designed ANOVA models exhibits significance. The Design of Experiments predicated on response surface methodology was highly subsidiary to design the experiment and the statistical analysis availed to identify the paramount parameters which are most influencing on the emission and performance characteristics. This design of experiment considerably reduced the time required by minimizing the number of experiments to be performed and represented statistically proven models for all the responses. Among selected and tested blends, optimum ethanol blend is 30% and Iso-octane additive 5% at varied compression ratio, engine load and at constant engine speed. The mathematical model from the statistical methods enables to estimate the nonexperimental value with multiple regressions methods for the opted approach of desirability value 87%. Better performance and emission characteristics were observed for the blended fuels than the pure gasoline.

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