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Optimization of the parameters of Alcohol Fuels for best Performance and Exhaust of Copper Coated Spark Ignition Engine

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Abstract: The main objective of this work to improve the engine performance of gasoline - Methanol blends in a variable compression ratio engine by using optimized engine parameters. In the present work, variable compression ratio spark ignition engine was designed to run with pure gasoline, and gasoline blended with 20% methanol (M20) by volume. Experiments are conducted at different ignition timings $25^{0,}$ 26^0,27^0,28^0, and 29^0 bTDC for conventional engine and for a copper coated piston and cylinder head of the engine. From the comparative evaluation the experimental results for the different ignition timing, it is revealed that there is an influence of the copper coated engine and methanol blend (M20). Optimization is carried out for efficiency and emission using response surface methodology with NSGA II as optimization tool and Non Parametric Regression for response surface generation. From the analysis, it was found that for 26.7^0 bTDC ignition timing, the copper coated engine blended with methanol (M20) has given best performance in terms of volumetric efficiency of 85 %, thermal efficiency of 31.238% and exhaust temperature of 339.2^0C. It is finally observed from the mathematical models and experimental data that pure gasoline and methanol blends have maximum efficiency and minimum emissions at optimized engine parameters.

Keywords - Gasoline, Methanol, ignition timing, Response surface methodology, NSGA-II

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I. INTRODUCTION

In the scenario of fast depletion of fossil fuels, ever increase of pollution levels with fossil fuels and increase of burden on developing countries like India, the search for alternative fuels has become pertinent apart from effective fuel utilization which has been the concern of the engine manufacturers, users and researchers involved in combustion & alternate fuel research. Alcohols (ethanol and methanol) are important substitutes for gasoline fuel in SI engine, as their properties are comparable to gasoline fuel. That too their octane ratings are very high. If alcohols are blended in small quantities with gasoline fuel, no engine modification is necessary. Methanol has higher C/H (C= Number of carbon atoms, H= Number of hydrogen atoms) ratio which leads to form water vapor during combustion. It has oxygen molecule in its composition. Many innovative technologies are developed to tackle these problems. Modification is required in the existing engine designs. Some optimization approach has to be followed so that the efficiency of the engine is not comprised. As far as the internal combustion engines are concerned, the thermal efficiency and emission are the important parameters for which the other design and operating parameters have to be optimized. The most common optimization techniques used for engine analysis are response surface method.**In this regard Kesign [1]** investigated on the effects of operational and design parameters on efficiency and NOx emissions of a natural gas engine using Genetic Algorithm and neural network analysis. The results showed an increase in efficiency as well as the amount of NOx emissions being kept under the constraint value of 250 mg/Nm3 for stationary engines. The most common optimization techniques used for engine analysis are response surface method and gray relational analysis **(Agrawal and Rajamanoharan [2]. Ge, H., Shi, Y et al., [3]** performed non-dominated sorting genetic algorithm II (NSGA II) used for the optimization. For the optimization of piston bowl geometry, an automated grid generator was used for efficient mesh generation with variable geometry parameters. The characteristic time combustion (CTC) model was employed to improve computational efficiency. The sensitivity of engine performance to the design parameters was evaluated using a response surface analysis method. The results show that significant reductions in engine-out emissions and fuel consumption can be achieved. **K.Siva Ramakrishna et al., [4]** Optimization of parameters was performed using the desirability response surface methodology for better performance and lower emission. A compression ratio 17.9% of fuel blend and 3.81KW of power could be considered as the optimum for the test engine. They concluded that

Desirability approach of the RSM is the simplest and most efficient optimization technique. A high desirability of 0.97 was obtained at the optimum engine parameters of CR of 17.9, fuel blend B10 and 3.18 kW power, where the values of BTHE, BSFC, CO, HC, NOX were found to be 33.65%, 0.2718, 0.109%, 158, and 938 ppm. **Maheswari et al., [5**] worked on multi objective optimization of parameters using nonlinear regression analysis has found optimum value to be 13% biodiesel blend with an injection timing of 24^0 bTDC. **D'Errico et al., [6]** used the nondominated sorting genetic algorithm II (NSGA-II) in order to find parameters that minimize the break specific fuel consumption and NO*x* emissions, as well as maximize the torque of a single cylinder SI engine. **Shi and Reitz [7]** minimized CO, unburned hydrocarbon (UHC), NO*x* emissions of a heavy-duty compression ignition engine fueled with diesel and gasoline by using NSGA-II to find optimal combinations of eight optimization parameters. **Atashkari et al., [8]** preferred NSGA-II to run a Pareto-based optimization of a variable valve-timing engine considering conflicting objectives such as fuel consumption and torque.**Alonso et al., [9]** combined ANNs with genetic algorithms to optimize the diesel engine settings reaching important reductions in emissions as CO, HC, NOx, break specific fuel consumption (BSFC), and PM for two engine operating conditions. **Sayin et al., [10]**studied the artificial neural network (ANN) modeling of gasoline engine to predict the brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature and exhaust gas emissions of a four-cylinder, four stroke test engine fueled with gasoline having various octane numbers (91, 93, 95, and 95.3) and operated at different engine speeds and torques. During their study the authors observed that the ANN model can predict the engine performance, exhaust emissions and exhaust gas temperature better with correlation coefficients in the range of 0.983–0.996, mean relative errors in the range of 1.41–6.66% and very low root mean square errors. Genetic algorithms have been used to solve multi objective optimization problems (MOPs) including minimization of exhaust emissions and fuel consumption. **Langouet et al., [11]** used a local linear model tree (LOLIMOT) and multi objective covariance matrix adaptation evolution strategy (MO-CMA-ES) algorithm to carry out the optimization problem of minimizing emissions of NOx, HC, CO, CO2, also for a diesel engine, utilizing six engine parameters for many engine operating conditions. **José D. Martinez-morales et al., [12]** used a multi-objective particle swarm optimization (MOPSO) algorithm and a non dominated sorting genetic algorithm II (NSGA-II) and optimize the operating parameters of a 1.6 L, spark ignition (SI) gasoline engine. The aim of this optimization is to reduce engine emissions in terms of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx).Few authors have been reported the optimum values of response surface methodology in diesel engines. **Bunce et al., Ganapathy et al., Maheshwari et al., Balajiganesh and Karuppaswamy et al., [13,14,15]** they are used various tool for optimization of engine performance and emission parameters such as Response surface methodology based on Central composite rotatable design(CCRD),Artificial neural network (ANN),Genetic algorithm (GA) ,Fuzzy logic etc.

From the review of literature, it can be noticed that a lot of research has been carried out to improve the performance of engine, studies on multi objective optimization to determine the most suitable set of operating variables, with modern optimization techniques are not many. Hence the aim of the present work is to set up an experimental study and to study the individuals and combined effects of combustion parameters on the performance and emission s of the gasoline engine, employing methanol (M20), using response surface methodology (RSM) based experimental design, and the NSGA-II is to determine the optimal values of performance and emission parameters.

II. DESCRIPTION OF THE EXPERIMENTAL SETUP AND TESTING PROCEDURE

The experiments were performed on a four stroke, single cylinder, water cooled, spark ignition engine is used with the specification given in Table 1. The engine is coupled to an eddy current dynamometer for measuring its brake power. Compression ratio of engine was varied with change of clearance volume by adjustment of cylinder head, threaded to cylinder of the engine. The compression ratio of the engine is varied from 3 to 9 with the change of the clearance volume by adjustment of cylinder head, threaded to the cylinder of the engine. The engine speeds are varied from 2200 to 3000 rpm. In the present investigations the piston crown and inside surface of the cylinder head are coated with copper by plasma spraying. A bond coating of NiCoCr alloy is applied for a thickness of about 100 microns using a 80 kW METCO plasma spray gun. Over the bond coating copper 89.5%, Aluminum 9.5% and iron 1.0% is coated for 300 microns thickness. The coating had very high bond strength and does not wear off even after 50 hrs of operation. Copper coating is made on the surface of cylinder head and piston combination. Copper element which can promote pre-flame reaction was coated on the surface of cylinder head and piston. The engine performance parameters are compared with conventional engine with pure gasoline operation. For the performance parameters of brake thermal efficiency, exhaust gas temperature and volumetric efficiency are evaluated at different spark timing with different fuels. Pollutants of carbon monoxide (CO) and unburnt hydro carbons (UBHC) are recorded at the peak load operation of the engine for different test fuels with different ignition timings 25^0,26^0, 27^0, 28^0 &29^0 the exhaust gas temperature of the engine is measured with thermocouples made of iron- constantan. Pollution levels of carbon mono oxide and unburnt hydrocarbon are measured with Netel Chromatograph CO/HC analyzer. The engine to be tested was started and allowed to run at no load about 30 minutes to reach the steady state for each fuel to be tested. Experiment has been carried out with pure gasoline on copper coated spark ignition engine. The fuels tested in the engine were commercial grade gasoline with blend (M20). Details of the fuel properties are given in Table 2. The BTE, Exhaust gas temperature, and exhaust emission such as CO and HC have been investigated.

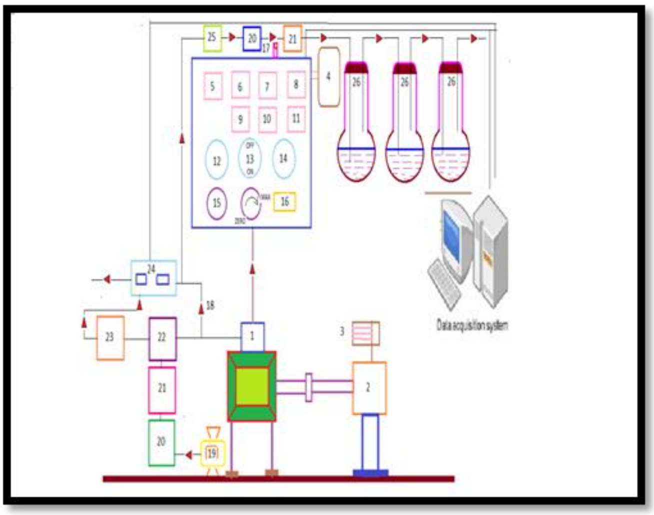


Figure 1.The Schematic layout of the engine test setup

Table 1. Engine specifications

1	Bore	70mm
2	Stroke	66.7mm
3	Rated output	2.5KW
4	Speed	2200-3000rpm
5	Compression ratio	3:1 to 9:1
6	Spark ignition timing	25^0bTDC
7	Specific fuel consumption	475 gm/ h KW
8	Loading	Eddy current dynamometer, Water cooling
9	Software used	Engine soft

Table 2. Properties of test fuels

S. No	**Character**	**Methanol**	**Gasoline**
1	Molecular weight	32.04	100-105
2	Composition	(O) = 50%	(c) = 85% (H) = 15%
3	Sp. Gravity	0.8	0.7-0.8
4	Density	791.8	700-780
5	Ignition Temperature	464	390-420
6	Air fuel Ratio	6.42	14.7
7	Octane number	111	80-99
8	Cetane number	55-60	0-10

Table 3 Properties of petrol methanol blends

BLEND	**DENSITY (Kg/m3)**	**CALORIFIC VALUE (Kj/Kg)**
M-20	**777.3**	**40.76**

III. EXPERIMENTAL RESULTS

3.1. Brake thermal efficiency

Test results for the BTE at various ignition timing and constant speed are shown in Figure 2. For conventional engine and copper coated engine with gasoline and methanol blended (M20) as fuels. The graph showed highest brake thermal efficiency 31.5 % at 27^0 bTDC for methanol blended gasoline operated with copper coated engine and lowest of 22% at 29^0 bTDC as it is too advanced in ignition timing. At this advanced timing combustion starts in the compression stroke itself which results in decrease in power in expansion stroke at engine speed of 3000 rpm. Similar observations are noted for conventional gasoline engine using methanol (M20) as fuel. It is also observed that methanol blended gasoline operation shows higher brake thermal efficiency throughout the experiment when compared to gasoline operation based on above reason, the improvement in brake thermal efficiency associated with the natural gas is due to the more advanced maximum brake torque timing and better mixing of methanol blended gasoline with air as compared to gasoline. This leads to increase in the proportion of energy captured from methanol fuel in comparison with gasoline fuel. In other words, the high thermal efficiency means that a larger portion of combustion heat has been converted into work. However, on average copper coated engine with methanol blended gasoline increased peak brake thermal efficiency by 24% in comparison with conventional engine with neat gasoline.

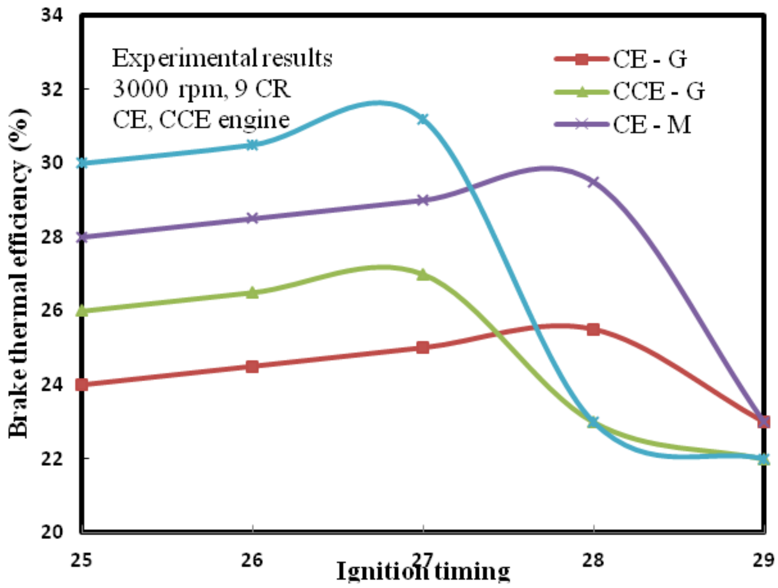


Figure 2. Experimental results of BTE at different ignition timings

3.2.Exhaust gas temperature

The variation of exhaust gas temperature with ignition timing is presented in Figure 3. It can be observed that exhaust gas temperature decreased with advanced spark timing which may be due to the increase in combustion temperature. Methanol blended (M20) gasoline showed lower exhaust gas temperature than gasoline operation on both versions of the engine at 27^0 bTDC because of the improvement in combustion efficiency and the reduction in combustion temperature for copper coated engine operated with methanol blend (M20) as compared to conventional engine. However, on average, the exhaust gas temperature of copper coated engine with methanol blended fuel (M20) operation is 40°C (6.8%) lower than that of gasoline operation.

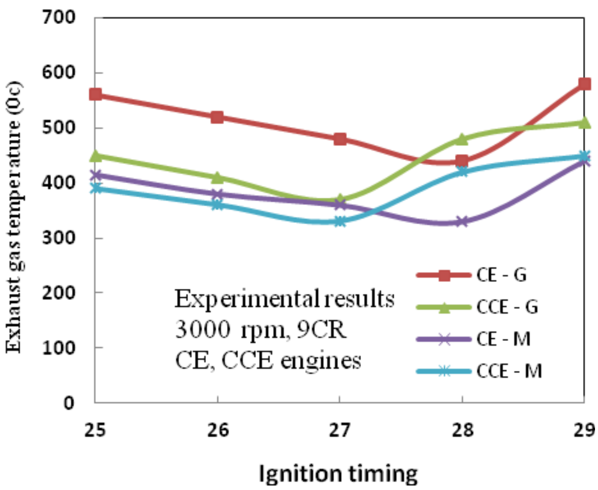


Figure 3. Experimental results of EGT at different ignition timings

3.3.Carbon monoxide

One of the most important emission from IC engines is CO. The level of CO emission in the exhaust of an IC engine varies with fuel air ratio. For fuel air mixtures high CO in the exhaust emission are observed. The carbon monoxide emissions from the engine were presented in Figure 4. The results indicate that CO values comparatively lower in copper coated engine with methanol blended (M20) against conventional engine. Because of prolonged combustion and more resident period of fuel with air at advanced ignition timing, high thermal conductivity of copper coating improves combustion thereby reducing CO emissions at 27^0 bTDC. Copper coating is the solution for reduction of CO emissions and performed for advanced spark timing. Copper coated engine with methanol blended gasoline reduced CO emissions by 4% when compared with gasoline operation on conventional engine.

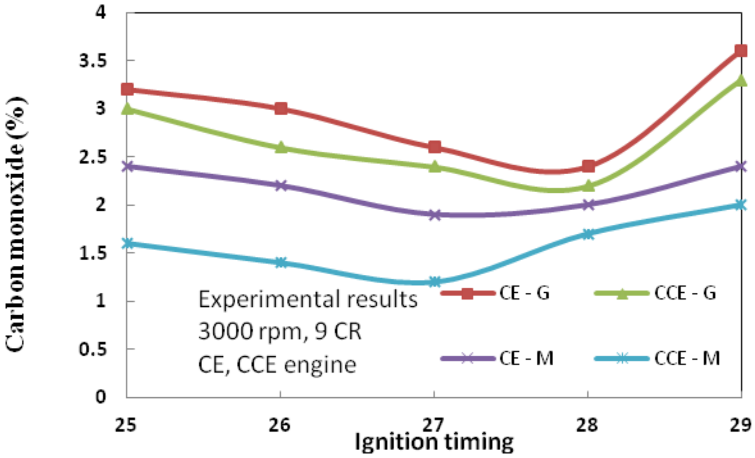


Figure 4. Experimental results of CO at different ignition timings

3.4. Unburned hydrocarbon

The unburned hydro carbon in the exhaust of an IC engine is another kind of emissions, which must be controlled. Most of the HC is caused by an unburned fuel air mixtutre, while the other source is the engine lubricant and incomplete combustion. Figure 5. It was observed that there is decrease in hydrocarbon emissions with copper coating methanol blended (M20) engine. Methanol blended gasoline reduced UBHC emissions in comparison with gasoline operation on both versions of the engine at 27^0 bTDC ignition timing. This is due to improved combustion and lower theoretical air fuel ratio of methanol in comparison with gasoline thereby more availability of oxygen leading to reduce UBHC emissions. Copper coated engine with methanol blended gasoline reduced UBHC emissions by 3.8% when compared with gasoline operation on conventional engine Observation in copper coated engine shows that hydro carbon emission at 27^0 bTDC is more compared to that at 25^0 to 28^0 bTDC

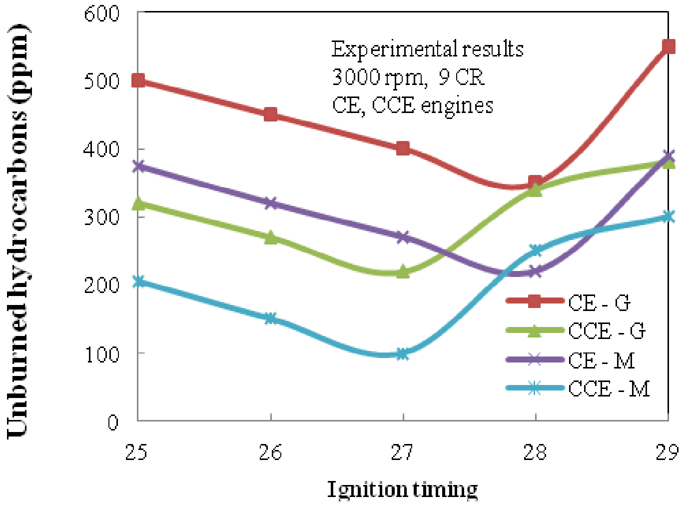


Figure 5. Experimental results of UBHC at different ignition timing

IV. RESPONSE SURFACE METHODOLOGY

Response surface methodology is a collection of statistical and mathematical techniques useful for developing, improving, and optimizing processes. The most extensive applications of RSM are in the particular situations, where several input variables potentially influence some performance measure or quality characteristic of the process. Thus, performance measure or quality characteristic is called the response. The input variables are sometimes called independent variables, and they are subject to the control of the scientist or engineer. The field of RSM consists of the experimental strategy for exploring the space of the process or independent variables, empirical statistical modeling to develop an appropriate approximating relationship between the yield and the process variables, and optimization methods for finding the values of the process variables that produce desirable values of the response.Response surface methodology was employed in the present study for analysis of response parameters to obtain the characteristics of the engine. The analysis of design experiment values in table 4. Using non parametric regression analysis response surface is generated for varied output with respect to input parameters.The goal of a regression analysis is to produce a reasonable analysis to the unknown response function f, where for N data points (X_i, Yi), the relationship can be modelled as

$$Y_i = m\,(X_i) + \varepsilon_i \qquad i = 1,...., N$$

A multiple regression analysis was carried out to obtain the coefficients and the equations can be used to predict the responses. Using the statistically significant model, the correlation between the process parameters and the several responses were obtained. Finally, the optimal values of the BTE, EGT, CO, UBHC were obtained by using the desirability approach of the RSM.

Table 4.Design of Experiments

	Ignition Timing	Type of engine	Type of Fuel	BTE	CO	UBHC	EGT
	P1	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**
1	25	1	1	30	1.83	205	390
2	26	1	1	30.5	1.4	150	360
3	27	1	1	31.5	1	100	330
4	28	1	1	24	2	250	420
5	29	1	1	22	2.4	300	450
11	25	0	1	28	2.61	375	415
12	26	0	1	28.5	2.2	320	380
13	27	0	1	29	1.8	270	360
14	28	0	1	29.5	1.4	220	330
15	29	0	1	23	2.8	390	440
6	25	1	0	26	3	320	450
7	26	1	0	26.5	2.4	270	410
8	27	1	0	27	2	220	370
9	28	1	0	23	3.2	340	480
10	29	1	0	22	3.6	380	510
16	25	0	0	24	3.75	500	560
17	26	0	0	24.5	3	450	520
18	27	0	0	25	2.6	400	480
19	28	0	0	25.5	2.2	350	440
20	29	0	0	23	3.9	550	580

Table 5. Optimal parameters of NSGA-II

Population size is	1000
Member of iterations	20
Mutation probability	0.01
Cross over probability	0.98
Maximum allowable pareto percentage	98
Convergence stability percentage	10

MOGA

The algorithm, takes the parent population of sample size ‘n’ and processes the sorting of these point towards the optimization goal. The sorted points were assigned ranks to denote their level of fulfillment in optimizing the goal parameters. Each of these points was then verified for their crowding distance from other points and the point that has farthest crowding distance is credited to be the best in the crowd. Such points were selected based on tournament selection principle applied to the attributes of points like ranks and crowding distance. Later in the algorithm, these points were subjected to crossover and mutation to synthesize new generation (child population). This starts the second iteration with the new sample formed by merging the parent and child generations according to their credit in crowding distance and front rank. This stage in the algorithm is referred as Elitism. The iteration proceeds until the point of convergence or until the reach of maximum iterations limit. The process algorithm of MOGA is shown in the flow chart Fig 6.

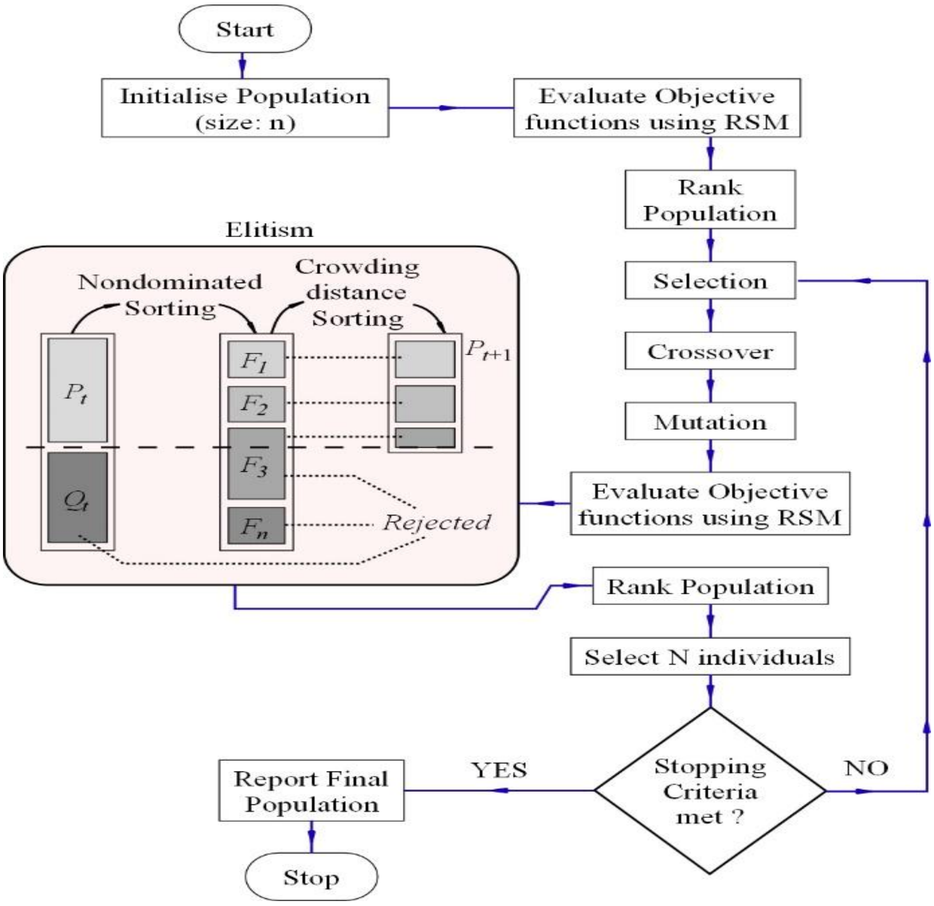
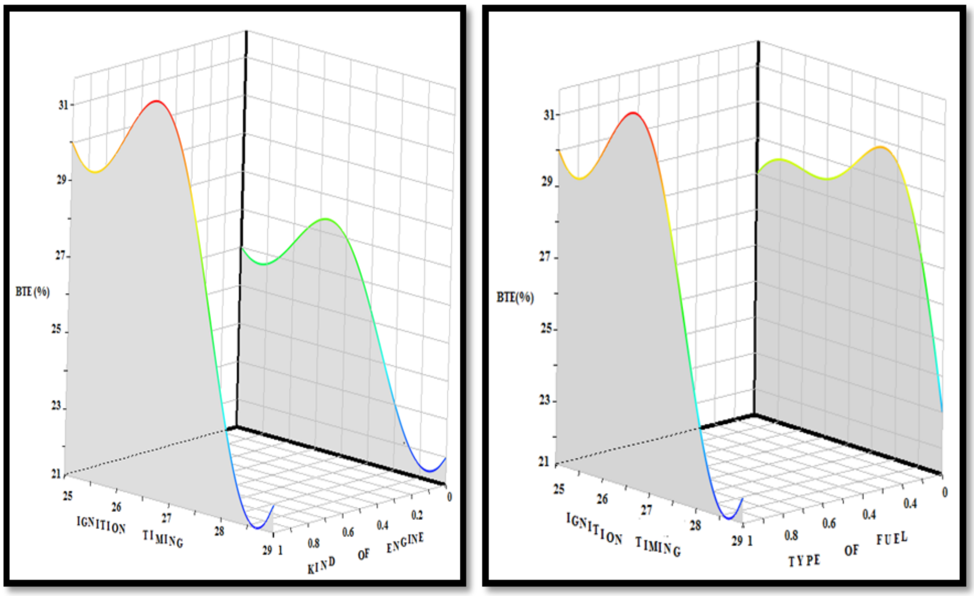


Figure 6. MOGA (NSGA-II) flow chart

For the prospects of optimization, experimental results are directed to ‘ANSYS workbench 15 Design explorer as per Central Composite Design (CCD) based DOE. These experimental values are processed to form a Response surface with Non-Parametric regression meta-model which can accurately represent highly nonlinear responses. This model relates all ‘Regression variables’ with ‘Response variables’ by incorporating adequate smoothing to the regression relation. Based on this regression model, several response plots were generated with the help of Design Explorer, to verify the dependence of each output parameter on various combinations of input parameters size is N. And hence the process repeats to generate the subsequent generations.

4.1. Brake thermal efficiency

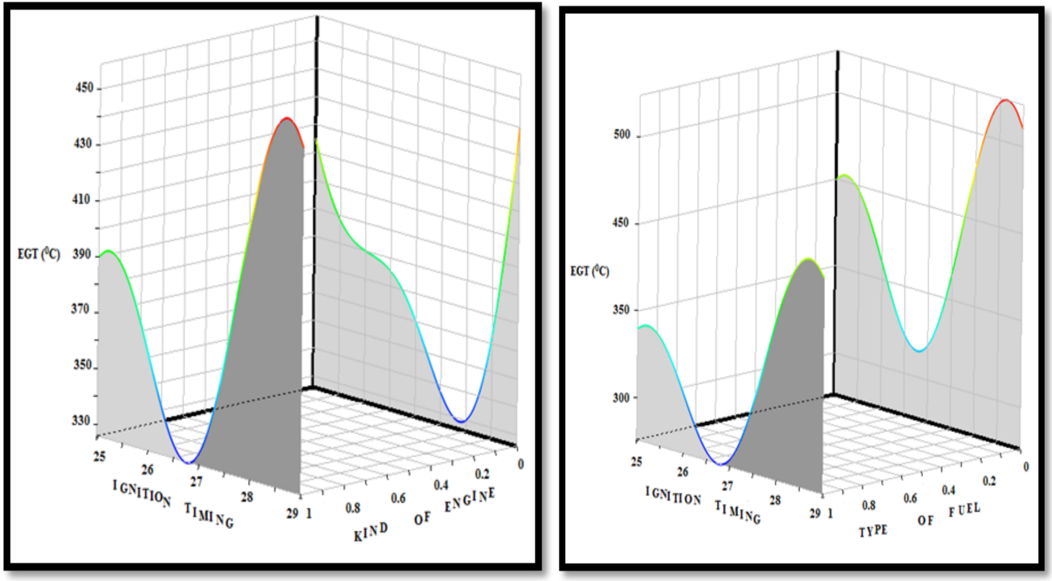
The regression equation generated was quadratic in nature and the various test created by NSGA-II showed the predicted model was significated. The three dimensional surface plots of BTE across the ignition timing, type of engine and type of fuel are as shown in Fig 7. That BTE first increases with the increase in ignition timing and type of engine as shown in Fig7 (a). It becomes maximum at ignition timing at 26.7^0 bTDC and copper coated engine, after that it starts decreasing continuously. Also BTE increases with increase ignition timing and copper coated engine with methanol blended gasoline fuel as shown in Fig 7(b).The design point for maximum BTE response is ignition timing 26.7^0 bTDC and fuel with M20.Therfore ignition timing is more the brake power is available at the shaft and brake power is directly proportional to thermal efficiency.



(a) (b)

Figure 7. Variation of Brake thermal efficiency against ignition timing

4.2.Exhaust gas temperature



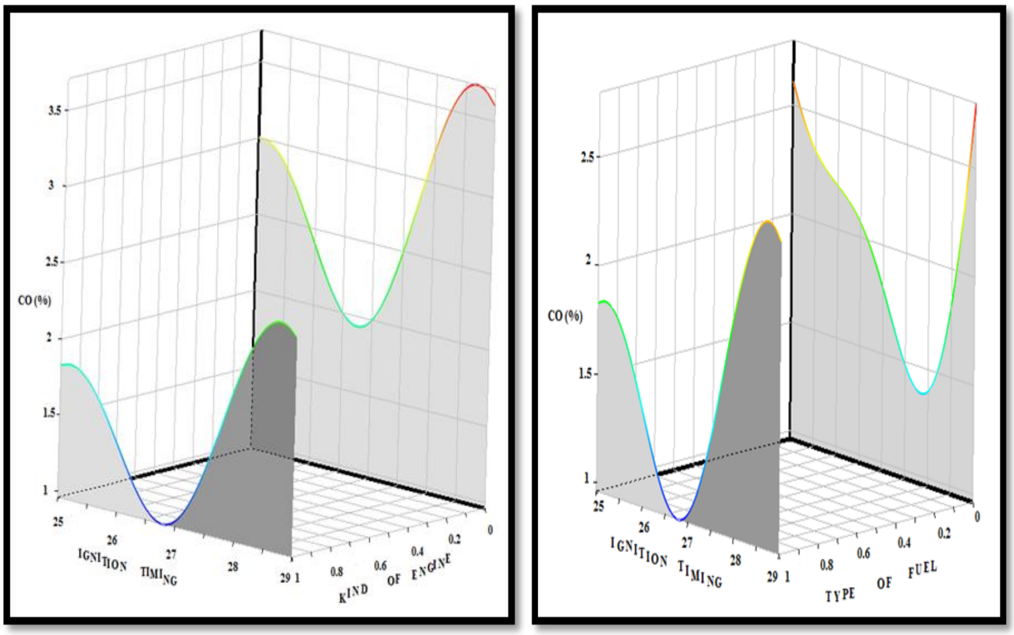
(a) (b)

Figure 8. Variation of EGT against ignition timing

The surface and conntour plots of exhaust gas temperature are as shown in Fig.8(a) and 8(b). It can be observed that exhaust gas temperature decreased with advanced spark timing which may be due to the increase in combustion temperature.

4.3.Carbon monoxide

The surface and conntour plots of are as shown in Fig.9(a) and 9(b).The gas analyzer was used to measure the amount of CO at different ignition timings. The results indicate that CO values comparatively lower in copper coated engine with methanol blended (M20) against conventional engine. Because of prolonged combustion and more resident period of fuel with air at advanced ignition timing, high thermal conductivity of copper coating improves combustion thereby reducing CO emissions

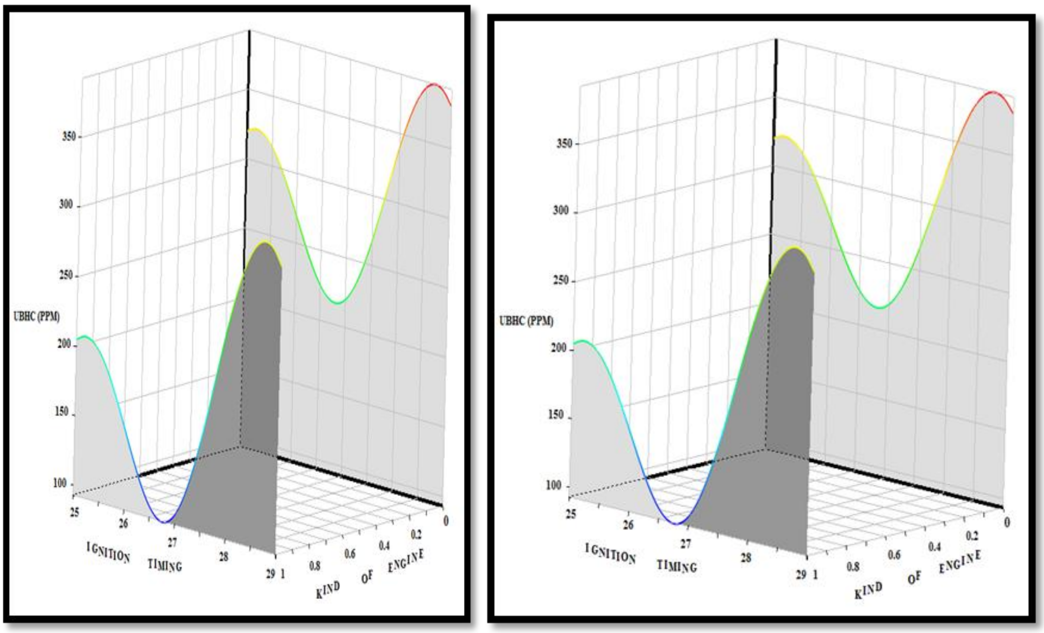


(a) (b)

Figure 9. Variation of CO emission against ignition timing

4.4. Unburned hydrocarbon

The main causes of UBHC emissions are the incomplete mixing of fuel mixing with air and quenching of oxidation process. The optimization values of NSGA-II results for different coefficient of the regression equation are shown in Table 4. The variation of UBHC with the ignition timing, type of engine and type of fuel are as shown in Fig 10 (a) and (b). It has been observed from the plots that the unburned hydro carbon emission decrease with increase the ignition timing.



(a) (b)

Figure 10. Variation of UBHC emission against ignition timing and kind of engine

Table 6.Comparison of predicated and experimental values

S.no	**value**	**Engine**	**Ignition Timing(b TDC)**	**Compression ratio**	**BTE (%)**	**EGT (^{0}C)**	**CO (%)**	**UBHC (ppm)**
1	Predicted	CCE	26.7^0	9:1	31.238	339.2	1.328	135
2	Experimental	CCE	27^0	9:1	31.5	330	1.2	100
3	Error				-0.262	-9.2	-0.128	-35

V. CONCLUSION

Optimization is carried out to find the optimal parameters for gasoline-methanol blends for different ignition timing and different kind of engine. The design of experiments was highly helpful to design the experiment and the statistical analysis helped to identify the significant parameters which are most influencing on the performance emission characteristics. This experimental design considerably reduced the time required by minimizing the number of experiments to be performed and provided statistically proven models for all response. It is clear from this research that CO and HC emissions have been reduced when methanol is fueled instead of gasoline.

The following conclusion can be made:

1. The experiments designed by the software helped to predict the accurate Responses
2. The design of experiments was highly helpful to identify the significant parameters which are most influencing on the performance and emission characteristics.
3. The optimum operating condition of the engine to get high performance and least emission from and copper coated engine blend with methanol (M20) blends are found to be at 26.7^{0}bTDC of ignition timing, compression ration of 9:1
4. Response such as BTE, EGT, CO, UBHC at optimized parameters are found to be 31.238%, 339.20c, 1.328%, 135ppm.
5. Brake thermal efficiency are found to be increasing at copper coated engine blend with methanol (M20)
6. It is also noted that with use of methanol blends CO and UBHC emissions are decrease.
7. The experimental results almost coincided with the validation results with very small deviations

The response surface methodology is demonstrated to find the process variables so as to achieve the desired objectives for any IC engine. In the present study the ignition timing, the percentage of blend and kind of engine are found to obtain the maximum thermal efficiency and minimum emissions. Thus RSM is found to be an effective method for multi objective optimization of IC engines.

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REFERENCES

[1]. Ugur Kesign, Genetic algorithm and artificial neural networks for engine optimisation efficiency and NOX emission. Fuel 83 (2004) 885-895.

[2]. Agrawal AK, Rajamanoharan K Experimental investigations of performance and emissions of karanja oil and its blends in a single cylinder agricultural diesel engine. Appl Energy 86(1) (2009) 106–112.

[3]. Ge, H., Shi, Y., Reitz, R., Wickman, D. et al., "Heavy-Duty Diesel Combustion Optimization Using Multi-Objective Genetic Algorithm and Multi-Dimensional Modeling," SAE Technical Paper 2009-01-0716, 2009.

[4]. K.Sivaramakrishnan P.Ravikumar “Optimization of operational parameters on performance and emissions of a diesel engine using biodiesel” Int. J. Environ. Sci. Technol. (2014) 11:949–958.

[5]. Maheswari N, Balaji C, Ramesh A (2011) “A non linear regression based multi objective optimization of parameters based on experimental data from an IC engine fuelled with biodiesel blends.” Biomass Bioenergy 35(2):2171-2183.

[6]. D’Errico, G., Cerri, T., Pertusi, G., 2011. Multi-objective optimization of internal combustion engine by means of 1D fluid-dynamic models. Applied Energy,88(3):767-777. [doi:10.1016/j.apenergy.2010.09.001]

[7]. Shi, Y., Reitz, R., 2010. Optimization of a heavy duty compression ignition engine fueled with diesel and gasoline like fuels. Fuel, 89(11):3416-3430. [doi:10.1016/j.fuel. 2010.02.023]

[8]. Atashkari, K., Nariman-Zadeh, N., Golcu, M., Khalkhali, A., Jamali, A., 2007. Modelling and multi-objective optimization of a variable valve-timing spark-ignition engine using polynomial neural networks and evolutionary algorithms. Energy Conversion and Management, 48(3): 1029-1041. [doi:10.1016/j.enconman.2006.07.007]

[9]. Alonso, J.M., Alvarruiz, F., Desantes, J.M., Hernandez, L., Hernandez, V., Molto, G., 2007. Combining neural networks and genetic algorithms to predict and reduce diesel engine emissions. IEEE Transactions on Evolutionary Computation, 11(1):46-55. [doi:10.1109/TEVC.2006. 876364]

[10]. Cenk Sayin,H.Metin Ertune,Murar Hosoz,Ibrahim kilicastan,Mustafa,canakci,Performance and exhaust emissions of a gasline engine Using artificial neural network. Appl.Therm.Engg.27 (2007) 46-54.

[11]. Langouet, H., Métivier, L., Sinoquet, D., Huy, Q., 2011. Engine calibration: multi-objective constrained optimization of engine maps. Optimization and Engineering, 12(3): 407-424. [doi:10.1007/s11081-011-9140-8].

[12]. José D. Martinez-Morales Eliva R. Palacios-Hernandez, Gerardo A. Velazqez-Carrillo Modeling and multi-objective optimization of a gasoline engine using neural networks and evolutionary algorithms J Zhejiang Univ-Sci A (Appl Phys & Eng) 2013 14(9):657-670

[13]. M. Bunce, D. Snyder, G. Adi, C. Hall, J. Koehler, B. Davila, S. Kumar, P. Garrimella, D. Stanton, and G. Shaver, “Optimization of soy-biodiesel combustion in a modern diesel engine,” Fuel 90(8), 2560–2570 (2011).

[14]. T. Ganapathy, R. P. Gakhar, and K. Murugesan, “Optimization of performance parameters of diesel engine with jatropha biodiesel using response surface methodology,” Int. J. Sustainable Energy 30(S1), S76–90 (2011).

[15]. N. Maheshwari, C. Balaji, and A. Ramesh, “A non-linear regression based multi-objective optimization of parameters based on experimental data from an IC engine fuelled with biodiesel blends,” Biomass Bioenergy 35(5), 2171–2183 (2011).

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