OPTIMIZATION MODEL FOR THE ANALYSIS ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF A CI ENGINE RUNNING ON ETHANOL-BUTANOL DIESEL BLENDS

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Abstract

The engines are one of the vital parts of automobile industry. Every nation is trying to reduce the pollution in many ways. The government's forthcoming rules and bills on mitigating emissions, such as formulating BS IV and BS VI regulations, have accelerated the pace of engine research. The aim and objective of the research is to study various optimization model for emission, performance and combustion and determine the best optimum alcohol-diesel blend. Ethanol and butanol were the alcohols that were blended with diesel for this purpose. Cylinder pressure, net heat release rate and mean gas temperature were the combustion parameters analyzed during the investigation. The emission parameters measured were the levels of CO, CO2, NOx and HC. While only marginal changes in the performance parameters were recorded by the values, the characteristics of some of those parameters were considered salient. Those parameters were brake thermal efficiency, brake power, torque and mechanical efficiency. We have tested various ratios of alcohol and diesel blends to obtain the optimized value. From the graphs obtained, it was clear that there was a slight increase in the performance parameters than that obtained when using neat diesel as fuel. When analyzing the emission characteristics, significant improvement can be noted, except in the level of unburnt hydrocarbon emission. Optimization is done to determine the best optimum alcohol diesel blend proportion which can be used in diesel engine. The optimum blend is selected based on the desirability value obtained during the results of the optimization

Keywords: *Artificial Neural Network (ANN), Ethanol-Butanol blends, Combustion, Emission, Performance.*

1. Introduction

Every nation, its economy and various other factors increased the demand for energy in some part of the world. There has been double-digit growth in demand for all fuels driven by natural gas, petroleum, solar and wind. Higher demand for electricity accounted for over half the rise in energy needs. Improvement in energy efficiency was seen as mediocre. CO_2 emissions increased 1.7 per cent in a year as a result of higher energy consumption. The biggest gains came from natural gas, which last year emerged as the fuel of choice, accounting for almost 45 per cent of the rise in overall demand for fuel Demand for all fuels increased, with fossil fuels accounting for almost 70 per cent of growth. Renewables rose at a double-digit rate but still not quick enough to satisfy the worldwide rise in electricity demand. Coal-fired power generation continues to be the single largest emitter, accounting for 30 per cent of all carbon dioxide emissions associated with electricity [1].

When using oxygenated fuels, the combustion and emission parameters can be significantly enhanced than when using traditional fuels. While performance characteristics are only marginally affected when using oxygenated fuels, the combustion parameters and emission parameters have improved adversely [2]. When using petrol, the average cylinder pressure was found to be lower than that. When using pure diesel as fuel at low and medium loads, the rate of increase in HC and CO emissions with increased load was lower as compared with coal. Nevertheless, the effect of such oxygenated fuel on the NOx ejection was almost zero, when using diesel, it was less than that [3].

When the research was conducted separately for studying the effects of the emission and performance characteristics of diesel engine when operated with ethanol-diesel blends as fuel, it was noted that 5% to 10% of ethanol is combined with diesel and used for testing as a fuel in diesel engine [4]. The experiment was carried out by running the motor under three loads at two speeds. In the phase, the emission parameters such as unburnt hydrocarbons, CO, NOx and strength of the smoke are measured. The study was also conducted on performance characteristics such as fuel consumption and brake power. When using the ethanol blended fuel, the emission characteristics witnessed an improvement except the hydrocarbon emission. The performance parameters displayed only a marginal improvement. To some extent, the CO emissions have been reduced, whereas HC levels had a contrasting trend [5]. The conclusion given was that the ethanol-diesel blends can be utilized more efficiently without any danger.

On considering the analysis of combustion, performance and emission characteristics when using butanol-mixed diesel as fuel in the diesel engine, it can be observed that the results are roughly identical when compared with ethanol-diesel blends. The parameters of combustion, such as peak pressure, combustion length, ignition delay and heat release rate were calculated and compared with the values obtained when using neat diesel as fuel. Even the emission parameters such as smoke visibility, carbon monoxide amount, hydrocarbons and nitric oxides were analyzed and compared with the same as the combustion. Performance parameters like BTE were also observed and compared with that of pure diesel [6]. The data and graphs observed a hike in the performance values. From the values it is clear that, there is a drop in the values of emission parameters. The explanation for the marginal difference in the NOx rates at lower loads may be attributed to high vaporization enthalpy and low butanol calorific value [7].

From the descriptions of the above literatures, we can come to a conclusion on the impact of ethanol-diesel and butanol-diesel mixtures on combustion, emission and performance characteristics of diesel engine and it also helped us to determine the ideal blending ratios, the ignition delay achieved in various blends, etc. The work is performed by mixing ethanol and butanol in equal proportions with diesel. The engine output is stalled by more than 10 percent of the alcohol levels in the fuel used. The alcohols are therefore mixed with diesel in amounts such as 2%, 4%, 6%, 8% and 10%. At different blending ratios, the engine is operated by varying the load from no load to full load.

Based on the obtained results from prediction and the inference of the comparative analysis, optimization has to be done to determine the best optimum blend that can be used in diesel engine. The optimization is performed using the Design Expert software with Random Surface Methodology. Two optimization models were identified for this project from 2 journals. The first one is the Artificial Neural Network (ANN) [8]. It was used to predict the BP, Torque, SFC and exhaust gas emission of the diesel engine operated using waste cooking biodiesel as fuel. The discussed results prove that the engine performance was enhanced and the emission characteristics of the diesel engine were also improved. The ANN model was used with backward propagation algorithm. The correlation coefficient of the ANN model was also found to be close to 1 which proves the high accuracy of the model.

Another model for optimization is Genetic Algorithm [9]. The objective of the study is the optimization of the fuel oil blending process to increase the profit, quality, production and reduce the use of lighter products such as kerosene and LCO and also to improve the calorific value of the blend. This process is also highly efficient. But, since the RapidMiner software suggested the use of Artificial Neural Network as the optimization model for this project, ANN is employed to determine the optimum blending proportion.

2. Experimental Setup

2.1 Interface of RapidMiner Studio

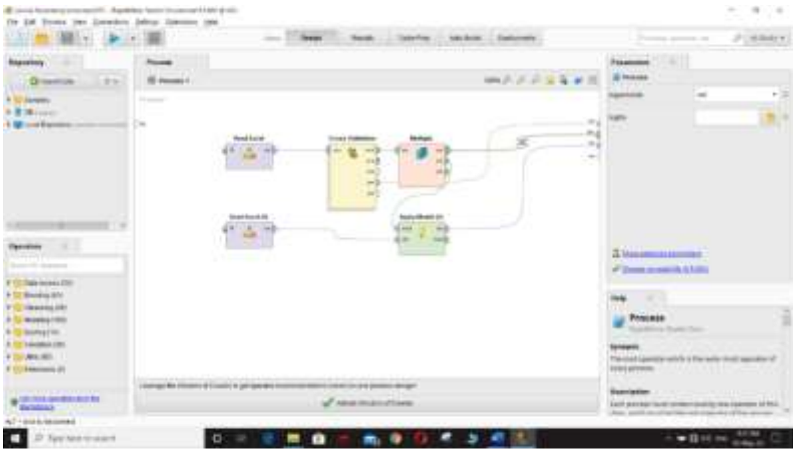

Figure 1. Interface of RapidMiner Studio

RapidMiner Studio is a visual data science workflow designer accelerating the prototyping & validation of models. Easy to use visual environment for building analytics processes: Graphical design environment makes it simple and fast to design better models. The interface of the RapidMiner software is displayed in the Figure 1. In this project, the software is used to determine the intermediate values between those available actual values with high accuracy. This process is known as prediction. This process can also be done using simple interpolation method, but it provides the results of linear order which has less accuracy. But this software provides results of quadratic and cubic order. The accuracy of the obtained intermediate values can be increased by increasing the order of prediction and number of cycles in the prediction. In the interface, there is a process workspace in which the operators that are required for the process are selected and placed from the operators section into the workspace and are connected as required. In this project, the operators used are Read Excel, Cross Validation, Multiply and Apply Model. The Read Excel operators allows the user to provide the input required for the prediction. The input operator situated above allows us to upload the excel sheet in which the actual data is present. The Read Excel 2 situated below the first one allows us to upload the worksheet in which we need the results. The cross-validation section in the center takes care of training and testing the uploaded data. It is the place where the optimization model is applied. Here Neural Network is applied as the optimization model.

2.2 Interface of Design Expert Software

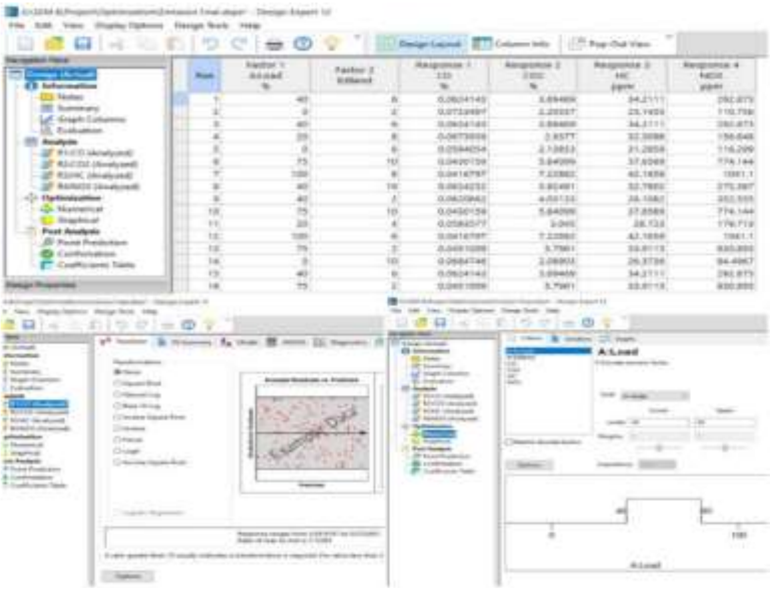

Figure 2. Interface of Design Expert Software

Design Expert is a statistical software package from Stat-Ease Inc that is specifically dedicated to performing or solving of problems in design of experiments. It offers comparative tests, screening, characterization, optimization, robust parameter design, mixture design and combined designs. In this project, this software is used for optimization of the combustion, emission and performance characteristics values of the diesel engine which are obtained from the RapidMiner software.

The interface of 3 parts of Design Expert software is displayed in the Figure 2. At first, the optimization model for the problem has to be selected. In this project, The Random Surface Methodology which lies under Artificial Neural Network is selected. The range of the applied load and blend proportions are provided at the required spaces. The first part of the interface is situated above the other 2 in the Figure 2. It is the part where the software allows us to provide the values of the combustion, emission and performance parameters for random load and blend proportion within the range. The second part of the interface is situated on the bottom left side of the Figure 2. This part analyses and creates model graphs for the parameters individually. It even allows to select the order of optimization. It can be selected from linear to sixth order. The optimization model has higher accuracy only if the R2 value is close to 1. Each and every parameter of the analysis section has to be manually analyzed before proceeding to the next step of the process. The third interface is displayed on the bottom right side of the Figure 2. This interface is the main optimization part and it displays the result of the optimization process. It displays results for the required range of applied load. The required range can be changed based on the criteria of the experiment. The solutions tab at the top shows the results table as displayed in Chapter 8. The solution from the table which has the largest desirability value and has possible parameter values will be considered as optimum solution.

3. Working Procedure

The diesel engine is operated using the different proportions of ethanol-butanol blends for the increasing load. The combustion, emission and performance analysis were carried out on the diesel engine and the values were collected using different sensors and recorded. The actual values are collected for a wide range of increasing load. They lack accuracy. The intermediate values in between the actual values are determined using the RapidMiner Studio with high accuracy and order

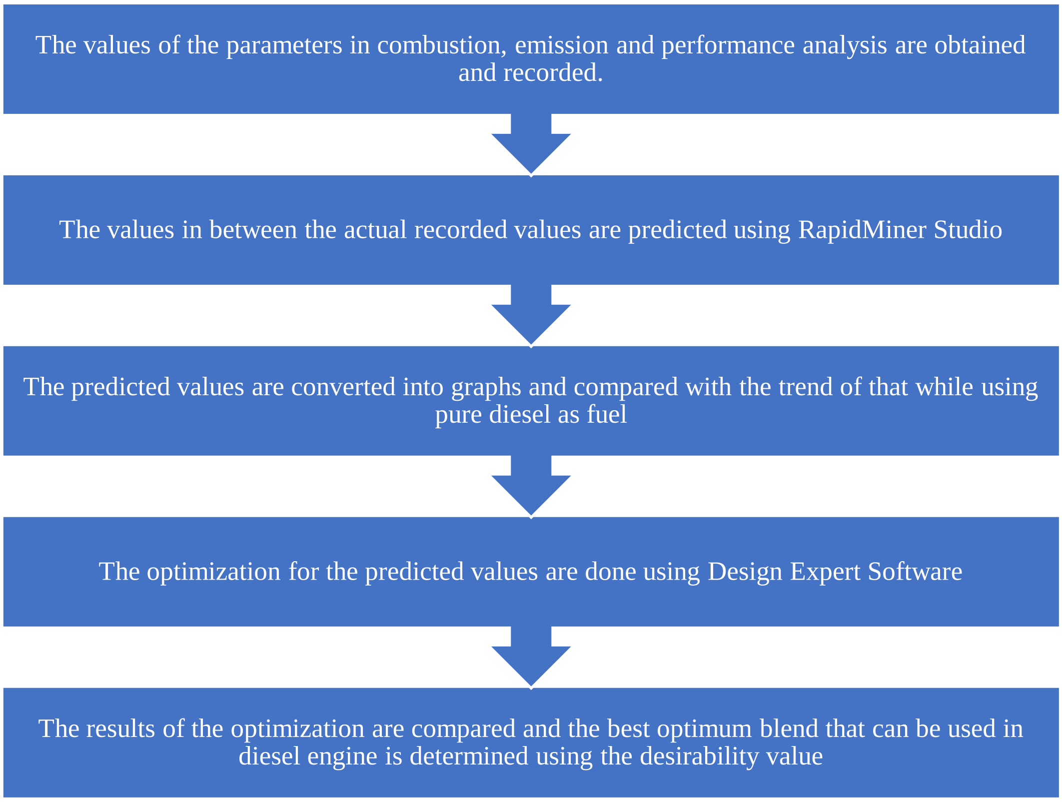

Figure 3. Working procedure of the experiment

Those determined values are recorded for the next stage. The predicted intermediate values are converted into graphs and the trends of those values with increasing load is compared with those obtained while operating the engine with neat diesel. The Design Expert software was used to optimize the values in order to find the best optimum blend proportion that can be used as fuel in diesel engine. The artificial neural network was used as the optimization model in the Design Expert software. The resulting solutions of the optimization process were compared with each other. The solution having the highest desirability value in the results table is considered as the best optimum solution.

4. Optimization

Optimization is the process of determining the best optimum blends for improving the performance and reducing the emission of the diesel engine based on the values obtained during the running of the engine. Here the optimization is done using the software, Design Expert. The Artificial Neural Network is used as the optimization model. Some of the random observation values of the parameters based on which the optimization takes place is given as input to the software. Then the most optimum blend is concluded based on the desirability value.

4.1. Optimization of Performance Parameters

4.1.1. Optimization of Brake Thermal Efficiency

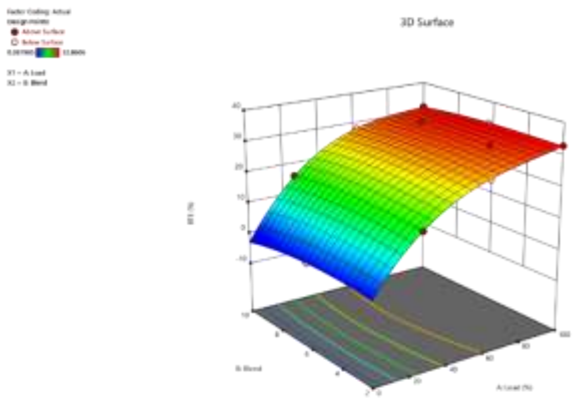

Figure 4. Optimization Characteristics of Brake Thermal Efficiency

The characteristic of Brake Thermal Efficiency (BTE) is shown in the Figure 4. It is similar for all the blends as there is negligible deviation in the graph above in the blend axis. The trend of the 3D graph is similar to that of the 2D chart shown in the comparison of engine characteristics. It can be seen that for all the blends, the brake thermal efficiency is minimum at no load condition and increases to maximum at maximum load following a curved path. The area in the blue indicate the minimum BTE which has value of approximately, 0.388% and the red area indicates the maximum BTE which has a value of 32.86%. We can see that at no load condition, the BTE is higher in the center meaning that the value is higher for the blends EB4, EB6 and EB8 than EB2 and EB10. And also, it is clear that the value is maximum for EB6 at no load condition. At maximum load, it can be seen that the BTE decreases with increase in the blend. It is maximum for the blend EB2 at full load condition. The red colored dots are placed above the surface and the pink dots are those below the surface. These points represent the values of the BTE which were given as input at specific loads and blends during the initialization of optimization process.

4.1.2. Optimization of Torque

The characteristic changes of the torque curve with the increasing load and blend is shown in the Figure 5. It can be seen that the torque curve has negligible deviation with all the changes in the blend proportions. The 3D graph is extremely similar to the 2D version. It can be observed that the engine torque is zero at no load condition for all the blends and the value of the torque increases linearly with increase in load. At no load condition the value of torque is the same for all the blends and it only shows a slight deviation with increase in the load at the maximum value. The area in the blue colorindicates the lowest value of the torque which is approximately 0.18Nm and that in the red indicates the maximum value of the torque which is approximately 21.6Nm. At maximum load, the value of torque is higher in the blend EB4 when compared with others as it has the intense red color. The red colored dots indicate that they are placed above the surface and those in pink color are placed below the surface.

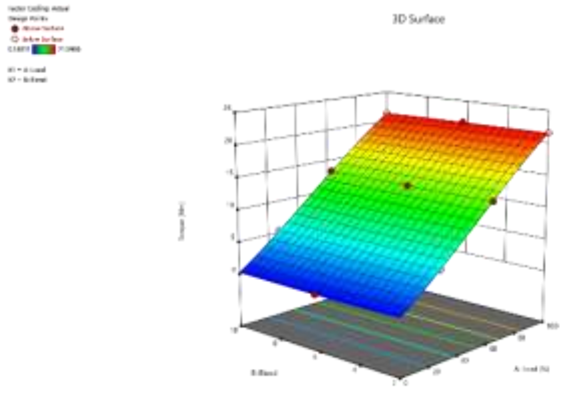

Figure 5. Optimization characteristics of Torque

These points represent the values of torque at specific loads and blends which were given as inputs for optimization in Design Expert 12.

4.1.3. Optimization of Specific Fuel Consumption

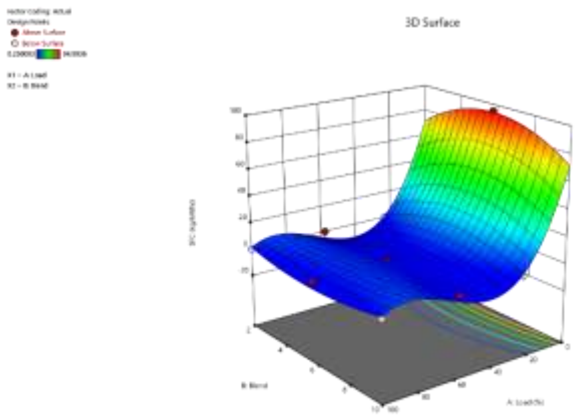

Figure 6. Optimization characteristics of Specific Fuel Consumption

The characteristic changes in Specific Fuel Consumption (SFC) with respect to increasing load and increasing proportion of blends is shown in the Figure 6. It can be seen that the deviation in specific fuel consumption when using different proportion of blends can be easily identified with the above graph. A certain part of the 3D graph is also similar to that of the 2D chart of SFC changes with increase in load. From the chart, it is clear that the SFC of the engine is maximum at lower loads. The reason behind this is the initial torque that is required to start the smooth working of diesel engine. It is clear that the SFC reduces with increasing load up to half loading condition and then maintains a nearly constant trend when the load is increased to its maximum value. In this experiment the goal is to reduce the Specific Fuel Consumption. The area in blue color indicates the minimum value of SFC which is 0.25 kg/kW-hr and that section in red color indicates the maximum SFC which has a value of 94.99 kg/kW-hr. Here the initial loading is considered for optimization because of the high SFC at low loads. At no load condition, the blend EB6 seems to have the highest SFC and in contrast the blends EB2 and EB10 have lower SFC than other blends at lower loads. The red colored dots indicate that they are placed above the surface and those in pink color are placed below the surface. These points represent the values of torque at specific loads and blends which were given as inputs for optimization.

4.1.4. Optimization of Mechanical Efficiency

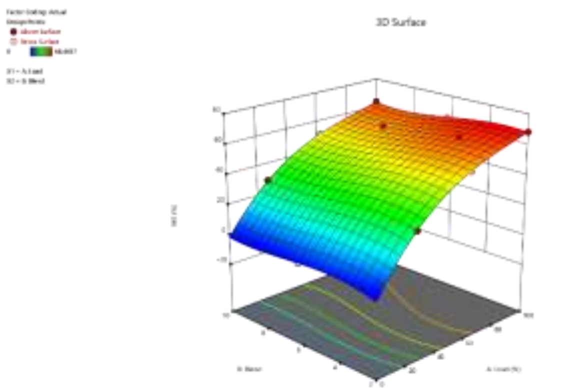

Figure 7. Optimization characteristics of Mechanical Efficiency

The characteristic changes in Mechanical Efficiency (ME) with respect to increasing loads and increasing proportions of blends is detailed in the Figure 7. The characteristic changes in the ME shown in the above figure is identical to that explained in the 2D. The trend followed by all the blends in changes in mechanical efficiency with increasing load is similar with slight deviations. It can be observed that the ME of the diesel engine increases with increase in load when operated with all the blends yet following a curved path. At no load condition the value of the ME for all the loads is nearly 0 and it increases to maximum value at maximum load. The area in the blue color represents the lowest possible mechanical efficiency which has a value of 0% and the highest possible efficiency is denoted by intense red color which has a value of 68.45%. The highest possible efficiency is achieved by the engine when using the blend EB2 at maximum load. The points in red and pink color represents the values of mechanical efficiency at specific loads and blends which were given as sample inputs to the optimization process.

4.2. Optimization of Emission Parameters

4.2.1. Optimization of Carbon Monoxide Emission

The characteristic changes in the emission of CarbonMonoxide (CO) with respect to the increasing loads and blendproportions are explained in the Figure 8. It can be observed that the deviation in the trends followed by CO emission by diesel engine when operated with different blend proportions can be easily identified from the graph above.The given graph is similar to that of the 2D chart.The percentage of CO emission by the diesel engine is higher at initial no load.This is because of the initial torque required by the diesel engine which consumes high amount of fuel leading to higher emissions of CO. The percentage of CO decreases with increasing load and is minimum at maximum load. With a slight increase in the proportion of blends, the ratio of CO decreases to a certain extent but after that increases after the blend EB4 and reaches maximum value at the blend EB10. However, with the increase in the load this trend changes. At maximum load the value of CO increases slightly with increasing the blend proportions up to EB4 and then decreases to the minimum value on reaching EB10. The points in red and pink color represents the values of CO emission percentages at specific loads and blends which were given as sample inputs to the optimization process.

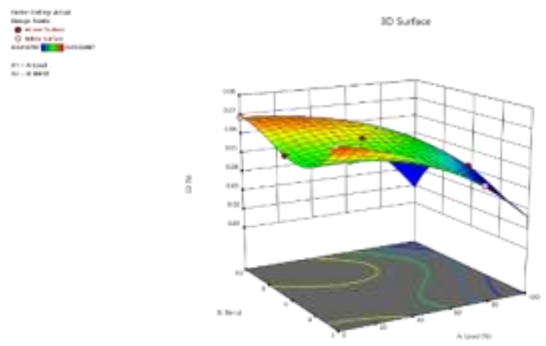

Figure 8. Optimization characteristics of Carbon Monoxide Emission

4.2.2. Optimization of Carbon Dioxide Emission

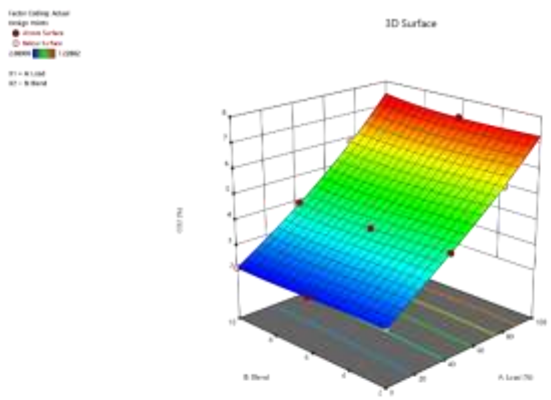

Figure 9. Optimization characteristics of Carbon Dioxide Emission

The characteristic changes in the emission of Carbon Dioxide (CO2) with respect to increasing loads and blend proportions are detailed in the Figure 9. It can be observed that the emission of CO2 from the diesel engine follows the same trend for all the blends with increase in the load. This chart is similar with 2D. The percentage of CO2 emission by dieselengine is minimum at no load condition and increases with increase in the load. It reaches the maximum value at maximum load. There is negligible deviation of the trends obtained when the engine was operated with different blends. The path of the CO2 curve increases linearly with increase in load. The blue coloured area represents the lowest % of CO2 emission within all the blends which has a value of 2.09% and that sector with a red colour represents the highest percentage of CO2 emitted which has a value of 7.23%. The points in red and pink colour represents the values of CO2 emission percentages at specific loads and blends which were given as sample inputs to the optimization process.

4.2.3. Optimization of Hydrocarbon Emission

The characteristic changes in the emission of Hydrocarbon (HC) by the diesel engine with respect to increasing load and blend proportions is shown in the Figure 10. The trend of HC emission obtained by using different blends in the diesel engine can be easily differentiated with the aid of this graph. The trends followed by each blend in the above

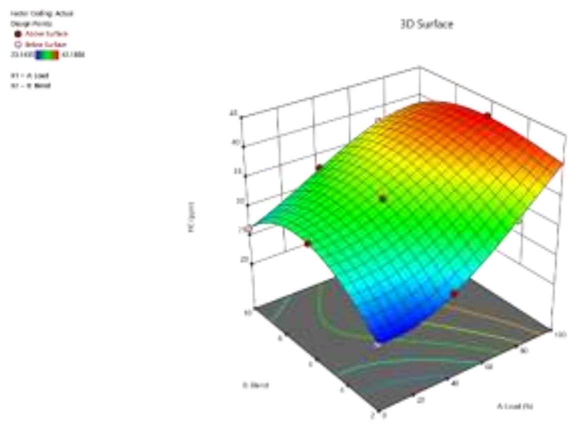

Figure 10. Optimization characteristics of Hydrocarbon Emission

graph is identical to those mentioned in the 2D graph. The amount of unburnt Hydrocarbons increases with increase in load for all the blends. The HC emission is minimum at no load condition and reaches its maximum possible value at maximum load. However, the rate of increase of HC emission with respect to load varies for each blend. With an increase in the proportion of blends, the amount of HC emitted increases up to the blend EB6 and after that it decreases and reaches a smaller value on using the blend EB8 and EB10 at no load condition. At maximum load the trend followed is the same except that the HC emission reaches a much smaller value in EB10. The highest possible HC emission is obtained near the blend EB6 at maximum load and the minimum is obtained at the blend EB2 when working under lower loads. The area in blue colour represents the lowest possible value of HC emission which is 23.14ppm and the intense red colour indicates the highest possible value of HC emission which is 42.19ppm. The points in red and pink colour represents the amount of unburnt hydrocarbons emitted at specific loads and blends which were given as sample inputs to the optimization process.

4.2.4. Optimization of Nitrogen Oxide Emission

The characteristic changes in the emission of NitrogenOxide (NOx) by the diesel engine with respect to increasing load and blend proportions is explained in the Fig 11. From the graph, it is clear that the trend of NOx emission followed by all the blends are identical with only slight variations in the curve. This 3D curve is similar to that in the 2D. The amount of NOx¬ increases with increase in the load for all the blends. The emission of NOx is minimum at no load condition and there is no change in the NOx emission among the blends at this load.It reaches a maximum possible value at the maximum load even when the engine was operated with different blends. The variation among the blends is clearly visible at maximum load.The emission of NOx reduces to a certain extent with the increase in the proportion of blends up to the blend EB6 and after that it increases with the increase in the blending proportions and it reaches the maximum value in the blend EB10. The area in dark blue colour indicates the lowest emission of NOx which has a value of approximately 84.5ppm and the intense red colour indicates the highest NOx emission which is 1041.1ppm.

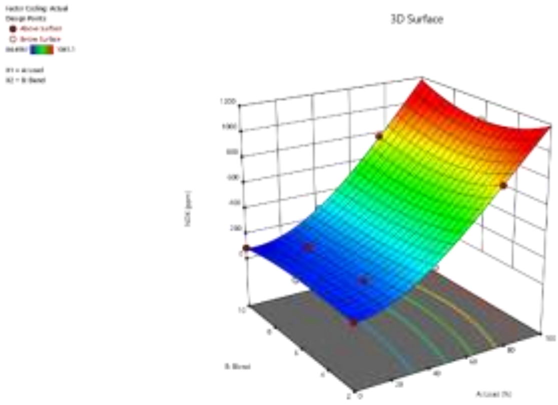

Figure 11. Optimization characteristics of Nitrogen Oxide Emission

5. Results

5.1. Results of Performance Optimization

The results of the optimization of performance parameters such as Brake Thermal efficiency, brake power, torque, mechanical efficiency and specific fuel consumption is based on the desirability value that is obtained in the results table. The blend which has the most desirability value will be considered as the best optimum blends when compared with the other blends.

5.1.1. Performance Optimization Results for no load to half load

Table 1.Results of Performance Optimization from no load to half load

No	Load	Blend	BP	BTE	SFC	Desirability
1	40	4.547	1.351	23.853	-0.365	0.595
2	40	4.516	1.351	23.842	-0.423	0.595
3	40	4.585	1.351	23.866	-0.293	0.595
4	40	4.371	1.351	23.787	-0.719	0.595
5	**40**	**4.839**	**1.351**	**23.952**	**0.137**	**0.595**
6	40	4.878	1.351	23.964	0.195	0.595
7	40	4.025	1.351	23.645	-1.536	0.595
8	40	5.314	1.354	24.084	0.711	0.594
9	40	3.417	1.356	23.356	-3.352	0.594
10	40	3.214	1.359	23.249	-4.067	0.593
11	40	3.116	1.360	23.196	-4.432	0.593
12	40	3.044	1.362	23.156	-4.708	0.593
13	40	2.753	1.367	22.990	-5.888	0.591
14	40	2.631	1.370	22.917	-6.420	0.591
15	40	10.00	1.413	22.959	-9.460	0.587
16	40	9.792	1.412	23.121	-8.399	0.587
17	40	8.999	1.404	23.631	-4.873	0.587
18	40	9.164	1.406	23.539	-5.540	0.586

The results of the performance optimization for the blends from no load to half load is displayed in the Table 1. The table displays 18 results that have the most desirability value when compared with the other possibilities. The possibility with the highest desirability value will be considered as the bestoptimum blend as of the performance sector. The table also displays the performance parameters those were considered for optimization and their values for different proportions of blends. Among the 18 possibilities the first 7 have the highest desirability value 0.595. Among those 7, the 5th possibility is considered as the best optimum possibility. This is because the other 5 have negative values of specific fuel consumption which is practically not possible. Hence the other 2 having the positive values of SFC are shortlisted and that having the lowest SFC value is considered as the best optimum blend. Since the 5th possibility has the lowest SFC value 0.137 kg/kW-hr, that blend is considered for optimum blend. But the blend should be absolute to be declared as optimum and hence it is rounded off to the blend EB4. The value of the blend is 4.839 which is less than 5 and hence the blend EB6 was not considered. Therefore, the blend EB4 will be declared as the optimum blend mixture for the load range of no to half load.

5.1.2. Performance Optimization Results for half load to full load

Table 2. Results of Performance Optimization from half load to full load

No	Load	Blend	BP	BTE	SFC	Desirability
1	**80**	**3.924**	**2.727**	**31.084**	**4.861**	**0.886**
2	80	3.955	2.727	31.094	4.853	0.886
3	80	3.895	2.727	31.075	4.869	0.886
4	80	4.000	2.727	31.109	4.841	0.886
5	80	3.844	2.728	31.058	4.884	0.886
6	80	4.099	2.727	31.140	4.815	0.886
7	80	3.698	2.728	31.009	4.926	0.886
8	80	4.196	2.727	31.170	4.791	0.886
9	80	4.421	2.726	31.235	4.741	0.886
10	80	4.529	2.726	31.265	4.719	0.886
11	80	3.333	2.731	30.879	5.046	0.886
12	80	5.034	2.727	31.388	4.637	0.884
13	80	5.140	2.727	31.411	4.624	0.884
14	80	2.812	2.736	30.678	5.248	0.884
15	80	7.268	2.733	31.558	4.679	0.875

The results of the performance optimization of the blends from half load to full load are displayed in the Table 2. The table displays 15 results that have the most desirability values when compared with the other possibilities. The possibility with the highest desirability value will be considered as the best optimum blend as of the performance sector. The table also displays the performance parameters those were considered for optimization and their values for different proportions of blends. Among the 15 possibilities the first 11 have the highest desirability value 0.886. Since there is no negative value of SFC in the above table, the first value is considered for the best optimum blend. The value of the blend proportion is 3.924 which is very close to the blend EB4 and hence the blend EB4 is considered as the best optimum blend for the performance sector.

5.2. Results of Emission Optimization

5.2.1. Emission Optimization Results for no load to half load

The results of the emission optimization of the blends from no load to half load are displayed in the Table 3. The table displays 8 possibilities of the results that have the most desirability values when compared with the other possibilities. The possibility having the highest desirability value will be considered as the best optimum blend for the emission sector from no load to half load. The table also displays the emission parameters those were

Table 3. Results of Emission Optimization from no load to half load

No	Load	Blend	CO	CO2	HC	NO_x	Desirability
1	**0**	**4.131**	**0.057**	**2.180**	**28.713**	**125.555**	**0.757**
2	0	4.105	0.057	2.181	28.660	125.385	0.757
3	0	4.168	0.057	2.179	28.784	125.786	0.757
4	0	4.063	0.057	2.182	28.577	125.114	0.757
5	0	4.030	0.057	2.183	28.510	124.895	0.757
6	0	4.287	0.057	2.176	29.012	126.514	0.757
7	0	10.000	0.069	2.091	26.399	80.669	0.567
8	17.7	10.000	0.067	2.869	28.950	112.076	0.551

considered for optimization and their values for different proportions of blends. Among the 8 possibilities, the first 6 have the highest desirability value 0.757. The value of the blend proportion is 4.131 which is very close to the proportion of the blend EB4. Hence the blend EB4 is considered as the best optimum blend for this emission sector.

5.2.2. Emission Optimization Results for half load to full load

Table 4. Results of Emission Optimization from half load to full load

No	Load	Blend	CO	CO2	HC	NO_x	Desirability
1	**40**	**2.991**	**0.058**	**3.995**	**28.668**	**337.958**	**0.626**
2	40	3.022	0.058	3.994	28.745	337.213	0.626
3	40	2.920	0.058	3.998	28.489	339.705	0.626
4	40	3.066	0.058	3.993	28.856	336.145	0.626
5	40	3.244	0.058	3.987	29.289	332.041	0.625
6	40	2.444	0.060	4.012	27.246	352.349	0.619
7	40	10.000	0.062	3.917	32.693	288.574	0.537

The results of the emission optimization of the blends from half load to full load are displayed in the Table 4. The table displays 7 possibilities of the results that have the most desirability values when compared with the other possibilities. The possibility having the highest desirability value will be considered as the best optimum blend for the emission sector from half load to full load. The table also displays the emission parameters those were considered for optimization and their values for different proportions of blends. Among the 7 possibilities, the first 4 have the highest desirability value which is 0.626. The value of the blend proportion is 2.991 which is less than 3. Hence it is considered as the blend EB2. Therefore, the blend EB2 will be proposed as the best optimum blend for this emission sector.

6. Conclusion

From the above-mentioned information about the experiment, it is clear that the combustion, performance and emission characteristics of a diesel engine can be improved by blending diesel with alcohols such as ethanol and butanol at various proportions. This experiment was conducted to determine the proportion of the blend which is capable of enhancing the combustion, emission and performance of the diesel engine to the greatest possible extent. The results which are obtained from the tables shows different blends which could be used to improve the performance and emission characteristics of the engine separately. The performance sector results prove that the blend EB4 can be used to improve the performance parameters in both the no load to half load and half to full load ranges. But the results in the emission sector prove that the blend EB4 can be used to reduce the values of emission parameters only for the load range of no load to half load, and for the range of half load to full load, the diesel engine should be operated with the blend EB2 to reduce the emission parameter values. However, it is significant that the diesel engine emits more harmful exhaust during the initial load than that after half load. So, the blend which is determined for the load range of no load to half load can be considered as the best optimum blend for the emission sector which is EB4. Since both the performance and emission characteristics of the diesel engine can be improved to the greatest possible extent only by operating the diesel engine with the blend EB4, it is considered as the best optimum blend which can be used along with diesel in a diesel engine.

7. References

[1] Höök, M. and X. Tang, "*Depletion of fossil fuels and anthropogenic climate change—A review"*. Energy policy,(2013). **52**: p. 797-809.

[2] Liotta, F.J. and D.M. Montalvo, "*The effect of oxygenated fuels on emissions from a modern heavy-duty diesel engine*." (1993), SAE Technical Paper.

[3] QIN Jun1,LIU Hai-feng2,YAO Ming-fa2,CHEN Hui1., "*Influence of Biology Oxygenated Fuel Component on Diesel Engine Characteristics [J]*. Transactions of CSICE", (2007). **3**: p. 014.

[4] D.C. Rakopoulos, C.D.Rakopoulos , E.C. Kakaras, E.G. Giakoumis, "*Effects of ethanol–diesel fuel blends on the performance and exhaust emissions of heavy duty DI diesel engine"*. Energy conversion and management, (2008). **49**(11): p. 3155-3162.

[5] Sahin, Z. and O. Durgun, "*Prediction of the effects of ethanol-diesel fuel blends on diesel engine performance characteristics, combustion, exhaust emissions, and cost"*. Energy & Fuels, (2009). **23**(3): p. 1707-1717.

[6] Javier Campos-Fernández a , Juan M. Arnal b , Jose Gómez b , M. Pilar Dorado., "*A comparison of performance of higher alcohols/diesel fuel blends in a diesel engine"*. Applied energy, (2012). **95**: p. 267-275.

[7] Swamy RL , Chandrashekar TK , Banapurmath NR, and Khandal SV, "*Impact of diesel-butanol blends on performance and emission of diesel engine.* Oil Gas Res", (2015). **1**(101): p. 2472-0518.1000101.

[8] Ghobadian, B., et al., "*Diesel engine performance and exhaust emission analysis using waste cooking biodiesel fuel with an artificial neural network"*. Renewable energy, (2009). **34**(4): p. 976-982.

[9] Khosla, D.K., S.K. Gupta, and D.N. Saraf, "*Multi-objective optimization of fuel oil blending using the jumping gene adaptation of genetic algorithm"*. Fuel Processing Technology, (2007). **88**(1): p. 51-63.