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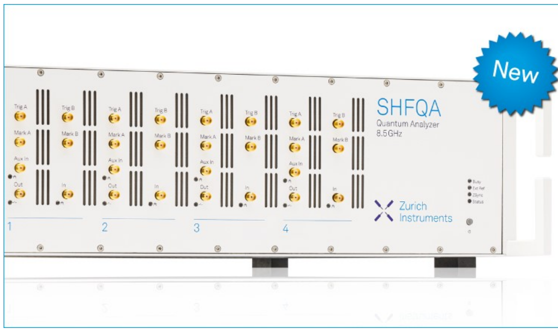

Influence of Nano Catalyst on Performance of DI Diesel engine with blends of citronella oil using Taguchi approach

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Abstract: India imported about 2/3rd of its petroleum requirements which involved a cost of approximately Rs. 80,000 crores in foreign exchange. Citronella oil is used as an input for biodiesel production via transesterification. Citronella biodiesel fuel properties are observed and tested in the fuel testing laboratory with standard procedure.Then an experimental set up is construct to study the performance VCR engine with different blends of Citronella Oil .L9 Orthogonal array was framed by Taguchi method . Green gasses emissions measured by AVL Gas analyzer. The optimum engine operating conditions were observed from response curve analysis.

Keywords Used: Citronella oil, Optimization, Response Curve, Taguchi method

INTRODUCTION

Population and economic growth are usually the fundamental drivers of the energy demand. The overall energy need can be divided into four demand sectors. They are power generation, transportation, industrial, and residential. It was reported that each of these major demand sectors will experience considerable growth through 2030 . The anticipated volume growth is the highest for the power generation sector followed by transportation sector. In the transportation sector, personal transportation, transportation of goods, non-road works such as construction and agriculture are mostly provided by IC engines. As the environmental concern rises and the demand for low-emissions vehicles increases, it has become a priority for the industry and scientific community to meet these challenges.

Diesel engines can offer better fuel economy and durability as compared to gasoline engines. While the high efficiency of diesel engines can benefit CO_2 emissions reduction, their PM and NOx emissions are subject to legislative limits due to their adverse effects on human health and environment(Yuvarajan Devarajan et. al). In the meantime, legislations also mandate the emissions of CO and HC .

Diesel combustion can be manipulated by many parameters such as EGR, injection pressure, and the injection profile(Devaraj Rangabashiam et. al). All these parameters will affect the combustion process, which in turn determines the emissions levels. Parameters which affect the combustion process are briefly explained below, followed by discussions on methods of optimizing engine performance for emissions reduction.
Ganesan et al conformed that canola oil can be used as the resource to obtain biodiesel. The methanol of canola seed along with diesel may reduce the environmental impacts of transportation and dependency on crude oil imports. The conclusions are drawn based on the performance and emission characteristics, comparing biodiesel with pure diesel

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(PD) . Hence, 20% methyl ester of canola oil and 80% of diesel blend at the injection pressure of 200 bar with standard injection timings of 27° bTDC and with a standard compression ratio of 17.5:1 gives a slightly better performance and reduced emission when compared to diesel fuel .NO*x* for B30 is low. For B10, B20 and B40, NO*x* is increased compared with that of B30. It was observed that, at the rated load, HC for B10 is low compared to that of B40. It was observed that, at the rated load, CO_2 for B20 is low. For B10, B30 and B40, CO_2 is increased(Sivasubramanian Rathinamet. al).

Padmanabhan et al done an exhaustive research on aloe-vera biodiesel with cerium oxide additive was carried out in this paper. Cerium oxide can be used to oxygenate the aloe vera biodiesel blends and improve the cetane number value for better combustion. All the performance experiments were carried out without any modification on the engine and rated speed. The additive cerium oxide is added to all the blends to satisfy homogeneity and avoid phase separation .Based on the experimental investigations of the aloe vera biodiesel blends with cerium oxide additive, it signifies an upright substitute fuel which gives good performance and better emission characteristics. In this study, the blend B30 (30% biodiesel, 70% diesel and 30 ppm nano additive) performed well when compared to other blends. This study also resulted in another new alternative in biodiesel category which is environment friendly.

Ganesan S et al. investigated the characteristics of exhaust emission and nano particle size distribution, as well as the number concentration of PM (particulate matter) from the CRDI diesel engine fueled with biodiesel-diesel blended fuel . Rajasekhar et al and S Mahalingham et. al). performed an extensive comparative experimentation by means of ASTM Standard testing methods to observe the influence of cerium oxide nano particles on various phsysicochemical properties of diesel. As a result it showed that flash point, fire point, kinematic viscosity, efficiency (up to 5%) increases and HC, NO_x reduces proportionally to the dosing level of nanoparticle.
Ganesan et al and S. Padmanabhan et. al were concluded from the investigation , the optimal combination of main effects plot for both mean of average grey grade and S/N ratio is found to be A4B3C2D4 and from the experimental view, the best blend is the B30 blend where the engine performance is comparable to that of diesel and the emissions are less than from diesel (Mathalai Sundaram C et. al).

Ganesan et al,Yuvarajan et. al Investigate that Cottonseed oil blended fuel with addition of Cerium Oxide nanoparticles in Kirloskar VCR engine setup on performance and emission characteristics, based on experiments ,it was observed that the Specific Fuel Consumption (SFC) of fuel is reduced up to 13.8%. Brake Thermal Efficiency (BTE) is optimized up to 8.3% by blending Cottonseed oil and CeO_2 nanoparticles in Biodiesel.Due to more Oxygen in combustion fuel, complete combustion can be accomplished (Sidheshware, R.K et. al and Dhanasekaran et. al).

Dhanasekar et al,Sujesh et.al attempted to replace 50%vol. of diesel (D) with a reuse fuel, Waste cooking oil (WCO) and renewable fuel, n-propanol (PR) up to 50% vol. with the objective to reduce the viscosity of WCO and smoke emissions(Mahalingam et.al). The engine emissions and performance were analyzed with respect to diesel and D50-WCO50 blend. Increase in the fraction of n-propanol improved the BTE gradually closer to but lower than diesel. CO, CO_2, smoke and NO_x emissions decreased with increasing n-propanol fraction in the blends. However the blends presented higher HC emission with increase in n-propanol percentage in the blends which could be after-treated favorably. Thus WCO could be effectively re-used with lesser viscosity and emissions by using n-propanol(Mathalai Sundaram et.al ,Sidhesware et. al).

Devarajan, Y et al Dhanasekaran et.al done the Experiment using rubber seed oil and jatropha oil, it was found that. the CO is increased by 0.06% when compared to diesel and decreased by 0.045% when compared with B100.The UHC is decreased as 11 ppm and it is closer to that of the diesel fuel. The NOx emission is decreased as 720 ppm with reference to that of diesel. Hence the blend B20 has a closer performance with pure diesel fuel and better than that of other biofuel blends.

Ganesan et. al et al,hemenandh et.al recommended that the load is more significant factor by using taguchi based Grey Relational analysis approach. Therefore, optimal setting is supposed to be affected due to the change in the level of load.

MATERIAL AND METHODOLOGY

Citronella oil

Citronella oil is popular as a 'natural' insect repellent and Citronella plant represent in Fig.1. Citronella oil is one of the essential oils gained from the leaves and stems of various species of Cymbopogon (lemongrass). The oil (Fig.2)is used extensively as a source of perfumery chemicals such as citronellal, citronellol and geraniol (S. Padmanabhan et. al,Devaraj et.al).

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FIGURE 1. Citronella Plant

FIGURE 2. Citronella oil

Design of Experiments

A well planned set of experiments, in which all parameters of interest are varied over a specified range, is a much better approach to obtain systematic data. Mathematically speaking, such a complete set of experiments ought to give desired results. Usually the number of experiments and resources (materials and time) required are prohibitively large. Often the experimenter decides to perform a subset of the complete set of experiments to save on time and money! However, it does not easily lend itself to understanding of science behind the phenomenon. The analysis is not very easy (though it may be easy for the mathematician/statistician) and thus effects of various parameters on the observed data are not readily apparent. In many cases, particularly those in which some optimization is required, the method does not point to the best settings of parameters.

Taguchi Method

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on “ORTHOGONAL ARRAY” experiments which gives much reduced “variance” for the experiment with “optimum settings “of control parameters. Thus the marriage of Design of Experiments with optimization of control parameters to obtain BEST results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal-to-Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results(Karthikeyan et al).

Calculation of S/N Ratio

Generally, a process to be optimized has several control factors which directly decide the target or desired value of the output. The optimization then involves determining the best control factor levels so that the output is at the target value. Such a problem is called as a "static problem".

This investigation involved Two Signal-to-Noise ratios for optimization of Engine process parameter. Taguchi method is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipment, and facilities.

Factors and Levels

Design of experiments (DOE) techniques support designers to determine the individual and interactive effects of many factors that could affect the Engine process parameters in any design. Table 1 deals with various factors at various levels (Table 1).

Based on Taguchi method, L9 Orthogonal array was developed by using MINI TAB software. Using orthogonal arrays significantly reduces the number of experimental work to be studied (Table 2).

TABLE 1. Factors and Levels

Factors	Level 1	Level 2	Level 3
Citronella Oil (%) –A	20	40	60
Injection Pressure (Bar) -B	200	220	240
BP (KW) -C	1.5	3	4.4
ZnO (ppm) -D	15	30	45

TABLE 2. Orthogonal Array

Ex. No	Citronella Oil (%)	IP (Bar)	BP (KW)	ZnO (ppm)
1	20	200	1.5	15
2	20	220	3.0	30
3	20	240	4.4	45
4	40	200	3.0	45
5	40	220	4.4	15
6	40	240	1.5	30
7	60	200	4.4	30
8	60	220	1.5	45
9	60	240	3.0	15

Fuel Preparation using Sonicator

The mixing of Citronella Oil - diesel with ZnO is primarily done by sonicating measure. Hielscher offers ultrasonic blending reactors for the creation of biodiesel at any scale (Hemanandh et.al,Joy et.al). The ultrasonic blending improves mass exchange and response energy prompting quicker transesterification and better return. It spares abundance methanol and impetus .

Sonicators either produce sound waves into a water bath, where samples are placed, or can be probes that are put directly into the sample to be sonicated. Such a machine will be used in the third part of this experiment to prepare the bead solution for application to the biosensor.

The Bioruptor System is based on a water bath with high power ultrasound generating elements located below the tank. With a better control on the parameters, the Bioruptor enables the automation of the sonication step which guaranties higher reproducibility and constant results. The frequency of the ultrasound energy produced by the Bioruptor and a probe sonicator is equivalent (20 kHz). A metallic bar in contact with the sample facilitates the transfer of the ultrasound inside the tubes. This metallic bar is not a probe but “reflects” the ultrasound originated from the water bath and improves the sample sonication efficiency by a patented resonance system.

FIGURE 3. Sonicator Machine

EXPERIMENTAL SETUP

A series of experiments was undertaken to investigate the Citronella Oil -diesel blends with addition of ZnO are conducted on experimental setup consisting of air cooled diesel engine with AC alternator for loading, Gas Analyzer, AVL415 Smoke Opacity meter, data acquisition system as shown in Fig 4. The engine and the dynamometer are interfaced to a control panel, which is conducted to computer for automatic recording the experimental observation such as heat release, injecting pressure, crank angle, loads etc. The loading is by means of an electrical dynamometer. The fuel tank is connected to a graduated burette, to measure the quantity of fuel consumed in unit time. The rig is installed with AVL soft ware for obtaining various curves and results during operation. A five gas analyzer is utilized to acquire the fumes gas sythesis. During experimentation, first, the Engine was worked in a diesel mode through a warm-up system, and afterward it was changed to mixed fuel activity.

After blending the fuel, fuel is ready to start the experiments on kirlosker engine on Citronella Oil -diesel blended fuel with addition of ZnO to perform the emission and performance characteristics. The blended fuel is poured into the graduated burette which is kept besides of the fuel tank from which one tube is use to supply the blended fuel to kirlosker engine through nozzle operating system.

FIGURE 4. VCR Engine Setup

RESULTS AND DISCUSSION

By experimental process on High speed, four stroke, vertical, and air cooled engine We get the value of CO, CO_2, O_2, HC, NO_X emission value (Table 3.). And also get other parametric value which is associate to calculate the performance characteristics brake thermal efficiency and specific fuel consumption value.

TABLE 3. Experimental Results

Ex. No	Citronella oil (%)	IP (Bar)	BP (KW)	ZnO (ppm)	BTE (%)	SFC (Kg/Kw hr)	HC (ppm)	CO (%)	NOx (ppm)
1	20	200	1.5	15	26.8	0.384	32	0.06	206
2	20	220	3	30	23	0.37	43	0.062	228
3	20	240	4.4	45	25.38	0.337	27	0.073	234
4	40	200	3	45	33.4	0.234	25	0.03	229
5	40	220	4.4	15	27	0.324	35	0.074	267
6	40	240	1.5	30	31	0.281	37	0.078	278
7	60	200	4.4	30	28.64	0.354	23	0.077	390
8	60	220	1.5	45	30.25	0.312	24	0.06	328
9	60	240	3	15	28.7	0.359	22	0.058	312

After than getting the optimum level and factors analyzing steps of Minitab software which give minimum emission and maximum performance at optimum level and factors. According to requirement we use larger the better, smaller the better and go to storage to store the optimum value as a graph. By analyzing these graphs we can easily recognize at which level and factors will give better performance and low emission characteristics.

Calculation of S/N Ratio

The S/N ratio for the corresponding responses is calculated by using the following formulae.

i) Smaller the better

$$n = -10 \, Log_{10} \, [\text{ mean of sum of squares of measured data }]$$

The generic form of S/N ratio then becomes,

$$n = -10 \, Log_{10} \, [\text{ mean of sum of squares of \{measured - ideal\} }]$$

ii) Larger-The-Better**:**

$$n = -10 \, Log_{10} \, [\text{mean of sum squares of reciprocal of measured data}]$$

This case has been converted to smaller-the-better by taking the reciprocals of measured and the values are represent in below table 4.

TABLE 4. S/N Ratio values

EX. NO	BTE(%)	SFC(Kg/Kw hr)	HC(ppm)	CO(%)	NOx(ppm)
1	28.5627	8.3134	-30.1030	24.4370	-46.2773
2	27.2346	8.6360	-32.6694	24.1522	-47.1587
3	28.0898	9.4474	-28.6273	22.7335	-47.3843
4	30.4749	12.6157	-27.9588	30.4576	-47.1967
5	28.6273	9.7891	-30.8814	22.6154	-48.5302
6	29.8272	11.0259	-31.3640	22.1581	-48.8809
7	29.1395	9.0199	-27.2346	22.2702	-51.8213
8	29.6145	10.1169	-27.6042	24.4370	-50.3175
9	29.1576	8.8981	-26.8485	24.7314	-49.8831

Response Curve Analysis for BTE

Response curve analysis is used to find out the most influential engine process parameters and their levels. It indicates the change in performance and emission characteristics with the mutation in each process parameter graphically. It also shows the pictorial representation of engine characteristics, when the engine process parameters changes form one level to another level (Ganesan et. al). The predicted optimized Engine parameter of A2B1C1 and D2 is represented in Figure 5. An experiment to be carried out with ZnO in 15ppm, BP in 1.1KW, 200 bar of injection pressure and Citronella Oil oil in 10% levels to obtain optimal values .

Response Curve Analysis for SFC

The optimized Engine parameter of A1B2C3 and D1 is represented in Figure 6.During investigation it was observed that, for better result the experiment were conducted with ZnO in 15ppm,BP in 4.4KW, 220 bar of injection pressure and Citronella Oil in 20% levels.

Response Curve Analysis for HC

The predicted optimized Engine parameter of A1 ,B2,C1 and D2 is represented in Figure 7. For lower HC values the experiment were conducted with ZnO in 30ppm,BP in 1.5KW, 220 bar of injection pressure and Cit. oil in 20% levels.

Response Curve Analysis for CO

The optimized Engine parameter of A1, B3, C3 and D2 is represented in Figure 8. It was noted that the experiment were conducted with ZnO in 30ppm,BP in 4.4KW, 240 bar of injection pressure and Cit.oil in 20% levels.

Response Curve Analysis for NOx

The mean is an average value for reading taken for a particular parameter. it was inferred that the optimized Engine parameter of A3, B4, C1 and D4 is represented in Figure 9.During prediction it was observed that, to get an optimal values, the experiment were conducted with ZnO in 45ppm,BP in 4.4KW, 220 bar of injection pressure and Cit.oil in 30% levels.

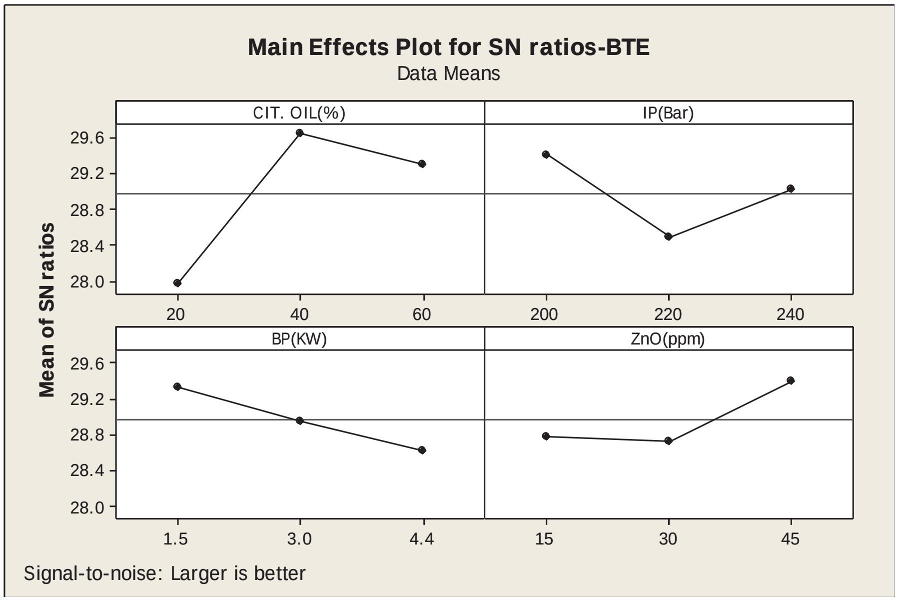

FIGURE 5. Response curve analysis for BTE

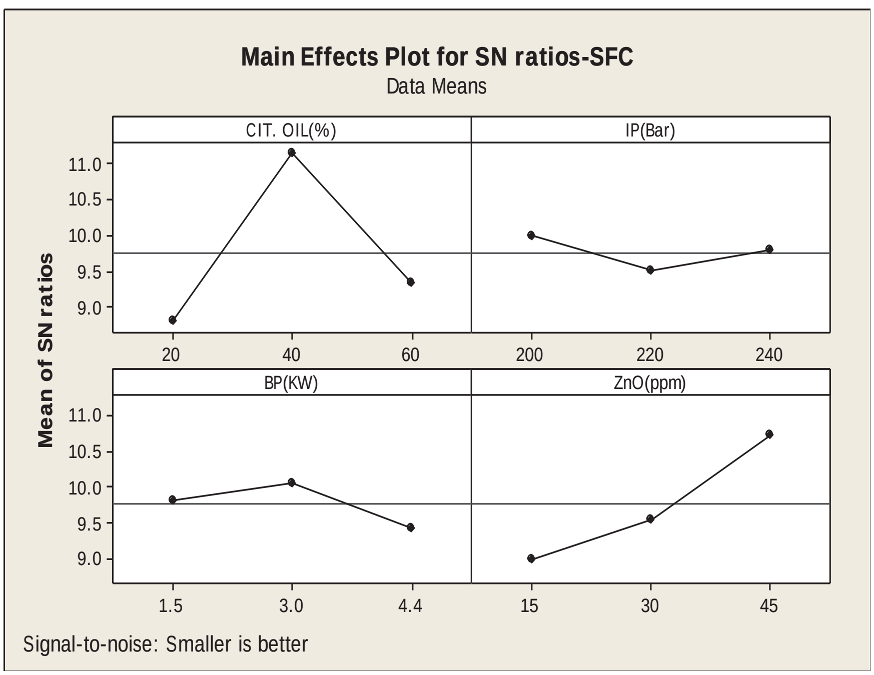

FIGURE 6. Response curve analysis for SFC

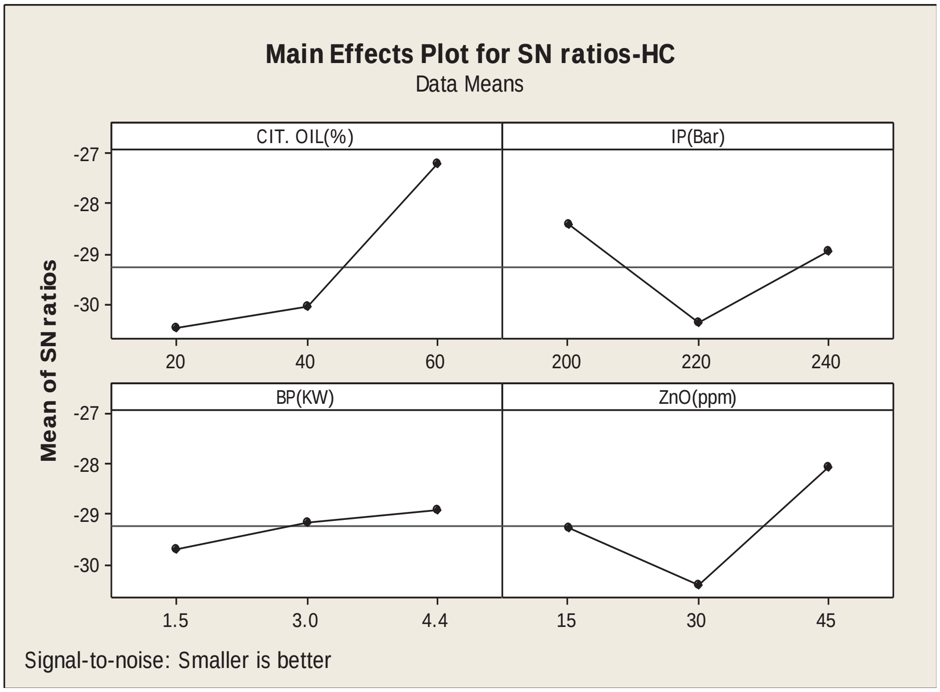

FIGURE 7. Response curve analysis for HC

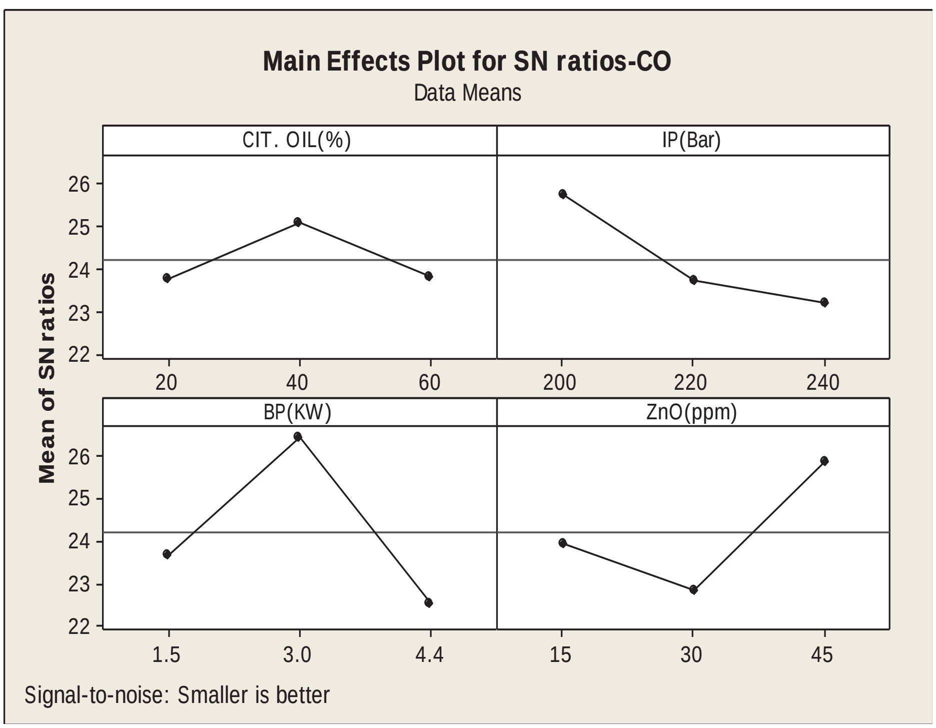

FIGURE 8. Response curve analysis for CO

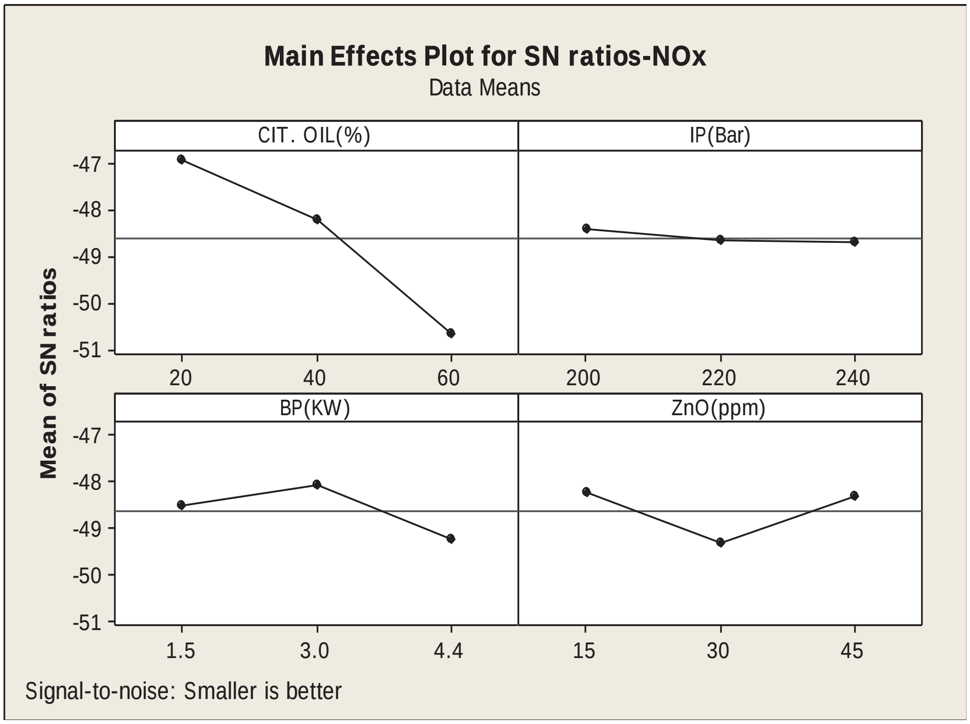

FIGURE 9. Response curve analysis for NOx

CONCLUSION

This study investigated diesel engine emissions characteristics under various engine process parameters such as Citronella oil , injection pressure ,brake power and ZnO were tested. The main effects plot for both mean of signal to noise ratio the optimized combination is found for various engine performance and emissions. The experimental data shows that at this combination the engine performance is comparable to that of diesel. The emissions are less than that for diesel.

An experimental evaluation of the cost, performance and emissions benefits of a diesel- dual fuel engine has been performed. Significant diesel displacement is achieved at all BP, Reasonable reductions in NOx was demonstrated but considerably higher CO and HC emissions results from fuel operations especially at low loads. It is observed that HC emission is formed where the mixture ratio is lean at low loads.

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