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Experimental Investigation on Perovskite Nanomaterial as an Additive for Biodiesel Fuel using Taguchi

Kalpana G. Joshi[1], S. B. Bajaj[2], Sumedh S. Ingle[3]
[1]*Research Scholar, Dr. B. A. M. U., Aurangabad, India*
[1]*Lecturer, Sanjivani KBP, Polytechnic, Kopargaon, India*
[2]*Associate Professor, JES College, Jalna, India*
[3] *Associate Professor, SRES, Sanjivani College of Engineering, Kopargaon, India*

Abstract: The most important environmental problem of the society and recent studies is the pollution and emission of harmful gasses like unburnt hydrocarbons, soot formation and nitrous oxide from the CI engines, which necessitates to search on alternative fuel with additives for IC engine. Perovskites showed great interest in several applications and useful properties in various fields. It can be utilized as catalytically active catalyst for several reactions like carbon monoxide and hydrocarbons oxidation, hydrogen evolution reaction and nitrogen oxides, and oxygen reduction reactions. In present research paper, experimentation is carried out to study the effect of perovskite ceramic nanomaterial as an fuel additive with biodiesel an alternative fuel for diesel. Optimization technic was made by using Taguchi Design of experimentation. Suitable orthogonal array L25 was selected for a design of experiment.
Keywords: Perovskite nanomaterial, palm biodiesel, castor biodiesel, Taguchi, etc.

I. INTRODUCTION

Although diesel engines are generally more efficient than spark ignition engines, emissions from the diesel engine are typically higher. This has resulted in a somewhat negative impact on its wide acceptance and use, especially in automotive applications. Recently, stringent emission legislation has been imposed worldwide on the oxides of nitrogen (NOx), and smoke and particulate matter emitted from automotive diesel engines. The different fuel properties such as the volatility, density, and the sulfur content in the fuel can be altered by the use of fuel additives. The fuel injection and mixture preparation processes are strongly influenced by properties such as the density, volatility, and viscosity, which are often interdependent. A number of experimental investigations have been reported with a wide variety of metal additives to improvethe fuel properties and the engine performance, as well asto reduce emissions. The effect of calcium, barium, iron, and nickel naphthenates have been studied, concluding that calcium and barium most efficiently reduce soot, by both suppressing soot formation and enhancing soot oxidation [1][2][3][4].

Diesel emissions from mobile sources have raised health and welfare concerns, but a number of technologies exist that can greatly reduce emissions from diesel-powered vehicles. One of the methods to vary the physicochemical properties and combustion characteristics of a hydrocarbon fuel is the use of additives, which are found to be especially effective in nanoparticle form, due to the enhancement of the surface area to volume ratio.Oxygenated fuel is nothing more than fuel that has a chemical compound containing oxygen. It helps fuel to burn more efficiently and reduce some types of atmospheric pollution. It can also reduce deadly carbon monoxide emissions and smog formation. Oxygenated fuel allows the fuel in vehicles to burn more completely. Because more o the fuel is burning, there are fewer harmful chemicals released into the atmosphere [2][3][5][18].

Perovskites attracted great interest of researchers because of its use in several applications , and their wide various and useful properties in photochromic, electrochromic, image storage, switching, filtering, and surfaceacoustic wave signal processing devices. It can be utilized as catalytically active catalyst for several reactions like carbon monoxide and hydrocarbons oxidation, hydrogen evolutionreaction and nitrogen oxides, and oxygen reduction reactions. They also have a good impactin many electrochemical applications like sensing, biosensing, photoelectrolysis of waterproducinghydrogen, and fuel cells [6][7][14][15][16].

II. TAGUCHI DESIGN OF EXPERIMENT METHOD

Taguchi design is an engineering method which provides a powerful and efficient method for designing products that operate consistently and optimally over a verity of conditions.This method allows us, the collection of necessary data to determine which

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factor most affect the quality with the minimum amount of experimentation, thus saving the time and resources. The orthogonal array shows total number of experimental runs and includes total number of parameters and their corresponding levels [10].
In present work the parameters and levels are as shown in Table 1.

TABLE 1.
PARAMETERS AND THEIR LEVELS

Parameter / Level	I	II	III	IV	V
Fuel	P+A	C+A	P+C+A	P	C
Blend	B20	B40	B60	B80	B100
Injection Pressure (bar)	190	195	200	205	210
Pre-heating Temperature (^{0}C)	27	45	50	55	60
Load (Nm)	0	6	12	18	24

Orthogonal array selection was made by using degrees of freedom.As degrees of freedom depend on parameters which involves in the experiments.In this experimentation, we used 5-level design and 5 no of factors,which are the four input used for the DOE and these are injector pressure, biodiesel, blends, load, pre-heat temp. Five-level design means factor consist of five different values that there are five injector pressure and five Pre-heat temperatures. So we have total 25 combinations of reading.The experimental orthogonal layout is as shown in Table 2 [13][17].

TABLE 2. L25 ORTHOGONAL LAYOUT

Runs	Fuel	Blend	Injection Pressure (bar)	Pre-heat temp (ºC)	Load (Nm)
1	PA	B20	190	27	0
2	C	B40	190	60	18
3	P	B60	190	55	6
4	PCA	B80	190	50	24
5	CA	B100	190	45	12
6	CA	B20	195	50	18
7	PA	B40	195	45	6
8	C	B60	195	27	24
9	P	B80	195	60	12
10	PCA	B100	195	55	0
11	PCA	B20	200	60	6
12	CA	B40	200	55	24
13	PA	B60	200	50	12
14	C	B80	200	45	0
15	P	B100	200	27	18
16	P	B20	205	45	24
17	PCA	B40	205	27	12
18	CA	B60	205	60	0
19	PA	B80	205	55	18
20	C	B100	205	50	6
21	C	B20	210	55	12
22	P	B40	210	50	0
23	PCA	B60	210	45	18
24	CA	B80	210	27	6
25	PA	B100	210	60	24

III. EXPERIMENTAL SET UP

The experiments were carried out on a single cylinder, vertical, 4-stroke cycle, single acting, totally enclosed, water-cooled, high speed compression ignition engine as shown in figure 1. Engine was coupled to an Eddy Current Dynamometer through universal coupling. The engine and the dynamometer were mounted on a common bed made from Iron C-Channel which was bolted to the cement foundation. In case of eddy current dynamometer, the loading is electrical i.e.by means of excitation current to the dynamometer coil [8][9]

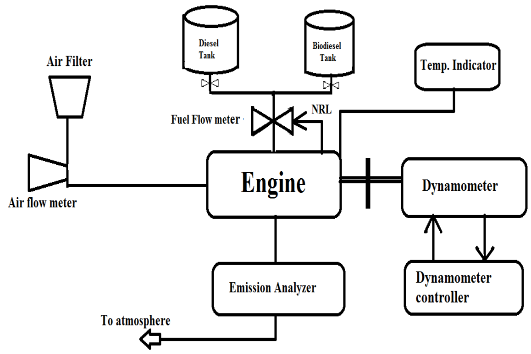

Fig.1 Experimental Setup

IV. EXPERIMENTATION

The experimental work was carried as per following steps:

A. Synthesis of Perovskite Nanomatrial

Initially composite perovskite nanomaterial is synthesized by solid state reaction method. Ceramic material under study was synthesized by taking the Barium oxide, Nickel oxide, Niobium oxide in stoichiometric proportion with 99.99% AR grade. All these materials are added together with the help of mortar pastel. Acetone is added drop wise and uniform crushing continues for four hours so that smooth material is formed in powdered form. Afterwards the material is kept in silica crucible and placed in muffle furnace at temperature 1000^0C for twelve hours.After 12 hours the material is allowed to cool naturally.Again the material is kept crushed for four hours by adding acetone drop wise, and forms BNN perovskite material.

B. Characterization

XRD of the BNN material was carried out which shows sharp single peaks and confirms the single phase nature and cubic structure. [9]

C. Testing of Biodiesel on Engine

The BNN material is mixed in the blend as per 2 gram in 1 litre. This mixture is stirred for half hours with the help of Flocculator machine at 200 rpm.In next step, the experimentation was carried out to investigate the Emission characteristics of palm oil biodiesel and castor oil Biodiesel and perovskite ceramic material as fuel additive. Bio-diesel (B100) and its blends B20, B40, B60, B80 were used to test the engine of the specifications mentioned in Table no.3 [6][7][8].The emission characteristics of the engine were studied at different engine loads (25%, 50%, 75%, 100% and 115% of the load corresponding to the load at maximum power at an average engine speed of 1500 rpm). At each load, the engine was stabilized for 10 minutes and then measurement parameters were recorded. The engine was loaded using the Eddy current dynamometer. The engine speed in rpm was sensed using a sensor pre-installed in the dynamometer and was recorded from the display on the control panel of the dynamometer.The emissions contents (CO, HC, CO_2,and NO_X) were recorded by AVL DiGas444 analyzer by inserting probe in exhaust port of engine. Compression ratio 16.5 was kept constant.

TABLE 3.
ENGINE SPECIFICATIONS

Make	Kirloskar
Type	Single Cylinder, 4 Stroke,C.I. diesel engine

C.R.	16.5:1
Stroke	110 mm
Bore	80 mm
Rated output	3.7 kW
BMEP at 1500 rpm	5.42 bar
Rated speed	1500 rpm
Dynamometer	Eddy current, water cooled with loading unit

V. RESULTS AND DISCUSSION

By obtaining the results from various observation, made from castor and palm oil biodiesel , its blends and BNN as fuel additive, the experimental results for emission at various load are as shown in table no. 5. Also the graph of emission characteristics for CO and NO_x were obtained from Taguchi Analysis and are as shown in figure 2 and figure 3 respectively.

TABLE 4.
EXPERIMENTAL RESULTS FOR CO AND NO_X EMISSION

Runs	Fuel	Blend	Injection Pressure (bar)	Pre-heat temp (ºC)	C0 %	NO_x (ppm)
1	PA	B20	190	27	0.09	166
2	C	B40	190	60	0.12	505
3	P	B60	190	55	0.11	205
4	PCA	B80	190	50	0.22	703
5	CA	B100	190	45	0.16	404
6	CA	B20	195	50	0.14	718
7	PA	B40	195	45	0.12	328
8	C	B60	195	27	0.18	968
9	P	B80	195	60	0.08	308
10	PCA	B100	195	55	0.09	158
11	PCA	B20	200	60	0.21	328
12	CA	B40	200	55	0.34	384
13	PA	B60	200	50	0.24	358
14	C	B80	200	45	0.16	382
15	P	B100	200	27	0.29	371
16	P	B20	205	45	0.35	439
17	PCA	B40	205	27	0.29	367
18	CA	B60	205	60	0.15	382
19	PA	B80	205	55	0.30	381
20	C	B100	205	50	0.21	382
21	C	B20	210	55	0.11	587
22	P	B40	210	50	0.07	169
23	PCA	B60	210	45	0.09	441
24	CA	B80	210	27	0.08	482
25	PA	B100	210	60	0.16	311

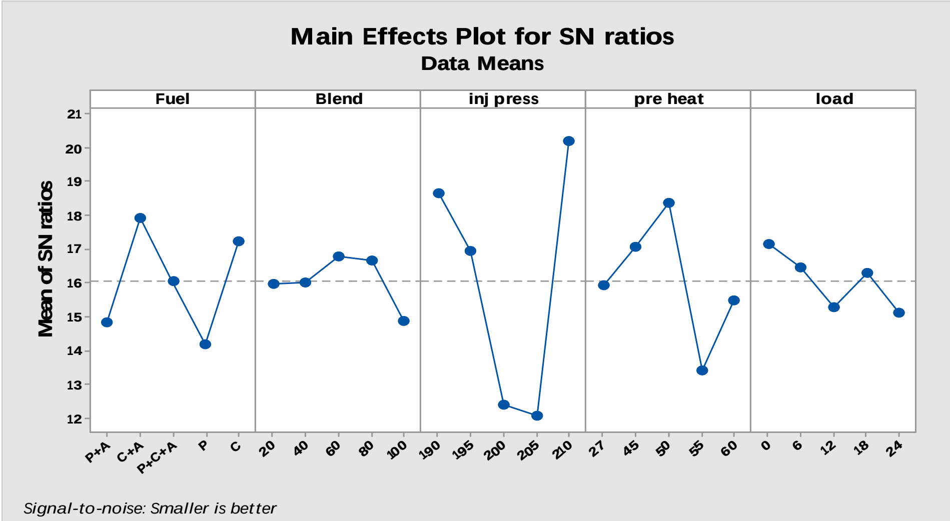

Fig. 2 Mean Effect plot of SN ratio for CO Emission

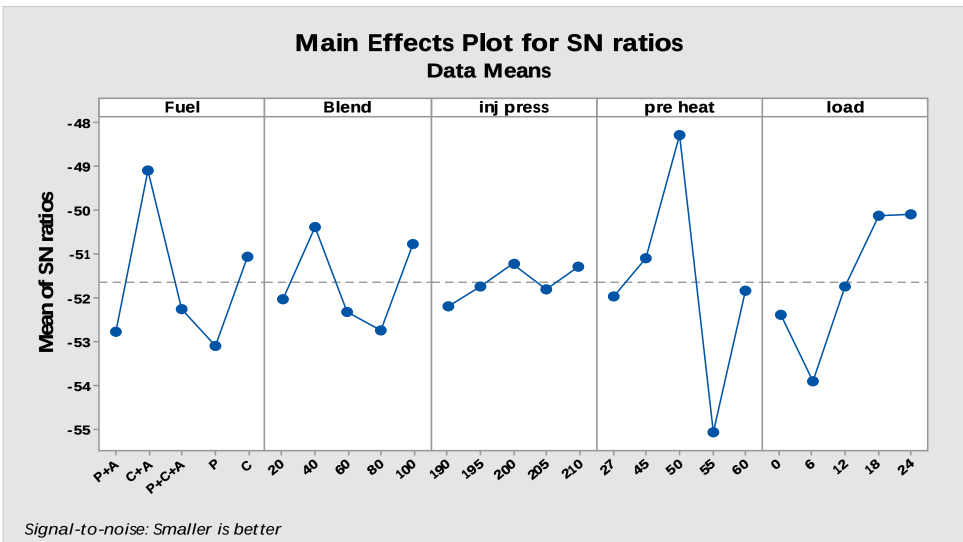

Fig.3 Mean Effect plot of SN ratio forNO_x Emission

VI. OPTIMIZATION RESULTS

From the graph of various emission, the optimized experimental results are as tabulated in table no.5.

TABLE .5

OPTIMIZATION OF EXPERIMENTATION

Emission	Biodiesel/Blend/Injection Pressure/Pre-heating temperature/Load
CO	C+A/B-60/210/50/0
NO_x	C+A/B-40/200/50/24

The figure 2. Shows the mean effect of plot for SN(signal to noise) ratios for CO emission and figure 3 shows the mean effect of plot for SN ratios for NO_x emission. SN ratio smaller is better considered for emission. The maximum points in the graph show the optimal level of input parameters. The optimum level found for emission of CO and NO_x shown in Table no.5. The results obtained from validation experiment were 0.068 % for CO emission and 155ppm for NO_x emission. Thus the optimum parameters showed minimum level of emission.

VII. CONCLUSION

In present experimentation work, an attempt is made to find out the parameters involved in emission of CI engine with the use of Palm biodiesel, castor biodiesl, their different blends and Perovskite BNN material as fuel additive. The optimum parameters and levels are identified as Injection pressure, load, fuel, Blend and pre-heat temperature for emission of CO and NO_x. The validation experiment also proves the optimum parameters provides lower emission of CO and NO_x emission from CI engine using perovskite nanomaterial as an additive.

VIII. ABBREVIATION

CI - Compresion Ignition
CR - Compresion ratio
BNN – Barium Nickel Niobiate
B20(P) – Palm Biodiesel 20% + Diesel 80%
B40(C) – Castor Biodiesel 40% + Diesel 60%
B60(P+C) – Palm Biodiesel 60% + Castor Biodiesel 40%
B80(P+A) – Palm Biodiesel 80% + Diesel 20% + BNN nanomaterial additive
B100(C+A) – Castor Biodiesel 100% + BNN nanomaterial additive
XRD-X-ray Diffraction
NO_x - Nitrous oxide
CO- Carbon Monoxide

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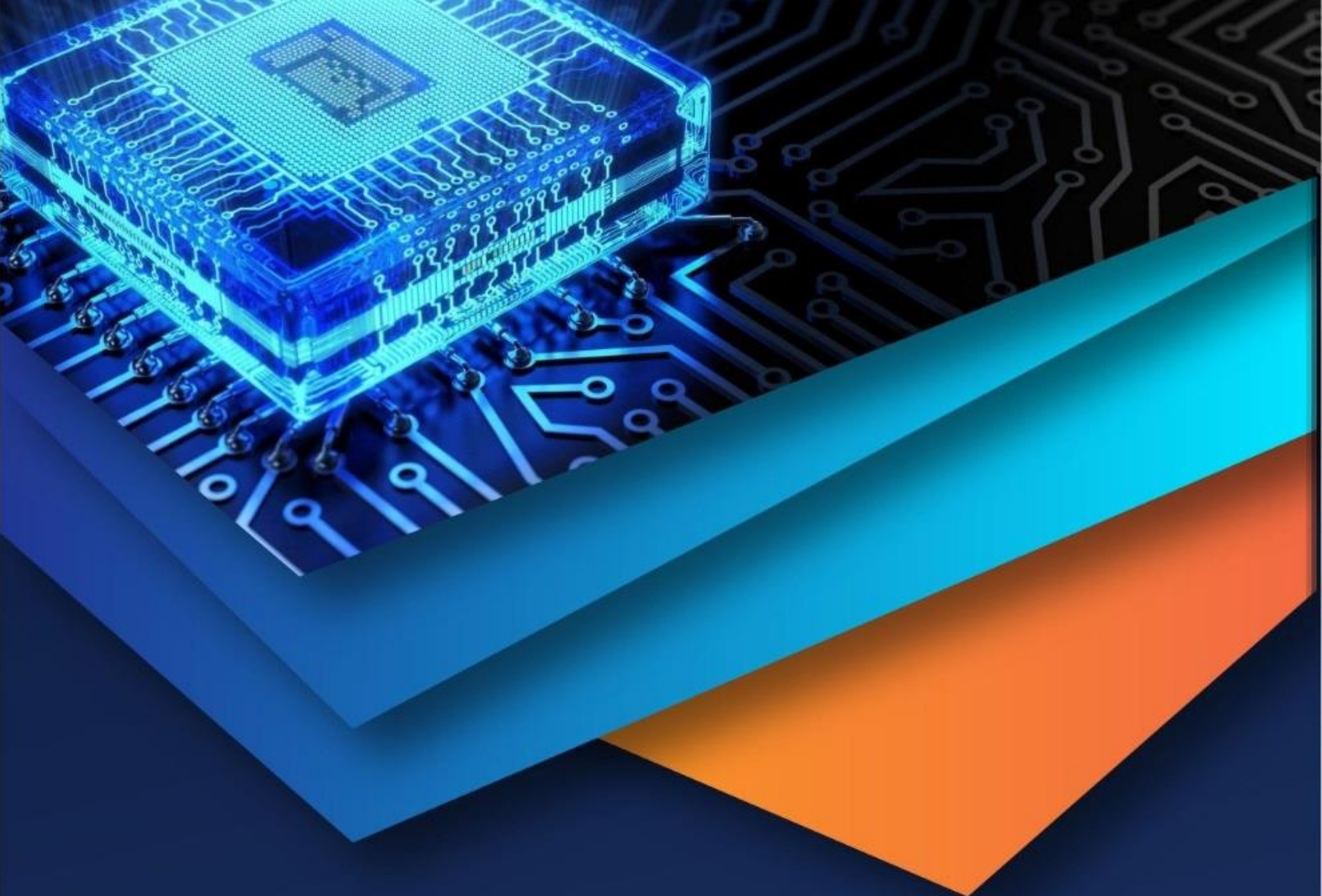

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