

COMBINED EFFECT OF COMPRESSION RATIO & HYDROGEN PEROXIDE ON PERFORMANCE OF SINGLE CYLINDER CI ENGINE, FUELLED WITH NEEM-OIL BIODIESEL

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Abstract— *The quantity of petroleum fuel is reducing all the time as the energy requirement is increasing at an exponential rate and the fossil fuel availability is decreasing, so researchers always try to find new alternate fuel or combination of fuels which can be directly use in internal combustion engine without any alteration or modifications. The many researchers found hydrogen as a powerful fuel for the engine but hydrogen fuel always associated with the problem of production, storage and transportation and safety aspects. The present study deals with overcoming both problems simultaneously by the application of Hydrogen Peroxide as a Diesel fuel additive on a variable compression ratio engine fuelled with Neem-oil biodiesel, as most industrial application involves diesel engine. Hydrogen Peroxide added in 0%, 2% and 5% in 20% blend of Neem Biodiesel. Taguchi method of Design of Experiments is used for reducing the number of experiments and to get optimum parameter set. Final experimentation was done with three different parameters like hydrogen peroxide blend, compression ratio and engine load to study the performance and emission characteristic.*

Keywords— *Neem Biodiesel, Engine performance, compression ratio, Hydrogen Peroxide, Taguchi, Blend.*

Abbreviations

BTE	Brake Thermal Efficiency
BSFC	Brake Specific Fuel Consumption
FC	Fuel Consumption
S/N Ratio	Signal to Noise Ratio
HP	Hydrogen Peroxide
VCR	Variable Compression Ratio
D.O.E	Design of Experiment
B0	100% Diesel, 0% Biodiesel
B20	80% Diesel, 20% Biodiesel

INTRODUCTION

Fossil fuels play significant role in transportation. Continuous fuel supply should be considered for future development of country. Recently, major difficulties associated with fuel are short supply, non renewability, increase in price, pollution in environment, adverse effect on human life. These problems gave direction to researcher for search of an alternative fuel, for efficient and environmental cleanliness is become highly requirement in the present context. In search of above, researcher has found many energy sources like methanol, CNG, ethanol, hydrogen, LPG, bio-diesel and many more. Among all alternative fuels, India has more scope for development of bio-fuel. Moreover, agriculture and transportation fields depend on diesel fuel. Therefore, it is preferred to use the alternatives of diesel fuels must be available. In concern for emission and availability, hydrogen has been proven as excellent fuel. Yet, onboard storage problem, absence of infrastructure for production, transporting and storing large quantity of hydrogen prevents its practical use. From previous study it is concluded that many more research has been done on the direct hydrogen addition in the air intake. A new way is derived to inject hydrogen in the form of hydrogen peroxide to overcome the issues of hydrogen gas storage. This study focuses on combined effect of various proportions of hydrogen peroxide & compression ratio on emission and performance characteristics of a VCR CI engine.

L. M. Das, et al. worked on neat hydrogen operated engine produce close to zero sulfur and nitrous oxides and other toxins which are usually present in a conventional fissile fuelled engine exhaust. .Kassaby et al. carried out experiments to check effect of compression ratio on emission of engine fueled with biodiesel made by trans-etherification of waste cooking oil and concluded that engine torque for all blends increases as the compression ratio increases. Y. Karagoz, et al. has worked on the enrichment of 30% hydrogen on different engine loads. A major reduction of CO is found at all load condition but drastically increase was found on HC emission at all load condition. Y. Karagoz, et al. carried out an experiment at different hydrogen percentage and noted that BTE is decreasing with increasing hydrogen content. The brake thermal efficiency is obtained as 29.43 at 0% hydrogen, 27.06 at 22% hydrogen, and 23.04 at 53% hydrogen enrichment. The BTE is reduced to 8.0% and 21.7% with 22% and 53% addition of hydrogen, respectively, compared with neat diesel. Ganji et al. used CFD analysis to optimize parameters such as CR, Start of Injection and EGR to reduce emission. They concluded that reducing the CR causes decrease in NOx and increases soot emissions. Nagaprasad K. S., et al. carried out experimental work with 0%, 2% and 5% hydrogen peroxide addition in diesel fuel and investigated that the maximum efficiency of 15.48% was observed at full load when the engine used 5% of hydrogen peroxide.

Table 1 Neem-oil Biodiesel properties

Parameter	Unit	Result
Density @ 15° C	kg/m ³	896
Kinematic viscosity @ 40° C	CP	16.10
Kinematic viscosity @ 100°C	CP	10.80
Flash point	°C	138
Sulphur content	mg/kg	13
Carbon residue content	%by mass	0.058
Sulphur ash content	Ppm	21
Water content	mg/kg	1184
Total contamination	mg/kg	15
Copper strip corrosion @3hr @50° C	-	Nil
Cetane number	-	625
Acid value	mg KOH/gm	29
Methanol content	%by mass	0.41
Ethanol content	%by mass	0.24
Ester content	%by mass	99.40
Free glycerol content	mg/kg	155
Total glycerol content	%by mass	0.26
Oxidation stability @ 110° C	-	13
Iodine value	-	119
CCR(10%Bottem)	%by mass	0.059(100%)
Sox	%	Nil
Nox	%	Nil
SPM	%	Nil
Shelf life study	In packing month	25
Gross Calorific Value	KJ/KG	42692

EXPERIMENTAL SETUP AND METHODOLOGY

The engine utilized for particular test is a variable compression ratio type single cylinder, naturally aspirated water cooled compression ignition engine. The compression ratio can be changed without stopping the engine.

The engine specifications are publicized in Table 2. The diagrammatic figure of investigational setup is shown in Figure 1. The engine is united with electronically controlled eddy current dynamometer which are run at desired load condition. The setup is equipped with essential instruments for measurement of cylinder pressure, fuel line pressure & crank position. These signals are diagnosed via main PC for various graph and statistical data.



Figure 1 Schematic Diagram of Experimental Setup

- | | |
|--|---------------------------------|
| 1. Single cylinder four stroke diesel engine | 7. Fuel control valve |
| 2. Eddy current dynamometer | 8. Load cell |
| 3. Rota meter | 9. Pressure sensor |
| 4. Air box | 10. Performance testing machine |
| 5. Fuel tank | 11. AVL exhaust gas analyzer |
| 6. Burette | 12. Exhaust probe |

The experiments were conducted at the estimated engine speed of 1500 rpm & at different load range, which is followed by 0%, 50% and 100%. Three blend ratios of HP and Neem-oil Biodiesel (B20) are as 0%, 2% & 5% (V/V %) were tested at every load.

Table 2 Engine Specifications

Parameter	Specifications
Make	Brand new kirloskar
Model	AV1
Method of cooling	Water cooled
Rated power	5 HP
Engine speed	1500 RPM
Bore × Stroke	87 mm × 110 mm
Volume	553 c.c
Compression Ratio	16.5:1

HP in a solution of water at a concentration of 30% was used to make the blend in this research. To make the emulsion fuel, a mixing system was used that (HP solution) and a static mixer. Mixtures of Neem oil with solutions of HP were created according to the Neem oil with mixing ratios of 0%, 2% and 5%. To keep fuels homogeneous and stable, three kinds of surfactants (Emulgen 103, Rheodol 440V, and Rheodol SP-L 10) were used.

For optimization process, three variable and three levels, 27 observation reading should be taken to study the complete effect of process parameter. These all data is used to study the effect of compression ratio, hydrogen peroxide neem biodiesel blend and engine load. To reduce the number of experiment DOE is useful. There are number of methods available in DOE but we have used Taguchi method to reduce the number of reading.

By taguchi method 9 set of different combination of hydrogen peroxide percentage, load percentage and compression ratio were obtained as shown in table 3 and final experimentation were carried out with these optimized nine sets .

RESULT AND DISCUSSION

Following DOE sets were obtained and these investigated experimentally and following results are obtained.

Table 3 Experimental Results Table

Sr. No.	CR	H2O2	Load	Load (kg)	Speed (RPM)	BP (kW)	BTE	BSFC (g/kW-s)	NOx (ppm)	CO (%V/V)	HC (ppm)
1	14	0%	0%	0.51	1500	0.20	3.80%	0.5859	31.3	0.111	39
2	14	2%	50%	2.24	1500	0.88	12.66%	0.1792	108	0.091	47
3	14	5%	100%	7.52	1500	2.95	22.99%	0.1015	746.1	0.064	55
4	15	0%	50%	2.24	1500	0.88	11.74%	0.1896	118.4	0.1	38
5	15	2%	100%	7.52	1500	2.95	21.79%	0.1041	754.3	0.061	49
6	15	5%	0%	0.51	1500	0.20	4.27%	0.5471	26.7	0.084	44
7	16	0%	100%	7.52	1500	2.95	20.86%	0.1067	760.2	0.061	41.5
8	16	2%	0%	0.51	1500	0.20	4.24%	0.5351	31.2	0.088	35
9	16	5%	50%	2.24	1500	0.88	13.29%	0.1757	112.1	0.083	44

(I) Effect on brake thermal efficiency

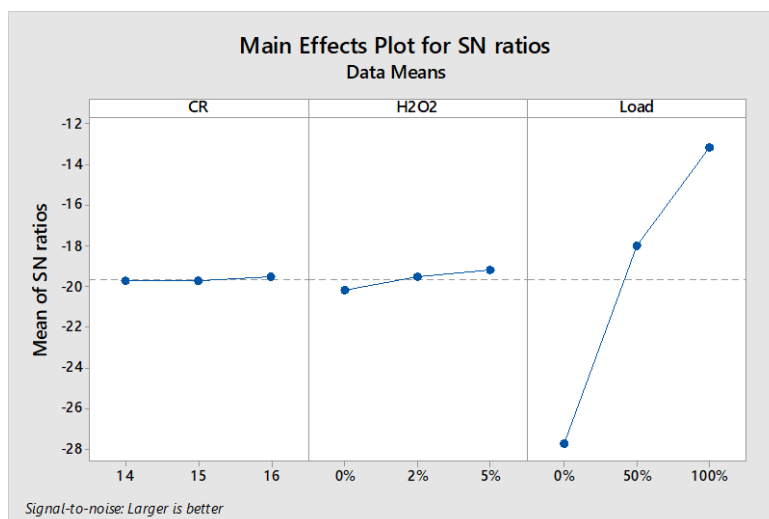


Figure 2 Main Effects Plot for S/N Ratio of Brake Thermal Efficiency

Table.4 Response Table for S/N Ratio of Brake Thermal Efficiency

Level	CR	H2O2	Load
1	19.71	20.21	27.75
2	19.74	19.55	18.03
3	19.53	19.23	13.21
Delta	0.21	0.98	14.54
Rank	3	2	1

The factor with highest S/N ratio gives optimum level for that particular parameter. It is observed that increasing the load will increase the BTE because the increase in load leads to more power output and thus it increases the BTE. Increase in BTE was also found with the addition of HP because addition of HP will increase the combustion. Referring Figure 6.3 the response curve for S/N ratio, the highest S/N ratio was observed at Engine Load (100%), HP (5%), and CR (16), which are optimum parameters setting for highest Brake Thermal Efficiency. It was observed that delta value for load was maximum (14.54) and minimum for compression ratio (0.21), So the parameter engine load is most significant parameter for Brake Thermal Efficiency. The optimum parameter set for BTE is shown in Table 5.

Table 5 Optimum Set of Parameter for Brake Thermal Efficiency

CR	HP	Load	BTHE (%)	SN Ratio
16	5%	100%	22.49	12.6449

By the optimum set of above table once again experimental investigation was carryout for BTE and following data were obtained as shown in Table 6.

Table 6 Validation Results for Brake Thermal Efficiency

Predicted Value	Experimental Value	% Variation
22.49%	24.18%	7.5

(II) Effect on Brake Specific Fuel Consumption

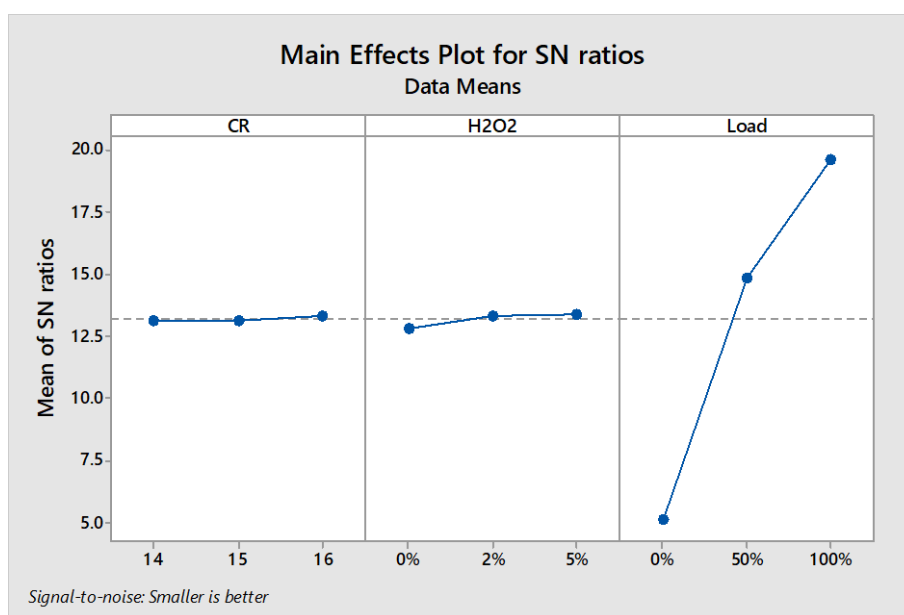


Figure 3 Main Effects Plot for S/N ratios of Brake Specific Fuel Consumption

Table 7 Response Table for S/N Ratios of Brake Specific Fuel Consumption

Level	CR	H2O2	Load
1	13.15	12.84	5.10
2	13.11	13.34	14.83
3	13.32	13.40	19.65
Delta	0.21	0.56	14.55
Rank	3	2	1

The factor with highest S/N ratio gives optimum level for that particular parameter. It is observed that BSFC is decreasing with the increase in the load because as the load increase brake power also increases and emulsion of hydrogen peroxide improve combustion characteristics which leads towards decreasing the BSFC. Referring Figure 3 the response curve for S/N ratio, the highest S/N ratio was observed at Engine Load (100%), H₂O₂ (5%) and CR (16), which are optimum parameter setting for Brake Specific Fuel Consumption. From delta values as mention Table 7, maximum (14.55) for engine load and (0.21) for CR. Parameter engine load is most significant parameter for Specific Fuel Consumption. From the table: 3 and table: 9 it is clear that saving in BSFC with 5% hp addition at 16 cr with full load condition was 9.55% .Optimum parameter set as shown in Table 8

Table 8 Optimize Set of Parameter for Specific Fuel Consumption

CR	H2O2	Load	SFC(kg/kWh)	SN Ratio
16	5%	100%	0.0903	19.99

Experiment has been carried out using optimum set of parameter. Experimental Specific Fuel Consumption for optimum set of parameter is 0.0903 kg/kWh. This experimental value is nearer to predicted value 0.0966 as shown in Table 9.

Table 9 Validation Results for Specific Fuel Consumption (kg/kWh)

Predicted Value	Experimental Value	% Variation
0.0903	0.0966	6.97

(III) Effect on CO (%)

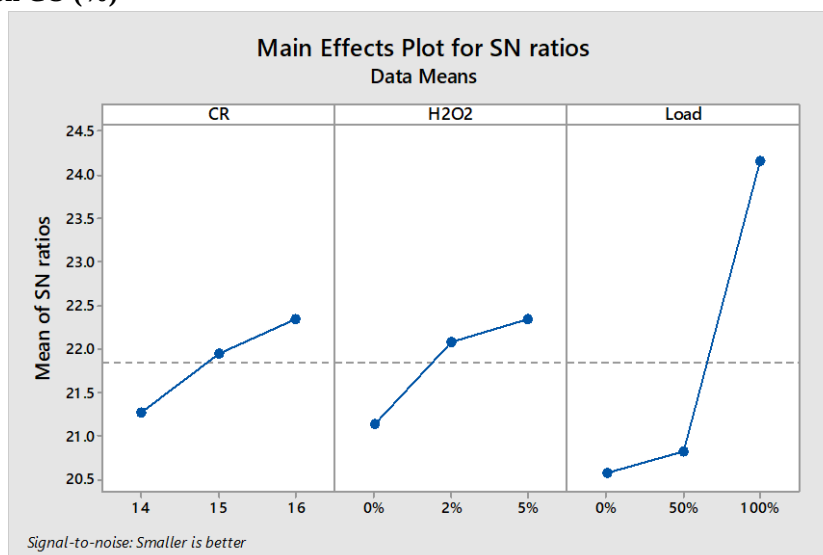


Figure 4 Main Effects Plot for S/N ratios of CO

Table 1 Response Table for S/N Ratios of CO

Level	CR	H2O2	Load
1	21.26	21.13	20.57
2	21.94	22.07	20.81
3	22.34	22.34	24.15
Delta	1.08	1.21	3.58
Rank	3	2	1

The factor with highest S/N ratio gives optimum level for that particular parameter. Major decrement in CO was found with the help of addition of HP because addition of HP gives additional Oxygen which leads to the complete combustion of CO to CO₂. Thus it leads to reduction of CO. Referring Figure 4 the response curve for S/N ratio, the highest S/N ratio was observed at Engine Load (100%), HP (5%) and CR (16), which is optimum parameter setting for CO. From delta values as mention Table 6.10, maximum (3.58) for engine load and (1.08) for CR. Parameter engine load is most significant parameter & parameter compression ratio is least significant for CO. Decrement in CO was found to be 6.55% with 5%HP addition. Optimum parameter set as shown in Table 11

Table 2 Optimize Set of Parameter for CO

CR	H2O2	Load	CO (%)	SN Ratio
16	5%	7.52 kg	0.0512	25.1384

Experiment has been carried out using optimum set of parameter. Experimental CO for optimum set of parameter is 0.057. This experimental value is nearer to predicted value 0.0512 as shown in Table 12.

Table 3 Validation Results for CO (%)

Predicted Value	Experimental Value	% Variation
0.0512	0.057	11.32

(IV) Effect on HC (ppm)

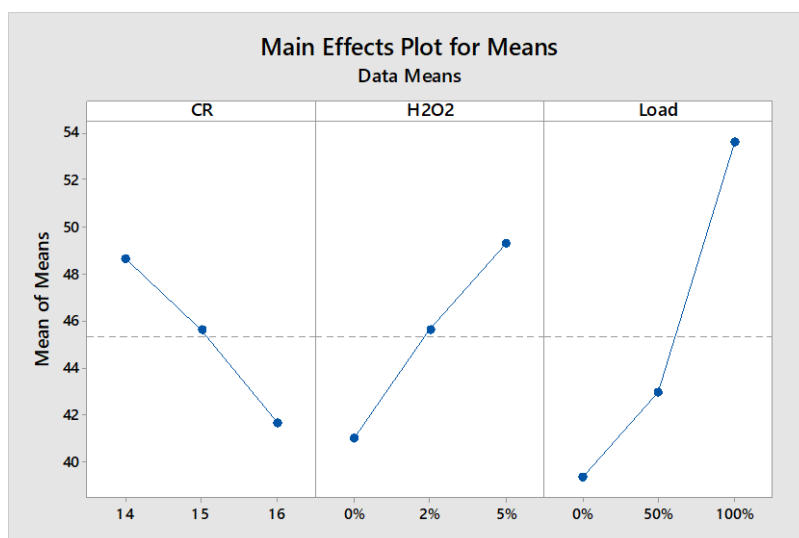


Figure 5 Main Effects Plot for S/N ratios of HC (ppm)

Table 13 Response Table for S/N Ratios of HC (ppm)

Level	CR	H2O2	Load
1	-33.61	-32.22	-31.86
2	-33.09	-33.04	-32.64
3	-32.34	-33.77	-34.54
Delta	1.27	1.54	2.68
Rank	3	2	1

The factor with highest S/N ratio gives optimum level for that particular parameter. HC emission is increasing with the increase in load because as the load increases it takes more fuel and thus more fuel means more HC in emission. HC is also increases with HP because HP contains hydrogen with it which leads to more HC emission. Referring Figure 5 the response curve for S/N ratio, the highest S/N ratio was observed at Engine Load (100%), HP (5%) and CR (14), which are optimum parameters setting for HC (ppm). From delta values as mention Table 13, maximum (14.33) for engine load and (7) for CR. Parameter engine load is most significant parameter for HC (ppm). Optimum parameter set as shown in Table 14

Table 14 Optimize Set of Parameter for HC (ppm)

CR	H2O2	Load	HC (ppm)	SN Ratio
14	5%	7.52 kg	55	-35.8945

Experiment has been carried out using optimum set of parameter. Experimental HC (ppm) for optimum set of parameter is 55. This experimental value is nearer to predicted value 61 as shown in Table 15

Table 6.15 Validation Results for HC (ppm)

Predicted Value	Experimental Value	% Variation
61	55	10.9

(V) Effect on NO_x (ppm)

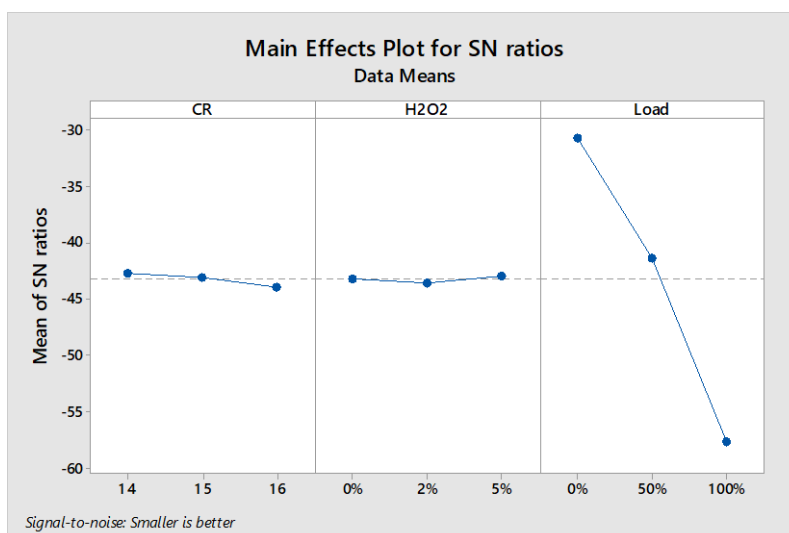


Figure 6 Main Effects Plot for S/N ratios of NO_x (ppm)

Table 16 Response Table for S/N Ratios of NO_x (ppm)

Level	CR	H2O2	Load
1	-42.68	-43.19	-30.66
2	-43.08	-43.56	-41.37
3	-43.93	-42.94	-57.66
Delta	1.25	0.62	27
Rank	2	3	1

The factor with highest S/N ratio gives optimum level for that particular parameter. NO_x emission is increasing with the increase in load because as load is increases temperature inside the engine cylinder is also increase and thus it increases the NO_x emission. NO_x emission also increases with HP addition as Oxygen is present in the HP. Referring Figure 6 the response curve for S/N ratio, the highest S/N ratio was observed at Engine Load (0%), HP (5%) and CR (14), which are optimum parameter setting for NO_x (ppm). From delta values as mention Table 16, maximum (27) for engine load and (0.62) for HP. Parameter engine load is most significant parameter and parameter HP is least significant parameter for NO_x (ppm). Optimum parameter set as shown in Table 17

Table 17 Optimize Set of Parameter for NO_x (ppm)

CR	HP	Load	NO _x (ppm)	SN Ratio
14	5%	0%	18.1	-29.81

Experiment has been carried out using optimum set of parameter. Experimental NO_x (ppm) for optimum set of parameter is 20. This experimental value is nearer to predicted value 18.1 as shown in Table 18.

Table 18 Validation Results for NO_x (ppm)

Predicted Value	Experimental Value	% Variation
18.1	20	10.4

CONCLUSIONS

- It can be concluded that Neem-oil Biodiesel and hydrogen peroxide blend can be used in CI engine without engine modification.
- For the parameter BTE, BSFC, NO_x, HC & CO the 5% HP addition gives overall best performance with neem oil biodiesel (B20) with all compression.
- The increment BTE at 16 CR was observed 15.92% with 5%HP addition.
- The reduction in BSFC was found 9.5% with 5%HP addition.
- Decrement in CO was found to be 6.55% with 5%HP addition due more oxygen release.
- CR 16 gives optimum performance for BTE, while the CR 14 gives optimal performance for HC and NO_x emission.
- All performance and emission characteristics for 5% HP B20 were found to be optimum for full load condition except NO_x emission.
- Experimental analysis data are giving very good agreements with taguchi data.

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