Evaluation of Engine Performance and Exhaust Emission Characteristics of Copper Coated Diesel Engine

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Abstract*—The energy crises and environmental pollution have promoted to use one of the concept of adiabatic engine with catalyst coated combustion chamber of internal combustion engine.[5] The concept of catalytic combustion in direct injection diesel engines has been adopted by various researchers which improve exhaust emissions due to oxidation of fuels by aid of catalyst. To achieve the present requirement of the automotive industries there is continues research to improve performance, exhaust emission and life of the internal combustion (I.C.) engine. The recent research has been focused on the reduction of diesel engine pollutions due to strict emission regulations. [6] Which directly affected to human and environments. The present investigation has been made to study mainly emission characteristics of copper coated diesel engine and performance evaluation. An experimental investigation is carried out on twin cylinder, water cool, 1500 RPM constant speed type vertical diesel engine. The cylinder heads surfaces, engine pistons top surfaces and engine valves surfaces were coated with copper material by electroplating processes with 400 microns thickness. The diesel engine combustion chamber inner walls insulated by electroplating copper coating. The performance and exhaust emission were compared with base engine and without copper coated diesel engine. The results strongly indicate that slightly improvement on performance and better improvement of exhaust emission. It is observed that the reduction in NOx and smoke level for Copper catalyst coated combustion chamber. It is also indicate that to change the coating technology and adopt, bimetallic ceramic thermal barrier coating (TBC) concept.

***Index Terms*—Efficiency, emission, TBC, Copper, Catalyst**

I. INTRODUCTION

Day by day world populations were increased and which is tends to use of auto vehicle. Therefore demand creates more manufacturing of auto vehicles in the auto industries.. Exhaust gas emission from diesel engine are more smoke, oxide of nitrogen and un burnt hydrocarbon. Therefore world facing very serious problem of air pollution.[7-10] The air pollutants such as dust, gas fumes, mist odour, smoke or vapor which causes injuries to human, plant, animal like. The main pollutants can contributed by the internal combustion engines were carbon monoxide (CO), carbon dioxide (CO_2) unburned hydrocarbons (HC), oxide of nitrogen (NOx), smoke density and particulate. Hence it is necessary to control the emission from I.C. Engine. In the present investigation, has been made to study performance and exhaust emission characteristics of a diesel engine with the use of electroplating copper coated combustion chamber.

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Thus attempt has been to study mainly the emission control from direct injection diesel engine using catalyst coated combustion chamber. Materials such as copper, nickel, zinc, chromium and cadmium have been used as catalyst [1-4]

II. THEORY OF PREPARATION OF ELECTROPLATING COATING FOR CATALYST CHARGE ACTIVATION

In conventional combustion systems, the control is maintained by manipulating with gas temperature, equivalence ratio and fluid mixing. Introducing catalyst surface in to a combustible environment supplies as additional control parameter, namely the surface reaction rate. This can be adjusted in a manner bellows a critical surface temperature. Above this temperature the reaction rate increase dramatically and the chemistry of the nearby gas phase can be modified. In the case of platinum catalyst, the surface ignition temperature is 300-400 ^{o}C less than the corresponding gas phase ignition temperature, the ambient gas temperature, which directly controls the catalyst reaction rate; it is possible to catalytically treat homogenous mixtures, which are below the surface ignition temperature. In the internal combustion engine, this means that the onset of catalytic activity does not depend on the compression temperature. Electroplating is the application of a metal coating to a metallic or other conducting surface by an electrochemical process. The article to be plated (the work) is made the cathode (negative electrode) of an electrolysis cell through which a direct electric current is passed. The article is immersed in an aqueous solution (the bath) containing the required metal in an oxidized form, either as an equated action or as a complex ion. The anode is usually a bar of the metal being plated. During electrolysis metal is deposited on to the work and metal from the bar dissolves. Copper Coating Specification mention as below. [11-14]

Table 1: Electro plating of Copper Coating Specification

Coated Material	Copper
Coating thickness	100 Microns
Power required	12.5 KW
Voltage	50 V
D. C. Current	100 Amp
Process time	90 minutes full dipped

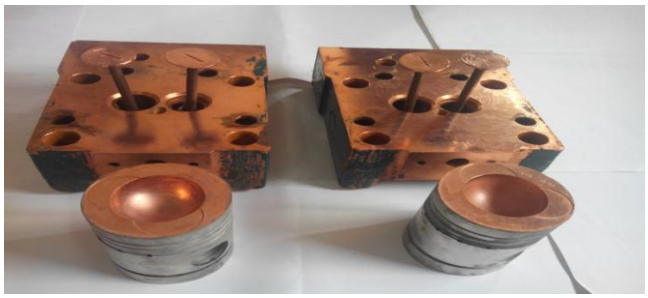

Figure 1: Copper Coated Components: pistons, heads, & Valves

III. EXPERIMENTAL METHODOLOGY

The experiments were carried out on water cooed twin cylinder four strokes direct injection constant speed maintained at 1500 RPM vertical diesel engine was use for investigation of performance and exhaust evaluation. The engine was converted in to a catalyst-coated engine coating copper, on the pistons bowl, engine heads, and engine valves surfaces. Experiments were carried out on standard base engine and along with the copper coated combustion chamber. The overall copper coating thickness is 400 microns. The engine was coupled to a generator and electrical dynamometer was applied through resistance used to measure the power output at constant engine speed. The engine is instrumented to measured parameters like fuel consumption, load, speed of engine, cooling water temperature, inlet air and exhaust gas temperature etc. The NOx level is measured by using NOx analyzer. Smoke is measured by using smoke density meter. Experiments were conducted at constant speed with various loads to determine the performance and emission parameters. In this study the effect of copper coating on emission were measured with multi gas analyzer and smoke meter and same also were measured for base engine. The first stage tested was performing at no load to full load conditions.

Table 2: Engine Specification

Engine type : Multi cylinder vertical water cooled self-governed constant speed diesel engine	
Injection pressure = 200bar	I.V.O= 5° BTDC
Piston dia = 80 mm	I.V.C= 35° ABDC
Compression ratio= 16	E.V.O = 35° BBDC
Power = 7.5 kw = 10 HP	E.V.C = 5° ATDC
Lubrication oil = 20w/40.	Injection timing= 23° BTDC
Lubrication oil required = 7 litrs	Mass flow rate of cooling water = 0.25 litr/sec
Dynamometer = 12 KVA	A/F ratio = 14.8 : 1
Speed (N) = 1500rpm	BMEP = 15 kg/cm^2
Rated power = 7.35 kw	Calorific value = 42000 kjg/kg k

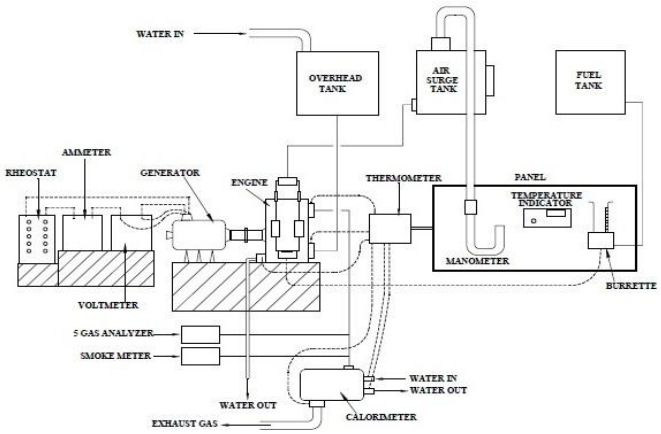

Figure 2: The block diagram of experimental set-up

IV. RESULT AND DISCUSSION

Specific Fuel Consumption (SFC): The variation of specific fuel consumption was higher at no load than full load conditions which shown in figure for without copper coated engine and with copper coated engine. The SFC of with copper coated engine has shown little improvement fuel consumption at almost all load conditions. There is no much more effect on SFC of copper coated engine because it is coated by electroplating. The copper coating is worn out after certain operation of the engine.

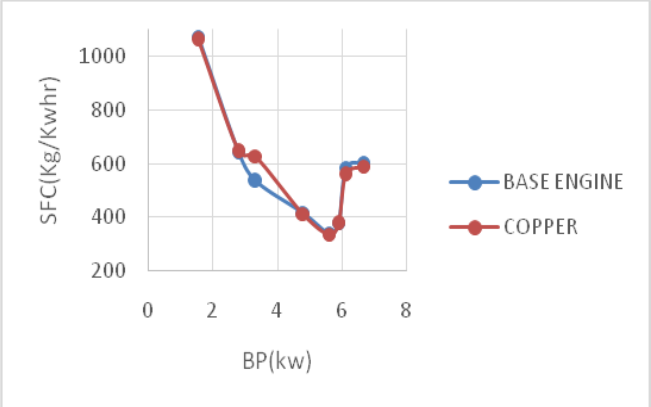

Figure 3: Comparisons of Brake power (BP) v/s SFC

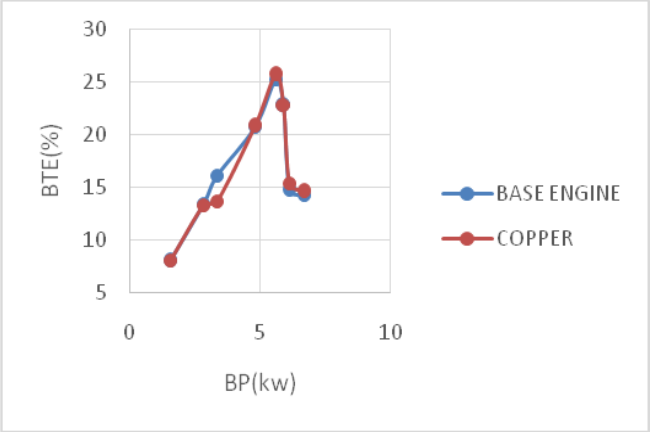

Figure 4: Comparisons of BP v/s BTE

Brake Thermal Efficiency (BTE) :It is seen that at all

load conditions no more change or improvement of brake thermal efficiency in both type of engine. At no lad conditions BTE was decrease than it was increases in both types of cases.

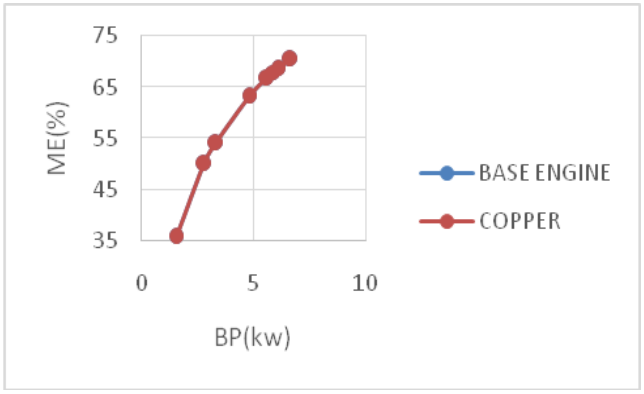

Figure 5: Comparisons of BP v/s ME

Mechanical Efficiency (ME): It is seen that there is slight improvement in mechanical efficiency in copper coated engine. Due to failure of electroplating coating in combustion chamber after certain operation.

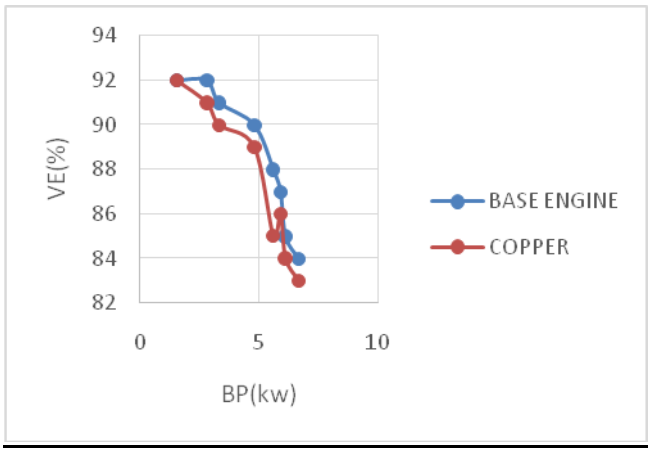

Figure 6: Comparisons of BP v/s volumetric efficiency

Volumetric Efficiency (VE): It is found that the volumetric efficiency of coated engine is about 1 % less than the base engine. This is due to failure of electroplating coating.

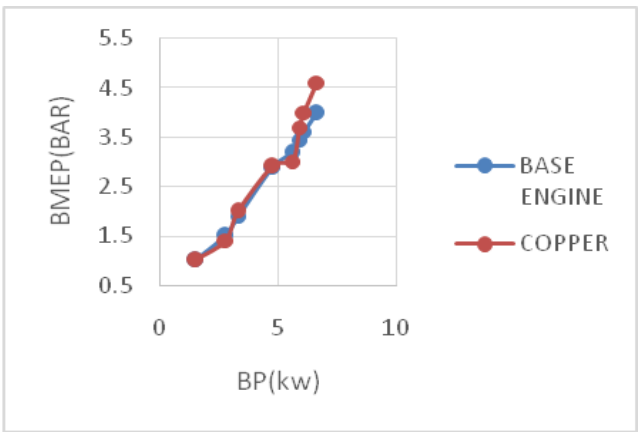

Figure 7: Comparisons of BP v/s BMEP

Brake mean effective pressure (BMEP): The brake mean effective pressure is also nearly same at all load condition in copper coating engine compare to base engine.

Exhaust gas temperature: It is found from the figure exhaust gas temperature of copper coated and base engine are almost nearly same temperature. Only about 1^{o}C to 9 ^{o}C temperature differences are found in comparisons of both types of engine.

Heat use in brake power (B.P): It is found from the graph heat use in brake power of copper coated engine are almost slightly increases than the base engine.

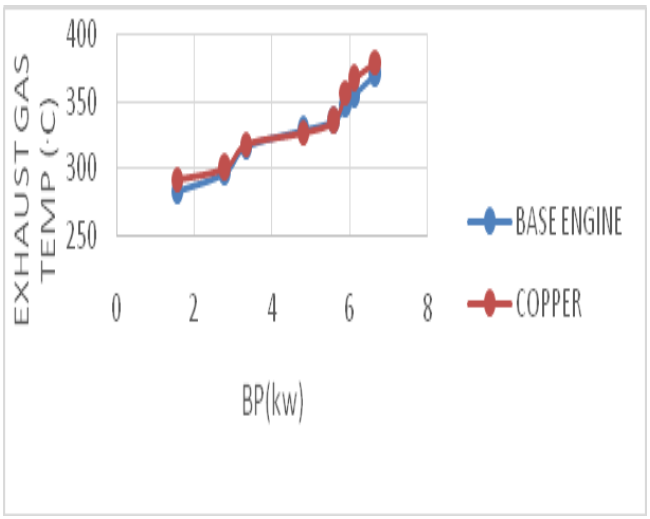

Figure 8: BP v/s Heat loss in exhaust gas Temperature

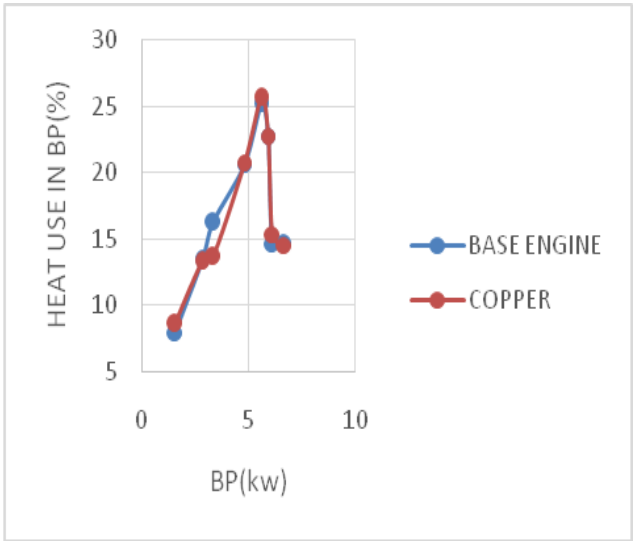

Figure 9: BP v/s Heat use in BP

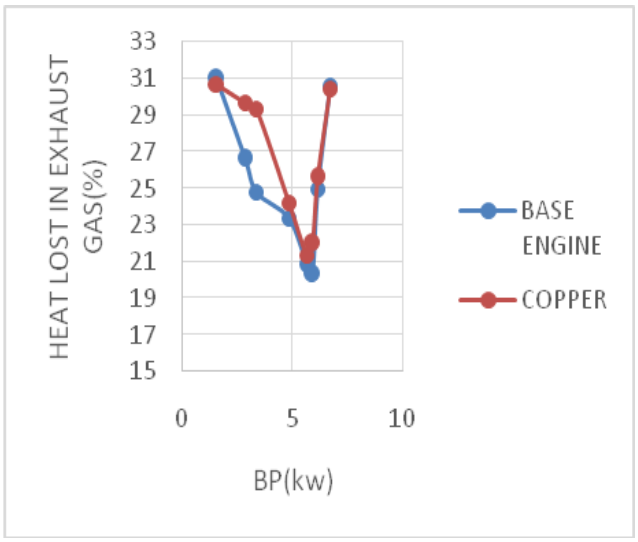

Figure 10: BP v/s Heat loss in exhaust gas

Heat loss in exhaust gas: It is found that the heat in exhaust for copper coated engine is slightly more than the standard engine.

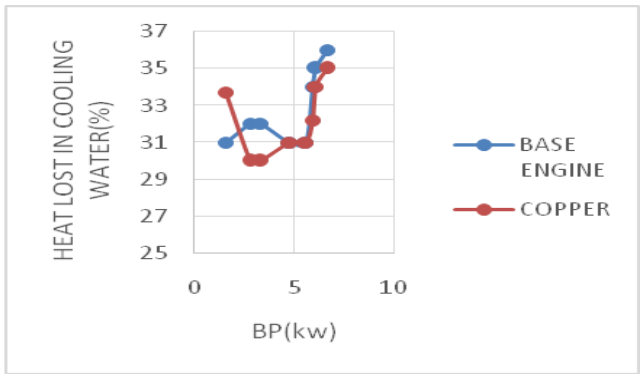

Figure 11: BP v/s Heat loss in cooling water

Heat loss in cooling water: It is found that the heat lost in cooling water for copper coated engine is slightly decreases than the standard engine.

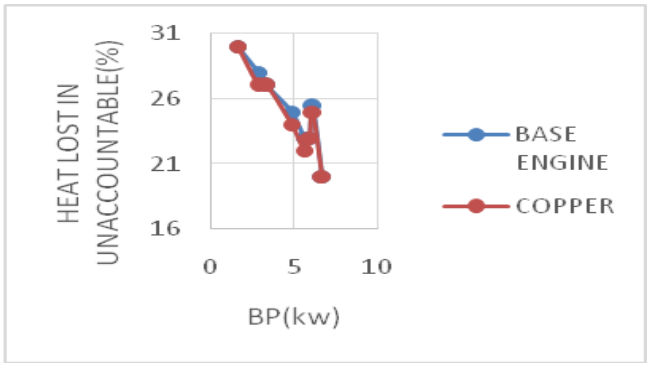

Figure 12: BP v/s Heat loss as an unaccounted

Heat loss as a UN accounts and radiations: It is found that the heat lost UN accounts and radiations for copper coated engine is slightly decreases than the standard engine.

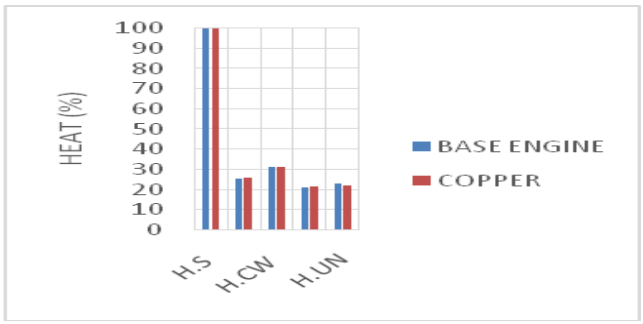

Figure 13: Heat Balance Sheet (At rated power)

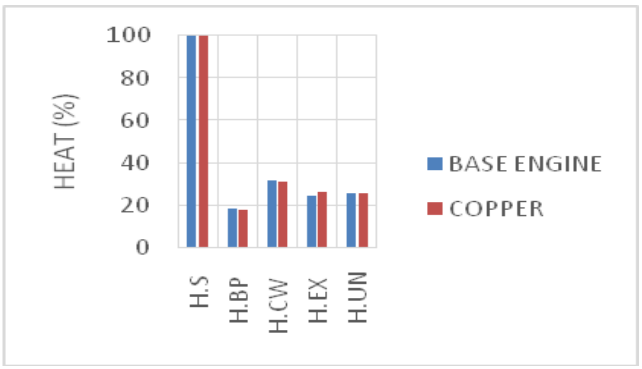

Figure 14: Heat Balance Sheet at Average Power

Heat Balance Sheet It is found that heat use in brake power is improved about 1.7% due to copper coating engine. It is seen that is same heat goes with coolant as compared to base engine.. Heat lost by radiation and unaccounted losses are decreases by 4.3 %. This is due to the copper coating incorporated in order to save the heat flow from the combustion chamber.

TABLE 3: Emission Test Result for Twin Cylinder Diesel Engine

Load In KW	CO In %	CO_2 In %	O_2 In %	HC In PPM
000	0.55	2.0	21	90
1.55	0.133	2.1	21	151
2.80	0.615	2.2	21	220
3.33	1.422	2.5	20	221
4.80	3.821	3.70	20	252
5.60	4.342	5.1	20	220
5.90	4.83	5.2	20	263
6.11	4.49	5.5	19	266
6.66	5.50	5.5	19	331

TABLE 4: Emission Test Result for Twin Cylinder Diesel Engine with Copper Coating

Load In KW	CO In %	CO_2 In %	O_2 In %	HC In PPM
000	0.57	2.00	21	99
1.55	0.134	2.00	21	160
2.80	0.655	2.10	21	221
3.33	1.424	2.35	20	224
4.80	3.911	3.50	20	258
5.60	4.351	4.20	20	226
5.90	4.84	4.80	19	265
6.11	4.51	5.10	19	277
6.66	5.507	5.30	19	344

Smoke Density: Graph shows the variation of smoke level with brake power of the engine for copper coated engine and base engine. It is observed from the figure that the smoke level increase with increase in load in all load conditions. There is little decreasing in smoke level in all load conditions of copper coated engine. At full load condition smoke density level is decrease about 2 % to 3.33. %. The smoke emissions of copper coated engine were comparatively lesser than the Base engine. It was found that from the results the thin copper coating reduced the smoke emissions for all the configuration of the engine. This was due to higher gas temperatures and enhancement in oxidation, which resulted in reduction of soot particles.

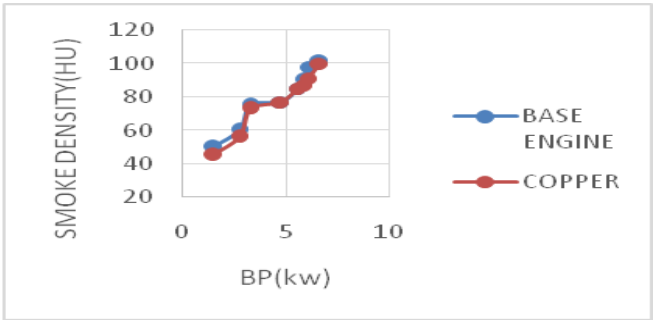

Figure 15: BP v/s Smoke Density

Emission Test: It is seen that from all graph of emission increase with increase in brake power with maximum emission occurs at maximum load condition in both the engine. Carbon monoxide (CO) a colourless, odourless, poisonous gas is generated in engines which nearly remain same in copper coated and base engine. In case of carbon dioxides (CO2) were also exhausted remain nearly same in both type of engine. But slightly positive result observed in case of unborn hydro carbon (HC). HC reduced almost at all load condition in case of copper coating compare to base engine. Unburned hydro carbons reduce by 1% to 9.1% that shows better combustion due to copper coating in combustion chamber. Oxygen level O_2 found nearly same as base engine.

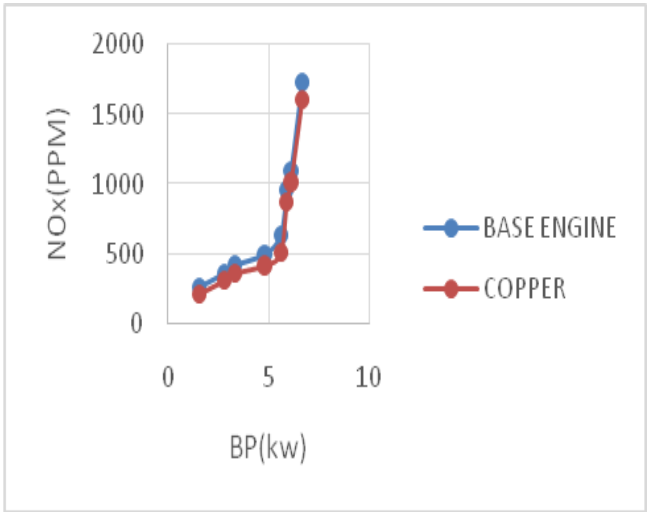

Figure 16: Brake power v/s Nitrogen oxide

Nitrogen Oxide (No_x): Chart shows the variation of NO_X in the exhaust with brake power for copper and Base engine. It is increased in all load condition for both engine conditions. It is observed that the NO_X level decreased in with copper coated engine with increase in load at all load conditions. At no load condition in case of copper coated engine NOx is decreased by 2.77%, at rated power load condition it is reduced by 20.31% and it is also reduce at over load condition by 7.78%. These results were due to copper coating in combustion & chemical reaction accrued at higher operating temperature.

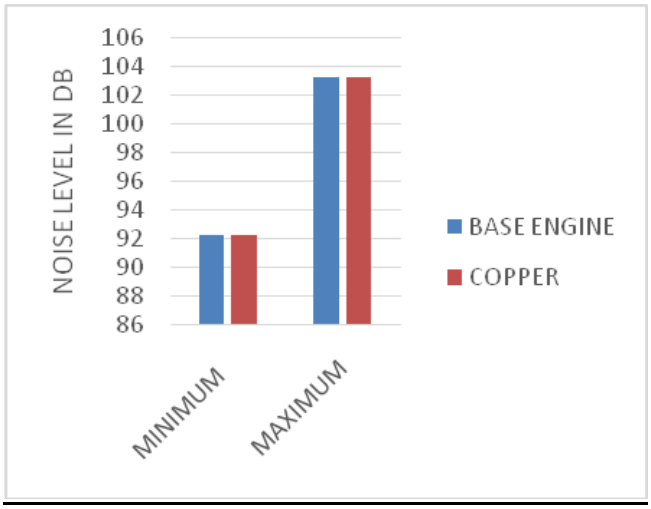

Figure 17: Noise level limit between minimum to maximum load condition

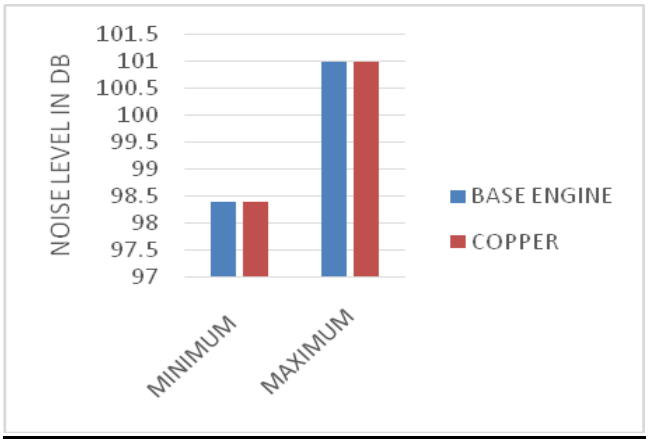

Figure 18: Noise level at Rated power condition

Noise level of diesel engine: Noise level limit between minimum to maximum load power condition in both engine are increased the db level. Minimum to maximum noise level in base engine is 93.2 db to 103.9 db and it is also same for copper coated engine. At rated power condition Minimum to maximum noise level in base engine is 98.4 db to 101. db and in copper coated engine is 98.4 to 101.0 db. It is indicated that almost noise level remain nearly same as base engine.

V. CONCLUSION

The performance parameters and exhaust emissions were investigated experimentally in electroplated copper coated diesel engine. The following were main conclusions drawn:

1. The specific fuel consumption remains same in both condition of engine.
2. There were no effective changes in, brake thermal efficiency, mechanically

efficiency. The volumetric efficiency of copper coated engine was about 1 % less than the base engine

3. The brake mean effective pressure is also nearly same at all load condition in copper coating engine compare to base engine

4. Heat balance sheet indicates that heat use in brake power is improved about 1.7% due to copper coating engine. Heat lost by radiation and unaccounted losses are decreases by 4.3 %.

5. There was little decreasing in smoke level in all load conditions of copper coated engine. At full load condition smoke density level is decrease about 2 % to 3.33. %.

6. It was found that from the emission test, the level of CO, CO_2, O_2 remain same in both type of engine. Hydro carbon level reduce by 1% to 9.1%,

7. It is observed that the NO_X level decreased in with copper coated engine with increase in load at all load conditions. At rated load condition NOx level reduced by 20.31%.

8. Noise level found satisfactorily in both condition

9.At end of experiment it was found that, The failure of electroplating coating.

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