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COMPARISON OF PERFORMANCE AND EMISSION CHARACTERISTICS OF C.I. ENGINE BY USING DIFFERENT PISTON COATINGS

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Abstract: **The objective of this study is to evaluate performance and combustion characteristics of thermal barrier coated direct ignition diesel engine Ceramic coatings are increasingly used to provide protection between different engine parts, helping to increase wear resistance, reduce friction, and improve heat shielding. Ceramic coatings like Chromium Carbide on piston crown are increasingly used to provide protection, helping to increase wear resistance, reduce friction, and improve heat shielding. Hence an attempt is made to analyze the performance and emission characteristics of diesel by using Chromium Carbide, Nickel Boron, Cobalt Molybdenum and Magnesium Zirconia coated pistons on a four stroke single cylinder water cooled Diesel Engine Test Rig in I.C Engines Laboratory.**

In this study, the piston crown will be coated with Chromium Carbide, Nickel Boron, Cobalt Molybdenum and Magnesium Zirconia of about 300microns.These factors have a significant influence on horsepower ratings, and reduce the emissions. The results obtained will be compared with standard diesel engine.

Experiments were carried out on a diesel engine using different coated pistons. Performance parameters such as brake power, break mean effective pressure, indicated mean effective pressure, specific fuel consumption, thermal efficiencies and mechanical efficiencies are calculated based on experimental analysis of the engine. Emissions such as carbon monoxide, carbon dioxide, NOX and unburned hydrocarbon are measured.

Keywords*:* Chromium carbide, Nickel-Boron nitride, Cobalt-Molybdenum, Magnesium-Zirconia, single cylinder 4-strokediesel engine, Engine performance.

I. INTRODUCTION

Majority of the world's energy needs are supplied through Petrochemical sources, coal and natural gases, with the exception of hydroelectricity and nuclear energy; of all, these sources are finite and at current usage rates will be consumed shortly. Diesel fuels have an essential function in the industrial economy of developing countries and are used for transport of industrial and agricultural goods, operation of diesel tractor and pump sets in agricultural sector. The high energy demand in the industrialized world as well as in the domestic sector and pollution problems caused due to the widespread use of fossil fuels make it increasingly necessary to develop the renewable energy sources of limitless duration and smaller environmental impact than the traditional one. This has stimulated recent interest in alternative sources for petroleum based fuels. Because alternate fuels are renewable, eco-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. If these fuels serve the purpose of diesel to some extent they will be useful to the rural areas in providing employment as well as agriculture energy needs. If these fuels serve the purpose to a larger extent they will be good substitutes in industrial, transportation etc.

Ceramic coatings used in diesel engine combustion chambers are aimed to reduce heat which passes from in-cylinder to engine cooling system. Engine cooling systems are planned to be removed from internal combustion engines by the development of advanced technology ceramics. One can expect that engine power can be increased and engine weight and cost can be decreased by removing cooling system elements (coolant pump, ventilator, water jackets and radiators etc.). More silent engine operation can be obtained considering less detonation and noise causing from uncontrolled combustion.

Another important topic from the view point of internal combustion engines is exhaust emissions. Increased combustion chamber temperature of ceramic coated internal combustion engines causes a decrease in soot and carbon monoxide emissions. When increased exhaust gases temperatures considered, it is obvious that turbocharging and consequently total thermal efficiency of the engine is increased.

II. LITERATURE SURVEY

Aydin Huseyin[1] examined the combined effects of thermalbarrier coating and blending with diesel fuel on usability of vegetable oils in diesel engines. The possibility of using pure vegetable oils in a thermally insulated diesel engine has been experimentally investigated. Initially, the standard diesel fuel was tested in the engine, as base experiment for comparison. Then the engine was thermally insulated by coating some parts of it, such as piston, exhaust and intake valves surfaces with zirconium oxide (ZrO_2). The main purpose of engine coating was to reduce heat rejection from the walls of combustion chamber and to increase thermal efficiency and thus to increase performance of the engine that using vegetable oil blends. Pure inedible cottonseed oil and

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sunflower oil were blended with diesel fuel. Blends and diesel fuel were then tested in the coated diesel engine. Experimental results proved that the main purpose of this study was achieved as the engine performance parameters such as power and torque were increased with simultaneous decrease in fuel consumption. Furthermore, exhaust emission parameters such as CO, HC, and Smoke opacity were decreased. Also, sunflower oil blends presented better performance and emission parameters than cottonseed oil blends.

Helmisyah A.J., Ghazali M.J [2] has studied the high temperature and pressure produced in an engine that uses compressed natural gas with direct injection system (CNGDI) which may lead to high thermal stresses. The piston crown fails to operate effectively with insufficient heat transfer. In this study, partially stabilized zirconia (PSZ) ceramic thermal barrier coatings were plasma sprayed on CNGDI piston crowns (AC8A aluminum alloys) to reduce thermal stresses. Several samples were deposited with NiCrAl bonding layers prior to the coating of PSZ for comparison purposes. Detailed analyses of microstructure, hardness, surface roughness, and interface bonding on the deposited coating were conducted to ensure its quality. High stresses were mainly concentrated above the pinhole and edge areas of the piston. In short, the PSZ/ NiCrAl coated alloys demonstrated lesser thermal stresses than the uncoated piston crowns despite a rough surface. Extra protection is thus given during combustion operation.

H. Hazar, U. Ozturk[3] studied the effect of Al_2O_3-TiO_2coating in a diesel engine on performance and emission of corn oil methyl ester, the piston, cylinder head, exhaust and inlet valves of a diesel engine were coated with the ceramic material Al_2O_3-TiO_2 by the plasma spray method. Thus, a thermal barrier was provided for the parts of the combustion chamber with these coatings. The effects of corn oil methyl ester that produced by the Transesterification method and ASTM No. D2 fuels performance and exhaust emissions' rates were studied by using equal in every respect coated and uncoated engines. Tests were performed on the uncoated engine, and then repeated on the coated engine and the results were compared. A decrease in engine power and specific fuel consumption, as well as significant improvements in exhaust gas emissions (except NOx), were observed for all test fuels used in the coated engine compared with that of the uncoated engine.

Abdullah CahitKaraoglanli, Kazuhiro Ogawa,AhmetTürk and Ismail Ozdemir,[4] ―Thermal Shock and Cycling Behavior of Thermal Barrier Coatings (TBCs) Used in Gas Turbines has presented Gas turbine engines work as a power generating facility and are used in aviation industry to provide thrust by converting combustion products into kinetic energy. Basic concerns regarding the improvements in modern gas turbine engines are higher efficiency and performance. Increase in power and efficiency of gas turbine engines can be achieved through increase in turbine inlet temperatures. The materials used should have perfect mechanical strength and corrosion resistance and thus be able to work under aggressive environments and high temperatures. The temperatures that turbine blades are exposed to can be close to the melting point of the super alloys. Internal cooling by cooling channels and insulation by thermal barrier coatings (TBCs) is used in order to lower the temperature of turbine blades and prevent the failure of super alloy substrates

III. EXPERIMENTAL WORK

In order to analyze the performance and emission characteristics of internal combustion engine, an experimental set-up was developed. In the present work Chromium carbide (Cr3C2), Nickel-Boron nitride (Ni-BN), Cobalt-Molybdenum (Co-Mo) and Magnesium-Zirconia (Mg-Zr) was coated on piston crown and these are compared. The experiment was carried out on a single cylinder water cooled direct injection diesel engine. Eddy current dynamometer is used for loading i.e. electrical loading. The engine specifications are given in Table-1.

Experimental procedure was explained below.

1. The engine is started at no load condition and allowed to work for at least 10 minutes to stabilize.
2. The readings such as time taken for 10cc fuel consumption, ammeter & voltmeter readings etc. were taken
3. The load on the engine was increased by 20% of FULL Load using the engine controls and the readings were taken
4. Step 3 was repeated for different loads from no load to full load.

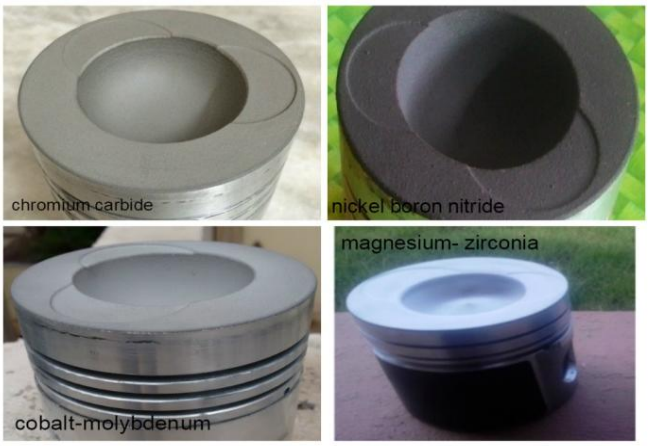

TABLE 1

TEST ENGINE SPECIFICATIONS

Particulars	Specifications
Make	Kirloskar oil Engine Ltd.
Arrangement of cylinders	Vertical

No of cylinders	1
Lubricant	SAE 20/SAE 40
Bore	85mm
Stroke length	110mm
Rated speed	1500 rpm
Rated power	5HP
Starting	Hand start with crank handling
Type of cooling	Water cooling

IV. Results and Discussion

1. Brake Specific Fuel Consumption:

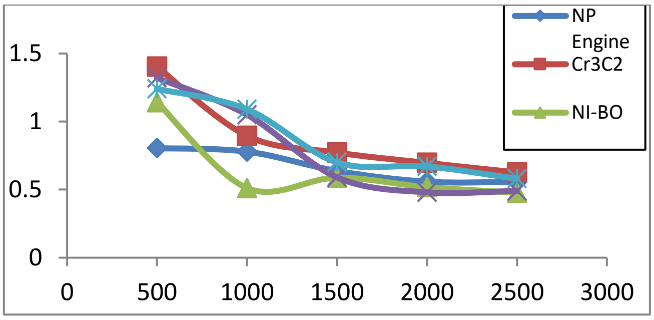

Fig 1: Load vs. Brake specific fuel consumption

The result for the variations in the brake specific fuel consumption (BSFC) with load is presented in the Fig.1. From fig.1 it can be clearly seen that the BSFC of Ni-BN coated piston is lower than the other coated pistons with diesel fuel at full load. The main reason is that the ceramic materials act as barrier for the heat transfer to the surroundings from the combustion chamber and reduces the heat loss from the engine. Also the reduction in heat loss will ultimately increase the power output and thermal efficiency of the engine and this lead to reduce the BSFC. The BSFC values at full load are 0.556 kg/kW-hr for normal piston. 0.626 kg/kW-hr for Cr3C2 and 0.484, 0.492, 0.580 kg/kW-hr for the Ni-BN, Co-Mo and Mg-Zr respectively.

*2. Brake Thermal Efficiency:*The variations of brake thermal efficiency with respect to load for these coated pistons with diesel are shown in Fig.2. It can be observed from the results that the Cr3C2 coated piston improves the brake thermal efficiency when compared with normal piston and other coated pistons. This may be due to increased temperature of the piston crown which increases the temperature of cylinder gas and wall results in higher temperature at combustion chamber. The combustion conditions become more favorable which results in shortening ignition delay time in coated engine affecting both the chemical and physical reactions positively. It can be observed that the Cr3C2 coated piston gives brake thermal efficiency of 18.25% which is more compared to the other coated pistons at full load

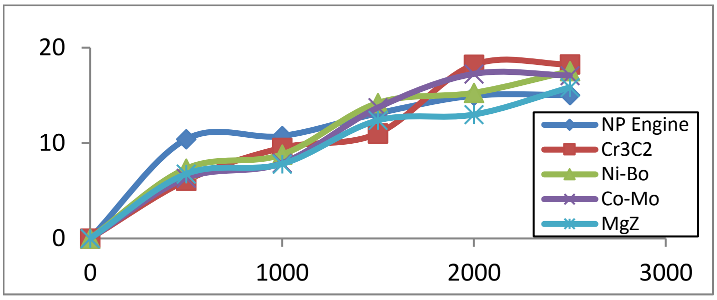

Fig 2: Load vs. Brake thermal efficiency

3. Exhaust Gas Emissions of Carbon Monoxide:

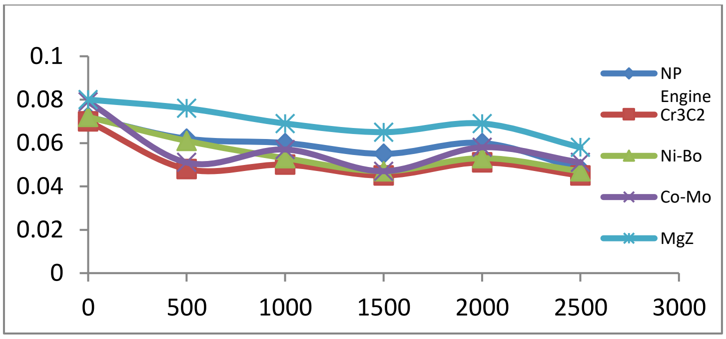

Fig 3: Load vs Carbon monoxide

From Fig.3 the variation of carbon monoxide with respect to load can be observed for both coated and normal piston engines. It is clear that CO is decreased after the coating due to the complete combustion. CO emission from diesel engine is related to the fuel properties as well as combustion characteristics. It is well known that better fuel combustion usually resulted in lower CO emission. The carbon monoxide, which arises mainly due to incomplete combustion, is a measure of combustion efficiency. Generally, oxygen availability in diesel fuel is high so at high temperatures carbon easily combines with oxygen and reduces the CO emission. The results show that CO emission of normal piston (diesel) slightly higher than Cr3C2 coated piston engine at full load condition. Carbon monoxide from the exhaust gas for the normal piston is 0.048% by vol. and for Cr3C2 coated piston is 0.045% and other coated pistons Ni-BN, Co-Mo and Mg-Zr are 0.047%, 0.051% and 0.058% by vol. respectively. It is clear that the emissions concentrations are lower than Bharath Stage III.

4. Exhaust Gas Emissions of Carbon dioxide

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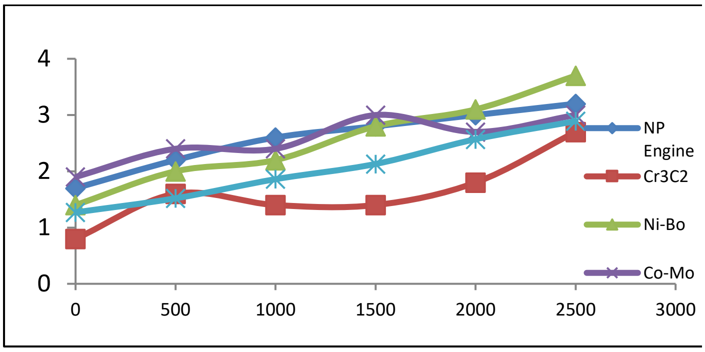

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Fig 4: Load vs. Carbon dioxide

As shown in Fig.4, the variation of carbon dioxide emissions with respect to load can be observed. From the results, it is observed that the amount of CO_2 produced while using other coated pistons are higher than Cr3C2 coated piston at full load condition. This indicates the complete combustion of fuel. Carbon dioxide from the exhaust gas for the diesel fuel by using Cr3C2 coated piston is 2.7% vol. and for normal piston and coated pistons Ni-BN, Co-Mo and Mg-Zr are 3.2, 3.7, 3.0 and 2.8% by vol. respectively. As a general rule, the higher the carbon dioxide reading, the more efficient the engine is operating.

5. Exhaust Emissions of Hydrocarbon Emissions

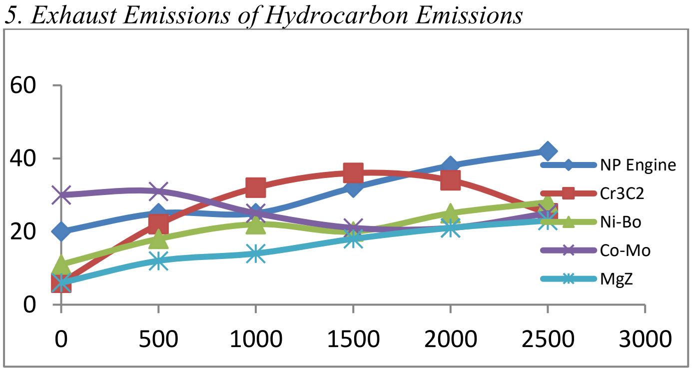

Fig 6: Load vs Hydro Carbons

The variation of hydrocarbons with respect to load for tested coated pistons is depicted in Fig.6. From the results, it can be noticed that the concentration of hydrocarbon of coated pistons are slightly lower than normal piston. Unburnt hydrocarbon from the exhaust gas at full load for the normal piston is 42ppm and for coated pistons Cr3C2, Ni-BN, Co-Mo and Mg-Zr are 25ppm, 28ppm 25ppm and 23ppm respectively. It can be observed from the results that Thermal Barrier Coating Mg-Zr coated piston crown decreasing HC when compared with uncoated piston and other coated pistons. The HC emission reduces because of an increase in residual gas temperature with in the cylinder and decrease in flame quenching thickness at higher load in the engine. It is cleared that the emissions concentration for all the coated pistons are lower than Bharath Stage III norms.

6. Exhaust Emissions of Nitrogen Oxides:

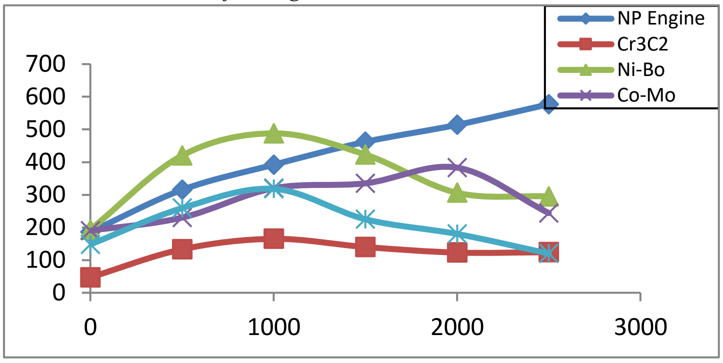

Fig 7: Load vs. Nitrogen oxides

From Fig.7, the variation of nitrogen oxides with respect to load can be observed for both coated and normal piston engine. The formation of nitrogen oxide emissions depends on the heat transfer rate and evaporation rate of the fuel. This increases further, with the availability of oxygen and the higher prevailing temperatures in the chamber. With the ceramic coating the heat in the chamber is higher which further increases the evaporation rate of the fuel. NOX from the exhaust gas Cr3C2 and Mg-Zr coated pistons are similarly equal 120 ppm and for normal piston and for other coated pistons Ni-BN and Co-Mo are 577ppm, 295ppm and 244ppm respectively.

V. CONCLUSIONS

In this study, the effect of ceramic coatings Cr3C2, Ni-BN, Co-Mo and Mg-Zr on the performance and emissions characteristics of a diesel engine operated on diesel fuel and there comparisons were experimentally investigated.
The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency and mechanical efficiency. The emission characteristics of the engine were studied in terms concentration of, CO, CO2, HC and NOX. The results obtained for all coated pistons with diesel were compared with the results of diesel.
Following are the conclusions based on the experimental results obtained while operating single cylinder water cooled diesel engine fuelled with Chromium carbide, Nickel boron nitride, Cobalt-Molybdenum and Magnesium-Zirconia coated pistons.

- The Ni-BN coated piston show lower specific fuel consumption than the other coated pistons at full loads.
- Brake Thermal efficiency of the Trialed diesel engine is improved when it is run with Cr3C2 coated piston when compared with other coated pistons.
- Mechanical efficiency is higher for Cr3C2 coated piston compared to Diesel fuel normal piston and other coated pistons is observed.
- Brake mean effective pressure is also increased with the normal piston when compared to coated pistons. But this increment in Brake mean effective power is insignificant.
- CO emissions decrease with Cr3C2 coated piston when

compared with other coated pistons so as normal piston at 2500W.

- CO_2 emissions of Ni-BN, Co-Mo, Mg-Zr and normal piston are slightly higher than that of Cr3C2 coated piston.
- HC & NO_X emissions of both Cr3C2 and Mg-Zr coated pistons are lower than that of normal and other coated pistons.

VI. SCOPE OF FUTURE WORK

The present work can be extended by varying the thickness of thermal barrier coating on piston crown. The engine can be tested for better performance with various coated pistons also.

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