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The Effect of Thermal Barrier Coatings on Diesel Engine Performance

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ABSTRACT

The performance of internal combustion engines should be improved depending on some technological requirements and rapid increase in the fuel expenses. On the other hand, the improvements in engine materials are forced by using alternative fuels and environmental requirements. Therefore, the performances of engine materials become increasingly important. For improving the performance of engine, thermal barrier coatings (TBCs) are a promising step forward. In this experimental study, alumina – (40 %) titania and nickel - chromium are used as the thermal barrier materials. The purpose of using these materials is to reduce the heat loss from engine. TBCs are done by atmospheric plasma spraying technique. Engine working conditions are maintained constant before and after coating. The results showed a reduction in specific fuel consumption. CO and HC emissions are slightly more than the conventional coated diesel engine at low and medium loads but lesser at higher loads whereas NO_x is reduced.

Keywords: *Aluminium Titanium; Nickel Chromium; Diesel engine; Performance; Emissions*

1. INTRODUCTION

Diesel engines are more fuel efficient than other fuelled engines because of the high calorific value of diesel. The leading role of diesel engines in both transport and agriculture sector is because of its good fuel economy and lower running cost. However, diesel engines can only convert one third of fuel energy into useful work and the remaining two third is lost as waste energy through coolant and exhaust. The piston crown and cylinder head of diesel engines are coated with thermal barrier materials to reduce heat transfer to the coolant and also to improve the power output along with an increase in the exhaust energy **[1]**.

The transfer of heat occurs through the combustion chamber elements, like valves, piston surfaces and liners. Ceramic coatings, with low thermal conductivity, on the combustion chamber surfaces, keep the heat in the chamber and hence increase the temperature **[2]**. Engines operating on higher temperatures can only be more efficient than the present engines available. Ceramics with high temperature resistance may offer an excellent coating surface with reduced amount of degradation and extended life.

The primary purposes of high temperature structural coatings are to enable high temperature components to operate at even higher temperature and to improve component durability of engines. Al-Ti and Ni-Cr are characterized by excellent mechanical and thermal properties with high chemical and corrosion resistance, low shrinkage on curing and the ability to be processed under a variety of conditions **[3]**.

2. ATMOSPHERIC PLASMA SPRAY TECHNIQUE

The plasma generator consists of a circular anode, usually of copper, and a cathode of thoriated tungsten. The cathode is made of graphite in a water stabilized torch. A strong electric arc is generated between anode and cathode. This ionizes the flowing process gasses into the plasma state. Now, powdered feedstock material is injected into the plasma jet. Plasma jet will melt the material and propel it onto the work piece surface. Atmospheric plasma spraying is carried out using a Sulzer Metco F4 gun operating at power levels up to 50 kW. A gas mixture of hydrogen and argon is used as a plasma gas. The argon gas is also considered as a carrier gas for the feedstock material injection. Compressed air was used as the cooling gas during plasma spraying.

Table 1: Plasma spraying parameters

Sl. No	Parameters	Value
1.	Spray gun	3 MB
2.	Nozzle	GH
3.	Current (A)	490
4.	Voltage (V)	60 – 70
5.	Powder feed (g/min)	40-50
6.	Spray distance	76.2 - 127 ± 10 % mm
7.	Particle velocity (m/s)	Up to 450
8.	Arc Temperature (^{0}C)	16,000
9.	Particle size (µm)	14.5 – 45
10.	Inert gas flow rate	
	a.)Argon (l/min)	100– 200 ± 5%
	b.)Hydrogen (l/min)	100 ± 5%

3. TEST ENGINE

Tests were carried out on a single cylinder, water cooled, direct injection, four stroke stationary diesel engine. Once the steady state condition was reached after loading, the readings such as time taken for 10cc fuel consumption, exhaust gas temperature, HC, CO and NO_x levels were taken. The pollutant emissions such as unburnt hydrocarbon, carbon monoxide, carbon dioxide and oxides of nitrogen concentrations were measured by AVL exhaust gas analyser. The analyser consists of an electrochemical sensor, which converts the concentration of different species in the exhaust gas into corresponding electrical signals. The exhaust gas temperature was measured by smoke meter.

The following Figure shows a photographic view of the Experimental set up.

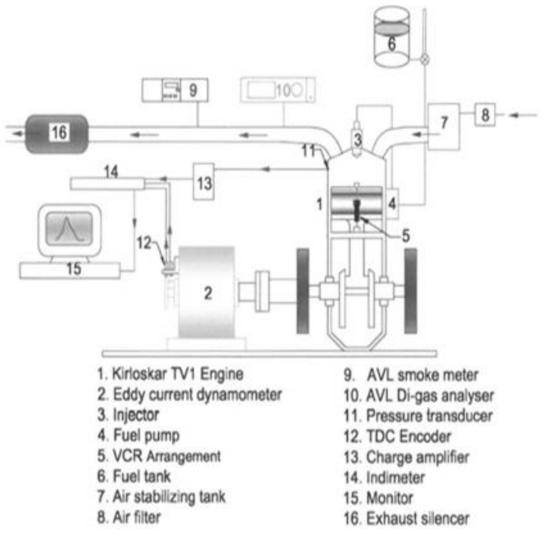

Figure 1:Schematic view of Experimental set-up.

Figure 2: Coated piston and cylinder head

The Technical specifications of the engine used in the experiment are illustrated in table 2.

Table 2: Technical specification of the engine used in the experiments

Engine Type	Vertical, Four stroke diesel engine
Bore Diameter	80 mm
Stroke Length	110 mm
Brake Power	3.728 kW
Compression ratio	16:1
Speed	1500 rpm
Injection Type	Direct Injection
Cooling	Water
Engine Power	5 bhp
No. of cylinder	1
Injection Pressure	210 bar

4. RESULTS AND DISCUSSION

The performance and Emission characteristics of Al-Ti and Ni-Cr coated piston crown and cylinder head diesel engine was investigated and compared with standard engine. The results obtained from the experiments conducted on the engine are presented in Figure 3 to Figure 7.

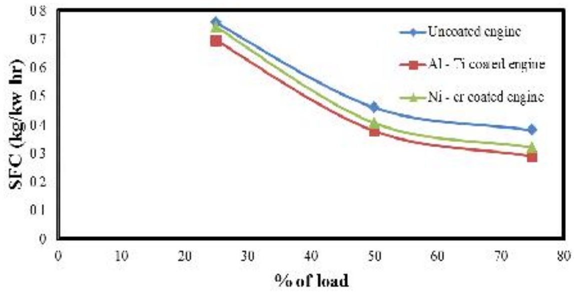

Figure 3: Comparison of Specific Fuel Consumption for different loads.

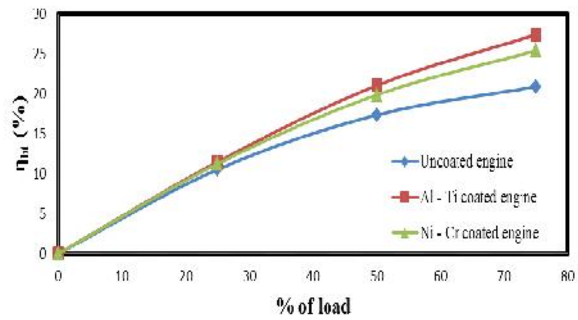

Figure 4: Comparison of Brake Thermal Efficiency for different loads.

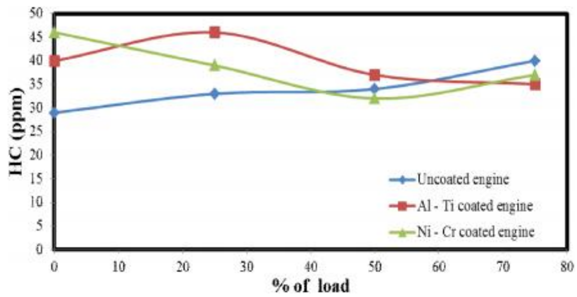

Figure 5: Comparison of Hydrocarbon emission for different loads.

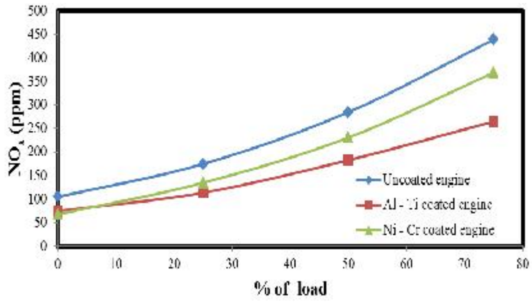

Figure 6: Comparison of Oxides of Nitrogen emission for different loads.

Figure 3 shows the variations of specific fuel consumption of standard engine and compared with Al-Ti and Ni-Cr coated piston crown and cylinder head. The specific fuel consumption is reduced by 16.6% for Al-Ti coating and 9.86% for nickel chromium coating compare to standard engine. Complete combustion of fuel inside the cylinder may reduce the amount of fuel consumed. T. Hejwowski and A. Weroński (2002) stated that specific fuel consumption for a coated engine decreases by 15–20% **[4]**.

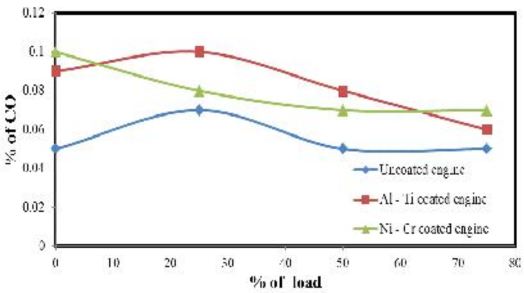

Figure 7: Comparison of carbon monoxide emission for different loads.

The variation of brake thermal efficiency with load for engine operating on Al-Ti and Ni-Cr coated engine and standard engine is shown in figure 4. It is significant that modified engine has higher efficiency than that of base line engine. Reduced thermal loss might be the reason for the improvement in brake thermal efficiency. The maximum brake thermal efficiency obtained for engine operating on Al-Ti coated and standard engine are 20% and 14.26 % respectively. Ilker Turgut Yilmaz (2010) also stated that break thermal efficiency for coated engine improved by 20-25% **[5]**.

Figure 5 shows the comparison of hydrocarbon emission for different loads. Combustion chamber temperature is inversely proportional to HC emission. So HC is slightly more than the conventional diesel engine at low and medium loads and lesser at high loads **[6]**. Modified engine HC emission is lower by around 10 % at full load condition.

Figure 6 indicated the variation of oxides of nitrogen with load for Al-Ti and Ni-Cr coated and standard engine. NO_x is generated mostly from nitrogen present in air and also from fuel. The inherent availability of nitrogen and oxygen in the fuel accelerates the formation of NO_x. NO_x formation is directly proportional to the combustion temperature. In Al-Ti and Ni-Cr coated engine, the NO_x level is reduced by 40 and 20 % respectively. Reduced combustion chamber temperature due to lower fuel consumption might be the reason for lower NO_x levels.

The measured CO emissions for Al-Ti and Ni-Cr coated engine and standard engine are shown in Figure 7. The reduction in CO emission is due to complete combustion and CO emission is slightly more than the conventional and nickel chromium diesel engines at low and medium loads and lesser at high loads.**[6]**

5. CONCLUSION

A conventional contemporary diesel engine is converted into Al-Ti and Ni-Cr coated diesel engine. SFC and emissions were measured to determine the performance and emission characteristics of the engine. The following conclusions can be drawn from the experimental results.

Al-Ti coated diesel engine shows better specific fuel consumption compared to conventional and Ni-Cr coated diesel engine which is 16.6% lower than the standard engine. NO_x emission from Al- Ti coated engine is lower by 40 % than the standard engine. Results show increase in brake thermal efficiency after coating.

With the results obtained it is clear that the coated engines are optimum for low and medium load conditions and more suitable for high load conditions when compared to standard engine.

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