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Effect of Thermal Barrier Coating on Piston Head of 4-Stroke Spark Ignition Engine

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ABSTRACT

The internal combustion engine is facing a severe confront to progress automobile energy effectiveness. In the internal combustion engine most of the heat generated during combustion process is absorbed by the piston by the direct heat loss. Thus, this reduces the indicated power and in turns the performance of internal combustion engine. In this study, the performance of the spark ignition engine was studied before and after the application of the ceramic coating on the piston crown. The experimentation was carried out on four stroke single cylinder computerized spark ignition engine for different load and different spark advance angles. There was an enhancement in thermal efficiency with reduced specific fuel consumption.

Keywords: - Thermal barrier coating, Silicon Nitrite, SI Engine, Indicated Power.

1. INTRODUCTION

The utility of the automotives are higher in the daily life by the human beings. Nowadays, human beings are more depend on the automotives for common purposes like purchasing of milk and food items from the nearest stores which leads to more utilization of petroleum products. The fuels and oils are needed to generate thermal energy in the combustion chamber of the automotives. Generally, internal combustions engines are used to generate thermal energy in all the automotives for smooth operation. Only 30% of the thermal energy was generated by the engine and converted into useful work and remaining 70 % energy was dissipated through cylinder walls, engine head and piston head by direct heat loss. Some of the energy is escaped through exhaust gasses. The overall efficiency of the internal combustion engine is only about 40% - 42%. This efficiency has to be improved to save fuel energy and oils. In recent days, there is a maximum demand for fuels and oils leads to higher cost and non availability. This demand can be reduced by improving the efficiency of the internal combustion engine which is challenge for the engineers [1-2]. The heat energy generated in the internal combustion engine can be increased by reducing the direct heat dissipation to surroundings by coating the combustion chamber with low heat dissipating ceramic materials. The ceramic materials are having less thermal conductivity, low coefficient of thermal expansion and good wear resistance. Few ceramic materials can be used as thermal barrier coating materials to increase the temperature in the combustion chamber. This high temperature will helps in burning the un-burnt gases, minimizes the pollutants and reduces the utilization of fuels [3]. Many researchers were studied the influence of thermal barrier coating materials in improving the thermal efficiency of the internal combustion engines with declined pollutants and some of the literatures were reviewed. G Sivakumar et al., [4] have reviewed many papers relating to the coating materials used in internal combustion engine to improve the thermal efficiency. J.Rajasekaran et al., [5] were studied the influence of thermal barrier coating in the SI engine. The result shows that the break power increases in coated engine as compared to the un-coated engine. The thermal efficiency of the SI engine enhances as compared to un-coated SI engine reported by many researchers [6-8]. Chan et al., [9] conducted similar tests using a piston with a coated crown with 0.45mm of YSZ with 0.15mm bond coat. The results indicating the decrease in fuel consumption of up to 6% at lower engine outputs and decreases in exhaust gas temperatures. Mendera et al. [10] experienced similar decreases in fuel consumption between 2% - 6%, as well as decreases in heat transfer. Kamo et al., [11] analytically studied the use of thermal barrier coating in SI engines can also play a significant role in reducing the unburned hydrocarbons [12, 13]. It was seen by Nakic et al. [14] that by increasing piston crown temperatures using ceramic insulating layers of varying thickness deposit accumulation was greatly reduced due to the inability of the fuel to condense to a carbonaceous film on the hot piston surface. Similarly, both Cheng and Kim [15] and by initiating thermal barrier coating in an SI engine, results in rising the temperature in the cylinder leads to increased in performance and controlled emission benefits [16]. The present investigation is to evaluate the performance of a spark ignition engine with and without Thermal barrier coating. Experiments were conducted on single cylinder water cooled spark ignition engine with eddy current dynamometer for loading and the results are discussed.

2. EXPERIMENTAL SETUP

The single cylinder computerized spark ignited petrol engine is an electrically loaded, air-cooled engine, which is directly interfaced with computer as shown in figure 1 and specification of the engine is depicted in the table 1. The different parameters like Load, Speed, Spark advanced crank angle can be varied. The pressure variation during each cycle at different crank angle has been measured using piezo-electric pressure transducer, which is fitted at the top of the head by drilling a hole into combustion chamber. The software supplied by the manufacturer gives the P-θ diagrams. The software also gives the indicated mean effective pressure values for 25 numbers of cycles. The number of cycles as per our requirement may be increased, but 25 cycles itself gives the repetitiveness in the readings and hence the readings are considered only for 25 numbers of cycles. The experimentation was carried out on the single cylinder spark ignited petrol engine having an off-centered single spark plug. The advanced spark angle is varied by angle controller and varying the load on the generator, which is electrically loaded type. The engine is operated for 20%, 35%, 50% 70% rated loads and for advanced crank angles of 12^0, 15^0, 18^0 and 20^0.The experimentations are conducted for both un-coated and 0.25 mm coated piston with silicon nitrate by using plasma spray coating method for different advanced crank angles and for different loads.

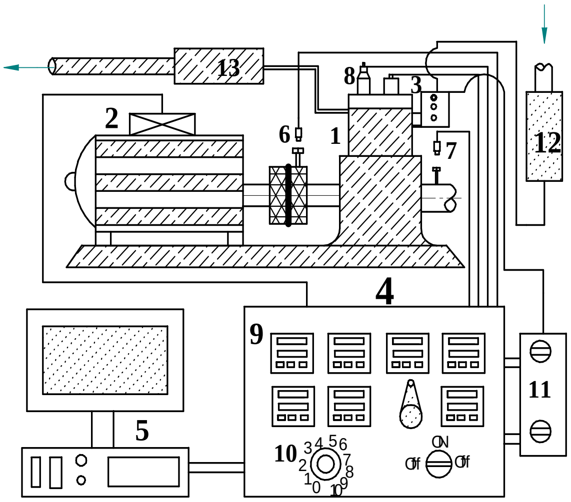

Figure 1: Schematic diagram of experimental test rig.

(1) Test engine, (2) Generator / Motor, (3) Pressure-transducer, (4) Controlling unit & data acquisition system, (5) Computer, (6) Speed sensor, (7) Advanced spark angle sensor, (8) Spark Plug, (9) Advanced spark angle controller, (10) Load Controller, (11) Fuel tank, (12) Air inlet analyzer, (13) Exhaust gas analyzer,

Table 1: Specification of the single cylinder computerized spark ignited petrol engine

Particulars	Details
Make	Greaves HSPPMK25
Type	4-Stroke, side valve, single cylinder, air cooled and horizontal shaft.
Bore mm	70.5
Stroke mm	66.7
Displacement	256 CC
Engine output	2.2 KW
Maximum Torque (Nm)	7 @ 3000rpm, 12.36 @ 1700rpm.
Cooling	Forced Air Cooling
C R	4.67
Spark Plug & gap	MICO M45 Z8, 0.5 mm
Carburetor	Greaves 1320 up draught type float system
Muffler	Pepper pot type

3.RESULTS AND DISCUSSION

Peak Pressure: Figure 2 shows the influence of thermal barrier coating and load on peak pressure developed in the cylinder at 18^{o} spark advance angle during the power stroke. The pressure development in the cylinder increases as the load on the engine rises. The peak pressure developed in the cylinder is higher when the engine operated with coated piston compared to un-coated piston. The peak pressure increases by 4.13% with coated piston as compared to un-coated piston.

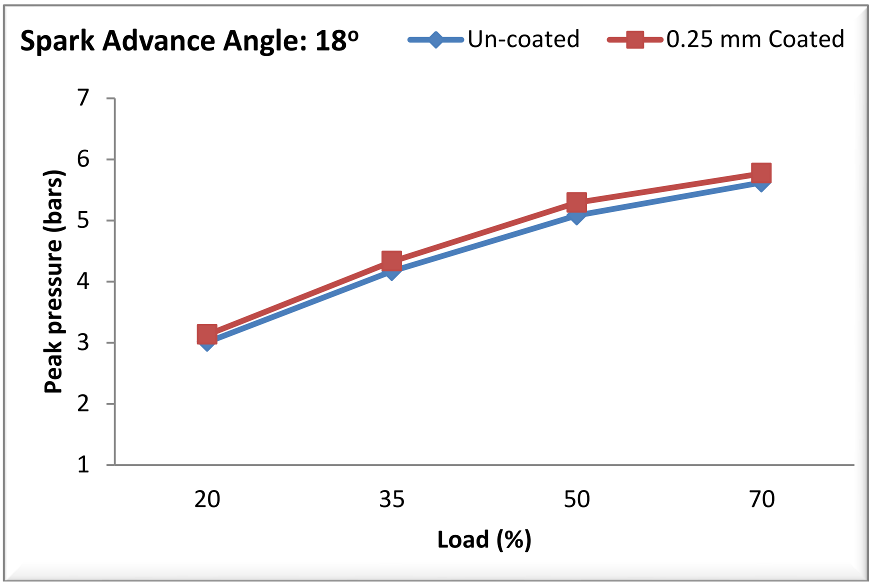

Figure 2: Influence of thermal barrier coating and load on peak pressure

The influence of thermal barrier coating and spark advance angle on peak pressure developed in the cylinder at 50 % rated load when operated with or without the coating on the piston head as shown in figure 3. The engine is operated for different spark advance angle which indicates that the peak pressure obtained at 18^o spark advance angle is higher for both coated and un-coated piston head. The peak pressure in coated piston enhances by 4.13% when compared to un-coated piston at 18^o spark advance angle. If the spark advance angle increases further then the peak pressure decreases. The thermal barrier coating on the piston increases the peak pressure in the cylinder by the reduction of heat loss.

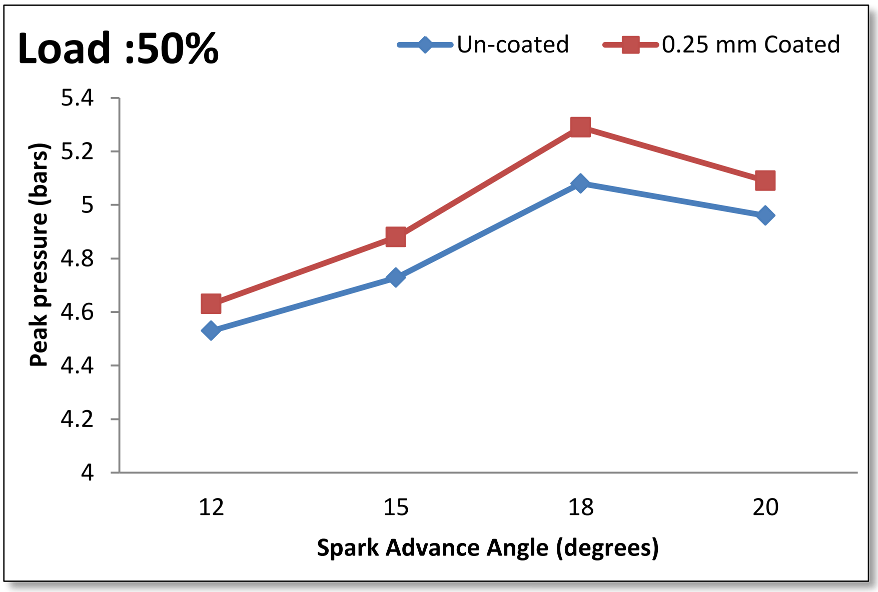

Figure 3: Influence of thermal barrier coating and spark advance angle on peak pressure

Indicated Power:

Figure 4 illustrates the variation of indicated power for different loads at 18^o spark advance angle when operated with or without the coating on the piston head. The indicated power increases as the rated load increases on the engine. The indicated power in coated piston enhances by 5.9% when compared to un-coated piston in 50% rated load at 18^o spark advance angle. The indicated power is higher in the coated piston for all the rated loads.

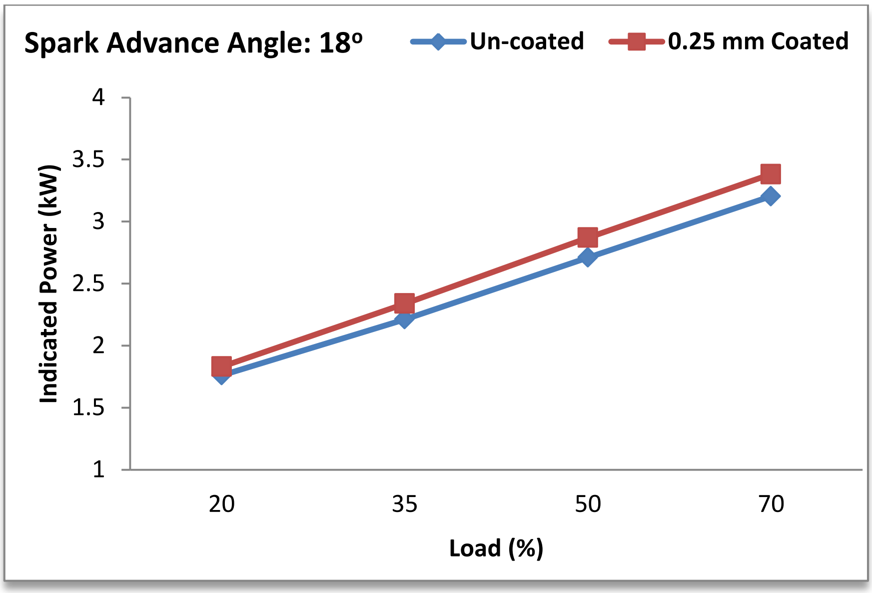

Figure 4: Influence of thermal barrier coating and load on indicated power

Figure 5 illustrates the variation of indicated power for different spark advance angle at 50 % rated load when operated with or without the coating on the piston head. The engine is operated for different spark advance angles and indicates that the indicated power obtained at 18^o spark advance angle was higher for both coated and un-coated piston head. The indicated power in coated piston enhances by 5.9% when compared to un-coated piston at 18^o spark advance angle.

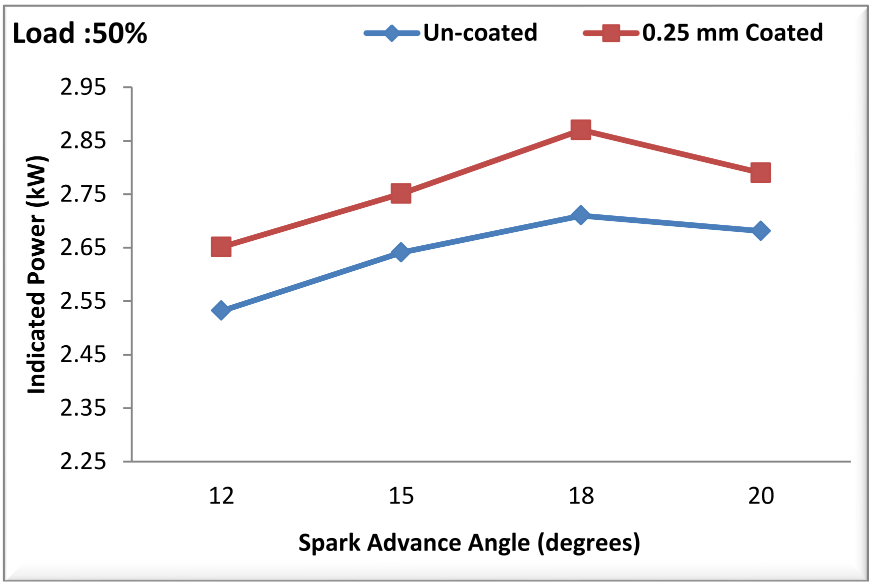

Figure 5: Influence of thermal barrier coating and spark advance angle on indicated power

Brake Thermal Efficiency:

Figure 6 illustrates the variation of break thermal efficiency for different loads at 18^o spark advance angle when operated with or without the coating on the piston head. The break thermal efficiency increases as the rated load increases on the engine. The break thermal efficiency in coated piston enhances by 5.74% at 35% rated load and enhances by 5.56% at 70% rated load when compared to un-coated piston at 18^o spark advance angle. The break thermal efficiency is higher in the coated piston for all the rated loads. This indicated that the thermal barrier coating on the piston increases the break thermal efficiency of the engine by the reduction of heat dissipation.

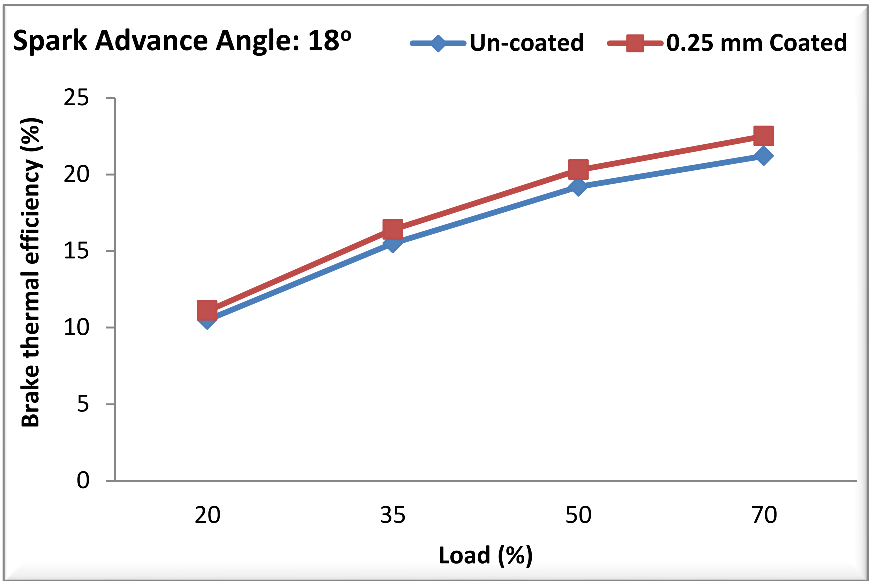

Figure 6: Influence of thermal barrier coating and load on brake thermal efficiency

4. CONCLUSIONS

The piston head of spark ignition engine is coated with low thermal conductivity silicon nitrate using plasma spray coating method. The peak pressure developed in the cylinder is higher when the engine operated with coated piston compared to un-coated piston. The peak pressure increases by 4.13% when operated with coated piston as compared to un-coated piston. The peak pressure in coated piston enhances by 4.13% when compared to un-coated piston at 18^o spark advance angle. The indicated power in coated piston enhances by 5.9% when compared to un-coated piston in 50% rated load at 18^o spark advance angle. The break thermal efficiency of coated piston enhances by 5.56% at 70% rated load when compared to un-coated piston at 18^o spark advance angle. The thermal barrier coating on the piston increases the break thermal efficiency of the engine by the reduction of heat loss.

REFERENCES

[1]. Imdat Taymaz, An experimental study of energy balance in low heat rejection diesel engine, Elsevier-Energy, 31(2-3), (2006), 364-371.

[2]. I.Taymaz, K.Cakir and A.Mimaroglu, Experimental study of effective efficiency in a ceramic coated diesel engine, Surface and Coating technology, 200, (2005), 1182-1185.

[3]. Roy Kamo, Walter Bryzik, Michael Reid, Melvin Woods, Coatings for improving performance, SAE Technical paper series, 970204, International congress and exposition, Detroit, Michigan, (1987), 1-10.

[4]. G Sivakumar, V. Shankar, G. Hemath Kumar, N. G. Renganathan & V.U. Garud, Is thermal barrier coating for low heat rejection in SI engines or diesel engines?, International Journal of Emerging Technology and Advanced Engineering, 2 (12), (2012), ISSN 2250-2459.

[5]. J.Rajasekaran, B.M.Gnanasekaran, T.Senthilkumar, B.Kumaragurubaran and M.Chandrasekar, Effect of thermal barrier coating for the improvement of SI engine performance & emission characteristics, International Journal of Research in Engineering and Technology, 02 (7), (2013).

[6]. Idris Cesur, The effects of modified ignition timing on cold start HC emissions and WOT performance of an LPG fuelled SI engine with thermal barrier layer coated piston, International Journal of the Physical Sciences, 6(3), (2011), 418-424.

[7]. Senthilkumar Tamilkolundu and Kumaragurubaran Balasubrmanian, Evaluation of engine performance and emission characteristics of zirconia coated piston surface in SI engine, Journal of Environmental Research and Development, 7 (1A), (2012).

[8]. P.Lawrence, P.Koshy Mathews and B.Deepanraj, Experimental investigation of zirconia coated high compression spark ignition engine with ethanol as fuel, Journal of scientific and industrial research, 70, (2011).

[9]. S.H. Chan and K.A. Khor, The Effect of Thermal Barrier Coated Piston Crown on Engine Characteristics, Journal of Materials Engineering and Performance, 9(1), (2000), 103-109.

[10]. K.Z. Mendera, Effectiveness of Plasma Sprayed Coatings for Engine Combustion Chamber," SAE Technical Paper Series, 2000-01-2982, (2000).

[11]. R. Kamo, D.N. Assanis, and W. Bryzik, Thin Thermal Barrier Coatings for Engines, SAE Technical Paper Series, 890143, (1989).

[12]. R.M. Frank and J.B. Heywood, The Effect of Piston Temperature on Hydrocarbon Emissions from a Spark-Ignited Direct-Injection Engine, SAE Technical Paper Series, 910558, (1991).

[13]. G.T. Kalghatgi, Depostis in Gasoline Engines - A Literature Review, SAE Technical Paper Series, 902105, (1990).

[14]. D.J. Nakic, D.N. Assanis, and R.A. White, Effect of Elevated Piston Temperature on Combustion Chamber Deposit Growth, SAE Technical Paper Series, 900948, (1994).

[15]. S.S. Cheng and C. Kim, Effect of Engine Operating Parameters on Engine Combustion Chamber Deposits, SAE Technical Paper Series, 902108, (1990).

[16]. M.A. Marr et al., An Investigation of Metal and Ceramic Thermal Barrier Coatings in a Spark Ignition Engine, SAE Journal, 2010-01-2090, (2010).