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CERAMIC-METAL COMPOSITE COATINGS IN PISTON FOR VARIOUS SMOKE EMISSIONS

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ABSTRACT

Piston is a major contributor for the mechanical losses in an engine. A major portion of oil consumption arises from bore distortion and poor piston ring sealing resulting from the piston ring and/or cylinder bore wear. Controlling the surface finish and texture of piston surface plays an important role with respect to friction (fuel efficiency), wear (durability and running performance) and oil consumption (noxious emissions) of an engine. The use of protective coating systems on piston region components in advanced diesel engine designs is being contemplated for a number of reasons. Coated piston skirts provide a dry sliding surface for engine startup, and feature increased resistance to abrasion and scratching while moving within the engine block. A ceramic coating can also be layered on the piston ring to reduce friction and enhance wear resistance between the ring and the cylinder's inner surface. A piston can be made more efficient with a ceramic coating on its crown which improves the device's heat reflection and transfers part of the detonation energy into the fuel burning phase. This can result in higher fuel burning efficiency and reduced carbon accumulation, which in turn makes detonation more effective. Thus a review is given in this paper

Keyword: Ceramic coating, Wear resistance, Detonation, accumulation

INTRODUCTION

The use of protective coating systems on piston region components in advanced diesel engine designs is being contemplated for a number of reasons. Coated piston skirts provide a dry sliding surface for engine startup, and feature increased resistance to abrasion and scratching while moving within the engine block. A ceramic coating can also be layered on the piston ring to reduce friction and enhance wear resistance between the ring and the cylinder's inner surface. A piston can be made more efficient with a ceramic coating on its crown which improves the device's heat reflection and transfers part of the detonation energy into the fuel burning phase. This can result in higher fuel burning efficiency and reduced carbon accumulation, which in turn makes detonation more effective. Even though the internal working parts of an engine are not seen, they are the most important. These parts are very important because of the jobs that they perform, and because of the intense work pressure that they endure. For these reasons, the internal moving parts of an engine must be made of high quality materials and they must be precise. Even though the parts are made of high quality materials, they are still subject to wear.

It has always been a wish of mechanical engineers to extend the lifetime of tools, mechanical components or wear parts, by increasing the "surface hardness". Over the last 50 years, many processes have been developed to increase the surface hardness by diffusion and/or coating deposition techniques; each of these techniques were designed to be applied on specific materials and for specific applications. The following surface modification techniques can briefly be mentioned in figure 1 given below.

PROBLEMS ADDRESSED

CVD (Chemical Vapour Deposition) was practised on a laboratory scale since early in the century. The first industrial application of this process to produce hard, wear resistant coatings, took place in the late sixties, when thousands of cemented carbide cutting inserts were coated with thin (typically 3 µm) layers of carbides (mainly in Ti), and oxides (mainly of Al). PVD (Physical Vapour Deposition) was also known many years before the breakthrough to produce hard, wear resistant coatings (consisting mainly of TIN) took place in the late seventies. Today, these two surface modification techniques are widely used in many different industrial fields. Besides, there have lately been serious efforts to improve the processes, to develop more performing CVD or PVD and to combine the two into complex advanced surface modification techniques.From this various types of coating techniques the plasma spray coating is used for coating piston ring, crown, skirt.

The AVL smoke meter works on light extinction principle. It consists of a flexible sampling hose with appropriate exhaust gas probe. The sampling probe is inserted in the exhaust pipe approximately 200 mm from the engine. A continuous exhaust sample is passed through the tube of about 46 cm length, which has a light source at one end the other end fitted with a photo cell. The amount of the light passing through the smoke column is sensed as an indication of smoke level. The smoke meter consists of display unit. The smoke density in HSU is displayed.

ELECTROCHEMICAL AND CHEMICAL METHODS

Hard Chromium Plating produced by electro deposition, is extremely hard and corrosion resistant. The coating is used for rebuilding defective or worn parts, for automotive valve stems, piston rings, bores of diesel and aircraft cylinders, and for hydraulic shafts. Hard chromium plating is deposited in thicknesses ranging from 2.5 to 500 µm;

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the Vickers hardness is between 900 and1100. Most hard chromium deposits are applied to parts made of ferrous alloys, however, numerous aerospace applications require the chromium plating of Al, Ti or Ni base alloys.

Electroless or Chemical Nickel Plating is used to deposit Ni without the use of an electric current. Electroless Ni is an engineering coating, normally used because of excellent corrosion and wear resistance. Composites are one of the most recently developed types of electroless coatings. These cement deposits consist of small particles of intermetallic compounds, carbides, or diamonds, dispersed in an electroless Ni-P matrix. The resulting apparent surface hardness is 1300 HV or more.

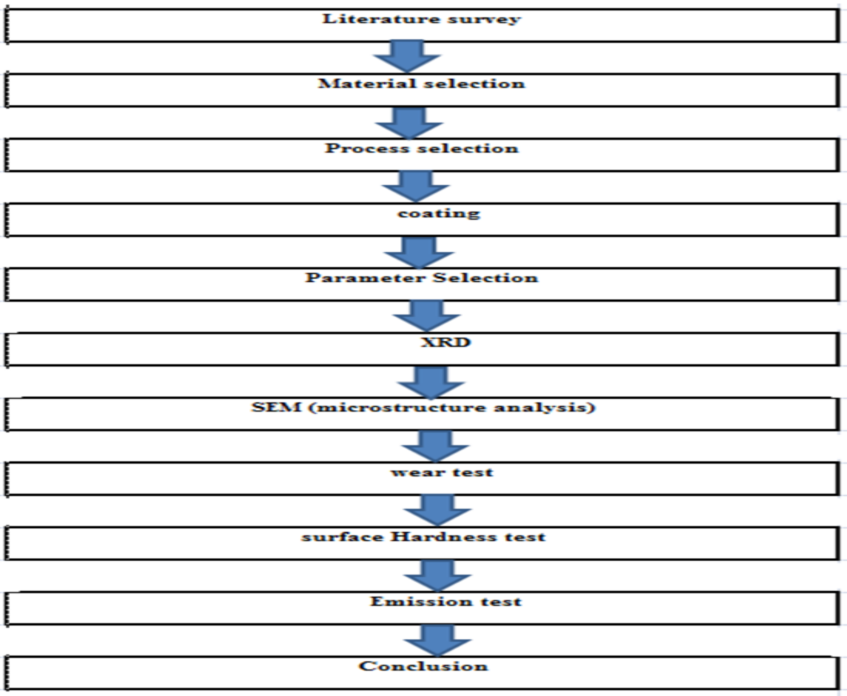

Figure 1. Methodology

SPRAY COATINGS

Flame Spray: Solid material, aspirated into the oxygen fuel-gas flame, is melted and carried by the flame onto the work piece (- 2800" C). The particle velocity is relatively low, and the bond strength of deposits is low. The porosity is high and the cohesive strength is low. Spray rates are usually in the range of 0.5 to 9 kg/h and the approximate particle impact velocity is 30 m/s.

Plasma Spray: Conventional plasma spraying provides free-plasma temperatures in the melting region in the order of 4000 to 5000" C. To generate the plasma, on inert gas is superheated by passing it through a DC arc. Solid material is introduced and carried to the work piece by the plasma stream. The substrate temperature can be kept at 100 to 200" C. Typical spray rates are 0.1 kg/h, and the approximate particle impact velocity is 250 m/s.

Detonation Gun: Suspended powder is fed into a 1 m long tube (barrel) along with the oxygen and fuel gas. **A** spark ignites the mixture and produces a controlled explosion. The high temperatures (- 3900" C) and pressures (1 MPa) that are generated blast the particles out of the end of the tube towards the substrate. The approximate particle impact velocity is 900 m/s.

Plasma Torch Flame: More recently, a new type of plasma spray has been developed. It is also based on a gas-jet, but the plasma is created by a RF induction coil; temperatures in the order of 8000" K can be reached. Such a torch can be used to produce hard coatings on selected substrates. The material to be deposited is introduced as solid powder, or as vapour of chemical compounds. In the latter case the coating is formed by chemical vapour processes in the torch itself and on the substrate surface. It can be considered as a high purity chemical reactor and be used for different kinds of deposition.

FORMULAE USED FOR CALCULATION

1. Brake power (BP) BP = (2 * л * N * T)/60000 kW
Where N = Speed in rpm
T = Torque in Nm
2. Total fuel consumption (TFC)
TFC = x/t *10-6 *3600 *ρ kg/hr
Where x = Volume for which fuel consumption time is noted (cc)
t = Time taken for X cc fuel consumption in sec

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ρ = Density of fuel (kg/m3)

3. Brake specific fuel consumption (BSFC)

BSFC = TFC/ BP (kg/kW-hr)

Where TFC = Total fuel consumption (kg/kW-hr)

BP = Brake power (kW)

4. Brake thermal efficiency (ηbth)

ηbth = (BP*3600)/(TFC *CV) *100 (%)

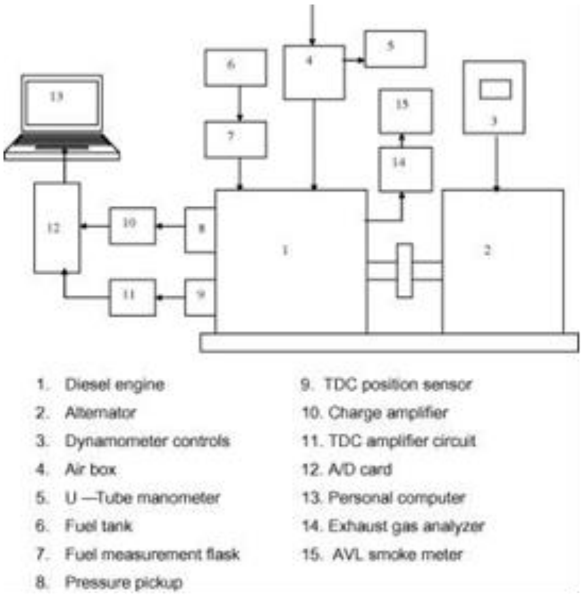

Figure.2.Experimental Setup

EMISSION CHARACTERISTICS

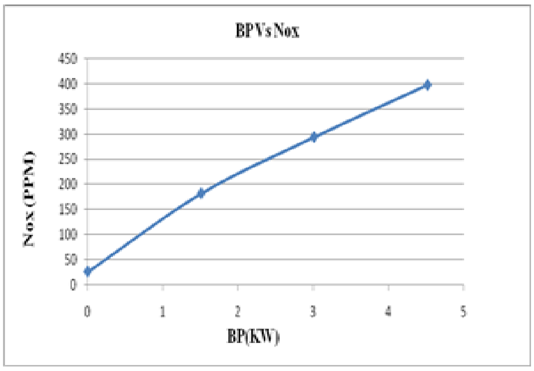

Figure.3.Effect of Engine Brake Power on NOx Emissions

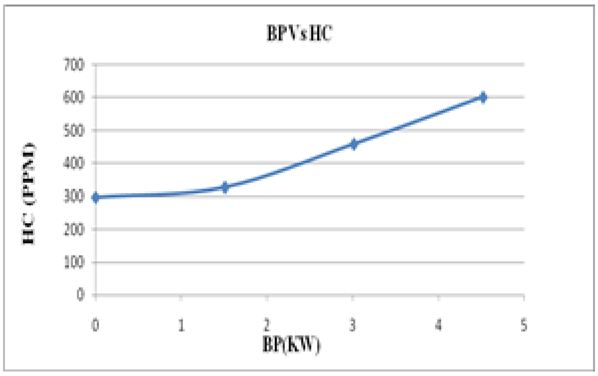

Figure.4.Effect of Engine Brake Power on HC Emissions

As the brake power increases, the total fuel required increase but the time required for combustion of fuel decreases which increases the unburnt hydrocarbons.

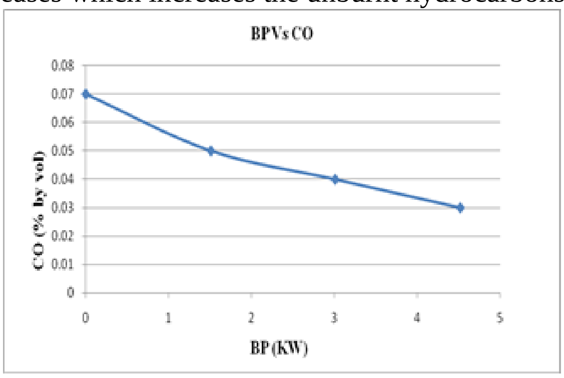

Figure.5.Effect of Engine Brake Power on CO Emissions

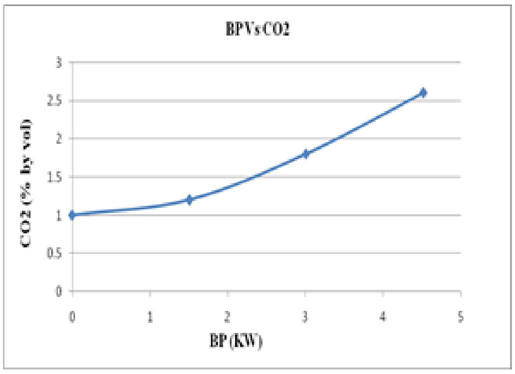

Figure.6.Effect of Engine Brake Power on CO2 Emissions

As the brake power increases, the specific fuel consumption decreases which decreases the CO emissions. As the brake power increases, the peak temperature inside the cylinder increases as more fuel is consumed and thus the oxides of nitrogen in the exhaust increases.As CO molecules are oxidised to CO2 molecules, CO2 emissions increase with increase in brake power.

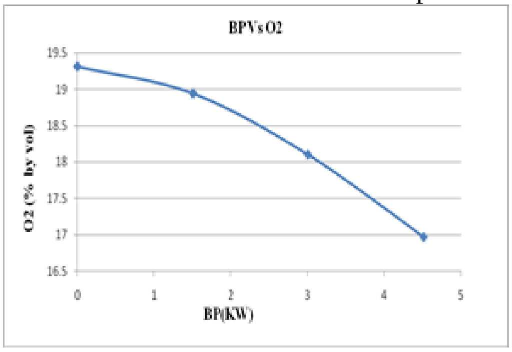

Figure.7.Effect of Engine Brake Power on O_2 Emissions

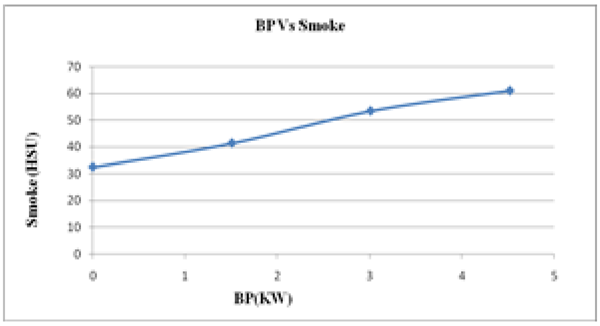

Figure.8.Effect of Engine Brake Power on Smoke Emissions

As the brake power increases, more oxygen is used for combustion, so O_2 emission decreases. As the brake power increases, more amount of combustion is takes place, so Smoke emission increases.

CONCLUSION

First the concept of wear and characteristics of wear were studied with the help of literature papers. Various coating materials used in piston crown ,skirt and piston ring were studied and it is conformed that ceramic is a good wear resistant coating material and Yttria stabilized Zirconia (thermal barrier coatings, ZrO_2-8% Y_2O_3) is a good ceramic coating material. Base engine readings were taken for future reference.

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