Improving the Life of LM13 using Stainless Spray-II Coating for Engine Applications

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Abstract: ***This work deals with reduction of surface roughness of reciprocating parts of an internal combustion engine and its frictional loss and thereby improving overall efficiency. Surface coatings can be used to reduce surface wear of components. The use of these coatings for engine applications presents a suitable solution to this problem. The materials coated can suddenly show very different properties compared to what they exhibit on a macro scale, enabling unique applications. A major part of the power produced by the engine is lost in overcoming friction between the reciprocating parts. Friction coefficient can be found by the test conducted on 'Pin on disk apparatus'. Before coating bench mark values are taken from uncoated and we compare those valued with values obtained after coating. The technique used for coating is Wire Arc Spray process.***

Keywords: Wear, Friction coefficient, Wire Arc Spray process, pin on disk apparatus.

1. Introduction

Fuel economy improvement is one of the major challenges of the future automotive industry. Two major factors impacting the fuel economy are vehicle weight and frictional loss. In addition to structural components, engine itself contributes significantly to the vehicle weight, and replacement of cast iron engine blocks by aluminum engines can appreciably improve fuel efficiency. Nearly half of the engine blocks to be manufactured worldwide in the current decade are anticipated to be made of aluminum.

In engine systems, friction accounts for a loss of over 40% of the total vehicle power. Majority of the power loss, about 50%, can be attributed to frictional loss between piston rings and cylinder bores. Compared to conventional cast iron, the surfaces of aluminum cylinder bores have relatively poor friction and wear characteristics and require cast iron liners. Cast iron liners, however, adversely affect weight and heat transfer and cylinder wall temperature. Elimination of cast iron liners also offers the flexibility of reduced engine components length with further weight reduction and increased engine displacement for greater power. Hence, the automotive industry is now moving to sleeveless aluminum cylinder blocks to achieve both lightweight and compact design requirements. Several alternative approaches have been evaluated or are now being pursued to eliminate cast iron liners and improve tribological characteristics of aluminum cylinder bores.

1.1. Thermal spray technologies:

Thermal spray technologies are important in a variety of different industries for the deposition of nano coatings. Thermal spraying techniques are coating processes in which melted (or heated) materials are sprayed onto a surface. The "feedstock" (coating precursor) is heated by electrical or chemical means. Combustion or electrical arc discharge is usually used as the source of energy for it. Different thermal spray processes are being used to provide coatings for cylinder bores out of which four thermal spraying systems are currently either commercially available or under research. They are Rotary powder plasma process (in serial production), rotating twin wire arc system (in serial production), High velocity oxygen fuel system (under research) and Plasma Transferred Wire Arc system.

In the specific case of the coating of cylinder bores the transfer of heat into the substrate unit must be considered with priority as the engine blocks are an AlSi cast alloy and overheating during the coating can result in an unacceptable level of distortion or change in microstructure and therefore in mechanical properties. Engine manufacturers have been going to aluminum to save weight. With aluminum cast engine blocks (now accounting for more than 60% of automotive engines), silicon is usually added to improve fluidity during pouring and to increase hardness. Major advantages of utilizing the Wire Arc Spray coating method include lower operating costs, higher material output per hour, and production of a more coarse coating than Plasma or HVOF coating methods. As well, Wire Arc coatings are exceptionally suited for dimensional restoration of both mis machined and worn parts, saving clients large amounts of time and money when such events occur. Wire Arc Spray coatings also have a rich history of proven and cost-efficient corrosion protection.

The available research article deals with investigation of the influence of spray gun nozzle parameters on sprayed particles velocity and strength of coating adhesion. Four different arc spray nozzles were chosen for research. All variables of the spray process were constant except the air debit [1].

The research work reveals friction and wear of copper and aluminum are investigated experimentally using a pin-on-disc apparatus. In the experiments, mild steel pin slides on copper or aluminum disc at different normal load conditions 10, 15, and 20 N. Experiments are also carried out at different sliding velocities 1, 1.5 and 2 m/s. The effects of duration of rubbing on the friction coefficient of copper and aluminum are investigated [2].

Micro arc oxidation of wire arc sprayed Al-Mg6, Al-Si12 and Pure Al coatings on low carbon steel has been performed [3]. The coatings have been analyzed using optic microscope, scanning electron microscopy, X-ray diffraction and surface roughness tester.

Al-12.5wt%Si alloy powder with 15 wt% SiCp was mechanically alloyed (MA) using attrition mill in purified nitrogen atmosphere. The MA processed powder was found to have nano grain size and uniform distribution of SiCp in the AlSi matrix. This MA processed powder was used for atmospheric plasma spraying (APS) for varying distances and currents densities. The coatings obtained were studied by image analyzer, SEM and XRD. Micro hardness and wear rate of the coatings were evaluated using Vickers indenter and pin on disk type tribometer, respectively [4].

Al_2O_3-13%TiO_2 coatings were deposited on stainless steel substrates from conventional and nano structured powders using atmospheric plasma spraying (APS). A complete characterization of the feedstock confirmed its nano structured nature. Coating microstructures and phase compositions were characterized using SEM, TEM, and XRD techniques [5].

The objective of the present study is thus to investigate the effect of particles velocity, temperature on the cored wire coatings properties [6]. The results of a systematic investigation of the influence of different nozzles configurations on the coatings properties are presented, including the gas dynamics properties of the spray jet were calculated by using the CFD code, temperature, velocity and diameter of the particles in flight measurements and the effects on the particles properties on coating adhesion, pores and oxide content.

2. Materials and Methods

2.1. LM13 Aluminum casting alloy:

The material on which the nano coating is done by the wire arc spray process is LM13 Aluminum casting alloy.

Table 1: Chemical Composition of LM 13

Elements	Specification %	Observation %
Copper	0.7-1.5	0.90
Magnesium	0.8-1.5	1.2
Silicon	10-12	10.3
Iron	1max	0.7max
Manganese	0.5max	0.3max
Titanium	0.2max	0.12
Zinc	0.5max	0.05

Table 2: Chemical composition of coated material SS-II (13 Cr) volume percentage stainless spray II, chrome alloyed.

Elements	%
Carbon	0.17-0.20
Manganese	0.70-0.80
Phosphorous	0.030 max
Sulphur	0.010 max
Silicon	0.20-0.40
Chromium	12.00-13.00

Table 3: Chromium steel for the application of hard layers, good wear resistance and emergency running characteristics, Substitute for hard chrome plating, fair corrosion-resistance

2.2. Surface Grinding

Surface grinding is a manufacturing process which moves or grinding wheel relative a surface in a plane while a grinding wheel contacts the surface and removes a minute amount of material, such that the flat surface is created. The term surface grinding designates any process which accurately grinds a surface.

2.3. Sand Paper

Sandpaper or glass paper is a heavy paper with abrasive material bonded to its surface. Sandpaper is part of the "coated abrasives" family of abrasive products. It is used to remove small amounts of material from surfaces, either to make them smoother (painting and wood finishing), to remove a layer of material (e.g. old paint), or sometimes to make the surface rougher (e.g. as a preparation to gluing).Grit size refers to the size of the particles of abrading materials embedded in the sandpaper.

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2.4. Surface Roughness Tester

The surface roughness tester determines both roughness parameters Ra and Rz accurately within a wide measuring range. The piezo-electric pickup stylus with diamond tip assures reliable measurements within tolerances that conform to ISO class 3. Surface roughness parameter Ra is computed to conform to ISO and Rz is computed to DIN

2.5. Hardness Test (Vickers Harness test)

The Vickers test can be used for all metals and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond Pyramid Hardness (DPH). The hardness number can be converted into units of Pascal's.

The hardness number is determined by the load over the surface area of the indentation and not the area normal to the force, and is therefore not a pressure. The hardness number is not really a true property of the material and is an empirical value that should be seen in conjunction with the experimental methods and hardness scale used. When doing the hardness tests the distance between indentations must be more than 2.5 indentation diameters apart to avoid interaction between the work-hardened regions.

2.6. Friction test on pin on disk tribometer (trb)

The pin-on-disk tribometer is a versatile laboratory apparatus for measuring the friction and wear properties of combinations of metals and lubricants under selected conditions of load, speed and temperature. A pin on disc tribometer consists of a stationary "pin" under an applied load in contact with a rotating disc. The pin can have any shape to simulate a specific contact, but spherical tips are often used to simplify the contact geometry. Friction is determined by the ratio of the frictional force to the loading force on the pin.

2.7. Test method for determining the friction coefficient of materials during sliding in a pin-on-disk configuration

This test method involves a pin shaped upper specimen that slides against a rotating disk as a lower specimen under a prescribed set of conditions. The pin specimen revolves about the disk is horizontal. The pin is pressed against the disk at a specified load of 5 kg by means of an arm. The frictional force and rotating speed can be indicated in the display board attached to the apparatus. Friction coefficient at different speeds and friction force is obtained by using software.

Testing is done on LM13 Aluminum with ball specimens and friction coefficient is calculated at different speeds and frictional forces under lubricated conditions and without lubrication too. By finding the friction coefficient values the relative or absolute wear can be obtained from measurements of mass loss, length loss and volume loss using a microscope but here we are only interested in finding out the . The friction coefficient signal is displaced by indicator on display board.

Table 3: Specifications of test specimen

Parameter	Value
Ball diameter	12.7mm
Disk size	149×9mm thickness
Disc rotation	600-1200 rpm
Normal load	5 kgf

These are the specifications required for testing procedure on pin-on-disk apparatus. This testing is done without lubrication before coating and after coating.

2.8. Wire Arc Spray Coating

Wire-arc spray is a form of thermal spraying where two consumable metal wires are fed independently into the spray gun. The wires are charged and an arc is generated between them such that the temperature it produced will transform the wire into molten state. The resulting material is then atomized into small particles and ultimately propelled onto the desired substrate by ultra-clean, compressed air jet from the gun.. The surface must be pre-treated by shot blast. The materials typically used are zinc, aluminum or their alloys such as Zinacor. This process is commonly used for metallic, heavy coatings.

2.9. Coating Material(SS-II)

Low-carbon steels contain up to 0.30 weight percent C. The largest category of this class of steel is flat-rolled products (sheet or strip) usually in the cold-rolled and annealed condition. The carbon content for these high-formability steels is very low, less than 0.10 weight percent C, with up to 0.4 weight percent Mn. For rolled steel structural plates and sections, the carbon content may be increased to approximately 0.30 weight percent, with higher manganese up to 1.5 weight percent.

2.10. SEM (scanning electron microscope)Test

The Scanning Electron Microscope (SEM) is a microscope that uses electrons rather than light to form an image.

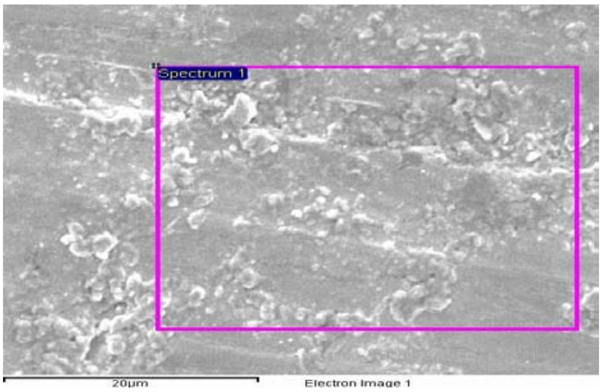

Figure 1: SEM image of a coated specimen

In Fig 1: we see SS II coated surface on LM13 substrate. Wire arc spray coatings were examined with the scanning electron microscope. There is considerable debate in the wire arc coating community over the presence or absence of porosity and the true amount of porosity. It would be quite tedious to define the true volume fraction of porosity. But we can see from Fig: 9 that porosity is very less and also homogeneity of coating is observed.

In fig 1: we see SEM image of worn out SS II coated LM13 disc after performing pin on disc wear test at rotational rate of 600-1200 RPM. Though, unidirectional wear mechanism on the surface of the disc can be clearly seen.

3. Results and Discussions

3.1. Surface Roughness Test

The surface roughness test is conducted on LM13 at four random points and the roughness values obtained are tabulated as follows:

Table 4: surface roughness values before and after coating

Sl. No	Before coating		After coating	
	R_a (μ_m)	R_z (μ_m)	R_a (μ_m)	R_z (μ_m)
1.	0.38	3.07	0.55	3.97
2.	0.29	2.64	0.38	3.88
3.	0.52	4.94	0.33	2.02
4.	0.32	2.71	0.31	1.95

The obtained surface roughness values show that the surface roughness is maintained before and after the nano coating which is a good sign.

3.2. Vickers Hardness Test

Vickers hardness test is conducted on the Universal Hardness Testing Machine in NSTL at three random points as per their convenience and the results obtained are as follows:

Table 5: Hardness values before and after coating

Sl. No	Hardness (HV)	
	Before coating	After coating
1.	99.3	672
2.	97.7	702
3.	110	710

From the above results we observe that there is an increase in the hardness after the application of coating.

3.3. Friction Test

The friction test using the pin-on-disk measurements principle is conducted at different track radii and speeds and the results obtained are tabulated and comparison is clearly defined by drawing graphs for the friction coefficient obtained with respect to time before and after coating with an applied load of 5kg without any lubricant. Experimentation was carried out for finding coefficient of friction of the material before and after coating.

Graphs are plotted at each speed and track radius between time and coefficient of friction of the material with and without the nano-coating.

Table 6: Coefficient of friction before and after coating at 50mm radius

RPM	Average Coefficient of friction	
	Before coating	After coating
600	0.2243	0.1418
1200	0.2139	0.1387

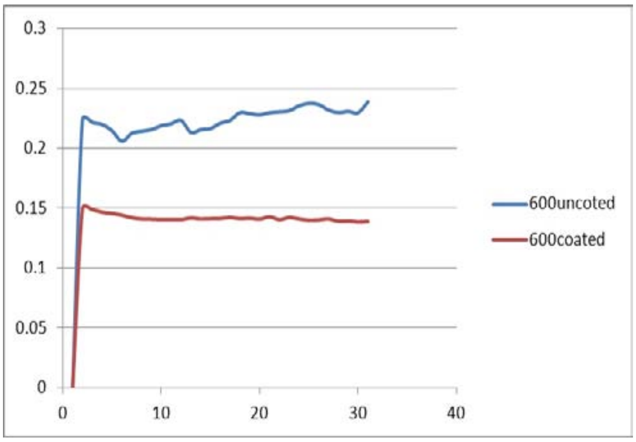

Figure 2: Time vs Coefficient of friction at 600rpm of 50mm track radius

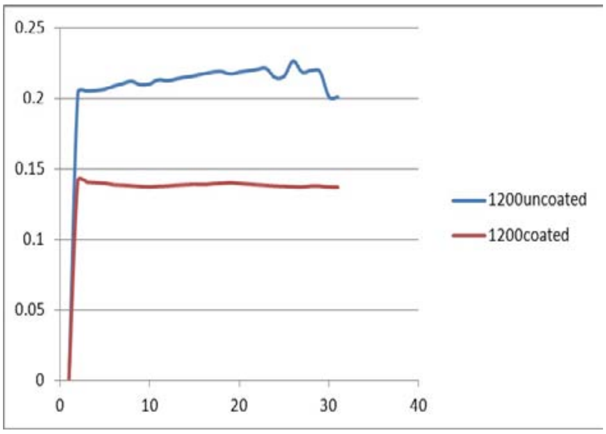

Figure 3: Time vs Coefficient of friction at 1200 rpm of 50mm track radius

Table 7: Coefficient of friction before and after coating at 60mm radius

RPM	Average Coefficient of friction	
	Before coating	After coating
600	0.3273	0.1530
1200	0.3238	0.1384

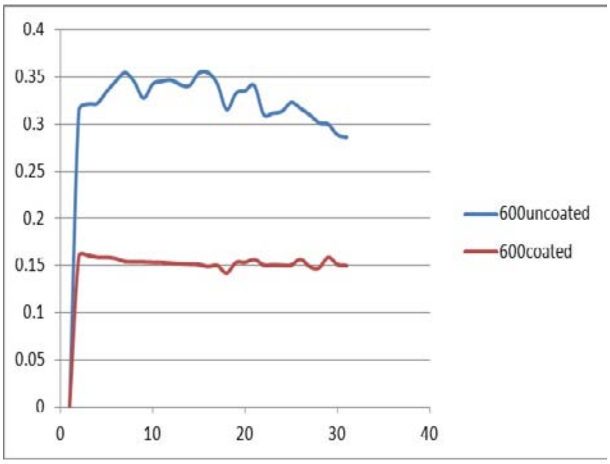

Fig 4: Time vs Coefficient of friction at 600 rpm of 60mm track radius

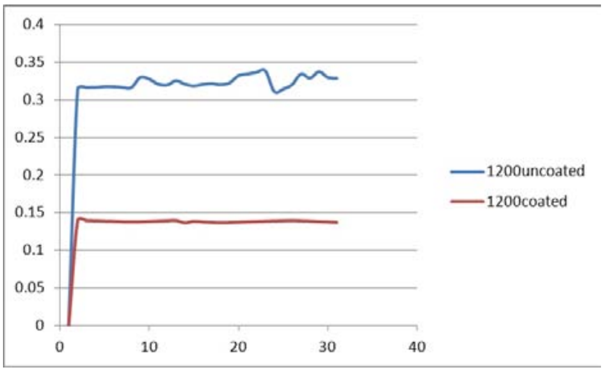

Figure 5: Time vs Coefficient of friction at 1200 rpm of 60mm track radius

Based on the literature search, surface roughness, hardness, the friction coefficient is calculated and the values obtained are tabulated.

From the values obtained we observe that the friction co-efficient is found to increase as the track radius decreased in the friction test before coat but there is a good reduction of the friction co-efficient when track radius is reduced after the application of the coating.

4. Conclusions

Based on the literature search, wear depends on number of parameters including material hardness and surface properties. The materials used in the experiment were all subjected to same load (5kg) and different rpm. After comparing the values of LM13 before and after coating the following conclusions have been drawn:

- After coating Hardness value is improved by 7 times the initial value
- Coefficient of friction and frictional force has been reduced.
- Reduction in wear.
- Heat generation is reduces.
- Lubricant life span increases.
- Weight decreases by three times compared to cast iron cylinders.

From the above observation it is clear that SS-II coated on Lm13 alloy can be used as substitute for cast iron engine liners and other heavier reciprocating parts of an engine

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