A Review on Surface Treatment on Piston Ring and Cylinder Linear

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Abstract - **Surface irregularities in conjunction with the type of lubricant play an important role to the engine performance and life. Piston skirt contributes to the total friction losses of the piston–cylinder system. This paper presents studies related to piston cylinder surface treatment and related theoretical and experimental works. This paper covering many references, aims to shed new light on the surface modification related to the piston assembly. The work is intended as a reference for surface treatment of piston skirt assembly, with particular emphasis on piston ring. Some studies prove that it is possible to reduce friction and/or reduce wear. It is possible to use special mechanical treatment or chemical coatings and laser structuring treatments to improve the triobological properties of cylinder.**

I. INTRODUCTION

Cylinder surface profiles can significantly affect the friction and the lubrication conditions of the internal combustion engines. It is important that the surface irregularities in conjunction with the type of lubricant play an important role to the engine performance and life. Tribological parameters such as friction, lubrication and wear influence strongly the cylinder's life[1]. In this study, surface modifications of piston ring and cylinder liner are taken in to account.

The piston–cylinder system is a significant source of mechanical friction in internal combustion engines. It has been shown that the piston skirt contribution to the total friction losses of the piston– cylinder system is substantial.[2-4].Studies have focused both on the piston ring–cylinder liner interface and piston skirt–cylinder interface. However, somewhat limited experimental work has been done on coated piston skirts in laboratory conditions simulating closely the conditions found inside the engine.[5]

The presence of coatings and surface topography play an important role in the tribological performance of sliding components. Depending on the surface treatment used, it is possible to reduce friction and/or reduce wear. However, although there may be low friction and wear-resistant treatment suitable for use in pistons, some treatment may hinder the tribological performance by changing the lubrication regime or by preventing additives from their intended function through chemical mechanisms. [6]

To improve the mechanical and tribological properties of different cylinder bores it is possible to use special mechanical treatment or chemical coatings and laser structuring treatments [7] .

A coating on the piston may offer advantages such as friction reduction and better scuffing resistance and wear Protection [8] .while reduced clearance due to the coating thickness may reduce oil consumption and engine noise. Although oil viscosity and oil film thickness affect the operating lubrication regime between the piston skirt and cylinder liner and are important, the friction between them will also be affected by clearance and surface roughness and hence are not to be overlooked. [9]

II. NICKEL PLATING

Nickel–ceramic composites applied via conventional electroplating over piston skirts slid against aluminum and cast iron bores have been investigated.6 these coatings varied in thickness depending on the coating and particles used in suspension during electroplating. Coating thickness between 6 and
25 mm were investigated with hardnesses of 5–6 GPa. It was found that Ni–P–BN has better selflubricating properties than Ni–P–SiC or Ni–P–Si3N4 coatings and exhibits low wear when slid against cast iron and aluminum liners. Counter face wear was reduced when commercially available composite polymer coatings were used. These coatings were applied onto the piston skirts by either screen printing or a spray process, and their thickness was approximately 25 mm. Their tribological properties were investigated over hard-anodized piston skirt surfaces, and it was found that the anodizing plays an important role to durability of the coating under starved lubrication conditions. [6]

III. DLC (DIAMOND LIKE CARBON) COATING

The DLC was an amorphous hydrogenated carbon (a-C : H) that was deposited by reactive sputter deposition using a carbon target and an Ar–CH4 gas plasma. The Ar and CH4 flow rates were 70 and 12 sccm, respectively. The graphite–resin consists of a high temperature-resistant resin with graphite that is applied by spray or silk screen printing. In paper [6] author extracted piston skirt segments from a commercial aluminum alloy piston were coated with a diamond-like carbon (DLC) coating, a graphite–resin coating or a nickel–polytetrafluoroethylene (Ni–PTFE) coating and were tribologically tested using a reciprocating laboratory test rig against commercial grey cast iron liner segments. The tribological tests used commercial synthetic motor oil at a temperature of 120 _C with a 20mm stroke length at a reciprocating frequency of 2 Hz. Results showed that the graphite–resin coating, although it may serve as a good break-in coating, wears rapidly. The Ni–PTFE coating showed friction reduction, whereas the DLC coating wore off quickly due to its small thickness. Furthermore, the higher hardness of the DLC coating relative to the cast iron liner surface led to pronounced changes on the liner counter face by polishing. In contrast with the uncoated piston skirt segments, all of the coatings prevented the formation of a visible tribochemical film on the cast iron surface.[6] author [6] resulted from experiment ,While coatings can be beneficial, their selection should be guided by surface roughness, clearance, piston skirt design and operational specifications of the engine. The Ni–PTFE coating used in formulated 10W30 oil showed a friction reduction compared with the uncoated sample. The DLC coating exhibited stable friction throughout with little initial wear. However, longer testing produced complete coating removal due to wear. Furthermore, due to its higher hardness and possibly harder wear debris, it caused polishing wear of the grey cast iron counter face. It was found that most of the wear for all samples, except for the sample coated with graphite–resin, occurs at the beginning of the tests up to 20 min, and little mass loss is accumulated beyond that. Coating thickness would play an important role in the tribological behavior or components, and the original profile of the commercial piston skirt may not be the most effective for lubrication, and a smoother surface topography may be desirable.

IV. LASER TREATMENTS

Laser treatments are widely used for surface modifications, from surface alloying to surface shock hardening to improve surface properties of sliding machine parts. Thus, laser surface treatments gain an increasing significance in the automotive industry. A wide range of automotive parts, from brake drums to engine parts, are laser treated to alter the surface and near surface properties of the materials. Or which is used by a large European automotive manufacturer– a special laser surface treatment on the cast iron V-block engines to alter the properties of the cylinder bores. Due to the laser treatment, the area near the surface of the cylinder bore becomes harder and more wear resistant. Furthermore, due to the inhomogenity of the pearlitic matrix and carbon lamellae, oil reserving holes are formed. This treatment results in an increased power output and reduced oil consumption [7].The goal of the laser treatment is to melt a thin layer of the surface. At the same time, the laser induced plasma over the surface evaporates the graphite lamellae, deeper than the metallic surface itself. So these "holes" are practically noncommunicating oil reservoirs. From the experiment author [7] drawn the following conclusions. Due to the laser treatment of the honed surface of pearlitic cast iron with graphite lamellaes. The top layer melts and an ultra fine grained structure was formed.[7]

Over the past decades, tribologists and lubrication engineers have been interested in surface modification for friction reduction and improved wear resistance. It is said that the surface is a novel material. Creating surfaces with controlled micro-geometry features is an effective method to improve tribological performance of sliding surfaces. In recent years, surface texturing has received a great deal of attention as a viable means to enhance the tribological performance of mechanical components; a large number of research studies have been carried out worldwide.[11-13].The current studies focus on the influence of texturing on the performance of various friction systems in internal combustion engines[10].

Handbook of lubrication shows that optimum conventional untextured barrel-shaped piston ring was compared with an optimum surface textured cylindrical piston ring in firing diesel engine, resulting in 4 % improvement in fuel consumption with optimum flat structured ring.[14]

Marian victor [14] described that textured surfaces create a lubrication film, which produces a load carrying capacity when there is no condition for the wedge effect. it leads to an improvement of fuel consumption in the case of internal combustion engines by texturing the rings or the liner ,their durability increases. It is well known that friction forces present an essential factor in fuel consumption and performance of the engine. It was established that about 40 percent of the friction losses of the engine are due to the contact of the piston ring and liner, so a reduction of this force is crucial. The texturing of the rings has positive effects: - the reduction of friction between the piston and the rings the good functions in conditions of "starvation", because of the properties of oil retention of the dimples. By surface texturing, the friction coefficient decreases by 20 to 30 percent. Textured surfaces generate a load carrying capacity even between two parallel surfaces. The friction forces can be reduced in the case of the piston – liner contact and consequently the fuel consumption[14]

V. CHROME COATINGS

Various surface treatment methods are currently used on cylinder piston group (CPG) components to increase service life of internal combustion engines and improve efficiency. Galvanic chrome plating of piston rings is the most common way to improve engine performance. Hard chrome electroplating reduces friction and increases wear resistance of the cylinder working surface, thereby increasing service life of medium speed engines to 20,000 hours [15]. Nearly 15 to 20% of piston rings produced in the world are manufactured with hard chrome plating. Disadvantages of galvanic chrome plating include difficult burnishing, low heat stability, poor oil adhesion on its surface, high internal stress (which leads to cracking and chipping), and formation of large amounts of aqueous waste containing highly toxic Cr (VI) in the chrome-electroplating process[16-19]. While improvements in galvanic chrome plating technology are being made, alternative methods to apply chromium and chromium-nitride (CrN) coatings have been developed including vacuum, flame, plasma, and electric arc. Antifriction coatings based on diamond-like carbon (DLC), metal containing diamond-like carbon (Me-DLC), and a number of similar composite materials are often used in industry[16-19]. Limitations of most industrial DLC coatings coatings are poor adhesion, high internal stresses, and low bearing capacity[17]. Adhesion of Me- DLC coatings is better, but they are relatively unstable under intense stress[17-18]. Further improvement can be achieved using a multilayer coating combining the useful properties of carbon and metal; for example, multilayer chromium-carbide coatings (CCC) on piston rings [19-21]. Optimizing coating structure increases abrasion and corrosion resistance and reduces friction [22,23]. Multilayer CCC have been produced using physical vapor deposition (PVD), such as magnetron sputtering technique.

Author of paper [24] in his paper deals with testing of hard chromium coatings, which are used for piston rings. There were tested the standard hard chromium, porous chromium and composite chromium coatings. Wear resistance was tested by pin-on-disc method and by engine test. Coatings for pin-on-disc test were deposited on a steel plate. Al_2O_3 and WC balls were used as a counter part. Engine test of coatings was performed on a diesel passenger car engine. Coating used for engine test were applied to piston rings made of ductile cast iron. The engine was tested on a engine test bench. The evaluation was performed by optical microscope. Loss of material on the piston rings was measured by micrometer. The standard hard chromium coating showed the highest wear so results were related to this coating. The rate of wear depends on the type of counter part. Results of individual test methods are not sometimes comparable.

Hard chromium coatings Hard chrome plating of piston rings was introduced during World War II. The first use was for aircraft engines. The reason was significant reduction of wear and friction in piston ring – cylinder system. At present, hard chromium is still used as a surface treatment of working surface of piston rings for both gasoline and diesel engines and for some compressors. Chrome plated are cast iron and steel piston rings. Because of ever increasing requirement for combustion engines and components life, the hard chrome coating is no longer satisfactory. The advantages of Cr coating applies only to certain thermal and mechanical loads of piston ring. Exceeding these conditions, there is a risk of disorder of the lubricating film. To improve the properties of chromium coating is used porous chromium. The microscopic cracks in the chromium holds lubricant. Another improvement is the addition of hard filler in chromium matrix. The first was used Al2O3 (company Goetze). [24]

Piston rings provide a seal between the engine piston and the cylinder wall. Since the advent of hard chromium plating on these components the service life of the rings has been dramatically improved. Hard chromium provides excellent wear resistance and low coefficient of friction that is especially important in engine applications.[25]

Diesel cylinder liners are hard chromium plated to provide excellent wear resistance and a low coefficient of friction. The need to replace these components has been greatly reduced since the advent of this surface coating.[25]

VI. COMPARISON BETWEEN CRN (CHROMIUM-NICKLE) COATING, DLC(DIAMOND LIKE CARBON) COATING AND LST

I. Etsion a designed a piston pin test rig was designed and built to allow investigation of the effect of different surface engineering techniques on the tribological performance of piston pins. Preliminary tests proved the concept and demonstrated the capabilities of the rig in terms of loads, speeds and lubricant supply. Three different surface treatments for piston pins namely, CrN coating, DLC coating and LST were tested in comparison with a standard reference pin. All three treatments gave, with SN90 base oil, similar lower friction compared to the reference pin up to a normal load of 900 N. The LST performed best at loads above 1000 N. Scuffing load with the LST pin and with SN90 base oil was 1450 N, representing 38% improvement over the reference pin and CrN coating, and 20% improvement over the DLC coating. With formulated 20W50 engine oil all the four pins reached the 1950 N load limit of the test rig without scuffing. At this maximum load, which corresponds to a contact pressure of 32.5 MPa, the LST performed only slightly better resulting in about 10% lower friction than both the reference and CrN coated pins, and about 5% lower friction than the DLC coated pin. The LST also resulted in 3–6 ◦C lower temperature than the other pins.[26]

VII. CONCLUSION

Different well known technique for surface modification studied in the paper. The effect of surface modification of piston cylinder linear and piston ring was analyzed by different researcher. The following conclusions summarize the results of the present study:

Textured surfaces generate a load carrying capacity even between two parallel surfaces. The friction forces can be reduced in the case of the piston – liner contact and consequently the fuel consumption by LST.

hard chromium plating on piston ring improve the service life of the rings. chromium provides excellent wear resistance and low coefficient of friction.

The Ni–PTFE coating showed friction reduction, whereas the DLC coating wore off quickly due to its small thickness. Furthermore, the higher hardness of the DLC coating relative to the cast iron liner surface led to pronounced changes on the liner counter face by polishing.

In contrast with the uncoated piston skirt segments, all of the coatings prevented the formation of a visible tribochemical film on the cast iron surface.

Coating thickness would play an important role in the tribological behavior or components. Selection of the coating affected by surface roughness, clearance, piston skirt design and operational specifications of the engine.

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