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APPLICATION OF LOW FRICTION COATING IN I.C. ENGINE

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ABSTRACT :- *Engine developers and lubricant formulators are constantly improving the performance of internal combustions engines by reducing the power losses and emissions. The majority of the mechanical frictional losses generated in an engine can be attributed to the main tribological components of an engine, the valve train, piston assembly and engine bearings. Around 13 to 18% frictional losses are observed in automotive vehicles. Approximately 40 to 50 % losses of total losses are contributed by only PRA system. If these losses are reduced even by in turn of 1%, it may results in saving of scare petroleum fuels. However no single method has been developed to measure the friction loss contribution of each component simultaneously in a firing engine. In this paper, low friction coating methods are studied for engine performance and wear.*

KEY WORDS: *Friction, wear, LFC, PVD, DLC, Diesel engine,*

INTRODUCTION

IC engine was invented two centuries back. In these two centuries more and more improvements were carried out and this process is still continuing. Referring to present scenario of energy crisis and environment pollution it has become a need, to check possibilities for improving fuel efficiency by decreasing losses, to make more environment friendly vehicle by decreasing pollutants and to check other options means alternative fuels to run an engine.

TRIBOLOGY AND SURFACE ENGINEERING

Wear and friction both with lubrication form the scientific discipline called tribology. A major area of tribology is to design surfaces sliding and rolling against each other in such a way that friction and wear is optimized. By reducing friction and wear many benefits like, economic and environmental, can be achieved in several technological fields of application. Less wear means that the interval between maintaining and even replacing expensive machines will be expand. Besides saving rare and valuable natural resources this also means that the production stops will be less. Low friction between the contacting surfaces in a engine results in reduce energy losses and there by less fuel consumption and less heat generation.
The low friction coating of a functional material is today successfully functional in various fields of technology such as electrical equipment, optical devices as well as in engine. Depending on the application, pure metals or reaction products, often ceramics, are used as coating material. Low friction 8coating gives the many advantages. Both batch and surface properties can be optimized at the same time and, moreover, materials that are not possible to integrate in any other way can be used as coating material. Another advantage is that also costly materials can be used since only very small quantity of material are needed to form the thin coatings.

WHAT IS LOW FRICTION COATING?

Now a days, thin dynamic surface coatings of many materials and for many applications have been developed. A particular group is the vapour deposited coatings. These coatings are formed on surface of the specimen that should be coated, called the substrate, from a vapour containing coating material elements. This is taking place in a chamber with moderated atmosphere at comparatively lower pressure and higher temperature. The VCD can be divided in two groups, physical vapour deposition (PVD) and chemical vapour deposition (CVD). The major difference between them is how coating materials evaporated and process temperature. Ideal deposition temperatures in PVD processes are 200 - 500 °C but recently also processes running at low temperatures have been developed. Traditionally, the temperature is in the range 600-1100 °C for thermally activated CVD processes. Today, as a result of massive research, in CVD processes where reaction is activated by like, plasma or laser at significantly less temperatures are available. Other low friction coating techniques are discussed in further

TYPES OF LOW FRICTION COATING

1. Anodizing LFC.
2. Dry film lubricants LFC.
3. Graphite LFC.

4. Mos2 LFC (molybdenum disulfide).
5. Plating LFC.
6. Teflon LFC.
7. Thermal spray LFC.
8. Deposition LFC Vapour
9. Ws2 LFC (tungsten disulfide).
10. Nitriding

ADVANTAGES OF LOW FRICTION COATING

- Reduction of friction and wear.
- Constant friction values with low variation.
- Application under most severe conditions like temperature, vacuum and dust.
- In many cases lifetime lubrication without oil and grease.
- Support for oil and grease lubrication, thus improved running-in of machine elements and emergency running properties.
- Suitable for all materials such as metals, plastics, elastomers and wood.
- Excellent corrosion protection.
- Reduction of vibrational friction wear (contact corrosion).
- Thin layers can be obtained (5 – 30 µm).
- Coverage rate amounts to an average of 15 m2/kg.
- Bonded lubricant coatings can be re-varnished.
- No hydrogen embrittlement.
- Improved assembly of machine elements.
- Minimization of maintenance costs.
- Mineral oil and chemical resistant coatings possible.
- Clean application, no contamination of the friction point and surroundings.

LITERATURE SURVEY

As per **Kenneth Holmberg, Peter Andersson, Ali Erdemir** research in global energy consumption due to friction in passenger cars, reached the following conclusions:

One-third of the fuel energy is used to overcome friction in theengine, transmission, tires, and brakes. The direct frictional losses, with braking friction excluded, are 28% of the fuel energy. In total, 21.5% of the fuel energy is used to move the car.

Worldwide, 208,000 million litres of fuel (gasoline and diesel)was used in 2009 to overcome friction in passenger cars. This equals 360 Mtoe/a or 7.3 million TJ/a. Reductions in frictional losses will have a threefold improvement in fuel economy, as it will reduce both the exhaust and cooling losses also at the same ratio.

Globally, one passenger car uses on average 340 l of fuel peryear to overcome friction, which would cost 510 euros according to the average European gas price in 2011 and corresponds to an average driving distance of 13,000 km/a.

By taking advantage of new technology for friction reductionin passenger cars, friction losses could be reduced by 18% in the short term (5–10 years) and by 61% in the long term (15–25 years).

Potential mechanisms to reduce friction in passenger cars include the use of advanced coatings and surface texturing on engine and transmission components, low-viscosity and low-shear lubricants and novel additives, and tires with reduced width and increased pressure for lower rolling friction.

Paulo j. R. Mordenteand**Rafael Antonio Bruno**investigate that experimental approach showed that CrN by PVD isa better solution in comparison to regular GNS rings because the applied coating lead to a wear reduction of60% on the contact surface and 10% lower frictionlosses. This friction impact can lead to a reduction of 0.7% on calculated fuel consumption. Such advantage is obtained without jeopardizing the lubrication oil consumption and blow by.

J. Vetter, G. Barbezat, J. Crummenauer, J. Avissar show that Piston rings have to seal the combustion gas and to controlthe lubrication oil. The surface treatment is used to reducewear and to prevent seizure. A variety of piston rings existsfor different applications. Besides the different substratematerials, also different surface treatments are used. Fig. 2shows surface treatments developed and/or

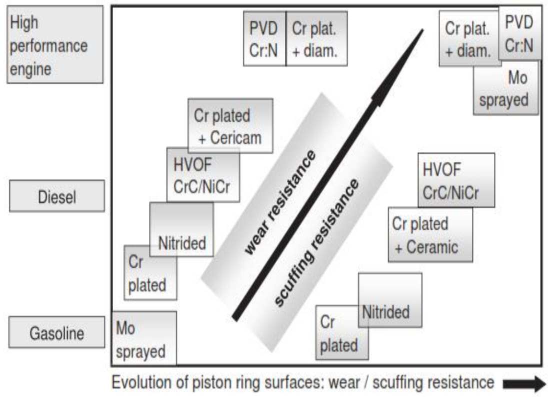
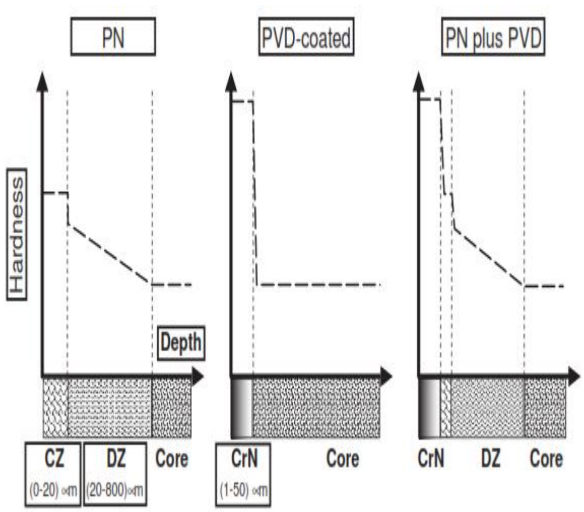


Fig. 2 Different piston ring treatments and the trend of the wear and scuffing resistance, where, HVOF: High Velocity Oxygen Fuel spray; Cr plat. +diam.: Cr plated+ diamond

Fig. 3. Hardness versus distance from the surface for soft steels with a plasma nitriding treatment (PN), PVD coating, and combination nitriding plus PVD coating, where, CZ: compound zone, DZ: diffusion zone.

applied over thepast 20 years. Today nearly all these treatments are in theindustrial praxis. Depending on the application and themanufacturing costs, spraying, galvanizing, nitriding, PVDcoatings and the combination nitriding plus PVD coating areused. The most expensive method is the PVD-method. About10–50 um thick Cr-based coatings are deposited mostly byvacuum arc evaporation.



PVD coatings are more wear resistant. The combination of nitriding and PVD provides a product superior to both. Fig. 3shows the change in hardness as a function of the distance from the surface for the separate treatments and the combined treatment. The nitriding before the deposition of the hard coating increases the load bearing capacity of the coating-substrate-system. This combination treatment is industrially used for high loaded piston rings.

PVD coatings become more and more interesting not only for decoration, but also for high loaded parts like piston rings. DLC coatings still have a high potential for lubrication reduction and or for the increase of the load, e.g. for gears.

P.N. Bindumadhavan, S. Makesh, N. Gowrishankar, Heng Keng Wah, O. Prabhakar investigate the surface hardness of the two plain carbon low alloy steels could be increased by nearly a factor of two when aluminized and nitrided as compared to plain nitriding.The case depth obtained compares well with thegeneral requirements of case depth on nitrided piston rings.The final nitrided depth of the component can becontrolled by controlling the initial aluminizing conditions,especially the Si content in the aluminizing bath.The Al concentration profile differed from the theoretically predictedprofile. This difference could be attributed tothe fact that Al diffuses through a complex combinationof ternary Fe-Al-Si and binary Fe-Al phases, andthe presence of Si in the alloy layer, which tends toinhibit Al diffusion. X-Ray diffraction studies have confirmed the presenceof AlN in the alloy layer and this could beinstrumental in the significant increase of surface hardnessin the two steels, when aluminized and nitrided.

Jianliang Lin, Ronghua Wei, Daniel Christopher Bitsis, Peter M. Lee carried out Development and evaluation of low friction TiSiCN nanocompositecoatings for piston ring applications. They investigate optimized TiSiCN coatings exhibited a typicalnanocomposite structure which showed excellent adhesion and dry COF in the range of 0.17 to 0.2 using a ball-on-disk tribometer. The tribological performance of the coated piston rings was evaluated using Plint TE77tests in SAE 10W-30 diesel engine oil. The TE77 tests showed a 10% reduction in the COF (0.058) of the optimized coating compared to the uncoated baseline (0.065) at test conditions of 20 Hz, 30 N, and 25 mm stroke length. Finally, the coated rings were evaluated in a single cylinder gasoline engine using SAE 5W-20 engine oil and in a heavy duty diesel engine using 4.1% sooted SAE 10W-30 diesel engine oil. The gasoline engine test showed that the uncoated piston rings contributed 25% to 34% of the frictional loss in two separate baseline engine tests. In contrast, the coated rings contributed to 18% of the total frictional loss in the engine test. The diesel engine durability test showed a 28% and 40% lower ring weight loss for the coated top and second rings, respectively, as compared to the uncoated baseline. In addition, the cylinder liner, which was not coated, showed an average 50% lower wear than that in the uncoated baseline engine test.

Carlos Eduardo Pinedo investigate the performance of selective plasma nitrided rings is superior to the gas nitrided counterpart. The wear rate is 30% higher for the plasma nitrided rings, but acceptable for practical purposes.

The plasma nitriding process is effective for removal of the passive film and homogeneously nitriding piston rings after hydrogen sputtering. The process avoids the compound layer formation and precipitation of grain boundary nitrides on the diffusion zone. The hardening effect is enough to increase the hardness up to 1100 HV0.1, without impairing the core hardness. Selective nitriding devices were developed in order to avoid the nitriding of the ring side surfaces and to optimise the performance of the pistonring system. Comparable nitriding response was obtained on inner and outer diameter surfaces, regarding microstructure and hardening effect.

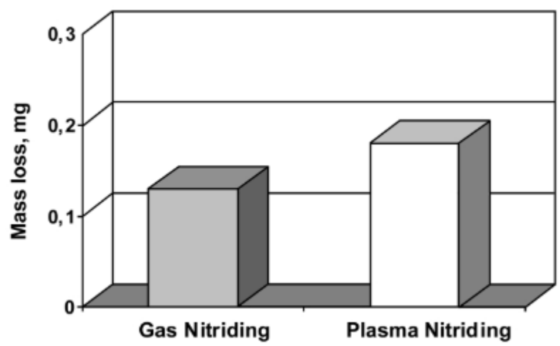


Fig. 4. Wear resistance on scuffing test for piston rings after gas and plasma nitriding.

Superior results of plasma nitrided rings on mechanical tests, compared to the gas nitrided ones, are a consequence of the best diffusion zone microstructure and selective nitriding. The wear rate for plasma nitriding is lower than that found for gas nitrided rings, but still acceptable by the manufacturer and for the application.

A. Borghi, E. Gualtieri, D. Marchetto, L. Moretti, S. Valeri, Tribological effects of micro dimpling on 30NiCrMo12 nitriding steel were investigated by measuring friction coefficients with a pin-on-disc machine. Under similar operating conditions, texturing was observed to reduce friction coefficient and wear, with respect to untextured surface. In "single drop" configuration, for normal loads larger than 3 N, friction coefficient is reduced of about 75% from untextured to textured surface (roughly from 0.8 to 0.2, respectively). Stribeck curve summarizes the friction measurements for untextured and textured surfaces pointing out that textured surfaces avoid the transition from hydrodynamic to mix or boundary lubrication regime: for all loads and velocities tested, the system operates in hydrodynamic regime. Long sliding condition test shows that micro dimples guarantee low and constant friction coefficient value for a long time.
In "dry contact" configuration, for a normal load of 1 N, friction coefficient is reduced of about 10% from untextured to textured surface. Debris are observed in contact region between pin and disc. In the case of textured surface they fill pores and this process contributes to the improved tribological performances of those surfaces. In the case of untextured surface, on the contrary, debris at the interface between the two contact surfaces increase friction coefficient and accelerate wear. In conclusion, good results obtained in "single drop" lubrication could suggest the idea of replacing buffer materials for engine components working in similar operating conditions, like piston pin and connecting rod, with metal-to-metal contacts treated by LST technique.

Andre Ferrarese, Robert Richard Banfield and Eduardo Tomanik in MAHLE Brazil Tech Center investigation suggest that high value PVD gives the supreme performance in High Speed Diesel engines as observed in Heavy Duty Diesel engines.

As passenger car engines are pointing out similar operating trends, but cost is a stronger concern, MAHLE has developed aHigh Value variant, applying the PVD on a less costly base material, ductile cast iron.

PVD showed to be the best coating for rings in terms of wear for bench and engine tests. Such wear resistance is in this case combined with excellent liner compatibility. Scuffing abusive tests showed that PVD is also more resistant than galvanic chromium based coatings.

As per investigation of **Roy Kamo, Walter Bryzik and Michael Reid, Melvin Woods**, It is concluded that the application of a thermalbarrier coatings to the cylinder liner produced a reduction in fuel consumption and was more effective from a performance viewpoint than applying thin thermal barrier coatings to the piston and cylinder headface surfaces.It is concluded that further analysis is required to assess the relationship between various operating conditions and the surface insulation requirements necessary to produce fuel consumption and heat rejection performance improvements.It is further recommended that the baseline and thin thermal barrier coatings be further evaluated using a conventionally cooled type of engine configuration as opposed to a partially air gap insulated partially cooled type.

As per **General Motors Research and Development Center**, The friction coefficient, μ, for a DLC coating applied to a pin, and run against an aluminum-390 disk, under unlubricated conditions, was 0.4 for 11,000 cycles over the Hertzian contact pressure range of 12.4 to 17.3 MPa. This value of μ compares to 0.5 for the cast iron/aluminum-390 material couple and is 50% lower than the critical friction coefficient value of 0.8 where scuffing occurs on the bench test.

For a DLC coated disk running against analuminum-390 pin under unlubricated conditions, the value of μ was 0.5 for Hertzian contact pressures up to 40 MPa and 11,000 cycles.

Thermal cycling the DLC coating between -74°C and peak temperatures as high as 300°C did not affect its adhesion to the aluminum-390 substrate. Pitting of the DLC coating started at 400°C.

Ali Erdemir and George R. Fenske investigate, Argonne's low friction carbon coating has a significant impact on friction and wearbehaviour of steel surfaces in both synthetic and mineral oils. The three variations of the coating evaluated produced a modest reduction in friction coefficient, because the friction in lubricated contact is often dominated by the contribution of the lubricant fluid film. The coatings all have a significant impact on wear.

Little or no wear occurred in all the coatings when slid against both coated and uncoated surfaces. More significant, all the coatings protected the uncoated counter face against wear. Thisfinding suggeststhat coating only one of the contacting surfaces with ANL's low-friction carbon coating is as effective as coating both surfaces in minimizing wear of lubricated components. The coatings are equally effective in both synthetic and mineral oil, as well as fully formulated and base-stock oils.

As per researched of **Yoshiteru Yasuda, Makoto Kano at Nissan Motor Co., Ltd**. Under a boundary lubrication condition, the friction coefficient of DLC coatings decreased with lower hydrogen content. The PVD-DLC coating, prepared by arc-ion plating and containing the least hydrogen, showed the lowest friction coefficient of the tested coatings in a pin-on-disk test.

Results obtained with a valve train friction bench test rig indicate that an arc ion-plated DLC coating on a valve lifter can reduce friction loss by almost 45% compared with a phosphated steel valve lifter in a conventional valve train. This paper has shown that PVD-DLC coatings improve the friction condition at the cam/follower interface in a bucket-type valve train. These coatings have the potential for use in a bucket-type valve train, achieving friction and wear performance that compares favourably with that of the roller follower type.

CONCLUSION

By using advanced techniques of surface coating like, PVD, DLC, TiSiCN, aluminizing, nitriding, plasma nitriding, thermal barrier coating can be reduce friction and wear in engine and transmission component.

It helps to achieving higher fuel economy and longer component life cycle due to reduced friction and wear.

So based upon the research and tests conducted it can be concluded that by use of surface treatment methods like PVD, DLC, TiSiCN, aluminizing, nitriding, plasma nitriding, thermal barrier coating the friction power of the engine can be reduced which will lead to improved brake thermal efficiency, fuel economy and engine output.

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