TYPES OF PISTON RING COATING TECHNIQUES- A REVIEW

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Abstract: In the current scenario, there is a global drive for light as well as heavy duty vehicles to meet the legal norms of vehicle emissions. The surface engineering approach has emerged to be the possible solutionwhich is attracting increasing attention worldwide. Through this approach certain light weight alloys such as Mo, CrC are employed to utilise the best of their properties towards fuel and energy saving thereby enhancing the overall engine life. This review paper caters to give an idea of broad category of different coating techniques that are currently being adopted by industries in the application of piston ring coating in order to increase engine efficiency and life. The paper also highlights the effect of different coating technique on the tribological behaviour of the piston ring such as wear resistance, surface morphology, surface hardness, adhesion, coefficient of friction etc. Apart from that, this paper also demonstrates the relative significance of coating techniques in the current piston ring industry.

Key words: piston ring, coatings, thermal spray

1. INTRODUCTION

Current day sector of automobile industry is relatively more technologically demanding sector as compared to the rest of the sectors. To enhance the fuel efficiency, lower emissions, reduce weight, rendering multi-purpose functional performance and comfort with reduced economic input and energy, various new materials and technologies are explored. Diverse range of technologies such as laser deposition, thermal spray coatings (high-velocity oxyfuel, plasma spray, detonation spray, wire arc), vapour based (chemical and physical vapour, nitrocarburizing, plasma nitriding) and electrolytic methods (electroless deposition, electrodeposition, micro arc oxidation/ plasma electrolytic oxidation, pulsed electrodeposition) are been explored and considered as potential techniques to cater to diverse range of automotive applications. The coatings mentioned above vary from each other in respect of structure, composition, thereby resulting in varying functional properties. Moreover, coating techniques also differ in various respects such as coating thickness, component geometry and size, substrate temperature et al.[1],[2]. In the present paper, an overview is presented of some of the coating techniques which have recently been adopted in piston ring industry or which are considered to be emergent.

2. COATING TECHNIQUES

2.1 THERMAL SPRAY TECHNIQUES

Thermal spray is defined as the technique of applying certain coatings which takes place by means of special devices/systems through which melted or molten spray material is propelled at high speed onto a cleaned and prepared component surface[3]. Developments in the field of thermal spray technique such as in the equipment, feedstock powders (its shape and type), process control and management have allowed to diverse the process there by developing various new techniques as shown in fig 1.[4].
There are different types of thermal spray coating techniques which provide a wide variety of industrial applications as well as process easiness according to the need, such as, High-velocity oxy- fuel process. This process is believed to produce better metal-carbide cermet coating having high

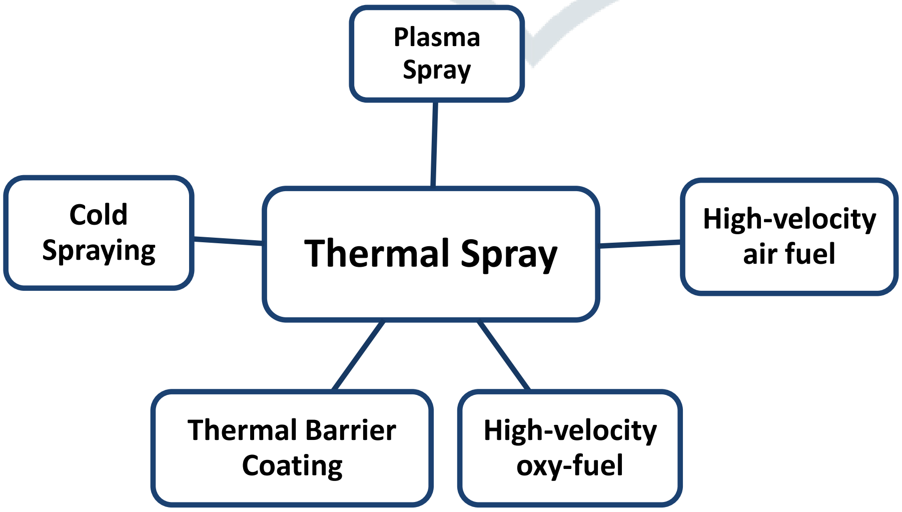

Figure 1 Types of Thermal Spray Techniques

hardness, high density, high bond strength, lower porosity and minimum decarburization than other thermal spray techniques[5],[6]. High velocity oxy fuel has emerged as the most promising technique for depositing a coating of $Cr_{17.7}Mo_{7.4}B_{15.2}Si_{2.4}Fe_{49.7}Mn_{1.9}W_{1.6}C_{3.8}$[4],[7].

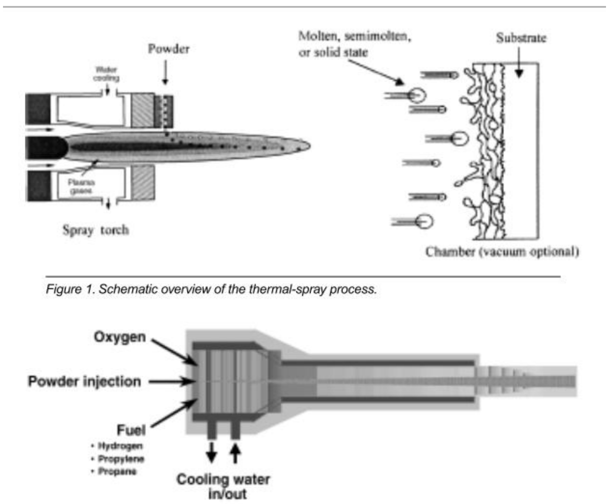

Figure 2 Schematic Overview of High-velocity Oxy-fuel process and illustration of HVOF spray torch.[8]

The newly developed thermal spray technique, which is, Solution Precursor Plasma Spray (SPSS) process, prevents the utilisation of costly feedstock powders and enhances the ability for the formation of nanostructures and thereby creating more opportunities for the deposition of thermal barrier coatings[9],[10].

Another type of thermal spray process is cold spraying technique which is also known as a cold gas dynamic spray as well as kinetic spray technique. Cold spray technique works through severe plastic deformation of mainly ductile materials by employing kinetic energy to in-flight feedstock particles rather than providing thermal energy as in the case of thermal spray process. It is used to produce coatings which cater to enhance tensile, fatigue, wear and corrosion resistance of metallic components [11],[12],[13],[14].

2.2. LASER ENGINEERED SURFACES

There are numerous different techniques employed by various industries to use laser technology for coating deposition. One such technology is Laser surface cladding or Laser surface texturing which is widely used to deposit several hundreds of micron thick coatings for restoring the right components as well as to yield heat resistant surfaces for light metal alloys[15],[16],[17].In Laser Surface Texturing, a pulsating beam is used to create thousands of micro-dimples on a surface by a material ablation process. These dimples generate hydrodynamic pressure between oil-lubricated parallel sliding surfaces[18].

The reason why these laser techniques are gaining such popularity in coating industry is that of the number of advantages these techniques used to offer. Such as they not only enhance the hydrodynamic load support but the dimples function as wear traps and also as lubricant reservoir thereby minimising the coefficient of friction and overall wear rate in piston ring/cylinder liner assembly and thus yielding highly efficient operation of diesel/petrol engines.

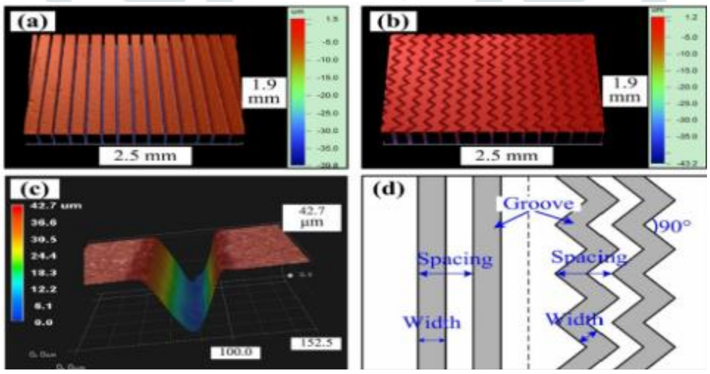

Figure 33-Dimensional surface topographies and schematic diagram of the textures. [19]

2.3. PULSE ELECTRO-DEPOSITED COATINGS

Pulse Electro-deposition is the technique in which current is imposed in a periodic manner with a rectangular waveform, is a powerful means for controlling the electro crystallisation process and producing deposits with unique structure and properties. PED technique uses the pulsating current to adjust the grain size and composition of the deposit around its thickness thus controlling film properties[20]. For example, on a comparison between Zn coating deposited using traditional DC plating and Zn coating deposited using pulse reverse condition exhibit high corrosion resistant and exhibit less porosity. Moreover, the ability of this technique to precisely manipulate the grain size of the deposit allows producing coatings having different mechanical properties. Following this approach, it has been observed that the hardness of the PED Nickel coating can be enhancedupto ~600 kg/mm^2. Apart from that, attempts are being made by researchers to enhance wear resistance, hardness, corrosion reduction with reduction in friction through nano-crystalline coatings such as Ni-W, Ni-Co-SiC, Ni-W-SiC

and Ni based composite coating to supersede hard chromium coatings which are widely used in automotive industry[21],[22],[23],[24].Also, the fact that this technique is gaining popularity among industries for piston ring coating is because of its cost effectiveness.[25]

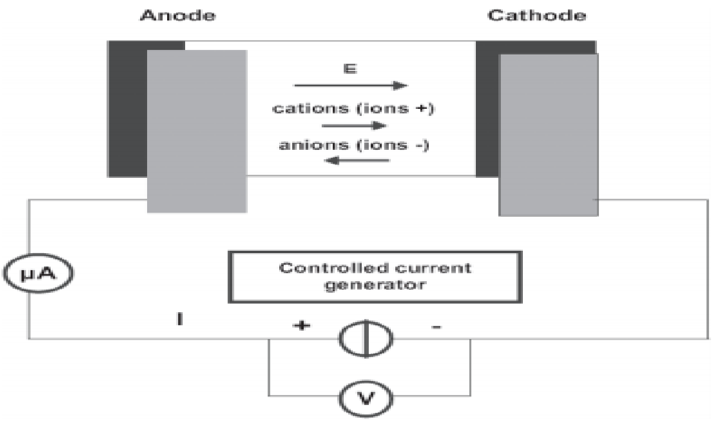

Figure 4 General Schematic diagram of Electro deposition Coating[25]

2.4. MICRO ARC OXIDATION COATINGS

The micro arc oxidation (MAO) coating technology which is also known by a different name of Plasma Electrolytic Oxidation (PEO), uses an environmentallysolid alkaline electrolyte and pulsed AC Power supply to form completely crystalline, dense, hard, corrosion and wear resistant coatings on numerous variety of Al, Zr. Ti and Mg alloys and also including the conventional alloys which were hard to anodise[26],[27],[28],[29]. Numerous automotive applications are emerging particularly associated with the engine because of superior heat shielding, corrosion and wear resistance characteristics of MAO deposited ceramic coatings on the cast and machined Al-Si alloys. MAO coated components such as cylinder heads, cylinder bores, pistons, valve, valve stems, fuel injection ports, valve guides and exhaust channels have shown considerable promise of commercialization[30],[31],[32],[33],[34]. Moreover, the capability to orient coating composition through the introduction of various electrolytic constituents or by channelizing the MAO technology with other dissimilar technologies such as sol-gel, cold spray,et al. to form duplex coatings with unique properties have opened new horizons for the automotive industry[35].

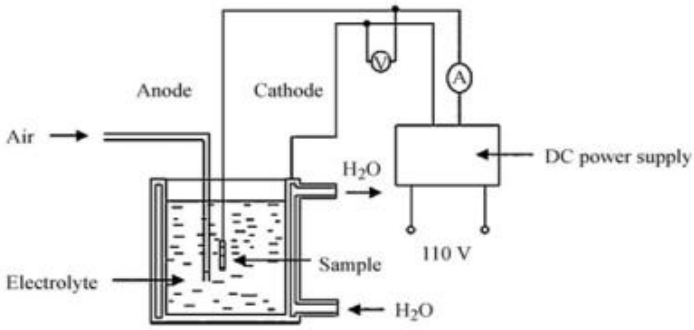

Figure 5 Schematic representation of micro-arc oxidation[36]

2.5. VAPOUR DEPOSITED COATING

Physical and chemical vapour deposition technique is used to produce Diamond like coatings which have already found application in a great variety of automotive industry such as a bucket, fuel injection system, tappets, piston pins and rings, bearing and gears. One of the most advantageous properties of DLC films is low CoF under sliding wear conditions. Because of the property mentioned above, DLC coatings are employed in numerous applications such as differential gears of SUV; torque controlled coupling clutches, forks of bikes, valve lifters and suspensions of luxury vehicles[37],[38]. Apart from this, another type of DLC coating, also known as super hard DLC coating having reduced percentage of hydrogen content which is deposited by magnetron sputtering in large scale installations have also found applications whose main objective is to reduce friction and increase wear protection. In addition to that, vapour deposited CrAlN. WC/C coatings are also under investigation especially for high load bearing lubricated tribo-contact applications[39].

The observed capability of the plasma nitriding treatment to improve fatigue, wear and corrosion properties of substrate materials such as ferrous alloys including martensitic and austenitic stainless steels[40],[41] as well as titanium[42] and aluminium[43] has made it an interesting process to protect clutch discs, piston rings and gears. Furthermore, the IONIT-OX process, which in fact is a combined technique of plasma activation, thermos-chemical oxidation and nitro-carburizinghave shown considerable prove of life enhancement of a wide range of components such as brake parts, ball pivots, synchronisation rings and differential gear shaft[44].

It is also apt to mention here that there are materials which are difficult to machine, for example, graphitic iron which is desirable material in the automotive industry[45], can now be machined using the PVD coated and nitride/nitro carburised tools. Apart from handling difficult to machine materials using coated tools, certain other requirements such as imparting decorative, optical, electromagnetic, electrical and signal processing properties are also met by employing diverse films[45],[46].

3. CONCLUSION

The field of surface engineering has undergone various changes to adopt newer technology and its variants, feedstock's, process control tools, precise part manipulation during processing,et al. to make it cost effective to address the high volume of requirement which is typically demanded by the automotive industry.

These developments have also improved the ability to conceptualise and implement oriented technology for particular use. One such illustrative example is the development of rotating torch plasma head to deposit corrosion, wear and thermally resistant coating onto several cylinder bores.

Use of hybrid-technologies for developing novel compositions with multi-functional characteristics has served to further enhance the potential application spectrum in the automotive industry in the next decade. The increasingly stringent environmental norms that are phasing out the hitherto widely used hard chrome coatings have also fuelled greater interest in alternative techniques such as thermal spraying and pulsed electro deposition. Considerable motivation to explore techniques such as micro arc oxidation technology to deposit ultra-hard ceramic composite coatings that impart heat shielding, wear and corrosion resistant properties are provided by the growing interest of the automotive industry in the light metal alloys.

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