"Surface Coating: An Overview of Research Work"

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Abstract— Surface coating, any mixture of film-forming materials plus pigments, solvents, and other additives, which, when applied to a surface and cured or dried, yields a thin film that is functional and often decorative Surface coating is an economic method for the production of materials, tools and machine parts that require the desired surface properties such as corrosion, erosion and wear resistance. Individuals and industry tend to focus on the wearing surface that has the greatest impact on their own economic situation. Research is going on over years to reduce the corrosion, erosion and wear either in the form of using a new corrosion, erosion and wear resistant material or by improving these properties in the existing material by using surface coating methods. In this paper an attempt has been made to review the work of some researchers who conducted the experimental studies on different surface coatings, which are employed on the substrate surface of material by different methods. The various coating methods used and their advantages have been discussed.

Index Terms—Wear, Resistance, Surface coatings, Thermal Spraying, Abrasive. etc

I. INTRODUCTION

Corrosion is an unintentional gradual degradation of metal that occurs because of chemical or electrochemical attack. As a result of corrosion metal gets converted to its compounds such as oxides, chlorides, nitrides, sulphides, etc depending upon the environment. Corrosion may be classified as dry corrosion, wet corrosion and hot corrosion. Erosion is the removal of material from a surface by high velocity fluids containing solid particles, or small drops of liquid or gas. It is the progressive loss of original material from a solid surface due to mechanical interaction between that surface and a fluid, a multi-component fluid of impinging liquid or solid particles. When two surfaces are in contact, wear occurs on both of them. Wear is the predominant factor that controls the life of any machine part. Most worn parts don't fail from a single mode of wear, but from a combination of modes, such as abrasion and erosion etc. Wear is a process of removal of material from one or both of two surfaces in solid state [1]. It occurs when solid surfaces are in sliding or rolling motion relative to each other. In welldesigned tribological systems, the removal of material is usually a very slow process but it is very steady and continuous [2]. Wear related failure of machinery components counts as one of the major reasons for inefficient working of machines in a variety of engineering applications. These wear and corrosion related problems can be minimized mainly by following two methods [3]:

• By using high cost wear resistant alloys/metals better than the existing low cost ones.

• By improving the wear resistance of the existing metals and alloys by applying certain modifications to the surface. Serviceable engineering components not only rely on their bulk material properties but also on the design and characteristics of their surface [4]. The behavior of a material is therefore greatly dependent on the surface of a material, surface area in contact and the environment under which the material must operate. The surface of these components may require certain treatments (called surface engineering) to enhance the surface characteristics. The surface characteristics of engineering materials have a significant effect on the serviceability and life of a component thus cannot be neglected in design [4]. Wear resistance of materials can be improved through surface modification techniques. Surface coatings may improve the surface's resistance to corrosion, erosion, impact breaks and abrasive wear. Surface engineering can be defined as the branch of science that deals with methods for achieving the desired surface requirements and their behavior in service.

The effect of surfacing on component life and performance will depend upon the surface material, alloy, service conditions and the application process [6]. In this paper an attempt has been made to review the work of some researchers who conducted the experimental studies on different surface coatings. The various coating methods used and their advantages have been discussed.

II. SURFACE COATING METHODS

Surface coating methods are classified as under:

• Thermal Spraying (Metal Spraying)

• Chemical Vapor Deposition (CVD)

• Physical Vapor Deposition (PVD)

A. Thermal Spraying: It is a group of processes wherein a feedstock material is heated and propelled as individual particles or droplets onto a surface. Sprayed particles impinge upon the surface, they cool and build up, splat by splat, into a laminar structure forming the thermal spray coating. A detonation gun unit mainly consists of a doubled walled barrel, a combustion chamber, a powder feeder, control panels to regulate gas flows and gas operation. The set-up also includes an appropriate manipulator to hold the work piece and control its movements. A barrel is filled with a small amount of powder and an explosive oxygen- acetylene mixture. With the use of a spark plug, the mixture is ignited. After ignition, a detonation wave accelerates and heats the entrained powder particles. Instead of a continuous combustion process, it uses an intermittent series of explosions to melt and propel the particles onto the substrate. After each detonation, the barrel is purged with nitrogen. This step is essential to remove all remaining "hot" powder particles from the chamber; otherwise these can detonate the explosive mixture in an irregular fashion. With this, one detonation cycle is completed. The above procedure is repeated at a particular frequency until the required thickness of coating is deposited. The process produces noise levels that can exceed 140 decibels and requires special sound and explosion proof rooms. Depending upon the ratio of the combustion gases, the temperature of the hot gas stream can go up to 3890°C and the velocity of the shock wave can reach 3500m/s. Depending on the required coating thickness and the type of coating material the detonation spraying cycle can be repeated at the rate of 1-10 shots per second.

C. Physical Vapor Decomposition (PVD): It is based on separating atoms from surfaces and accumulating (atomic or ionic) them to sub material surface to be coated, by evaporating or sloping materials under vacuum. Coating material, in PVD method, is transmitted to surface in atomic, molecular or ionic form, obtaining it not chemically but physically from solid, liquid and gas source. Chemical reactions can exist on main material surface too colder than CVD coating (50500 °C); however such a reaction formation is no necessary. It is more interesting that PVD operation is performed in relatively lower temperatures. In addition, after completion of coating micro structure and properties of main material are not affected. PVD Method is carried out by three methods called as evaporating, dispersion and ionic coating. Advantages of Physical Vapour Decomposition (PVD) coatings are: • Covered material reaches very high surface hardness levels (3000 – 4000 HV about 85 – 90 HRC) without loss of its resistance and its abrasive resistance increases. • As coating penetrates to main material, it adheres to perfectly material and it is inseparable as result of being exposed to thermal expansion or trauma. • As thermal transmittance of coating is on low level, it can move up to high speed (approximately 30 % speed and penetration are obtained.). For this reason, work item surface becomes smooth. • Coefficient of friction on cutting edge decreases; lubricity level increases and edge accumulations don't exist in the course of cutting. • As coating thickness is between 2–15 μm, tolerances of covered items are unchanged. Tools can be used without necessity of an additional operation. • As its color is different from tools, tools wearing can be easily definable.

III: CHARACTERISTIC OF COATING METHODS

Characteristic	Thermal Spray	CVD	PVD
Equipment Cost	Low to Modera	Moderate	Moderate to High
Operating Cost	Low to Modera	Low to Moderate	Moderate to High
Substrate Temperature	Low to Modera	Moderate to High	Low
Coating Thickness	Thick 50um-cm High Coating Rates	Thin – Thick 0.1-	Very Thin to Moderate
Adherence	Good Mechanical Bond	Very Good Chemical Bond	Moderate Mechanical Bond Very Good Chemical Bond

IV. SOME STUDIES RELATED TO SURFACE COATINGS

Current research on surface coating focuses on using various coating methods, parameters, different base materials and materials to be coated. Lozano D.E., Mercado-Solis R.D. (2009) evaluated wear performance of the new hypereutectic Al-Si-Cu alloy using Pinon-disc tribometer [1]. Modern engine blocks use grey iron liners from the engine bore; however a new hypereutectic Al alloy was developed to eliminate grey iron liners from engine block. Wear evaluation was carried out at different loading conditions, various sliding speeds and various sliding distances under lubricated and un-lubricated conditions. Bobzin K., Lugscheider E. (2007) examined magnetron sputtered three (Cr 1-x Alx) N coatings on their tribological characteristics with different aluminum contents (x = 0; 0.23; 1) .The tests were performed on BoD tribometer. The ceramics Al2O3 and Si3N4 were used as counterpart materials [2]. The counterpart wear for Al2O3 was less than for Si3N4. On the contrary the highest wear rates of coated samples were measured for Al2O3. With regard to coatings, Cr 0.77 Al 0.23 N showed the lowest wear rates in all cases, though the friction coefficient of Cr 0.77 Al 0.23 N against Si3N4 was the highest. Shaffer S.J., Rogers M. J. (2007) assessed the tribological performance of a variety of coatings under un-lubricated sliding conditions [3]. Coatings types investigated include: TiCN, PTFE filled resin-bonded coatings, electro less nickel- cobalt alloy coatings, ferritic nitro-carburizing treatment etc. Substrate included medium carbon steel, D2 tool steel and 6061-T6 aluminum. The tests were run using a cylinder-on-flat geometry with self-mated coatings in both reciprocating and unidirectional conditions. These tests ranked the tribological performance of the coatings using both coefficient of friction and wear coefficient. The best performing samples were tested up to total sliding distance of 3.6 km. Sidhu et al (2003) studied and concluded that the thermal sprayed Ni3Al coatings on boiler tube steels was very effective in decreasing corrosion rate in air and molten salt at 900ºC in case of ASTM-SA210 grade A1 steel and ASTM-SA-213-T11 type of steel whereas coating was least effective for ASTM-SA-213-T22 steel [4]. They further proposed that uncoated ASTM-SA-213-T22 steel showed very poor resistance to hot corrosion in molten salt environment with spalling of oxide scale.

Singh et al (2003) investigated the NiCrAlY, Ni-20Cr, Ni3Al and satellite-6 coatings on Fe-based super alloy at temperature 900 ºC in the molten environment under cyclic conditions [5]. After performing XRD, SEM/EDAX and EPMA, they found that all these coating showed better resistance to hot corrosion as compared to that of uncoated super alloy and NiCrAlY was found to be most protective followed by Ni-20Cr coating. The Ni3Al coating was also effective in decreasing the weight gain to about one third as compared to uncoated super alloy. They further found that satellite coating was least effective but still decreases the weight gain to about 60% that of uncoated super alloy. The formation of oxides and spinels of Ni, Al, Cr or Co may be contributing to the development of hot corrosion resistance. Gulene & Kahraman (2002) examined that the abrasive wear rate can often be reduced by the application of hard materials [6]. The transition from low wear to high wear with increasing hardness of the abrasive is very instructive and abrasive wear resistance of flame sprayed coatings observed to be dependent on the chemical composition and characteristics of coating materials and coating condition. Gitanjali et al (2000) reported that by controlling the various process parameters (air /fuel ratio, temperature, pressure, etc.) of boiler and gas turbines were also useful to some extent in combating oil ash corrosion [7]. The low excess of combustion air can

V. CONCLUSION

Surface coating improves the life of the worn out component and reduces the cost of replacement. It reduces downtime by extending the service life and hence few shutdowns are required to replace them. The purpose of surface technology is to produce functionally effective surfaces. A wide range of coatings can improve the corrosion, erosion and wear resistance of materials. The various commercially viable coating techniques are thermal spraying, Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD) methods.

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