Coating on surface by different methods – A review

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ABSTRACT

The material has different properties, because of this properties material have different application. Sometime due to chemical reaction corrosion is done on material surface, due to oxide material degradation is occur and impact of solid particles on surface erosion is occur. So to increase the corrosion resistance different kind of coatings can be done on surface like steel, aluminums, alloys. This corrosion decreases the life of the material and decrease the properties. For coating deposition laser cladding, magnetron-sputtering, thermal spray (HVOF) methods are use. This coating is requiring in aerospace application, oil and gas industries, high temperature application and turbine industry.

KEYWORDS

Degradation,
Coatings,
Hot Corrosion,
Erosion,
Oxidation,
Prevention.

1. Introduction

In many equipment like power generation equipment, gas turbine, internal combustion engines, oil and gas industry hot corrosion is a very serious problem. To increase the corrosion resistance behavior for high temperature application super alloys have been developed. Sometimes fused thin film of salt covered the material surface in oxidizing atmosphere at elevated temperature, this is called as corrosion of material surface [1]. Corrosion is also defining as the physical-chemical interaction between environment and material surface, which is result into changes the material properties and also affect the function of the particular material [2]. To increase the - Corrosion resistance different types of surface treatment methods are available and previous data conclude that this method is very effective to prevent corrosion of material [3]. Like, corrosion, erosion is also affect the material properties. When the solid particle impact at metal surface with high velocity the solid particle degrades the material surface [4]. Erosion is occurring at wind turbine, marine industry, oil and gas industry. In hydro turbine erosion wear is a critical issue and it is depending upon different parameter like material hardness, concentration, water velocity etc. with the increase in erosive wear the efficiency of the hydro turbine will decrease and final breakdown is occurring [5]. It is very important to stop the erosion wear because turbine is very useful to produce large amount of energy, in 2010 81 GW of onshore and 2.9 GW of off shore wind was brought by use of 70,488 onshore turbines and 1132 wind turbine [6]. Oxidation is also occurring on surface of material, oxidation is a corrosion process in presence of oxygen between material and atmosphere [7]. Ni-Cr based material are widely used to decrease the rate of oxidation in high temperature application [8]. In aero engine hot end components thermal barrier coatings are used because of excellent adiabatic performance and high temperature oxidation resistance [9]. Coating is the process in which a layer of any material is produce on substrate material by different method to increase the properties, ability and application of the material. Because for high temperature application the material must have excellent mechanical properties and corrosion resistance [10]. There is a common solution to increase properties of material is to develop alloy with maximum mechanical properties and then deposit a protective coating [11]. In oil – gas industry the resources of raw material, oil and gas sources, market for product selling are so far from the manufacturing plant. To transport this material from one place to another place pipelines are used. Strong corrosion material like chloride ions (Cl^-), carbon dioxide (CO2), hydrogen sulphide (H2S) are available in oil and gas and they quickly degrade the pipe material and equipment [12]. From the data immersion tests of the Ni-Cr coating proved that Cr3C2-25NiCr had the slowest corrosion rate and the best corrosion resistance among the other material.

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Sadeghimeresht et al. studied about the HVOF iron-based coatings of NaCl solution and conclude that the increasing Cr content did not increase the corrosion resistance of Fe based HVOF coatings [13]. S0, in this paper how the corrosion - oxidation rate can be decrease by using coating with different method and how to improving life of material has given.

2. Coating Alloys

Different-different alloys are use in coating according to the properties of substrate material and the application of that material. From the research Aluminide coatings are widely used and it was developed by the GE research laboratory in 1911. Because aluminide has good oxidation resistance and has less cost. After that researchers try to enhance the hot corrosion resistance by applied material element like Cr, Si, Y in aluminide and found that this element could increase the rate of corrosion resistance by improving the scale of adherence or by the selective oxidation of Al [14]. Like aluminide magnesium and its alloys are also having good physical and mechanical properties (heat conductivity and electromagnetic shielding effectiveness with light weight. Magnesium have high specific strength and anti-shock resistance. Because of this ability it is light metal and use in several applications like aerospace, sports, automotive industries and also in manufacturing electrical equipment like cellular phones and televisions, etc. [15]. Among various ceramic materials titanium diboride is used as coating deposit material because of unique properties. Titanium diboride has low density (4.52 g/cm^3), high melting point (3225 °c), high micro hardness (3400 kg/mm^2), good tribological properties and also have good electrical- thermal conductivity [16]. Combination of properties in titanium diboride is beneficial for many applications but most of it is use in reinforcement of the metal composites [17]. Alloy 617 is a super alloy of Ni, Co and Mo and has a great resistance to high temperature and it is specially developed for high temperature application above 800°c. Alloy 617 has been used in various high temperature application like power generation structure, gas turbine, chemical manufacturing component, heat exchanger and in metallurgical processing facilities [18].

3. Hot Corrosion and Erosion

Corrosion is the form of oxidation that occurs when the metals are heated up in the temperature range from 700°c to 900°c in the presence of sulphate deposits formed as a result of reaction between sodium chloride and sulphur. According to Khanna and Jhasulphur present in coal yields so2 on combustion, which oxidized to so3. Vanadium and sodium are impurities present in low-grade petroleum fuels [1].

Erosion can be classified according to forms of wear. First one is friction. In whole world major issue is how to overcome friction in one form or another form. Erosion is a serious problem and it is occurring due to impact of solid particle on material surface. Stachowiak and Batchelor have discussed seven types of mechanism for solid particle erosion, like brittle fracture, abrasive erosion, surface fatigue, surface melting, ductile deformation, macroscopic erosion and atomic erosion. From the previous data generally abrasive erosion occur between guide vanes and facing plates. The erosion in the stay vanes occurs due to the secondary flows from the spiral casing causing non-uniform flow angles at the inlet with high absolute velocities [19]. In abrasive wear oxide layer will break down on the flow guiding surface and because of this the surface will be uneven, it is also considering as the origin for cavitation erosion [20]. From the data of some paper it is found that actual mechanism of erosive wear was not fully understood. Kjolle studied about the reason of parts damage in hydro turbine and found that the major reasons for this damage is material defects, fatigue, sand erosion and cavitation problem. And conclude that the cavitation erosion will be reduce by improving design of turbine, implementation of erosion resistance material and component production [5].

4. Laser Cladding Process

The basic principle of laser cladding is to make cladding layer on substrate material by melting the coating material with the help of laser beam to increase properties of substrate material [21]. Laser cladding is widely used to cover the substrate with a particular material which have superior properties, under laser irradiation the material is melted with a thin layer on metallic substrate and form a thin coating which is metallurgically bonded with a substrate [22]. In laser cladding process less distortion of substrate material compared to another coating method because of low energy [23]. Laser cladding is use to improve wear resistance, high temperature oxidation resistance and good biocompatibility of a particular material.

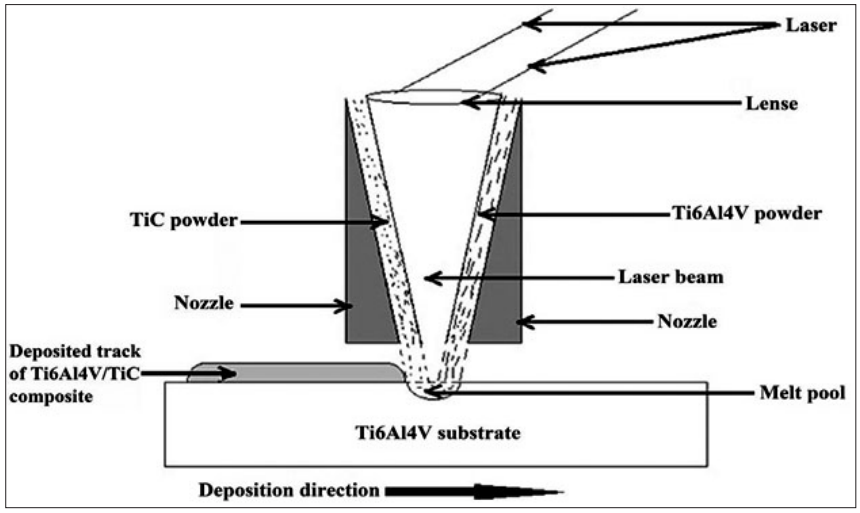

Fig. 1. Schematic diagram of laser cladding process [24].

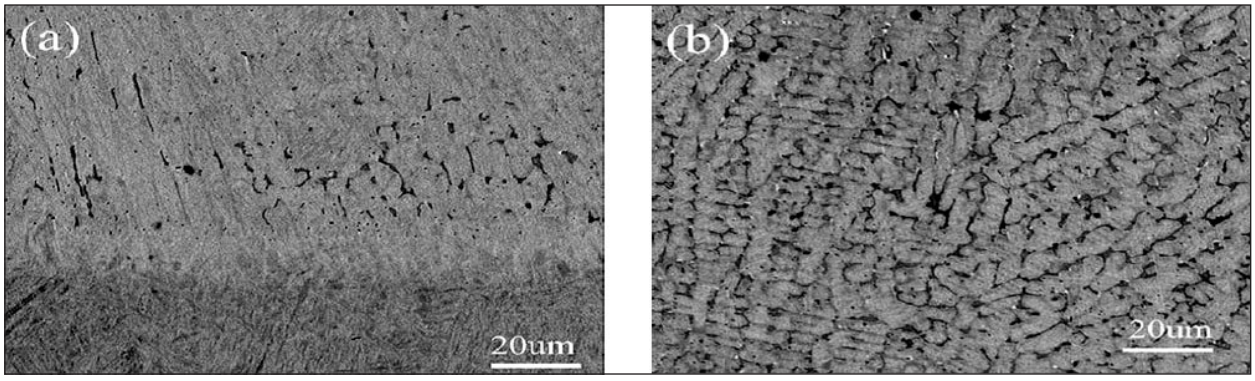

Fig. 2. (a): SEM photographs at the interface region [25] (b): SEM photographs at center region [25].

Researchers are studied about the design of cladding material to achieve desired properties. Titanium and its alloys are used in aerospace, biomedical industry, marine and chemical industry. Because of poor tribological properties the titanium and its alloys are not preferable in some wear and friction condition. Alloy are used in high temperature and because of poor high temperature oxidation and wear resistance the use of titanium and alloy are limited. So to improve the properties of titanium and its alloy like carburizing, nitriding, oxidation, physical vapour deposition, chemical vapor deposition and ion implantation laser cladding process is use. It is very important that substrate material and cladding material should have same physical properties like co-efficient of thermal expansion (γ), modulus of elasticity (E), melting point (Tm). For safety and reliability purpose high speed train brake disc is one of the most important component [24]. Laser cladding is also used to repair worn out component with high value, to recover the original dimension and also to improve mechanical properties [21]. In potential application of engineering laser cladded high-entropy alloy are worth studying and many experiments are done on laser cladding to increase the wear resistance of the material (5). Zhang et al. studied about the tribological performance of high temperature alloy CoCrFeNi made by spark plasma from 20 °c to 800 °c. Few literatures concluded about high entropy laser cladded alloy and its wear behavior at elevated temperature. And Shu et al. studied about the wear behavior of high temperature alloy amorphous coating CoCrBFeNiSi alloy at 773 °c [25].

Above figure shows SEM photographs of laser cladded FeNiCoAlCu high entropy alloy. From figure 2(a) there is a strong bonding between substrate and coating material and columnar grains can be seen in perpendicular to the interface, which is due to high temperature gradient.

Figure 2(b) represent a typical uniform dendrite microstructure with dendritic region (DR) and interdendritic region (IR) in the center region (CR) of the coating [25].

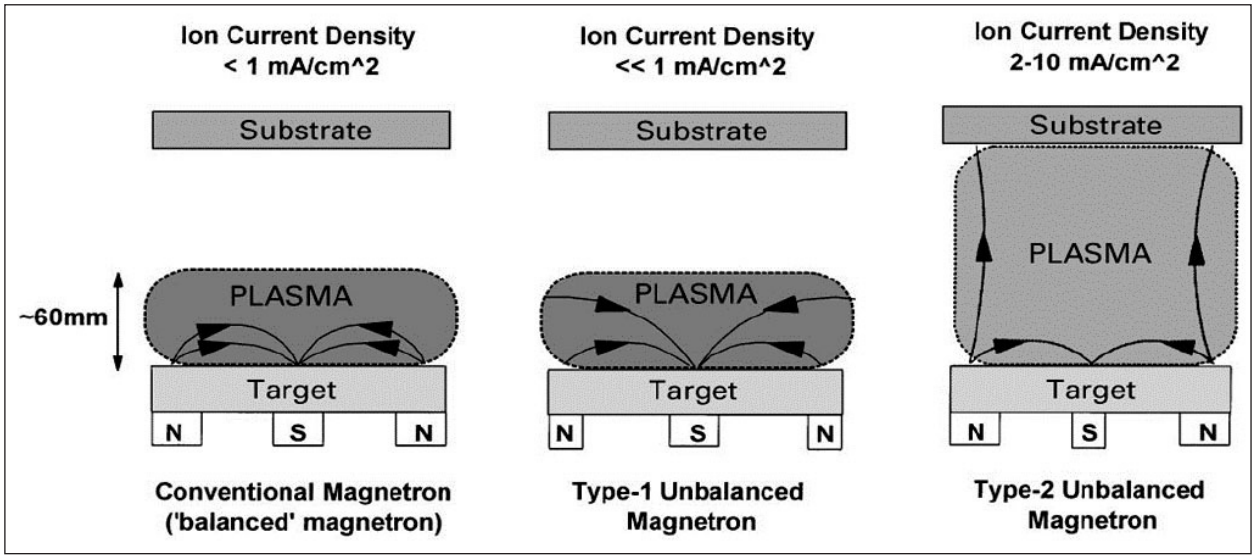

Fig. 3. Schematic representation of the plasma confinement observed in conventional and unbalanced magnetrons [27].

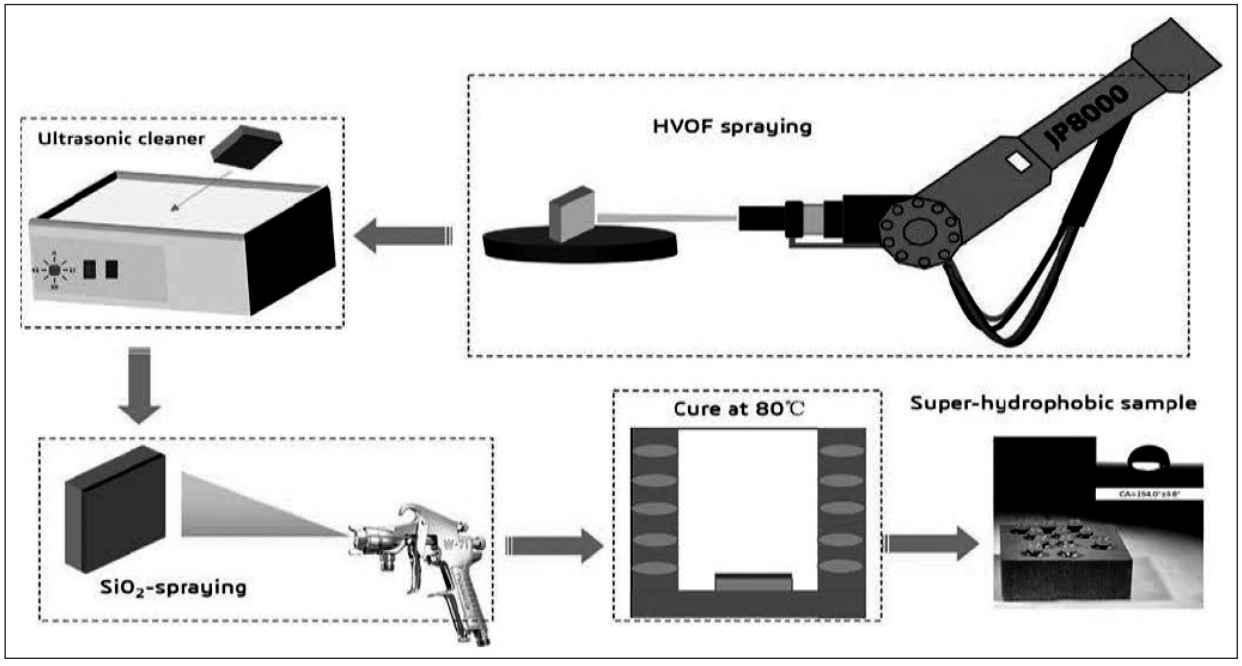

Fig. 4. Schematic diagram of the fabrication procedure of super – hydrophobic coatings [34].

5. Magnetron Sputtering Process

Chemical vapour deposition (CVD) became a commercial reality in late 1962s to enhance the performance of cemented carbide cutting tools by the coating of titanium carbide (TiC) or titanium nitride (TiN) and these are able to extend the life of the material [26]. For coating any material deposition different methods are use and one of them magnetron sputtering is used for coating. In magneto sputtering process, energetic ions generated in a glow discharge plasma attacks on target plate (cathode), because of ions attack material removal takes place as "sputtering" of target atoms, which may have condensed on substrate material as a thin coating. Secondary electrons emitted from the substrate material and maintain the plasma. This technique is much known and many materials have been successfully deposited using magnetron sputtering. Because of some reasons like low - Ionization efficiencies in the plasma, low molten metal deposition rates, heating effect in substrate etc. but it can be overcome by development of unbalanced sputtering [27]. For coating aluminium oxide is used because of its good properties. It has high

melting point, high hardness, high electrical resistance etc. it is used in refractory material, abrasive tool material, dielectrical material and diffuser barrier [28]. The figure 3 shows the conventional (balanced) magnetron, type-1 unbalanced magnetron, type-2 unbalanced magnetron. In first figure the inner and outer magnets placed in a way that all the magnetic lines coming out of the pole were closed to another pole over target surface. While in unbalanced magnetron (type 1 and 2) only few lines of magnetic field closed between the inner and outer poles in the magnetic system [29]. Magnetron sputtering is use in coating of tube and hollow bodies [30]. Because of some disabilities, it was not successful as tool coating like it did not give high bombardment on substrate material. And also dense plasma produce next to the target surface, plasma is tightly confined to the face of the target and because of this low ion current are collected on substrate [26].

6. Thermal Spray Coating (HVOF)

HVOF is also use for coating purpose on substrate material. HVOF spray is a process in which metallic or non- metallic particle are deposited in molten or semi-molten condition to form a coating. The coating material are in the form of powder, wire, ceramic-rod, molten material. In HVOF process tungsten carbide or chromium carbide particle in a metallic alloy matrix with various combination of Co, Ni and Cr are commonly used. Chromium and tungsten carbide coatings with ductile metal binder (cobalt or nickel) are commonly used in industry for protection against wear and corrosion [31]. HVOF is one of the best alternative of chrome replacement because it produces low porosity (<1%), low oxide content (<1%) and highly adherent. In HVOF the high kinetic energy ensures excellent cohesion in coating and produce carbide based coating with a minimum porosity. In HVOF spray coating the corrosion behavior is slightly complex because of multiphase microstructure, which involves corrosion cells like phase boundaries, pores, oxide inclusions, interlayer boundaries and non- uniform carbide dissolution in metal matrix [32]. The main drawback of this method is their brittleness, which often their usability in application where impact resistance and ductility are beneficial. Ibrahim et al. found that high elastic modulus and compressive residual stresses are desired for fatigue life improvement. Because of this they found the improvement in HVOF spray over APS - spray. HVOF method is require for good chemical resistance [33].

7. Summary

- High temperature, friction, corrosion, erosion are the reasons of material degradation.
- Coating deposition is applicable in oil and gas industry, aerospace, water application, high temperature application, turbine industry, etc.
- Laser cladding is use to improve wear resistance, high temperature oxidation resistance and good biocompatibility of a particular material.
- In laser cladding process the heat affected zone is greatly reduced and increase the strength of the part compared to arc cladding process.
- Coating increase the mechanical properties as well as tribological properties of substrate material.
- In place of changing the whole bulk material, coating is more efficient and cost effective.
- Multiple clad layer can be applied to achieve any coating thickness.

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