Different Coating Processes for Surface Hardening of Aluminium

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Abstract - *Materials engineers constantly create and improve the properties of materials by applying the existing knowledge of science. This is because newly developed materials can easily be used as replacement of the current ones. The requirements of individual components with regards to properties like hardness, corrosion, wear, impact, strength, and economic considerations finally decide the material to be preferred. Technological progresses compel the use of materials in increasingly extreme and aggressive conditions, such as corrosive atmospheres. Corrosion is one of the most frequently encountered causes of failure of components. Corrosion is a complex series of oxidation/reduction reactions between the metal/alloy surfaces and liquid media. Nearly all metals will corrode to some degree. Corrosion can be concentrated locally to form a pit or crack, or it can extend across a wide area more or less uniformly corroding the surface. Because corrosion is diffusion controlled process, it occurs on exposed surfaces. Localized corrosion could result in structure failure of metallic materials if it is allowed to reach critical levels.*

Key Words: Different Coating Processes, Alloying, Spraying, Laser Coating, Laser Surface Hardening.

1. INTRODUCTION

Aluminium and its alloys are high potential non-ferrous materials used universally. These alloys are of great interest to a wide range of industries because they exhibit quite an attractive variety of favorable mechanical and chemical properties. Aluminium and its alloys exhibit excellent mechanical strength, low specific weight, good formability and have relatively low cost and thus are widely used for industrial applications. The automotive industry is the dominant market for aluminium products throughout the world. Cylinder heads, engine blocks, closure panels, such as boots, trunk lids and door panels. Structural components made from aluminium and its alloys are vital to the aerospace industry. Inspire of all the attractive properties exhibited by these alloys, industrial applications are still limited. The surface properties of aluminium alloys are insufficient for many engineering requirements. Aluminium alloys possess poor tribological properties and load bearing capacity due to their low melting points, low hardness and weak interatomic bond.

To avoid all these problems we need to develop a proper material with proper coating process. So for this reason we will discuss the different types of coating for aluminium.

1.1 Different Coating Processes

1.1.1 Chemical vapor deposition

1. Metal organic vapour phase epitaxy.
2. Electrostatic spray assisted vapour deposition (ESAVD).

1.1.2 Physical vapour deposition

1. Cathode arc deposition
2. Electron beam physical vapour deposition (EBPVD)
3. Ion plating
4. Ion beam assisted deposition (IBAD)
5. Pulsed laser deposition
6. Vacuum deposition
7. Magnetron sputtering
8. Sputter deposition
9. Vacuum evaporation

1.1.3 Chemical and electrochemical techniques

1. Anodizing
2. Chromate conversion coating
3. Plasma electrolytic oxidation
4. Ion beam mixing
5. Plating
6. Electro less plating
7. Electroplating
8. Sol-gel

1.1.4 Spraying

1. High velocity oxygen fuel (HVOF)
2. Plasma spraying
3. Thermal spraying
4. Laser coating

1.2 Chemical vapour deposition

1.2.1 Metal organic vapour phase epitaxy

Metal organic Vapour Phase Epitaxy is a technique which used for forming high quality single crystalline thin films of different materials on different based material. The MOVPE system at SINP is used for research in III-V compound semiconductor hetero structure materials for optoelectronic, photovoltaic and high speed electronic applications. There are lot of scopes for research in improving the growth process of such materials. Among the various III-V semiconductors plays important role in quantum well based optoelectronic device applications and as well as study of fundamental quantum phenomena which are undertaken in the MOVPE laboratory of SINP.

Fig -1: Metal organic vapour phase epitaxy

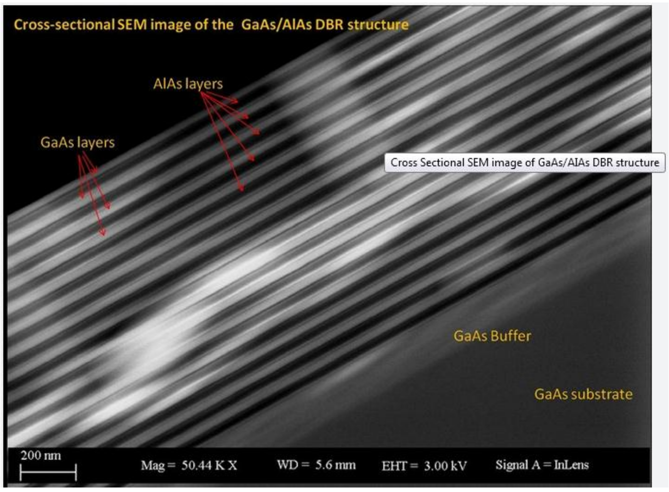

Fig -2: Cross-sectional SEM image of the DBR structure

1.2.2 Electrostatic spray assisted vapour deposition (ESAVD)

Electrostatic spray assisted vapour deposition is a technique to deposit thin and thick layers of a coating onto various substrates. Electrostatic spraying techniques were developed in the 1950s for the spraying of ionized particles on to charged or heated substrates.

Electrostatic spray assisted vapour deposition (ESAVD) is used for many applications in many markets including:

1. Corrosion protection coatings
2. Thermal barrier coatings for jet engine turbine blades
3. Glass coatings (such as self-cleaning)
4. Biomedical coatings
5. Electronic components

The process has advantages over other techniques for layer deposition in that it does not require the use of any vacuum, electron beam or plasma so reduces the manufacturing costs. It also uses less power and raw materials making it more environmentally friendly and also the use of the electrostatic field means that the process can coat complex 3D parts easily.

1.3 Physical vapor deposition

1.3.1 Cathode arc deposition

Cathodic arc deposition technique can be used to deposit metallic, ceramic, and composite films.

Fig -2: Aluminium Titanium Nitride (AlTiN) coated end mills using Cathodic arc deposition technique

1.3.2. Electron beam physical vapour deposition (EBPVD)

This technique is a form of physical vapor deposition in which a target anode is attacking with an electron beam given off by a charged tungsten filament under high vacuum and the electron beam causes atoms from the target to transform into the gaseous phase, due to these atoms then precipitate into solid form.

1.3.3. Ion plating

Ion plating is a physical vapor deposition process and sometimes it called as ion assisted deposition and is a version of vacuum deposition. Ion plating uses concurrent or periodic bombardment of the based material and deposits film by atomic-sized energetic particles.

In the ion plating the energy flux and mass of the attacking species along with the ratio of bombarding particles to depositing particles are the important processing variables. The depositing material may be vaporized either by sputtering, evaporation, arc vaporization or by decomposition of a chemical vapor precursor chemical vapor deposition (CVD). The energetic particles are used for bombardment and usually ions of an inert or reactive gas, in some cases ions of the condensing film material ("film ions").

Ion plating can be easily done in a plasma environment where ions for bombardment are extracted from the plasma or it may be done in a vacuum environment where ions for bombardment are formed in a separate ion gun. The latter ion plating configuration is often and is called Ion Beam Assisted Deposition. By using a reactive gas or vapor in the plasma films of compound materials can be deposited.

1.3.4. Ion beam assisted deposition

The ion beam assisted deposition (IBAD) is a materials engineering technique which combines ion implantation with simultaneous sputtering deposition technique. Besides providing independent control of parameters such as temperature, ion energy and arrival rate of atomic species during deposition and this technique is especially useful to create a transition between the based material and the deposited film and depositing films with less built-in strain that is possible by other techniques. These two properties can result in films with a much more durable bond to the based material.

1.3.5. Pulsed laser deposition

Pulsed laser deposition is the process of a physical vapor deposition (PVD) technique and which is a high-power pulsed laser beam is focused inside a vacuum chamber to strike a target of the material that is to be deposited and this material is vaporized from the target which deposits it as a thin film on a based material. This process can occur in the process of oxygen which is commonly used when depositing oxides to fully oxygenate the deposited films.

While it's basic setup is simple relative to many other deposition techniques and the physical phenomena of laser-target interaction and film growth are quite complex. When the laser pulse is absorbed by the target and then the energy is first converted to electronic excitation and then into thermal, mechanical and chemical energy resulting in evaporation, plasma formation. The ejected species expand into the surrounding vacuum in the form of a plume containing in many energetic species like electrons, ions, molecules, clusters, atoms particulates and molten globules, before depositing on the typically hot based material.

1.3.6. Vacuum deposition

Vacuum deposition is used to deposit layers of material atom-by-atom or molecule-by-molecule on a solid surface. These processes can be operating at well below atmospheric pressure. Multiple layers of different materials can be used for to form optical coatings. The process can be qualified based on the vapor source and physical vapor deposition uses a liquid or solid source and chemical vapor deposition uses a chemical vapor.

1.3.7. Magnetron sputtering

The magnetron sputtering is a plasma coating process in which a sputtering material is ejected due to bombardment of ions to the target surface.

1.3.8. Sputter deposition

Sputter deposition is a process of thin film deposition by sputtering. This process involves ejecting material from a "target" on the "based material". Sputter deposition is re-emission of the deposited material during the deposition process by ion bombardment. Sputtered atoms ejected from the target have a wide energy distribution and it is typically up to 100,000 K. The sputtered ions can ballistically fly from the target in straight lines and impact energetically on the based material or vacuum chamber.

1.3.9. Vacuum evaporation

The vacuum evaporation is the process of causing the pressure in a liquid-filled container to reduced below the vapor pressure of the liquid and that causing the liquid to evaporate at a lower temperature. Although the process can be applied to any type of liquid at any vapor pressure and it is generally used to describe the boiling of liquid.

In this process interior pressure of the evaporation chamber reduce to below atmospheric pressure. This reduces the boiling point of the liquid to be evaporated and reducing or eliminating the need for heat in both the boiling and condensation processes.

1.4 Chemical and electrochemical techniques

Following are the different techniques of chemical and electrochemical techniques
1. Anodizing
2. Chromate conversion coating
3. Plasma electrolytic oxidation
4. Ion beam mixing
5. Plating
6. Electro less plating
7. Electroplating
8. Sol-gel

1.5 Spraying

1.5.1. High velocity oxygen fuel (HVOF)

High velocity oxygen fuel (HVOF) coating is a high-velocity and low-temperature spraying process which is used for the production of metallic and hard facing coatings.

In HVOF spraying the fuel and oxygen are pressed into a combustion chamber in a continuous flow and producing a jet of combustion products at extremely high speed. Powder particles injected into this gas steam are accelerated to a high velocity. Fusion is obtained by the kinetic impact of the powder particles rather than by their increased temperature and the process is carried out in an ambient atmosphere.

There are different types of HVOF spraying, based on

1. The fuel used for process:- either hydrogen, natural gas, or kerosene
2. The source of oxygen: either pure oxygen or compressed air

1.5.2 Plasma spraying

Plasma Spray is the process in which spraying of molten or heat softened material onto a surface to provide a coating. Powder material is injected into a very high temperature plasma flame and where it is rapidly heated and accelerated to a high velocity. The hot material impacts on the based material surface and rapidly cools forming a coating and this plasma spray process carried out correctly is called a "cold process" as the based material temperature can be kept low during processing avoiding damage, metallurgical changes and distortion to the based material.

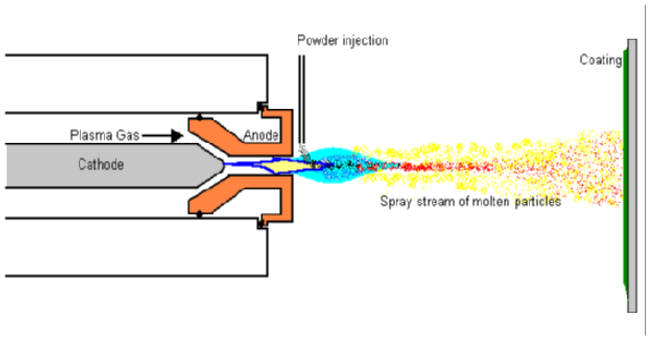

Fig -2: Schematic Diagram of the Plasma Spray Process

1.5.3. Thermal spraying

Thermal spraying technique is a coating processes in which melted materials are sprayed onto a surface of based material. Thermal spraying can provide thick coatings and its thickness is approx. in the range of 20 micrometers to several mm, depending on the process, over a large area high deposition rate as compared to other coating processes such as electroplating, and chemical vapor deposition. Coating materials are available for thermal spraying like metals, alloys, ceramics, plastics and composites. They are fed in powder form which is heated to a molten or semi molten state and accelerated towards based material in the form of micrometer-size particles. The source of energy for thermal spraying are used as a combustion or electrical arc discharge. Resulting coatings are made by the accumulation of numerous sprayed particles. The surface may not heat up significantly and allowing the coating of flammable based material.

1.5.4. Laser coating

Cladding is the process of bonding dissimilar metals together of. Cladding is achieved by extruding two metals through a die and pressing or rolling sheets together under high pressure.

Laser cladding is a method of depositing material by which a powder form material is melted and consolidated by use of a laser in order to coat part of a based material.

1.5.4.1 Process

The powder used in laser cladding is basically of a metallic nature, and is injected into the laser system by either coaxial or lateral nozzles. The interaction of the metallic powder and the laser causes melting of powder, and is known as the melt pool. And this melt pool is deposited onto a based material. Based material allows the melt pool to reduce the temperature and thus produces a track of solid metal. This is the most common technique and some processes involve moving the based material assembly over a stationary substrate to produce solidified tracks. The motion of the laser is guided by a CAD system which interpolates solid objects into a set of tracks and which is producing the desired part at the end of the trajectory.

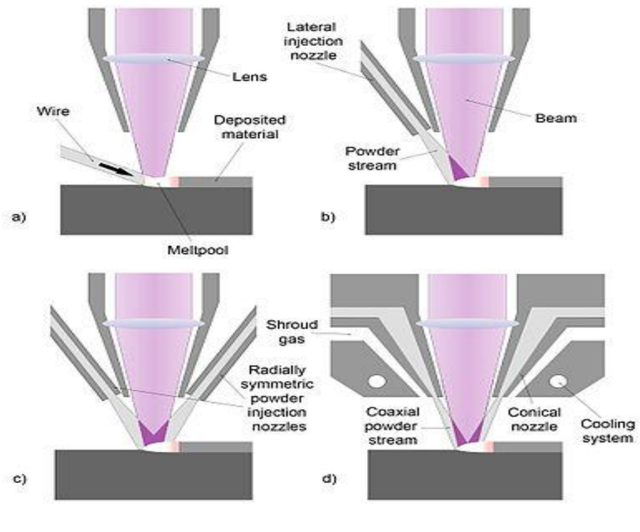

Fig -2: The available different feeding systems.

It's a great deal to researcher is now being concentrated on developing automatic laser cladding machines. Maximun process parameters must be manually set like laser power, laser focal point, substrate velocity, powder injection rate, etc., and thus it requires the attention of a specialized technician to ensure proper results of given parameters. With some sensors, control strategies are being designed such that constant observation from a technician.

1.6 CONCLUSIONS

Few are the best techniques for coating any shape like Spraying. It increases the life-time of wearing parts. Particular dispositions for repairing parts.

Most suited technique for graded material application. Well adapted for near-net-shape manufacturing. Low deformation of the substrate and small heat affected zone (HAZ). High cooling rate and due to this it will gate fine microstructure.

It gives a lots of material flexibility (metal, ceramic, even polymer). Built part is free of crack and porosity. Compact technology.

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