UNIT 4 METAL COATING PROCESSES

Structure

4.1 INTRODUCTION

Coating is a covering that can be applied to the surface of an object, normally called as substrate. The purpose of application of coating is the value enhancement of the substrate by improving its appearance, corrosion resistant property, wear resistance, etc. Process of coating involves application of thin film of functional material to a substrate. The functional material may be metallic or non-metallic; organic or inorganic; solid, liquid or gas. This can be genuine criteria of classification of coatings.

Objectives

After studying this unit, you should be able to

- metallic and non-metallic coatings their comparison,
- different coating processes,
- applications of various coating processes, and
- advantages and disadvantages of coatings.

4.2 METALLIC AND NON-METALLIC COATINGS

4.2.1 Non-Metallic Coatings

Non-metals are used as coating material in case of non-metallic coatings. Common types of such coatings are plastic or rubber coating. This involves application of a layer of the given polymer onto a substrate material. Different categories of such coating are described below.

(a) Wire and Cable Coating

(b) Planer Coating

(c) Contour Coating

Wire and Cable Coating

In this case whole length of conducting wire or electrical cable is coated with plastic or polymer to provide thermal or electrical insulation.

Planer Coating

It involves coating of a flat film over a flat surface.

Contour Coating

It is applied over a three dimensional object. It can be accomplished by dipping or spraying.

4.2.2 Metallic Coatings

Metallic coating can be applied over metallic as well as non-metallic substrates. Sometimes non-metallic like plastics are coated to give metallic appearance. Some important metallic coating methods are described below.

Electroplating

Electroplating is also known as electro-chemical plating, is an electrolytic process. In this process metal ions in an electrolyte solution are deposited onto a cathode. In the electrolytic process, anode is generally made of metal being plated so it serves as source of coating metal. Workpiece where coating is to be applied made as cathode. Direct current from an external power source is passed through electrolyte solution. The electrolyte is an aqueous solution of acids, bases or salts. Electrolyte conducts electric current by the movement of plate metal ions in solution. For optimum results the parts to be plated should be chemically cleaned.

Working Principle

The process of electroplating is based on Faraday's law (two laws). According to these two laws it is stated that :

(a) the mass of a substance liberated in electrolysis is proportional to the quantity of electricity passed through the cell, and

(b) the mass of the material liberated is proportional to its electrochemical equivalent (ratio of atomic weight to valence). Mathematically effect can be stated as

$$V = K I t$$

where V is the volume of metal plated in m^3,

I is the flowing current in ampere,

t is the time for which current passes through, and

K is a constant depending on electrochemical equivalent and density of electrolyte is $m^2/A - S$.

Methods of Electroplating

Large variety of equipment can be used for electroplating. Selection of electroplating equipment depends upon workpiece size, geometry, throughput requirements, electrolyte and metal to be plated. Main methods used for electroplating are :

(a) Barrel plating

(b) Rack plating

(c) Strip plating

Barrel Plating

Barrel plating is done in rotating barrels. These barrels are oriented either horizontally or at an angle of 35^o. This method is used for plating of many small pats in a batch. In this case electrical contacts are maintained through the tumbling action of the parts themselves and by means of an externally connected conductor that projects into the barrel.

There are some limitations in barrel plating, the tumbling action which is inherent in the process may damage the soft metal parts, threads, other parts with good finish, and some other parts with sharp edges.

Rack Plating

In some cases when barrel plating is difficult and impossible like parts to the plated are too large and heavy and complex, rack plating is recommended. In rack plating racks are made of heavy gauge copper wire formed into suitable shape for holding the workpiece and passing current through the same. Workpiece are hanged on hooks or held by clips. To avoid plating on the racks, themselves, these are covered with insulation except the locations where workpiece make contacts.

Strip Plating

In case of strip plating, a continuous strip is pulled through the plating solution by means of a take up reel. Long wires can be plated by this way. Small sheet metal parts held in a long strip can also be plated by this method. This process can maintain high production rates. The process can be set up so that only specific regions of the parts are plated, examples are contact points plated with gold or silver to make electrical contacts.

Electroplating may have plating of different metals. Plating of some of important metals are described here.

Zinc Plating

Zinc plated steel products are fasteners wire goods, electric switch boxes and sheet metal parts. Zinc coating provide high resistant to corrosion. Zinc can also be plated on large area sheet metal wiring galvanization.

Nickel Plating

Normally nickel plating is done for corrosion resistant purpose and decorative purpose. In these cases brass, steel, zinc die castings serve as substrate material. Automotive trims are also plated with nickel.

Gold Plating

It is a method of depositing a thin layer of gold on the substrate of other metal. Most often substrate is silver or copper. It provides corrosion resistant and highly electrically conductive layer which is used in electrical connectors and printed circuit boards. The major problem in gold plating on copper is copper atoms have a tendency to diffuse through the gold layer, causing tarnishing of its surface and formation of an oxide/sulphide layer. To avoid this a layer of some barrier metal like nickel is applied before gold plating on the substrate of copper as nickel atoms do not defuse to good. Some metal may also be gold plated to improve their aesthetic value for ornamental purpose.

Chrome Plating

Chrome plating is a finishing treatment given to a metal surface using electrolytic deposition of chromium (chromium plating). A decorative bright chrome plating of thickness 10 μm over nickel plating is done on steels. It is used in case of metal furniture, automotive trims, etc. Chromium plating is a hard plating providing wear resistance properly to the surface.

Tin Plating

Tin plating is used for ferrous and non-ferrous metallic surfaces. Tin is a non-toxic, ductile and corrosion resistance material so it is widely used in food packaging. Sheet metal coated with tin can be processed further without any

damage to their surface, this is possible due to excellent ductility of tin and its alloys. Electroplating of tin is also used in electronics industry because of its ability to protect the base metal from oxidation. It is used to protect solderability.

Alloy Plating

In some cases electroplating of two metals is done simultaneously, it is called alloy plating Nickel-Cobalt is a common electroplated alloy.

There are some more methods like electroplating having a light difference, which are being described here.

4.3 ELECTROFORMING

In this method electrolytic deposition of metal onto a pattern until the required thickness is achieved, the pattern is then removed to leave the formed part. The part produced so is called electroformed part and its thickness may be upto 0.05 mm. Electroformed parts are commonly fabricated of copper, nickel and Ni-Co alloys. Its applications include fine mouldes and dies, moulds for lenese, plates for embosing and printing.

Electroless Plating

As indicated by its name it is a plating process done entirely by chemical reaction, no external source of electric current is required in this case. Deposition of metal onto a part surface occurs in an aqueous solution containing ions of the desired plating metal. The process uses a reducing agent, and the work part surface acts as a catalyst for the reaction. Normally, Ni and Ni alloys are used for this plating. It is costlier as compared to other similar methods. Nickel plating by this method is used to get high resistance to corrosion end wear. Electroless copper plating is used to plate through holes of printed circuit boards. Electroless plating has the following advantages too :

(a) Uniform thickness of plating even on complex part geometry. This is a problem in case of electroplating.

(b) This process can be used to both metallic as well as non-metallic substrates.

(c) No current is flowing in this process so DC power source is not required.

Hot Dipping

Hot dipping is a process in which a metal is immersed in a molten bath of another metal that has to be coated on to the first. For this process melting point of first metal (substrate) should be higher than the melting point to be plated. Common substrate metal for hot dipping are steel and iron. Common coating materials are zinc, aluminium, tin and lead. Working principle of hot dipping is forming transition layers of varying alloy compositions. Next to the substrate are normally inter-metallic compounds of the two metals; at the exterior are solid solution alloys consisting predominantly of the coating metal. Presence of transition layer provides excellent adhesion of the coating.

Metal Spraying

It is also called spray metallizing, it involves impregnating a base material with a metal or metal compound by spraying the coating metal or compound to the surface of the base metal. The metal used for deposition may be either in the form of wire or powder. Before coating the surface of substrate metal is first cleaned perfectly to ensure adhesion of the sprayed metal and deposition of an even and uniform layer. When coating material is used in powder form it is known as power metallizing. When it is in wire form the process is called wire metallizing. In both the cases coating metal is automised before spraying it under pressure on the metal substrate.

Wire Spraying

In this process, special type of spray gun is used. The spray gun consists of a gas torch. The gas torch is connected to oxygen and acetylene cylinders in the same way as in case of oxy-acetylene welding. The torch draws mixture of two gases through high pressure in the cylinders and develops an oxy-acetylene flame. The metal to be sprayed is fed into the gun in the form of wire. The flame at the end of torch melts the fed metal and it is automised. The gun is also equipped with another passage which is directly connected to the output of an air compressor. The compressed air coming out from the compressor carries the automised metal particles on the surface of the substrate metal with very high velocity. The high velocity bombardment of the particles is done by maintaining a certain distance from the substrate metal and so these particles spread over the substrate metal surface. The sprayed molten metal cools down and freeze to form a deposited layer. The required thickness of coated metal can be maintained by laying down many such layers one over another.

Powder Spraying

It is also called powder metallizing process. In this case, coating material is used in powder form. The coating material is filled in a hopper, from where it is fed to the spray gun by suitable means. A gas flame is used as usual to melt the powder. Compressed air is than used to automise and spray the molten metal on to the surface of workpiece in the same way as described in case of wire spraying.

There is one more important technique of powder spraying named as plasma spraying. In this case, plasma gun is used. Plasma gun is made of copper carrying a non-consumable tungsten electrode. The gun body is made of doubled wall and water is circulated between the walls to cooling purpose. A DC powder supply is used to supply a high intensity current in to the circuit in which the copper body is made an anode and the tungsten electrode a cathode. A high intensity arc is struck between the anode and cathode. The established arc is shielded with the help of inert gas. The hot gas comes out from the nozzle of the body at very high velocity in the form of a very bright and shining flame (plasma) carrying a very high heat intensity. The powder of coating material is fed into the stream of plasma, which melts it readily and automise it. The automised molten metal is carried to the work surface at high velocity by this plasma stream and deposited there.

The wire gun process is generally preferred due to easy availability of coating material in wire form and low cost of its operation. Powder coating by spray is denser and faster. Plasma coating is preferred in case of coating of carbides of metals, titanium, chromium, oxides of zireorium, titanium, etc.

Vacuum Metallizing

It is a vapour deposition process, any metal can be coated on a base material through this process. Some non-metals can also be coated on substrate metal. This process is very effective for deposing a thin metal film or a film of a metal compound on a substrate base. Normally coating materials used in this method are aluminium, chromium, silver, nickel, gold, platinum, germanium, etc. The substrate material can be different metals, cermics, glass, plastics, paper and cloths.

In this process, substrate (workpiece) and coating material are placed in a high vacuum chamber. The coating material is heated by electrical means. Due to vacuum, hot coating material atoms leaves the surface in metal vapour form and condense at the surface of the substrate material. The workpiece is kept slowly rotating during the process so that the entire surface is exposed to the advancing coating metal vapours.

Advantages

Advantages of vapour deposition method are listed below :

(a) Thin coating of metal is possible by this method so little quantity is consumed here. This method is most suitable for coatings of very costly metals.

(b) Decorative coating on household items are possible through this method.

(c) Effective and low cost coatings for corrosion and thermal resistance are possible.

Coating quality is usually assessed by measuring its porosity, oxide content, macro and micro hardness, bond strength and surface roughness. Generally, in case of metal spraying coating quality increases with particle velocities.

High Velocity Oxygen Fuel Spraying (HVOF)

It is one of the ways of metal spraying. In this case, a mixture of gaseous or liquid fuel and oxygen is fed into a combustion chamber, where they are ignited and burnt continuously. The generated hot gas at a pressure approximately 1 MPa emanates through a conversing-diversing nozzle and travels through a straight section. The velocity of gasses at two exit of barrel (straight section) exceeds the velocity of sound. A powder feed stock is injected into the gas stream, which accelerates the powder upto 800 m/s. The stream of hot gas and power is described towards the surface to be coated. The powder partially melts in the stream, and get deposited on the substrate. The resulting coating in this way has low porosity and high bond strength.

Applications

HVOF is recognized to deposit wear and corrosion resistant coatings on material. Common coating materials are WC-CO; chromium carbide, alumina. It is used to deposit coatings of required properties on inserted tool bits.

4.4 GALVANIZING

Galvanizing is a electrochemical plating of highly corrosion resistant material on the surface of another metal. This technique is widely used to coat zinc over the iron and steel. Galvanized sheet metals are available in the market for their commercial use. This technique is very popular and widely accepted due its effectiveness and economy. A number of methods can be employed for galvanizing of zinc to the metal substrate. Some of important techniques are described below.

4.4.1 Hot Dip Galvanizing

The first step of this process is cleaning of the workpiece that involves its degreasing by acid rinsing followed by water cleaning. The second step is its annealing and cooling in an oxide free atmosphere. During cooling when temperature of workpiece reaches near to the temperature of molten zinc bath temperature. The workpiece is dipped in to the bath. Very thin and uniform coating layer can be maintained by passing the sheets through rollers just after the coating.

This method is not recommended for galvanizing of very delicate and complex shaped parts having complex interior designs.

4.4.2 Flow Galvanizing

It is also a type of crude way of galvanizing. In this process, hot zinc bath is made to flow over the surface of the sheet metal to be galvanized. Molten zinc is spread over the whole areas (surface) of the sheet metal. Excess zinc flowing down the surface is

collected back for its recycling. This process is suitable for galvanization of flat sheet metals only. The thickness of coating by this process can be maintained to a uniform value. This process was later modified on the base of metal spraying process.

This modified process uses a metal spraying gun. The gun is equipped with a device to produce oxygen flame, through which a zinc wire is fed and melted. Air pressure is used to spray this molten zinc on to the surface of sheet metal. The limitation of dipping very large workpiece in hot dip galvanizing is overcome. It also maintains a thin and uniform thickness layer of coating.

4.4.3 Sherardizing

This process is used for galvanizing of those small parts having intricate shapes. In this process there is a box or container having filled with fine zinc powder. The parts are placed in this box, surrounded with the powder. The box is then heated in an oxygen. Zinc powder vapourises. Zinc vapour comes in contact with the surface of workpiece and zinc is deposited on the workpiece. The workpiece is then taken out of over and it is allowed to cool down to room temperature. In this way galvanizing of workpiece can be completed.

4.4.4 Electroplating Galvanizing

In case of electroplating galvanizing, zinc is deposited on to the workpiece by making it cathode. It is just like a electroplating process. Walking of electroplating has already been discussed.

This process is time consuming so it is not recommended for mass production. Thickness of coating layer is very thin so it is not capable to provide corrosion resistant property to the workpiece.

4.4.5 Cold Dip Galvanizing

This process involves cleaning, buffing, degreasing of the work surface before galvanizing. Cold bath is used in this process. No heating of flow of current through electrolyte solution is required. The cold bath is prepared by dissolving shafts, like zinc chloride, tin chloride, ammonium chloride and potassium bitartrate, etc. in water and it is filled in a tank. The tank used in this process is a metallic tank, carrying a thick lining of rubber or PVC sheet on its internal surface. During the preparation proportion of tin chloride should always be less than half of the quantity of zinc chloride.

The parts to be galvanized are suspended immersed in the bath. How long these should be kept immersed depends on the thickness of the coating required. Dipping time varies from 3 to 12 hours. For thicker coating dipping time should be large.

This is cheaper as there is no artificial heating and no electric current is required. Periodic stirring of bath is required. As the process progress quantity of metal start falling short so more metal salts are need to the added as par the requirement.

4.5 ANODIZING

Anodizing is a process of deposition of oxide film on a metal surface with the help of an anode and oxidation. The process involves cleaning of workpiece either in a hot soak cleaner or in a solvent bath. After cleaning the workpiece is dipped in an electrolyte and made anode. The electrolyte used should give up oxygen on electrolysis. There is no any deposition from outside. When current passes through electrolyte a chemical reaction takes place and oxygen is librated which reacts with the metal surface to convert it into an oxide. In this process, the reaction progress inwards into the metal. The coating deposited is the integral part of the metal itself. Deeper the penetration of the chemical reaction the thicker will be the oxide film formed. After the formation of oxide layer into third stage of the process is providing desired colour and stability to anodizing film.

Colour of the deposited layer depends upon selection of an acid as an electrolyte. Sulphuric acid provides a thin transparent film over the metal surface. The anodized metal exhibits its own natural colour after the process. Chromic acid can also be used as electrolyte to deposit oxide layer. It provides milky white colour to the surface and that can also be changed to grey colour depending upon variations of bath temperature. Copper and its alloys are not anodized by this bath. Oxalic acid bath can provide a oxide film of light yellow colour. Thickness of the coating depends upon concentration of the bath, intensity of current passing through electrolyte, and its temperature.

The coating can be made stable by treating it with a hot and dilute aqueous solution of potassium chromate, nickel acetate or cobalt acetate. The porous deposition can also be sealed by applying oil of wax to it.

Anodizing of different type of metals are possible. Some of the useful commercial examples are discussed here.

(a) Anodizing of steel is done to make it wear and corrosion resistant. It appears as a block film over different types of steels.

(b) Several galvanized machine parts are anodized to improve their resistance for rusting and corrosion.

Mn, Brass, Copper, Bronze, Zinc, Silver parts can also be anodized.

Main purpose of anodizing are listed bellow :

(a) It provides protective coating on the metal surface which is corrosion resistant and wear resistant up to some extent.

(b) To provide decorative appearance to the surface.

(c) It can provide a specific colour base to a surface that can be a substitute of painting.

(d) Aluminium provides very good surface properties after anodizing.

4.6 ORGANIC COATINGS

Organic coatings are also a type of non-metallic coatings. This coating provides a barrier between the surface of substrate and its surroundings. It also improves appearance of surface. However, there is no appreciable improvement in mechanical properties of the substrate surface. Organic coatings can be applied to both metallic and non-metallic surfaces.

Different organic coatings are listed below :

(a) Oil painting

(b) Varnishing

(c) Enameling

(d) Lacquering

(e) Rubber based coatings

(f) Taflon coatings

(g) Bituminous painting.

4.7 SUMMARY

This unit describes various metal and coating processes. Metal coating processes are the surface finishing processes in addition to surface finishing operations explained in Unit 3. Metal coating have some other advantages too in addition to surface finishing. These advantages are described in this unit. Out of all metal coating processes, galvanizing is very widely accepted coating process having large number of commercial applications. The unit also has coverage on the procedure adopted for different coating and equipment used there in.