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Optimization and Improvement of Plastic Decoration using Chrome Plating Process

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ABSTRACT

This paper mainly deals with the performance requirement for chrome plating plastic components. These days, decorative parts have taken a big space in the market and specifically in automobile market; chrome plating over the plastic has replaced decorative steel chrome plated parts. Therefore the performance of metal layer with the plastic substrate is an important factor. In spite of various researches on adhesion of metal layer with plastic and problem of early corrosion of chrome plating layer, there is a lot of scope for improvement.

Decorative chrome plating involves the electroplating of nickel on the object which is followed by chrome plating layer. In most of the cases, first copper plating is performed on the substrate. Nickel plating is performed over the copper plating and the chrome layer comes over the nickel layer which is the top most layer of electroplating.

Nickel plating provides smooth surface finish and good corrosion resistance. Chrome plating layer gives the decorative finish to the part. The chrome plating is a very thin layer.
The metal plating and zinc coatings have been replaced with the plastic chrome plating. The increasing demand for plastic chrome plating is due to following reasons:

- ***Plastics can be molded into any shape and design by injection molding process which is performed in a hard tool called mold.***
- ***Being light in weight, Plastics chrome plating parts are used for automobiles. It reduces the weight of vehicle and vehicle requires lesser torque to move. It increases the fuel performance.***

Processing of plastic material is very easy. Part of any shape and design can be molded and then chrome plated to give it good aesthetic appearance

A decorative chrome plated surface, such as monograms, grills and wheel rims are actually the effects of the chrome plating. These are manufactured by a critical manufacturing process of electroplating. Plastic components can be chrome plated from various chemical tanks of Acid, Copper, Nickel, and Chrome. Electroplating process has lot variables which sometimes result in poor adhesion of plating layer and poor corrosion resistance. Experts have been continuously working over to improve the plating adhesion, corrosion resistance life and to control rejections. Over the years, the chrome plating manufacturing process has been upgraded. In spite of these improvements, a very good process control and quality of plastic base material are required.

In this paper work and experiments on injection molding process parameters, mold design and role of plating thickness to improve thermal cracks will be covered. Tool design section has also considered improving the adhesion of metal layer with the plastic substrate. In this paper, the thickness of metal layer has also considered improving its adhesion with the substrate.

This paper also covers the research on the factors to improve another failure mode of corrosion over the chrome plating surface. Research factor such as micropore and a potential difference of nickel layers has also been taken into consideration.

Keywords: *Chromium Coating, Adhesion and Early Corrosion Problem, Prevention Methods, Surface Treatment.*

1. INTRODUCTION TO ELECTROPLATING

1.1. Electroplating

Electroplating is a metal deposition process in which electric current is used to dissolve metal from positive terminal called Anode so that it can be deposited on negative terminal called Cathode. The solution used to transfer the ions from anode to cathode is called as the electrolyte. Examples are a silver and gold coating on utensils (steel), chrome coating on steel and plastic etc.

Electroplating is used to improve the aesthetic of part, improve abrasion and wear resistance, protection from corrosion etc. This is also used to increase the thickness of undersize parts. Some objects can also be formed by electroforming process which also works on this principle.

Electroplating is performed by various methods such as covering the solid surface with a metal sheet which is then heated and then pressed to fuse them. This method is called as hot stamping. Other plating techniques are vacuum metalizing in which metal vapors are sputtered on the object. Due to advancement in technology, both metals and nonmetals can be coated by these methods.

1.1.1 Electroplating Principle

The principle of electroplating is simple and is just the reverse action of a galvanic cell. This process is called as Electro-deposition. Part of which the metal deposition is required is made as a cathode and the metal that we have to deposit is made as an anode. Both anode and cathode are immersed in the solution called Electrolyte. In addition to one or more dissolved metal salts, Electrolyte contains other ions also which permit the flow of electricity. This current used to oxidize metal atoms from the anode is direct current. Electrolyte carries the metal ions from anode and transfers to the cathode where these are deposited. The metal oxidation rate is equal to the metal deposition rate and it depends upon the current passing through the system.

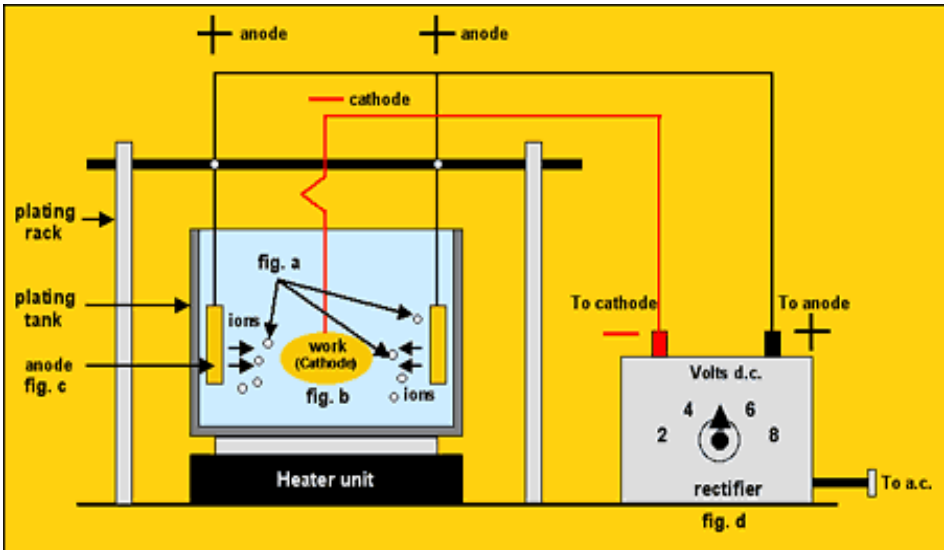

Fig.1. Simple Schematic Diagram of Electroplating Process

Chrome plating has three categories, hard chrome plating, decorative chrome plating and hard chrome anodizing. Decorative chrome plating has further two categories, Cr+6 called Hexavalent chrome plating & Cr+3 called trivalent chrome plating. The byproducts from hexavalent chrome plating are more hazardous to the environment as compared to trivalent chrome plating. Decorative chrome plating is available in different shades such as bright, black, grey or smoke finish, satin finish. These shades can be developed by using different types of chemicals.

Decorative chrome plating has a thickness of 1 µm to 20 µm and it requires lower current densities and immersion time of few minutes. On the other hand, hard chrome plating has a thickness of 20 µm to 100 µm which are developed by plating as high current densities for multiple hours.

1.2 How Plastic can be converted into Conductive Material

For plastic components requiring a high degree of surface durability, like automotive applications, the metal needs to become integrated with the plastic surface and this can be achieved by electroplating the plastic components.

The coating is chemically and physically bonded to the substrate, with metal layers applied to this surface through electrolytic deposition - passing an electric current through the metal to be deposited and then through the workpiece, removes atoms from the coating material and attaches them to the workpiece.

The plastic material must be made electrically conductive, which is done by first depositing a layer of nickel in a chemical dipping process. The nickel is applied over a catalytic palladium layer, which must become integral with the surface of the material for the bonding to be effective; one of the restrictions of plating plastic.

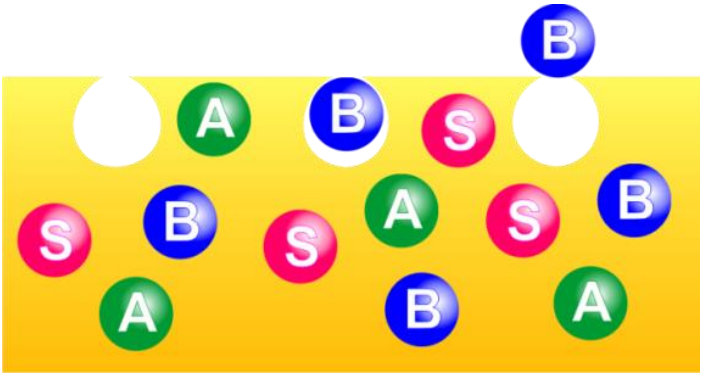

Fig.2. Composition of Plastic for Chrome Plating

Although Nylon and Polypropylene can be successfully plated, about 90% of the world's plastic plated components will use Acrylonitrile Butadiene Styrene (ABS). This is because the butadiene molecules at the surface can be removed relatively easily with chemicals to leave spherical undercuts in the surface which act as an excellent key for the palladium/nickel.

1.2.1 Multi-layer Nickel Plating

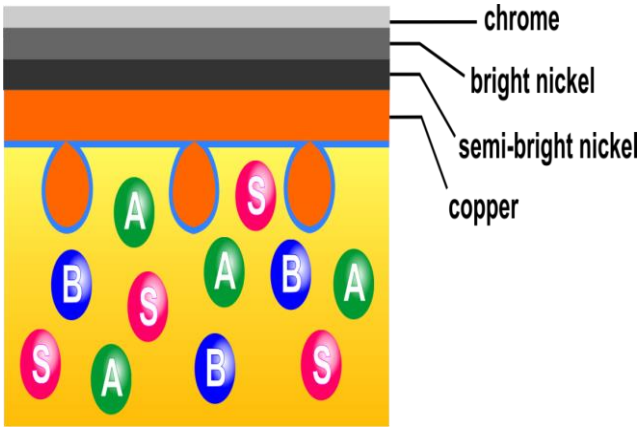

Fig.3. Plastic Chrome Plating Structure

As new applications for plated plastics were developed, the size and complexity of the components to be plated also increased, requiring a higher grade ABS. This offered a lower coefficient of thermal expansion of the plastic substrate, enabling large and complex units to overcome any disparities in thermal coefficient between the plastic and the metal plating - important for exterior automotive components.

It is essential that designers and platers consider the effect plating has on the properties of ABS. The plating process effectively bonds a skin of very hard and inflexible chromium to the surface of the plastic - with the added complication of sandwiched layers of copper and nickel. All of which clearly has an effect on the behavior of the finished component.

Plating ABS makes it brittle. It is not difficult to imagine that once a material with the surface mobility of ABS is closely confined in a chromium jacket, it will not bend easily. Some designers and molders do not take this reduction in flexural strength into account and this can lead to failure of parts in service, with a crack which starts in the chromium layer continuing through into the ABS. This situation can be overcome by selectively plating components, which generally perform better than parts with an allover plating.

1.3 Constraints in Electroplating

In Industrial hard chrome coating, the following coating problems are observed through data collection. These problems directly affect the performance of parts. Other problems line surface defects (scratch mark, blisters, burn marks etc.) are also a big problem, but the outflow of these can be controlled by visual checks. The performance issues are:

1. Adhesion of metal layer with the plastic substrate due to which the metal layer delaminates and affects the aesthetic of part.
2. Corrosion on the surface of chrome plating which makes the blemish appearance.

1.3.1 Objectives of Study

The main objective of the project is to improve the hard chromium coating performance so that the parts used for the decorative purpose have a long life and its aesthetic quality remains for the long service period.

Following objectives are reported based on the literature survey:

1. To evaluate the effect of plating thickness on adhesion of chrome plating layer
2. To evaluate the quality and design of base material (injection molded components)
3. To improve corrosion resistance property by study of Micropores

4. To improve corrosion resistance property by study of Simultaneous Thickness and Electrochemical potential difference of Electroplating

The brief details of these problems have been mentioned here:

1.3.2 Adhesion of Electroplating on Plastics

Since the plating on plastic came into existence in the year 1920, adhesion of metal over the plastic was a big challenge for the manufacturers. Mechanical roughing of plastic substrate didn't Lot of research works carried out on this subject and additional processes have emerged out which helped to improve adhesion. Successful results were found by etching of plastic surface in a chemical solution having strong acids and oxidizing agents. This process was followed by activation of the surface with precious metals like palladium, gold etc. Further application of electro less nickel or copper layer over it proved very good results in adhesion of metal layer. ABS based plastic found the best grade to get good adhesion of metal because micro-etching happens on the plastic surface when butadiene molecules come out and leave cavities for the conductive metal layer. Thus it increased the bonding strength of metal layer with plastic. It worked on two theories:

a) Mechanical interlocking of the metal film on to the cavities developed during removal of butadiene molecules by etching of the plastic surface.

b) Chemical forces between the polar surface of plastic resulted from the exposure to etching solution and its Vander Waals attraction with metal have helped to bond the metal layer with a plastic substrate.

These mechanisms play a vital role in the adhesion of metallic films to plastic.

1.3.3 Corrosion Mechanism - Early corrosion of part:

Chrome layers fail due to corrosion effect.

- Corrosion is a natural phenomenon when metal (M) comes in contact with nonmetals like O, S, OH, Cl (X) etc. because MX is stable compound (Dry Corrosion).
- When a metallic object (Plating layer) comes in contact with water and nonmetal both, dry & wet corrosion takes place simultaneously resulting in to fast corrosion of metal.
- Since it is evident that corrosion can't be eliminated, corrosion protection system is designed to delay corrosion reaching copper layer which if occurs will spoil aesthetics of part premature.
- Corrosion can be delayed by a multi-layer plating process and in addition, micropores are also provided on the top layer.

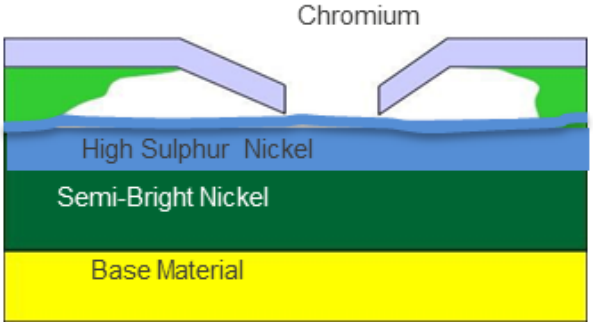

Fig.4. Corrosion Mechanisms of Nickel Layers

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