NICKEL PLATING

Electroplating metals is a crucial step in the manufacturing of many end-user products in industries like automobile, electronics, engineering, etc. It makes a metal part stronger, more durable, beautiful and conductive when it comes to non-conductive surfaces. Many metals can be used for electroplating like chromium, gold, zinc, nickel, etc. but when you need electroless plating, Nickel is always the best choice. The process of nickel plating as a surface finishing process is very popular in the industry because there are so many things you can achieve on the surface of the substrate by using nickel plating process. Nickel plating can be used to enhance the appearance of an otherwise dull and unattractive metal part to an attractive and part of the manufacturing of appealing end-user products. It can also work in the engineering processes for manufacturing as well as electro-forming applications.

When it comes to achieving decorative coatings on a metal part, you can electroplate nickel through specialized solutions that contain nickel and other organic agents. The results of such processes are a coating that will be smooth, protective and mirrors bright on the surface of the substrate. If it is for engineering applications, you need to prepare a solution that will only deposit nickel and nothing else. The main reason for applying nickel coating on engineering metal parts is to make them highly resistant to corrosion but, to achieve solderability, wear resistance, magnetic capacity or some other properties may become important if there Is a specific metal or product that requires them.

When it comes to the process of electroforming, it all involves the electroplating of nickel on a mandrel, and afterward, it is removed to achieve an all-nickel article or component. Some of the products of this specialized use of electroplating like dies, seamless belts, record stampers, textile printing screens and molds are important commercial goods.

Although nickel plating contributes immensely to key industries, there are important things you must consider if you want to use the process. The process of nickel plating is an electrolytic deposition of nickel on a metal part. It involves the dissolution of an anode and depositing the metallic nickel on the cathode.

To achieve this result, there must be the application of direct current (DC) between the positive part of the anode and the negative part of the cathode. The conductivity of these electrodes comes from the aqueous solution that is made up of nickel salts.

If you dissolve nickel in water, it appears as a divalent that is it becomes positively charged ions. When you then apply the direct current, the ions will react with 2 electrons and turns to metallic nickel at the cathode. The reverse of this same process also occurs at the anode where the nickel dissolves and form divalent ions.

How to estimate the thickness of Nickel

If you want to know the amount of nickel that will be deposited on the cathode, you can get this by the products of the time in hours and the current in amperes. For instance, if every other factor is accurate, 26.8 A that is flowing for one hour will give a nickel deposit of 29.4 g (1.095 g/a-hr.) If you already know the area that is being electroplated, you can easily estimate the average thickness of the coating. However, no matter the approach, make sure you use units that are consistent. The measure of Thickness is dividing the nickel weight by the product of the area and the nickel density which is normally 0.322 lb/in3.

Also, when you want to estimate the weight and the thickness of the metallic nickel that will be deposited on the metal part, you have to know that the efficiency of the deposition will not be 100%. The reason is that; a small percentage of the direct current is lost at the cathode when discharging hydrogen ions.

Ensuring Proper Nickel Distribution

It is not enough to put a substrate through the nickel plating process without ensuring that there will be a proper distribution of the metal. It is very important that you deposit a uniform thickness on every important surface so that you can be sure that the substrate can last very long and also meet the surface thickness specifications.

One thing you must bear in mind is that the amount of nickel that will deposit on the metal surface under electroplating is proportional to the direct current that gets to the surface during the process. Areas that are far from the surface are usually receiving less current and less metal deposition than those areas projecting from the surface.

This means that recessed areas get thinner coatings while projecting areas gets thicker electrodeposited coatings due to the positions.

Although this situation is usually the case with recessed and projecting areas on the substrate when it comes to proper distribution of nickel, there is something you can do to change it. If you want to control the deposits and distributions of the nickel metal, make sure that you use a racking system that works and also place the parts properly in the nickel solution by using auxiliary anodes, thieves, and shields.

You can also ensure that the parts to be electroplated are designed properly to reduce the problem. Also, if the situation becomes uncontrollable, you can also deposit more nickel than the specified amount so that you can achieve the minimum thickness that is required for a particular particle.

When it comes to engineering, electroforming, and decorative nickel processes, you can expect the same electrochemical reaction. The weight of the deposit at the cathode is usually controlled by the laws of nature, and this is why you can easily estimate the nickel thickness deposited on the substrate. However, you must adjust these estimates to accommodate variations that may occur in cathode efficiency when it comes to specific processes.

Ideally, the values of cathode efficiency are between 93% & 97% for some nickel processes, but in some fast and bright processes, the cathode efficiencies may be lower. The thickness of nickel coating on a shaped metal part is fully dependent on the flow of the current. Therefore, you must measure the thickness of the coatings on the main metal parts so that you can adjust the racks, shields, and thieves before you use a particular to control the thickness.

Now that we have an idea of what nickel plating is, how to measure the thickness and to ensure a proper nickel coating distribution, let's look at the three applications of nickel plating one after the other.

Decorative Nickel Plating

Nickel plating for decorative purposes has taken another approach since the development and introduction of bright nickel plating solutions, semi-bright nickel electroplating solutions, micro-porous and micro-cracked chromium, multi-layer nickel coatings, etc. Now, there are good improvements in the corrosion performance and appearance of decorative nickel finishing.

The process of decorative nickel plating

In building the plating solution, there will be organic addition agents that will help to modify the level of nickel deposit growth so that it can produce surfaces that bright, semi-bright and satin-like. The main constituents of the plating solution will be, nickel chloride, nickel sulfate, and boric acid. Nickel sulfate produces nickel ions; boric acid is responsible for achieving smoother and more ductile deposits while nickel chloride takes care of improving the dissolution of the anode and to increase the conductivity of the nickel plating solution. Also, there are wetting agents and anionic antipitting that will help to minimize pitting that may occur because of the hydrogen bubbles that will be clinging to the substrates to be electroplated. Finally, there is also the availability of non-foaming wetting agents responsible for lowering surface tension that occurs as a result of air-agitated solutions. Most decorative nickel electroplating follows the same plating solution composition, but sometimes, there are maybe differences in nickel chloride and nickel sulfate concentrations. But when it comes to operating and composition conditions, it is advisable to follow the recommended limits from the supplier.

Bright nickel plating solutions

Bright nickel solutions is a combination of two complementing types of organic addition agents that also yield fully-bright nickel coatings. One of them is responsible for producing mirror-bright deposits at the beginning but fail to maintain the appearance when the thickness increases. The agents that fall within this class are benzene di-sulfonic acid, benzene sulfonamide, benzene tri-sulfonic acid sulfonamides like saccharin. It is important that the bright nickel solution contains the sulfonate group and an unsaturated bond to achieve the desired result. The unsaturated bond aids the adsorption of all the addition agents onto the nickel deposit growth site, edges or points of crystals and also at dislocation.
The organic compound in the solution reduces at the cathode electrochemically accompanied by both reduction and addition of sulfur in the nickel deposit. The deposit contains 0.06% to 0.12% of sulfur.

The number two type of organic addition agents is called leveling agents because they are responsible for smoother surfaces even as the thickness of the deposit increases during the nickel plating process. These agents are free of sulfur, they are bath-soluble compounds that contain unsaturated groups, and also, introduce little quantity of carbonaceous materials in the nickel plating deposits. Some of the brighteners in this second level are coumarin, butanediol, formaldehyde, ethylene, and cyanohydrin.

When you combine organic addition agents to the solution, you can be sure of achieving brilliant, smoother, lustrous deposits on different ranges of direct current density. The deposits on the substrate have a banded structure that consists of laminations that are closely spaced which relates to co-deposition of sulfur. Some cations like selenium, cadmium, and zinc will improve the luster of the nickel and are usually used with organic additives.

Semi-Bright Nickel Plating Solutions

To create a semi-bright solution, you will ensure that there is an addition of nickel chloride, nickel sulfate, a leveling agent and boric acid. In the main process, coumarin serves as the solution principal additive. But right now, there are coumarin-free processes available for use. This process produces nickel deposits that are not as lustrous as the bright nickel solution. They are smooth and has a columnar structure instead of the bright nickel banded structure of the deposits.

This semi-bright solution was formed to aid polishing and buffing. One characteristic of semi-bright nickel deposits is that they can be polished effortlessly to achieve a mirror finish. In the bid to eliminate polishing entirely, the combination of bright deposits and semi-bright deposits became a necessary practice.

Through experience, electroplaters have discovered that multi-layer nickel coatings have higher corrosion resistance than single-layer nickel coatings that have the same thickness.

Multilayer and single-layer nickel coatings

Multilayer and single layer coatings are a process that electroplaters use to achieve decorative coatings on substrates to resist corrosion. Single layer nickel coatings are usually recommended when there is the need for a mild corrosive service; double layer deposits work for severe and more severe corrosive service. When applying the double layer, the first layer deposition comes from a semi-bright nickel solution bath. Afterward, the next layer will then come from a bright nickel bath. In cases where the severity of the corrosive service is higher, it is better to use the triple-layer deposit for a better result. When this process is needed, there will be a deposit of a thin layer of a bright and high-sulfur nickel between the first layer which came from the semi-bright nickel bath and the top layer that came from the bright nickel. This thin layer will be made up of 10% of the whole coating thickness and greater than 0.15% of sulfur.

Multilayer coatings are for high-level protection because the bright nickel layer that is bearing sulfur protects the other layer that has no sulfur. To achieve the highest level of corrosive performance, the semi-bright must not contain any co-deposited sulfur.

Micro-discontinuous Chromium

Electrodeposited chromium usually comes on the top of decorative multilayer coatings so that the nickel will not be tarnished when it comes out to the atmosphere. This chromium coating is very thin when you compare it to nickel coating because it is not intrinsically bright but becomes duller as the thickness builds more than the acceptable level. Researchers have discovered through their studies that the corrosion performance of a conventional chromium coating and multilayer nickel tends to form one or more corrosion pits that penetrate the basis metal at high speed. The wide belief was that the cause is the low porosity of the chromium at the top. As a result, the investigators concluded that if pore-free chromium electroplating is used, there will be greater improvement in corrosion resistance capacity. This conclusion led to the development of pore-free chromium process in the 1960s, but it did last because the investigators also discovered that the layer doesn't remain pore-free when they used it.

Some other investigators then concluded that it would be better to use chromium deposits that have crack densities or high porosity on a microscopic scale. This conclusion led to developing the micro-discontinuous chromium deposits. This process was developed in two different types: microcracked and microporous. The good thing about these chromium deposits is that they enhance the corrosion performance of the coatings by uniformly distributing corrosion current on the tiny cells that are on the coating surface. This action slows down the rate at which pit penetrates the surface since the corrosion proceeds in a uniform manner over the whole surface instead of one or more pits. For example, a double-layer coating of 1.5 mils that is plated with either micro-cracked or micro-porous chromium can resist corrosion for more than sixteen years even in cases of severe service.

How to specify decorative nickel deposits

It is always easy to understand the specifications for decorative nickel coatings even though there are standards like ISO Standard 1456 and ASTM Standard B 456 to follow for guidance. However, you must ensure that you get the right requirements before you start the plating process. Make sure that you get the right ductility of the semi-bright layer, the sulfur that will be in each layer and how thick the layer will be which will be a percentage of the total thickness. For instance, if you are applying a double-layer of nickel on a steel part, the semi-bright layer will be 60% of the whole nickel thickness. You have to understand that this ratio is crucial if you want to control the deposit corrosion performance, the cost of the double-layer deposit and the ductility. The cost implication is that the bright nickel process is more costly than the semi-bright process.

Also, the available standards for decorative coating will also give the recommended thickness of nickel and chromium coatings required for different service conditions. These standards also provide more information to ensure that the quality of the electrodeposited decorative nickel plus chromium coatings will be high. These standards that come from years of experience with corrosion proves that if you want to achieve a more corrosion resistant coating, make use of multilayer nickel coating instead of single nickel coatings. When it comes to micro-discontinuous chromium and conventional chromium, the former is the right option if you want to achieve more protection.

The truth of the matter is that if you don’t understand and follow the technical standards that are valid, you will not achieve the quality improvement you require.

Engineering nickel plating

This type of electrodeposited nickel plating application is as a result of the important properties of the metal. The reason for using nickel coatings in engineering applications is to improve or modify the surface properties, like making it more resistant to corrosion, wear and to improve its magnetic characteristics. Although it is important to improve the appearance and also make the electroplated surfaces free from defects, it is necessary to achieve the same mirror-like and lustrous deposits required in decorative nickel plating.

Mechanical Properties of engineering nickel plating

These properties are usually affected by the chemical composition and the operation of the electroplating bath. If you vary the electrolyte and the conditions under which the process operates, you can achieve a tensile strength of the nickel ranging from 410 to 1.170 Mpa (60 to 170 psi) and also achieve a hardness of 150 -470 DPN.

You have to bear in mind that the operating conditions have a great influence on the mechanical properties of the nickel. The properties vary depending on the temperature which you expose the nickel coatings. The yield strength, tensile strength, and ductility of the nickel reach 480 degrees centigrade.

Corrosion Resistance capacity

The main places where engineering nickel coatings apply are in petroleum, chemical, beverages and food industries to stop corrosion, prevent contamination and maintain the purity of the product. It is a general knowledge that oxidizing conditions usually favor corrosion of nickel in any chemical solution but reducing conditions prevent corrosion. Nickel can protect itself from some attacks by forming an oxide film. When this oxide film is destroyed locally, nickel may develop pits. The idea is that nickel resists alkaline and neutral solutions but cannot resist some forms of mineral acids. To ensure corrosion resistance in these engineering applications, you can optimize the thickness of the nickel coating. This nickel thickness will depend on how severe the corrosive environment is to nickel. If the environment is highly corrosive, then you must increase the increase the nickel thickness to match it, but if not, you will still apply a thickness that is necessary. This means that the higher the corrosiveness, the thicker the nickel coating. This situation is why the nickel thickness is usually higher than 0.003 when it comes to engineering applications.

Fatigue life of Nickel Plating

The thickness of the nickel deposit on a steel material can cause reductions in the fatigue strength in a cyclical stress loading. This reduction is greatly influenced by how hard, and strong the steel is and how thick and the level of internal stress of the nickel deposits. If you lower the internal stress of the nickel deposits, it will lower the degree of fatigue life reduction which will be beneficial. To enhance the fatigue life of steel, you need to increase its strength and hardness and also, you need to specify the minimum thickness of the deposit that will match the design criteria. Also, if you shot peen the steel before3 electroplating, it will help to minimize the fatigue life reduction during cyclical stress loading.

Hydrogen embrittlement

It is common for high-strength and highly-stressed steel to get hydrogen embrittlement while passing through the electroplating process. Due to the highly efficient nature of nickel plating, the damage from hydrogen may not occur. During pretreatment carried out on steel material before plating, they may have come across alkalis and acids. As these processes are going on, huge amounts of hydrogen can evolve and may cause damages to those steels that are prone to hydrogen embrittlement. Therefore, it is advisable to heat-treat those steels that are prone to hydrogen embrittlement to remove the hydrogen. The required time for the heat treatment may vary from eight to twenty-four hours depending on the steel type and the quantity of hydrogen that needs to be removed.

Nickel Electroforming

This is the electro-deposition that is applied to metal products during production. The process is usually to produce or reproduce products by plating onto a mandrel which will be separated afterward from the nickel deposit. This technology is very useful, and its continued growth in the industry is a proof of its importance.

The conventional processes

The composition, mechanical properties of the nickel deposits and the operating conditions are used for the electroforming. The popular solution for this process is Nickel sulfate because the stress level of its deposits is usually low, it is also possible to achieve high rates of deposition, and the deposit thickness is not affected by current densities variations.
If you make sure that the solution is very pure and the chloride is very low, the nickel sulfate deposit internal stress can be maintained closer to point zero. On the other hand, if you want to spend less, you can use Watt solutions.

High-speed, Low-stress process

Using a concentrated sulfamate solution is better in electroforming at high rates and low-stress deposit levels that don't use organic stress reducers which will come with sulfur. When the plating bath is in the right condition and also operated rightly, you can control the internal stress at zero or close to it because of current density, solution temperature, and interrelations stress.

After the carbon is purified to remove every organic contamination, then, give a preliminary electrolytic treatment to the concentrated solution to condition it. The treatment should consist of:

(1) Electrolysis at 0.5 A/din 2 on the cathode and anode, up to 10 A-hr/L
(2) Anode Electrolysis at 0.5 A/dm 2 and Cathode Electrolysis, 4.0 A/dm 2 up to 30 A-hr/L of solution.

Don't forget that the anode must be sulfur-free for this treatment. You can use a corrugated steel sheet as your cathode. After conditioning the solution, you can achieve a lustrous deposit by using a current density of 5 A/dm2 at 60 degrees Centigrade that you can also determine its internal stress to be 48 _+ 14 MPa (7,000 -+ 2,000 psi) if you use spiral contractometer or any other applicable device.

If you want to control the internal stressor other properties during the operation, you have to electrolyze the plating solution regularly at a low current density. All you have to do is circulate it through a small but separate tank from the rest. Let the tank for this conditioning have at least 10-20% of the main tank's capacity and circulate the solution through the tank 2-5 times every hour. To achieve the best result, make sure that the anode present in the tank must be non-active. The anode material in the main plating tank will contain sulfur (fully active).

This is how you can control the potential of the anode in the conditioning tank so that you can produce a stress reducer that will not increase the sulfur content in the nickel. Why you have to use an active anode in your main plating tank is to prevent sulfamate oxidation products from forming.

Quality Control

It is compulsory to improve the total quality of your activities in the industry, and this is also applicable to nickel plating. What quality assurance requires is that you maintain the purity of the plating solution and also control the properties of the nickel deposits. There are some procedures you can carry out for this purpose like:

Solution Purification

It is necessary to purify the plating solution because there are inorganic and organic impurities in the baths due to the technical salts. You can't use the bath like that without removing these impurities.

One of the ways to remove the impurities is to use an electrolytic treatment known as "dummying" which involves placing a large corrugated cathode in the plating solution and carrying out the electroplating operation at low current densities. The preference for a corrugated cathode is because it allows for a wider range of current density. Also, you can use a high pH treatment which will involve transferring the solution to another auxiliary treatment tank. Then, you can add adequate nickel carbonate so that the pH level will be higher than 5.2.

If you want to remove organic impurities, you should add activated carbon before the high pH treatment in the auxiliary tank. Also, add hydrogen peroxide and nickel carbonate in the tank. Afterward, filter the solution then you can carry out electrolytic purification.

Conclusion

You can control the properties of the nickel deposits by measuring the adhesion, corrosion resistance, and thickness of the coatings. You must take cognizance of such properties like tensile strength, porosity, ductility, internal stress, wear resistance and hardness are very important if you want to control the quality of the plated articles.

There are methods which you can use to measure them like using the micrometer readings to measure thickness and carrying out the STEP Test. You can also test for porosity and corrosion by immersing the electroplated part in hot water for 2-5 hours and then examining them afterward.

For measuring the hardness, you can make an indentation on the plated article surface deposit with a specified load. You can use the Vickers method by pressing a diamond into the metal surface under a certain load which may be 100g.

To measure the internal stress, plate onto one side of a strip of the basis metal and measure the force that is causing the strip to bend. Ductility can be measured by using the two bend test which was described in ASTM B489 & B 490. Or you can use a tensile testing machine to determine the elongation of a specimen.