ZINC PLATING

If metals are exposed to rust and its corrosive effects the result can be devastating. NASA is of the opinion that the annual record of the cost of corrosion-related cases in the United States industries accrues to $276 billion approximately while the worldwide figure is nearly getting to $1 trillion. Researchers on this issue found out that the sectors most affected by rust and corrosion are the following; production and manufacturing industries, transportation, government, utilities, and infrastructures.

The recent development in science and evolution lead to the advent of a zinc plating process which serves as a means of protecting metals like iron and steel from irresistible forces of corrosion. This process electroplating involves the act of electro-depositing of a light coating of the zinc metal on another metal object [the substrate] surface.The coating process forms a physical wedge which stops rusting of metal surfaces. Its possession of the ability to prevent corrosion distinguishes it from other metals and gives it peculiarity as the most wanted corrosion-prevention workhorse. Though zinc compound has been in use for more than 2,500 years ago, metallic zinc came into existence around the fifteenth [15th] century in Indian history. Presently, almost one-third of the metal [zinc] is engaged in the galvanizing process of electroplating of metals against rust. The most popularly known and used method of galvanization is zinc plating.

Zinc Plating as a Bio-Alternative method

Zinc plating as a modern method gained popularity and acceptance around the 1980s approximately. Before then, it was “cadmium” a highly toxic substance with a high probability of cumulative poisoning effect, in the long run, is the preferred metal for electroplating especially in cases where maximum protection is needed against corrosion.

Though zinc is not a match for cadmium regarding its anti-corrosive properties, its bio-friendly capacity gives it priority over others [cadmium plating]. Cadmium plating has a restriction to cases where zinc plating won't provide the quality of protection required or such extra protection as needed. Current environmental rules state that plating operations that require the use of cadmium must do so by complying with the regulations as stipulated.

Different Zinc plating processes

Since zinc plating process has been available for many years, and as such, many procedures have been developed to apply zinc coatings depending on the type of substrates, the cost and the coating requirements.
There are some crucial factors you have to consider. You must check the processes available and their advantages and disadvantage. Therefore, before you chose any zinc plating process, consider the following:

What does the specification for the substrate require? Is it a zinc deposit or zinc alloy deposit?

1. The type of substrate you are plating
2. The corrosion protection requirement
3. The uniformity of the deposit thickness required.

After you have determined these factors, there are other secondary factors you have to consider like:

1. Deposit characteristics
2. Make-up and the cost of operation
3. Operating factors (pre-plate, corrosiveness, efficiency, etc.)
4. Environmental restrictions like heavy metal removal, air quality, ammonia, etc.

When you have evaluated these factors and compared them to your circumstances, you can narrow down the best choice for plating process that will work for you.

1. Cyanide Zinc Electroplating

This process of electroplating was formally prevalent in the industry, but as a result of the regulations attached to using cyanide in zinc electroplating, the popularity dwindled gradually.
One good reason for preferring this type of zinc plating process is that it can use a low current density to zinc electroplate parts. However, one major setback to cyanide plating is the hydrogen embrittlement problem which disturbs the process.

2. Acid Chloride electroplating

This process is newer than other methods. It brought a vast change in the industry and right now many people are using the process for all their zinc plating baths especially in developed countries.
One main advantage of this process is that is has a high cathode efficiency which makes the plating faster with fewer side reactions. Also, it requires minimal treatment of waste depending on the process you select.
However, it still has an advantage in that, the chemical used in the process is highly corrosive, and this nature cause's solution is laying in recesses thereby posing a danger to the final coating if you fail to rinse it thoroughly.

3. Alkaline Non-Cyanide electroplating

In the industry today, people are still using this process because it is cost-efficient and reliable like chloride zinc process. One

setback to using this process is that the solution usually contains high-levels of carbonates which causes a reduction in the solution conductivity that hinders the depositing process.

There are some miscellaneous requirements which you have to know about each of these three zinc plating processes. They are:

Requirements	Acid Chloride	Alkaline Cyanide	Cyanide zinc
Bath solution condition	It must be excellent	It will depend on C.D	Fair
Heating	Yes	Not required	Not required
Anode polarization	Rarely	Yes	Yes
Air Agitation	Needed	Not needed	Not needed
pH Adjustment	Yes	No	No
Filtration	Yes	Yes	No
Chromate Receptivity	Good	It will depend on C.D	Excellent
Purifier for impurities	No	Yes	Yes
Iron treatment using oxide	Yes	No	No
Waste Treatment	Easy	Easy	Difficult

The plating proper

Due to its complexity zinc plating requires a high level of technical knowledge, expertise, special machinery and equipment, a rectifier, ancillary tank where the zinc anode will pass through a proper dissolution, plating stationand the required reservoir are needed.

The following is a typical zinc electroplating process.

1. Preparation and cleansing of the surface.

The substrate's surface should be adequately cleaned before plating so that any contaminants remaining on the surface will not prevent adequate adhesion of the zinc coating. Surface cleaning is done using alkaline detergent solution after which acid treatment is applied to wipe off surface rust.

2. The preparation process of the electroplating solution.

In other to prepare the solution needed, you will have to immerse the substrate into a specially formulated electrolyte solution otherwise known as the plating bath which consists of the zinc metal ionic solution and other chemicals that facilitates or catalyzes the plating processes. The ionic solution, as well as the compounds, also enhance the production of the desired chemical and physical properties of the finished product.

Acid zinc and alkaline zinc are the particular types of zinc used in this process.

Acid zinc is a popularly used plating technology. Its popularity base on its high efficiency, fast deposition, and superior covering power, although its demerit comes from its ability to provide low throwing power and thickness distribution. Alkaline zinc offers less plating efficiency and a slower electrodeposition rate, though its degree of thickness distribution and flexibility is more pronounced than that of zinc.

3. Choose the best plating procedure

After the preparation of the solution, the parts involved are ready for plating. One might choose rack plating, in which larger particles are firmly fixed to the metal racks that are placed within the tank with the plating bath, and these parts remain stable during the plating process. Or Barrel plating in which the components are kept in the barrel and then rotated to provide smoother finishing. It is usually used in cases involving too smaller pieces for plating tank.

4. Electrical current

Electroplating is otherwise known as Electrodeposition because electric current is used to deposit metals on metals or the surface of the substrate. The substrate serves as the cathode in zinc plating. There is an introduction of a direct current [DC] that originates from the anode into the bath. This current flows to the substrate and the zinc ions are deposited onto the surface. The circuit is then completed by the current flowing back to the anode from the cathode.

5. After production treatment procedure [post-treatment activities]

The parts are ready for post-treatment which involves rinsing the components in the water to remove any left-over contaminates and remnants of the plating bath at the finished or final stage of the electroplating process. The parts are expected to pass through thorough rinsing if heavy contamination is detected or suspected to ensure absolute dryness of the zinc plated parts. The application of passivates and sealers is necessary in the post-treatment process in cases where additional corrosion protection is highly needed.

The Factors that influence the zinc plating process

Several factors adversely affect the outcome of zinc plating process. These factors can as well be managed and efficiently controlled by a highly skilled metal finishing solution provider. These factors include; Current density, Temperature, Concentration of the zinc deposit, Position of both the cathode and the anode. Others like the surface condition of the substrate, Bath agitation [or lack of it] Using additives like brighteners and surfactants, Hydrogen ions concentration, Plating time duration, Rinsing operation efficiency, Contaminants and Pollutants concentration in the electroplating bath.

The current density of the DC flowing from the anode to the cathode may have a significant impact on the thickness of the zinc coating if the current density is high the thickness coating becomes high if it exceeds its practical limits, production of a crumpled substrate surface occurs.

The temperature on the other hand, of the plating bath, has a direct influence on the zinc plating result. The higher temperature of the plating bath reduces hydrogen diffusion on the cathode and catalyzes consumption of brighteners and other chemicals used.

Temperature and current density are strictly interdependent of each other since the increase in both factors leads to a brighter zinc deposit. And if the temperature rises while current density is constant, the metallic crystals formed will be huge. The concentration of zinc deposits affects the brightness and texture of the plated product in the following ways; Production of a rougher surface is noticed when there is a higher concentration of zinc deposits while a brighter finishing with beautiful crystals is seen with a lower frequency of the zinc deposit.

Though post-treated chromates are common in various colors ranging from yellow, red, blue, black and olive drab, applied zinc coating makes for the dull-gray colored product. Some electroplated parts can be plated if needed or desired. Pure zinc coating has a type of hardness that is one-half to one-third of steel.

Benefits of Zinc Plating

1. Corrosion resistance
Zinc plating significantly enhances the corrosion resistance ability of the substrate. The next puzzle is how? This is done in addition to creating a physical barrier; it provides a sacrificial coating which means that it corrodes in place of the metal substrate it is protecting.

2. Low Cost
Zinc plating is more affordable than other types of plating because the zinc metal is ubiquitous. If you are making use of metals like palladium or gold, you will spend more than what you will when making use of zinc. So if your company is operating on a tight budget, consider zinc plating.

3. Low-stress deposits
The process of zinc plating does not expose your metal parts to unnecessary stress which may, in turn, reduce the quality of the parts.

4. Increased strength
A coating of zinc on your metal part makes it stronger and durable.

5. Ductile capacity
Zinc is a flexible metal, and as such, you can stretch it into thin and long strands, and it will not break. As a result, the metal can fit appropriately into the contours of the substrate.

6. Zinc tolerates high temperature
The metal can tolerate a temperature of 120 degrees Fahrenheit, and as a result, the cost of cooling it is usually low.

7. Environmental friendly
The process of zinc plating is eco-friendly when you compare it to cadmium. Also, the metal is recyclable.

8. It controls hydrogen embrittlement
Zinc plating is usually safe from hydrogen embrittlement which is a condition that occurs when there is diffusion of hydrogen in the surface.

9. Aesthetic Appeal
If you want to enhance the appearance of steel or iron, use zinc plating.

Zinc plating troubleshooting

The zinc plating is not without some problems that may reduce the quality of the coating after the whole process.

Thickness inconsistency in the plating bath

There are many variables in the alkaline non-cyanide solution that can affect the cathode efficiency or the plating speed

Zinc metal; if the concentration of the zinc metal is low, the plating speed will be little, or you will experience the poor efficiency of the cathode. If you want to improve the speed, you must ensure that the zinc concentration will be between 12 -15 g/l. But it is advisable to ask your supplier if you must add other things after you increase the zinc metal.
Temperature; if the temperature of the bath is low, you can expect reduced efficiency and slow electroplating speed. If you want to improve it, maintain the temperature of 26-35 degree Celsius while carrying out the operation.
Sodium carbonates; if the concentration of sodium carbonate is high, you can expect slow speed and cathode inefficiency. Therefore, maintain the level of sodium at below 75g/L. Or you can do what is known as "batch freeze' if the weather is good or you do bath cuts if the weather is not suitable.
Proprietary additives; if you make use of excess Purifiers and Brighteners, the plating speed can be a low or inefficient cathode. Therefore, let the supplier carry out an analysis of your solution to know the highest level of additives concentration that will work.

Blistering in Alkaline baths

It is always challenging to process heat treated steels or high carbon through the process of the alkaline non-cyanide plating process. However, if you succeed, you can achieve adhesion through suitable pretreatment sequence.

If you want to pretreat these two substrates, there are two options which you can explore for better results. These options are suitable because you will get the pretreatment system you require. Any of the options are capable of removing oil, excessive carbon/smut and scale which the heat-treated substrates or high carbon materials possess.

The similarities between these two options are that both use an acid inhibitor in the hydrochloric acid prickle. This inhibitor helps to prevent carbon from forming on the substrate's surface. This carbon is allowed to be excess can reduce the adhesion of the zinc metal deposits.

Also, these two options make the two substrates to pass through anodic cleaning before they enter the alkaline non-cyanide

electroplating solution. The anodic brushing helps to remove carbon residue on the substrate so that it will not reduce the adhesion of the deposit.

Option one

1. Hot Alkaline Soak Cleaner
Concentration will be 60-90 g/L
Time will be 4-6minutes
The temperature will be 65-85 degrees Celsius.

2. Hot Alkaline Electro-Cleaner
Concentration will be 60-90 g/L *
Time will be 4-6minutes
The temperature will be 65-85 degrees Celsius
Current Density 2-15 amperage/dm2

3. Two-Three Counterflowing rinses or Coldwater cascading
Flow rate 4-8 liters each minute
Temperature Ambient

4. Hydrochloric Acid Pickle
Concentration will be 30-50% by volume
Time will be 3-5minutes
The temperature will be Ambient
Acid Inhibitor 0.2% - 2.0% by volume

5. Two to Three water cascading or counter flowing rinses
Temperature- ambient
Flow rate 4-8 liters a minute

6. Electro-Caustic
Concentration will be 100-150 g/L of Sodium Hydroxide
Time will be 1- 2 minutes
The temperature will be ambient
Current Density 2-15 amperage/dm2
Alkaline Non-Cyanide Plate

Option Two

1. Hot Alkaline Soak Cleaner
Concentration will be 60-90 g/L
Time will be 4-6minutes
The temperature will be 65-85 degrees Celsius

2. Two-Three Counter-flowing rinses or Coldwater cascading
Flow rate 4-8 liters each minute
Temperature Ambient

3. Hydrochloric Acid Pickle
Concentration will be 30-50% by volume
Time will be 3-5minutes
The temperature will be Ambient
Acid Inhibitor 0.2% - 2.0% by volume

4. Two to Three water cascading or counter flowing rinses
Temperature- ambient
Flow rate 4-8 liters a minute

5. Hot Alkaline Electro-Cleaner
Concentration will be 60-90 g/L *
Time will be 4-6minutes
The temperature will be 65-85 degrees Celsius
Current Density 2-15 amperage/dm2

6. Two to three water cascading or flowing rinses
The flow rate is 4 – 8 liters each minute
The temperature will be ambient
Alkaline Non-Cyanide Plate.

Zinc plating thickness

The decision to use any zinc electroplating thickness, you must first analyze the environment where the component or part will stay. Two things influence the ability of zinc coating to resist corrosion adequately.

1. Zinc thickness; this thickness will provide a protective shield against corrosion for the base metal.
2. Passivation; this is responsible for preventing corrosion of the zinc itself.

Therefore the thickness of the zinc plating is essential as it affects the protection capacity of zinc plating. What it all means is that the thicker the zinc, the more protection on the base metal. However, when it comes to white rust resistance, there is no relation with thickness whatsoever because it has to do with the zinc coating itself.

Let's use some of the following environmental conditions to describe the appropriate thickness that can work very well.

Dry, clean and indoor environment

The wear conditions will be minimal, and some situations like this include domestic premises not including the bathrooms, kitchens and office spaces. If the part will be in such environment, the suggested thickness should be 5 µm with ISO 2081 designation of Fe/Zn5/A

Indoor, minimal condensation and clean environments

If the part is in such settings as light assembly workshops, warehouses, etc., the minimum thickness should be 8 µm with ISO 2081 designation of Fe/Zn5/A. Also, there will be minimal abrasion conditions.

Covered outdoors or indoors

Some light industries that are not exposed to corrosive substances like private gardens that usually has roof coverings. A zinc thickness of 12 µm. can be suitable for ISO 2081 designation of Fe/Zn12/A

Outdoors environment

If the parts are used outdoors like where there is little exposure to substances that can cause corrosion, marine ecosystems and other outdoors, the thickness of 25 µm can be suitable with ISO 2081 designation of Fe/Zn25/A

It is also important to remember that some corrosive environments that have high risks of salt spray, it is not enough to do zinc plating but also apply paints in an area that is exposed. However, don't use powder coating in any case.

Zinc Plating chemicals and the equipment

Some of the chemicals used in zinc plating include Nitric Acid, Hydrochloric Acid, Ammonium Hydroxide, Sodium Cyanide, Ammonium Chloride, 0.153 N Silver Nitrate, 10% Formaldehyde, and Eriochrome Black T Indicator.

The major zinc electroplating equipment includes Industrial Tanks that can either come from Polypropylene and SSTL, Filtration systems, Rectifiers, Heaters, Air Agitation lines, Cranes, Load Bars, Fume hoods, Copper Cathodes, Racks, Anode Baskets and Zinc Anodes.

Tank Design

The first significant step in getting your plating line running is your smooth tank design. There are few parameters you must carefully examine the size of the tank, location of the tank and the entire set-up of the electroplating tanks.

1. **Size**
   It is essential to know the tank size because it will help to determine the quantity of plating you can carry out in a shift of eight hours. For example, if you design a small tank, it will only be suitable for small parts, but if the part size is large, that means, you will spend more time plating them in a small tank. What the situation implies of this situation is that you will spend more time than necessary thereby increasing the lead time requirements of your clients. When it comes to tank size, the area is also important because it will determine the type of metal parts that will fit into the tank. If your tank size is 8 X 2, be aware that you can only plate long elements in it. If however, the container is 6 X 4, large parts can be the best fit for the tank.

2. **Design**
   The design of the plating tank has to do with the location of the anodes, airlines, heater, cathode and filter pumps. You can design the tank anyway you want, but if you get wrong, the results may not turn out to be great. For example, if you place the anodes very far apart in the bath, the thickness of the coating on the parts will be different on both ends. Also, if your heater is too small to heat the plating solution, then the time it will take to heat up the solution.

Tank Material

There are two available criteria for selecting the tank material. Number one criteria are basing it on the pH solution you will use for instance, if you are using acidic or alkaline solution. A tank made with Polypropylene can carry acidic solutions without issues, but if it is an alkaline solution, the container can withstand it to some extent or degree.

The number two criterion is the temperature of the plating solution. SSTL tanks can't withstand high heat but if you are using a container made of polypropylene material, you can apply excessive temperature, and it can withstand it.

If you bear these two criteria in mind, you will get the right tank design that will meet your requirements.

Solution Agitation

Another important thing in the plating line is the solution agitation mechanism. There are two ways of replenishing ions to your materials or substrates. You can use mechanical agitation, or you use air agitation. Some electroplaters use air agitation in their facilities because of it is affordable and straightforward. An essential factor to consider is the size and spread of the air agitation holes because it also affects the bubbles size. Also, to know the air agitation requirements, determine the solution gravity, the temperature and the chemical.

Filtration

Filtration helps to remove unwanted materials in the electroplating bath. If you do not remove these materials, they will deposit on your parts and prevent adhesion. If you want to select your filtration system, base your search on these two variables.

1. Solution turnover
2. Size of the filter

Your solution turnover represents the number of gallons you filter per hour. If you have a large tank, you must get a large filtration pump and vice versa. The filter size, on the other hand, represents the micro ratings of the filter pumps. These ratings can be from 5 to 200 microns.

Most electroplating solution uses the micron range, but more massive microns does not remove impurities like smaller microns. However, you must determine the material you want to filter to aid your decision on the filtration you will need.

Placement of the Cathode and Anode

Anode material usually depends on the content you are plating. Anode functions to complete the electrical circuit and also introduces an electrical current into the electroplating bath. In the case of zinc plating, you can use titanium basket to hold the anodes.

Heating Element

Some electroplating tanks usually need the heat to speed up electroplating operations. The number of kilowatts you will need for the heater will depend on the composition of your chemical, the temperature of the solution and the ambient temperature that the tank will work with, the cubic feet of the plating tank, the number of gallons, the necessary heat-up time. However, you must add the temperature loss factor.

Zinc plating applications

There are many industrial applications of zinc plating. Due to the ability of the coating to be resistant to corrosion, many industries use the metals to electroplate small parts like fasteners, nuts, screws, and bolts. Secondly, many hardware parts you see all contain zinc plating.

When it comes to industries, the automotive industries use zinc plating to protect vehicle parts like brake calipers, power steering components, and brake pipes.

Producers of armored carriers, tanks and heavy vehicles used in the military also feature zinc plating in their manufacturing.

Conclusion

Zinc plating has many benefits, but it does not work for every condition. When you expose the steel parts are at a temperature level of 500 degrees Fahrenheit or more, you should avoid zinc plating.

Also, don't use zinc plating for seawater or marine applications or in any tropical environment because they can contribute to forming heavy corrosion. Finally, don't use zinc plating on equipment or products that you can ordinarily keep in closed areas where there is heavy moisture condensation.