DEVELOPMENT OF THREE TANK PLATING CYCLE (TTPC) FOR ELECTROLESS NICKEL PLATING

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Abstract

Nickel plating plant at RMP, Mysore, is a special facility to deposit corrosion resistant High Phosphorous Electroless Nickel (HPEN), a highly corrosion resistant coating, on carbon steel and Aluminium components deployed in corrosive fluoride environment. Plating line was designed to plate carbon steel components with the maximum dimension as 1500mm. Necessity arose to plate hollow cylinders of 2000 mm long, which are larger than the designed size of the tanks.

Conventional plating cycle consists of a series of tanks for surface activation and components move from one to another in a sequential manner. Space constraints did not permit to create a separate line for the new requirement. Instead, if chemicals are pumped one after the other into the same tank, number of tanks and footprint will be considerably reduced. This new line of thinking for a compact plating line has been evolved into Three Tank Plating Cycle (TTPC).

This paper presents the conceptualization, technical details, challenges and strategies adopted in developing TTPC to carry out electroless nickel plating on long components successfully.

Introduction

Plating of metals is generally carried out to improve or alter some of the engineering properties of the base material, like hardness, wear resistance, corrosion resistance, conductivity etc. In Electroplating, deposited metal gets reduced from its ionic state to metallic state with the help of electrical energy supplied externally. If the metal is reduced by a chemical reducing agent without using electricity, it is known as Electroless plating. Electoplated Nickel is pure nickel, whereas electroless nickel is a supersaturated alloy of Nickel and Phosphorous or Nickel plus Boron. High Phosphorous Electroless Nickel (HPEN) coating consists of 10-12% Phosphorous and exhibits superior corrosion resistance and higher degree of thickness uniformity than the electroplated nickel. At BARC, Mysore, a special facility to plate carbon steel and Aluminium components of varying dimensions and geometry, exposed to severe corrosive fluoride environment, are coated with 50 microns of HPEN.

Quality of the surface coating depends on good surface preparation and Electroless Nickel is no exception to it. Proven Pretreatment cycle for Electroless Nickel deposit on Carbon Steel components consists of degreasing, soak cleaning, pickling, anodic activation with intermediate water rinse (single or double) prior to entering the plating bath, making a plating line to consist 12-14 tanks of identical height and width.

A new requirement has come up, to plate 2000 mm long hollow carbon steel cylinders, to meet the growing needs of the Project. These components are longer than the existing tank size, and the requirement demands for setting up of a new plating line with larger footprint and
investment. But, limited floor area as well as inadequate head room became constraints to accommodate a new plating line and the new requirement became a challenge. It called for an out of the box thinking to plate these oversized components within the existing facility. This gave birth to a new concept of compact plating line with only 3 tanks instead of 12-14 tanks as in the conventional plating line.

**Electroless Nickel**

In Electroless plating, nickel gets deposited from an aqueous solution of Nickel salt using a chemical reducing agent without external electrical energy. Electroless Nickel deposit can contain 2-14% of Phosphorous. HPEN contains 10-12% Phosphorous and this gives the deposit metallic glass like structure with unique properties such as higher wear resistance, higher corrosion resistance, non magnetic nature etc. Specific advantage of Electroless Nickel over electroplated nickel is its higher degree of uniformity in thickness distribution. Agitation of plating bath and efficient filtration are to be ensured to achieve quality plating. Reaction mechanism of Ni-P coating on a catalytic surface is as given below:

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\begin{align*}
H_2PO_2 + H_2O &\rightarrow HPO_3^- + 2H^+ + H^+
\\
Ni^{2+} + 2H &\rightarrow Ni + 2H^+
\\
H_2PO_2 + H &\rightarrow OH^- + P + H_2O
\\
H_2PO_2 + H_2O &\rightarrow HPO_3^- + H^+ + H_2
\end{align*}
\]

**Surface Preparation**

Adhesion, porosity, continuity, appearance, finish, coverage and corrosion resistance are the quality parameters for any Nickel coating and pretreatment / surface preparation plays an important role in ensuring the same. Removal of surface contamination to leave a clean, oxide-free surface prior to plating is essential for good quality of the deposit. Following is the generally practiced pretreatment cycle for Ferrous substrates:

Same number of operations are carried out in TTPC in 3 tanks by carrying out multiple operations in a single tank, as shown below.

**Design and development of TTPC**

In any conventional plating line, components are processed by moving from one tank to another with predefined immersion times. Thorough water rinsing
between any two treatments is essential to avoid cross contamination of chemicals and also to keep the surface free from foreign particles. Naturally it demands as many tanks as the number of steps involved in pretreatment cycle. To plate HPEN on carbon steel it needs 12-14 tanks of identical height and width. Contrary to the conventional practice, if components are made stationary and chemicals are pumped into the same tank, one after the other, then the requirement of number of tanks and their footprint can be considerably minimized.

With this new concept, initial trials were taken in an experimental set up with a single tank for all the operations. Though plating could be accomplished, a few practical problems like intermixing of chemicals, over exposure of active surface to atmosphere, complexity in discharge of chemicals to different destinations, long processing time etc. were experienced. To overcome them, entire operation was divided into three groups namely alkaline cleaning, acidic etching and nickel plating bath, and 3 tanks were installed accordingly.

To make the system efficient and user-friendly, the following engineering works were designed, executed, finetuned and adopted for regular production.

**Process Tanks**

To minimize the cross contamination of chemicals and total processing time, three tanks i.e. SS316L tank for HPEN plating, Polypropylene tank for activation with sulfuric acid and MS tank for soak, electro cleaning and rinses. Dimensions of these tanks are 2500 X 700 X 1000 mm, facilitating horizontal loading of cylinders. Both MS and SS tanks are fitted with heating/filtration/pumping systems. Vertical tanks were not considered due to limited headroom of the building. There was no space to accommodate 14 tanks of such dimensions in the existing plant, where as, three horizontal tanks could be accommodated with minor adjustments.

**Pumping of Chemicals**

Filling and draining time of chemicals has to be as minimum as possible to avoid exposure of activated area to atmospheric oxygen. Accordingly, three high capacity centrifugal pumps along with necessary piping were installed to pump the chemicals from their respective storage tanks to TTPC and back. Sloped bottom, multiple drains and water jetting arrangements were made to flush out the last traces of chemical before the next chemical enters the same tank.

**Preheating**

Heating time of chemicals is more than their residence time. *In situ* heating of the solutions is a time consuming one and hence, chemicals are preheated in their respective storage tanks and hot solutions (60º - 85º C) are pumped to TTPC to minimize the processing time. Existing vertical tanks of nearby plating line are utilized as storage tanks for all the chemicals.

**Loading pattern**

Horizontal loading pattern was selected for long components due to space constraint. It has given an additional benefit of avoiding critical sealing area (N6 face with no tolerance for rough deposit) in horizontal plane, thus ensuring smooth plating on critical surface. A SS304L fixture was designed and fabricated in-house to accommodate two tires of cylinders with two numbers in each tier. For easy and uniform flow of plating solution filled inside the cylinders, and to ensure easy dislodging of Hydrogen bubbles from the plating surface, 5º inclination was given to all the components.

**Material handling**

Plating operation needs the components to be lifted from the ground level to a height of 3000 mm, longitudinal movement for processing over 3 tanks and again bringing back to zero level after the plating is over. This requirement is also different from conventional plating lines, where in, a loading stand and a Wagon are used in combination for this purpose. Here, both the operations i.e. lifting and longitudinal movements are to be combined in a single material handling Wagon trolley. The conceptual design for such a wagon with telescopic mast was designed totally in-house and executed by a vendor.
Automation

Frequent and precise operation of valves and pumps is important for this process and for this purpose, pneumatically actuated ball valves were installed and all the operations of valves/pumps were planned from a panel to avoid manual intervention and manpower requirement.

Roller Jig

Rotation of components during plating helps in minimizing the un-plated spots at firm contact areas and also gas trapping areas on the internal surface. For this purpose, smooth rollers have been positioned to rotate the heavy components freely during plating thus avoiding jig marks/patch marks.

Operational Sequence:

i. Make the horizontal jig of degreased components and position it in Tank no.1
ii. Pump the preheated soak cleaner into Tank no.1
iii. After 20 minutes, pump back the soak solution to its storage tank.
iv. Fill the Tank 1 with rinse water.
v. Transfer the components to Tank 2.
vi. After 1 minute, transfer the components to Tank 1 for rinsing.
vii. Drain the water and pump the preheated electro-cleaning solution to Tank 1 from its storage tank.
viii. Anodic electrocleaning at 60°C for 5 min. with a current density of 1-2 A/dm²
ix. Pump back electrocleaning solution to its storage tank, and fill Tank 1 with water.

Major Benefits

- It has occupied minimum floor space and could be accommodated within the existing plant, thus saving considerable time and investment of creating a new facility.
- Rejection rate of plated components is bare minimum due to horizontal loading.
- Processing of a single jig is enough instead of processing multiple jigs.

Air agitation

There is a likelihood of plating solution filled inside the hollow cylinder experiencing lesser agitation, leading to temperature and concentration gradients. To overcome this problem, an air sparger with apertures on 360º was designed, fabricated and inserted in all the four components to improve internal circulation of plating solution, which has helped a lot in attaining high degree of uniformity in thickness distribution.
• Higher and constant Operating ratio (Area/Volume) can be maintained throughout the plating time.
• For future needs, this concept can be upgraded for still longer components.

Conclusion

This in-house developed set-up has been under continuous usage and till now plating on a few hundreds of long components has been accomplished successfully. This developmental work has immensely helped in plating the 2000 mm long components and played an important role in achieving the overall targets of the Project.

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