A REVIEW ON ELCTROPOLISHING PROCESS AND ITS AFFECTING PARAMETERS

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ABSTRACT

Electropolishing is surface finishing process of metals and alloys, getting good surface finish with very low surface roughness values. Electropolishing (EP) is a process by which metal is removed from a work piece by passing of electric current while the work is submerged in a specially designed solution. The process is essentially the reverse of electroplating. The main aim of EP is to reduce microroughness, thus dramatically reducing the risk of dirt or product residues adhering and improving the cleanability of surfaces. Electropolishing is also used for deburring, brightening and passivating. The objective of this study was to understand the EP process, factors affecting the EP process and applications of EP process. This paper represents review of EP process and factors affecting the EP process. The affecting parameters of EP process are current density, bath temperature, Electrolyte, EP time, spacing between anode and cathode, electrolyte stirring, initial texture etc. The 1st section of paper represent about EP process. The 2nd section reviews different parameters that affect the EP process. It also describes the effect on EP process when some additives are used in electrolytic solution.

Keywords: EP, Electrolyte, Surface Finish

I. INTRODUCTION

Electropolishing is also known as electrochemical polishing or electrolytic polishing. It is a chemical surface finish technique, by which metal is removed electrolytically, ion by ion, from the surface of object. The main objective of EP is to reduce micro roughness, thus dramatically reducing the risk of dirt or product residues adhering and improving the cleanability of surfaces. Electropolishing is also used for deburring, brightening and passivating. The process exposes an undisturbed, metallurgically clean surface. Electropolishing has become a common treatment for stainless steel in industries because a corrosion-resistance and cleanability requirement of stainless steel is generally high. Typical applications are found in the pharmaceutical, biochemical and food-processing industries. Since electropolishing involves no mechanical, thermal or chemical impact, small and mechanically fragile parts can be treated. Electropolishing can be applied to parts of almost any shape or size[1].

Electropolishing is a process by which metal is removed from a work piece by passing of electric current while the work is submerged in a specially designed solution. The process is essentially the reverse of electroplating. In a plating system, metal ions are deposited from the solution on to the work piece; in an electropolishing system, the work piece itself is dissolved, adding metal ions to the solution. Fig.1.1 is a schematic illustration of a typical electropolishing cell. The work piece is connected to the positive (or anodic) terminal, while the negative (cathodic) terminal is connected to a suitable conductor. Both terminals are submerged in the solution, forming a complete electrical circuit. The current applied is direct (DC) current. The principal chemical reactions occurring at the electrical anode, that is, at the part, are as follows:

Metal - Electrons $\longrightarrow$ Metal ions

The reaction states that metal is dissolved from the anodic electrode, passing into the solution to form a soluble salt of the metal. All of the components of stainless steel, namely the iron, the chromium, and the nickel, undergo this reaction simultaneously, producing the controlled smoothing of the surface. Several side reactions also occur, creating by-products that must be controlled in order to produce the highest possible quality of electropolishing. The quantity of metal removed from the work piece is proportional to the amount of current applied and the time. Other factors, such as the geometry of the work piece, affect the distribution of the current and, consequently, have an important bearing upon the amount of metal removed in local areas. Fig.1.2 illustrates both high and low current density areas of the same part and notes the relative effect of electropolishing in these two areas.

The principle of differential rates of metal removal is important to the concept of deburring accomplished by electropolishing. Fine burrs become very high current density areas and are, subsequently, rapidly dissolved. Low current density areas receive lesser amounts of current and may show negligible metal removal. In the course of electropolishing, the work piece is manipulated to control the amount of metal removal so that polishing is accomplished and, at the same time, dimensional tolerances are maintained.[2]

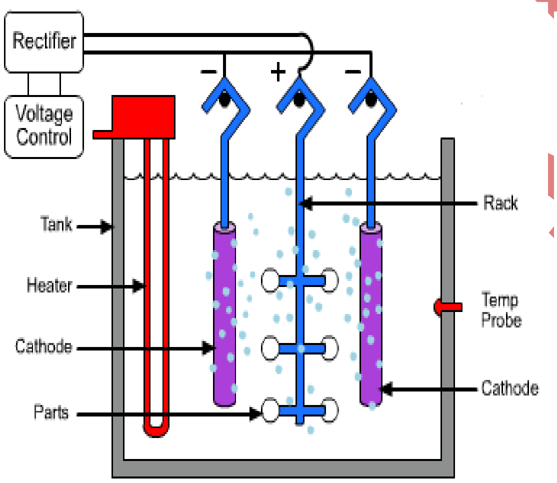

Fig -1.1 Schematic Illustration Of Typical Electropolishing

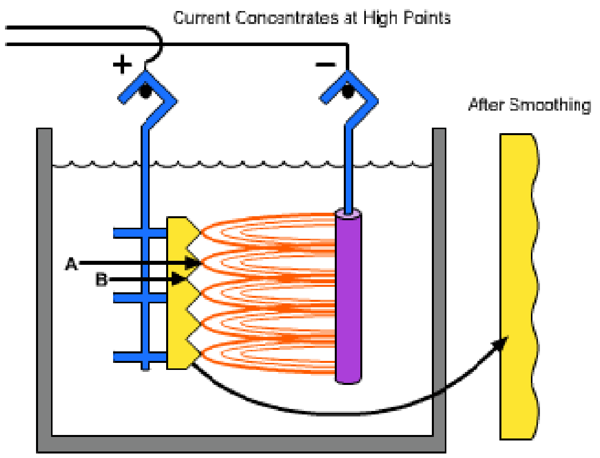

Fig -1.2 The Effect Of Electropolishing On Surface Finish

II. ELECTROPOLISHING PARAMETERS

Electropolishing is one of the useful tools to improve the surface finish of a metallic work piece by anodic dissolution process. In Electropolishing the anode surface is smoothened and brightened by the use of appropriate electrolyte under optimum conditions of current density and temperature. Stainless Steel is generally Electropolished in industry from phosphoric acid based electrolytes. Electropolishing of stainless steel have large number of applications in industry. Electropolishing technique plays important role in vacuum technology, preparation of samples for metallography and electron microscopy.

K. Srinivasan, K.S.Ranga krishnan [3] studied the effect of current density, time, and temperature on the weight loss metal. The electropolishing baths for stainless steel with various concentration of phosphoric acid from 10-75% by volume were tried. The optimum concentration of phosphoric acid for electropolishing of stainless steel was found out. The brightness of the stainless steel is best at 50% by vol. of phosphoric acid bath conditions compared to other baths.

According to P.J. Núñez, E. García-Plaza[4], The most common electrolytes for the electropolishing of stainless steel are varying concentrations of phosphoric and sulphuric acid, and occasionally additives such as chromic acid. The main aim of this study was to check the performance of three commonly used industrial electrolytes in terms of the surface finish of electropolished stainless steel. Each electrolyte had different concentrations of phosphoric acid, sulphuric acid, and chromic acid. The following electropolishing conditions were assessed: current density, bath temperature, electropolishing time, initial textures, and electrode positions. This study on the performance of three industrial electrolytes for the polishing of stainless steel AISI 316L revealed that adding chromic acid does not significantly enhance surface finish, and electropolishing ranges were quite similar for all three electrolytes. Neither electrode position nor initial surface texture had a significant impact on polishing range using any of the three electrolytes assessed, with maximum polishing ranging (80÷90%) for both textures and positions. Similarly, temperature (*T*) had no significant influence on process performance given that minimum polishing range were obtained regardless of the electropolishing time, temperature, and current density conditions. The results indicate that the best electropolishing performance was achieved with the lowest temperature (in this study 35 C), which ensured optimum electrolytic conductivity, reduced energy costs, avoided producing toxic vapours, and degrading the electrolyte. The parameters electropolishing time and current density were the variables that had the greatest influence on electrochemical polishing, and were slightly correlated. Increasing treatment time to 25 (minutes) and current density to 48 (A/dm2) significantly improved surface finish (*Ra*), reaching maximum polishing ranges of 80÷90%. Above these reference values the process stabilizes, without any significant improvement in roughness (*Ra*), but with the risk of losing material that may undetermine the design specifications of manufactured component. The best polishing results (*Ra*) were obtained with electrolyte sulphuric acid 35% and orthophosphoric acid 45% in comparison to electrolyte sulphuric acid 15% and orthophosphoric acid 63%. The addition of chromic acid (3%) to electrolyte had no significant impact on process performance, and the outcome was similar to that obtained with the reference electrolyte. Anshuman Bhuyan, Brandon Gregory[5] studied that The optimized conditions for the electropolishing of austenitic type 304 and 316L stainless steels in commercially-available EPS 4000 solution (based on a mixture of phosphoric and sulphuric acids) for use in cardiac stenting applications. Electropolishing parameters such as electrolyte temperature and concentration, current density, polishing duration, use of pulsed current and ultrasonic agitation have been explored and optimal conditions have been found. Quality of the polishing was determined on the average surface roughness, amount of thickness reduction, and overall surface appearance. Samples polished in an ultrasonic bath with pulsed currents of 50 Hz, and 60°C achieved the lowest surface roughness with little or no evidence of surface defects which were present in other recipes.Similar results were seen in both types 304 and 316L stainless steels. Optimal conditions were chosen so as to meet the surface roughness and reduction requirements, minimize the amount of pitting, and obtain a surface with high chromium and nickel content. In most cases, surface roughness and thickness reduction are inversely related.

Shuo-Jen Lee and Jian-Jang Lai [6] extensively studied the improvement of the corrosion resistance capability of a work piece being processed by the electropolishing (EP) is one of the most importance process characteristics. In this paper, the effects of the EP process parameters on the corrosion resistance performance of the SS 316L stainless steel were studied based on the uniform and localized intergranular corrosion (IGC) analyses. The IGC is the prominent characteristics of localized corrosion in stainless steel. The work piece (anode) material was the SS 316L stainless steel. The cathode material under study was platinum. The electrolyte was composed of sulphuric acid, phosphoric acid, glycerine and DI water. The test specimens were all polished before experiments in order to reduce the effect of the bail by layer. Variables of the EP process parameters gap between the electrodes and the process time. The specimens were analyzed, first, by the surface roughness measurement. Secondly, they were observed under the optical microscope for surface marks and defects. It was followed by the linear polarization analysis for the uniform corrosion performance. The electrochemical potentiokinetic repassivation (EPR) test was employed to study the localized, IGC. Finally, X-ray photoelectron spectroscopy (XPS) and Auger electron spectroscopy (AES) analyses were conducted to analyze the metallurgical composition and the thickness of the passive film.

The EP process is a very effective technology to improve the corrosion resistance of stainless steel. However, the process parameters may greatly affect the results. From this study, the optimal electrolyte gap was 5mm and polishing time was 5 min. The surface roughness had improved by more than threefold. These values may be different for different variables such as electrolyte and cathode material. The polarization resistance method verified that the uniform corrosion improved by more than 60%. With EPR analysis, the IGC resistance improved by more than 85%. The AES and XPS analyses also verified that the passive film had changed to Cr rich after the EP process.

MIAO Wei-dong and MI Xu-Jun [7] has carried out the effect of processing parameters on nitinol electropolishing. Electropolishing has been used in NiTi alloy in several fields for its special characteristics, but it's essential details and electropolishing mechanism have not been reported yet as a demand from business competition, which, to a great degree, restricts the application and extension of the electropolishing technology. Besides the electrolyte, other factors that influence the electropolishing are temperature, current density, time, spacing between anode and cathode, electrolyte stirring, etc. Studies on the effect of the temperature on the electropolishing process show that the higher the temperature is, the bigger the electropolishing rate is, following the near Gauss law. The relationship between the temperature and the surface roughness follows a near parabolic law, and the relationship between the temperature and the surface reflectivity follows a near sigmoidal law. The relationship between the electropolishing voltage and the current density follows a near cubic law, while that between the electropolishing rate and current density follows a near linear law. The relationship between the electropolishing rate and the time follows a near sigmoidal law. The practical spacing between anode and cathode is confirmed by the Hall bath experiment.

2.1 Additives Used In Eletrolyte

Tarnishing and roughness of copper surface can be removed by electropolishing treatment (EP) imparting a bright and smooth surface at suitable conditions, e.g. current density, time, temperature, and viscosity. It was carried out by A.M. Awad, N.A. Abdel and T.H. Dahy[8] using an electrolytic cell containing phosphoric acid

55% as the electrolytic solution. Both copper working electrode and lead counter electrode, and reference electrode (SCE) were connected to a Potentiostat/Galvanostat to allow an electric current to pass through the solution. Some additives such as soluble starch, ethylene glycol, and methanol were added to reduce defects formed on the copper surface during EP process. The results showed that the highest gloss value was obtained by applying electric potential 1.5V at the passive region of polarization curve. The surface was investigated after EP treatment, where SEM and EDX showed lower roughness in case of addition of both soluble starch and ethylene glycol more than methanol. Moreover, AFM analysis showed the lowest roughness in case of soluble starch more than other additives.

Ching An Huang, Jo Hsuan Chang, Fu-Yung Hsu and ChihWei Chen[9] have proposed Electropolishing behaviour and microstructures of copper deposits electroplated in an acidic copper-sulphuric bath with different thiourea contents.Cu electro deposition was performed on a rotating cylindrical Ti electrode in Cu-sulphate plating baths with different thiourea contents up to 8 ppm. The hardness, microstructure and electropolishing behavior of the Cu deposits were studied. Some sulphur-rich particles in the Cu deposits prepared from the thiourea-containing baths were identified. The sulphur-rich particles dissolved preferentially during electropolishing in a 40 vol.% H3PO4 solution, forming a thin amorphous phase containing P in patches on the outer surface of the Cu deposit. The deposits prepared in the baths with thiourea showed higher dissolution current during polishing and formed a brightened and leveled surface with a surface roughness (Ra) lower than 30 nm.

With the addition of a small amount of thiourea to the Cu-sulphate plating bath, the hardness of the Cu deposit was clearly increased because of grain refinement. The preparation of the TEM samples by the twin-jet etching in a 40 vol.% H3PO4 solution caused the development of a thin amorphous phase containing P on the outer surface of the Cu deposit prepared in the thiourea-containing plating bath. For the Cu deposits prepared in the baths with thiourea a brightened surface with a surface roughness (Ra) lower than 30 nm was obtained by electropolishing, and their anodic dissolution rate during electropolishing was obviously higher than that of the deposit prepared in a thiourea free bath.

2.2 Applications of Electropolishing Process

A.M. Awad and E.A. Ghazy [10] have carried out the study of Electropolishing of AISI-304 stainless steel for protection against SRB biofilm. Electropolishing treatment (EP) can be used to remove the biofilm formed on AISI-304 stainless steel surface and protect it against bacterial colonization. High levels of both smoothness and brightness of AISI-304 stain-less steel surfaces can be attained by using electropolishing technique, where the sample was fixed as anode and a suitable current was applied in to electrolytic cell containing H3PO4. AISI-304 stainless steel was ex-posed to stabilized mixed culture of sulfate reducing bacteria (SMC-SRB) under different conditions as, temperature, pH, salinity, and incubation time and inoculums size. The present study recorded the main indicators of bacterial activity such as S−−, Fe++, most probable number (MPN) of SRB and weight loss (corrosion rate) by milinches per year (mpy).

As the roughness of AISI-304 stainless steel surfaces is decreased, the resistance against bacterial growth is increased. Electropolishing process is successfully used to increase the smoothness of AISI-304 stainless steel surface by elimination of bacteria may harbor through the burrs of the surface. Under all conditions of pH, temperature, incubation time, salinity and inoculums size of cultivation, the bacteria was reduced to less than

10% of the original concentration after EP. SEM analysis revealed that the morphology of the surface was regularly smoothed out and a high gloss value of the surface was obtained at 3.75 A/dm2. EDX analysis showed that the elements S, C and O formed over the surface due to bacterial growth were completely disappeared after EP while, the main elements of AISI 304 stainless steel Fe, Cr, Ni
and Mn were obviously present. Electropolishing technique can be recommended in different fields to improve disinfection of the surface of AISI-304 stainless steel.

Prakash Sojitra, Chhaya Engineer, Devesh Kothwala, Ankur Raval, and Haresh Kotadia [11] have done An Investigation of Material Removal, Surface Roughness and Corrosion Behaviour by Electropolishing of 316LVM Stainless Steel Cardiovascular Stents. Smooth surface of a cardiovascular stent is an important factor in determining biocompatibility. Electropolishing is an effective method for improving surface smoothness of the stents. Electropolishing has been employed on laser cut SS316L cardiovascular stents to increase surface smoothness. Acid pickling has been used as a pre-treatment for electropolishing followed by passivation to enhance its corrosion resistance in biological environment. Stent has been characterized by strut dimension analysis, Scanning Electron Microscopy for its surface smoothness, gravimetric analysis and potentiodynamic corrosion analysis. It was found that surface roughness after electropolishing has been reduced to significant level and also long-term corrosion behaviour of stent material in simulated biological fluid (PBS) is very stable. The quality of the surface of 316LVM stainless steel coronary stents was very much improved when subjected to electropolishing followed by passivation.

III. SUMMERY

Electropolishing is surface finishing process of metals and alloys, achieving brilliant surface finish with very low surface roughness values. K. shrinivasan investigated that the brightness of stainless steel is best at 50% by volume of phosphoric acid bath conditions compared to other baths, for 316SS, phosphoric acid, sulphuric acid as electrolyte. The best EP performance was achieved with lowest temperature (350C), which ensure optimum electrolytic conductivity, reduced energy cost and avoided producing toxic vapours. In most cases the surface roughness and thickness reduction are inversely related. Studies on the effect of the temperature on the EP process shows that higher the temperature is, the bigger the EP rate. EP is also used to improve the corrosion resistance of stainless steel. EP has been employed to improve surface smoothness of medical instruments, also to protect it against bacterial colonization. Addition of additives like starch to the electrolytic solution enhances brightness.

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