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SURFACE ROUGHNESS ANALYSIS OF SS202 STAINLESS STEEL BY ELECTROCHEMICAL POLISHING

Rajendra P. Bansod[1] , Dr. Ashish B. Deoghare[2]

Research Scholar, Mechanical Engineering Department, G.H.Raisoni Academy of Engineering and Technology, Nagpur, Maharashtra, India[1]

Professor, Mechanical Engineering Department, G.H.Raisoni college of Engineering, Nagpur, Maharashtra, India[2]

Abstract:-Electro-chemical polishing is a process of improving micro smoothness, micro topology, and material brightness. Electro polishing streamlines the microscopic surface of a metal object by removing metal from the object's surface through an electrochemical process. In Electro polishing the anode surface is smoothened and brightened by the use of appropriate electrolyte under optimum conditions of current density and temperature. The process is carried out by anodic dissolving the substrate in an electrolyte with an external source of electricity. In Electro polishing the anode surface is smoothened and brightened by the use of appropriate electrolyte under optimum conditions of current density and temperature. Traditional mechanical polishing processes results in deformed layer and induces residual stresses in material and hence it affects performances of the material. .It has advantages of high removal rate and no tool wear in process. It is also cost effective. In the present work, investigation is carried out to obtain extent of improvement of smoothness for SS202 stainless steel by electrochemical polishing. The process variable parameters considered are electrolyte temperature, current density and electrolysis time. The two methods are employed for measuring the surface roughness. In first method Total fifteen samples are examined by changing the process parameters and corresponding surface roughness is recorded using surface roughness tester then in second method there are twenty seven samples are taken and corresponding readings are measured by changing its parameters simultaneously.

Keywords: Electrochemical Polishing (ECP); SS202 Stainless Steel; SRR (Surface Roughness Reduction).

I. INTRODUCTION

Polishing is a tedious and necessary finishing operation for many products. The manual operations of grinding and polishing are labor intensive and prompt for human error. The disadvantages point out by various researchers are hardening of the surface, induction of residual tension and oxide incorporation, scratch marks and damaged layer. The other mechanical polishing methods such as shot peening and sand blasting are rough and imprecise. The chemical etching/polishing methods is simple and cost effective. However, there are safety and environmental concerns. It is one of the useful techniques to improve the surface finish of a metallic work piece by anodic dissolution process. Electro polishing technique plays a vital role in vacuum technology, preparation of samples for metallography and electron microscopy.

II. MATERIALS AND METHODS

A. EXPERIMENTAL DETAILS

In the present study, electrochemical polishing effect on surface finish for 10 mm diameter and 60 mm length specimen of SS202 stainless steel is examined for variable functions of anodic current, time, temperature and constant electrolytes concentration. A phosphoric acid based electrolyte is used for electro polishing the Stainless Steel. The process consists of an anode (work piece), a cathode (electrode) and electrolyte. Ortho-phosphoric and

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concentrated hydrochloric acid is used as electrolyte with 10 % weight of water. Initially at 0.02 Amp/mm^2 current is set to create an ionized vapour envelope between the aqueous electrolyte and the substrate. A viscous film is developed on the anode along with deposition of metal particles.

The effects of electro polishing of work piece immersed in an electrolyte tank are shown in Figure 1. The SS202 stainless steel specimens with a fine finish of *R*a 0.21µm are used as substrates. The testing of samples is carried out in a 1 liter capacity glass beaker, with an aqueous solution of Orthophosphoric acid, Sulphuric Acid and Water. The substrates are cathodically biased using a DC power supply with high (30 V) current capability. To investigate temperature effect on the electro polishing temperature of electrolyte is changed from 30 ^{0}C to 100 ^{0}C in steps of 4 ^{0}C to 5 ^{0}C increments.

Figure 1 Experimental set up of ECP

Actually the process is carried out in three manifolds: - In macro polishing operation the bulge larger than 0.1 mm in size is removed to make surface smooth, while the brightness of the surface is not guaranteed. Micro polishing is second step which removes the bulge on the surface of about 0.01 mm in size makes the surface more reflective and bright, while the smoothness of the surface might not get improved. The Passivation is third process which produces a chemically passivated layer that other mechanical polishing processes cannot produce.

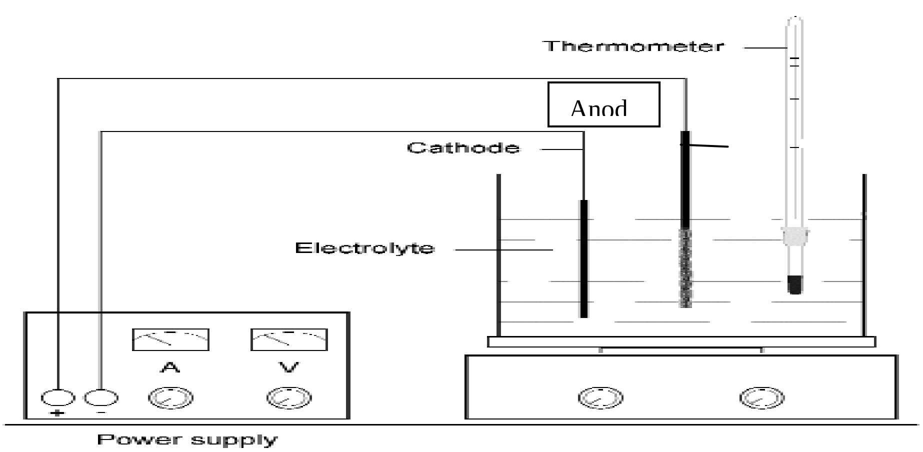

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Figure 2 Experimental set up of ECP

III. SURFACE ROUGHNESS ASSESSMENT

Cylindrical SS202 stainless steel specimen is cut on power saw. Sharp edges and burrs are removed using high speed portable grinder. Prior to begin polishing process, specimen is wash by immersing in hot steelex 20 (alkaline soap cleaner) solutions for 10 minutes followed by dry soakings. Soaked, specimen is cleaned by tap water. To remove the alkaline film formed on the specimen it is dipped in 10% HCL solution for 20 s. Further it is cleaned in running water followed by washing with distilled water. Uniformly formed thin film of distilled water on specimen indicates that specimen is completely clean. The specimen is dried and placed in muslin cloth. Details consideration of specimen for experimentation is provided in Table 1 and metallurgical compositions are shown in Table 2.

Table 1
Basic Testing Parameters and Polishing Conditions

Sr. No.	Particulars	Specification
1	Electrode and work piece material	SS202
2	Electrode and work piece dimensions	60 mm x 10 mm Φ
3	Electrolyte composition	H_3PO_4+H_2SO_4+WATER
4	Electrolyte quantity	150 ml

Table 2

Metallurgical Compositions of SS202 Test Specimen

Sr. No.	Elements	Chemical Composition (%)
1	Carbon	0.12
2	Manganese	5.5/7.5
3	Silicone	0.9
4	Chromium	16/18
5	Nickel	0.5/4.0
6	Molybdenum	0.2
7	Phosphorus	0.06
8	Nitrogen	0.25

Table 3

Physical Configurations of 202 Test Specimens

Sr. No.	Property	Value
1	Density	7.80 Kg/cm³
2	Thermal Expansion	17 x10-6 /K
3	Modulus of Elasticity	200 GPa
4	Thermal Conductivity	15 W/m.K

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While performing experimentation temperature, current density and bath time is varied and the corresponding effect on surface roughness is measured using MITUTOYO SJ-201 surface roughness tester. During the subsequent level of experimentation, the temperature and time is incremented with 5 & 3 unit respectively whereas current density by 0.01 unit. Comparison between surface roughness before and after electro polishing process is noted as shown in Table 4.

Single specimen is partially immersed in electrolyte for 5 minutes by maintaining 30^0C temperature and D.C. current 0.03 A. as shown in figure 4. Similarly experimentation is executed for given specimens by changing magnitude of variable parameters, results is depicted in Table 4.

Table 4.1

Values of Surface Roughness on SRT

Before ECP			After ECP					
Sr. No	Roughness Average(Ra)µm	Root Mean Square(Rq) µm	Roughness Average(Ra) µm	Root Mean Square(Rq) µm	Temp. (^{0}C)	Current density (A/mm^2)	Time (min)	Voltage (v)
1	0.21	0.35	0.15	0.19	30	0.03	5	0.6
2	0.26	0.29	0.20	0.24	35	0.04	8	0.7
3	0.25	0.31	0.16	0.21	40	0.05	11	0.8
4	0.24	0.35	0.17	0.21	45	0.06	14	0.9
5	0.39	0.44	0.16	0.19	50	0.07	17	1.0
6	0.28	0.35	0.20	0.20	55	0.08	20	1.1
7	0.28	0.35	0.24	0.25	60	0.09	23	1.2
8	0.41	0.53	0.19	0.23	65	0.10	26	1.3
9	0.17	0.24	0.16	0.19	70	0.11	29	1.4
10	0.10	0.14	0.07	0.10	75	0.12	32	1.5
11	0.09	0.13	0.07	0.13	80	0.13	35	1.6
12	0.09	0.12	0.08	0.11	85	0.14	38	1.7
13	0.13	0.19	0.10	0.15	90	0.15	41	1.8
14	0.09	0.13	0.09	0.10	95	0.16	44	1.9
15	0.14	0.19	0.11	0.14	100	0.17	47	2.0

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Table 4.2.

Values of Surface Roughness on SRT

	Before ECP		After ECP					
Sr. No	Roughness Average(Ra) µm	Root Mean Square(Rq) µm	Roughness Average(Ra) µm	Root Mean Square(Rq) µm	Temp. (^{0}C)	Current density (A/mm^2)	Time (min)	Voltage (v)
1	0.26	0.35	0.07	0.09	35	0.25	10	2
2	0.22	0.28	0.20	0.25	50	0.30	13	2
3	0.2	0.28	0.08	0.11	65	0.35	15	2
4	0.21	0.29	0.14	0.21	50	0.25	10	2
5	0.15	0.21	0.13	0.20	65	0.30	13	2
6	0.13	0.18	0.08	0.12	35	0.35	15	2
7	0.27	0.39	0.12	0.17	65	0.25	10	2
8	0.12	0.15	0.06	0.10	35	0.30	13	2
9	0.12	0.15	0.09	0.15	50	0.35	15	2
10	0.16	0.21	0.15	0.21	35	0.30	10	2
11	0.09	0.14	0.07	0.09	50	0.35	13	2
12	0.2	0.30	0.18	0.27	65	0.25	15	2
13	0.06	0.08	0.05	0.07	35	0.35	10	2
14	0.1	0.12	0.09	0.12	50	0.25	13	2
15	0.24	0.32	0.20	0.27	65	0.30	15	2
16	0.13	0.18	0.10	0.15	35	0.25	10	2
17	0.18	0.26	0.11	0.14	50	0.30	13	2
18	0.12	0.16	0.06	0.10	65	0.35	15	2
19	0.08	0.12	0.07	0.10	35	0.25	13	2
20	0.21	0.28	0.10	0.14	50	0.30	15	2
21	0.11	0.18	0.10	0.12	65	0.35	10	2
22	0.07	0.10	0.07	0.09	35	0.25	15	2
23	0.11	0.15	0.09	0.11	50	0.30	10	2
24	0.15	0.20	0.11	0.15	65	0.35	13	2
25	0.18	0.24	0.15	0.21	35	0.25	10	2
26	0.11	0.16	0.10	0.12	50	0.30	13	2
27	0.12	0.18	0.11	0.11	65	0.35	15	2

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Figure 4. Surface Roughness Tester (MITUTOYO SJ-201)

B. ACID PICKLING

An aggressive form of acid cleaning intended to remove tough deposits of scale and oxides. Acid pickling is harsh enough to etch metal surfaces. Acid pickling is carried out to remove slag and metal oxides attached on the surface of the material. Pickling is a metal surface treatment used to remove impurities, such as stains, inorganic contaminants, rust or scale from ferrous metals, copper, and aluminum alloys. A solution called pickle liquor, which contains strong acids, is used to remove the surface impurities. It is commonly used to clean steel in various steelmaking processes.

C. EFFECTIVE ELECTRO CLEANING

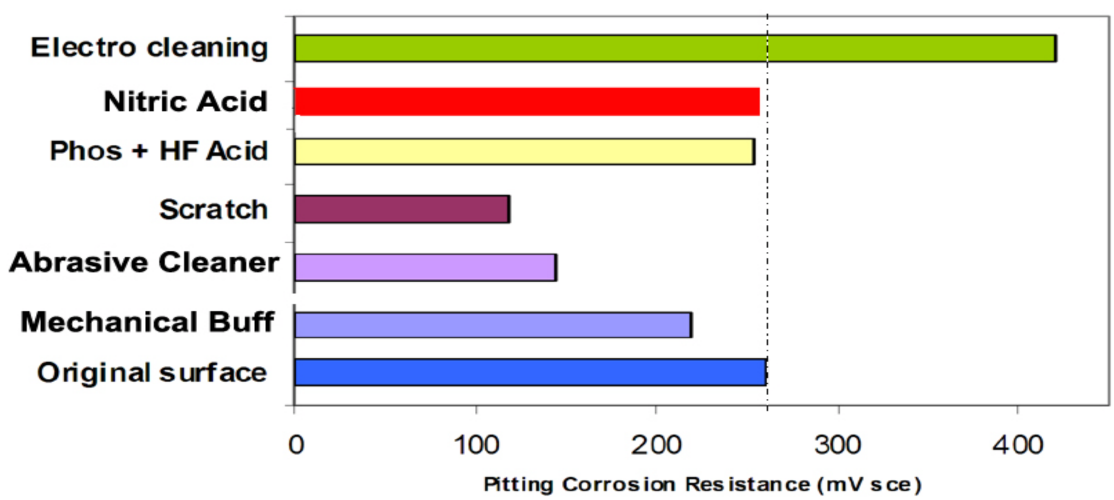

Figure 5. Comparison of the corrosion resistance of different cleaning methods.
Corrosion Resistance *(mV SCE, 5M NaCl, 20C, 316L 2B)*

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IV. REGRESSION ANALYSIS

Regression Analysis is a statistical technique for estimating the relationships among variables. It includes many techniques for modeling and analyzing several variables, when the focus is on the relationship between a dependent variable and one or more independent variables. More specifically, regression analysis helps one understand how the typical value of the dependent variable changes when any one of the independent variables is varied, while the other independent variables are held fixed.

Regression analysis is widely used for prediction and forecasting, where its use has substantial overlap with the field of machine learning. Regression analysis is also used to understand which among the independent variables are related to the dependent variable, and to explore the forms of these relationships. In restricted circumstances, regression analysis can be used to infer causal relationships between the independent and dependent variables. However this can lead to illusions or false relationships.

V. ANALYSIS OF VARIANCE

The purpose of the analysis of variance (ANOVA) is to reveal the process parameters that significantly affect the performance characteristics. The traditional statistic technique can only obtain one parameter in a single sequence; one has to do the analysis repeatedly to obtain other factors for the experiment. Using the experimental design module in the Statistical software, one obtains the results of two parameter sets. ANOVA is a statistically based, objective decision-making tool for detecting any differences in the average performance of groups of items tested. ANOVA helps in formally testing the significance of all main factors and their interactions by comparing the mean square against an estimate of the experimental errors at specific confidence levels.

VI. APPLICATIONS OF SS202 STAINLESS STEEL

200 series austenitic are typically used to replace types 304 and 301 as well as Carbon (Chrome-Manganese) Steels mainly for indoor use for low corrosion applications a t room temperature.

Furniture
Bins
Cookware & Serving Bowls
Window Channel Spacers
Safety Shoes (mid-sole protector)
Deep drawn kitchen equipment – e.g. Cookware &
Sinks
Hose Clamps
Trailer Frames
Industrial Strapping
Railway Rolling Stock

There is also grade 201LN for welded constructions, Structural uses and low temperature applications - Examples include sides & roofs of trains, liquefied gas storage vessels, structural members/chassis of railway rolling stock, trucks & trailers, coal handling equipment.

VII. BENEFITS OF ELECTRO POLISHING

D. THE ELECTRO POLISHING PROCESS PROVIDES:

a. *BETTER PHYSICAL APPEARANCE*
- No fine directional lines from abrasive polishing.
- Excellent light reflection and depth of clarity.
- Bright, smooth polish; uniform luster of shaped parts

b. *ENHANCED MECHANICAL PROPERTIES*
- Less friction and surface drag.
- Increased production and duty cycles in process equipment. Electro polishing greatly reduces fouling, plugging, scaling and product build-up.

- Surface retains the true grain structure and properties of the bulk metal.
- Fatigue strength is not reduced. Electro polishing allows the true fatigue strength of a part to be accurately determined.
- Higher fatigue strength can be promoted by particle-blasting the surface to reintroduce compressive stress without losing electropolishing's advantages.
- Stress-relieving of the surface.
- Reduces galling of threads on stainless and carbon steel and other alloys.

c. BETTER CORROSION PROTECTION

Electrochemical polishing yields maximum tarnish and corrosion resistance in many metals and alloys. Stainless steel contains metallic and non-metallic inclusions, which are unavoidably included during manufacture. Mechanical polishing not only fails to remove inclusions, but also tends to push them further into the surface and even increase them by further pick-up of abrasive materials. These inclusions eventually can become points of corrosion.

VIII. RESULT AND DISCUSSION

The experimental values of surface roughness were measured by using surface roughness measurement tester which gives the Ra and Rq i.e. Roughness Average and Root Mean Square (RMS) values of the finished electrochemical polished specimens. The Analysis of Variance and the Regression analysis software is used to reveal the process parameters that significantly affect the performance characteristics**.** These two analysis software gives the graphical result of the electrochemical polishing method. The result of ECP is directly measured by using EXCEL sheet. The testing of material is done on UTM (Universal Testing Machine). Hence surface roughness reduction was considerably improved by this experimentation.

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