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Application of Signal-To-Noise Ratio Analysis for Optimizing Process Parameters for Surface Roughness Reduction in Electrochemical Polishing Process

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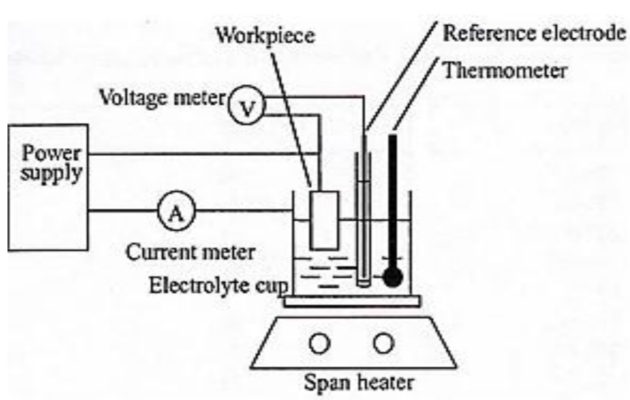
Abstract: - **This paper reports on the optimization of electropolishing process and its effect on process parameters by applying Taguchi methods for determination of best possible condition for electropolishing of stainless steel. The specimen used in the experiment is SS304. The chemical composition of electrolyte consists of Orthophosphoric acids (H3PO4), Sulphuric acid H2SO4 and distilled water. The three different parameters were chosen they are current density, time and temperature. Taguchi orthogonal array is designed with three levels of polishing parameters. Different experiments were performed and number of readings was taken according to Taguchi orthogonal array. To determine the value of surface roughness reduction stylus type portable surface roughness tester of Mitutoyo made model SJ – 201 has been used. The surface roughness reduction was considered as quality characteristic with the concept of "larger- the- better" using signal to noise (S/N) ratio. With the advancement in technology and due to development in new materials we need suitable and economical methods to process them. It is also predicted that the Taguchi method is good method for the optimization of various process parameters in electropolishing. The results obtained were validated by conducting confirmation experiments.**

Keywords: - **Electrochemical polishing (ECP), surface roughness reduction, Taguchi method, and 304 stainless steel.**

I. INTRODUCTION

Electropolishing is an electrochemical process which polishes, passivates and deburr metal parts. The workpiece is immersed in the electrolyte and it serves as anode which is connected to the positive terminal of the DC power supply. The cathode (electrode) is connected to negative terminal. The electrolyte is composed of viscous acid fluid. During the process, the hydrogen gas will be formed from the cathode and oxygen gas will be formed at the anode along with metallic dissolution. In basic terms, the object to be electropolished is immersed in an electrolyte and subjected to a direct electrical current. The object is maintained anodic, with the cathodic connection being made to a nearby metal conductor. Smoothness of the metal surface is one of the primary and most advantageous effects of electropolishing. During the process, a film of varying thickness covers the surfaces of the metal. This film is thickest over micro depressions and thinnest over micro projections. Electrical resistance is at a minimum wherever the film is thinnest, resulting in the greatest rate of metallic dissolution. Electropolishing process is reversed of electroplating process where the material is removed rather than depositing. The electropolishing process smoothes and streamlines the microscopic surface of a metal object. As a result, the surface of the metal is microscopically featureless, with not even the smallest speck of a torn surface remaining. In electropolishing, the metal is removed ion by ion from the surface of the metal object being polished. Electrochemistry and the fundamental principles of electrolysis (Faraday's Law) replace traditional mechanical finishing techniques, including grinding, milling, blasting and buffing as the final finish.



Sketch

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Actual Photo

II. PROPOSED METHODOLOGY

This paper uses Taguchi's method, which is very effective to deal with responses influenced by multi-variable. This method provides a simple, efficient and systematic approach to determine optimal machining parameters. In the Taguchi method, the results of the experiments are analyzed to achieve objectives such as establishing the best or the optimum condition for a product or process, estimating the contribution of individual parameters and interactions and estimating the response under the optimum condition. The optimum condition is identified by studying the main effects of each of the parameters. The main effects indicate the general trend of influence of each parameter. The knowledge of contribution of individual parameters is a key in deciding the nature of control to be established on a production process.

There are many different S/N ratios. Six basic ones are
1) Nominal-the-best

2) Smaller- the-best
3) Larger-the-better
4) Target-the-best
5) Classified attribute
6) Dynamic

In this Experiment we have used "Larger-the-better" because we were aiming for the maximum surface roughness reduction.

The equation for Larger-the-better is
$S/N = - 10 \log10 [\Sigma (1/y^2)/n]$

Where n = number of measurement y = measured value
Selection of Specimen

Austenitic stainless steels are widely used in chemical processing, transportation industries, food processing industries, furnace parts, machine parts, and aircraft industries. Stainless steel is available in the form of sheets, annealed strips and cold finished high tensile bars. Here we have selected 304 stainless steel. The following are the chemical composition and mechanical properties of the specimen

Cr: 18% - 20%	Si: 1% max
Mn: 2% max	C: 0.08% - 0.8 %
S: 0.03% max	P: 0.045 % max
Ni : 8 % - 10.5 %	Hardness – 92 RB

Yield strength - 207Mpa
Tensile strength - 517 Mpa
Percentage elongation – 40

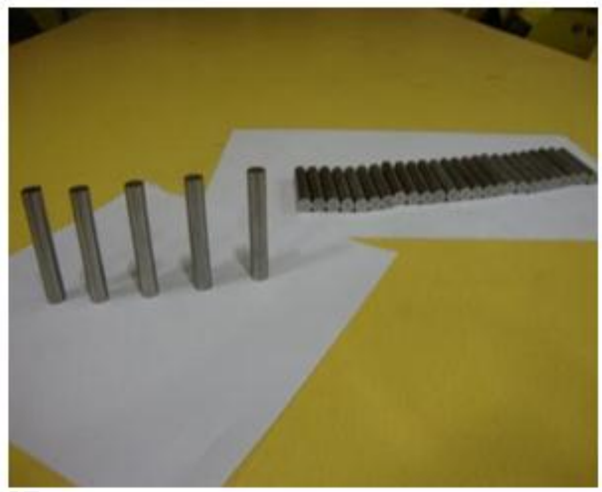

Figure 2 Specimens for electropolishing

Figure 3 Surface roughness testers

Bath Ingredients
Following bath ingredients are used
- Orthophosphoric acid (H_3PO_4) – 90 ml
- Sulphuric acid (H_2SO_4) - 30 ml
- Distilled water – 20 ml

A total of 140 ml of solution was used to do the test and the solution was changed after every 4 specimen were electropolished in order to get better result.

III. EXPERIMENTATION

Sample is centrally placed which is held in position by a stand fixture. Stand fixture clamp is of screw type which allows easy removal and insertion of sample. Stainless steel Sample is given positive connection and electrode is given negative connection by a crocodile clip. Sample and electrode M.S. and rubber tubing sheathed and electrical connection clamp was of stainless steel a corrosion resistant material which ensures that only the specimen is exposed to the solution. The specimen is only in contact with electrolyte and supported at bottom by non-conducting, non-reactive small porcelain support.

The current is switched ON before the specimen is immersed in the electrolyte and as soon as the specimen is removed current is switched OFF and specimen washed. Only the portion of the specimen to be polished is in contact with the electrolyte rest of the portion was masked by lacquer. The position of the specimen with respect to the cathode remains fixed during electrolysis. The anode i.e. the work piece is placed vertically to allow easy escape of gas bubbles. During electropolishing, metal is deposited on cathode in a very loosely adherent form, since the conditions are unfavorable for coherent electro deposition. Thus the cathode has very large area compared to anode so that the metal deposited is sparsely deposited over its surface and the danger of discrete particles leaving the cathode and interfering with the polishing proves is reduced to a minimum. A large cathode also tends to even out the current distribution of the anode. Temperature is controlled within reasonable limits of +3 – 4 0 above 40 0C.Current is set at very low limit of the order of 3 to 4 amperes. Temperature is noted, specimen is put in fixture and positioned on porcelain stopper, air blowers started, then current increased to the required value and stop watch started. After the required time, current is reduced to 3 to 4 amperes temperature noted, specimen removed with connector and connector disconnected. After polishing, with least delay, specimen is cleaned in running water and then in distilled water. It is then cleaned by liquid detergent. After detergent cleaning the specimen is cleaned in hot water then running water and finally it is cleaned in distilled water. After this cleaning procedure the sample is dried. After test is over and all specimens cleaned and dried they are weighed and their roughness at pre marked area is measured in longitudinal as well as transverse directions on both sides. Then specimens are also usually inspected with hand held magnifying lens (10X) for brightness and any pitting.

Surface roughness measurement
For roughness measurement "Mitutoyo" made stylus type surface roughness tester model 178 – 201 P/M series has been used. Measurement of roughness before and after polishing at the same place of the specimens was taken. This instrument provides the following facilities namely the selection of the cut off length in 2 ranges of 3 steps each i.e. (0.25, 0.8 and 2.5) mm. (0.01, 0.03 and 0.1) inch, with one selector switch for mm or inch reading.

Control Parameter
The preliminary studies revealed that among all the factors, most significant factors on the electropolishing performance, were found to be polishing time, current density, electrolyte temp, other parameters held constant.

Table 1 Electrochemical parameters & Levels

Sr. No.	Fixed parameter	Fixed level
1	Electrode material	304 S.S.
2	Work piece material	304 S.S.
3	Work piece height	31.85 mm
4	Work piece length	60 mm
5	Electrolyte composition	Same
5	Electrolyte quantity	140 mm
6	Work piece area	1000 mm^3

Table 2 Fixed Parameter

Factor / parameter	Level 1	Level 2	Level 3
C.D. (A/mm^2)	0.003	0.005	0.007
Time (Min.)	5	7	10
Temp. (^0c)	30	50	70

Experiment performed
Experiments were performed by using Taguchi orthogonal array design of L'27. Surface roughness of each specimen was noted before and after polishing. Signal to Noise ratio values were calculated by using Minitab 16 software.

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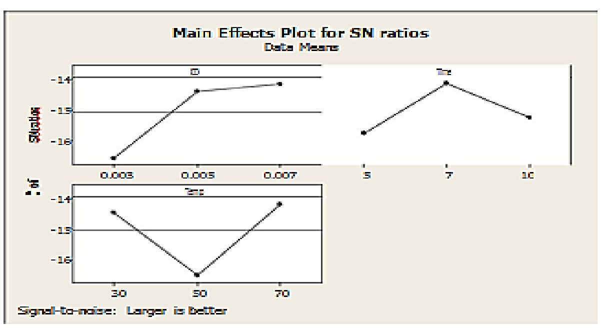
Sr. No.	CD (A/mm^2)	Time (min)	Temp (°c)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)	Ra 4 (µm)	S/N Ratio	MEANS
1	0.003	5	30	0.30	0.25	0.27	0.25	-11.5251	0.2675
2	0.003	5	50	0.28	0.19	0.21	0.22	-13.2115	0.2250
3	0.003	5	70	0.13	0.10	0.15	0.17	-17.7491	0.1375
4	0.003	7	30	0.18	0.15	0.14	0.19	-15.8554	0.1650
5	0.003	7	50	0.21	0.25	0.22	0.19	-13.3765	0.2175
6	0.003	7	70	0.18	0.21	0.23	0.20	-13.8669	0.2050
7	0.003	10	30	0.19	0.15	0.17	0.13	-16.1784	0.1600
8	0.003	10	50	0.01	0.09	0.05	0.10	-34.2421	0.0625
9	0.003	10	70	0.25	0.22	0.19	0.20	-13.4909	0.2150
10	0.005	5	30	0.15	0.10	0.12	0.18	-17.8667	0.1375
11	0.005	5	50	0.13	0.15	0.17	0.19	-16.1784	0.1600
12	0.005	5	70	0.24	0.28	0.23	0.20	-12.6729	0.2375
13	0.005	7	30	0.31	0.36	0.29	0.27	-10.3872	0.3075
14	0.005	7	50	0.21	0.17	0.19	0.23	-14.1448	0.2000
15	0.005	7	70	0.05	0.10	0.12	0.11	-22.1225	0.0950
16	0.005	10	30	0.27	0.20	0.22	0.26	-12.6818	0.2375
17	0.005	10	50	0.22	0.22	0.18	0.20	-13.8555	0.2050
18	0.005	10	70	0.36	0.35	0.29	0.33	-9.6559	0.3325
19	0.007	5	30	0.20	0.18	0.17	0.21	-14.5156	0.1900
20	0.007	5	50	0.12	0.11	0.13	0.15	-18.0568	0.1275
21	0.007	5	70	0.07	0.12	0.10	0.15	-20.1909	0.1100
22	0.007	7	30	0.15	0.19	0.12	0.17	-16.4393	0.1575
23	0.007	7	50	0.31	0.28	0.27	0.25	-11.2122	0.2775
24	0.007	7	70	0.39	0.36	0.29	0.28	-9.8830	0.3300
25	0.007	10	30	0.17	0.20	0.22	0.16	-14.7467	0.1875
26	0.007	10	50	0.22	0.18	0.17	0.20	-14.4376	0.1925
27	0.007	10	70	0.45	0.38	0.40	0.37	-8.0308	0.4000

Temp - Temperature
Ra - Surface roughness
Ra1, Ra 2, Ra 3, Ra 4 - Replicates
Where
CD - Current density

IV. RESULT AND DISCUSSION

A greater S/N ratio corresponds to a better performance. Therefore optimal level of electrochemical polishing parameters is the level with the greatest value.



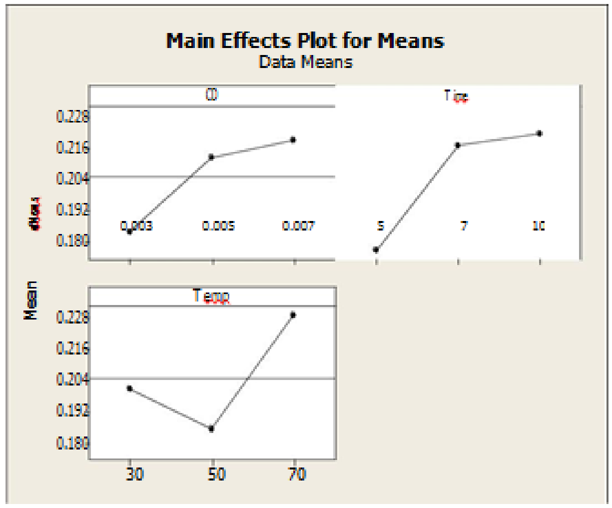
Effect of Electrochemical Polishing Parameters on Surface Roughness Reduction for S/N Ratio

Observation

Current density – The effect of current density on surface roughness reduction is shown in above figure. Its effect is increasing with increase in current density. So the optimum value of current density is 0.007 A/mm2.

Time - The effect of time on surface roughness reduction is shown in above figure. Its effect is increasing with increase in time up to 7 minutes beyond that it is decreasing. So the optimum value of time is 7 minutes.

Temperature - The effect of temperature on surface roughness reduction is shown in above figure. Its effect is gradually decreasing till 50 °C after that it increases gradually till 70 °C. So the optimum value of temperature is 70°C



Effect of electrochemical polishing parameters on surface roughness reduction for Means

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