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Analysis of voltage and current during the Plasma electrolytic Polishing of stainless steel

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Abstract

Plasma electrolytic Polishing (PeP) is a non-conventional technology for the surface treatment of electrically conductive materials. It is an effective machining technique for cleaning and polishing of metals and considered as a more environmentally friendly alternative to the electropolishing process. The electropolishing process uses aggressive media such as acids, whereas in PeP, acids or toxicants are replaced by low concentrated water solutions of various salts. In PeP, high DC voltage is applied to the electrodes in the aqueous electrolyte solution, which establishes a thin steam-gas layer around the surface of the work piece resulting in the generation of plasma.

From the previous research, it is found that the formation of stable plasma generally takes place between 180-370 volts, where it results in better surface conditions. The aim of this study is to analyse the behaviour of current according to different voltages and their effects on surface roughness and material removal rate (MRR) of stainless steel in Plasma electrolytic Polishing process.

Plasma electrolytic Polishing; surface treatment; voltage; current; MRR; stainless steel

1. Introduction

Austenitic stainless steel is the most widely used steel in the world, the percentage of application is 60-70% of total steel consumption. Chemical industry can be considered as one of the main consumers of austenitic stainless steel. Polishing is applied in the industry mainly to increase corrosion resistance and reduce surface roughness [1]. However, the currently used methods of electrochemical processing are limited in achievable surface roughness and have some drawbacks; such as use of toxic electrolytes and environmental contamination. These drawbacks can be reduced by applying a new method - Plasma electrolytic Polishing (PeP). In this method a high DC voltage is applied to the electrodes in a liquid electrolyte solution, resulting in thin plasma layer near to the anode [2]. PeP makes the surface smoother, removes defects of metal surface and burrs, also increases the gloss [3]. The most important advantage of this technology is the ability to polish metal parts with complex and irregular shapes using nontoxic electrolytes.

The Plasma electrolytic Polishing process is more suitable for reducing surface roughness as compared to electropolishing process. The material removal rate in PeP process is two times lower than electropolishing process [4].

The aim of this study is to analyse the behaviour of PeP machining current according to different voltages and their effects on surface roughness and MRR of stainless steel.

2. Experiment of PeP

2.1. Investigated material

A rolled sheet is used to prepare samples for experiments. The samples are made of austenitic stainless steel grade AISI 304 (X5CrNi18-10) having dimensions 30 mm × 30 mm × 2 mm. Two holes of diameter 5 mm are drilled into samples to fix it on the holder during polishing.

The experiments are performed on three samples for each particular voltage and averaged. The surface of the samples is not pre-treated, so average initial value (before polishing) of surface roughness is Ra=0.3 µm (on both sides).

2.2. Experimental Procedure

The experiment is focused mainly on the influence of different voltages on current behaviour and their effects on the surface roughness and MRR. The applied voltages are 200V, 250V, 300V, 350V and total treatment time is 5 minutes. The time is divided into 5 steps. The current is measured for each voltage from starting to end of every treatment step. The surface roughness on both sides and the mass (to calculate MRR) of each sample are measured before and after polishing. The surface roughness is measured always in the same area of the samples. The process parameters which are kept constant during experiment: temperature and conductivity of electrolyte are ϑ=75°C and σ=120 mS/cm respectively and immersion depth of sample is 40 mm.

To determine MRR (removal layer thickness), the samples are weighed before treatment (m_1) and after treatment (m_2) and calculated by the following formula:

$$MRR = \frac{\Delta m}{\rho A t}$$

Where ρ=7.9 g/cm^3 and the surface area A=20 cm^2.

The surface roughness Ra, Rz of samples is measured using HOMMEL TESTER 1000. The resolution of used surface tester is 0.01 µm and it conforms to DIN4772. The surface roughness Ra, Rz are measured four times at the geometric centre of each sample after every treatment step and averaged. To calculate

MRR, the mass of each sample is also measured four times after each treatment step and averaged.

During the treatment process there is a change in current values for every step, so average values of current are calculated.

3. Results

The Table 1 shows the average values of current, surface roughness Ra and MRR for three samples at a particular voltage after every treatment step.

Table 1. Properties of sample after each plasma electrolytic polishing process step.

V	Time (min)	0	1	2	3	4	5
200	**I**	0	7.95	7.11	6.7	6.53	6.37
	Ra	0.3	0.18	0.13	0.11	0.10	0.09
	Rz	2.91	1.57	0.99	0.80	0.60	0.50
	MRR	0	3.17	3.19	3.19	3.10	3.08
250	**I**	0	6.42	5.83	5.73	5.65	5.53
	Ra	0.3	0.18	0.15	0.13	0.11	0.10
	Rz	2.61	1.86	1.21	0.96	0.71	0.62
	MRR	0	2.25	2.39	2.29	2.29	2.25
300	**I**	0	5.65	5.25	5.08	4.92	4.92
	Ra	0.3	0.18	0.15	0.12	0.11	0.10
	Rz	2.77	1.92	1.17	0.94	0.73	0.66
	MRR	0	1.69	1.92	1.87	1.87	1.85
350	**I**	0	5.17	4.92	4.75	4.47	4.45
	Ra	0.3	0.19	0.15	0.13	0.12	0.11
	Rz	2.64	1.92	1.51	1.07	0.88	0.69
	MRR	0	1.41	1.57	1.49	1.49	1.45

V- Voltage (V), Ra- Surface roughness (µm), I- Current (A), MRR- Material removal rate (µm/min)

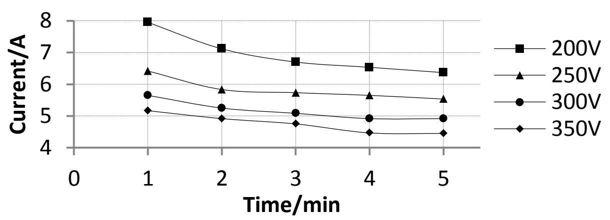

Figure 1. Current over time at a particular voltage.

From Figure 1, it is clear that current decreases as the treatment time increases for applied voltages, at first it decreases sharply then decrement slows down. The reason is that current depends on initial surface roughness. In starting surface roughness is high, so current is high; but after each treatment step roughness decreases, so current also decreases.

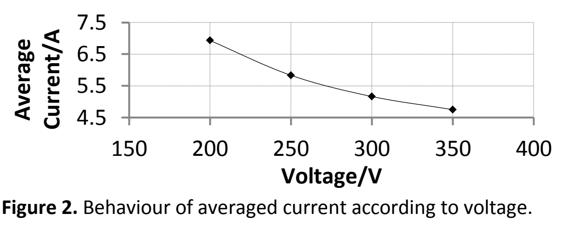

Figure 2. Behaviour of averaged current according to voltage.

From Figure 2, it is clear that current at 200V is highest; but at high voltages (more than 200 V), current continuously goes down. This may happen because as the voltage increases, the thickness of steam-shell around the anode also increases; so the electrical resistance increases and current goes down.

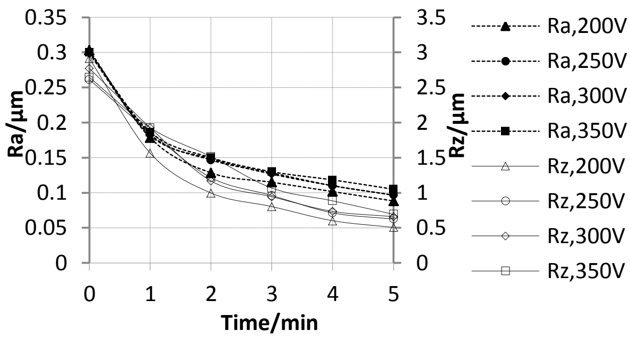

Figure 3. Surface roughness over time at a particular voltage.

Surface roughness Ra, Rz decreases with treatment time, at start decrement is fast then it slows down. After treatment, It is found that roughness values Ra, Rz at 350V is higher than that of 200V (Figure 3).

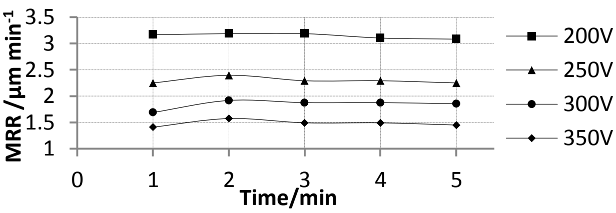

Figure 4. MRR over time at a particular voltage.

MRR is nearly constant over time for applied voltages, with a very small increase at two minutes polishing time. From Figure 4, it is clear that MRR at 200V is highest and at 350V it is lowest; so it can be concluded that as the voltage increases MRR decreases.

4. Conclusion

The current and surface roughness decrease as the treatment time increases at a particular voltage. For higher voltages the transferred energy increases, leading to higher roughness values at 350V than at 200V. MRR at 200V is highest and at 350V is lowest. From the above discussion, it can be concluded that 200V is best suitable for obtaining better surface roughness with little bit higher MRR.

Further studies will focus on applying these parameters to other grades of stainless steel (like 316L) which can be used in biomedical applications.

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