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THE CHANGE OF SURFACE PROPERTIES ON TESTED SMOOTH METAL SURFACES AFTER PLASMA POLISHING

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ABSTRACT: The article deals with the change of surface gloss level and roughness of the metal surfaces after plasma polishing due to time change. The surfaces have been micro grinded to low roughness before polishing. The specimens of stainless steel X10 CrNi 18/8 has been used for experiments. The experimental specimens have been treated with plasma polishing in electrolyte - an unconventionally and environmentally friendly polishing technology of the metal surfaces. The plasma polishing technology is considered to be one of the alternatives which are common for electrochemical polishing. The results of experiments depicts that the surface roughness has been increased during polishing and its value is much greater than its value before polishing. The surface gloss level was changing during polishing and its value depended on polishing time.
KEYWORDS: Electrolyte, plasma discharge, stainless steel, polishing, water-steam film, gloss

INTRODUCTION

The technology of stainless steels polishing is implemented in the industry, mainly due to corrosion resistance increase of surface and due to reduction of the surface roughness. Polishing is quite often used surface finishing operation in the medical, pharmaceutical, food, and chemical industry. The corrosion resistance improvement is not the only benefit of the polishing. What's more, the surface becomes smoother and more resistant to dirt, bacteria, mould etc. Furthermore, Plasma polishing removes defects of metal surface and burrs, too. Apart from these properties, the technology also increases the gloss of the metal surface [2, 4].

PRINCIPLE OF THE TECHNOLOGY

The treated metal part is immersed into the electrolyte and is connected to the plus pole of the electric current supply. This part becomes the anode. Second electrode is connected to the minus pole of power supply (Fig. 1).

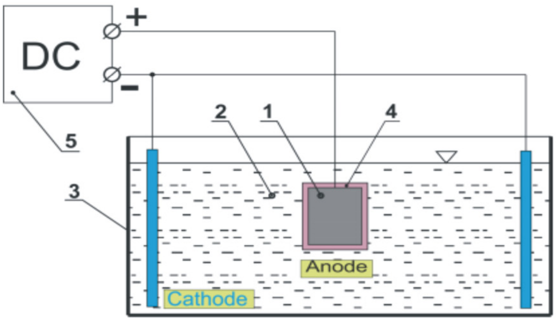

Figure 1. Principal scheme of the process
1 – treated specimen, 2 – electrolyte, 3 – work vessel, 4 – ionized water-steam film, 5 – power supply

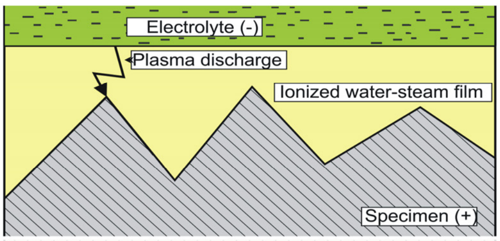

Figure 2. Plasma polished micro surface

So the principal scheme is similar to the conventional electropolishing. Due to high voltage among electrodes a water-steam film is formed on the entire treated surface. The film is electrically non-conductive and it separates the metal surface from the electrolyte. The electric current is broken in that way and as a result of that the electric circuit is disconnected. If the voltage among electrodes is high enough, the water-steam film becomes ionized. Due to high electric field, the electric current flows through the water-steam film in the form of glow discharge. Plasma discharges act on the metal surface in this polishing process. The discharge runs toward the micro surface "peaks" in the form of thin columns at places, where the distance of the water-steam film between the treated surface and the electrolyte is the smallest and it heats up and vaporize the surface of the metal (Fig. 2).

Discharging process lasts for a short time and the material of surface vaporizes. After that, the discharge runs to another place. By this way the surface becomes smoother. If a proper chemical *composition of the electrolyte and suitable parameters of the process are used, the treated surface becomes glossy. The most important advantage of this technology is in its possibility to treat metal parts with complex and irregular shapes. Furthermore, there is no shielding effect as it is in the electrochemical polishing case. The further advantage of the plasma polishing process is in the environmental friendly composition of the electrolyte. The electrolytes are based on harmless solution of various salts. The solutions of concentrations 4 ÷ 6 % are prepared by dissolving granulate in the water without an extra demand on its quality. In the spent solution, iron is bound in the form of oxides [1, 3, 4].*

THE EXPERIMENT OF THE PLASMA POLISHING

☐ ***Specimens***

A rolled square sheet has been used as a specimen during experiments (Fig. 5). The specimen was made of austenitic stainless steel X10 CrNi 18/8. Its dimensions were 50 mm × 50 mm × 3 mm, two holes of diameter 5 mm were drilled into specimen to fix it on the rack during polishing.

Two experimental specimens were used during the experiment, due to verification of results – four different surfaces were studied. Each side of the specimen was prepared on an equivalent surface roughness before experiment. The specimens were prepared with wet rubbing (the set of abrasive coated papers with final no. of the grain 4000). Therefore, the surface roughness of the specimens was ultralow (average value of Ra was 0.009 µm for both specimens) and the average value of the surface gloss level was 505 GU before polishing.

☐ ***Experimental procedure***

The experiment deals with the study of the influence of time during plasma polishing on the surface gloss and roughness level. The observed properties (gloss level, roughness) of the metal surfaces were measured before and after polishing on each side of 2 specimens. The total time of the treating was 10 minutes (600 seconds). The time was divided in to 10 steps, each polishing step lasted some time (Table 1). The properties of the surface were always measured after each treatment step and on places located on the geometric centre of the specimens. The parameters of the process during the experiment were kept at constant values: the voltage between electrodes was stable and the immersion dept of specimen was 100 mm. The specimen was polished in the electrolytic solution of concentration 6 % at temperature 70°C.

Table 1. The measured values of the change the surface gloss for each time step

Time of polishing [s]	The gloss level [GU]				
	1a	1b	2a	2b	Average value
0	514	499	490	514	505
20	526	526	534	521	527
40	532	536	543	536	537
60	534	539	546	534	539
90	530	535	541	530	534
120	526	521	530	520	525
180	519	516	528	518	521
240	517	519	527	510	519
300	515	521	523	514	519
420	513	508	510	509	510
600	507	502	512	497	505

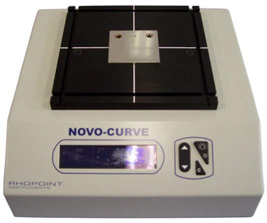

Figure 3. The gloss-meter Novo-Curve with measured specimen

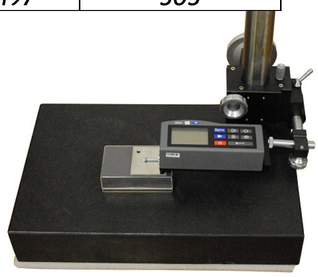

Figure 4. The surface roughness measurement on a specimen using surface tester TR 200

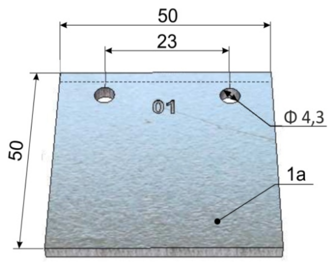

Figure 5. Experimental specimen with measured area 1a

☐ ***The surface gloss level***

The gloss-meter Novo Curve (Fig. 3) made by Rhopoint Instruments, has been used for accurate assessment of gloss level of the surface. The apparatus uses 60° measurement angle and it conforms to ASTM D523, ISO 2813. Figure 4 shoves one of the measured areas (1a). The apparatus was connected to the computer. The values of gloss level were measured 3 times on each area and the values were recorded into the Table 1. Fig. 6 depicts the graphic characteristics of the change gloss level for every step.

☐ ***The surface roughness***

In this case the apparatus TR-200 (Fig. 4) has been used to measure the change of surface roughness Ra. The final result of this measurement is 0.01 μm and it is conforms to DIN4772. The procedure of the measuring was similar to what was described in the previous part. Moreover, the tested area was the same as in the case of the gloss level measurements; which was placed around the geometric centre of the specimen. The surface roughness of Ra has been measured three times at the same spot and the average values of Ra are in Table 2. Fig. 7 depicts the graphic characteristic of the measuring.

Table 2. The measured values of the change of surface roughness in time

	Surface roughness Ra [μm]				
Measured areas	1a	1b	2a	2b	Average value
Time of polishing [s]					
0	0.008	0.001	0.009	0.009	0.009
20	0.015	0.017	0.018	0.015	0.016
40	0.021	0.028	0.024	0.027	0.025
60	0.025	0.031	0.027	0.022	0.026
90	0.037	0.038	0.028	0.040	0.036
120	0.044	0.056	0.043	0.047	0.048
180	0.070	0.063	0.048	0.060	0.061
240	0.068	0.074	0.058	0.066	0.067
300	0.058	0.074	0.053	0.085	0.062
420	0.091	0.083	0.088	0.083	0.086
600	0.106	0.108	0.097	0.096	0.102

RESULT OF THE CHANGE OF SURFACE GLOSS LEVEL WITH TIME

Fig. 6 depicts the changes of the surface gloss level during the experiment. The curve is constructed from the average values of 4 measurements on the tested surfaces 1a, 2a, 1b, 2b. The rapid increasing of the surface gloss level is typical for treated specimen after short time polishing (about 60 seconds).

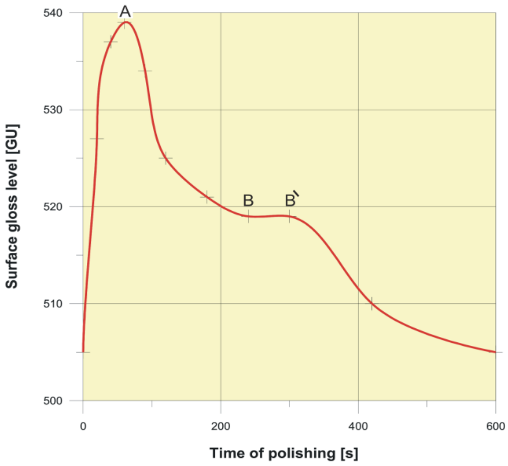

Figure 6. The change of surface gloss level

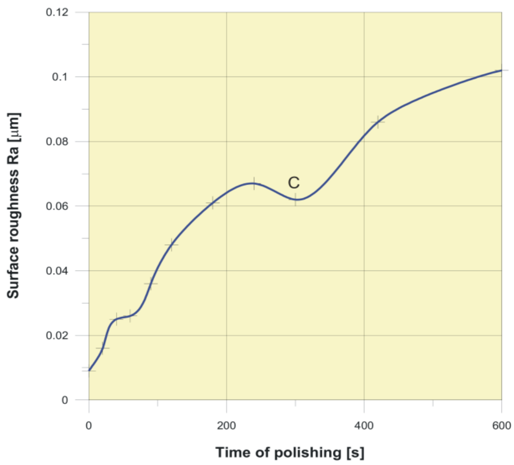

Figure 7. The change of the surface roughness in time

The specimens have local maximum of the surface gloss level at this time and then its value decreases. The surface gloss level rapidly decreases after further polishing (in the range of 60 – 200 seconds). Then the decreasing of its value is stabilized. The gloss level slightly decreases again with the following polishing (after 300 seconds). The value of gloss level before polishing was comparable with the value of the gloss level after 10 minutes of polishing. We can assume the stabilization of surface gloss level with the following polishing time (longer than 10 minutes as is possible to see in Fig. 6). From obtained results and graphs is evident that several factors influence the surface gloss level. The first rapid increasing of the surface gloss level was possible to explain by the removal of the surface specimen layer (include contamination, surface oxides and defects) and thus the clean metallic surface was obtained. The surface gloss level achieved the maximum at this time and with following time of polishing it decreases. This effect was connected to the change of the surface roughness – the creation of the secondary surface relief (it will be described later).

RESULT OF THE CHANGE OF THE SURFACE ROUGHNESS WITH TIME

The theoretical background of this process explains that the surface roughness decreases after polishing [1, 4]. The results of our measurements depict different results. The surface roughness was increased with polishing time in this case, because the secondary surface relief was created on the surface after polishing (Fig. 8B, 8D). The material ablation was more intensive on the grain boundary. It causes the increase on the surface roughness Ra and the decrease on the surface gloss level. The surface relief was rougher and reflection of light was not so intensive from the surface.

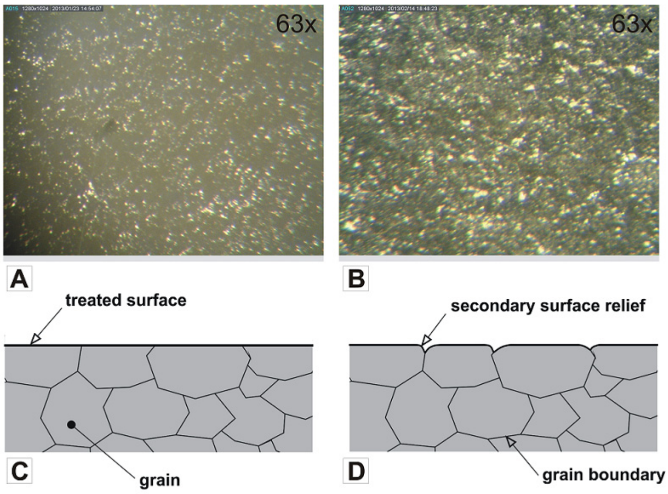

Figure 8 A, C - Fine grinded surface before plasma polishing (Ra=0.009 μm, Gloss = 505 GU); B, D - Fine grinded surface after 600 seconds of plasma polishing (Ra = 0.102 μm, Gloss = 505 GU)

CONCLUSIONS

A very short polishing time has a radical influence on the increase of the surface gloss level – defects, dirt and contaminations are removed from surface. The surface gloss level does not increase only on very smooth surfaces. The maximum of the gloss level is achieved after 60 seconds of polishing (point A in Fig. 6). Then, the secondary surface relief is created by an increase in polishing time. Its influence is enormous and it causes the surface gloss level decrease, because of the light reflection is not so intensive from rougher surface.

The surface roughness increased after first 240 seconds of polishing. Furthermore, the polishing caused local drop of surface roughness (point C in Fig. 7). After that the increase of the surface roughness continued until the maximum polishing time 600 seconds. The graph in Fig. 6 depicts almost constant surface gloss between 240 ÷ 300 seconds of polishing (range B – B` in Fig. 6). This indicates an important result. The highest value of the surface gloss level is already achieved after the first minute of the polishing (local maximum). Longer polishing time does not have any positive effect on the increasing of the surface gloss level and there is a dependency between surface roughness and gloss level. There are specific cases such as on machines where longer polishing time is effective unless the precise machine parts with tight tolerances are polished. The removed layer thickness is 2.25 $\mu m.min^{-1}$ for austenitic stainless steel during plasma polishing [4].

The plasma polishing cleans the surface, removes defects, and contaminations. The polished surface is therefore more resistant to corrosion. On the other hand, it is possible to assume, that the increase of the surface roughness (on very smooth surfaces after long polishing time – creation of the secondary surface relief) will have negative effects on corrosion resistance, because the area of active surface will expand. Further studies will be focused on the increase of the corrosion resistance of stainless steel after plasma polishing. The results will be compared with a usual mechanical and electrochemical polishing.

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