THE POSSIBILITIES OF PLASMA POLISHING OF THE STEEL DIN 1.0570
IN ELECTROLYTE

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Abstract

The paper deals with a relatively new method of surface treatment of metals, with the technology of plasma-electrolytic polishing. The technology of plasma-electrolytic treatment is based on physical phenomena occurring in the thin steam-gas layer, forming in electrolyte around the treated surfaces. Medium of the steam-gas layer is ionized under the influence of voltage of a few hundreds of volts. The topic of the paper treats with the possibilities to utilize the technology for surface pre-treatment of low carbon steel DIN 1.0570 (STN 11 523). The purpose of this pre-treatment is the surface preparation before galvanic chrome plating with aim to remove scratches and surface levelling after grinding. The surface roughness modification of the treated specimen is examined.

1. INTRODUCTION

The recent trends of rising environmental rules, strict hygienic requirements and continually increasing claims of customers upon the production quality force the producers to invest into new advanced surface finishing methods. The technology of plasma-polishing of metal surfaces in electrolyte is a new, more environmental friendly alternative to the traditional electrochemical polishing methods (electropolish). The high-concentrated mixture of acids, which are usually required by the traditional electro polishing methods, is superseded by small quantities of water solved non-toxic salts when the plasma-polishing technology is used. The next considerable difference between the plasma polishing technology and the traditional ones is the value of the voltage on the electrodes. The plasma-polishing technology uses much higher voltage level than it is used during the regular electrochemical processes. Because of the high voltage on the electrodes a thin ionised layer of water-steam forms in the electrolyte around the treated object. Detailed information on the process is hard to find in the literature, although information on the plasma-polishing technology has been published about twenty years before. Even nowadays, the available information on the technology is usually commercial ones.

The technology of plasma polishing in electrolyte has been developed at our laboratory for surface finish of stainless steel products. In this case the bright gloss of the treated surface can be achieved. This paper deals with the study of the possibilities of the surface pretreatment of a mechanical component made from low carbon steel. In this case, the high gloss of the surface was not the purpose of plasma-electrolytic pretreatment. The components were plasma-polished to remove fine scratches from the grinded surface because these become more obvious after galvanic chrome plating. In this context, the mechanism of the surface levelling and the surface roughness reduction has been examined.
2. BASICS OF THE PLASMA-ELECTROLYTIC PROCESS

An electrolytic circuit is shown on the Figure 1. It consists of a tank containing an electrolytic solution and of two sets of metallic electrodes fed by a direct-current power supply of voltage that is much higher than it is used at the traditional electropolish. One of the electrodes has much less surface than the second one or ones, and it is called the **active electrode**, regardless if it is the anode or the cathode. The active electrode is the object or objects to be treating. When the voltage on the electrodes is about a few volts or few tenth of volts the value of the electric current is proportional to the voltage accordingly to the Ohm law. The common electrolysis is running with the validity of Faraday's laws. But the density of the electric current is much higher on the active electrode than on the auxiliary one and it is increases when the voltage on the electrodes is become higher. At certain level of electric current density on the active electrode the ions with opposite electric charge start break each other, e.g. the electrolytic resistance increases around the active electrode. Therefore the voltage drop at this area is also higher. If the voltage on the electrodes further increases, the voltage’s drop on the surrounding area of the active electrode increases proportionally as well. The passage of an electric current through a resistance releases heat (Joule heat) and the produced amount of heat is proportional to the resistance and to the square of the current. In this way heat is generated on the treated surface and the heating effect is swollen when the voltage on the electrodes is further increase. At certain intensity of heating effect a water steam blanket forms around the active electrode due to the local boiling of the electrolyte [1]. If the steam blanket is compact all around the active electrode the electrolytic solution in this way is pushed out from the surface of the active electrode. If the voltage between electrodes is high enough, the volume of steam blanket getting ionised, e.g. the interior of the steam blanket become electrically conductive so some kind of stable electric discharge, e.g. plasma is forming. Having chosen a suitable set of the parameters and the right solution of electrolyte, the surface of the active electrode becomes shiny and smooth under the influence of this **steam-plasma blanket**.

The surface smoothing mechanism of the plasma-electrolytic process differs from one that acts at standard electrochemical process [1]. Caused by the pinch effect, the electrical charge carriers in the steam blanket are concentrated into narrow columns having high conductance forming narrow discharge columns having only a point-contact with the metallic electrode. These discharge columns act shortly on the treated surface as the moving point-sources of heat, evaporating peaks on the metal surface. Every part of the treated surface after the very short heat exposition is in contact with the moving colder volumes so the average temperature of the treated surface is slightly above 100 °C.
3. PLASMA POLISHING OF CARBON STEEL

The technology of plasma polishing in electrolyte has been applied to mechanical components made of the low carbon steel DIN 1.0570 (STN 11 523) in our laboratory. As mentioned above, the purpose of this treatment was to remove the scratches from the grinded surface without need of intensive mechanical polishing. A few specimens have been plasma polished at various operational times to find out the necessary time for complete scratch removal. The result is 4 minutes and it was validated by plasma polishing of higher number of the specimens. It is known that the reached gloss level of the treated surface depends mainly on the carbon content in the steel. In this case the carbon content is about 0.2 % so the resulted gloss of the plasma polished specimens was not extremely high. But surprisingly, specimens that were plasma polished for a longer time had lower gloss level than those that had been polished for a few minutes. In the case of stainless steels the resulted gloss level of the treated surface increases by the duration of the treatment, after a few minutes it reaches the maximum value of the gloss and then not increases obviously. Although the gloss level of the treated surfaces was not in our interest in that case, the reason of the gloss reduction after long lasting plasma polishing has been further examined. When the surface roughness of such polished specimens was tested we found out that the value of the roughness had increased. Therefore the relation between the roughness of the treated surface and the treating time was experimentally studied. For the experiment new specimens with defined value of the surface roughness were prepared. The surface of the specimens was finished using rotating metallographic grinder by silicon carbide paper of grade 120 in water. The initial value of the surface roughness of the specimens had been about $Ra = 1$ μm. The surface roughness was measured twice on each specimen using Surtronic 3+ contact profilometer. All three prepared specimens were polished at the same time using plasma polishing in the electrolyte of type RZ2. This electrolyte solution is intended for low and medium carbon steels. The specimens were plasma polished during 2 minutes consequently four times. The value of surface roughness $Ra$ has been measured twice on each specimen after every plasma-electrolytic treatment and the average values were calculated. The surface roughness dependence upon the treatment time for the specimens is shown in the Figure 3 – specimens No. 1, 2 and 3. You can see that the value of the surface roughness of these specimens quickly decreases after the first 2 minutes of plasma polishing. After the next two minutes of the treatment the surface roughness decreases only slightly and then after next two minutes of treatment it practically does not change or even slightly increases. These results were surprising, since in the case of stainless steels we get much less values of the surface roughness after such long polishing time.

Figure 2. The surface roughness dependence of the specimens upon the treatment time.
These three specimens were plasma polished at usually used parameters of the process, so the reason for the impossibility to reach lower level of the surface roughness must be caused either by some material properties of the specimens or by the used electrolyte solutions. To eliminate the second possibility, two other specimens were plasma polished in another kind of electrolyte solution, marked as NRZ1. This electrolyte is usually used for austenitic stainless steels. The specimens were prepared in the same way as it was described before. The resulting courses of the surface roughness are similar to previous ones. One of these courses is shown in Figure 2 – the curve No. 4. It is obvious that the results are practically the same. In other words, the used electrolytic solution is not responsible for the low reduction of the surface roughness. The surface of the plasma polished specimens was explored under the optical microscope. It has been found out that the velocity of the local material removal from the treated surface is microstructure dependant. This is also the reason why the microstructure of the steel and grains boundaries are visible under the optical microscope after the plasma polishing even when no chemical etching has been applied on the specimen's surface, as it is shown on Figure 3.

4. CONCLUSION

When the technology of plasma polishing in electrolyte is used for the steel DIN 1.0570, the resulting surface roughness rapidly decreases just only in the first few minutes of treatment. If the treatment time is long, the surface roughness usually slightly increases. It is caused by the facts that during the treatment two contrary processes are running at the same time: 1.) the primary surface relief is smoothed by surface peaks removal [1]; 2.) different speed of material removal from various microstructural items cases the formation of secondary surface relief. In the case of this steel the minimal reachable value of the surface roughness is about ten times worse than it is in the case of most stainless steels. The average speed of the material removal from the treated surface is higher approximately four times than it is at stainless steels. The ablation rate is between $7 \pm 8 \mu\text{m}.\text{min}^{-1}$.

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REFERENCES