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Environmental Friendly Replacement of Standard Electrochemical Polishing

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Abstract

There is a wide scale of possible surface finishing methods for metals; the choice of the appropriate method is always a compromise between the required surface properties and the financial aspect of the chosen procedure. Electrochemical polishing method (electropolish) is often used in the industry for metal finishing especially in case of complex shape of the products. It uses a combination of electrolyte bath and direct electric current to remove the surface layer from the metal part. The electrolyte bath consist of a blended chemicals, usually high concentrated acids are used. This fact presents some safety and environmental issues. The spent acid mixture is manifested as hazardous due to resolved metal content and pH as well. Replacement of the standard electropolishing plants by a technology of plasma polishing in electrolyte can avoid these problems. The technology is based on physical phenomena occurring in thin water-vapour layer, which is formed in electrolyte around the treated surface. Medium of the water-vapour layer is ionized under the influence of voltage of a few hundreds of volts. In this case low concentrated water solved neutral salts replace the concentrated acids mixture, used at standard electropolish. Non-toxic and environmental-harmless chemicals are used for the preparation of the electrolyte solution.

Keywords
metal polishing, environment, electrolyte, plasma.

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 The high-concentrated mixture of acids, which are usually required by the traditional electropolishing methods, is superseded by small quantities of water solved non-toxic salts when the plasma-polishing technology is used.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-vapour forms in the electrolyte around the treated object. Detailed information on the process is hard to find in the literature, although the first 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. This paper deals with the basic of the plasma-polishing technology.

2 THE PRINCIPLE OF THE PLASMA-POLISHING PROCESS

An electrolytic circuit is shown on the *Fig. 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.

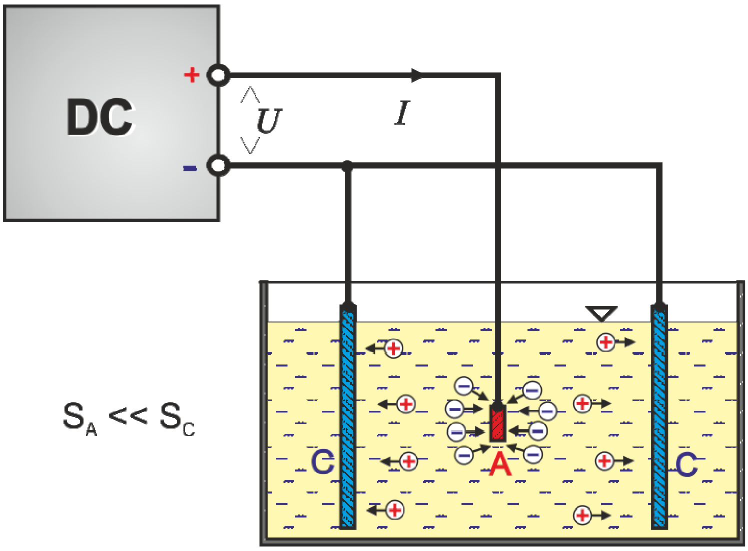

Fig. 1 Electrolytic circuit of the electrolytic-plasma process;
C – auxiliary electrode = cathode; A – active electrode = anode

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-vapour blanket* forms around the active electrode due to the local boiling of the electrolyte [1].
If the water-vapour 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 water-vapour blanket getting *ionised*, e.g. the interior of the water-vapour 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 ionised water-vapour 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 water-vapour 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 ADVANTAGES OF THE PLASMA-POLISHING METHOD

Aqueous solutions of salts used for electrolytic-plasma polishing are usually chemically neutral, with concentration typically from 4 to 8 %. The technology is thus very different from the electrochemical polishing process, where highly concentrated acid mixtures with the environment unfriendly elements (e.g. CrO_3) are used. A low concentration of electrolytic solution is an advantage in terms of both the economic costs of chemicals in the preparation of a new solution, as well as the losses caused by rinsing the electrolyte in water. Lower pollution of the rinse water means lower water consumption in the technological process. The electrolytic solution is prepared from water of no specific requirements for quality. Neither the purity of the chemicals used is a prerequisite, which has been experimentally verified. Sanitary and environment friendliness of the electrolyte solutions is one of the biggest advantage of the technology [1].

Contrary to electrochemical polishing, the principle of the smoothing mechanism of the plasma-polishing process is physical, as it was described in previous chapter. So the process properties are not such sensitive on the changes of the composition of the electrolytic solution, as it is in the case of electrochemical polishing [1]. Therefore the properties of the treated surface practically do not change by the time as the electrolytic solution becomes more and more exhausted. This fact brings the advantage of constant material removal rate for the polished metal. This fact is particularly important in the practical utilisation of the process of polishing the engineering components with the strict requirements of dimensional tolerance. Gloss level and surface roughness of the polished surface are also much less influenced by the changes of the chemical composition of the electrolyte [1]. Furthermore, there are no shielding effect, as it is in the case of electrochemical polishing, so the intensity of the polishing process is absolutely not depend on the relative positions of the opposite electrodes – cathodes. Inner holes can be directly polished and no auxiliary electrodes are required.

4 CONCLUSION

We can assume, that regarding the advantages and possibilities of this unconventional technology of surface treatment and regarding the introduction of ever stricter environmental requirements and hygiene regulations, the traditional methods of electro-chemical polishing technology will be soon replaced by the technology of electrolytic-plasma polishing.

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