Electrolyte plasma treatment in crossed electric and magnetic fields

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Abstract. Providing reliability and durability of gas turbine parts is closely connected to the necessity of constant improvement of its treatment technologies especially on final operations. Forming the required quality of multiprofiled part surface layer quality provides for overcoming a list of technological issues. One of these issues is provision of set operational characteristics of gas turbines parts with perforations.

1. Introduction

For intensive turbine blade cooling blade aerofoil is equipped with a significant number of perforations [1]. Therefore, parts piercing process performance is essential.

Currently for treating small diameter perforations a laser or electroerosive piercing is used, because they have high performance and do not depend on physical and mechanical properties of the treated material, also they allow heat-resistant alloy treatment [1-4]. Parts treatment technology based on laser and electroerosion methods has a list of advantages such as no mechanical efforts required for treatment and possible process automation. However, the above-mentioned methods involve high temperature and erosion factors causing defects in surface layer material. It results in a necessity of following holes’ edges treatment and surface layers’ quality improvement.

Present holes treatment technologies do not provide high enough surface material quality and have low performance, in some cases they are complicated for treating high number of perforations.

Hydroabrasive holes treatment method [5] has significant performance but the difference in hydraulic resistance on various areas of the blade with perforations of different size and geometry characteristics results in uneven treatment.

Cavitational treatment method results in defects decreasing parts fatigue characteristics, while a list of other methods [6-9] can be used only subject to sequent hole treatment, that decreases treatment performance in case of high quantity.

At the same time electrolyte plasma part treatment method [10,11] has a range of characteristics that allow its usage for final treatment of perforations on gas turbine engine blade made from heat-resistant alloys. It is related to new opportunities for electrolyte plasma treatment (EPT) method compared to the traditional technologies of electrochemical treatment (ECT). The main difference of EPT method from the latter is in vapour and gas cover (VGC) around the treated part inside of which chemical, electrochemical, microarc and plasma process are happening [10]. Plasma in VGC allows usage of magnetic and electric fields for treating part surface as well as for final treating of
perforations. Consequently, the goal of this work was to study impact magnetic field application on EPT on quality of the treatment of parts with perforations.

2. The research part

Sharp edges of perforations are formed after laser piercing (figure 1) and require high performance removal methods to be worked out.

![Figure 1](image1.jpg)

**Figure 1.** Laser pierced perforations (1 - plate with perforations, 2 perforations, 3 - welding depositions on the edges).

EPT method allows simultaneous treatment of all the surface. Yet EPT without magnetic field application in polishing mode provides even electric fields over all the treated surface (figure 2a), that leads only to lower surface roughness [11]. With magnetic field application EPT provides magnetic field concentration on rough ridges on the surface (depositions) [12] that causes also electric field concentration over these areas (figure 2b) and its consequently more intensive treatment.

![Figure 2](image2.jpg)

**Figure 2.** Diagrammatic model of the electric field spread around the plate with perforations during EPT; a - without application, b - with application, magnetic field (1 - plate with perforations, 2 - perforations, 3 - deposits on edges, 4 - vapour and gas cover (VGC), 5 - electric field, 6 - line between the electrolyte and VGC, 7 - electrolyte).
EPT with magnetic field application (EPT MF) provides intensive removal of the material from prominent areas of the treated part surface. In this case holes edges and depositions on them caused by laser piercing are considered such areas.

Further during polishing material is slowly removed from the edges and the edges are rounded (figure 3). Perforations edges rounding is justified also by increased concentration of the electric field on these areas. Along with the treatment intensity of the electric field intensity of the treated part with perforations becomes even.

Figure 3. Diagrammatic model of electric field spread around the plate with perforations during EPT MF after holes edges rounding a - without application, b - with application, magnetic field (1 - plate with perforations, 2 - perforations, 3 - rounding on edges, 4 - VGC, 5 - electric field, 6 - line between the electrolyte and VGC, 7 - electrolyte)

To assess EPT MF impact on holes treatment plate samples from stainless steel X18H10T were prepared. The plate samples were as thick as 2 mm, 3 mm, 4 mm, 5 mm and 8 mm and laser pierced holes in them with the diameter of 1 mm, 2 mm, 3 mm, 4 mm and 5 mm. After piercing the samples underwent EPT and EPT MF on various modes. Before and after the treatment the samples were cut along the perforations and sections for metallographic studies were prepared.

3. Research results
EPT MF method resulted in the removal of rough edges depositions caused by laser piercing and in polishing of the samples outside surface, edges and holes inside surface (figure 4).

Figure 4. Microphotographs of sections of perforations treated with EPT MF (1 - sample with perforations, 2 - perforation, 3 - rounded perforation edge)

Yet inside perforation surface has a part of laser piercing deposition left (figure 4a).

4. Conclusion
The conducted studies showed a possibility to use EPT MF method for final treatment of the perforations after laser piercing.
Magnetic field application allows to increase electric field concentration in perforations edges area and remove above stated depositions, round and polish them.

During EPT MF not only perforations edges but also their inside surface is treated. EPT and EPT MF methods have high performance and help provide even treatment of all the perforated surface.

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