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Electrochemical Machining to Remove Cross-Hole Burr Cathode Surface Design for Electric Field Simulation

Chen Wang, Qingming Fan, Yixin Li, Fan Zhang, Jijiu Liu

School of Mechatronic Engineering, Xi'an Technological University, Xi'an 710021, China

Abstract

In the electrolytic machining of the reaction process of complex interaction between the electric receiving field and the flow field, the electric field model of the electrolytic machining process under different conductive angles and conductive heights was established through computer simulation software, and the profile change diagram of the machining surface of the workpiece in the electrolytic machining process was obtained by solving the different conductive angles of the inner cavity by dividing the different positions of the inner cavity. The simulation results show that the optimization of the conductive angle can effectively protect the non-processing area of the inner cavity, and the selection of the appropriate conductive height can effectively improve the processing efficiency.

Keywords

Cross-hole Deburring; Electrochemical Machining; Electric Field Simulation.

1. Introduction

As a harmful by-product of mechanical parts in the manufacturing process, burrs greatly reduce the performance of the whole product and shorten its normal service life. As shown in the figure, the part has a cross-hole structure, which is easy to burr at the cross-hole in conventional machining. At present, there are thermal energy, high-pressure water injection, abrasive flow, electric spark, and electrolysis [1-3], and electrolytic deburring is a non-contact process, which can effectively improve the accuracy and processing efficiency of the edge at the intersection of two holes compared with traditional mechanical deburring. Burrs directly affect the accuracy and quality of parts, Zhou Zhao qi [4] designed a MATLAB image quantitative analysis system for the electrolytic polishing of stainless steel materials with complex structures, Wang Xiao shi [5] and others studied the removal of burrs from the hole of aerospace aluminum alloy materials, Tian Dongjin [6] et al. proposed machining deburring technology for the processing characteristics and burr characteristics of shell parts, and Shen Zhen [7] proposed the removal of burrs from aluminum alloy castings. Based on finite element analysis, a mathematical model was established to theoretically analyze the main factors of deburring effect. In the process of electrolytic machining, the distribution of the electric field mainly depends on the geometry and mutual position of the workpiece and the cathode.

2. Mathematical Model of Electric Field

In this paper, a mathematical-theoretical model is used to remove burrs along the top, as shown in Figure 1. Since the designed tool cathode is axisymmetric for the overall assembly structure of the tube electrode and the cross hole, a two-dimensional symmetrical rotator model with the axis of the tube electrode as the axis of rotation is designed to simplify the calculation, and the axis of rotation of the model is the Z axis.

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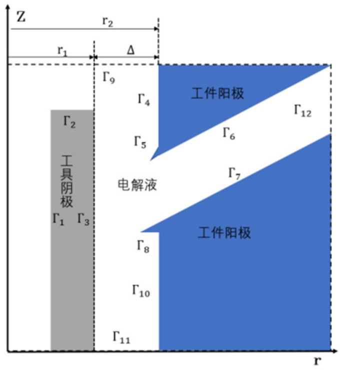

Figure 1. Simulation model of electrochemical deburring

As shown in Figure 1, the dark gray area is the tool cathode, the light blue area is the workpiece anode, and the white area is the electrolyte. And the r_1 is the wall thickness of the tool cathode, the r_2 is the radius of the cross lumen, and the Δ is the initial machining clearance. Γ1, Γ2 , Γ3 are the surface boundaries of the cathode in contact with the electrolyte; Γ4, Γ5, Γ6, Γ7, Γ8, and Γ10 are the surface boundaries of the anode in contact with the electrolyte. Γ9, Γ11, and Γ12 are the electrolyte boundaries. The boundaries Γ5 and Γ8 characterize the proximal and distal burrs, respectively. To solve the Laplace equation, it is necessary to define the potential boundary, the first type of boundary condition is to calculate the value of the given electric potential at the boundary, and the second type of boundary condition is the normal number of the given electric potential function at the boundary of the computational domain. Since both the tool cathode and the workpiece anode are metal conductors, the potential distribution of the solid is described by the first type of boundary conditions, namely:

$$\emptyset|\Gamma_{1,\ 2,\ 3} = 0 \tag{1}$$

$$\emptyset|\Gamma_{4,\ 5,\ 6,\ 7,\ 8,\ 10} = \emptyset \tag{2}$$

$$\frac{\partial\emptyset}{\partial n}|\Gamma_{9,\ 11,\ 12} = 0 \tag{3}$$

$$\begin{cases} \nabla^2\varphi = 0 \\ \emptyset|\Gamma_{1,\ 2,\ 3} = 0 \\ \emptyset|\Gamma_{4,\ 5,\ 6,\ 7,\ 8,\ 10} = U \\ \dfrac{\partial\emptyset}{\partial n}|\Gamma_{9,\ 11,\ 12} = 0 \end{cases} \tag{4}$$

where the cathode potential of the tool is 0, the potential of the anode of the workpiece is U, and the other free boundaries are insulated or perpendicular to the z-axis or r-axis, so the partial derivatives of the boundaries are all 0. This electric field simulation uses primary current distribution, corrosion, and transients, and the physical interface has a small overpotential compared to the ohmic drop in the electrolyte and electrode, which can ignore the activation overpotential due to the charge transfer reaction.

2.1. Establishment of Conductive Angular Electric Field Simulation Model

The research method adopted in this paper is to take the axis of the two small holes as the edge, take the outer diameter of the tube electrode as the radius, and extend the same angle inward, and the arc made is used as the conductive wire. On the target that needs to be processed, choose between those who have burrs that need to be removed and form a smooth transition, and those who do not have burrs and only need to form a smooth transition. As shown in Figure

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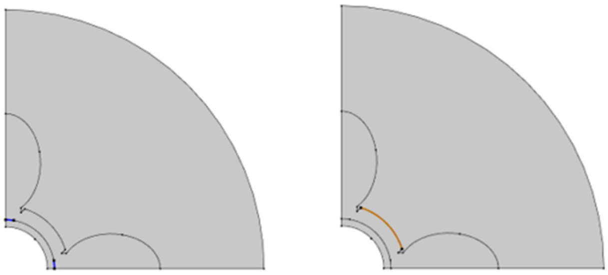
2(a), the blue line is located in the conductive area and the other outer diameter areas are insulated.



(a) Tube electrode conductive area (b) Non-machined area between two crossed holes

Figure 2. Conductive angle two-dimensional electric field model

As shown in Figure 3, the local expansion of the inner cavity of the cross hole. The yellow area is the non-machined area between the two cross holes, and the red area is the non-machined area that needs to be protected at the same height. It is observed that the height is 1.4 mm, and it is a symmetrical figure, and it is proposed to divide 13 areas with 0.1 mm as the dividing line. The divided position is used as a profile, and the assembly of the solenoid valve and the tube electrode is dissected as a model to study the conduction angle. At the same time, it is observed that the figure is symmetrical up and down with the seventh position as the axis of symmetry, and only one of the parts needs to be studied. The first half of this article is an example.

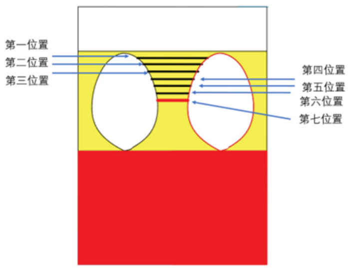
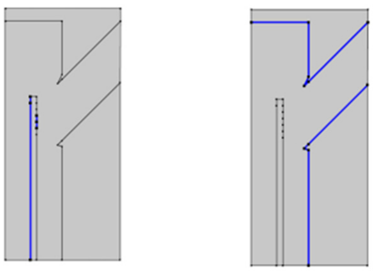


Figure 3. Location distribution of non-processing areas

2.2. Establishment of Conductive Height Electric Field Simulation Model

The two-dimensional electric field model of the conductive height electric field simulation can be obtained from the assembly scheme, as shown in Figure 4, the blue area in Figure 4(a) is the conductive area, and the burr removal is studied by changing the height of the conductive area. The blue area in Figure 4(b) shows the inner surface of the anode, and the protection of the non-processed area needs to be taken care of while removing the burr.



(a) Cathodic conductive area (b) Anode internal surface

Figure 4. A two-dimensional electric field model of the conductive height

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3. Analysis of Simulation Results

3.1. The Influence of Conductivity Angle on the Machined Surface

The most important simulation result of the electric field analysis of electrolytic machining is the change of anode topography, which is obtained by electric field analysis of the following three positions, as shown in Figure 5-7. In the simulation, it is found that due to the small size of the whole workpiece, the amount of burrs to be removed is not large, and the distance difference between the divided positions is 0.1mm, which leads to the high overlap of the regional conductive angle range of an adjacent position. Under the condition that the first and second positions coincide with the conductive angle of 8-10 degrees, the processing effect is basically the same; The third, fourth, and fifth positions coincide at a conductive angle of 13-16 degrees; The sixth and seventh positions coincide at the conductive angle in the range of 19-21 degrees; As shown in Figure 5, the first position is taken as an example, the conductive angle is set to 8 degrees, the processing time is 5s, the burr is completely removed, and a basic smooth transition is formed. As shown in Figure 6, when the conductive angle of the fourth position is 9 degrees, the processing time is 5s, and the burr is completely removed and a basically smooth transition is formed. As shown in Figure 7, when the conductive angle of the seventh position is 21 degrees, the processing time is 5s, the burrs are all removed, and the non-processed surface is not affected by stray corrosion.

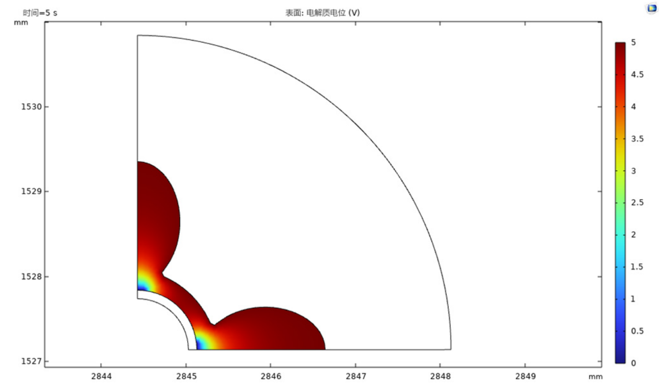

Figure 5. The first position conducts electricity at an angle of 8 degrees

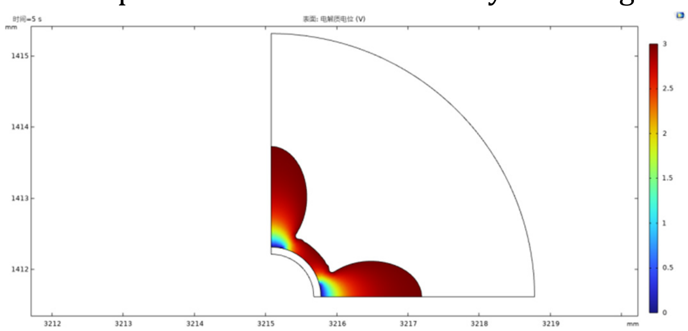

Figure 6. The fourth position conducts electricity at an angle of 14 degrees

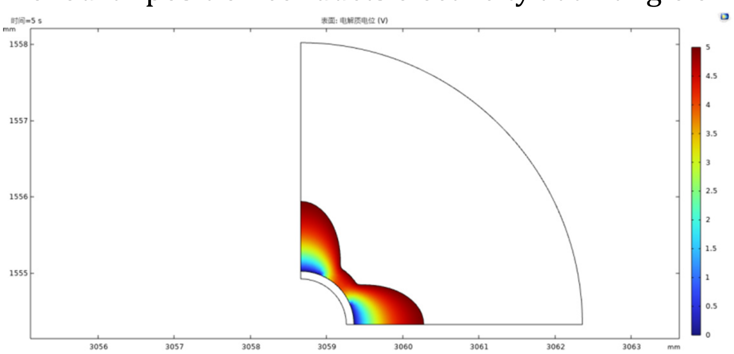

Figure 7. The seventh position conducts electricity at an angle of 21 degrees

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3.2. The Influence of Conductive Height on the Morphology of Burrs

As can be seen on the burr morphology change diagram, the maximum current density on the electrode surface is at the junction between the conductive height and the surface of the electrode participating in the reaction, so it can be seen that the cathode conductivity height has a certain influence on the electrolytic processing to remove the burr.

Set the simulation parameters: the voltage is 5V, the conductivity height is 1.2 mm, the processing time is 5s, as shown in Figure 8, and the burrs are not completely removed. As shown in Figure 9, when the conductive height is 1.4 mm, the root of the burr is completely removed in 5 seconds, and the intersecting line position forms a smooth transition. When the conductivity height is further increased, as shown in Figure 10, significant stray corrosion can be seen in the non-machined area of the lower burr.

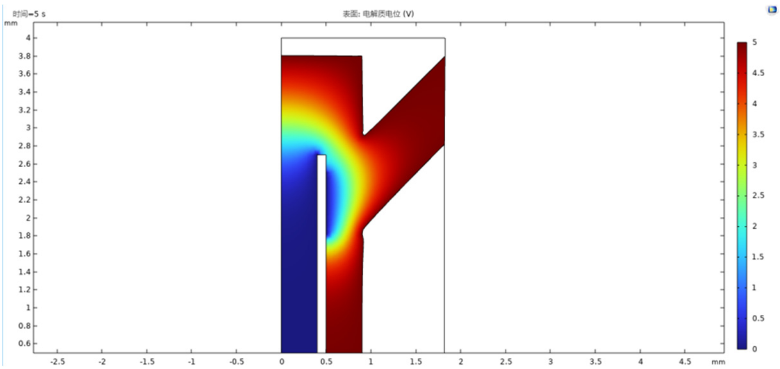

Figure 8. has a conductive height of 1.2 mm

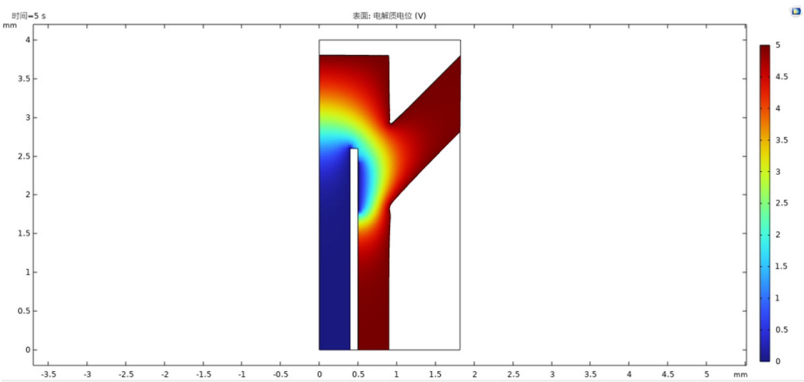

Figure 9. has a conductive height of 1.4 mm

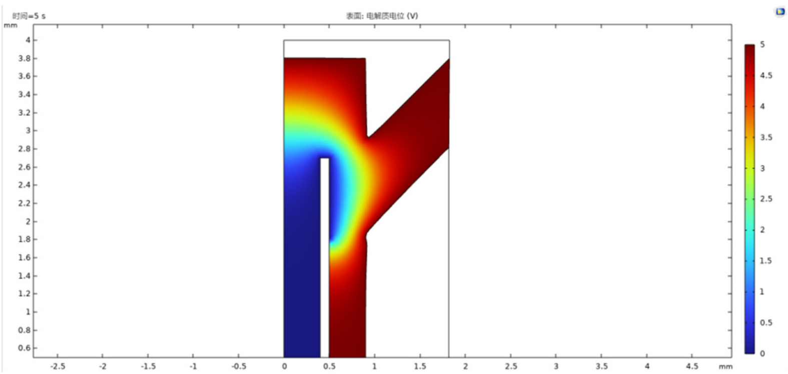

Figure 10. has a conductive height of 1.6 mm

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4. Fitting Results

The above results are comprehensively obtained: the conductive angle is 9 degrees in the first and second positions, 14 degrees in the third, fourth and fifth positions, and 21 degrees in the sixth and seventh positions. The conductive height is selected as 1.4mm, and the above parameters are fitted to the three-dimensional surface to obtain as shown in Figure 11, the green area is the conductive surface, and the same structure of the intersection line is adopted in the layout of the conductive surface.

Figure 11. Schematic diagram of the cathode profile

5. Conclusion

In this paper, the simulation software is used to simulate and analyze the electric field of the machining gap of electrolytic machining deburring, and the simulation models are established for different processing parameters such as conductivity angle and conductivity height. The influence of each parameter on the deburring effect of electrolytic machining was analyzed by comparing the changes of anode morphology, and finally the cathode profile was fitted and optimized.

References

[1] Shao Renen.2017 Agricultural Diesel Engine Development and Reform Report [J]. Agricultural Machinery,2018,(08):46-52.

[2] Zhao Min, Liu Zheng lei, Yi Xi. Machine Tool & Hydraulics,2020, 40(08): 173-174.

[3] Li Ying guang. Study on the influence of abrasive particle size on abrasive flow machining[D]. Taiyuan University of Technology,2021.

[4] Zhou Zhao qi, Ding Yue ming, Zhu Qingqing, et al.Quantitative analysis of MATLAB images of 316L stainless steel electropolishing [J].Electroplating & Fine Finishing,2024,46(01):97-104.

[5] Wang Xiao shi, Yang Guo lin, Dong Zhigang, et al. Research progress on drilling outlet burrs for assembly holes of aerospace aluminum alloy components[J]. Diamond and Abrasives Engineering, 2022, 42(04):385-409.

[6] Tian Dongjin, Shang Xian jun, Zhang Ye. Metal Processing(Cold Work),2023,(07):39-43.

[7] Shen Zhen. Research on burr removal processing technology of aluminum alloy castings [D]. Qin huang dao:Yan shan University,2023.