Study of gas flow in a discharge chamber of a pulse plasma generator

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Abstract. This paper focuses the features of computer simulation of gas flow in a gas-discharge chamber of a pulsed plasma generator using the STAR-CCM + program. The influence of the method of supply and consumption of plasma-forming gas on the output parameters of the plasma generator is shown.

1. Introduction
The plasma torch is the main element of the installation for plasma processing of materials and represents a device which generates a spatially stabilized arc plasma stream with a temperature of up to ten thousand degrees. The following basic requirements for plasma torches used in mechanical engineering can be distinguished: required power, high energy efficiency, stability of plasma flow parameters, long life of the plasma torch elements, structural reliability, ease of maintenance, the ability to use various plasma gases, etc.

High technical and economic efficiency of the plasma treatment process depends largely on the design of plasma torches.

Plasma torches with a transversely blown arc can be divided into coaxial, toroidal, rod and plasma torches with a circular arc [1]. In such plasmatrons, plasma flows with large transverse dimensions are obtained. The life of the electrodes for such plasmatrons is higher than traditional linear plasma torches [2].

2. Experimental studies
In this paper, a pulsed plasma generator with a moving electric arc is considered [3-8]. The transversely blown arc, moving along the surface of parallel electrodes, heats the plasma-forming gas. At the ends of the electrodes, the arc is separated from the surface of the electrodes. The compressed arc plasma together with the flow of heated gas exits the nozzle and enters the workpiece. The rapid movement of the arc over the electrode under the action of electrodynamic and gas-dynamic forces distributes the thermal load along the length of the electrode, which significantly increases the life of the electrodes and allows the use of relatively low-melting materials such as steel or copper. In this case, the tangentially supplied gas (air) serves not only as a working gas to create a plasma jet, but also to relieve the heat load from the walls of the body of the pulsed plasma generator.

As a result of the research, it was established that in a pulsed plasma generator with a moving transversely blown arc, the plasma-forming gas flow has a significant effect on the speed of the electric arc (Figure 1).
Figure 1. The dependence of the speed of the arc from the plasma-forming gas flow with the electrode diameter $d = 6$ mm, the electrode gap $L = 5$ mm; • - $I = 230$ A; ■ - $I = 200$ A; ▲ - $I = 180$ A; ● - $I = 140$ A

An increase in the plasma gas flow by a factor of 2 results in an increase in speed of about 1.5 times (figure 1).

The method of supplying plasma-forming gas affects the life of the plasma torch, so the main task is to visualize the pattern of gas flow in the plasma discharge chamber of the plasma torch, identifying areas with high flow velocity and areas in which flow is braked.

3. Modeling
Numerical simulation was used to determine the gas flow in the discharge chamber of a pulsed plasma generator. The simulation was based on the STAR-CCM + package. The STAR-CCM + program uses a modeling approach based on the specification of physical models and provides complete control over the solution process.

The calculations were conducted at various plasma-forming gas flow rates: 62 l/min, 93 l/min, 124 l/min, 155 l/min. Scenes of scalar and vector velocity fields are shown in figure 2.

According to the data obtained from the calculations, it was visually determined that at the initial section of the gas discharge chamber the flow is twisted (figure 2. a), b) and this movement is maintained until the exit from the nozzle, which allows to effectively cool both the walls of the plasma torch body 0 and the electrodes. From figure 2. c) it is clear that areas with different velocity fields are formed in the gas-discharge chamber, in figure 2. c) the darker areas correspond to the areas where flow deceleration occurs, light areas with higher speed. From figure 2. c) it is clear that the swirling flow along the walls of the body has the highest speed, and in the interelectrode gap the flow velocity is significantly reduced.
Figure 2. Results of numerical simulation at a flow rate of 124 l/min: a) vector velocity field of the plasma-forming gas, b) vector velocity field in the cross section in the middle of the discharge chamber, c) scalar velocity field of the plasma gas.
The values of speeds in the most important points are presented in figure 3.

![Figure 3](image)

Figure 3. Distribution of speed at various points of the discharge chamber.

4. The conclusion

As a result of the comparison of experimental studies, it was determined that the flow rate and the method of supplying the plasma-forming gas has an effect on the output parameters of the pulsed plasma generator and the operation of the plasma torch as a whole [4, 5]. The calculations showed that the electric arc flow velocity (VG) is at G=62 l/min VG=0.664 m/s, G=93 l/min VG=1.36 m/s, G=124 l/min VG=1.89 m/s, G=155 l/min VG=2.73 m/s Vector velocity field shows that around the arc formed by the swirling flow, which allows compressing the arc in the central part of the discharge chamber. The tangential supply of plasma gas allows to cool the plasma torch effectively and increase its service life. The increased flow rate at the walls of the plasma torch body removes most of the heat supplied to the walls from the electric arc, and a lower plasma gas flow rate in the central part of the discharge chamber increases the gas enthalpy at the exit of the plasma torch.

References

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