

TECHNOLOGICAL PARAMETERS OF TRANSFERRED DC “TUBULAR” PLASMA ARC

ТЕХНОЛОГИЧНИ ПАРАМЕТРИ НА ПРЕХВЪРЛЕНА ПОСТОЯННОТОКОВА ПЛАЗМЕНА ДЪГА „ТРЪБА”

Angelova V¹, Mihovsky M², Petkov V³, Mihailov E⁴
 Institute of Metal Science¹, Bulgarian Academy of Science, Sofia, Bulgaria

University of Chemical Technology and Metallurgy^{2,3,4}, 8 “Kl. Ohridski” Blvd, Sofia-1756, Bulgaria

Abstract: For reduction processing of powder raw materials and for remelting of dispersed metal charge in water-cooled crystallizer, a new plasma torch construction is designed. Replacement of the tungsten cathode by hollow graphite one is a specific feature of the plasma torch design. The plasma gas is blown bilaterally between the nozzle and the cathode and through the cathode. This manner of plasma gas introduction ensures the achievement of a “tubular” transferred plasma arc. The main purpose of this study is to determine the optimal relation between plasma gases velocities for obtaining a steadily burning well-configured plasma arc. The V-A characteristics for current in the 100÷280 A ranges and constant plasma arc length of 100 mm are determined.

Keywords: transferred DC plasma arc, V-A characteristics, hollow cathode

1. Introduction

The working directions of the Plasma Metallurgy Research Laboratory - “PLASMALAB” in University of Chemical Technology and Metallurgy (UCTM)-Sofia are:

- fine scrap plasma melting in water-cooled crystallizer;
- reduction extraction of metals and alloys through plasma remake of disperse raw and waste materials;
- building up by plasma welding of worn-out parts with high-melting-point disperse materials. For this purpose an universal metallurgical DC plasma torch with hollow graphite cathode is designed, which generates transferred arc and the powder material is introduced through the graphite cathode in “tubular” plasma arc volume [1].

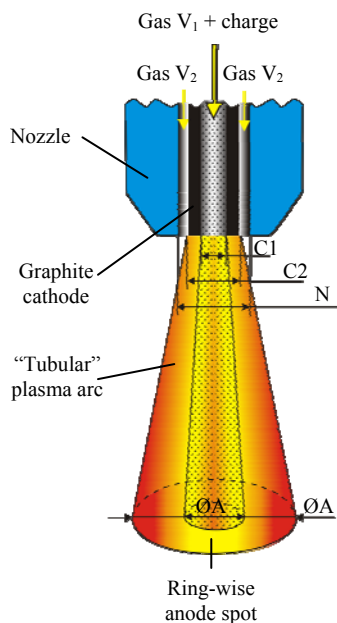


Figure 1. “Tubular” plasma arc [2].

A specific feature of plasma torch construction is that the plasma gas is blown through and around a hollow cathode simultaneously. By means of mass flow rate, respectively velocity of both gas flows (through the hollow cathode V_1 and through nozzle around cathode V_2) Fig.1 [2] a “tubular” transferred plasma arc is obtained. Such plasma arc enables feeding of the material in the high temperature volume of the plasma arc, which ensures a maximal

convective and radiative heat transfer.

The plasma torch designed at PLASMALAB with hollow cathode can be used in a plasma arc melting equipment. In this case the disperse metal particles are introduced through a hollow cathode at the “tubular” plasma arc axis, and they are melted between the cathode and metal bath-anode. By means of plasma arc length and power variation enough time can be ensured for the particles to remain long enough in melting status for completion of the refining processes.

With that manner of disperse material organization and the right plasma gas at optimal pressure in the furnace chamber the proper gas volume alloying of metal can be achieved [3].

The main purpose of this study is to determine the influence of energy and gas-dynamic “tubular” plasma arc parameters on the geometric parameters of the arc and the technological possibilities of disperse material introduction and its heating in arc volume; and also to specify the necessary data for developing of a mathematical model of the process.

2. EXPERIMENTAL EQUIPMENT

For generating a transferred plasma arc a newly designed plasma torch is used [1].

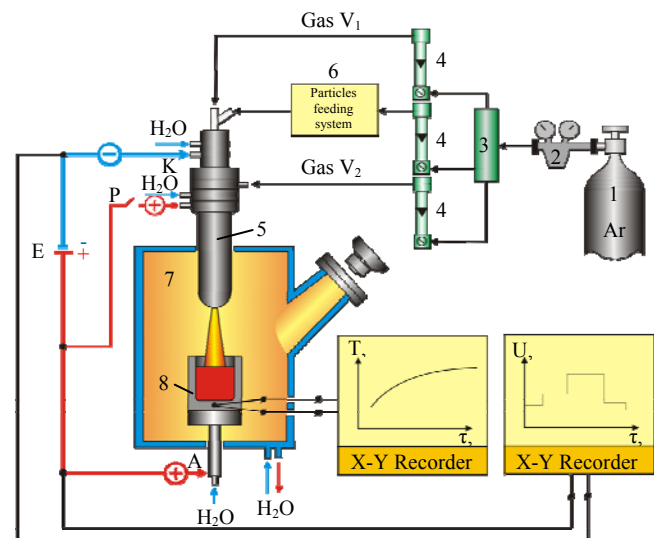


Figure 2. Scheme of the experimental installation for investigation of particle heating in “tubular” plasma arc: 1-argon cylinder, 2- reducing valve, 3- collector, 4- rotameter, 5- plasma torch, 6- particles feeding system, 7- chamber, 8-graphite crucible.

The main parameters are: nozzle diameter $D_N=12$ mm, external graphite cathode diameter $D_{C2}=10$ mm and internal graphite cathode diameter $D_{C1}=4$ mm (Fig.1), presented in Fig. 2. The main purpose of the plasma torch is to ensure a possibility to heat disperse material in arc volume. Argon is used as plasma gas. Establishment of well configured "tubular" plasma arc with definite length geometric characteristics depends on plasma gases velocities v_1 and v_2 , respectively mass flows rates and the proportion between the two gases (Fig. 1).

3. EXPERIMENTAL RESULTS

The experiments have been carried out at uniform outlet plasma gas velocities v_2 (gas flow rate $V_2=1500$ l/h) and three different inner gas velocities v_1 . The first objective is to obtain the parameters of steadily burning well configured "tubular" plasma arc at current 250 A. The flow rate correlation between both gases at arc length 100 mm is investigated (Table 1). The flow rate V_1 is calculated for steady V_2 . At flow rate $V_2=1500, 2000, 2500$ l/h the flow rate V_1 , which ensure approximately equal velocities of both gases (Table 1).

Experimental plasma gas flow rates V_1 and V_2 (velocities v_1 and v_2)

(Table 1)

| Gas velocities | V_1 , l/h | v_1 , m/s | v_2 , m/s | V_2 , l/h |
|----------------|-------------|-------------|-------------|-------------|
| $v_1 < v_2$ | 450 | 9,94 | 12,06 | 1500 |
| | 350 | 7,73 | | |
| | 250 | 5,52 | | |
| $v_1 = v_2$ | 550 | 12,15 | 12,06 | 1500 |
| | 730 | 16,13 | | |
| | 910 | 20,11 | | |
| $v_1 > v_2$ | 650 | 14,36 | 12,06 | 1500 |
| | 750 | 16,57 | | |
| | 850 | 18,78 | | |

Fig. 3 shows that, at velocities v_1 lower than v_2 ($v_1 < v_2$) the "tubular" plasma arc retains the clear boundary of roundabout surfaces with insignificant augmentation of arc cone and anode spot diameter (Fig. 3 a). At higher outlet velocities v_1 ($v_1 > v_2$) the arc expands and anode spot dilutes its outline (Fig. 3 c). From the experiments at equal gas velocities ($v_1 = v_2$), the most steadily burning and best-configured plasma arc is obtained at external plasma gas flow rate $V_2=1500$ l/h (Fig. 3 b). For technological and economic considerations, work with minimum plasma gas flows is the most advisable. Lower flow rates ensure lower outlet velocity and prolonged particle stay in arc volume. This is also related to the reduction of operating costs. The optimal proportion between both gases is $v_1/v_2=0,83 \pm 1$. For this reason the further experiments have been carried out at 1500 l/h flow rate of plasma gas.

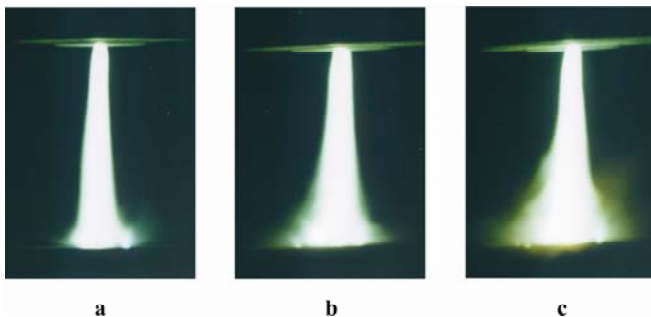


Figure 3. Photographs of "tubular" plasma arc (current 250 A and 100 mm length):

a - $v_1 < v_2$ ($v_1=10$ m/s, $v_2=12$ m/s); **b** - $v_1 = v_2$ ($v_1=v_2=12$ m/s);
c - $v_1 > v_2$ ($v_1=14$ m/s, $v_2=12$ m/s).

Investigation of the energy parameters involves obtaining of the voltage-ampere (V-A) characteristics. The V-A

characteristics for classical plasma arc and "tubular" plasma arc at gas velocities $v_1 < v_2$ and $v_1 = v_2$ and current at the range 100÷280 A are shown in Fig. 4.

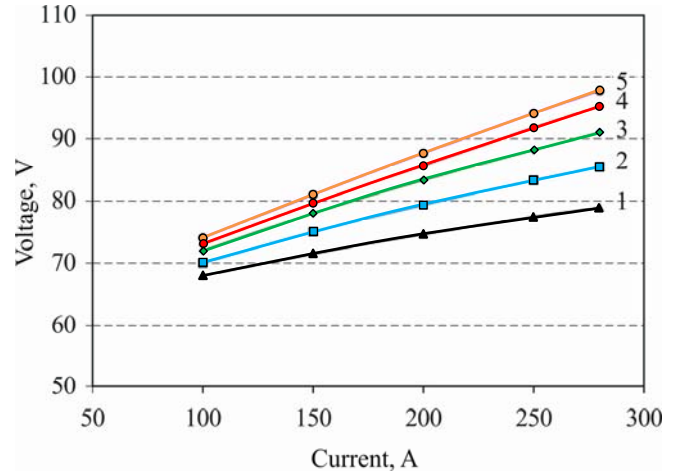


Figure 4. V-A characteristics for classical plasma arc (1) at $V_2=1500$ l/h, and "tubular" plasma arc at $V_1=250$ l/h (2), $V_1=350$ l/h (3), $V_1=450$ l/h (4), $V_1=550$ l/h (5).

Fig. 4 shows that the characteristics rise slightly and upon injection of additional plasma gas in the hollow cathode the overall voltage increases proportionately. That can be explained with the plasma arc cross section decrease. Because of the inner gas cooling effect the "tubular" plasma arc wall hammers out. In order to obtain the optimal technological results (maximum voltage and save the "tubular" plasma arc character on the one hand, and "tubular" plasma arc wall limiting the disperse material on the other hand), for future experiments it is assumed that the plasma arc gas velocities to be approximately equal.

4. CONCLUSIONS

For reduction processing of powder raw materials and for remelting of dispersed metal charge in water-cooled crystallizer, a new plasma torch construction is designed. The V-A characteristics for current in the 100÷280 A range and constant plasma arc length of 100 mm are determined. At equal gas velocities ($v_1 = v_2$), the most steadily burning and best-configured plasma arc is obtained at flow rate of the external plasma gas $V_2=1500$ l/h. The optimal proportion between both gases is $v_1/v_2=0,83 \pm 1$. For obtaining an optimal technological parameters in the future experiments, equal plasma arc gas velocities are recommended.

5. REFERENCES

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