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PLASMA TORCH FOR PLASMA TRANSFERRED ARC SURFACING WITH TWO POWDER FEEDING SYSTEMS

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ABSTRACT

A new design of the PTA torch (PTA torch) for surfacing of nickel, cobalt and iron-based alloys was developed. It combines two systems of powder feeding into the arc: the internal and external one. Such a combination expands the technological capabilities of the PTA torch, and allows surfacing magnetic and nonmagnetic materials. These systems can be used both separately from each other and together for surfacing composite alloys with separate feeding of the matrix and reinforcing powder material. In order to increase the efficiency of powder heating at external feeding into the PTA torch, an auxiliary stabilizing gas flow is used, which allows reducing the powder losses by 10–15 % and improving the deposited bead formation. Optimal flow rates of stabilizing gas are 4–5 l/min. The PTA torch effectively operates in the current range of 50–300 A.

KEYWORDS: plasma transferred arc surfacing, PTA torch design, powder feeding systems, heating efficiency

INTRODUCTION

The PTA torch is the main working tool of equipment for plasma transferred arc surfacing. The quality and stability of the surfacing process as a whole depends in many respects on its efficient and reliable operation. In its turn, the efficiency of PTA torch operation is determined by its thermal characteristics and effectiveness of heating and melting of powder in the arc, which greatly depends on the scheme and parameters of its feeding into the arc.

At present two schemes of powder feeding into the arc are the most widely used: internal and external [1–3]. In the first case (Figure 1, *a*), the powder is fed into the arc from inside the PTA torch in the form of a flow of particles uniformly distributed around a circle through a conical slot formed by the plasma and focusing nozzles. In the second case (Figure 1, *b*), it is fed from outside the PTA torch through one or several openings in the end face of the plasma nozzle. In this case the focusing nozzle is not used.

Mathematical model [1] and experimental studies performed by the author [3, 4] show that the internal scheme of powder feeding is more efficient. It ensures lower powder losses, better formation of the deposited bead, and lower power consumption at the same deposition rate. This scheme, however, has two significant disadvantages. First, at long-term surfacing, particularly of low-melting materials, liquid metal drops can form at the outlet of the focusing nozzle, which leads to violation of the process stability, blocking of powder feed and deterioration of the deposited bead formation.

Secondly, surfacing of ferromagnetic materials with a large quantity of the ferrite phase in their struc-

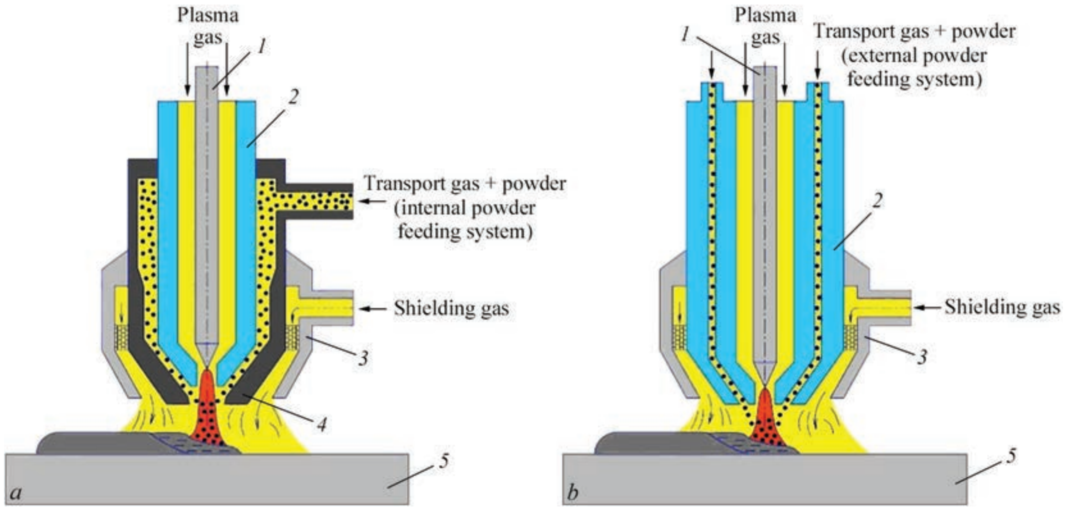

Figure 1. Schemes of powder feeding into the arc: *a* — internal; *b* — external (*1* — electrode; *2* — plasma nozzle; *3* — shielding nozzle; *4* — focusing nozzle; *5* — part)

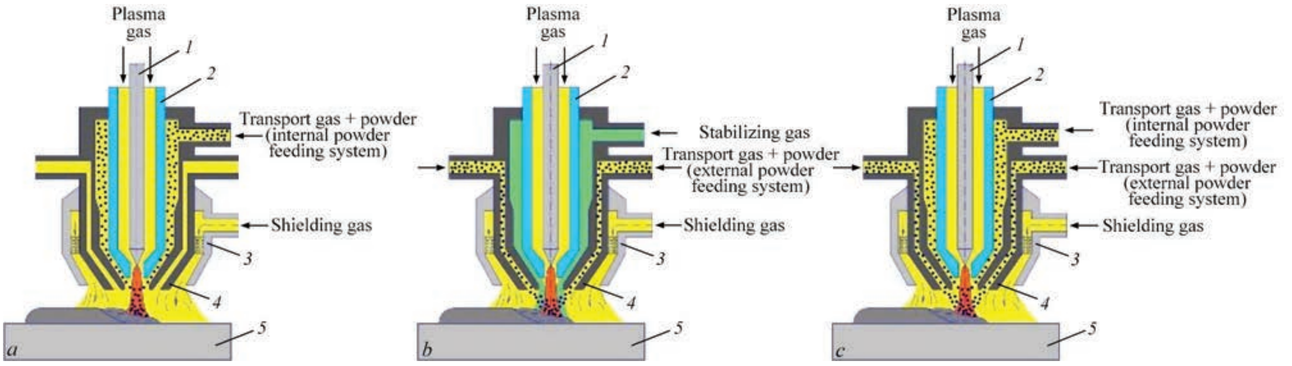

Figure 2. Scheme of PTA torch nozzle part with different variants of powder feeding into the arc: *a* — internal; *b* — external with stabilizing gas; *c* — combined (internal + external); *1* — electrode; *2* — plasma nozzle; *3* — shielding nozzle; *4* — focusing nozzle; *5* — part

ture is complicated. Under the impact of the magnetic field of the arc, the powder particles hang in the PTA torch distribution chamber, forming a kind of plugs. This is the most noticeable at current above 150 A. This drawback is absent with external scheme of powder feeding.

The objective of this work was to combine these two schemes in one PTA torch and to develop such a design of the nozzle part, which would expand its technological capabilities and improve the operation stability.

FEATURES OF THE NEW PTA TORCH DESIGN

Figure 2 shows the schematic of the PTA torch nozzle part, which combines the internal (Figure 2, *a*) and external (Figure 2, *b*) schemes of powder feeding. These schemes can be used both separately from one another and together (Figure 2, *c*; 5, *c*). The latter variant is highly effective at surfacing composite alloys with separate feed of matrix and reinforcing materials [5]. In this case, two separate powder feeders, operating synchronously, are used, as well as two separate flows of transport gas.

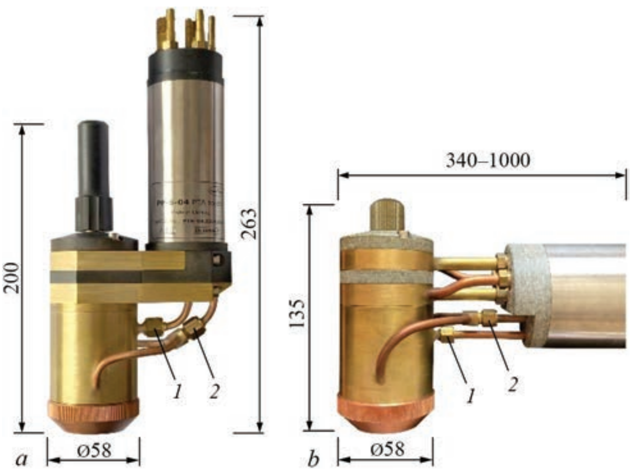

Figure 3. Appearance of PTA torches with two systems of powder feeding: *a* — vertical type PP-6-04; *b* — horizontal type PP-6-03M

This idea was the base for development of two PTA torch variants: vertical (Figure 3, *a*) and horizontal (Figure 3, *b*) modifications. They have the same design of the nozzle part. Selection of either variant depends on the design features of surfacing equipment layout. The horizontal variant is more versatile, as it allows surfacing both the internal and external surfaces to different depth.

Technical characteristics of the PTA torch

Current of indirect (pilot) arc, A	30–50
Direct arc current at duty cycle of 100 %, A	50–300
Kind of current	direct
Polarity	straight
Working gas	argon
Deposition rate, kg/h	1.0–8.0
System of powder feeding into the arc	internal and external
Powder particle size, μm:	
internal system	63–200
external system	53–150
Powder losses, %:	
internal system	< 5
external system	5–10
Total gas flow rate, l/min	14.0–22.0
Cooling system	liquid
Cooling liquid flow rate, l/min	> 4.0

PTA torches allow surfacing nickel, cobalt and iron-based alloys and composite alloys based on tungsten carbides.

POWDER FEED VARIANTS. INTERNAL POWDER FEED

When the system of internal feeding is used, the powder through inlet nipple *1* (Figure 3, *a*, *b*) enters a special distribution chamber, where it is uniformly distributed around a circle by the transport gas and then is blown into the arc through a system of slots uniformly located on the conical surface of the plasma nozzle (Figure 4). The slots promote better cooling of the nozzle and direct the powder particles straight into the most heated central part of the arc. The angle of powder entering the arc is equal to 35° relative to the vertical. The focus of powder particles collision is located at 5 mm distance below the end face of the focusing nozzle (Figure 5, *a*). This is done so as to eliminate powder particles hitting the focusing nozzle walls and thus to improve the reliability of PTA torch operation.

For effective heating of powder in the arc, the initial velocity of particles entering the arc should be as small as possible [1]. In this PTA torch, it was possible to bring this parameter to a minimal value, due to original design of the distribution chamber and optimization of transport gas flow rate. For a PTA torch of vertical type, it is equal to 1.5–2.0 m/s, for horizontal type it is 2.0–2.5 m/s, that is quite acceptable for heating powder particles of 50–160 μm diameter, which are widely used for PPS process [6]. To maintain such velocities of powder flowing out, the optimal flow rate of transport gas is 3.5–4.0 l/min for the vertical variant and 4.5–5.0 l/min for the horizontal one. Particle movement velocity was determined by photographic method of time-lapse photography [7].

EXTERNAL POWDER FEED

With this scheme the powder together with the transport gas is divided into two uniform flows through a special tee-nipple (Figure 3, *a*, *b*), and is then fed into the arc through two openings of 1.4 mm diameter, located on the focusing nozzle end face diametrically opposed to one another. The angle of powder entering the arc is the same as at internal feeding — 35°. The point of powder particle collision is located at 8 mm distance below the focusing nozzle end face (Figure 5, *b*). The velocity of powder particles flowing out at the PTA torch outlet is noticeably higher than at internal feed both in the vertical and in the horizontal modification, and it is equal to 2.5–3.0 and 3.0–3.5 m/s, respectively. This is an essential disadvantage of this scheme of powder feeding into the arc, as increased velocity head of the cold transport gas flow penetrates deeply into the arc column, deforms it (Figure 6, *b*) and lowers the plasma temperature in the heating zone. Arc deformation leads to deterioration of powder heating, and, consequently, to increase of its losses and worse formation of the deposited bead.

Figure 4. Appearance of plasma nozzle

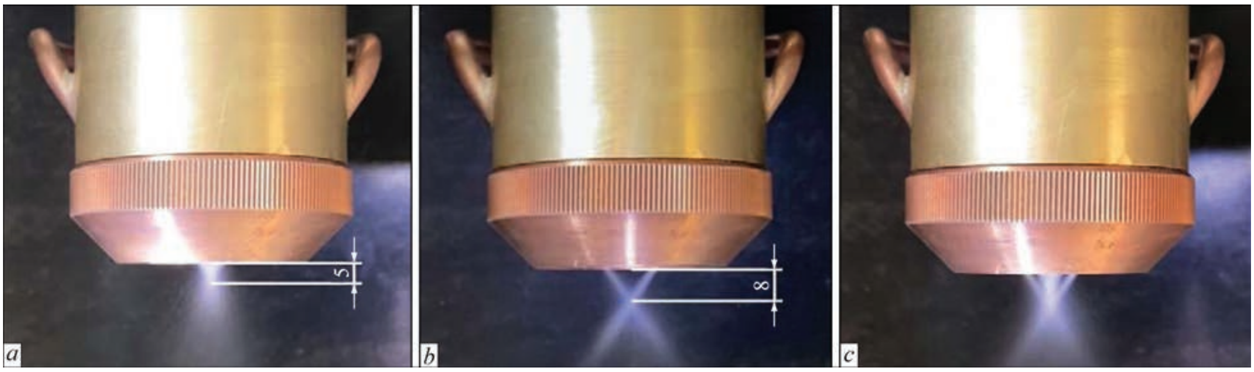

Figure 5. Appearance of plumes of powder flowing out of the PTA torch with internal (*a*), external (*b*) and combined (*c*) powder feeding schemes

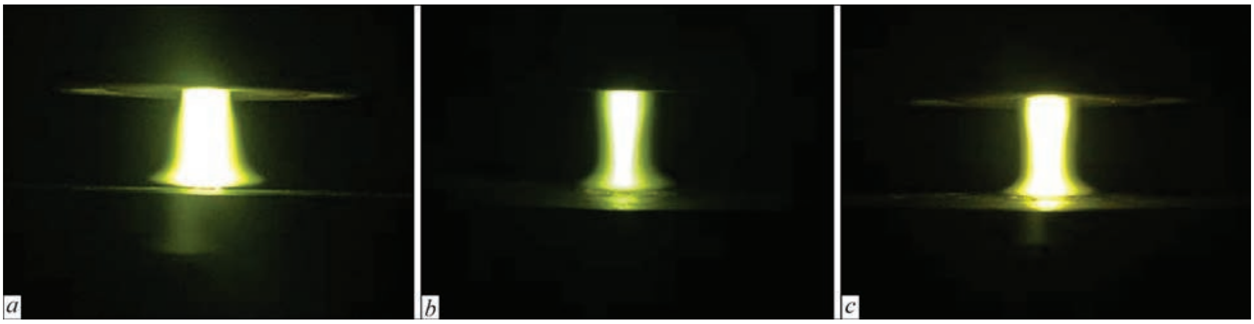

Figure 6. Appearance of arc columns at internal (*a*), external (*b*) and combined (*c*) schemes of powder feed

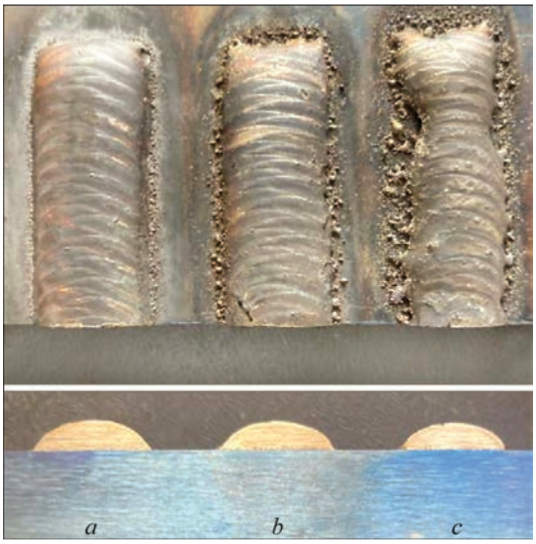

Figure 7. Appearance and cross-section of beads deposited in the same modes at different schemes of powder feeding into the arc: *a* — internal; *b* — external with stabilizing gas; *c* — external without stabilizing gas. Surfacing mode: I_a = 160 A; V_d = = 80 mm/min; G_f = 16 g/min; $Q_{st.g}$ = 4 l/min, deposited material is 304 stainless steel

In order to neutralize this harmful impact, in this PTA torch a gas flow is used, which is blown into the central orifice of the focusing nozzle, similar to transport gas feeding with internal system of powder feed. This flow has a stabilizing role. Concentrically washing the peripheral region of the arc from above, it is heated well, and ousts the cold flows of transport gas in the area of lateral entry of powder. The arc column is straightened, taking a more cylindrical shape (Figure 6, *c*), and it becomes close to the arc shape at internal powder feed (Figure 6, *a*). The spatial stability of the arc is improved, allowing increase of its length to 14–15 mm, and thus raising the powder heating temperature owing to its longer stay in the arc. Due to that, powder losses decrease by 10–15 % relative to external feed without the stabilizing gas, and deposited bead formation is improved. Figure 7 shows the appearance, as well as the cross-section of beads, deposited in the same modes with different schemes of powder feeding into the arc. In it one can clearly see that the additional (stabilizing) gas flow essentially improves bead formation (Figure 7, *b*), making it more similar to the appearance of the bead deposited with internal powder feed (Figure 7, *a*).

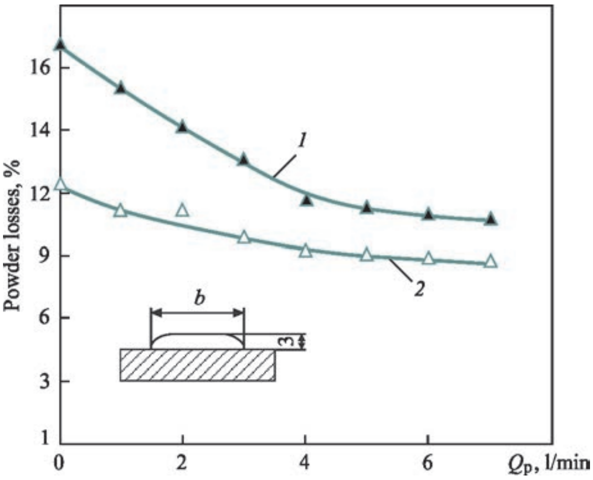

Figure 8. Dependence of powder losses on stabilizing gas flow rate at different bead width *b*: *1* — 10; *2* — 20 mm

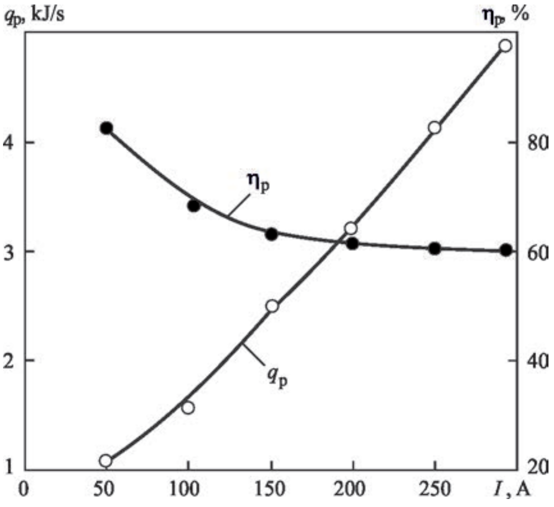

Figure 9. Dependence of effective thermal power q_p and effective efficiency of part heating η_p on arc current in the developed PTA torch

Bead fullness is also increased, which is a confirmation of smaller powder losses (Figure 7, *b*). As shown in Figure 8, the maximal effect is achieved at stabilizing gas flow rate of 4–5 l/min. This is valid both for narrow (curve *1*), and for broad (curve *2*) beads. A further increase of its flow rate no longer enhances the positive effect.

THERMAL CHARACTERISTICS

Thermal characteristics of the developed PTA torch were studied by the method of flow calorimetry on a model sample by a procedure described in [3]. Attention was focused on investigation of effective thermal power and effective efficiency of part heating for the given design of the nozzle part of the PTA torch. Investigations were conducted without the indirect (pilot) arc.

Figure 9 showed that the dependence of effective thermal power q_p and effective efficiency of part heating η_p on arc current for a combination of plasma and focusing nozzles of 4/8 mm at flow rates of plasma (2 l/min), transport (4 l/min) and shielding (8 l/min) gases, characteristic for plasma surfacing.

One can see that with increase of arc current q_p grows practically linearly, but η_p decreases. In the range of currents of 50–250 A, it decreases from 80 to 60 %, which is related to increase of heat losses at the nozzle. On the whole, this index is sufficiently high, close to those for welding and cutting PTA torches [8].

CONCLUSIONS

1. Combination of internal and external schemes of powder feeding into the arc in one PTA torch significantly widens its technological capabilities, as it allows surfacing of magnetic and nonmagnetic materials with a high efficiency and productivity.

2. Additional flow of stabilizing gas with the external scheme of powder feeding reduces the harmful influence of cold flows of transport gas and lowers the powder losses by 10–15 % due to its more effective heating. Optimal flow rate of stabilizing gas is equal to 4–5 l/min.

3. Developed PTA torch ensures a high enough efficiency of part heating. It is not lower than 60 % at maximal currents.

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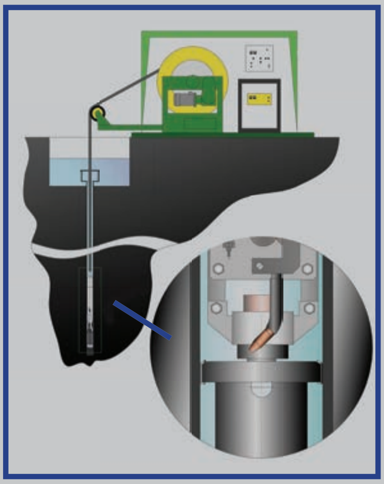

Automatic welding machine at 200 m depth