Profiles containing a hole with a triangular cross-section and their application in welding technology

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***Abstract**: Pipe products with a triangular cross-section of the hole have been manufactured. These products have found effective application in welding equipment for the manufacture of contact current-carrying nozzles, guide tips, etc., used in welding in a protective gas environment and in submerged arc welding. In addition, the qualities of the nozzles have been studied in laboratory and production conditions on the basis of manufactured pilot batches. The conducted studies of the quality characteristics of the new class of nozzles showed that those with a triangular cross-section of the hole guarantee increased quality of the welding process and the weld seam, as their service life is 30%÷60% longer compared to the durability of conventional nozzles with a round hole.*

***KEYWORDS:** TWO-STEP EXTRUSION, TRIANGULAR CROSS-SECTION, NOZZLE, WELDING*

1. Introduction

The developed method for manufacturing profiles containing a hole with a non-circular cross-section is based on the methods of plastic processing created in IMSETCHA: multi-stage extrusion [3-5] and mandrel-free pressing [6-10]. They are a technological prerequisite for developing of new technical solutions, which are the subject not only of the present work. A essential characteristic of the technological process of multi-stage extrusion is achieved ultra-high degrees of cold deformation, which define high mechanical properties of the products. The mandrel-free pressing method is highly effective in producing thick-walled pipes with a small hole. Under these conditions (very small hole sizes and holes with a non-circular cross-section), pressing with a hard needle is very difficult or even impossible because of strength considerations, related to the destruction of the needle. These difficulties are greater when it comes to be obtained thick-walled pipes by multi-stage extrusion. For these reasons, the joint applying of the multi-stage extrusion and mandrel-free pressing processes creates unique opportunities for cold production of thick-walled and extra-thick-walled pipes, tubular wires and profiles with very long lengths and very small cross-sectional dimensions of the longitudinal cavities (including capillary holes). These profiles are very suitable for subsequent processing on automatic lathes and thus obtaining final products with high exploitation qualities, based on high-productivity and economically advantageous technologies. One of the many possibilities is for these products, to be find an effective application in welding equipment for production of contact nozzles, guide tips, etc., used at welding in a protective gas environment and in submerged arc welding.

2. Description of the technological scheme

The method, subject of the present development, is realized using a two-stage extrusion device, shown schematically on Fig. 1c. In essence, this is a principle scheme of the tool presented in [2]. In the starting billet (B), a non-passable hole with a triangular cross-section is made (Fig. 1a), which is filled with a deformable material (M). Thus obtained billet is placed in the container of the container-matrix (CM) of the two-stage pressing device (Fig. 1c), with the hole oriented against the face P1 of the punch for straight pressing . After that discrete extrusion process follows, in which the first (performed by P1) and second (performed by P2) partial extrusions are sequentially and repeatedly realized. Under the action of the pressing force, the face of the punch P1 hermetically seals the material M in the opening of the billet. forming the opening of the pressed product (PP). After completing the process of deformation, the defective frontal l_f and back l_b , (Fig. 1b) parts of the product are cut off and the filling medium is removed, or it is also possible the medium to be removed from the final products after lathe processing of the extruded product .

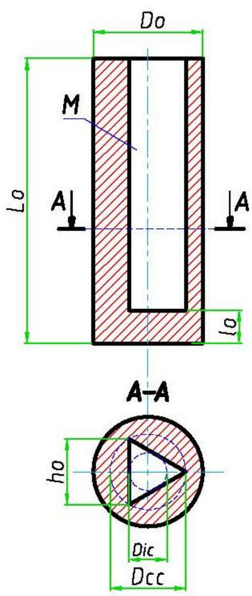


***Fig.1a.** Initial billet*

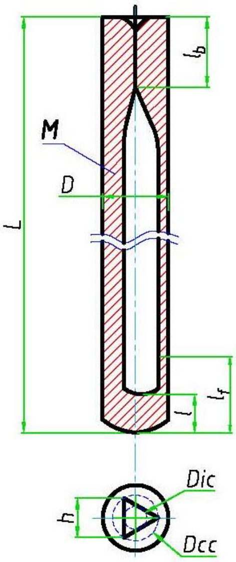


***Fig.1b.** Final product*

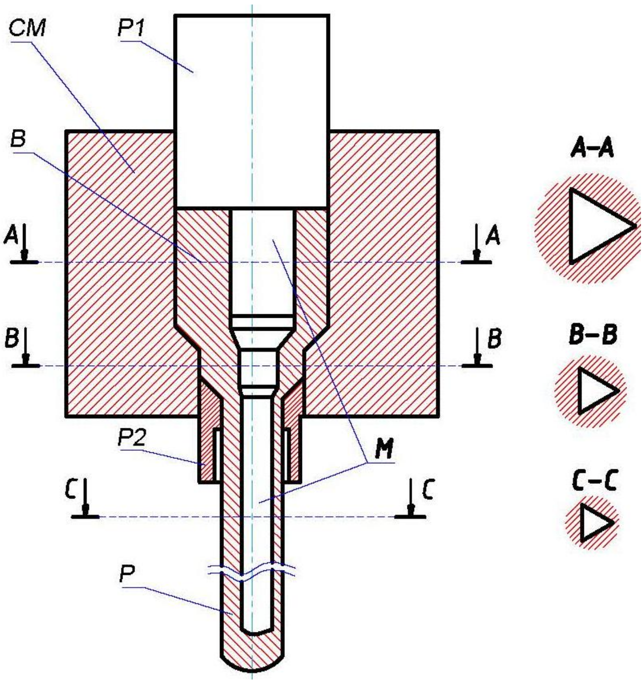
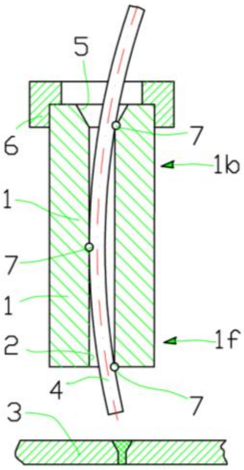


***Fig.1c.** Device for two-stage extrusion*

3. Creation and research on new technical solutions of nozzles for welding in a protective gas environment.

The contact nozzles for gas-shielded arc welding are a tubular body with a central opening serving to feed the electrode wire from the wire feeder through the gun to the welding area. In addition to guiding the welding wire, the contact nozzle also performs the function of transmitting electric current to the welding wire. As can be seen from Fig. 2 and Fig. 3, the nozzle 1 is a tubular body with a central through-hole 2, which hole has a straight axis and is usually of circular cross-section. The nozzle is attached by its back end l_b to an element 6 (diffuser), by means of which it is connected to the welding gun or to the machine carrier. The electrode wire 4, which has a natural curvature, passing through the hole 2 of the nozzle 1 is elastically deformed and thus pressed against the hole 2 at three points 7, i.e. three-point current supply is realized.



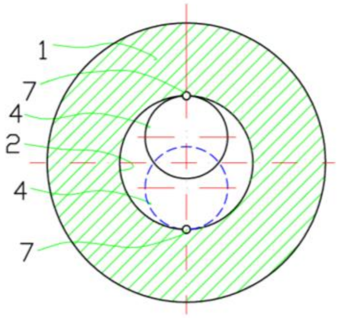


Fig.2. *Schematic diagram of the process*
Fig.3. *Cross section of the nozzle*

The wire emerges from the front end of the nozzle forming a short positively charged front part, as between it and the processed material, which is charged oppositely, an electric arc is created. This arc melts the bodies, thus continuously supplying material for the welding joint. In most devices, the welding wire is wound on a spool, from which it is unwound using the wire feeder and automatically fed to the gun. The wire emerges from the spool with a certain curvature, and inside the nozzle opening it elastically straightens and presses against the walls of the opening. This favors the current transfer process because it maintains good electrical conductivity. The opening of the contact nozzle is made with a minimum, optimal clearance to minimize friction between the wire and the opening. However, increasing the clearance beyond a certain limit leads to poor contact and deterioration of the welding process. A disadvantage of the nozzles described above (Fig. 2 and Fig. 3) is their short service life due to intense mechanical and electroerosion wear. This is due to the fact that the current loads are very high (the welding current amounts to 100-800A), and the current supply is carried out on the basis of a very limited three-point contact between the welding wire and the nozzle (at the beginning, in the middle and at the end of its opening - position 7 in Fig. 2), while the pressing forces on the contact surfaces are insignificant and variable in magnitude. The desire to reduce the gap in order to improve the contact does not lead to an increase in the contact area, but only worsens the passability and increases the probability of blocking the wire inside the opening. In addition, due to the fact that the opening has a circular cross-section, the wire rolls in it during the welding process, which prevents its accurate guidance to the weld seam. Consequently, of this rolling and electro-mechanical wear, the contact spots change their position and size over time, which makes the current supply process non-stationary. As a result, the welding arc is unstable, which leads to a deterioration in the quality of the welded joint.

In nozzles with a triangular cross-section opening, some of the above-mentioned functional disadvantages of the nozzle with a cylindrical central opening with a circular cross-section have been eliminated to a certain extent. In nozzles with a triangular cross-section of the opening (Fig. 4 and Fig. 5), there is a much better contact of the wire in the nozzle opening. The nature of this contact is justified by the position of the wire 4 in the prismatic triangular opening 2. This position is the most stable of all possible, since it is associated with a minimum of the potential energy of elastic tension of the wire 4. It makes linear contact 10 with the side 8a of the triangular prismatic opening 2 and additionally contacts at three more points with the other two sides (at two points 7b located at both ends of the wall 8b and at one point 7c located in the middle part of the side 8c). In this way, a balance is achieved between optimal current supply conditions (characterized by appropriate clearances, increased contact areas and pressures and stable angular fixation) and good wire passability, especially when using nozzles with longer lengths. Here, the rotation of the electrode wire in the nozzle opening is significantly prevented, as it stands in the corners of the opening, thus being fixed angularly (the arc is stabilized).

Due to the above circumstances, the welding arc is stable, the amount of molten metal splashes is much less, the accuracy of wire feeding to the welding site is greater, the probability of blockage of the wire in the hole is significantly reduced and the life of the nozzle is extended. And in general, the welding process is of high quality.

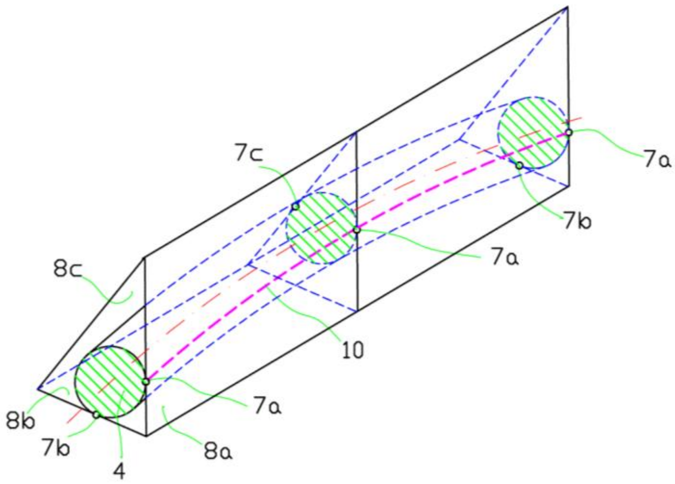


Fig. 4. *Position of the wire in the triangular hole*

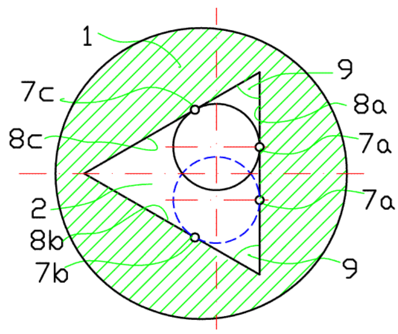


Fig. 5. *Cross section of the nozzle*

In triangular nozzles, the wire must have a smaller diameter than the diameter of the circle inscribed in the triangular cross-section, so that it can pass through it. Regarding the dimensions of the equilateral triangle of the cross-section, first of all it can be said that for the case under consideration it is most appropriate to define them with the diameter of the inscribed circle (Dic), the diameter of the circumscribed circle (Dcc), considering that Dcc=2.Dic and the side of the triangle is $h=\sqrt{3}.Dic \approx 1.73.Dic$).

It has been established, from experience, that the gap Δ_0 between the hole of the conventional nozzle (with a round hole) and the wire for the most commonly used wires ∅0.8; ∅1.0; ∅1.2 is Δ_0 = 0.15; 0.2; 0.25. In order to maintain the same elastic tension of the wire in the triangular hole (taking into account the position of the wire in the corners of the triangular hole, Fig. 2. -7) the following condition must be met:

Δ_{tr}=Dic – Dw =Δ_0/1,73≈ 0,577. Δ_0.

Based on the above dependence, the copper current-carrying nozzles prepared for experimentation for welding in a protective gas environment, indicated in Table 1, have been dimensioned.

Geometric dimensions of the experimental nozzles Table 1

General data		Round hole nozzle		Triangular hole nozzle	
d_{wire}	L_{nozzle}	Δo	d_h	Δtr	Dic
0,8	25	0,15	0,95	0,1	0,9
1	25	0,2	1,2	0,1	1,1
1,2	25	0,25	1,25	0,15	1,35
1,2	30	0,25	1,25	0,15	1,35

The triangular hole in the blank parts (Fig.6) was made using the tool from [1]. A two-step extrusion was performed using the tool from [2].

Fig.6. Initial billets with triangular holes

Fig.7. Nozzles with triangular hole

The conducted experimental studies of nozzles with a triangular opening (Fig. 7) showed that they have the advantages indicated in the above analyses. From the conducted experiments in connection with the assessment of the durability of the nozzles and their quality indicators, it can be said that cases in which they to show deteriorated (compared to conventional nozzles) quality indicators and reduced durability have not been observed. In a significant part of the cases, increased durability within 30-50% was found.

Conclusion

Highly efficient methods and tools for manufacturing a new class of tubular products with a non-circular cross-section hole have been investigated. These products can find effective application in welding equipment for manufacturing contact nozzles, guide tips, etc., used in welding in a protective gas environment and in submerged arc welding. The research is based on methods of plastic deformation developed at the Institute - multi-stage extrusion and mandrel-free pressing, in which ultra-high degrees of cold deformation are realized. In addition, the qualities of the nozzles have been investigated in laboratory and production conditions on the basis of manufactured pilot batches of nozzles. The conducted studies of the quality characteristics of the new class of nozzles under development showed that nozzles with a triangular cross-section of the hole possess some characteristic qualities that guarantee increased quality of the welding process and the weld seam, as their service life is 40%÷70% longer compared to the durability of conventional nozzles with a round hole.

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