

# Enhancing a service life of torch components for MIG/MAG welding

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**Abstract.** The paper analyzes the main vulnerable elements of torches used in mechanized gas-shielded welding. Particular attention is given to the gas nozzle designs, materials they are made of, and other welding torch elements exposed to increased electrical and thermal stresses during the welding process.

## 1. Introduction

For mechanized gas-shielded welding (MIG/MAG welding), torches of a GDPG type are used (Russian analogues: GS-250, A-547uM; foreign analogues: RF and MB types made by Abicor Binzel: AL and AW types by Fronius, TBi – TBI, SB and SBT by Merkle). The main advantage of these torches is their light weight and simple design. The torches of this type are designed for welding with a current of up to 300 A, and owing to their advantage they can be used for welding at higher currents after their modernization [1].

Efficiency of torches depends on their design and materials used. In welding, some parts of torches are subjected to heating from welding arcs and contact with droplets of molten metal. Nevertheless, main structural components and units in this type of torches are able to withstand increased electrical and thermal stresses without a loss of their serviceability and functionability.

## 2. Analysis

Nozzles of welding torches, ensuring the gas flow to a weld zone, are subject to thermal impact from the arc and are warmed to a temperature of 180-320 °C and above when continuously operating for a few minutes without insufficient cooling. In strong heating, spatters of molten metal are firmly welded to walls of metal nozzles. Building of spatter on the inside surface of nozzles causes the reduction of their inside diameter and weaker gas-shielding protection of molten metal. Arc tracking can occur between a contact tip and the nozzle. If a nozzle is made of electrically conductive material, then in cases of accidental contacts it can melt causing its failure.

According to working conditions, the following basic requirements are imposed on nozzles' designs and material they are made of: fire-resistance, mechanical strength both in a heated and cold condition, low spatter adhesive strength, a simple design and low cost of manufacture.

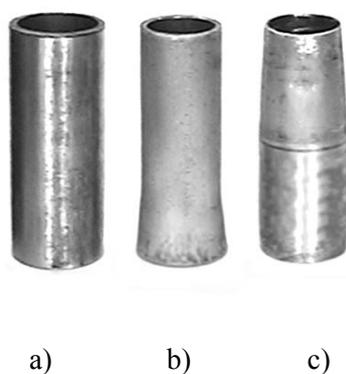
Heating a nozzle increases the intensity of metal spatter in it. Cooling a nozzle contributes to a sharp weakening of this process and increases the efficiency of cleaning weld spatter off the welding nozzle. Life service of nozzles when they are cooled increases approximately 3-4 times [2]. In order to



increase reliable operation of nozzles and their heated parts, they are cooled with water or air, depending on welding conditions [3]. Besides, the quality of a nozzle surface coating can contribute to reducing the amount of weld spatter [2].

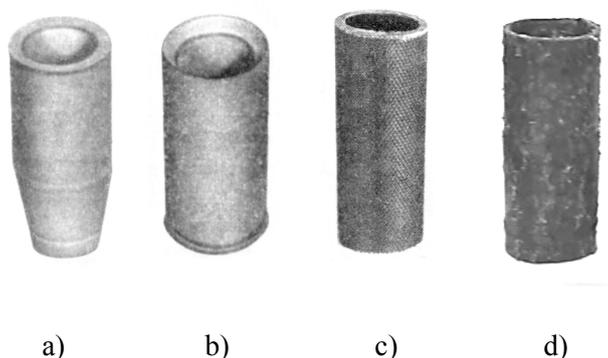
The nozzles cooled with air can operate at a current of 300 A. When the current exceeds 300 A, the nozzle must be cooled or structurally provided for the possibility of operating at high temperatures. The nozzles cooled with water are of limited use in industry, as in this case the weight of hoses and the nozzle are higher that results in reduced manoeuvrability, and it is not always possible to provide a working area for water. In most cases, designs of hoses and nozzles are modified in the way that to apply natural cooling.

Brass or copper are mainly used for the manufacture of nozzles. Service life of nozzles made of brass and other alloys is approximately 2 times less than of copper. The nozzle surface is often chrome plated to reduce the adhesion of spatter. The shapes of nozzles are usually cylindrical (Figure 1, b) or slightly conical (Figure 1, c) that provides a more uniform outflow of gas. Copper nozzles in cylindrical configuration are the most widely used [4].



**Figure 1.** Copper nozzles for welding torches:  
a – cylindrical; b – cylindrical with broadening; c – conical

Due to the relatively high cost of copper tubes, commonly used for the manufacture of nozzles, a lot number of attempts were made to replace copper with non-metallic materials. Non-metallic nozzles (Figure 2) are used mainly in welding with a low current.



**Figure 2.** Non-metallic nozzles for welding torches:  
a, b – ceramic; c – fibreglass; d – paronite

One of the first attempts was made to use heat-resistant ceramics in the manufacture of nozzles in torches for argon-arc welding with non-consumable electrodes. However, the drawback of ceramic

materials is their ability to break down under thermal stresses as well as low mechanical strength in cases of spatter cleaning and accidental bumps.

The manufacture of ceramic nozzles (Figure 2, a, b) by hot die casting is a more advanced technology [5]. For this purpose, dispersed slurry is prepared, where talc and clay in the dispersed phase are mixed, with paraffin as a binding agent in an amount of 8-10% of mixture's weight, which is used as a technological binder. The nozzle is 3-4 shifts in operation. Due to low mechanical strength and relative complicated manufacturing technique, the ceramic nozzles have found in limited use. There are the same limitations to the nozzles made from asbestos cement slabs 25 mm thick by cutting them out. They are not widely used as well, although their resistance is equal to 6 shifts.

Attempts were made to use combined copper and asbestos cement nozzles, i.e. asbestos cement sleeves were attached to the ends of copper nozzles. This, to some extent, excluded short circuiting and copper nozzle burning, but did not exclude mechanical damage due to shocks.

Nozzles made of fibreglass reinforced plastic AG-4B, which consists of a base (matted fibreglass) loaded with phenol-formaldehyde resin, have good performance characteristics [6]. The nozzles are made by pressing followed by heat treatment. The strength of these nozzles compared with asbestos cement nozzles is higher 2-3 times; cleaning spatter off during their use is not required.

High performance torch nozzles for wire welding from fibreglass fabrics are simple to manufacture (Figure 2, c) [7]. When FA, FB or FAU monomers are used as a binding agent, four layers of fibreglass fabrics are wound around the brass plated rods with impregnating with one of the said monomers. Then the fibreglass tube with the rod is exposed to heat treatment. After heat treatment, the tube is detached from the rod and cut to the desired lengths. The fibreglass nozzles have no drawbacks that are typical for copper, brass, ceramic and asbestos cement nozzles. Service life of fibre glass nozzles is approximately 10 shifts of continuous work with their gradual melting.

The nozzles based on fibreglass fabrics can be made using bakelite varnish, although in this case, their service life will be reduced.

Instead of monomers and varnish as a binder, in the manufacture of nozzles andesine paste can be used [8], consisting of sodium silicofluoride and andesine or diabase power, which can be replaced with powdered bricks or glass mixed with liquid glass. The paste is applied between the layers of fibreglass during its winding on a rod and dried at a normal temperature. The ready tube is cut to the desired lengths. Under the influence of arc welding temperature, the nozzles become embrittled to the small extent, but their strength is sufficient. Spatter building up on the nozzles can be easily removed. Service life of the nozzle based on the andesine paste is shorter than of the nozzles on monomers. However, they do not require high-temperature treatment and therefore cheaper.

There are other variants for replacing the nozzle material (copper) with lighter, less expensive and non-conductive materials. For example, it is proposed to use a sheet paronite, folded up in a tubular lining (Figure 2, d) and fixed in the casing [9]. Such nozzles have a number of drawbacks: first, because of the gap at the spot of liner joining, a gas shield in arc and weld area can be disturbed and, second, at high temperatures paronite burns out that leads to frequent replacement of nozzles.

There is a variant of nozzles in the form of a seamless tube from heat-resistant fibreglass plastics with an epoxy organ silicon binder reinforced with fibreglass fabrics [10]. Its mass is 10 times less than copper. Spatter building-up on the inner surface of the nozzle can be easily removed. A glass-plastic nozzle is efficient for 1.5-2 shifts under heavy operating conditions of welding.

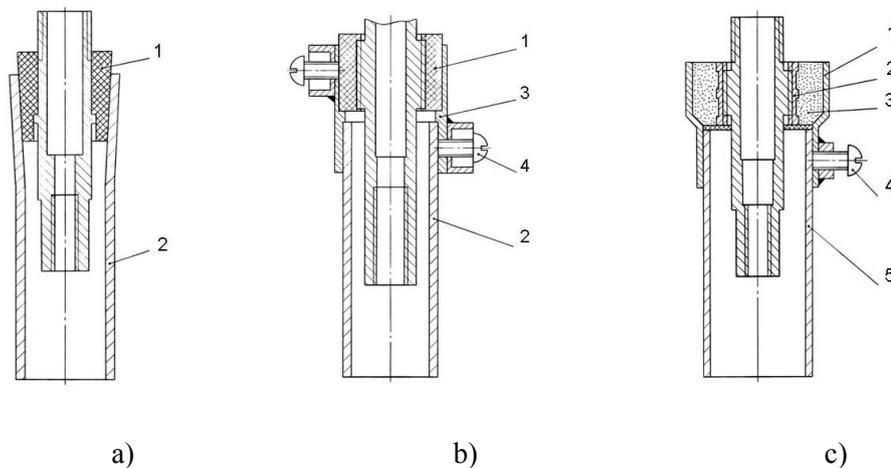
In heavy duty welding (300-450 A), copper nozzles are largely preferred for use, because of thermal and physical characteristics of copper complying with operating conditions to a larger degree.

To protect metal nozzles from molten metal spattering, special protective lubricants can be applied, which are designed for use at temperatures ranging from 100 to 250 °C. The lubricants are supplied in aerosols that allow their easy application by spraying onto nozzles. After the solvent evaporating, the surface is covered by a thin solid film that protects the surface of the nozzle against weld spatter.

As a protective cover, it is suggested using other insulation materials such as synthetic resin. Molten metal spatters appearing during the welding process do not adhere to the inner surface of the nozzle. The service life of the nozzle increases.

An effective way to increase a service life of welding torch components is applying, for example, heat-resistant coatings by ion-assisted deposition onto the working surfaces of the nozzles. One of the known coatings is a heat resistant diamond-like film [11, 12] with the use of ion-beam deposited carbon on the nozzle surface. In addition to the diamond-like coating, heat-resistant coatings based on titanium, nitride titanium and nitride zirconium have been developed. It is established [13] that the nitride titanium (TiN) coating is preferable for the nozzles used in semi-automatic welding machines. The service life of the nozzles with heat-resistant coatings increases by 30-80 % and, respectively, the demand for such nozzles decreases.

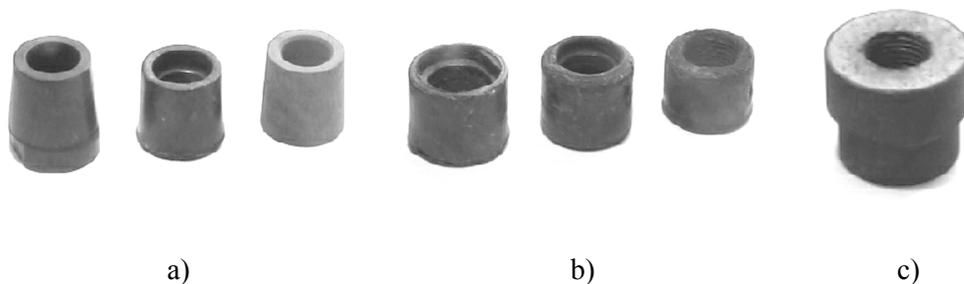
The electrically insulated nozzle has a property of accumulating heat energy from an electric arc. This heat energy causes heating of other parts. Especially dangerous is the heating of insulating sleeves. An insulating sleeve serves to isolate the current-carrying parts from the nozzle. It is a constructive element designed to hold and centre the nozzle itself on the torch (Figure 3).



**Figure 3.** Variants for fixing nozzles in insulating sleeves:  
 a – conical; b – cylindrical; c – ceramic metal

The insulating sleeves for torches used in carbon dioxide welding, operating in heavy duty environments, are exposed to repeated heating and reach high temperatures. Therefore, the materials need to meet the following requirements: high isolating properties, good thermal and mechanical properties, cheap and available for supply materials, basic manufacturing processes, and a small weight.

A range of insulating sleeves is not diverse with reference to their designs (Figure 4).



**Figure 4.** Insulating sleeves for semiautomatic welding torches:  
 a - tapered; b - cylindrical; c – ceramic metal

They have a conical (Figure 4, a) or cylindrical (Figure 4, b) shape with a plain and (or) a threaded bore, depending on design features of the welding torch and contact welding tip in particular.

The insulating sleeve form determines the way of how the nozzle is attached to the welding torch. The nozzle 2 is held inside the conical sleeve 1 (Figure 3, a) by means of the tapered extension at the end of the nozzle. This attachment is not reliable because of the insulating sleeve breakdown under high temperatures that leads to spontaneous fallout of the gas nozzle. A special coupling 3 is used to hold the nozzle 2 attached to the cylindrical sleeve 1 (Figure 3, b) and screws 4 fix the attachment. This technique is much more reliable, but it also has limitations: a massive structure and inconvenience in service due to the large number of structural elements.

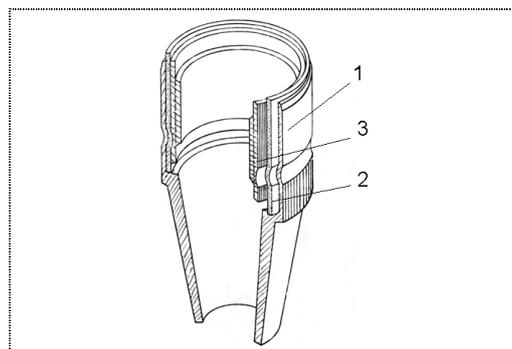
Electrical insulating properties are important in material used in the manufacture of sleeves. The most common are fabric-reinforced laminate and glass-fibre-base laminate. The fabric-reinforced laminate sleeves have good insulating properties but low mechanical and high temperature resistance. This type of sleeves is nondurable due to their quick embrittlement when in contact with the heated nozzle. The permissible operating temperature can reach a high of 105 °C [14] for fabric-reinforced laminate. The glass-fibre-base laminate sleeves can operate at temperatures up to 200 °C and for 1-2 hours at temperatures up to 250 °C [14]. There are also insulating sleeves from asbestos cloth, which is made by pressing and using sodium silicate for binding [15]. Operating temperatures inside the asbestos sleeves can reach as high as 450 °C.

Problems that appear while manufacturing and using the sleeves of the above materials are due to various reasons. Thus, the fabric-reinforced laminate sleeves are, first, expensive, because they require machining in manufacture, and, second, as already mentioned, easily damaged. In heavy duty operation, they burn out in 4-4.5 hours of operation on a semiautomatic welding machine [15]. As to glass-fibre-base laminate sleeves, special auxiliaries - moulds are required for their manufacture. The service life of such sleeves is seven working shifts in the average. The sleeves from asbestos cloth with sodium silicate binding have a higher resistance (112-115 hours) [15], however the manufacturing process is quite complicated.

The ceramic metal sleeves can be put to a separate category of insulating sleeves (Figure 4, c), consisting of a steel casing 1 (Figure 3, c), a steel threaded bushing 2 and a ceramic insulator 3 [1]. The nozzle 5 is fixed by means of a screw 4. Such mounting eliminates spontaneous shifting and distortion of the gas nozzle during welding. The manufacture of ceramic metal sleeves is relatively complex, and their service life is 600-800 hours.

With their remarkable resisting properties, the ceramic metal sleeves are prone to destruction as well. Due to the difference in thermal expansion coefficients of the materials, the sleeve is made of, and under the influence of mechanical actions while cleaning the nozzle from spatter, the ceramic insulator spalling takes place, the inner sleeve is loosened from the screw that is indicative of the ceramic metal sleeve losing its efficiency. At the moment, there are a number of compositions for stuff used in ceramic metal sleeves [16-19]. The main compounds in material are sodium silicate, kaolin, corundum and borax. The most widely-spread composition contains the following: sodium silicate electrode 57-62 %, corundum 28-30 %, kaolin 9-10 %, boric acid 0.5-1.5 % and borax 0.5-1.5 %.

One-piece design is known where the insulating sleeve is integral to the nozzle [20]. The insulating sleeve housing 1 (Figure 5) is rigidly connected to the heat-resistant insulation 2 and sleeve with internal thread 3.



**Figure 5.** A Welding torch nozzle.

There is a modification wherein the insulating sleeve is not used at all. The nozzle [6], made of non-conductive heat-resistant material, is screwed directly onto the contact tube. Increased service life of the nozzle is achieved through higher thermal stability of the material and due to the possibility of replacing the contact tip upon its burning out.

### 3. Conclusion

Analysis of Russian and foreign findings shows that the main vulnerable elements of torches in mechanized carbon dioxide shielded welding are nozzles, insulating sleeves, contact tips and contact tubes. Their vulnerability causes their excessive consumption during the operation, and this certainly have influence on the final price of products. In addition, replacing wear parts and cleaning spatter off the nozzles lead to the loss of working time.

There are two ways to increase a service life of torch parts: the first is development of electrical and metallurgical techniques that reducing spatter; the second is development of materials and designs enabling the reduction of the amount of metal spatter that welds to and builds up on the working surface of torches.

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