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Welding copper - steel experimental welding of copper nozzles, selection methods welding

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Abstract— Experimental welding copper nozzles steelworks in Smederevo has contributed to the adoption of welding technology and provide adequate reserves with minimum cost of producing. Experimentation in the laboratory for welding process has been successfully confirmed TIG and MIG welding of dissimilar metal steel copper in the case of nozzles. Adequate preheating (select the appropriate temperature) and the corresponding additional material to a certified welders have proven that the default technology meets the needs of the welding nozzles at 100% penetration testing and testing of pressure .

Keyword: welding, copper, nozzles, technology, resources, steel, methodes .

1 Introduction

Nozzles f 140 inlet cone made of copper strip (Cu 99.25) dimensions 6 x 420.19 x 641.8 and outer cone of copper (Cu 99.25) dimensions 6 x 486.5 x 1092 it is necessary to weld the inner and outer copper cone flange copper (Cu 99.25) f dimensions 263 x 70 at the front side and welding the steel flange (č.0361) f dimensions 384 x 70 on the other side of nozzles. Welding pipe flange does not present difficulties because it is a merger of steel č.1212 with steel č.0361. Developed and won technologies combining copper with cooper and cooper to steel was performed under experimental conditions, and due to the lack of new elements nozzles welding technology was successfully applied for welding copper spears ockets for the integrated steelworks. Welded a total of 10 pieces of sleeves nozzles for steel plant and met the same test pressure of 20 bars, and submit to exploit the steelworks. Applying this technology for welding nozzles is significant because it is the replacement of import additional material and it opened the possibility of welding copper spigot nozzles for steel plant and sated with an excess furnace within the Smederevo Steelworks.

2 Technology of welding copper

The main difficulties when welding copper are the consequences of its high thermal and thermal conductivity, good flowability and high activity towards oxygen and hydrogen in the heated and molten state. Due to the high thermal conductivity of copper (which is almost six times higher than that of steel) are very strict criteria for the joint form and technique of fusion welding. [1]

The most suitable for welding of copper are the counterbalanced compounds (a), seams at an angle (b) and overlapping seams (c) to exercise very difficult.

High temperature and thermal conductivity of copper significantly increases the cooling rate of weld metal and HAZ (Heat affected zone) which shortens the time for which the melt is in liquid form as a bad influence on the formation of the seam and hinders metallurgical processing of the melt.

In order to improve formation of the seam and the conditions of crystallization, as well as to minimize the internal stresses and the tendency of formation of cracks during welding elements of copper with a thickness of 15 mm, it is recommended preheating and additional heating during the welding process.

Copper has high flowability (about 2 - 2.5 times higher than the same indicator for steel) which makes it necessary to retain and forming the melt using substrates of graphite, ceramics, asbestos and similar materials, therefore it is difficult to weld in a vertical position and overhead.

Liquid copper actively absorbs oxygen and hydrogen, which adversely affect the mechanical properties of welded joints. Copper oxide Cu_2O, resulting from the oxidation reacts with hydrogen dissolved in the metal, creating steam which tends to separate from the weld metal, affects the creation of pores and tiny cracks ("hydrogen disease").

In addition Cu_2O dissolving copper eutectic formed having a melting 1068^0C which is lower than the melting temperature of copper 1080^0C. The resulting eutectic crystallization when expanding the edges of the weld beads and the area around the weld and can cause increased brittleness and spraying metal weld. Ingredients that are found in copper, primarily antimony, bismuth, sulfur and lead with the metal also readily soluble form a eutectic that reduce the strength of welded joints.

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Therefore, the content of impurities in copper, which is designed for welded structures were limited to 0.03% O_2; Sb to 0.005%; S up to 0.01%; Pbup to 0.003%. For elements that are of particular importance, content of harmful impurities, in particular oxygen should be even lower. [1]

Copper and its alloys arewelded arc using carbon electrodes and soluble coated electrodes, flux under shielding gas as well as autogenous welding.
On this occasion, welding copper nozzles experimentally we only use methods of arc welding copper shielding gas Argon MIG and TIG welding.

3 Available welding procedures gas, arc welding coated electrode and arc welding MIG and TIG

3.1.Gas welding of copper

For gas welding of copper preparation edge is the same as for welding low carbon steel. In simultaneous welding with two burners copper thickness above 10 mm is used to 'X' preparation edges. Power burner flame is determined on the basis of the budget flow of acetylene from 0.42 ÷0.4 l / sec at 1 mm thickness for welding copper thickness up to 4 mm and 0.49÷ 0.63 l / s for 1 mm thick copper thickness to 10 mm.
For larger thickness is recommended to use two burners simultaneously, thereby consumption in the burner for preheating is 0.42 ÷ 0.56 l / sec, and the welding torch 0.28 l / sec to 1 mm thickness.
Welding of Copper and bronze is carried out by flame normal (β = 1 ÷1.10), brass oxidizing flame (β = 1.2÷1.4) to reduce the intensity of the evaporation of the zinc. Welding shall be performed only in one pass with a maximum speed so as to avoid create derivative cracks and grain growth. It is advisable to protect the graphite or steel mat with shaped groove.When gas welding of copper thickness up to 5 mm are used additional material forms of copper rod copper without oxygen, and the welding of copper thick copper wire should be used which contains 0.2% phosphorus and 0.15 - 0.3% silicon. The basic parameters of the gas welding are given in Table 1.
The fluxes for gas welding of copper has the following chemical composition: 34% ofborax, boric acid, 33%, 33% salt. In (Table 1) are given orientation parameters gas welding of copper.

[1] Adamovic, Z., Spasic, D., Meza, S., Alargić P., Nikolić N.,: Maintenance of machines according to technical condition, the Society for Technical Diagnostics Serbia, Belgrade, 2015.

The Thick-ness of the metal (mm)	Numb. of subjects	Consumption l / sec		Method of welding
		acetylene	oxygen	
1,5 ÷2,5	2 ÷ 3	0,06 ÷0,07	0,06 ÷ 0,08	One welder
3 ÷4	4 ÷ 5	0,13 ÷ 0,2	0,13 ÷ 0,2	One welder
5 ÷ 6	5	0,29 ÷ 0,12	0,31 ÷ 0,44	Two welders (one preheated, Second welded)
8 ÷ 10	6 ÷ 7	0,56 ÷ 0,84	0,58 ÷ 0,84	Two welders (one on each side)

Table 1. parameters gas welding of copper

3.2. Arc welding of copper coated electrode

Arc welding process, coated electrode is carried out primarily by direct current reverse polarity, because in welding AC power increased spraying of metals. To create electrodes used cores which are chemically the same as the base material. Coating thickness (δ) of electrodes depending on the diameter of its core (d) may be determined on the basis of the relationship: $\delta = (0.1 \div 0.12)\, d$

Copper thickness of 4 mm welded arc process without preheating and separating edges. If the copper element has a thickness of 5 - 10mm is necessary preheating of 250÷ 300 ^{0}C and is evaluated edge angle from 60 - 700 and the flat part of the root edge 1,5 ÷2,0 mm. When it is necessary to weld a greater thickness of copper is recommended to form the separation edge of the form "X", and when the thickness is above20 mmisthe pre-hearing of 700 - 750^{0}C. Welding is performed with a short arc electrodes with a diameter of φ 4.0 to φ 6.0 mm without oscillations of the tip electrode. [1]

Welding for cooper is determined from the relationship: I weld = 50 .del
The use of special electrodes can be welded copper thickness up to 15 mm without preheating or with minimal heating (250 - 400^{0}C). Welding current at the mentioned types of electrodes is determined from the ratio: Ist = (85÷100) del pri U=45÷50V.
Mechanical properties of the compounds of copper coated welding electrodes are quite high, however, present conductivity of the seam amounts to 20 - 22% compared to the conductivity of the base material (copper).

3.3. Welding copper EPP - procedure

Weldingcopper EPP process is carried out using a copper wire electrode as the protection of powder. Copper thickness from 4 to 10 mm is specified welding procedure without any problems with the application of flux according to GOST-in 16130 (ANSI 20 S, S -26 AN, AN - 348A and OSC - 45) [1].

When the weld thicker copper suggested to use a mixtures of flux AN - AN 26S and 20 S in the ratio of 80 to 20% or special fluxes AN - M13.

Copper is the EPP - procedure successfully welded using the electrode of copper oxide andoxygen free copper or hardened in the process of plastic deformation.

Welding and carried out in a single pass with full penetration of the edges that are connected. Orientation regime copper welding under flux is given in Table 2.

The sape of the re-ceived base materi-al	The thick-ness of the metal (mm)	Diam-eter elec-trode wires (mm)	Current intensity (A)	Volt-age (V)	Welding speed 1 x 10-3 m / sec.
No space edging	2 4 5 - 6 8 10 - 12 16 - 20 22	1,4 2 4 4 5 4 - 5 4 - 5	140 - 160 250 - 280 500 - 550 600 - 620 700 - 820 850 - 1100 1200 - 1250	- - 38 - 42 40 - 42 42 - 44 44 - 46 46 - 48	7 5,5 12,6 - 11,2 11 6,4 - 4,5 3 - 2,2 2,6
"U"-prepa-ration	25 - 30 35 - 40	4 - 5	200 - 1100 1200 - 1400	45 - 50 48 - 55	8 - 6 6 - 4

Table 2 - Orientation welding parameters copper EPP – procedure

3.4. Arc welding coppershielding gas MIG and TIG

Welding copper shielding gas is performed with soluble (MIG process) and insoluble electrode (TIG - process). Shielding gases for welding of copper are used: argon, helium, nitrogen and mixtures thereof.

1.When welding copper TIG as additional material is applied oxygen copper rod of copper alloy, then copper - nickel: bronze. Welding is performed using direct current of direct polarity. TIG –the proedure using the welding of copper with a thickness of 6 - 8 mm in the protection of argon, helium and nitrogen.

Copper thickness 5 - 6 mm can be welded without separation edge (Table 3) and with a thicker copper apply to "V" and "X" preparations with the angle of the taper of 60 - 70^0.

2.MIG welding of copper is carried out using direct current of opposite polarity. Copper is MIG welded wire made of copper or copper alloy with nickel, silicon, tin and zinc. For a successful transport wire through the gun it is necessary to wire tensile strength is greater than 350 MPa. MIG - welding is recommended in compounds of copper thickness of 4 mm or more.

When copper elements whose thickness exceeds 10 mm preheating is carried out and supporting heating (MIG – welding of copper thicker compression arch) has a number of advantages and possibility of greater heat input to be welded thenbutt welding seams withoutseparating edge and the minimum amount of mechanical treatment before and after welding.

Preparing the edges of the groove	The thick-ness of the metal (mm)	Di-ameter tung-sten elec-trode (mm)	Number of passes, including root	Diam-eter of filler mate-rial (mm)	Current intensity (A)	Ar-gon flow l / sec
Bez razmaka	1,2	2 - 3	1	1,6	120 - 130	0,12-0,14
	1,5			2	140 - 150	
	2	3 - 4		2 - 3	200 - 230	
	2,5				220 - 230	0,13-0,16
	3				230 - 250	
	4				260 - 300	
"V" prepara-tion	6	3 - 4	2	3 - 6		
	10		4		200 - 400	0,12-0,13
	12	4 - 5	5		250 - 450	
	16		5		300 - 400	0,13-0,17
"X" prepara-tion	19	5 - 6	6		250 - 550	0,17 - 0,2
	25		8	3 - 6	250 - 600	0, 2 - 0,23

Table 3: - Orientation regimes copper welding TIG

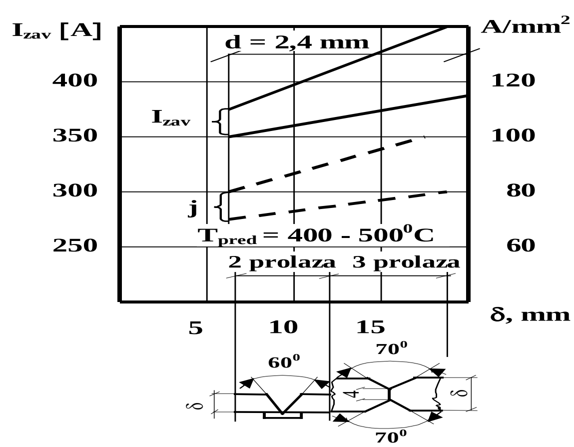

Figure 1: Recommendations of welding parameters soluble copper electrode

4. Experimental welding copper

For copper thickness of 6 mm and length of 486 mm seams when welding copper sheath (internal and external) it is reasonable to use any automatic and semi-automatic welding. However, in this technology emphasis is given to semi-automatic MIG and TIG welding - process.

EPP - the welding process is not taken into consideration because the steelworks in Smederevo there is no adequate equipment for experimental work.

REL - welding process (E-procedure) has been considered in the development of coated electrodes within our state. However, domestic producers have not adopted the appropriate electrode for welding dissimilar and non-ferrous metals.

In the experimental part of the paper, MIG and TIG welding process.

MIG - welding method showed good weld characteristics, high efficiency and cost effectives.

TIG welding process provides a good quality of welded joints, with the difficult work of welders, for preheating of copper and a short distance arm of the copper element to be welded.When it comes to deciding which of the above two processes to give priority then this is the MIG process because it is semi-automatic, however, is more difficult to determine uncertain (speed positioner in relation to the speed of the wire, while the TIG process for small series optimal for depreciation when working welders. During welding with MIG - welding were selected welding parameters and selection of appropriate filler material.

5. Choice of optimal parameters and procedures for welding copper

In the process of welding select welding procedures, materials and welding parameters. For copper welding nozzles selected TIG and MIG welding process.TIG welding process recommended additional material forms rods with a diameter of φ3.25 mm ofoxygen free cooper. Manufacturer: HP "Cables" Jagodina and "Nail wire" Bar.

For MIG welding process recommended by oxygen free copper wire diameterφ1.2 mm andφ1.6 mm. Manufacturer: HP "Cables" Jagodina.

6. Selection and purchase of additional material

Additional materials for welding copper was purchased from domestic manufactures and processors of copper wire and HP "Cables" - Jagodina, RTB - Copper Institute - Bor, Copper Mill – Sevojno.For experimental samples arc welding copper TIG procured copper rod of oxygen: Free copper (SRPS C.D1. 008) with a diameter of φ3.25 and φ 40 mm and alloy rod with silicon quality CuSi6φ3.25 mm diameter filler material. The first two qualities were obtained from the Institute for copper - Bor and the other from the copper mill - Sevojno. Additional material shaped wire diameter φ 1.2 and φ 1.4 mm for gas metal arc welding is obtained from the Copper Institute inBor and HP "Cables" Jagodina. wire is wound on the spool of welding standard sizes. Theseadditional quality materials were applied for welding copper samples with copper and copper and cooper to steel. Selectedquality supplementary materials practically applied for welding copper spigot nozzles for steel works (a total of 10 pieces).

7. Design of technology and equipment selection

Welding technology of nozzles for blast furnace requires a certain number of operations that follow the welding process. Technological operations include certain stages of the design elements of the nozzles, preparing the edges of the compound preheating, the hestingduring welding, preheating temperature measurement and duringwelding and execution of the the welding process.

Preheating elements nozzles is performed using the gas burner (natural gas with oxygen or acetylene with oxygen). During the preheating, it is necessary to measure the temperature.

Temperature measurement is performed using a digital meter. During preheating and welding elements nozzles are placed in the appropriate tool. Perform circular weld is performed by placing the nozzles to tool rotary table (positioners).

Welding elements nozzles MIG or TIG welding is performed in a single pass.Welding nozzles is performed on TIG unit mark LKB 250 and MIG unit mark LAX 320.

Testing of the weld is performed using penetrant, and finished by pressure water nozzles.

TIG welding and MIG – procedure

Based on the experimental welding quality with supplementary materials is determined by the TIG and MIG welding process.

Preparation of the groove:

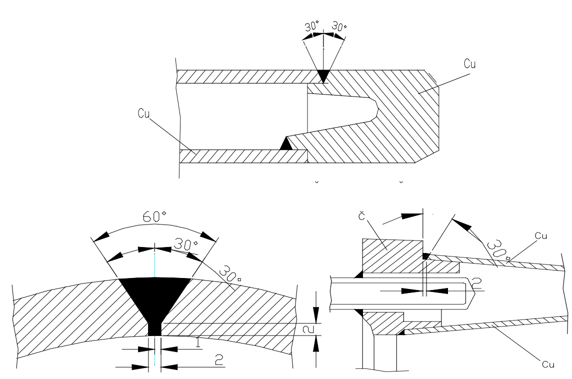

Figure 2: copper nozzles

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TIG welding and MIG – PROCEDURE Copper nozzles for VP

1. General information: Working pressure: 10 bar; Test pressure: 20 bar; Working temperature: 12000C;
2. Procedure Welding: TIG - process (Arc tungsten electrode in argon); MIG – procedure (Arc soluble electrode in argon).
3. Basic material: Copper Cu 99.25; Carbon steel Č.0361; Boiler plate č.1212
4. Additional material TIG process: oxygen less copper rod diameter φ 3.25 φ4.0 mm. Manufacturer: HP "Cables" Jagodina. Additional material MIG process forms of oxygen: Free copper wire diameter wire φ 1.2 φ 1.6 mm .Wound on awire or PVC - coil, standard size.
5. Perform welding TIG: All welds are performed in a single pass, and the elements are turning on the positioned. Performing MIG welding process: All welds are performed in a single pass, and the elements are turning to the positioner.
6. Preheating: Preheating gas burner is carried out at a temperature of 750 – 800 ºC
7. Heat treatment is not required.
8. Welders: certified welders with valid certificate for TIG-welding process or by certified welders with valid certificate for MIG welding process.
9. Control: Penetration 100% (individual), test pressure 20 bar (finishing).
10. Note: Before welding clean the surfaces to be welded. During preheating protect surfaces to be welded by applying flux.

Align the rotational speed of the positioner withwelding speed.When performing welding operations comply with all safety measures at work, especially from preheating.

8. Conclusion

Technological welding conditions copper nozzles for blast furnace nozzles require quality production being welded joint should possess good mechanical properties, thermal conductivity and homogeneity in the section. I just selected two welding procedure TIG and MIG provide reliable quality realized copper compounds - copper and copper – steel.
Compared to welding coated copper electrode welding, MIG and TIG welding has the following advantages. Better quality of welded joints, much better thermal conductivity of welds, additional material is domestic production, which completely replaces the import of coated copper electrodes.The acquired technology is successfully thus providing stress welding couplers Cu spears nozzles for oxygen, a total of ten pieces during the arc welding, for the purposes of the steelworks. Exploiting conditions of the welded joint of the nozzle nozzles are far sharper compared to nozzle blast furnace, which confirms the quality of the chosen welding technology. Also, the technology of welding in addition to the successful merger of elements of the new nozzles, can suuccessfully be used to repair damaged nozzles in operation as well as othercopper partswhicch are used in the production facilities in Smederevo. Welding copper nozzles in Smederevosteelworks contributed to provide adequate reserves with minimum cost of producing them from its own resources. Experimentation in the laboratory for welding processhas been successfully confirmed TIG and MIG welding of dissimilar metal steel copper in the case of nozzles. Experimental trials to come up with new technology and experience that develops welding and nondestructive testing reduces spoilage and increase challenging the limits of technology and the executor. The constant monitoring of development, education, training, and coaching of weldersgives a higher quality welds with quality professional staff and quality welders are possible faster adoption of new special technology.

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