K. FRANCZAK, P. KWAŚNIEWSKI, G. KIESIEWICZ, M. SADZIKOWSKI,
W. ŚCIĘŻOR, S. KORDASZEWSKI, D. KUCA

ISSN 0543-5846
METABK 61(3-4) 631-633 (2022)
UDC – UDK 669.3.296:621.74.04.:621.775:621.791.052.002.61=111

RESEARCH ON THE CONTINUOUS CASTING PROCESS OF CuCrZr ALLOYS WITH THE ADDITION OF SCANDIUM DEDICATED FOR RESISTANCE WELDING ELECTRODES

Received – Primljeno: 2021-10-25
Accepted – Prihvaćeno: 2022-02-20
Original Scientific Paper – Izvorni znanstveni rad

The article presents the results of research on the metallurgical synthesis of CuCrZr copper alloys with the addition of scandium as a new material for spot welding electrodes for the resistance spot welding of Zn-coated steel sheets. The tested material was manufactured in a continuous casting process in a horizontal arrangement in the form of rod. The alloys were heat treated to determine their hardness and electrical conductivity properties. Zinc diffusion tests into the material structure were carried out on the produced castings, reflecting the conditions accelerating the wear of electrodes during resistance welding of Zn-coated steel sheets.

Key words: CuCrZr alloy, continuous casting, rod, resistance welding, properties

INTRODUCTION

The resistance spot welding process is commonly used in many manufacturing processes, however, mostly in industries where two metal sheets are welded together such as automotive industry. Due to its constant development by increasing the standards the manufactured vehicles have to meet including, but not limited to, the susceptibility to corrosion, car bodies are made with corrosion-resistant coating made of zinc [1,2]. A typical car is estimated to have between 3 000 and 5 000 of welds and the consumption of welding electrodes in just one car factory reaches even 1 million per year.

Throughout the resistance spot welding process of the car body parts the F0 type electrodes made of group A 2nd class copper alloys with a diameter of 16 mm are mainly used and the most popular representative being Cu-Cr-Zr alloy (electrical conductivity 43 MS/m; hardness 100-150 HV30) [3,4]. The main problem of the spot welding of the galvanized steel sheets is their zinc layer. Resulting from high temperature the melting and evaporation of zinc occurs which further penetrates the electrodes' structure. Such phenomenon is the reason for the change of physical properties, thus causing faster wear of the electrodes [5-7].

Many research papers describe the improvement of electrodes life during the welding process. For instance H. E. Emre et al. applied Cr-Ni coating using ESD method, which increased the mechanical properties of the tested samples [8]. Other research works proved that by adding another alloy additives like Sc to the Cu-Cr-Zr alloy has a positive effect on their mechanical properties, heat resistance and only slightly lowering their electrical conductivity [9,10].

The research on the horizontal continuous casting process of Cu-Cr-Zr alloy with various Sc addition using graphite crystallizer which has proven to be an excellent heat transferring material during copper alloy casting [11] have been conducted in order to manufacture batch material for manufacturing welding electrodes dedicated for galvanized sheets. Obtained copper alloys after heat treatment and hot die forging process for the defined shape have been subjected to not only mechanical and electrical properties tests but also the resistance to zinc diffusion into the material structure tests

EXPERIMENTAL PROCEDURE

Continuous casting process

Research consisted of continuous casting process of 14 mm in diameter Cu-Cr-Zr cast rods with various Sc wt. % as presented in Table 1. Casting process was carried out on a laboratory line presented schematically at Figure 1.

Metallurgical synthesis and continuous casting process has been conducted in analogical conditions for all selected materials. The charge material was granulated Cu-ETP, preliminary alloys CuCr8 and CuZr10, and pure Sc which were added to molten copper at 1 250 – 1 300 °C. The homogenization process of the alloy was carried out for 5 minutes prior casting. The cast rods were obtained with a

Table 1 **Chemical compositions aimed for in continuous casting process /wt. %**

#	Nominal chemical composition			
	Cu	Cr	Zr	Sc
1	99,25	0,7	0,05	-
2	99,24	0,7	0,05	0,01
3	99,2	0,7	0,05	0,05

K. Franczak (e-mail: kfranczak@agh.edu.pl), P. Kwaśniewski, G. Kiesiewicz, M. Sadzikowski, W. Ścieżor, S. Kordaszewski, AGH University of Science and Technology, Faculty of Non-Ferrous Metals, Cracow, Poland
D. Kuca, Kuca Sp. Z o.o., Stargard, Poland

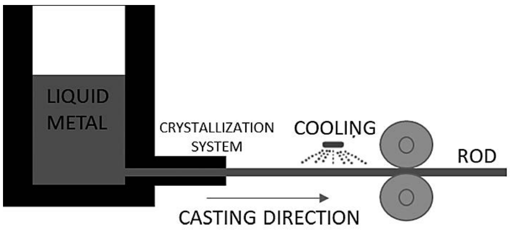

Figure 1 Schematics of horizontal laboratory continuous casting line

casting feed of 6 mm and standstill of 2 s. The cooling medium velocity was set to 0,5 l/min at primary cooling system and 0,2 l/min at secondary cooling system.

Research on the materials properties

The obtained alloys were subjected to chemical composition analysis using spark method with SPECTROTEST device to determine the proper synthesis of the alloys additives with copper. Casted materials were hot forged at 900 °C with simultaneous supersaturation (intensive cooling with water immediately after forging) into ø16 F0 type electrode (Figure 2) with further artificial aging at 450 °C for up to 5 hours. Using Tukon 2500 device the hardness of electrodes with Vickers method and the load of 10 HV was determined. Additionally, electrical properties using SigmaTest 2.069 were determined.

The tests on zinc diffusion were carried out on each of the obtained chemical compositions of alloys. In order to guarantee the same test conditions identical samples were prepared (dimensions 3 x 16 x 10 mm). Each sample prior testing was degreased and etched in 60 % HNO_3 acid for 30 s. The samples were immersed for 1 minute in pure liquid zinc with a constant temperature of 450 °C ± *5 °C*. On such samples the zinc diffusion layer into the structure of the materials was analysed using the Olympus GX51 light microscope which should simulate the behaviour of welding electrodes during welding process of galvanized sheets.

RESULTS AND DISCUSSION

The chemical composition analysis results of the obtained in continuous casting process CuCrZr with Sc addition cast rods were collectively presented in Table 2.

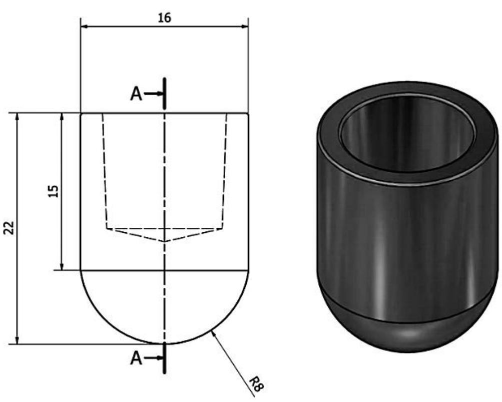

Figure 2 Schematics of ø16 F0 type electrode

Table 2 **The chemical composition of the obtained in continuous casting process copper alloys / wt. %**

#	Chemical composition				
	Cu	Cr	Zr	Sc	Other
1	99,13	0,68	0,04	-	~ 0,15
2	99,10	0,69	0,05	0,008	~ 0,15
3	99,07	0,68	0,04	0,045	~ 0,15

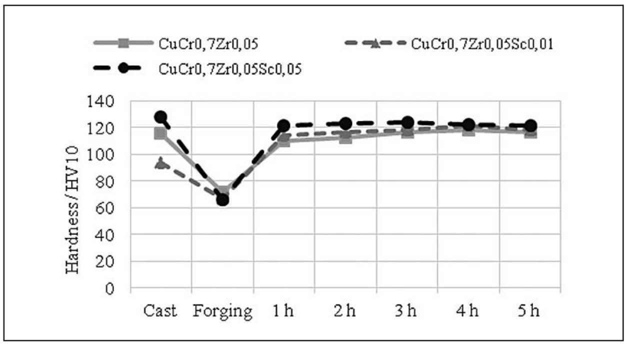

Figure 3 Hardness of the obtained copper alloys after heat treatment in 450 °C

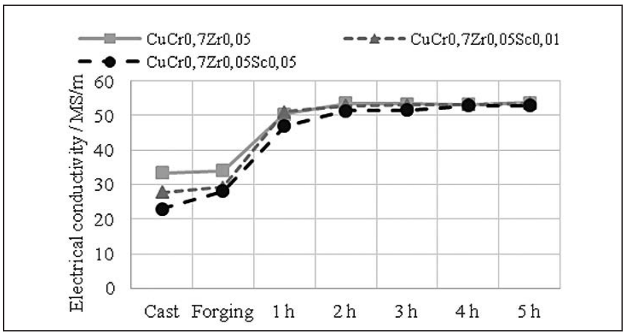

Figure 4 Electrical conductivity of the obtained copper alloys after heat treatment in 450 °C

By analysing the results of the chemical composition tests it may be stated that Cu-Cr-Zr alloys with addition of Sc was obtained correctly. Slightly lower amount of Sc indicates evaporation of Sc during metallurgical synthesis process.

The analysis of the mechanical properties of the obtained alloys indicates that the addition of Sc has a positive impact on Cu-Cr-Zr alloy. With just 0,01 wt. % of Sc the hardness increases to 118 HV after 3 hours of aging and with 0,05 wt. % to 122 HV for analogical sample (Figure 3). Electrical conductivity on the other hand slightly decreases with the addition of Sc, however, after 4 hours of heat treatment it is equal to 52,8 MS/m (Figure 4).

The zinc diffusion into Cu-Cr-Zr alloys tests proved that the addition of Sc has a positive impact on the limiting of zinc absorption into the structure of the material with copper matrix. The base alloy with no Sc shows diffusion of 26 µm. The addition of 0,01 wt. % of scandium lowers the absorption to 16 µm and increasing the amount of alloy additive to 0,05 wt. % lowers it further to 13 µm (see Figures 5 – 7).

CONCLUSIONS

On the basis of the conducted research it may be stated:

The horizontal continuous casting process enables the manufacturing of Cu-Cr-Zr alloys with the addition of Sc in a controlled manner.

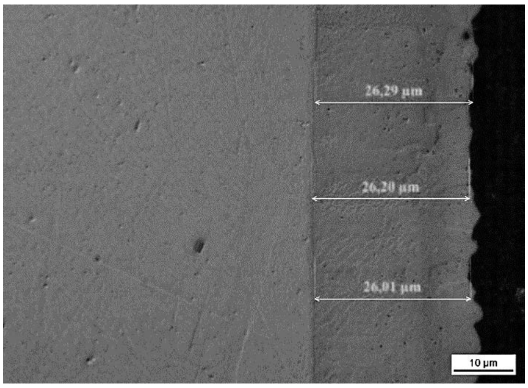

Figure 5 Microstructure of CuCr0,7Zr0,05 after zinc diffusion test

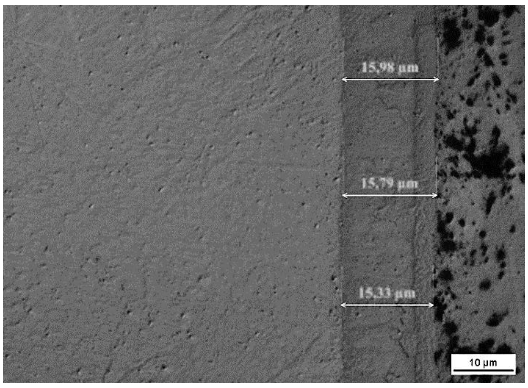

Figure 6 Microstructure of CuCr0,7Zr0,05Sc0,01 after zinc diffusion test

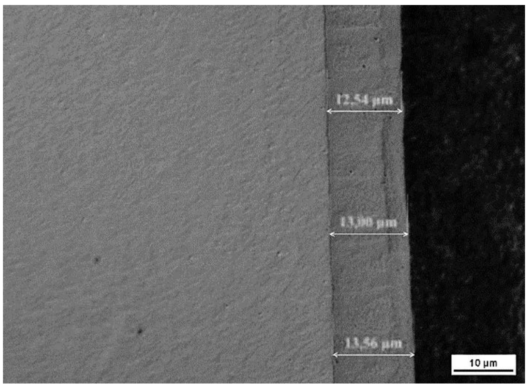

Figure 7 Microstructure of CuCr0,7Zr0,05Sc0,05 after zinc diffusion test

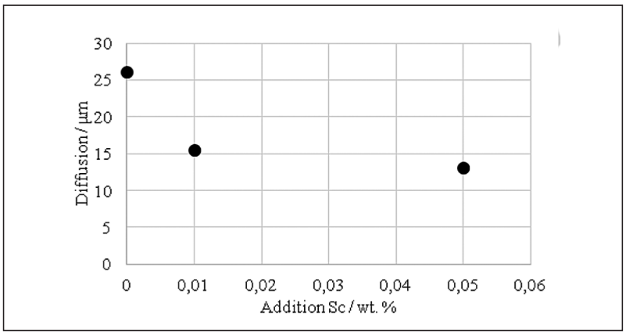

Figure 8 Characteristics of the influence of scandium addition in CuCrZr alloy on Zn absorption

The artificial aging process of Cu-Cr-Zr alloy with the addition of Sc proved that mechanical properties improve by increasing its hardness. At the same time electrical properties slightly decrease.

Zinc diffusion tests of Cu-Cr-Zr alloy proved the formation of a visible layer of brass resulting from the absorption of Zn into the material structure. The observed effect is analogous to the conditions occurring during the resistance spot welding process of galvanized sheets. The addition of scandium has a positive effect on the zinc absorption into the Cu-Cr-Zr alloy structure which was presented at Figure 8.

Acknowledgments

The research was produced as part of TECHMAT-STRATEG1/347960/6/NCBR/2017 project financed by the National Centre for Research and Development.

REFERENCES

[1] W. Mazur, A. Kyriakopoulos, N. Bott, D. West, Use of modified electrode caps for surface quality welds in resistance spot welding, Journal of Manufacturing Processes 22 (2016), 60-73

[2] J. Zou, Q. Zhao, Z. Chen, Surface modified long-life electrode for resistance spot welding of Zn-coated steel, Journal of Materials Processing Technology 209 (2009), 4141-4146

[3] ISO 5182:2016 (E) Resistance welding – Materials for electrodes and ancillary

[4] J. Vinas, L. Kascak, M. Abel, Analysis of Materials for Resistance Spot Welding Electrodes, Strojarstvo 54 (5) (2012), 393-397

[5] X.Q. Zhang, G.L. Chen, Y.S. Zhang, Characteristic of electrode wear in resistance spot welding dual-phase steels, Materials And Design 29 (2008), 279-283

[6] H.C. Lin, C.A. Hsu, C.S. Lee, T.Y. Kuo, S.L. Jeng, Effects of zinc layer thickness on resistance spot welding of galvanized mild steel, Journal of Materials Processing Tech. 251 (2018), 205-213

[7] H. Zhang, J. Senkara, Resistance Welding – Fundamentals and Applications 2^{nd} ed., CRC Press Taylor & Francis Group, Boca Raton 2012, p.31-33

[8] H. E. Emre, B. Bozkurt, Effect of Cr-Ni coated Cu-Cr-Zr electrodes on the mechanical properties and failure modes of TRIP800 spot weldments, Engineering Failure Analysis 110 (2020), Article 104439

[9] K. Franczak, P. Kwaśniewski, G. Kiesiewicz, M. Zasadzińska, B. Jurkiewicz, P. Strzepek, Z. Rdzawski, Research of mechanical and electrical properties of Cu-Sc and Cu-Zr alloys, Archives of Civil and Mechanical Engineering (2020), 20-28

[10] P. Ostachowski, W. Bochniak, et al., Strength properties and structure of CuCrZr alloy subjected to low-temperature KOBO extrusion and heat treatment, International Journal Of Advanced Manufacturing Technology 105 (2019), 5023-5044

[11] P. Kwaśniewski, P. Strzępek, G. Kiesiewicz, et al., External surface quality of the graphite crystallizer as a factor influencing the temperature of the continuous casting process of ETP grade copper, Materials 14 (2021), 6309

Note: The translator responsible for English language: Paweł Strzępek, AGH University of Science and Technology, Kraków, Poland