Proceedings of XIX International Scientific Conference "New Technologies and Achievements in Metallurgy, Material Engineering, Production Engineering and Physics", Częstochowa, Poland, June 7–8, 2018

Research in Possibilities of Manufacturing Composite Ti–Cu–Ni Brazing Wire

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The article presents results of preliminary studies into obtaining a Ti–Cu–Ni braze composite for titanium and its alloys. Dimensions and properties of CuNi50 strip and titanium core wire were specified with regard to requirements for composite constituents' weight proportions: 70%Ti, 15%Cu, 15%Ni. The study determines operating conditions of longitudinal welding of copper–nickel strip to obtain tubes with titanium core. Tests of processing composite Ti/CuNi50 through drawing allowed to define the process parameters necessary to obtain wire of required diameter. Initial tests in brazing properties of composite wire, conducted using flux-free arc brazing method, show proper Ti rod wetting by melting Ti/CuNi composite, which is confirmed by metallographic analysis.

DOI: 10.12693/APhysPolA.135.125

PACS/topics: brazing of Ti and alloys, brazing composite, drawing

1. Introduction

The development of construction materials based on titanium and its alloys forces the search for new, effective types of binders to combine these materials using various methods, including the brazing [1, 2]. The most commonly used method of brazing of significant elements made of titanium and its alloys, is brazing in vacuum furnaces or in controlled protective chemically neutral atmospheres. In the case when the soldered element has a larger size or is a component of a larger construction, it is not possible to use vacuum brazing. It is then possible to use brazing in air atmosphere using silver or titanium based braze alloys, e.g. Ti–Cu–Ni type and special high-temperature brazing fluxes to ensure the required wettability and spreadability of braze on bonded materials [3, 4]. Literature data in this respect indicates the possibility of an alternative use of Ti–Cu–Ni composite layered materials in the form of a Ti/CuNi50 bimetallic wire (Ti as an outer metal sheath with a core of CuNi50 alloy) [5]. The basic feature of such binder is the possibility of making joints using a flux free arc brazing method in air atmosphere.

The scope of the research included the selection of dimensional parameters and the preparation of semi-finished products made of CuNi50 and titanium alloys intended to make a preliminary composite in the form of a CuNi50 alloy tube with a Ti Grade 2 titanium core. The plastic processing of initial Ti/CuNi composite with a diameter of 7 mm was carried out by drawing to the final dimension of ø1.2 mm with determination of the process parameters. A metallographic assessment and testing of the properties of the layered material were carried out at selected stages of the manufacturing process.

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2. Material and methodology of research

The first stage of the research included the selection of dimensional parameters and the preparation of semi-finished products made of CuNi50 alloy and titanium for making the initial Ti/CuNi composite. In order to conduct research in the field of obtaining a composite in the form of a bimetallic filler wire, a Ti–Cu–Ni type binder containing 70% titanium, 15% copper, and 15% nickel was selected. It was assumed that the outer layer of the layer wire will be copper–nickel alloy, while the core will be a titanium rod in the Grade 2. After melting the components (Cu, Ni) in a graphite crucible, a 50 mm in diameter rod was cast, which was cold-set to thickness of 20 mm. After heat treatment in a furnace with protective atmosphere of 530 °C for 2 h, the flat bar was rolled to a thickness of 5 mm. After another heat treatment, rolling was carried out to thickness of 2 mm. The final thickness of the strip was 0.4 mm. The strip was cut to 24.2 mm in width. Strength properties of obtained CuNi50 strip and the titanium core wire are presented in Table I.

TABLE I

Strength properties of CuNi50 strip and Ti core.

Material/dimensions [mm]	R_m [MPa]	$R_{0.2}$ [MPa]	A [%]
CuNi50 strip 24.2×0.4	273	172	9.3
Ti wire ø6	567	452	24.3

Metallographic examinations of microstructure of the cross and longitudinal section of the composite material at selected stages of the processing were carried out on an Olympus GX71F metallographic microscope with a DP71 digital camera. Strength tests were carried out on the Instron 4505/5500K universal testing machine. Observation and analysis of the structure was also carried out using the Zeiss Evo MA10 scanning electron microscope with the Bruker XFlash® 5010 EDS spectrometer.

The evaluation of hardness of the composite wire components was conducted using the Future-Tech FM-700 microhardness tester.

3. Findings

The annealed CuNi50 strip was longitudinally welded into a tube of 8 mm in diameter. The TIG welding process was carried out using welding current of 61 A at speed of 2 m/min. An exemplary image of the weld zone is shown in Fig. 1. Figure 2 shows structure of the composite after the initial drawing.

Fig. 1. Microstructure of cross-section of CuNi50 strip weld area.

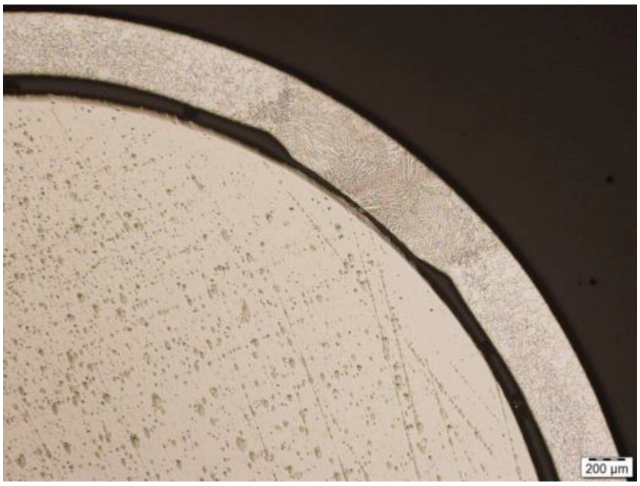

Fig. 2. Structure of Ti/CuNi composite wire (ø7 mm).

The tube semi-finished product with internal titanium core 6 mm in diameter was subjected to multiple drawing operations and heat treatment. In the first phase of the research, the annealing operations were carried out in a cup furnace in the atmosphere of 5%H_2+95%N_2 at 650 °C over 3 h. While drawing, especially for diameters below 3 mm, wire breaks occurred. Annealing was then applied at 600 °C for 15 min [6]. As a result of these change, the further drawing process proceeded smoothly. Composite wire of 1.2 mm in diameter was obtained.

At selected stages of the composite plastic processing, the cross-sectional structure was analyzed, observing even distribution of the outer layer on the core and good mechanical cohesion of the composite components. Exemplary microstructures of the cross and longitudinal section of laminated wires after selected operations are shown in Figs. 3–5.

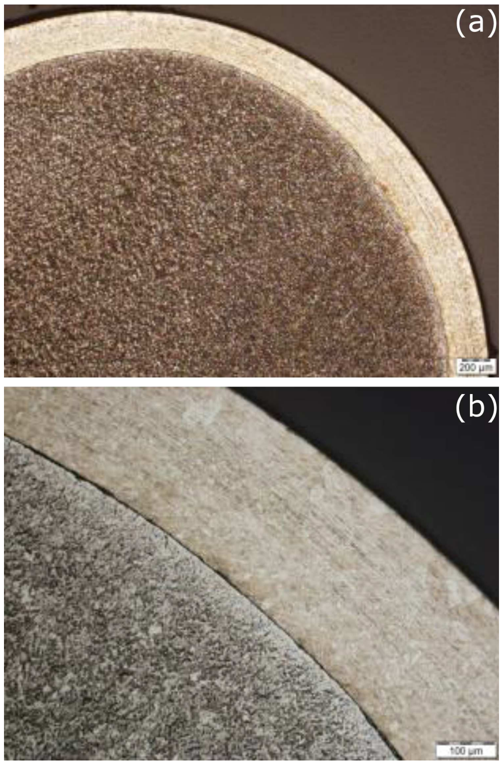

Fig. 3. Structure of Ti/CuNi composite, diameter 5.2 mm, annealed at 680 °C/1 h: (a) magnification 50×, (b) magnification 200×.

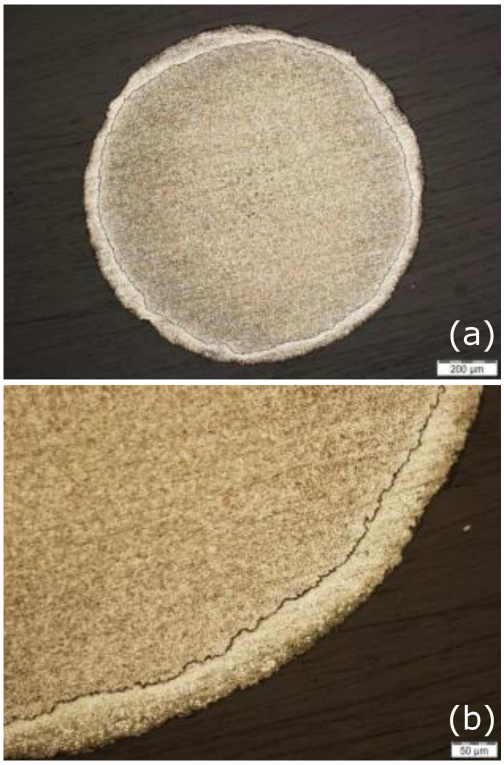

Fig. 4. Microstructure of cross-section of Ti/CuNi composite wire, diameter 1.2 mm, after drawing: (a) magnification 100×, (b) magnification 300×.

Fig. 5. Microstructure of longitudinal section of Ti/CuNi composite wire diameter 1.2 mm.

Analyzing the geometry of the cross-sectional structure elements of the wires, the weight proportions of individual components of the composite were determined, finding the proportion of CuNi strip in the composite wire 1.2 mm in final diameter accounts for approximately 30% and is in line with the assumptions. At selected stages of plastic forming process, samples were taken for strength tests, the results of which are presented in Table II.

TABLE II

Mechanical properties of layered Ti/CuNi wires.

Diameter [mm]	R_m [MPa]	$R_{0.2}$ [MPa]	$R_{0.05}$ [MPa]	A [%]
3.15 annealed 600 °C/15'	570	511	430	22.3
1.42 drawn	913	780	495	8.5
1.42 annealed 600 °C/15'	580	467	418	23.9
1.20 drawn	837	689	483	7.8

TABLE III

Results of hardness measurements of individual layers of Ti/CuNi wires in selected processing stages.

Description		$HV0.2_{av}$
ø5.2 mm, drawn	CuNi	246
	Ti	231
ø5.2 mm, annealed 680 °C/1 h	CuNi	138
	Ti	186
ø2.4 mm, drawn	CuNi	200
	Ti	242
ø2.4 mm, annealed 600 °C/15'	CuNi	189
	Ti	216

The changes in the hardness of the outer layer of the wire and the core at selected stages of the drawing process and heat treatment were also evaluated. The results are presented in Table III.

For the preliminary assessment of the technological properties of the Ti/CuNi composite wire obtained in the research, brazing test on a 6 mm diameter titanium rod was performed using the TIG arc method without the addition of a flux (Fig. 6).

Fig. 6. Ti rod surfaced of Ti–Cu–Ni braze layer.

Fig. 7. Structure of cross-section of Ti–Cu–Ni braze layer on Ti rod ø6 mm.

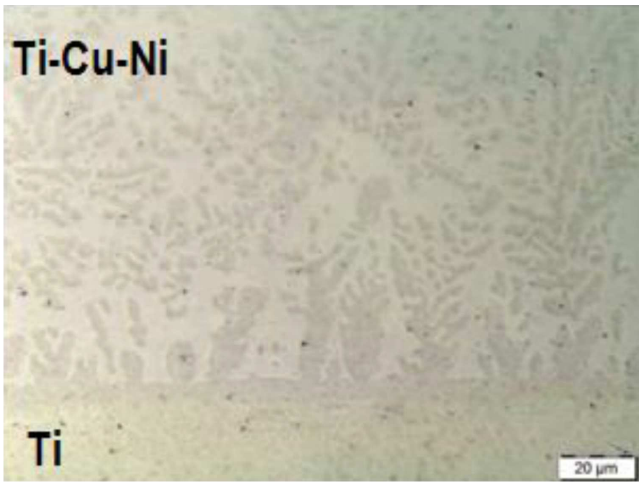

Fig. 8. Microstructure of cross-section of Ti–Cu–Ni braze layer on Ti rod.

The cross-sectional structure of the joint zone of the welded Ti–Cu–Ni brazing layer on Ti rod was analyzed using a light microscope. The results of the observations are presented in Figs. 7 and 8.

The metallographic evaluation of the joint zone obtained in the initial brazing test showed good cohesion of the material of the rod and the binder. A good wettability of the Ti rod surface with a molten Ti–Cu–Ni composite was confirmed. Observation of the weld structure shows complete melting of the composite wire components with evenly distributed microstructure components in the area. For more complete assessment of the weld structure homogeneity, chemical composition tests with use of EDS spectrometer scanning electron microscope were performed. The results of the observations confirm the uniform distribution of microstructure components in the joint cross-section.

4. Summary

Taking into account the requirements for the weight contributions of individual components of the composite, their dimensions were determined for the Ti/CuNi composite manufacturing process. The conditions for making the CuNi50 strip were determined using the forging and rolling process. On the basis of the conducted tests, the conditions for conducting the copper–nickel strip welding process as well as the conditions of drawing and heat treatment of the Ti/CuNi50 composite were determined to obtain a laminated wire with a final diameter of 1.2 mm. Metallographic examinations of the cross-section structure of the wires at the individual processing stages confirmed the even distribution of the copper–nickel layer around the Ti core.

Initial tests in the field of brazing properties of composite wire, conducted using the arc method (TIG) without the use of a flux, showed good wettability of the Ti rod with a molten Ti–Cu–Ni brazing alloy. The metallographic assessment of the connection zone showed a good cohesion of the material of the rod and filler metal.

Acknowledgments

The work was carried out as part of statutory research carried out at the Institute of Non-Ferrous Metals in Gliwice.

References

[1] A.E. Shapiro, Yu.F. Flom, "Brazing of titanium at temperatures below 800 °C: review and prospective applications", Materials of Titanium-Brazing Inc., 2014.

[2] A. Shapiro, A. Rabinkin, *Weld. J.* **10**, 36 (2003).

[3] D. Majewski, *Inżynieria Materiałowa* **33**, 296 (2012) (in Polish).

[4] A. Winiowski, D. Majewski, E. Kropiński, "Flux for brazing titanium in air", Polish patent PL395242, 2011.

[5] M.A. Swider, T. Hassel, *Wire* **1**, 62 (2014).

[6] V.P. Severdenko, V.Z. Zhilkin, *Metalloved. Term. Obrabotka* **10**, 21 (1959).