Research on the Development of Melting and Continuous Casting Technology of Feedstock Materials based on Modified Copper Alloys, Intended for the Use in 3D WAAM Additive Manufacturing Technology

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Abstract: Due to the continuous development of Additive Manufacturing Technologies and the search for new material solutions in this area, research was undertaken to develop a technology for producing feedstock materials based on copper alloys for the use in the WAAM (Wire Arc Additive Manufacturing) Additive Manufacturing Technology. The research in this work focused on modifying the chemical composition of commercial copper alloys, i.e. aluminum-nickel bronzes and cupronickel bronzes intended for operation in corrosive conditions and showing good mechanical and welding properties. The modification of the chemical composition of the selected alloys was aimed at producing feedstock materials in the form of rods enabling the production of wires with a target diameter of 1 mm, as well as the possibility of obtaining 3D printed products with improved mechanical properties while maintaining an appropriate level of corrosion resistance. Modification of the chemical composition of selected copper alloys resulted in the need to develop melting and continuous casting technology for them, as well as wire drawing technology with inter-operational heat treatment. This work presents selected test results of rods cast using variable conditions of the continuous casting process for aluminum bronzes and cupronickel with modified chemical composition.

Keywords: melting and casting, continuous casting, copper alloys, feedstock material for 3D printing, Metal 3D Printing, Additive Manufacturing Technology, Wire Arc Additive Manufacturing

1 Introduction

Additive manufacturing offers building of components or products layer-by-layer using materials in powder or wire forms and depositing them over a defined toolpath of the given 3D design data. Wire Arc Additive Manufacturing is emerging as a new promising economical technique for metal additive manufacturing. Large volume custom-built metallic structures can be produced in relatively less time using WAAM techniques [1]. Additive Manufacturing (AM) technologies are developing dynamically and are becoming increasingly important in industry. The advantages of WAAM are rapid manufacturing of three-dimensional objects, low price of feedstock materials, and the possibility of implementation for commercial production. [2]. WAAM technology has proven that it can produce medium to large components because of its high deposition rate and potentially unlimited build size. Like all additive manufacturing technologies, however, an optimized process planning that provides uniform, defect-free deposition is key for the production of parts. Moreover, AM, particularly WAAM, is no longer just a prototyping technology, and most of today's attention is on its transformation to a viable and cost-effective production [3]. Therefore, WAAM technology still requires the search for new material solutions, including continuous development and modification of currently used feedstock materials.

2 Experimental procedure

Pure components were used for producing the alloys: cathode Cu, Al, electrolytic Ni and the master alloys: CuMn30, CuMn50, CuFe20, and CuTi20. The alloys being the input material for the continuous casting process were cast statically in the form of bars using the PIT10 and PIT100 crucible induction furnaces. The melting process was done in graphite crucibles and chamotte-graphite crucibles (PIT100). Gravity casting was carried out into a pre-heated cast iron ingot mould, obtaining an input material in the form of bars for the continuous casting process and in the form of Ø 50 mm ingots for further tests. Produced alloys were the input material for the continuous casting process. The process was carried out using the ConCasTech MINI SCC station for horizontal continuous casting for aluminum bronze alloys. The continuous casting process was carried out with the use of graphite double-strand crystallizer (2x Ø 8 mm). The loaded material in the form of bars was melted, and then, after stabilizing the bath temperature, the continuous casting process was started. The parametres of the process were: feed 10-12 mm, feed speed 20 mm/s with a reverse feed equal to 1 mm. During the process, the temperature of the casting surface at the exit from the crystallizer was monitored using a contact temperature meter and the ThermaCAM SC640 thermal imaging system. Rods with a diameter of 8 mm made of the CuNi11Fe2Mn1.5Ti0.5 alloy were cast on a vertical VCC3000 continuous melting and casting system from Indutherm. The melting and casting system uses elements made of boron nitride.

The melting of the charge material was carried out after initially obtaining a vacuum and then under an argon flow. The continuous casting process of the alloy was conducted in the temperature range of 1280°C-1300°C, using a strand stroke in the range of 3 to 5 mm and a strand stop in the range of 1-1.5 s.

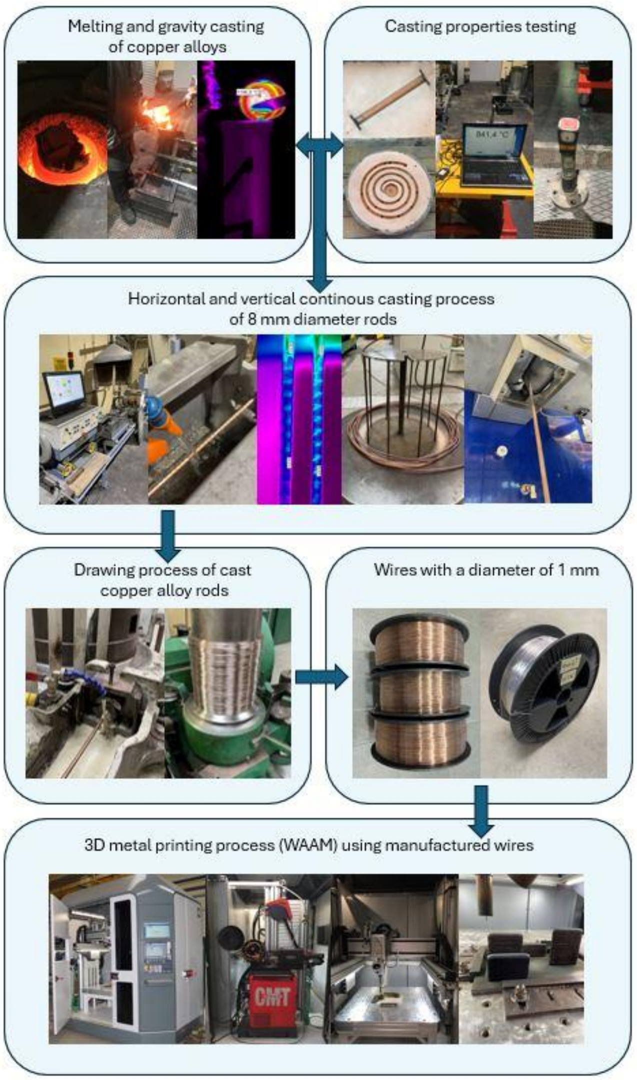

Fig.1. Production technology of the wires (feedstock materials intended for 3D Metal Printing process) and their verification by means of WAAM

3 Result and discussion

The developed technology of continuous casting of copper alloys enabled the production of high-quality, defect-free rods with a diameter of 8 mm, intended for further processing. The as-cast hardness of the CuNi11Fe2Mn1.5Ti0.5 alloy ranged from 153 to 160 HV10. The cast rods material was coiled and intended for further processing: plastic working by drawing with inter-operational heat treatment in a protective gas atmosphere

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4 Conclusion

The production technology of wires from multi-component alloys from aluminum bronzes and cupronickel group includes the process of melting and gravity casting of bars, continuous casting of semi-finished products in the form of rods in a horizontal or vertical arrangement and plastic working with inter-operational heat treatment.

The conducted technological tests of continuous casting have shown that the use of the process parameters: feed 10-12 mm, feed speed 20 mm/s with a reverse feed equal to 1 mm for alloys from the aluminum bronze group (horizontal continuous casting) and strand stroke in the range from 3 to 5 mm and strand stop in the range from 1-1.5 s in the case of cupronickel (vertical continuous casting) enable the production of high-quality castings being input material for further processing, in this case, the production of high-quality wires as a feedstock material for WAAM 3D printing technology.

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