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ISSN 0543-5846
METABK 61(3-4) 628-630 (2022)
UDC – UDK 669.71.3.721:621.74.04:620.178.1:541.122:66.014=111

DETERMINATION OF THE PROPERTIES OF AlCu4,5Mg3 ALLOY OBTAINED IN THE CONTINUOUS CASTING LINE

Received – Primljeno: 2021-10-25
Accepted – Prihvaćeno: 2022-02-28
Original Scientific Paper – Izvorni znanstveni rad

The presented research work covered both metallurgical synthesis of the AlCu4,5Mg3 and the continuous casting process of casts rods with a diameter of 14 mm. The obtained cast rods were further subjected to the chemical composition tests in order to determine the homogeneity and distribution of the alloy additives. Additionally the materials were tested not only in terms of their mechanical properties in the Vickers hardness test but also in terms of their structure using light microscopy and scanning electron microscopy.

Key words: AlCuMg alloy, continuous casting, hardness, macrosegregation, chemical composition

INTRODUCTION

Modern materials based on not only aluminium but also other metal matrices are facing higher and higher requirements in terms of the entire set of functional and operational properties simultaneously with a tendency towards reducing both its weight and final price. It may be obtain with the increase of mechanical properties of manufactured materials. Obtaining such properties is possible by either the development of a new alloys (determined by the selection and range of appropriate alloying additives) or the application of the most favourable set of process parameters for a given product and further processing path [1-5]. Taking into account the research results focused on the influence of individual alloying elements on aluminium it may be stated that among the mainly used alloy additives the addition of magnesium enables the higher increase of mechanical properties as it activates solid solution hardening depended to a minor extent on the proper heat treatment. Al-Cu alloys on the other hand are mainly characterised with solution hardening also occurs [6 – 11]. The proposed idea for new, high-strength alloys is therefore a combination of favourable strengthening mechanisms of Al-Cu and Al-Mg creating a superposition of precipitation and solid solution hardening. New grades of Al-Cu-Mg alloys are designed to be manufactured in an innovative, economical and technologically efficient process (continuous casting process) which should ensure the production of materials with properties similar to those obtained after metal working.

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EXPERIMENTAL PROCEDURE

Experimental part of the conducted research consisted of continuous casting process of aluminium alloys with a diameter of 14 mm and complex analysis of their properties. The initial stage of the metallurgical synthesis was the process of melting aluminium and increasing its temperature in a melting and casting furnace to 780 °C – 800 °C which was followed by introducing proper alloy additives (pure magnesium and AlCu50 preliminary alloy). The alloy in the liquid form was thoroughly stirred and left in the furnace for another 20 minutes in order to homogenize its chemical composition which proceeded the continuous casting process. The laboratory process was conducted with controlled feed (8 mm) and standstill (5 s), with cooling medium velocity at primary cooling system of 0,12 – 0,18 l/min and secondary cooling system of 0,07 l/min. The obtained materials were tested on the Foundry Master Xpert spectrometer in order to determine their chemical composition. The samples taken from the beginning, middle and the end of the cast rod and the samples were tested at the middle, 1/4 and the edge of the cross-section. Such measurements allowed the determination of the chemical composition variations both at the longitudinal and cross-section. Each of the tested samples was subjected to five measurements and the average value was calculated in every case. The obtained samples were also subjected to Vickers hardness test with the load of 5 kgf. At each of the cast materials taken from the beginning, the middle and the end 13 indentations along the axis of the cross-section were made and again an average values were calculated. The last stage of the conducted research was structural analysis carried out with Olympus GX51 light microscope and microstructural analysis carried out with Hitachi SU-70 scanning electron microscope (SEM).

Table 1 **Chemical composition research results of AlCu4,5Mg3 alloy / wt. %**

Place of measurement at the longitudinal-section	Place of measurement at the cross-section	Cu	Mg	Si	Fe	Mn	Zn	Ti	Al
Beginning	Middle	4,41	2,97	0,07	0,14	0,003	0,001	0,047	rest
	1/4	4,58	3,17	0,068	0,12	0,003	0,001	0,044	rest
	Edge	4,55	3,05	0,071	0,11	0,003	0,001	0,051	rest
Middle	Middle	4,33	2,99	0,072	0,13	0,003	0,001	0,049	rest
	1/4	4,59	3,08	0,066	0,14	0,003	0,001	0,05	rest
	Edge	4,56	3,08	0,064	0,12	0,003	0,001	0,052	rest
End	Middle	4,38	3	0,07	0,1	0,003	0,001	0,052	rest
	1/4	4,61	3,07	0,077	0,15	0,003	0,001	0,048	rest
	Edge	4,52	3,1	0,08	0,13	0,003	0,001	0,045	rest

RESULTS AND DISCUSSION

The results of the chemical composition analysis of the AlCu4,5Mg3 alloy obtained in the continuous casting line are presented in Table 1. It is worth noting that the weight % concentration of the two main alloy additives (Cu and Mg) at the longitudinal-section are not significant and the changes mainly concern the cross-section. The samples taken from the beginning of the cast rod are characterised with segregation levels of copper at 3,7 % and magnesium at 6,3 %. In the case of the middle samples these values are 5,7 % for copper and 2,9 % for magnesium, whereas in the case of the end samples the values are 5 % for copper and 2,3 % for magnesium. Thus, it may be concluded that the segregation of the alloy additives of newly developed AlCuMg alloy obtained in the continuous casting line occurs to some extent at the cross-section rather than longitudinal-section, however, it is much smaller than in the case of traditionally casted aluminium alloys or those of semi continuous casting line origin (DC casting) [12].

The hardness tests results presented at Figure 1 show that the mechanical properties vary at the cross-section of the obtained cast rods in all of the tested samples (taken from the beginning, middle and the end). The average hardness of the material is 90,7 HV5, whereas it needs to be stressed that for each of the tested samples the lowest values were observed at the axis of the cast rod (88,2 HV5 – 89,1 HV5) and the closer to the edge the higher the recorded values (92 HV5 – 92,5 HV5). The spread of the sample taken at the beginning at its cross section is 4,8 %, for the middle sample it is 3,7 % and for the end samples it is 4,3 % which suggests that along the entire longitudinal-section of the cast rod the changes in hardness values are similar.

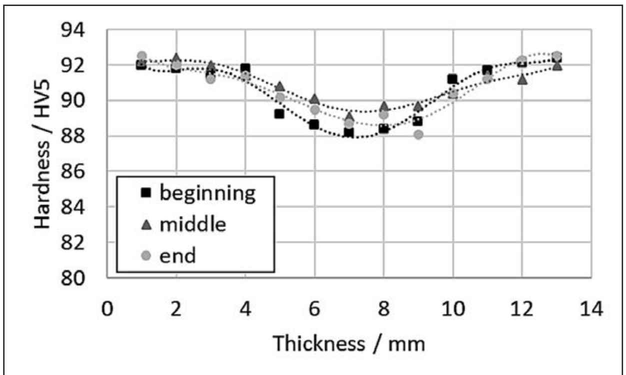

Figure 1 Collective data of Vickers hardness tests of AlCu4,5Mg3 cast rods

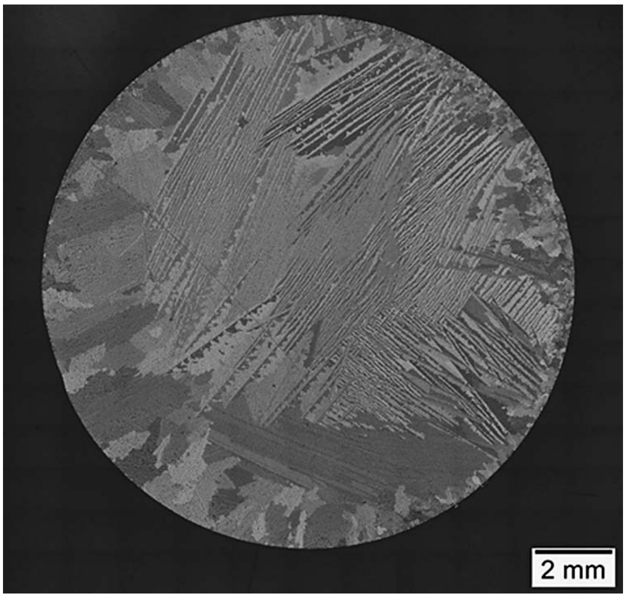

Figure 2 Macrostructure of AlCu4,5Mg3 cast rod

What needs emphasizing is the fact that the hardness distribution at the cross-section of the cast rod correlates well with the results of the prior conducted chemical composition tests where the amount of main alloy additive (Cu and Mg) is also depleted at the axis of the cross-section of the axis.

The macrostructure analysis of AlCu4,5Mg3 alloy presented at Figure 2 shows a classic casting structure with an irregular grain distribution of various sizes ranging from a few to even several millimetres. Equiaxial grains located at the outer part of the cast rod and elongated columnar grains in the middle with the length of even 8 mm may be distinguished in the obtained macrostructure. Equiaxial grains form a zone of frozen crystals existing for instance in the die casted alloys whereas the elongated columnar grains are aimed towards the direction of the heat exchange from the liquid metal by the crystallizer.

Additionally, the materials in the as-cast state were subjected to SEM analysis as presented at Figure 3. The observed microstructure is typical for continuously

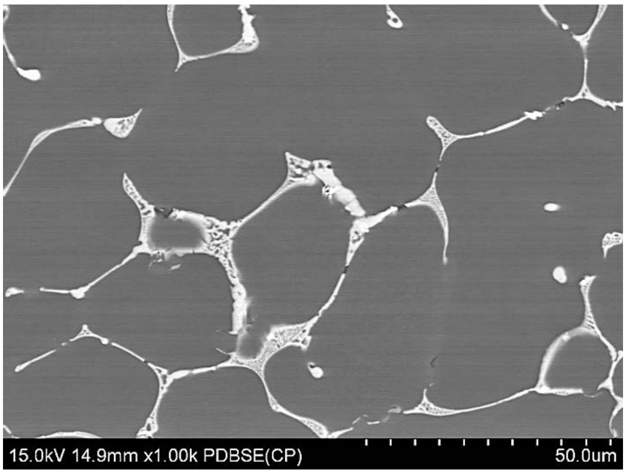

Figure 3 Microstructure of AlCu4,5Mg3 cast rod (SEM)

casted cast rods with precipitates present in the interdendritic spaces of the solid solution. Based on the obtained and presented research result it may be stated that in the obtained alloy both solid solution hardening (by locating alloying additives in a solid solution) and precipitation hardening (strengthening with precipitates of intermetallic phases) is possible to achieve.

CONCLUSIONS

Based on the conducted research and obtained test results it may be stated that a new grades of Al-Cu-Mg alloys can be effectively obtained in the continuous casting process. The chemical composition tests of the obtained material show homogenous results both at the longitudinal-section and cross-section despite observable macrosegregation of the main alloy additives (depletion at the axis of the cast rod). The recorded differences in the chemical composition along the whole length of the cast rod are not significant and mainly relate to the changes at the cross-section and do not affect the mechanical properties of the obtained material (its hardness) as the obtained values are similar across the whole volume of the cast rod (slightly lower values of hardness were recorded at the axis of the cast rod). The observed macrostructure of the material consists of fine equiaxial grains located at the outer part of the cast rod and elongated, columnar grains in the middle with numerous precipitates visible in the interdendritic spaces of the solid solution at the microstructural level.

Acknowledgments

The research was produced as part of LIDER/29/0107/L-9/17/NCBR/2018 project financed by the National Centre for Research and Development

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Note: The translator responsible for English language: Paweł Strzępek