ARPN Journal of Engineering and Applied Sciences

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RESEARCH OF EUTECTIC Al-Cu ALLOY MICROSTRUCTURE AND PROPERTIES AFTER TYXOTROPIC HEAT TREATMENT

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ABSTRACT

Today aluminum alloys are widely used in the industry. Therefore, improving the quality of castings from aluminum alloys is one of the essential tasks in the field of foundry. This is achieved by the development of new alloy compositions, their modification, refining, and heat treatment. The purpose of this research was to study the effect of processes occurring at the eutectic transformation temperature range on the formation of the structure of the aluminum-mini-copper alloy. The influence of processes developing in the temperature range 5-7°C above the onset of eutectic transformation temperatures on the formation of the alloy structure was studied. The research showed that the microstructure of the eutectic aluminum-copper alloy is divided into separate components with their subsequent combination (α-solid solution and CuAl2 phases). Based on the study on Al - 33% Cu and Al - 12% Si alloys, it can be stated that being slightly overheated, microstructures with dispersed phases are formed at the eutectic equilibrium temperature range, both in the eutectic components and secondary phases.

Keywords: eutectic, aluminum-copper alloys, heterogenization, dendrites, microstructure, foundry, heat-treatment.

INTRODUCTION

Today aluminum alloys are quite widely used in industry [1-5]. Therefore, the improvement of the quality of castings from aluminum alloys is one of the essential tasks of foundry production. This is achieved by the development of new alloy compositions, their modification, refining, and heat treatment [6-10].

A large number of studies are devoted to the effect of heat treatment on the structure of eutectic of aluminum alloys at the temperature range near eutectic equilibrium temperatures [11-14].

The purpose of this research was to study the effect of processes occurring at the eutectic transformation temperature range on the formation of the structure of the aluminum-mini-copper alloy.

MATERIALS AND METHODS

Preparation of the Al - 33% Cu alloy was carried out as follows. Primarily, aluminum was melted in the crucible at 750°C. After removing the slag from the surface of the melt, copper was added thereto. The samples were cast into a cast-iron mold at 720°C.

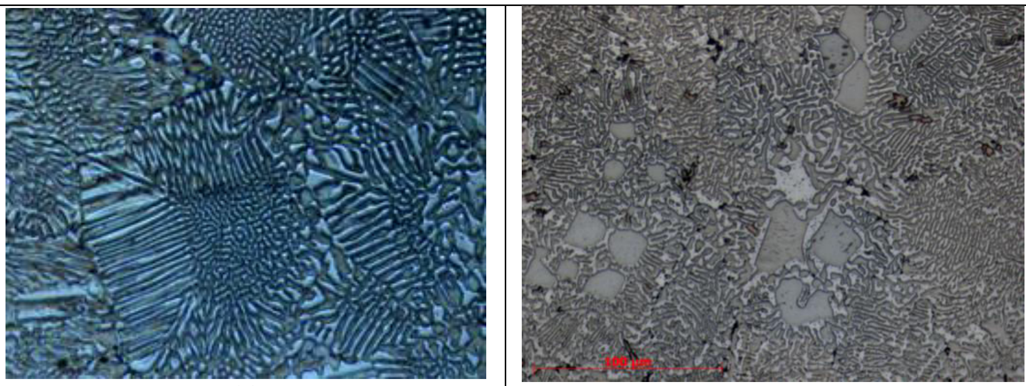
The heat treatment of the cast samples previously placed in the quartz backfill was carried out in a batch furnace LMV 02/12 [15]. The quenching temperature exceeded the eutectic temperature of the alloy by 5-7 °C and was 590-592°C. The samples were cooled at a rate of 0, 01-0, 03 deg/s in a batch furnace to 480°C. Further cooling was carried out in cold water after the removal of the samples from the quartz backfill [16, 17].

Alloy structure in the cast and heat-treated states was studied on AXIOObserver. Almr microscope, the characteristics of which are given in [18]; mechanical properties were studied on LFM 20 kN - universal tensile machine [19].

Fractographic analysis of the samples is performed on stereomicroscope CarlZeissStemi 2000-C under small magnifications. The characteristics of the microscope are described in [20].

RESULTS AND DISCUSSIONS

The structure of the cast sample of the eutectic composition is classical in the sectorial structure of single crystals [20]. Figure-1a shows a cross-section of α + $CuAl_2$ colonies in an alloy of eutectic composition [67% by Al weight] crystallized under accelerated cooling conditions (casting into a metal mold).



(a) (b)

Figure-1. The microstructure of Al-33% Cu alloy in the cast (a) and quenched (quenching temperature 545 °C; holding time 30 min., cooling in water) conditions, increasedx200.

Heating the sample near the eutectic equilibrium temperature and holding at this temperature results in melting in the alloy at interfacial boundaries, and redistribution of structural components. Cellular structure, uneven phase distribution, the prismatic shape of $CuAl_2$ phase is preserved (Figure-1, *b*).

Significant overheating over the liquidus line leads to the release of a greater amount of interfacial heat, which in turn is accompanied by different rates of diffusion flows and the formation of spatially reoriented eutectic colonies (Figure-2).

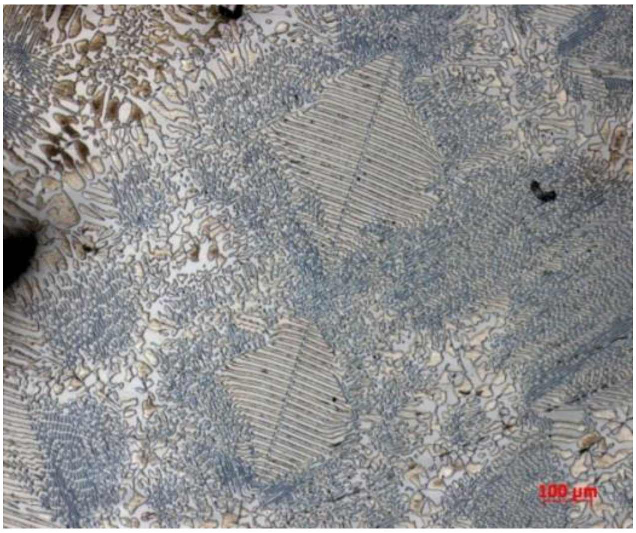


Figure-2. The microstructure of the Al-33% Cu sample, quenched at a temperature exceeding the liquidus line.

Using a scanning electron microscope, the elemental composition of the heat-treated sample was analyzed (Figure-3). In Figure-3, a series of spectra was selected, which confirmed by its data a decrease in the amount of the $CuAl_2$ phase in the α-solid solution as it moves away from larger rounded $CuAl_2$ particles. Thus, one can clearly see the redistribution of components and the occurrence of heterophasic phase separation due to heating near the eutectic equilibrium point.

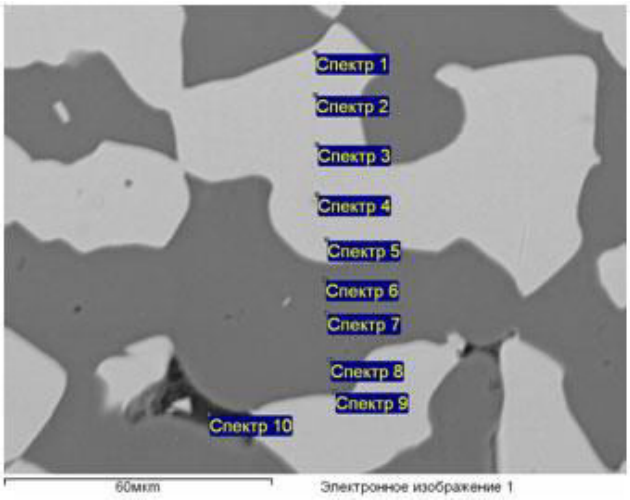


Figure-3. The structure of the Al-33% Cu alloy in the heat-treated state:

Spectrum No	Element		
	Al	Si	Cu
Spectrum 1	49,05	0,93	50,20
Spectrum 2	48,39	–	51,61
Spectrum 3	48,71	–	51,29
Spectrum 4	49,61	1,32	49,08
Spectrum5	48,33	–	51,67
Spectrum6	93,43	1,39	5,18
Spectrum7	93,32	1,08	5,59
Spectrum8	94,58	0,84	4,58
Spectrum 9	93,21	0,87	5,92
Spectrum 10	79,13	1,17	6,30

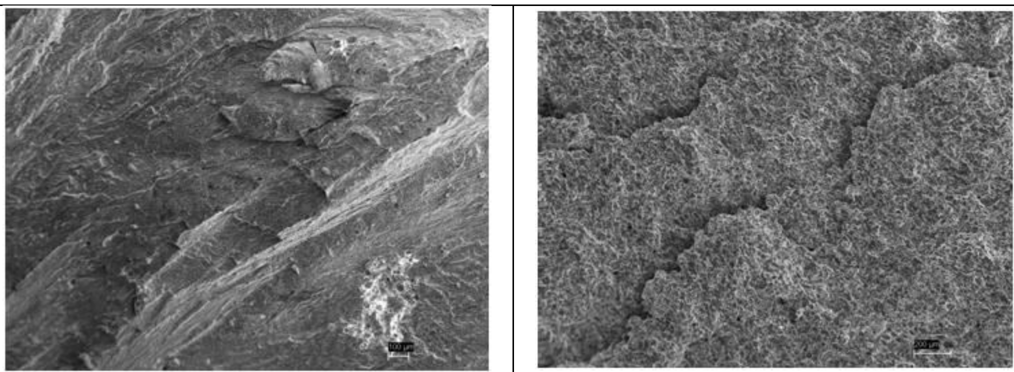
The research results demonstrate a noticeable increase in the mechanical properties of the sample after the proposed heat treatment (Table-1).

Table-1. Mechanical properties of Al–33% Cu alloy.

Alloy condition	Yield strength, MPa	Destruction narrowing, %
Cast	392	0
After heat treatment	514	0,89

Fractograms of the eutectic Al-Cu alloy were obtained on a microscope. The presence of a river line in the cast sample indicates a significant fragility of the material (Figure-4, *a*). After heat treatment, a crystalline fracture can be observed (Figure-4, *b*).

The $CuAl_2$ phase, having a faceted shape and being a more fragile component, acts as the separation boundary. The fracture is intercrystalline and extends along the boundaries of the crystals of the $CuAl_2$ phase. Due to phase redistribution as a result of heat treatment, a stronger sample was obtained, as evidenced by the value of temporary tensile strength.



(a) (b)

Figure-4. Fractogram of Al-33 % Cu alloy in the cast (*a*) and quenched (*b*) conditions.

The shape of $CuAl_2$ crystals depends on the occurrence of hetero- and homogenization processes of the formation of structural components. A slight superheat (5-7 °C) above the eutectic equilibrium temperature contributes to the onset of melting and the formation of a cluster mixture, which consists of micro volumes, which are the characteristics of the crystalline phase structure.

CONCLUSIONS

The influence of processes developing in the temperature range 5-7 °C above the onset of eutectic transformation temperatures on the formation of the alloy structure is studied. The studies showed that the microstructure of the eutectic aluminum-copper alloy is divided into separate components with their subsequent combination (α-solid solution and $CuAl_2$ phases). Based on the study on Al-33% Cu alloys, it can be stated that being slightly overheated at the eutectic equilibrium temperature range, microstructures with dispersed phases are formed both in the eutectic components and in the secondary phases.

REFERENCES

[1] Belov N.A., Korotkova N.O., Akopyan T.K., Pesin A.M. 2019. Phase composition and mechanical

properties of Al–1.5%Cu–1.5%Mn–0.35% Zr(Fe,Si) wire alloy. Journal of Alloys and Compounds. pp. 735-746.

[2] Fhilatov Yu. A. 2017. Research Works Undertaken at VILS in the Field of Al-Mg-Sc Wrought Alloys. History of Development, Structure, Properties, Applications, Problems and Prospects. Tekhnologiya legkih splavov. (3): 7-24.

[3] Bazhin V.Yu., Sizyakov V.M., Vlasov A.A. 2013. Surface defects in foil direct chill strip from highly-alloyed aluminum alloys. Metallurgist. 56(11-12): 863-866.

[4] Uskov I.V., Belyaev S.V., Uskov D.I., Gilmanshina T.R., Kirko V.I., Koptseva N.P. 2016. Next-generation technologies of manufacturing of waveguides from aluminum alloys. ARPN Journal of Engineering and Applied Sciences. 11(21): 12367-12370.

[5] Diallo A.B., Klyushin A.YU., Kemajkin V.K. 2016. Primenenie alyuminiya i ego splavov s drugimi metallami na praktike. Nauchnye issledovaniya: ot teorii k praktike. 4-2(10): 22-24.

[6] Illarionov I.E., Gilmanshina T.R., Kovaleva A.A., Kovtun O.N., Bratukhina N.A. 2018. Destruction mechanism of casting graphite in mechanical activation. CIS Iron and Steel Review. 15. pp. 15-17.

[7] Mamina L.I., Gil'manshina T.R., Anikina V.I., Baranov V.N., Lytkina S.I., Abkaryan A.K., Khudonogov S.A. 2016. Influence of the activation time on parameters of a graphite structure. Russian Journal of Non-Ferrous Metals. 57(1): 52-56.

[8] Illarionov I.E., Bogdanova T.A., Gil'manshina T.R., Merkulova G.A., Bogdanov A.Y. 2018. Technology for Modifying Aluminum Alloys with Ultrafine Silicon. Metallurgist. 62(5-6): 476-481.

[9] Semenov B.I., Kushtarov K.M. 2010. Proizvodstvo izdelij iz metalla v tverdozhidkom sostoyanii.-M.: Izd-vo MGTU im. N.E. Baumana. p. 223.

[10] Guan R.-G., Tie D. 2017. A Review on Grain Refinement of Aluminum Alloys: Progresses, Challenges and Prospects. Acta Metallurgica Sinica (English Letters). 30(Is. 5): 409-432.

[11] Kolachev B.A., Elagin V.I., Livanov V.A. 2005. Metallovedenie i termicheskaya obrabotka cvetnyh metallov i splavov. - M.: MISIS. p. 432.

[12] Nikitin K.V., Nikitin V.I., Krivopalov D.S., Glushchenkov V.A., Chernikov D. 2017. GInfluence of various treatment types on the structure, density, and electrical conductivity of Al-Mg system wrought alloys. Izvestiya vysshih uchebnyh zavedenij. Cvetnaya metallurgiya. (4): 46-52.

[13] Białobrzeski A., Pezda J., Jarco A. 2017. Modification of aluminium-silicon near-eutectic alloy with use of electrolysis of sodium salt. Archives of Metallurgy and Materials. 62(4): 2371-2374.

[14] Zakharov V.V. 2018. Prospects of Creation of Aluminum Alloys Sparingly Alloyed with Scandium. Metal Science and Heat Treatment. 60(3-4): 172-176.

[15] Laboratory furnace [Electronic resource]. - Access mode: http://www.soctrade.com/equip_groups/pechi-i-termoshkafy.phtml?page=1

[16] V.S. Biront, V.I. Anikina, A.A. 2009. Kovalyova Dilatometer Analysis of Structural Transformations in the Aluminum-Silicon Alloys during the Thermo-Cyclic Processing. Journal of Siberian Federal University. Engineering & Technologies. 4(2): 384-393.

[17] RU 2525872 C1. Formation of Microstructure of Eutectic Al-Si Alloy / AnikinaV.I., Zhereb V.P., Anikin A. I., Burlutskaja D.M., Kovaleva A.A.; заявитель и патентообладатель Federal'noe gosudarstvennoe avtonomnoe obrazovatel'noe uchrezhdenie vysshego professional'nogo obrazovanija "Sibirskij federal'nyj universitet" (RU); 20.08.2014, Byul. № 23.

[18] Inverted light microscopes Axio Observer.A1m, Axio Observer. D1m, Axio Observer.Z1m, AxioObserver 3, AxioObserver 5, AxioObserver 7[Electronic resource]. - Access mode: https://www.zeiss.com/microscopy/int/products/light-microscopes.html.

[19] Universal breaking machine LFM 20kN [Electronic resource]. - Access mode: https://www.walterbai.com.

[20] Taran Yu. H., Mazur V.I. 1978. Struktura evtekticheskih splavov. - M.: Metallurgiya. p. 312.