SHAPED CASTINGS FROM LOW ALLOYED COPPER ALLOYS

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ABSTRACT

Low-alloyed copper alloys are the most important materials in creation of products in a number of technical industries, including transport engineering. These alloys generally belong to the class of wrought, but there is a possibility of their use for shaped casting. In machine-building technologies, copper–iron alloys with alloying additives are promising, providing sufficiently high electrical conductivity in combination with high strength properties, which primarily concerns wear-resistant parts. Studies that allowed to recommend such alloys for the transport engineering technologies were carried out.

Keywords: *low-alloyed alloys, copper, iron, electrical and thermal conductivity, wear resistance, casting, mechanical and technological properties, resource-saving technologies, smelting, transport engineering, phase analysis.*

Background. *Copper continues to be the main conductive material in electrical engineering and new technologies. Until now, approximately 70 % of pure copper produced in the world is consumed for manufacture of conductive products. The main disadvantage of pure copper products (wire, cables, current-carrying parts, etc.) are low mechanical properties and intensive formation of scale (copper oxide) in the production process, which leads to noticeable losses of scarce metal. Inclusion of low-alloyed alloys in the composition expands the technical capabilities of copper. However, industry uses few low-alloyed alloys based on it [1].*

Among the reasons we can name limited technological resources of some alloys that make it difficult to obtain derivative types of deformation (rolling, drawing, etc.) or high-quality semi-finished products (ingots) in the casting process (insufficient fluidity, tendency to film formation, hot brittleness, etc.) [2].

Objective. *The objective of the authors is to consider different issues related to shaped castings from low alloyed copper alloys used in transport engineering, and particularly to determine the optimal content of iron and phosphorus in the considered alloys.*

Methods. *The authors use general scientific and engineering methods, comparative analysis, scientific description.*

Results. *Low-alloyed copper cast alloys, which are used in modern technology, are divided into two groups [1–4]. The first group includes dispersion-hardening, that is, those in which the increase in heat-resistant properties is acquired as a result of thermomechanical processing. The other group is based on alloys, in which similar properties are determined by the strength of interatomic bonds between the alloy base and alloying components. These alloys have higher technological and casting qualities, but lower characteristics of electrical and thermal conductivity. Low-alloyed copper is one of the first materials that found its application in cryogenic technology. This is due to the fact that copper does not have a cold break threshold, and the lower temperature limit of its use is close to absolute zero.*

Standard low-alloyed copper alloys mainly belong to the class of wrought alloys. The volume of production of cast alloys for production of shaped castings for electrical engineering industries (contacts, powering and connecting, brush holders, heat exchangers, tuyeres, etc.) is significantly smaller [5–8].

Significant prospects for new technologies in the electronic and electrotechnical industry, cryogenic engineering, transport engineering are opened with the use of low-alloyed alloys based on the copper-iron system in manufacture of shaped castings.

Iron introduced into the alloy increases the electrical resistance of copper and at the same time provides additional higher strength values. The US standards include four alloys (C19600–C19200) with an iron content of 0,8 to 2,6 %. The country produces various products in the form of sheets, strips, tapes, rods for various branches of power engineering. The copper – iron alloys group is characterized as materials with high electrical conductivity, and ferrous bronzes (precipitation hardening alloys) as competitors of chromium bronzes with highly profitable output, since the cost of iron is significantly lower than other traditional alloying in low-alloyed copper alloys [7, 8].

For manufacture of alloys of this group, it is permissible to use copper of industrial purity – with a higher initial oxygen content, which allows the use of waste generated in non-ferrous metallurgy [9, 10].

At the moment, shaped casting of transport engineering [11], contact network fittings for railways (feed, connecting clamps, etc.) are produced according to melted and gasified models from M0 and M1 copper according to GOST [Russian state standard] 859-2001 and Br99ZHL aluminum bronze according to GOST 493-79. The strength properties of pure copper are significantly inferior to ferrous bronze, and the electrical conductivity of aluminum bronze does not exceed 50 % of the electrical conductivity of pure copper, which leads to significant energy losses in transmission of current to electrical wires. In this regard, it is advisable to use copper alloys with a higher conductivity. These alloys include ferrous bronzes, the conductivity of which reaches 80 % of the conductivity of pure copper while maintaining the level of strength properties inherent in aluminum bronze.

According to the copper angle of the state diagram of the Cu-Fe system (Pic. 1), iron is practically insoluble in copper and does not have a significant effect on its thermal and electrical conductivity. When remelting copper scrap contaminated with iron, the latter is oxidized primarily with the formation of iron oxides (mainly Fe_3O_4), which again does not significantly reduce the physical and mechanical properties of copper. In the presence of small additions of phosphorus, the alloys of this system have relatively high casting properties and can be recommended for shaped castings.

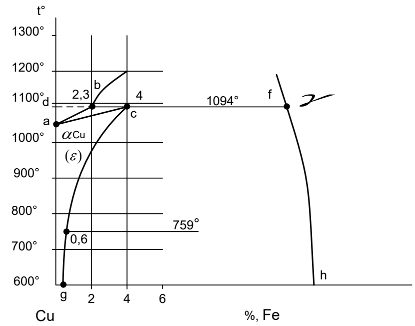
The task was to determine the optimal content of iron and phosphorus in the identified alloys. For this purpose, the state diagram of the Cu-Fe-P system was studied, the composition of the phases included in the alloys was determined, and the efficiency of improving the properties of the alloys was evaluated [11].

Based on the above criteria, a comprehensive assessment was made of the possibility of using copper–iron system alloys for modern transport engineering [10].

As a result of the research, preference is given to copper alloys with the content of alloying components shown in Table 1.

For preparation of alloys, cathode copper of M1 grade (GOST 859-2002), Armco iron, Cu ligature – 10 % P and Cu ligature – 37 % Zn (in the form of brass L63) were used. The calculation of the input amount of iron was carried out taking into account its possible intoxication to 0,3 %. The calculation of the amount of phosphorus introduced in the form of a master alloy was made taking into account phosphorus carbon loss by 50 %, as well as deoxidation of the copper melt by phosphorus by 25 %. The calculation of the amount of zinc injected as a ligature of Cu – 37 % Zn took into account the probability of zinc loss to 1 % [13, 14].

The working out of the technological regimes of smelting low-alloyed copper-iron alloys was carried out taking into account the specifics of physicochemical processes, since the various



Pic. 1. Copper angle of the nonequilibrium phase diagram of the copper–iron system.

properties of the resulting oxidation products impede the subsequent refining of copper and copper alloys.

Melting of low-alloyed copper alloys was carried out in an induction high-frequency furnace IST-006 in a graphite-chamotte crucible [14, 15]. The temperature of alloy casting was 1220–1240˚C. Filling was carried out in thin-walled one-piece shell forms of an LVM with a temperature of 480–500˚C.

As a result of the experiments, five to six high-quality castings were obtained from the considered alloy compositions. All castings had a fairly clean and even surface of red-yellow (golden) color [16]. The highest strength characteristics, as one would expect, was alloy No. 3: tensile strength – 280–300 MPa, relative elongation – 33–35 %, Brinell hardness – 60–70, electrical conductivity – 80 % pure copper.

Conclusion. *The developed alloys and castings made of them are proposed for use in manufacture of shaped casting on investment patterns instead of castings from aluminum bronze of the brand Bra9ZHZL according to GOST 493-79.*

Low-alloyed copper–iron alloys can be recommended for use in electric propulsion systems, including products of railway transport engineering. They form the largest market for such motor systems, since copper components are an integral part of them.

Table 1

Compositions of the experimental alloys

No.	Fe,%	P,%	Zn,%	Cu,%
1.	0,25	0,06	–	Rest
2.	1,0	0,3	0,35	Rest
3.	2,0	0,15	0,05–0,2	Rest

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