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The influence of wall thickness on the microstructure of bronze BA1055 with the additions of Si, Cr, Mo and/or W

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Abstract

Aluminium bronzes belong to the high-grade constructional materials applied on the put under strongly load pieces of machines, about good sliding, resistant properties on corrosion both in the cast state how and after the thermal processing. It moves to them Cr and Si in the aim of the improvement of their usable proprieties. Additions Mo and/or W were not applied so far in the larger concentration, these elements were introduced to the melts of the copper as the components of modifiers. It was worked out therefore the new kind of bronzes casting including these elements. Make additions to the Cu-Al-Fe-Ni bronze of Si, Cr, Mo and/or W in the rise of these properties makes possible. The investigations of the influence of the wall thickness of the cast on size of crystallites were conducted: the primary phase β and intermetallic phase κ and the width separates of the secondary phase α precipitate at phase boundary. It results from conducted investigations, that in the aluminium bronze BA1055 after simultaneous makes additions Si, Cr, Mo and in the primary phase β it undergoes considerable reducing size. The addition W reduce size of the grain phase β in the thin walls of the cast 3-6 mm, and addition Cr in the range of the thickness of the wall of the cast 3-6 mm it favors to reducing size the phase β, in walls 12-25 mm the growth causes it. The addition Mo does not influence the change of the size of the grain of the β phase significantly. The make addition singly or simultaneously of the Cr, Mo and W to the bronze CuAl10Fe5Ni5Si it influences the decrease of the quantity separates of the phase α on the interface boundary and of width it separates independently from the thickness of the wall of the cast. The simultaneous make addition of the Si, Cr, Mo and W it enlarges the surface of the phase κ_{Fe}, κ_{Mo}. The make addition to the bronze CuAl10Fe5Ni5Si of the Cr, Mo or W the quantity of crystallizing hard phase κ enlarges and the hardness HB of the bronze raises. The make addition singly the Mo or W, if also simultaneous with the addition Cr reduces their make addition it sensibility on the change of the thickness of the wall of the cast (3-25 mm) guaranteeing the possibly small fall the hardness the bronze about 22-28 HB. More far works over new multicomponent aluminium bronzes will be guided in the direction of the identification of the changes of mechanical properties of studied bronzes under the influence of the thermal processing.

Keywords: Metallography, Size of the grain of microstructure, Width of separates, Multicomponent aluminum bronze, Cast state, Mechanical properties

1. Introduction

Aluminium bronzes make up the group of high-grade constructional materials applied on casts of the strongly load pieces of machines, resistant on abrasion and corrosion especially in seawater. [1]. Raising mechanical properties of applied so far aluminium bronzes will make possible steering microstructure through alloy additions will make possible decrease of the dimensions of the piece of machines and aspect ratio the time of their exploitation. They the boride of the tungsten W_2B_5 as and his

carbide of the WC with the hexagonal of the structural lattice of the type AlB_2 (lattice A3) can modify the structure of copper and its melts [2]. They show the full similarity of the distribution of atoms in crystallographic planes (111) to the lattice A1 (the phase α in the melts of Cu-Al) and (0001) in the lattice A3. These compounds can function as the part of preferential sites to the heterogeneous nucleation the alloys of the copper. It was affirmed the profitable influence deoxidizes the copper the phosphorus on following after this the treatment of the modification using the modifiers including among others W and Mo. Makes addition in this way Mo and W or their compounds function as the part of microadditions to the alloys of the copper. To the modern investigations of the influence of chemical composition as and technological treatment carried out on the liquid alloy on its microstructure in the solid state appertain the computer scanning of the image of microstructure [3,4] enabling estimate of stereological microstructure received in the process of casting the constructional material [5].
They are guided the investigation over new high-grade Cu-Al-Fe-Ni bronzes with additions in the Department of Material Engineering and Systems Production of Technical University of Lodz singly or the simultaneous of Si, Cr, Mo and/or W [6-8].

2. Methodic of research

The pattern of test cast with the changing thickness of the wall g was introduced on Figure 1. The field of the surface F by which warmth is carries off to mould, volume V of the chosen piece of cast with the thicknesses of the wall g and the module of coagulation M characteristic for the cast with the thickness of the wall g was represented in Table 1.

The mould was made from the synthetic moulding sand about type -matter: quartz sand, water 3%, bentonite 6% and coal dust 3%.

The investigations the influence the thickness the wall on microstructure the bronze BA1055 with the additions of Si, Cr, Mo and/or W samples made from bronzes: CuAl10Fe5Ni5Si (P1), CuAl10Fe5Ni5CrSi (P2), CuAl10Fe5Ni5MoSi (P3), CuAl10Fe5Ni5SiW (P4), CuAl10Fe5Ni5CrSiMoW (P5) were subjected. Bronzes P2, P3, P4 and P5 were got on the base of the bronze P1. Aluminium bronzes were smelted from pig sows BA1055 in the laboratory inductive furnace in the graphite crucible. Investigations were conducted on metallographic microsections made on samples low-cut from the test cast (Fig.1) etched the reagent Mi17Cu. The picture of microstructure were subjected the scanning image with use of the system measuring MultiScanBase v.11.06. On the picture of the microstructure of the bronze, by the magnification x100, the following measurements of the phase β were conducted:

– field of the surface (F, mm^2);
  the following measurements of phases were conducted by the magnification x400:
– the width separates of the phase α on the interface boundary (W, mm),
– field of the surface of phases κ (F, mm^2).

The field of the surface of phases β and κ and the width separates of the phase α it was marked with use of the computer system measuring MultiScanBase the planimetric method. As the surface of the crystallite of the primary phase β the area separates eutectoid α + γ_2 was accepted differentiate the continuous zone separates of the phase α on the interface boundary. The line of the contour was guided the centre the separates of the phase α zone. As the width separates of the phase α smallest distance was accepted among the separates of the bevel γ_2 in two neighbouring crystallites of the former primary phase β.

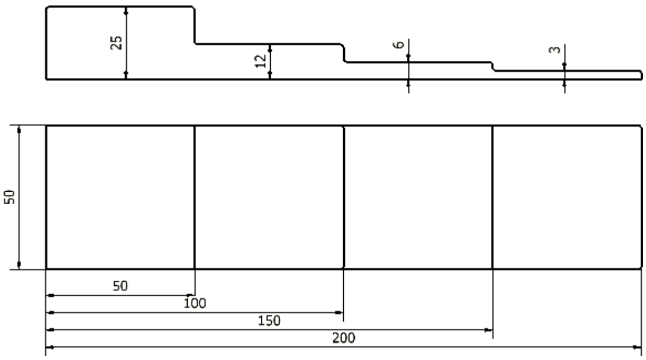

Fig. 1. The pattern of test cast with the changing thickness of the wall

Table 1.
The characteristic parameters of the test cast

g, cm	0,3	0,6	1,2	2,5
F, cm^2	54,5	57,5	65,0	94,0
V, cm^3	7,5	15,0	30,0	62,5
M=V/F, cm	0,138	0,261	0,462	0,665

Brinell hardness was conducted the investigation by following parameters 2,5/187,5/15.

2.1. Crystallization of multicomponent aluminum bronzes

On the Figure 2 was introduced the model of the crystallization of the bronze with the concentration C_0, introduced on the background of the segment of the phase equilibrium diagram Cu-Al-5% Fe-5%Ni [9,10]. The influence of the change of temperature on the equilibrium of phases was described six stages.

Stage 1
The bronze is in liquid state L to the temperature liquidus (TL).

Stage 2
It begins nucleation and the growth of the primary phase β after the over-cooling of the melt below the equilibrium temperature liquidus (TL) from liquid L. In the borders of the temperature TL-TS (TS - the temperature solidus) the whole volume of the liquid bronze crystallize as the phase β.

Stage 3
Till the moment over-cooling of the bronze below the equilibrium temperature Tκ melt with the microstructure of the phase β it cools down in the solid state.

Stage 4

After the over-cooling of the bronze below the equilibrium temperature solvus T κ in the phase β it nucleate and grows up the intermetallic phase κ.

Because of the fall of the dissolubility of Fe, Ni in the phase β process this lasts in the borders of the temperature Tκ-Tα.

Stage 5

After the over-cooling of the bronze below the equilibrium temperature solvus Tα in the phase β it nucleate and grows up the phase α. Because of the growth of the dissolubility of Al in the phase β process this lasts in the borders of the temperature Tα - TEs. Aluminium from the borders of the phase β enriching it diffuse to its interior, and the impoverished in Al borders of the primary phase β they become transformed in the phase α on the road of diffusion.

Stage 6

After the over-cooling of bronze below the equilibrium temperature of the eutectoid transformation TEs (s - start) from the remaining phase β it nucleate and grows up eutectoid $\beta \rightarrow \alpha + \gamma_2$. Process this lasts in the borders of the temperature TEs-TEf (f-finish) exhaust in the transformation eutectoid the phase β. Below the temperature TEf the bronze with microstructure $\alpha + \kappa + \gamma_2$ cool down in the solid state.

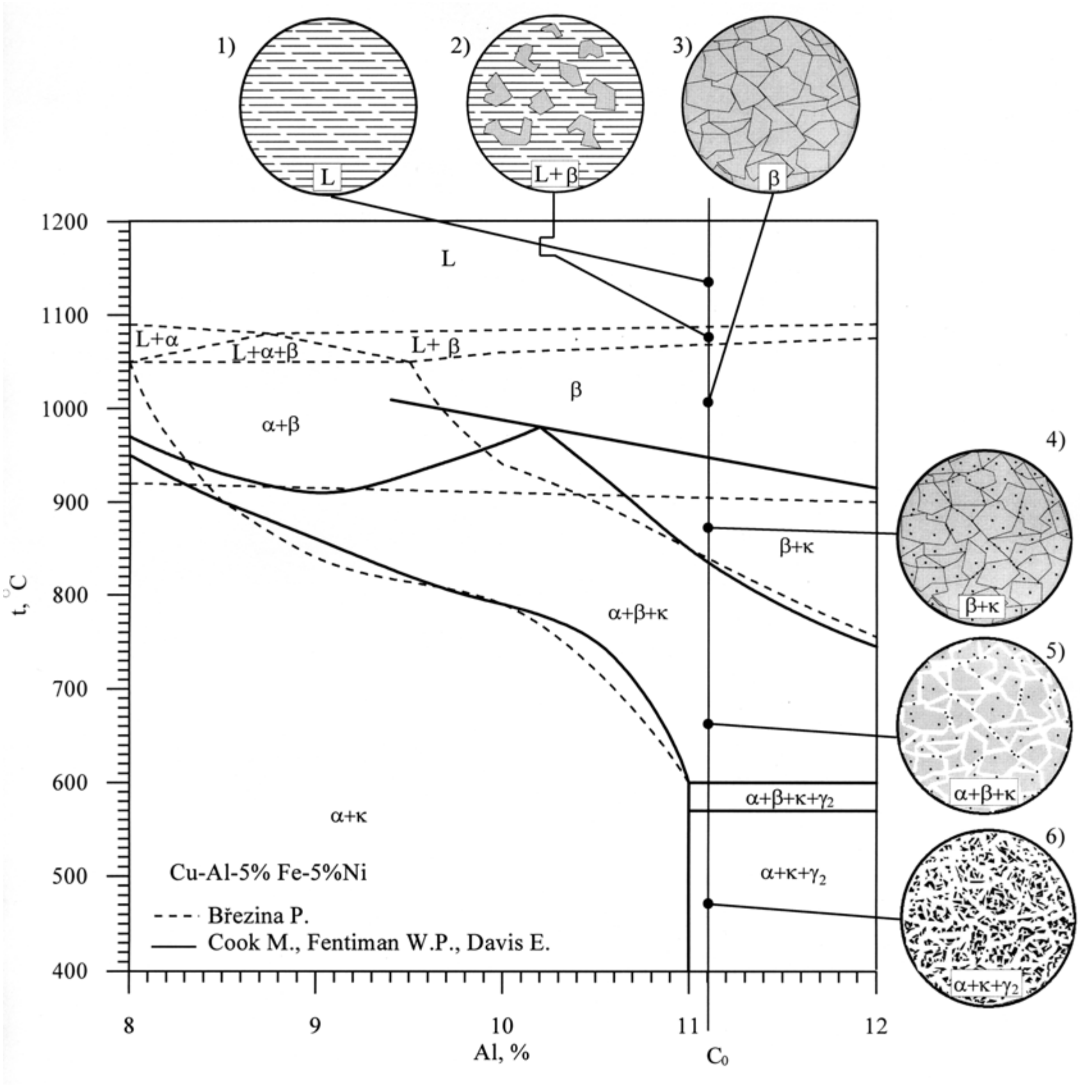

Fig. 2. The model of the crystallization of the bronze with the concentration C_0

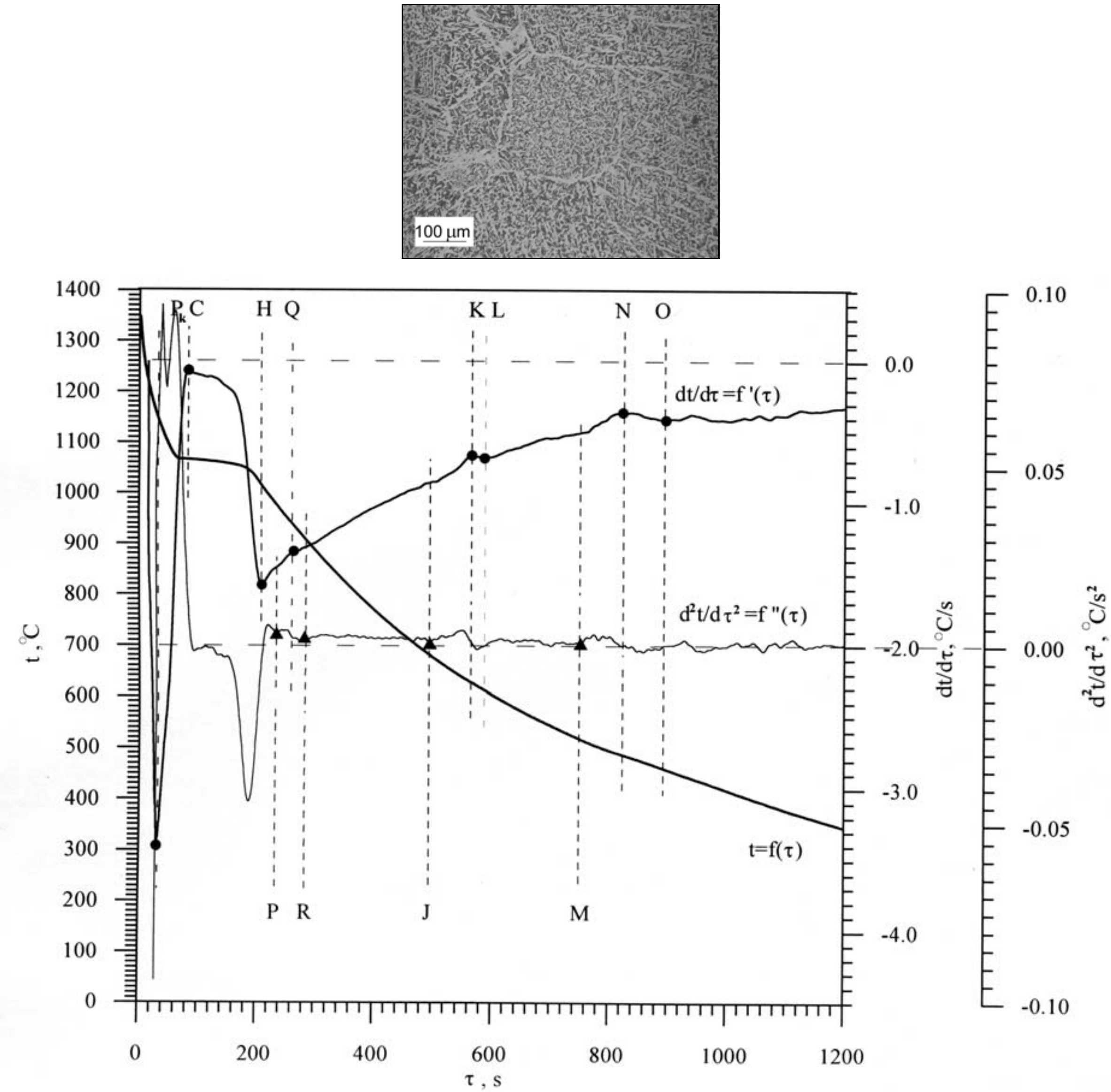

Fig. 3. Microstructure $\alpha+\kappa+\gamma_2$ (a) and the ATD curves (b) of the bronze CuAl10Fe5Ni5Si [7]

The microstructure and ATD curves of the bronze CuAl10Fe5Ni5Si was introduced on the Figure3 [7]. Characteristic points marked on the curves thermal and derivative analysis make possible the qualification for the individual stages of crystallization the real temperature of the process: TLrz = tC, TSrz = tH, $T_{\kappa\ rz}$ = tQ, $T_{\alpha\ rz}$ = tK, TEsrz = tN, TEfrz = tO. On curve derivative individual thermal effects are called out the crystallization of phases suitably: Pk-C-H - β, P-Q-R - κ, J-K-L - α, M-N-O - the eutectoid transformation $\beta\rightarrow\alpha+\gamma_2$.

3. The description of got results

3.1. The microstructure of studied multicomponent aluminium bronzes

The microstructure of studied bronzes created in the wall of the test cast with thickness: 3 mm, 6 mm, 12 mm and 25 mm was introduced by the magnification suitably: x100 on the Figure 4 and x400 on Figure 5.
The average values of parameters characterizing the size of the crystallites of microstructure of studied bronzes were showed

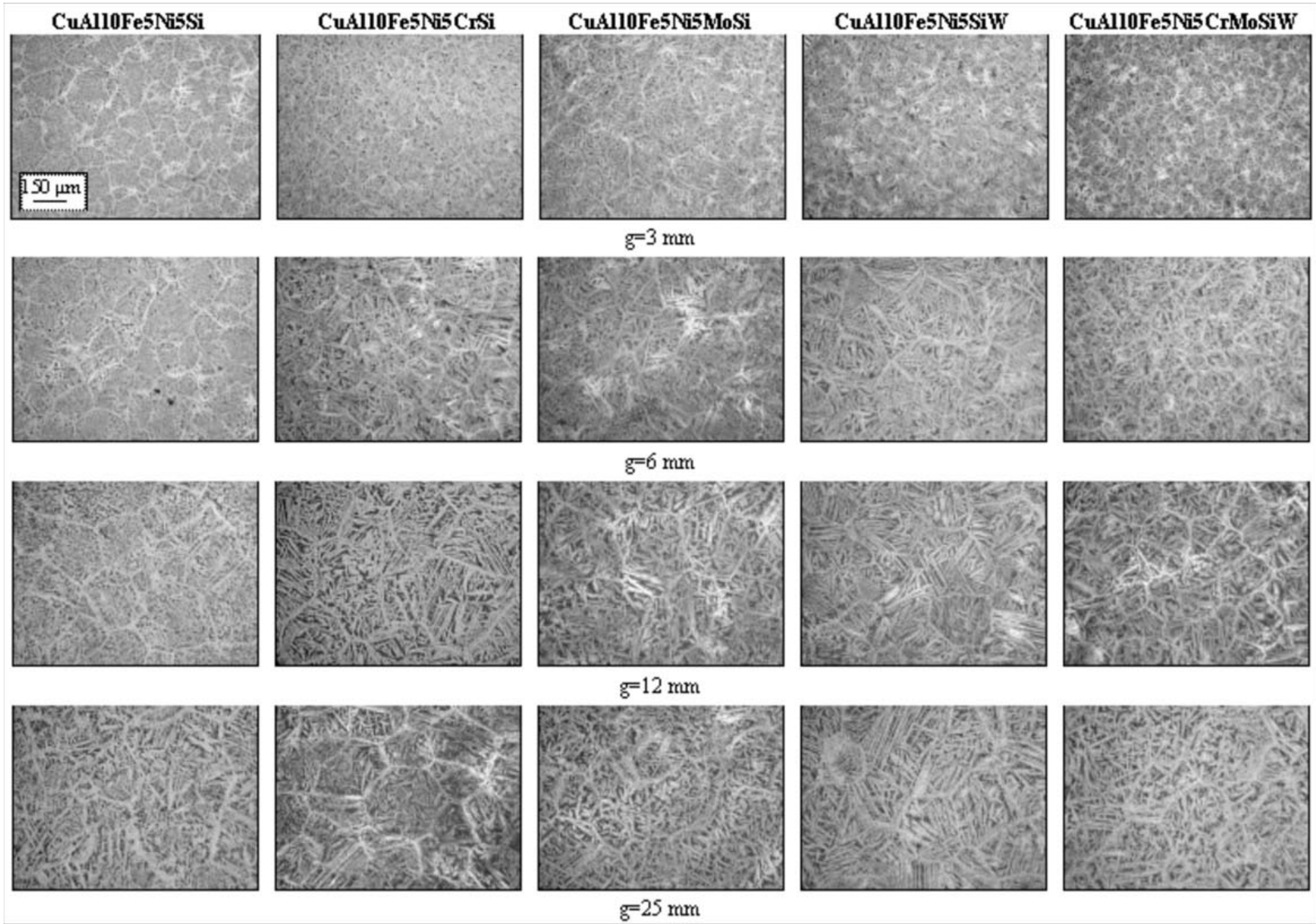

Fig. 4. The microstructure of studied bronze in dependence from the thickness of the wall of the cast, magnification x100

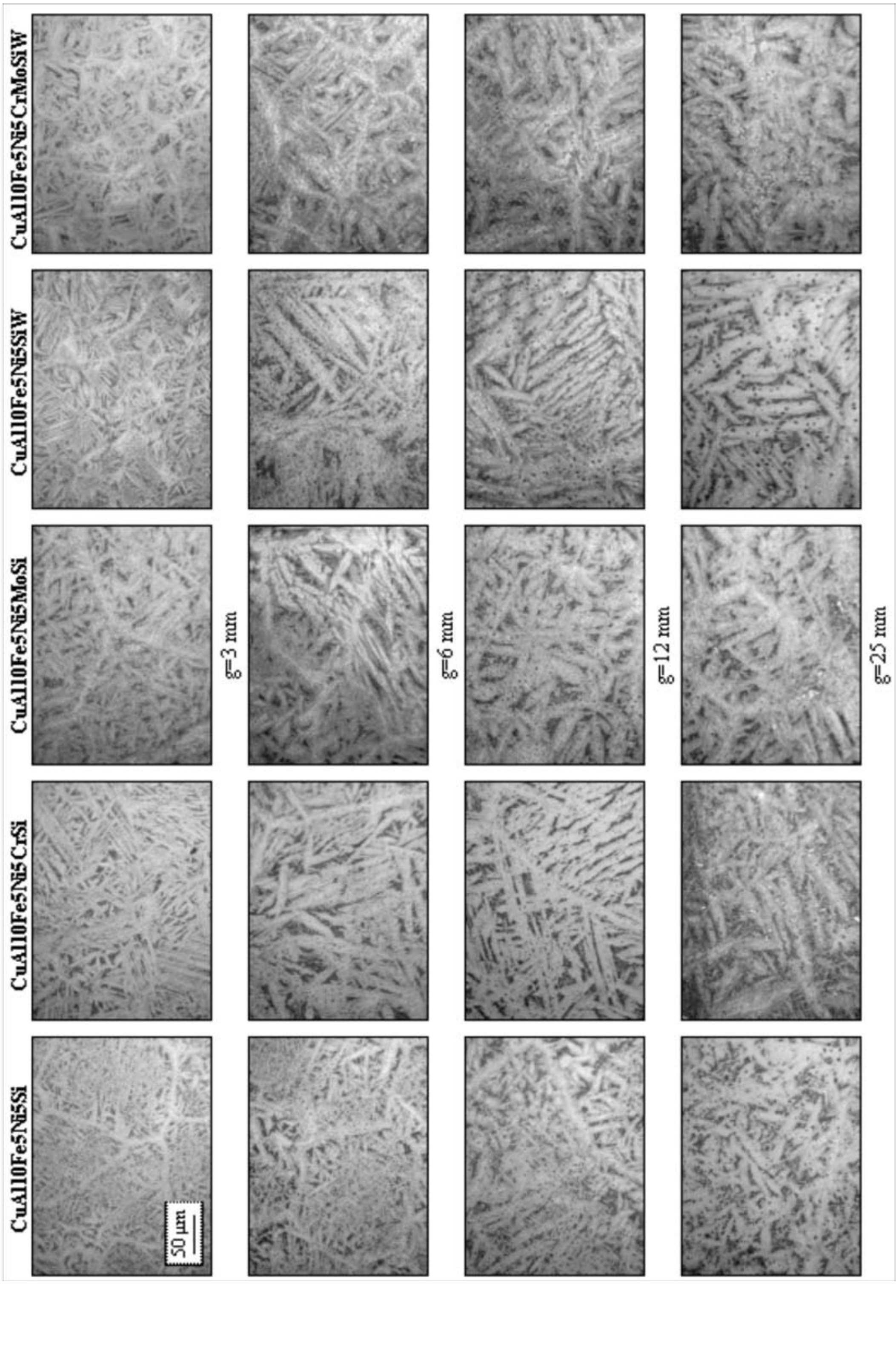

Fig. 5. The microstructure of studied bronze in dependence from the thickness of the wall of the cast, magnification x400

on drawings suitably:

- field of the surface of the primary phase β – Fig. 6,
- width of the separates of the phase α on the interface boundary – Fig. 7,

field of the surface of phases κ – Fig. 8.

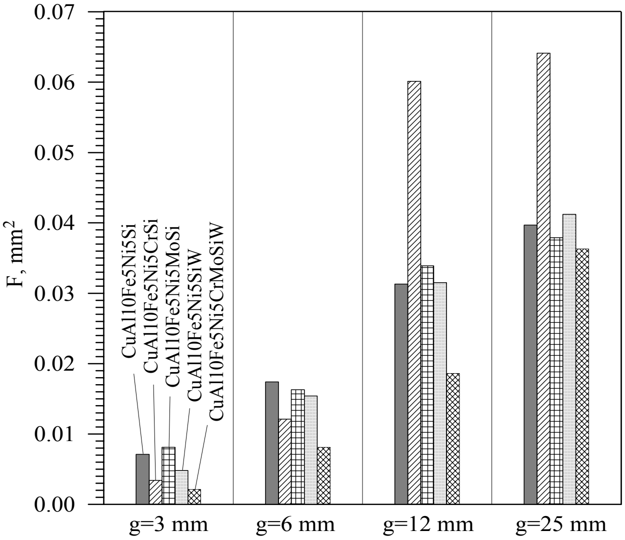

Fig. 6. The average value of the field F of the surface of the primary phase β

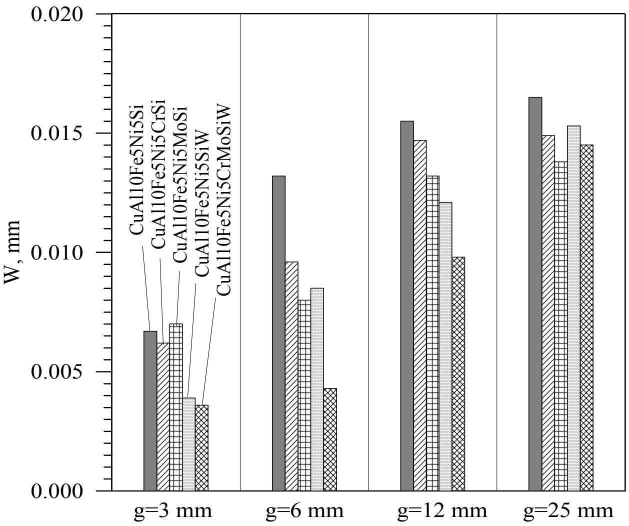

Fig. 7. The value the average width W the separates of the phase α on the boundary of the primitive phase β

The make addition to the bronze CuAl10Fe5Ni5Si singly W or Cr in the considerable way influences on the size reduction of the primitive phase β in casts with the thickness of the wall 6-12mm (Fig. 6). Observe, that the effect of size reduction the phase β in casts both with thin walls 3-6 mm as and with walls 12-25 mm it is the largest in the bronze including simultaneously the additions of Si, Cr, Mo, W.

In casts from the bronze CuAl10Fe5Ni5Cr with the thickness of the wall 12-25 mm was observed the considerable growth of the phase β. The make addition Mo to the bronze CuAl10Fe5Ni5Si does not exert the significant influence on the size reduction of the phase β in casts in the whole range of the changeability of the thickness of the wall 3-25 mm.

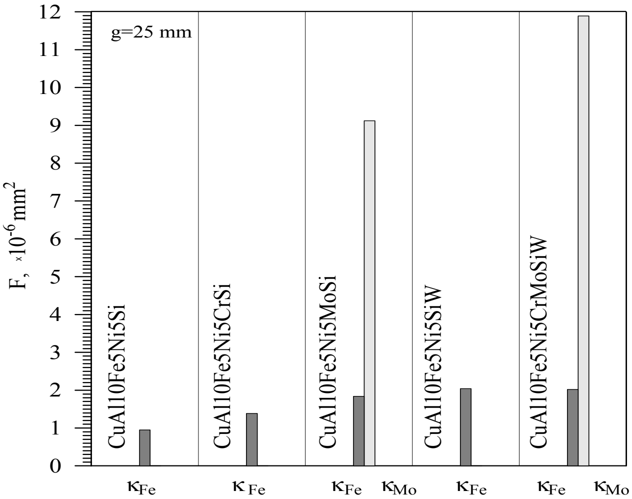

Fig. 8. The average value of the field F of the surface of phases κ

The make addition to the bronze CuAl10Fe5Ni5Si singly or simultaneously the additions Cr, Mo and in he influences the shift of the line of the temperature solvus T α in the equilibrium diagram Cu-Al-5% Fe-5% Ni (Fig. 2) in the direction of the lower concentrations of Al, causes decrease of the quantity the separates of the phase α on the interface boundary, and in the consequence decrease of the width its separates (Fig. 7).

The make addition to the bronze CuAl10Fe5Ni5Si singly or simultaneously additions Cr, Mo and W influences the growth of the size of the separates of the intermetallic phase κ_{Fe} (Fig. 8). Including Mo in the bronze (CuAl10Fe5Ni5MoSi, CuAl10Fe5Ni5CrMoSiW) was identified large the separates of the phase κ_{Mo} including except the high concentration of Fe considerable quantities Mo.

3.2. Hardness HB of multicomponent aluminium bronzes in dependence from the thickness of the wall of the cast

Average hardness HB the bronze CuAl10Fe5Ni5Si including singly or simultaneously the additions Cr, Mo and W in casts with the thickness of the wall 3-25 mm was showed on the figure 9. The make addition to the studied bronze Cr effect in the whole range of the thickness of walls the growth of its hardness. In the range of thin walls 3-6 mm Mo and W it causes the small fall of the hardness of the bronze. In the range of the thickness of walls 12-25 mm all made addition elements to the studied bronze they raise considerably its the hardness. It probably is caused this first of all the growth of the quantity of phases κ_{Fe} and κ_{Mo} in the microstructure of the studied bronze.

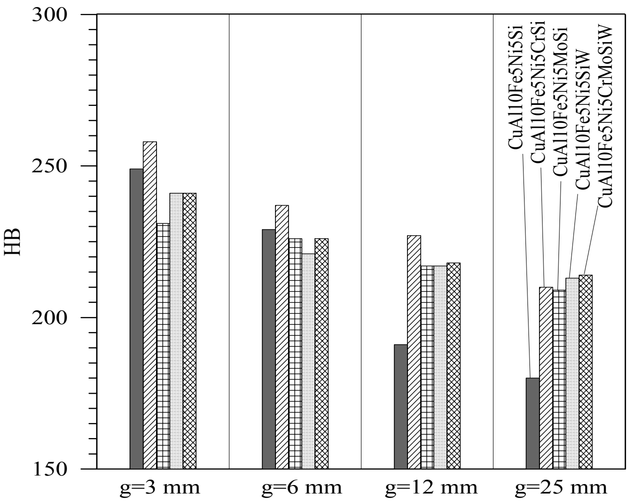

Fig. 9. The value average of HB hardness

The difference was introduced on the figure 3 ΔHB among the average hardness HB of the wall of the test cast of studied bronzes about the thickness 3 mm and 25 mm.

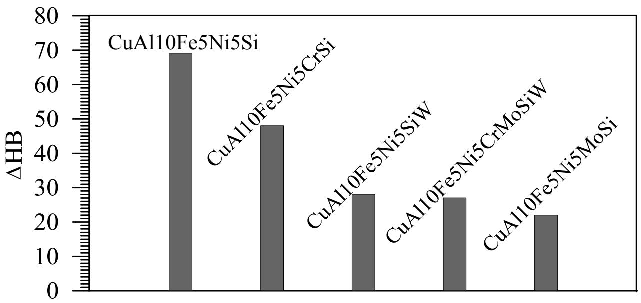

Fig. 10. Range of fall of hardness HB on thickness of wall of cast from 3 mm to 25 mm

The bronze CuAl10Fe5Ni5Si is characterizes the comparatively large sensibility on the change of the thickness of the wall in the cast. Difference among the hardness of the wall 3 mm and 25 mm it equals Δ HB = 69. It is characterizes the smallest sensibility on the speed of cooling down connected with the thickness of the wall of the cast the bronze CuAl10Fe5Ni5MoSi, for which ΔHB=22. It the approximate fall of hardness in test casts is characterizes bronze CuAl10Fe5Ni5CrMoSiW and CuAl10Fe5-Ni5SiW ΔHB=27-28. The addition Cr to the bronze CuAl10Fe5Ni5Si in the comparison with the addition Mo or W it reduces the difference of hardness among the thin and fat wall the test cast in the smallest stage, Δ HB = 48.

4. Conclusions

It results from conducted investigations over new high-grade aluminium bronzes, that the make addition to the bronze CuAl10Fe5Ni5:

- simultaneously the addition Cr, Mo and W reduce size the primary phase β in the considerable stage independently from the thickness of the wall of the cast,
- the addition W reduce size phase β of the crystallites in the thin wall of the cast 3-6 mm,
- of addition Cr in the range of the thickness of the wall of the cast 3-6 he favours mm to reduce size the phase β, however in walls 12-25 the growth causes its,
- of the addition Mo does not influence the change of the size of the crystallites of the phase β significantly ,
- it singly or simultaneously the additions Cr, Mo and W influences on decrease of the quantity the separates of the phase α on the interface boundary and decrease of the width its separates independently from the thickness of the wall of the cast,
- simultaneously the addition Cr, Mo and W it enlarges the surface of the phase κ_{Fe},
- simultaneously the addition Cr, Mo and W or only Mo enlarges the surface of phases κ_{Mo},
- of the addition Cr, Mo or W the quantity of crystallizing hard phases κ enlarges and the hardness of the bronze raises,
- singly the addition Mo or W, if also simultaneous reduces their make additin with the addition Cr its sensibility on the change of the thickness of the wall of the cast (3-25 mm) guaranteeing the possibly small fall the hardness the bronze about 22-28 HB.

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