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Aluminium composites casting in rotating magnetic field

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Abstract

In this paper technological and material conception of composite manufacturing with intensify of ex-situ powders and some results was shown. Technology of powders stirring with liquid metal in the crucible was shown. For composites required dispersion of reinforcement and matrix crystallization was assisted with rotating electromagnetic field. Improvement of reinforcing particles distribution can be observed. Composite structure was studied with use of light microscopy. Electromagnetic field processing positive influence on reinforcing phase distribution and matrix crystallization process was proved.

Keywords: Casting, composite, Solidification, Particles, Stirring

1. Introduction

As amplify particles in ex-situ composites to use: carbides (TiC, SiC, ZrC, B_4C), oxides (Al_2O_3, MgO, ZrO_2), nitrides (BN, Si_3N_4, TiN, ZrN), borides (TiB_2, ZrB_2, SiB_2), silicides ($MoSi_2$, Mo_3Si_5) and also Ni_3Al, NiAl, Fe_3Al, FeAl, Ti_3Al, TiAl. Among composites resistance to abrasive wear with small coefficient of friction dominate composites with graphite participles, glassy carbon and some with multiphase reinforcement [1-7]. Use composites powders to manufacture materials with nitride phases (fig. 1) it is the next group of composites production to casting methods. In recent years many different technologies such as Plasma Source Ion Implantation (PSII), Plasma Nitriding (PN), conventional ion implantation, reactive ion sputtering deposition and plasma deposition including ECR CVD process have been reported for the formation of AlN. Use to different variety of particles to manufacture of casting composites are presents in many works. In this area are leading numerous scientific research and experiments [9-16].

Size reinforcing particles contain to wide borders from fractional micrometers to even 300 µm. Selection to size and quantity of particles mainly results from expectation properties and technological possibility to creation of composite.

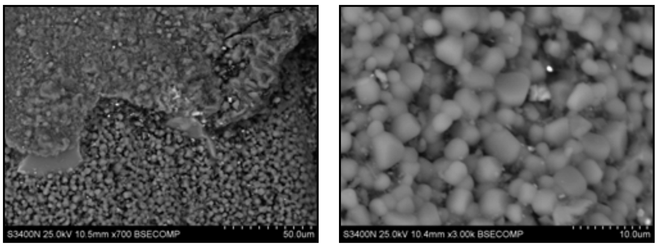

Fig. 1. Morphology of synthetic aluminum nitride powder [16]

2. Purpose, materials and methodology of research

Purpose to this investigations was definition of effectiveness influence spin magnetic field on to uniform distribution of reinforcing phase in the matrix of casting composites.

Reinforcing phases were the following participles:

1. NiCr – Cr_3C_2 (20-45μm)
2. Fe(Cr) – TiC (45-90μm)
3. NiCr-Cr_3C_2 – TiC (20-56 μm)
4. CrFe33C7 (300 μm).

Ones of factors influence to correct course formation of composites is suitably good wettability of components. Elements of manufacturing which facilitate wettability is use the activator of surface phenomenon. Stimulate active solution was make as hydrous solution oxides of boron and sodium. Next powders were roasted in temperature 380ºC through about three hours.

As the matrix of composites the aluminum alloy with silicon AlSi11 was used (table 1). This silumin have good castability, little propensity to cracks, little coefficient of thermal expansion and little contraction. Composition of matrix was completed of antimony (0,4%) as additives modify to effect surface and cast structure.

Table 1.
Chemical composition of AlSi11 used to investigation according to norm PN-EN 1706:2001 [17]

Alloy sign	Chemical composition, %						
	Si	Cu	Mg	Mn	Fe	Ti	Zn
EN AC-AlSi11	10,9	≤0,05	≤0,45	≤0,4	≤0,19	≤0,15	≤0,07

Composite was produced in ex-situ technique with part of weight reinforcing phase 10% comparatively to liquid aluminum matrix. AlSi11 alloy was melted in inductive furnace. Temperature of liquid metal during introduced surface-active participles was 680ºC. Liquid dispersion through mechanical stirring in crucible was produced. After stirred components and measured temperature of thermoelement NiCr-NiAl liquid composite was poured in temperature 700ºC to sand forms to lose phenol mass hardening CO_2. Perform 5 experimental casts:

0 - Cast AlSi11
1 - Cast AlSi11 + NiCr–Cr_3C_2
2 - Cast AlSi11 + Fe(Cr)–TiC
3 - Cast AlSi11 + NiCr-Cr_3C_2 – TiC
4 - Cast AlSi11 + CrFe33C7.

Geometrical shape obtained cast was shown in the figure 2a), b) and form was shown in the figure 2c), d).

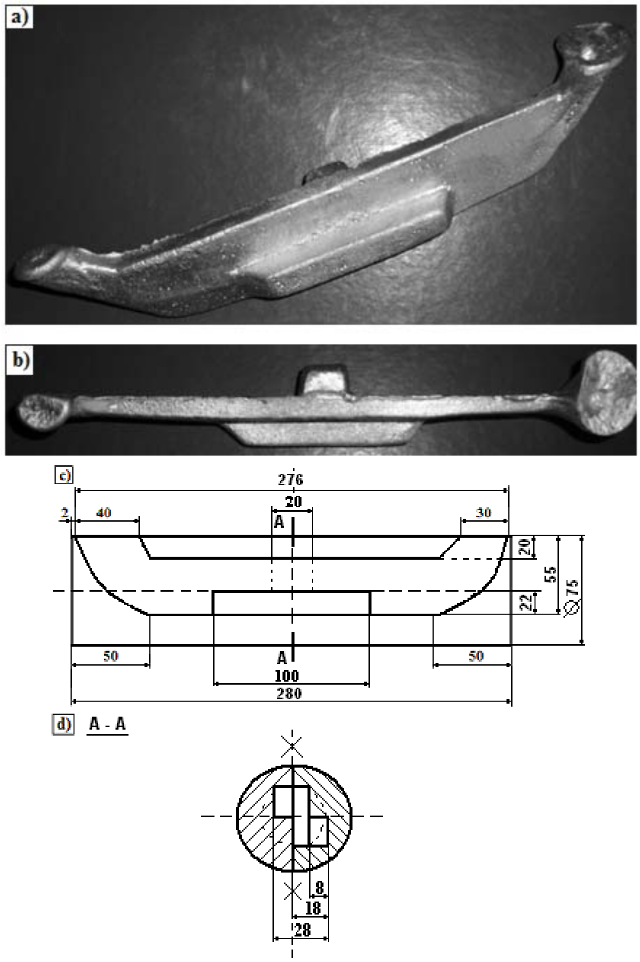

Fig. 2. Experimental cast: a), b) geometrical shape of casting, c) form – view looking front, d) view looking side.

Casting sand forms was in rotating electromagnetic field with intensity of current to feeding inductor 5A. Value magnetic induction, depending on value to intensity of current was defined before casting form on internal wall of form for to help of teslometer. Affect to induced magnetic field of current rotation caused to formation of magnetohydrodynamics forces introduce to liquid metal to rotation move compatible with direction to rotation of magnetic field.

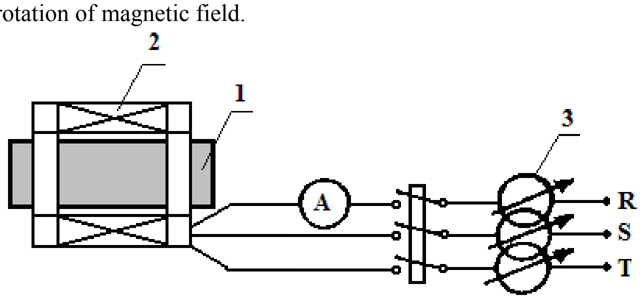

Fig. 3. Diagram of installation (stator asynchronous motor): 1 – form, 2 – inductor, 3 – transformer, A – ammeter.

In the figure 3 diagram of installation to manufacture rotating magnetic field with level axis rotate was shown. This place was composed with the following composition:

- inductor production to magnetic field fulfil the function of heating inductor
- sand form
- ammeter to measurement of current supply the inductor,
- autotransformer regulate to voltage the heating inductor supply.

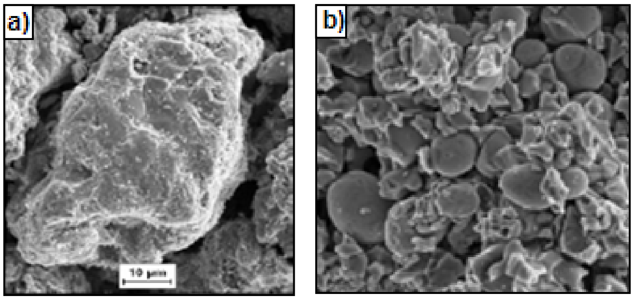

Fig. 4. Morphology and component structural of reactivity participles: a) NiCr-Cr_3C_2-TiC, b) NiCr-Cr_3C_2, globular participles of matrix NiCr [4].

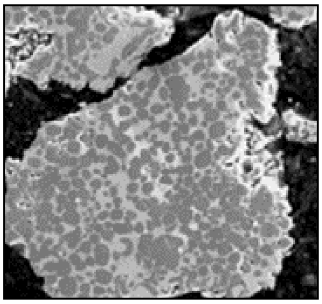

Fig. 5. Morphology of powder Fe(Cr)-TiC [4].

In the figure 4a) shape single grain of powder used to produced ex-situ composites was shown. Whereas in the figure 10b) morphology participles close to globular with evolute surface was shown. NiCr matrix with very minute carbides Cr and Ti completed participles carbides of chromium was allowed for to get advantageous properties of matrix and controlled to properties and size zone of transient in surroundings of participles. Reactivity participle NiCr-Cr_3C_2-TiC was allowed to get in AlSi11 alloy matrix of in-situ carbides phases in type Cr_xC_y and TiC. Example the another powder was show in the figure 5.

3. Results of the investigation

One of main problems through to casting metallic composites is uniform spacing reinforcing phase in the matrix. During the pour and next stirring ex-situ participles with alloy matrix existed danger to non-uniform introduce participles inside the composite.

In results introductory microscopy observed was show that participles reinforcement was tendency to located in upper and lower parts of cast whereas in the middle parts frequency of participles was considerably lesser. This phenomenon was observed in all of composites cast what was show in figures 7 – 10. Cause of this distribution participles in cast was affected rotating magnetic field what caused segregation in obtained cast composites. Centrifugal force was caused throw out participles on the borders of casts.

In purpose correction influence of rotating magnetic field for locate participles in composites matrix in the future investigation is predict to change technological parameters manufacturing of composites (for example: temperature of introduced participles, time and velocity stirring of components) and parameters of magnetic field (for example: intensity of current, time to affect of magnetic field), also produce rotating movement reversing liquid suspension instead of unidirectional movement. In the figure 6 action rotating magnetic field with reversion was shown.

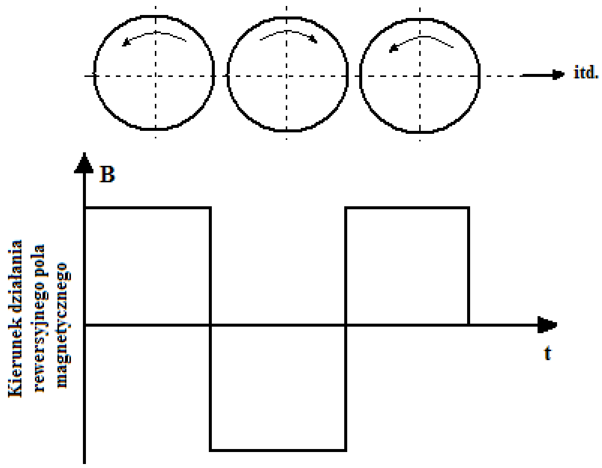

Fig. 6. Scheme of action rotating magnetic field with reversion.

Use rotating magnetic field with reversion give additional possibility steering phenomenon connected with homogenizing and size reduction of cast structure [18]. Influence also on more uniform spacing participles in metal matrix.

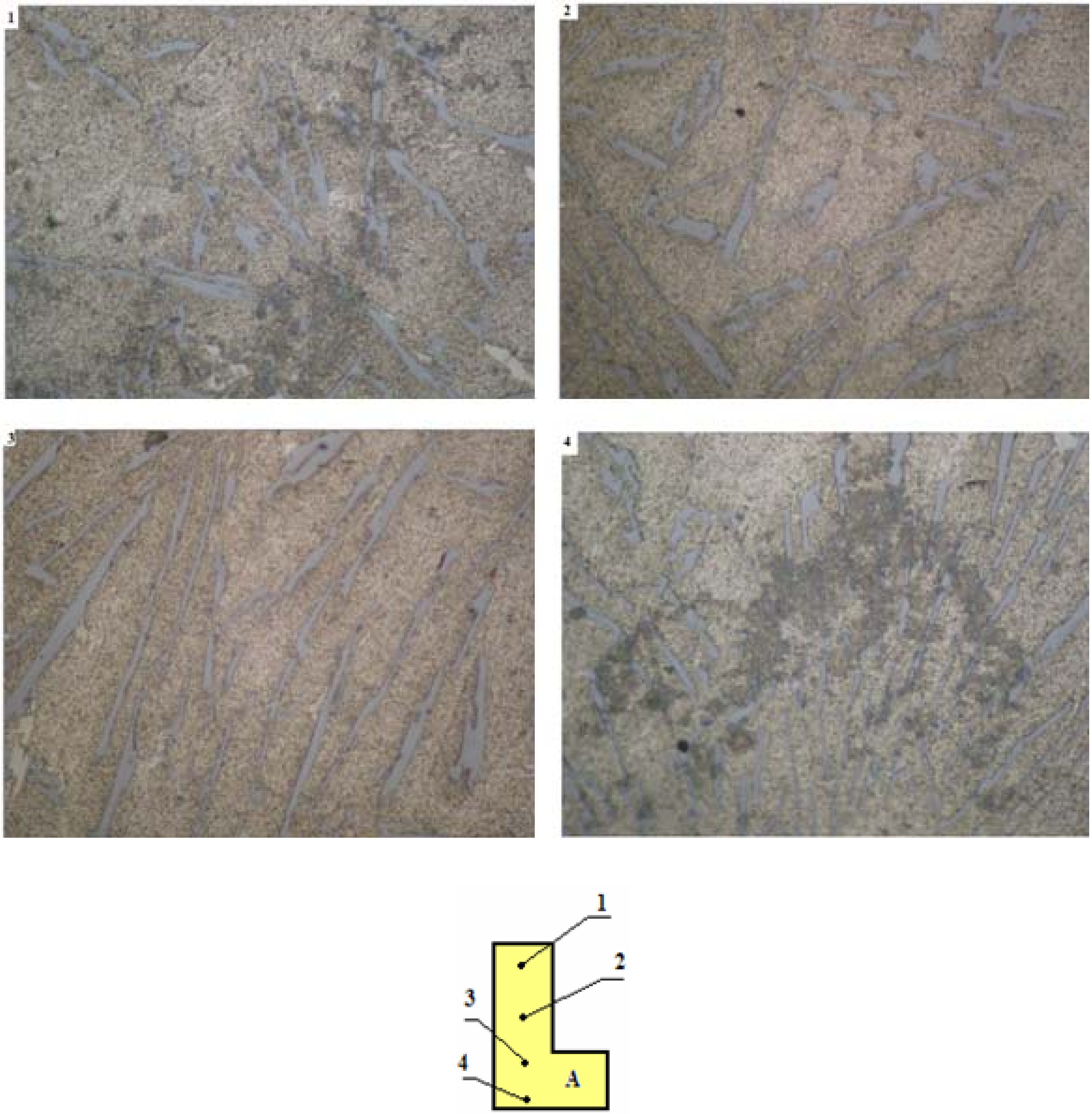

Fig. 7. Microstructures of composite (magnification 600x): A) AlSi11 - NiCr-Cr_3C_2. Visible grey and oblong silicon crystals on background eutectic mixture α+Si. In microstructures 1 and 4 is the biggest content reinforcing phase (dark cluster). Reinforcing phases type Cr_xC_y in matrix of powders.

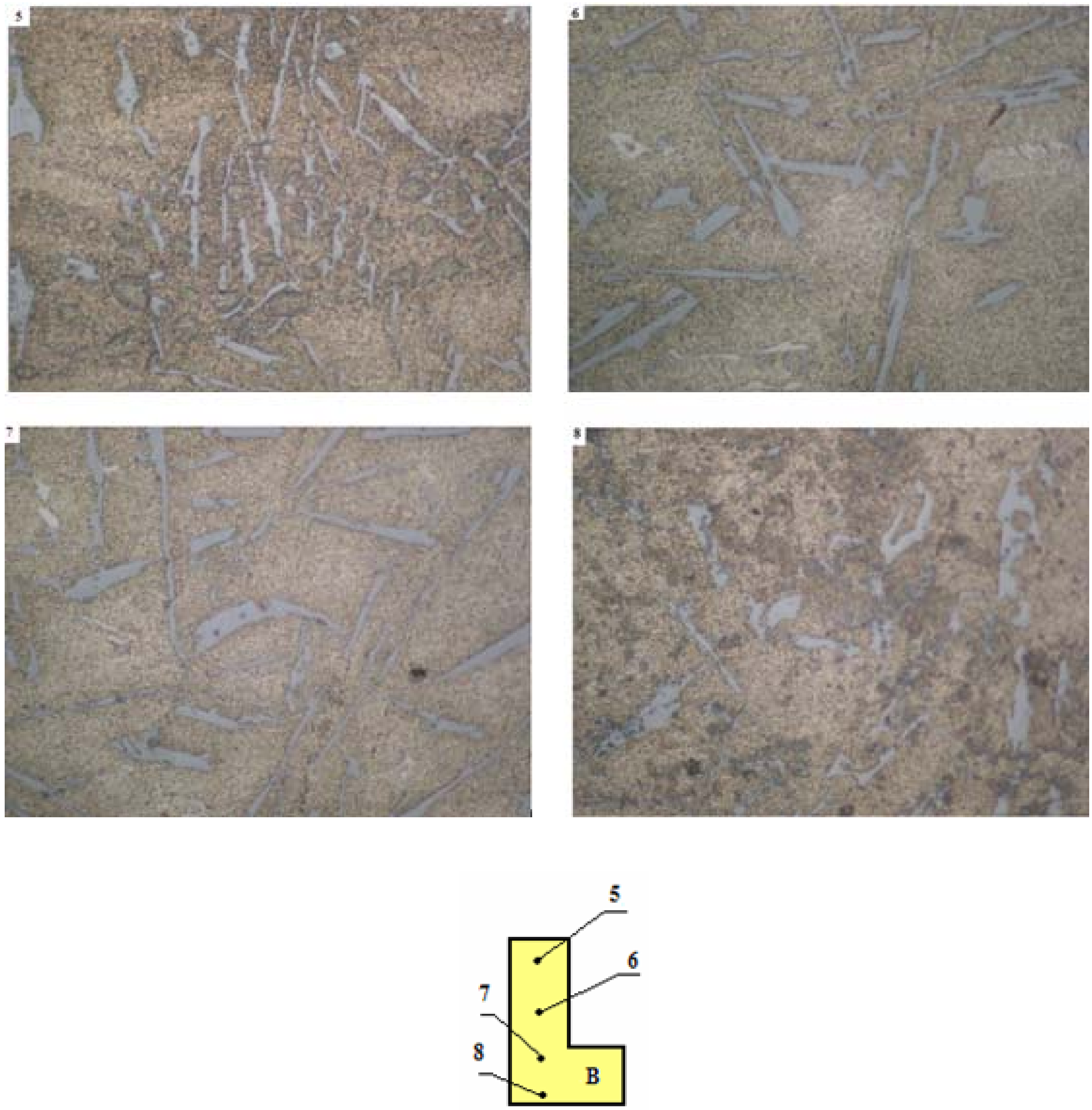

Fig. 8. Microstructures of composite (magnification 600x): B) AlSi11 - Fe(Cr)-TiC. Visible grey and oblong silicon crystals on background eutectic mixture α+Si. In microstructures 5 and 8 is the biggest content reinforcing phase (dark cluster). Reinforcing phases TiC in matrix of powders.

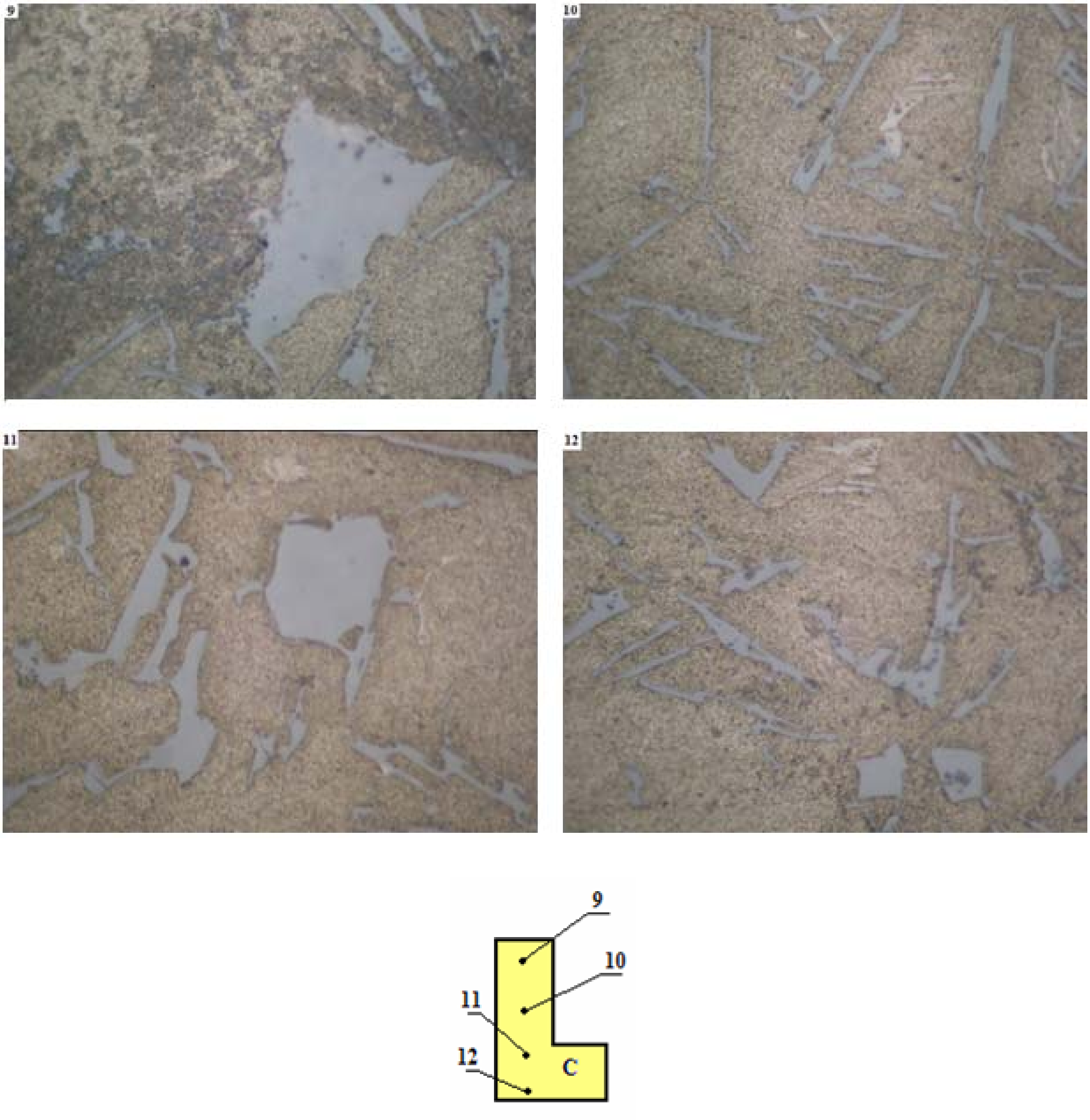

Fig. 9. Microstructures of composite (magnification 600x): C) AlSi11 – NiCr-Cr_3C_2-TiC. Visible grey and oblong silicon crystals emitted from solution on background eutectic mixture α+Si and big grey primary silicon crystals. In microstructures 9 and 12 is the biggest content reinforcing phase (dark cluster). Reinforcing phases type Cr_xC_y and TiC in matrix of powders.

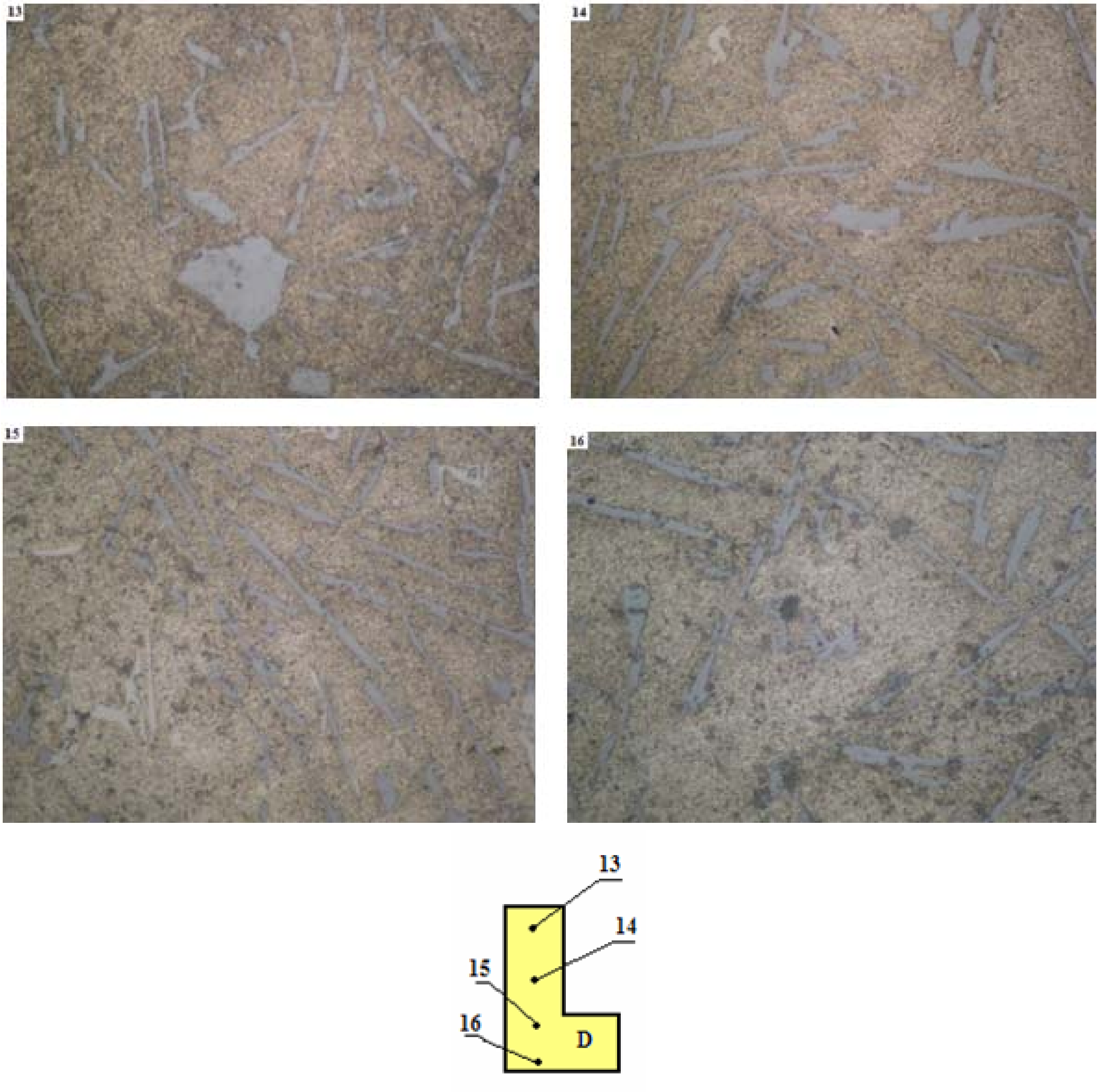

Fig. 10. Microstructures of composite (magnification 600x): D) AlSi11 - CrFe33C7. Visible grey and oblong silicon crystals emitted from solution on background eutectic mixture α+Si and big grey primary silicon crystals. In microstructures 13 and 16 is the biggest content reinforcing phase (dark cluster). Reinforcing phases type Cr_xC_y in matrix of powders.

Received effect performed initial investigations was admited from sufficient to continuation study. However advisable is quantitative analysis to influence parameters magnetic field on the structure. In the futures investigations plan is analysis phase composition fragments of structure in purpose disclosure structural components.

4. Conclusions

Action rotating magnetic field for cast composites caused non-uniform spacing reinforcing phases and segregation components in obtained casts. Control to parameters of magnetic field for solidification cast composites is possibility use technologies shown in article to produce gradients composites. Casting in rotating magnetic field could be equally effective in produce gradients composites like centrifugal casting.

However the purpose this investigation was another and results of investigation disclosed positive influence active rotating magnetic field for distribution participles in composites matrix.

In the future investigation is predict change parameters of magnetic field and substitution rotating magnetic field to reversion field in purpose to correct distribution of participles in alloy matrix through cyclical change direction rotating of liquid suspension (fig. 6).

Presented technological process to manufacturing ex-situ composite create the realizability to selection different reinforcing participles according to technological and consumption needs. Definition structure manufactured compositions with use quantitative analysis allow to effective definition influence magnetic field for advisably distribution and dispersion reinforcing phases in metal matrix. Subject of next investigation will be also correction technological parameters and composites structure for optimization properties resistances and tribology.

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