

**ALUMINIUM MATRIX CAST COMPOSITE (AMCC) WITH
HYBRID REINFORCEMENT**

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ABSTRACT

The process of producing and the structure of aluminium matrix cast composites with composite powders containing chromium and titanium carbides has been presented in the article. The reinforcing phases were obtained by means of NiCr-Cr₃C₂-TiC powder mixtures formed during self-propagating high-temperature synthesis process.

A composite alloy was produced by casting methods (mechanical mixing and centrifugal casting) after which its structure was determined. The designed process allows for the structure modification of the applied casting aluminium alloys in different technological variants.

Key words: aluminium alloy, intermetallic and ceramic phases, casting methods structure.

1. INTRODUCTION

Among the methods of *in situ* composites production the powder metallurgy and casting technologies are used [1-12]. By casting methods, Al, Ti, Cu, NiAl or TiAl based composites can be obtained with dispersion particles: TiC, TaC, ZrC, B₄C, SiC TiB₂, Si₃N₄, AlN, BN, and Al₂O₃, whose size, depending on the production technology, ranges between 0.1 and a dozen or so μm, with a volume fraction of 5÷55%. In the literature data, there are only some signals about aluminium composites containing

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carbide phases different than silicon carbide, aluminium carbide or titanium carbide [1-3,5,13-16]. There is no information, however, about the production and application of two carbide phases for hybrid reinforcement of aluminium alloys.

It has been assumed in own investigations that chromium and titanium carbides, due to their physicochemical properties, can form effective reinforcement in composite aluminium alloys, in particular those intended for centrifugal casting of products. The Cr_3C_2 chromium carbide with a NiCr matrix in the form of powder is most often used for plasma or supersonic spraying of coatings of high wear resistance, e.g. abrasive or erosion resistance at ambient and elevated temperatures [11,12,17,18]. Chromium carbide coatings are intended for use in power installations up to a temperature of 800°C . Titanium carbide, which has higher microhardness (32HV_μ) compared to the chromium carbide Cr_3C_2 (13HV_μ), should enhance the tribological properties of products.

The application of a composite NiCr/ Cr_3C_2 -TiC powder for the modification of the Al-Mg alloy is the subject matter of the technological and structural investigations presented in this paper. It was assumed that due to the difference in the density of chromium and titanium carbide phases, it would be possible to form casts with a layered structure and hybrid reinforcement [9]. The content of a solid solution NiCr 80/20 in the chemical composition of a composite powder should undergo dissolution in an aluminium alloy, where an additional, dispersion reinforcement from Al-Ni or Ni-Cr-Al intermetallic phases will be formed [19]. The final structure of the cast will be also influenced by stability of the carbide phases in the dissolved Al-Mg alloy.

2. PURPOSE AND SCOPE OF RESEARCH

The goal and scope of the research has been determined based on literature data, own investigations and the assumptions made. To accomplish the principal purpose of the research were determination of the application possibility of composite powders intended for thermal spraying processes for the modification of aluminium casts. The principal purpose of the research was to determine the technological conditions and parameters of the production of an aluminium matrix cast composite with chromium and titanium carbides.

It was assumed that the planned research cycle should provide information whether:

- carbides included in the chemical composition of a composite powder retain their morphology and phase composition during the process of liquid aluminium mixing, and subsequent remelting and centrifugal casting;
- agglomerates of the composite NiCr/ Cr_3C_2 -TiC powder undergo partial solubilization and phase transition to phases with aluminium share;
- composite powders introduced into a liquid alloy of aluminium with magnesium are wetted;

- the incorporation of composite powders containing carbides of high density will allow the formation of an external layer of the cast with an increased amount of reinforcing phases.

The scope of the research included:

- determination of the structure and phase composition of a powder with chromium and titanium carbides,
- fabrication of a composite with an aluminium matrix and carbides
- determination of the structure and phase composition of the composite,
- fabrication, in a centrifugal casting process, of a composite with a layered distribution of reinforcing phases and determination of its structure.

3. EXPERIMENTAL MATERIALS AND METHODS

As the matrix material for the produced composites, a casting alloy of aluminium and magnesium, AlMg10 (AG10), was used. A composite powder containing chromium and titanium carbides as well as a phase of solid solution NiCr (NiCr/Cr₃C₂-TiC) were used to form the composites. The composite powder was obtained in the self-propagating high-temperature synthesis (SHS) [11,12]. The phase composition and structure of the powder used for the modification of the matrix alloy are shown in Figure 1.

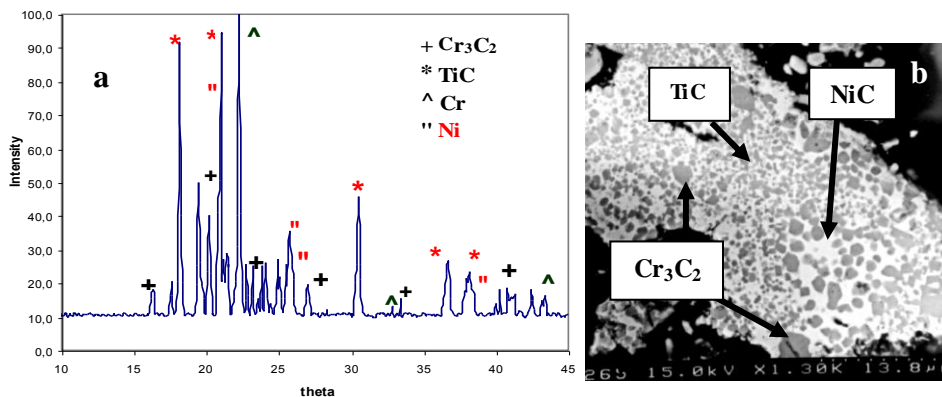


Fig. 1. Diffraction pattern a) and the structure b) of NiCr-Cr₃C₂-TiC powder mixture used for the matrix alloy modification, the powder surface, polished section, SEM.

Rys. 1. Dyfraktogram a) i struktura mieszaniny proszków NiCr- Cr₃C₂-TiC użytej do modyfikacji stopu osnowy, powierzchnia proszku, zgląd, SEM

The composite powder, 20-40 μm in size, was incorporated into mechanically mixed liquid aluminium in the range of temperatures from 720⁰C to 740⁰C [9]. Thus obtained composite suspension was subjected to mixing for 10 minutes and then cast

into a graphite mould. By this method, casts of a different composite powder volume fraction were formed: 15, 7.5 and 5%, respectively. Material for structural investigations was sampled from the composites obtained. Next, composite ingots were remelted and cast into a rotating mould in order to obtain centrifugal casts [13,14]. The structure of the powders and composite casts was analyzed using optical and scanning microscopy as well as an X-ray phase analysis.

4. THE RESEARCH RESULTS

The phase composition and the heterophase structure of the cast obtained as a result of incorporating the composite NiCr-Cr₃C₂-TiC powder into the AlMg10 alloy are presented in Figure 2.

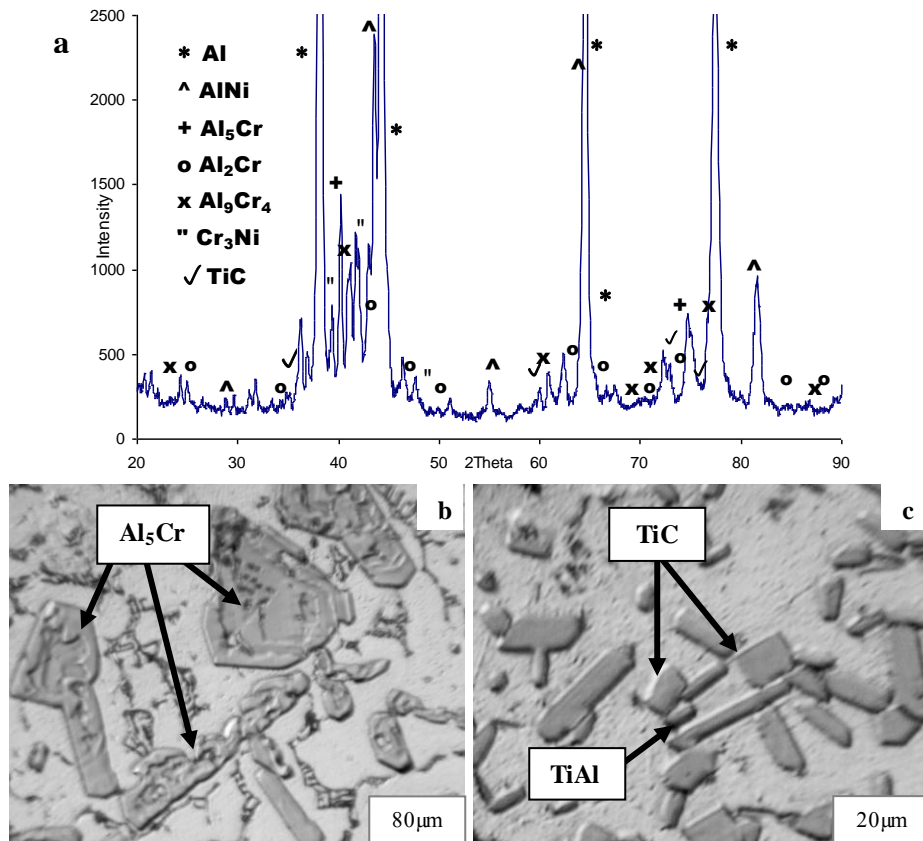


Fig. 2. The diffraction pattern a) and the structure of aluminium cast composite with hybrid reinforcement after gravitational casting, OM, b), c).

Rys. 2. Dyfraktogram a) i struktura kompozytu aluminiowego ze zbrojeniem hybrydowym odlewane grawitacyjnie, MŚ, b), c).

Based on structural investigations and X-ray analysis, presence of phases of varied dispersion, morphology and chemical composition in the aluminium matrix was corroborated (Fig. 2,3).

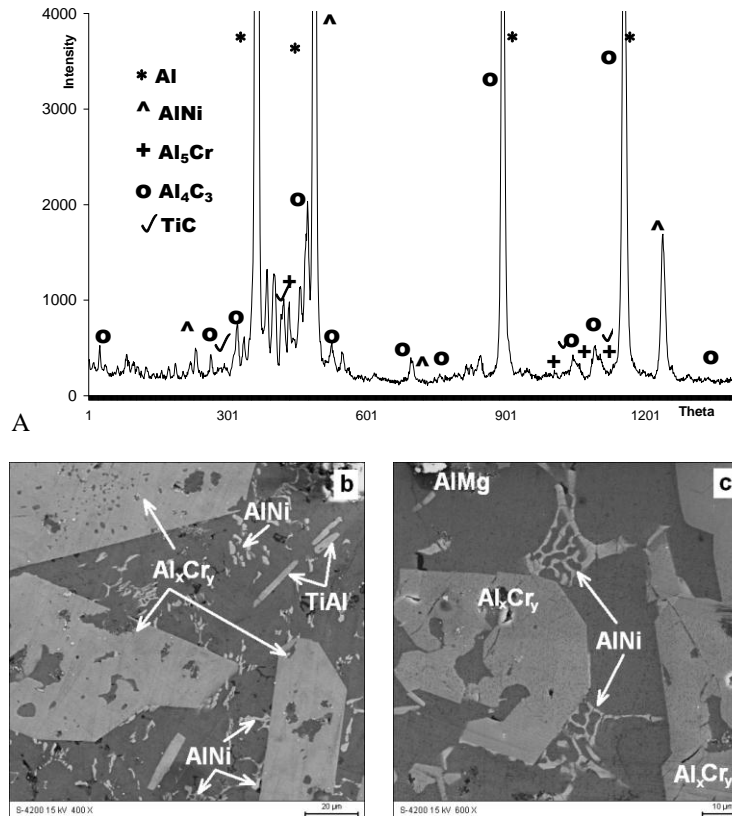


Fig. 3. The diffraction pattern a) and the structure of aluminium cast composite with hybrid reinforcement after gravitational casting, SEM, b), c).
Rys. 3. Dyfraktogram a) i struktura kompozytu aluminiumowego ze zbrojeniem hybrydowym odlewanego grawitacyjnie, SEM, b), c).

The X-ray analysis of the phase composition of the casts shows low corrosion resistance of titanium carbide in the AlMg10 alloy and its transition to a AlTi phase. The X-ray investigations also corroborated the occurrence of the Al₄C₃ carbide [1,5]. The precipitations formed in the dissolution process, larger than the chromium carbide grain in the composite powder, are phases of Al₅Cr and Al₂Cr type, whereas the binding NiCr matrix in the composite powder is reactive in melted aluminium, causing destruction of its shape and formation of NiAl phases (Figs 3,4).

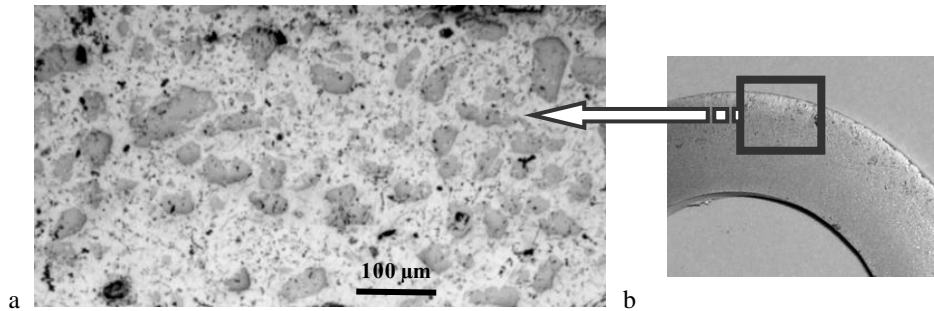


Fig. 4. The structure of aluminium cast with reinforcement phases obtaining by the centrifugal casting: a) structure of outside layer, OM, b) macrostructure.

Rys. 4. Struktura kompozytu aluminiowego z fazą zbrojącą uzyskanego przez odlewanie odśrodkowe a) struktura warstwy zewnętrznej, MŚ, b), c).

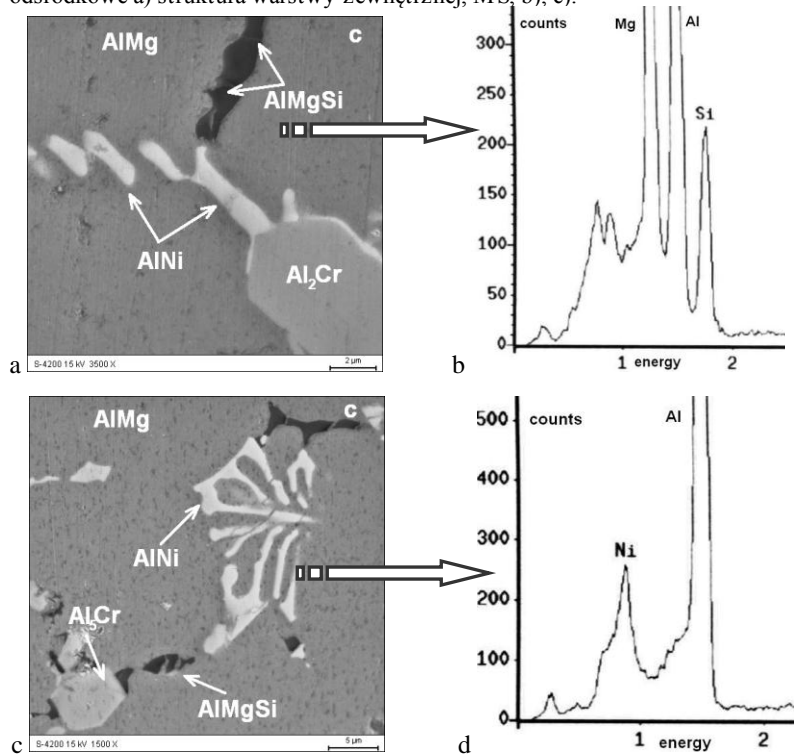


Fig. 5. SEM micrograph of aluminium composite with reinforcement phases after centrifugal casting, a), c); the AlMgSi eutectic qualitative analysis, EDS, b); the AlNi eutectic qualitative analysis, EDS, d).

Rys. 5. Zdjęcie SEM kompozytu aluminiowego z fazą zbrojącą uzyskanego przez odlewanie odśrodkowe a),c); analiza jakościowa eutektyki AlMgSi, b); analiza jakościowa eutektyki AlNi.

5. CONCLUSIONS

The investigations carried out have corroborated that there is a technological possibility of producing composite casts with aluminium matrix and hybrid reinforcement by incorporating the NiCr-Cr₃C₂-TiC powder in the composite alloy. Bearing in mind the properties of melted aluminium composite and the technological parameters of the centrifugal casting process [9], it seems beneficial to produce an alloy with a 7.5% fraction of reinforcing phases (Fig. 3,4). The AlMCs thus obtained characterize with a structure of a varied dispersion of phases, which were formed as a result of carbides and NiCr dissolution in the aluminium matrix.

At this stage of the research, the obtained results show that it is purposeful to produce aluminium composites with hybrid reinforcement by combining the processes of powder metallurgy and casting methods. In the on-going research, a correction of the technological parameters of composites production is taken into account and investigations of the mechanical and tribological properties are performed. The presented results are part of a wider research project investigating the influence of the type of reinforcement and its phase composition on the structure and properties of heterophase cast composites with an aluminium matrix [5-9].

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**ODLEWANY KOMPOZYT ALUMINIOWY (AMCC)
Z HYBRYDOWYM UMCNIENIEM**

STRESZCZENIE

W artykule przedstawiono proces otrzymywania i strukturę odlewanych kompozytów aluminiowych z kompozytowymi proszkami zawierającymi heterofazowe umocnienie w postaci węgla chromu i tytanu. Fazy zbrojące otrzymano stosując mieszaninę proszków kompozytowych typu NiCr-Cr₃C₂-TiC uzyskaną w procesie samorozwijającej się syntezy wysokotemperaturowej (SHS).

Stopy kompozytowe wytworzono metodami odlewniczymi (mechanicznego mieszania i odlewania odśrodkowego) i przebadano ich strukturę. Opracowany proces wytwarzania kompozytów pozwala w różnych wariantach technologicznych na modyfikację struktury stosowanych odlewniczych stopów aluminium.

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