METHOD OF PREPARATION OF BLEND FOR ALUMINIUM MATRIX COMPOSITES BY HIGH VOLTAGE ELECTRIC DISCHARGE

МЕТОД ПОДГОТОВКИ ШИХТЫ АЛЮМОМАТРИЧНЫХ КОМПОЗИТОВ ВЫСОКОВОЛЬТНЫМ ЭЛЕКТРИЧЕСКИМ РАЗРЯДОМ

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Abstract. Changes of dispersity, form factor and phase composition of powder mixtures of 75 % Ti + 25 % Al, 50 % Ti + 50 % Al, and 25 % Ti + 75 % Al mass compositions after treatment by high voltage electric discharge in kerosene are experimentally studied. Regularities of their dispersion and synthesis of TiC, $AlTi_3$, AlTi, Al_2Ti, Al_3Ti, double carbide Ti_3AlC, MAX-phases Ti_3AlC_2 and Ti_2AlC, Lonsdaleite are found.

KEY WORDS: HIGH VOLTAGE ELECTRIC DISCHARGE, POWDER METALLURGY, BLEND PREPARATION, ALUMIMIUM MATRIX COMPOSITES, PHASE COMPOSITION, SYNTHESIS, DISPERSION

1. Introduction

Creation of new highly wear-resistant dispersion-hardened by nanoparticles composite materials, based on Ti – Al system, which have increased physical, mechanical and performance characteristics for work at extreme conditions, is necessary for development of aerospace industry. Such composites can only be created by the usage of prospective methods of powder metallurgy.

2. Preconditions and means for resolving the problem

Properties of materials, obtained by methods of powder metallurgy, are highly dependent on dispersity and phase composition of initial powders blend [1]. It is known that mechanical and physical methods are used for preparation of blend for metal matrix composites (MMC). But mechanical methods of blend preparation have serious drawbacks, including oxidation and contamination of powder by milling bodies material. High voltage electric discharge (HVED) is one of physical methods of blend preparation [2, 3] which doesn't lead to contamination of powder. HVED in "hydrocarbon liquid – powder" disperse systems excludes oxidation and leads to destruction of hydrocarbons molecules inside HVED channel and microplasma channels between powder particles. Synthesized nanocarbon particles interact with particles of processed powder which leads to synthesis of dispersion-hardening carbide phases [4, 5].

The goal of present work is to study the changes of morphology and phase composition of Al – Ti powder mixtures of different mass composition after HVED treatment.

2.1 Methods of studies

Powder mixtures of Ti – Al system of such mass compositions: 75 % Ti + 25 % Al, 50 % Ti + 50 % Al, and 25 % Ti + 75 % Al, were treated by HVED in kerosene. Selection of Ti and Al percentage was justified by the necessity of preparation of blend for aluminum-matrix composites 50 % Ti + 50 % Al and 25 % Ti + 75 % Al as well as of synthesis of Titanium nanolaminates (MAX-compounds) 75 % Ti + 25 % Al. Studies were conducted on experimental stand, described in detail in work [2]. Treatment of all considered powder mixtures was performed at single discharge energy W_1 = 0,5 kJ and variation of specific treatment energy which ensure synthesis of nanocarbon in quantity necessary for synthesis of high-modulus fillers and MAX-phases according to [2, 3, 4, 5, 6]. Value of specific energy was 3.33 MJ/kg for 25 % Ti + 75 % Al composition, 6.66 MJ/kg for 50 % Ti + 50 % Al composition, and 10 MJ/kg for 75 % Ti + 25 % Al composition.

Two main types of electrode systems, namely point – plane and multipoint anode – plane in two variations (3 points and 15 points), were used during experiments (see Fig. 1). As it was shown in work [7], changing construction of electrode system (ES) from point – plane to multipoint – plane allows controlling distribution of plasma formation in the volume of processed powder, which promotes intensification of erosion and hydrodynamic dispersion processes and synthesis of chemical compounds during HVED treatment.

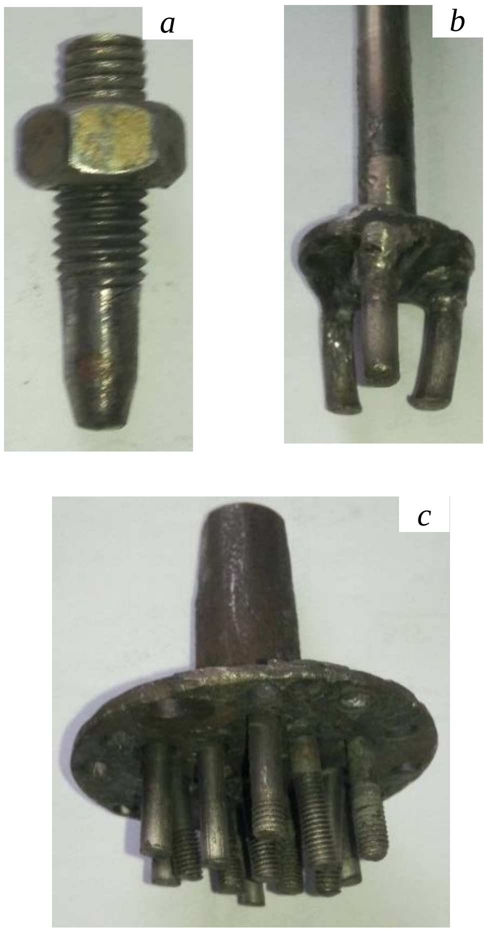

Fig. 1 – Exchangeable anodes of ES, used during studies: a – point – plane; b – 3 points variation of ES; c – 15 points variation of ES

Oscillograms of discharge current and voltage were registered during studies and transferred on personal computer, where electric and hydrodynamic characteristics of discharge (including current rise rate and pressure wave amplitude) were evaluated with MathCAD 14 software basing on methods, described in [2]. Value of current rise rate in selected treatment regimes was in range from 8 up to 14 GA/s, and amplitude of pressure wave on the wall of discharge chamber was around 100 MPa.

Powders were studied before and after HVED treatment. Methods of studying size and morphology of powders are described in detail in work [2]. Following software and equipment was used in studies: BIOLAM-I optical microscope with × 1350 maximal magnification, REMMA-102 raster electron microscope with magnifications range from × 10 up to × 250000, scanning electron microscope EVO-50 (Carl Zeiss, Germany) with magnifications range from × 10 up to × 1000000, Canon digital photo camera. After obtainment of sharp picture of studied powders on optical microscope, magnification was fixed and photos were made, which were subsequently processed on Adobe Photoshop CS3 software for further analysis with Image-Pro Plus 6.0 software. Basing on this analysis, differential distributions of powder particles by size were plotted. X-ray diffraction analysis of powders before and after treatment was conducted on X-ray diffractometers Bruker D8 DISCOVER, Rigaku Ultima IV and DRON-3 in Cu-K_{α} radiation. Bruker: EVA software was used for phases identification.

3. Results and discussion

HVED treatment in all studied regimes and impact schemes leads to dispersion of treated mixtures particles (see Fig. 2). Distribution of particles by size from initially bimodal becomes monomodal after treatment. Usage of 3 points ES for HVED treatment of mixtures of 25 % Ti + 75 % Al composition with specific energy of 3.33 MJ/kg and of 50 % Ti + 50 % Al composition with specific energy increased to 6.66 MJ/kg allows obtainment of better results in terms of dispersion than usage of single point and 15 points ES (see Fig. 2, a, b).

Main peak of size distributions of 25 % Ti + 75 % and 50 % Ti + 50 % Al powder mixtures in this case moves to point of ~ 3 µm and is ~ 64 %, while about 30 % of particles have sizes less than 1 µm. In case of treatment of mixture of 75 % Ti + 25 % Al composition with specific energy of 10 MJ/kg main peak of distribution moves to point of ~ 3 µm, ~ 51 %, while about 20 % of particles have size less than 1 µm.

The largest portion of initial particles (~ 40 %) for all studied Ti – Al system mixtures had sponge-like shape. HVED treatment with the use of single point electrode system leads to the increase of fragment shape particles content and to the decrease of spherical shape particles contents for all considered mixtures. In our opinion, this is connected to predominant hydrodynamic impact of HVED.

Use of 3 points ES in all considered cases leads to the increase of spherical shape particles by ~ 5 %, which can be explained by the intensification of electric current processes that leads to electric erosion of particles during HVED treatment. Use of 15 points ES doesn't have significant impact on particles shape.

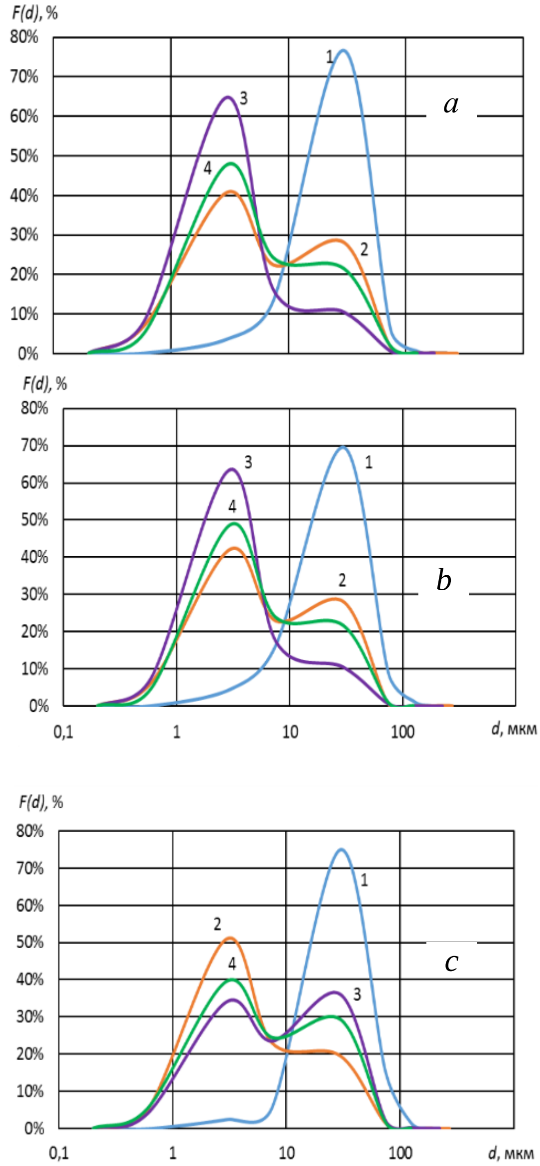

Fig. 2 – Distributions of particles of Ti – Al system powder mixtures by size: 1 – initial mixture; 2 – single point ES; 3 – 3 points ES; 4 – 15 points ES; *a* - 25 % Ti + 75 % Al (3.33 MJ/kg); *b* – 50 % Ti + 50 % Al (6.66 MJ/kg); *c* – 75 % Ti + 25 % Al (10 MJ/kg)

X-ray diffraction studies of all initial mixtures indicated the presence of titanium and aluminum peaks (see Fig. 3, a). Changes of dispersion and shape of particles after HVED treatment is accompanied by changes of their phase composition. HVED treatment of 75 % Ti + 25 % Al powders mixture with 3 points ES, in particular, leads to the synthesis of such compounds as TiC, $AlTi_3$, AlTi, Al_2Ti, Al_3Ti, Ti_3AlC double carbide, Ti_3AlC_2 and Ti_2AlC, Lonsdaleite (see Fig. 3, b).

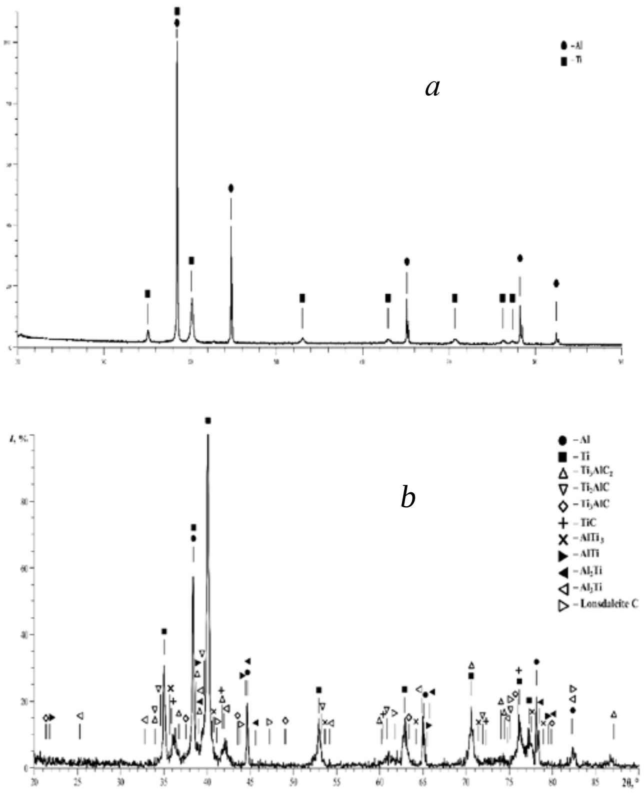

Fig. 3 – X-ray diffraction specters of 75 %Ti + 25 % Al; *a* – initial powder mixtures; *b* – after HVED treatment with W_{sp}= 10 MJ/kg, 3 points electrode system

Blend, treated with the use of 15 points ES, contains less intermetallic compounds, titanium carbide and MAX-phases. Powder mixtures, treated with the use of single point electrode system has the least quantity of new-formed compounds and is the closest in composition to the initial blend.

4. Conclusions

It is experimentally found out, that HVED treatment of Ti – Al powder systems of 75 % Ti + 25 % Al, 50 % Ti + 50 % Al and mass composition 25 % Ti + 75 % Al in kerosene leads to their dispersion, while main peak of size distribution moves to point of ~ 3 µm and no less than 20 % of particles have size less than 1 µm.

The possibility of efficient control of the impact of different factors of HVED treatment on Ti – Al powders system aimed at directed synthesis of dispersion-hardening components (titanium carbide TiC, intermetallic compounds $AlTi_3$, AlTi, Al_2Ti, Al_3Ti, Ti_3AlC, MAX-phases Ti_3AlC_2 and Ti_2AlC, and Lonsdaleite) by changing the configuration of electric field due to usage of different ES types, is shown.

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