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PULSE DISCHARGE PREPARATION OF AL–TI–C SYSTEM GRAIN REFINER FOR MODIFICATION OF MELTS

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Adding grain refiners into melt is one of the traditional methods of obtaining fine-grained metal structures. The more nuclei there are per unit volume of melt, the more crystals are formed and the smaller they are. In turn, lower grain size leads to better mechanical properties of metal in foundry and welding. The study of the efficiency of nanomodification in welding and surfacing technologies by introducing nanoparticles of refractory chemical compounds into the welding bath are urgent tasks of materials science and engineering practice [1].

Most grain refiners are made using powder metallurgy methods, and ultrafine nanostructured powder mixtures are the most promising for use. Currently, the main directions of development of methods of obtaining such mixtures are as follows [2–4]:

a) improvement of existing equipment and technological processes, based on common mechanical methods of materials grinding;

b) search for fundamentally new ways of grinding, research, and development of effective types of equipment and technology, based on them.

The first direction aims to the increase of the efficiency of destruction and specific productivity as well as to improve existing and create new machines (crushers and mills) with increased productivity [3]. This direction has significant drawbacks, including increased energy consumption, the metal consumption of constructions, the use of expensive high-quality steels and alloys, accompanied by relatively low growth of technical and economic indicators.

The second direction aims to find fundamentally new grinding methods, particularly, electrophysical ones [5–7]. Pulse discharge preparation of powders by high-voltage electric discharge (HVED) in a dispersed system "liquid – powder" is one of the efficient electrophysical methods. This is a cyclic process, which is characterized by the release of energy in the discharge channel for microseconds and is accompanied by the impact of compression waves (which under certain conditions transform into shock waves), powerful hydraulic streams, cavitation, electromagnetic and thermal fields.

In [2], on the example of the application of the grain refiner during casting, it was shown that the introduction of 0.01% (wt.) Ti – TiC powder (which was synthesized by HVED treatment on Ti powder in kerosene and briquetted by spark plasma sintering) allowed reducing grain size from 1–2 mm to 0.2–0.6 mm in all modified samples of SM88U high-temperature alloy. The tensile strength of studied specimens at a temperature of 900°C was 65–69 MPa, and long-term strength increased by an average of 20%. This indicates the prospects of using metal powders after HVED treatment to modify the structure of cast alloys.

However, the possibility of using metal powders after HVED treatment to modify the structure of the weld metal, similar to cast, has not been sufficiently studied. To establish the prospects of using such powders, it is advisable to analyze the impact of adding the grain refiner of Ti–Al–C system after HVED synthesis on the grinding of the structure and improvement of the properties of $AK7_{pch}$ (A357) cast alloy.

Modification of aluminum alloys was studied on the example of silumin and involved the production of fine-grained eutectic silicon in a cast structure. This structure of eutectic silicon increases the mechanical properties of the casting, including the elongation, and in many cases – the casting properties of the aluminum melt. Typically, silumin modification is performed by adding small amounts of sodium or strontium [8].

To study the effect of the grain refiner on the crystallization of A357 cast aluminum alloy, a powder blend, obtained by HVED treatment of a mixture of powders of 15% Al + 85% Ti with initial average diameter $d_a = 40$ μm in kerosene, was used. The studies were performed on an experimental stand, described in detail in [5, 6, 9].

During the HVED, conditions for pyrolysis of kerosene with the formation of solid-phase nanocarbon are created. Pressure in the discharge channel reaches 1 GPa, and the temperature in the discharge channel can reach 50,000 K. Synthesized carbon nanoparticles of various allotropic modifications, in particular, C60 and C70, are able to chemically interact with titanium particles, forming nanostructured reinforcing carbide phases [5–7; 9; 10]. Therefore, HVED treatment of Al – Ti system powders in kerosene, in addition to grinding, allows the synthesis of titanium carbide and Ti_3AlC and Ti_2AlC phases without adding graphite during powders preparation.

After HVED processing in the mode with single discharge energy $W_1 = 1$ kJ and specific treatment energy $W_s = 20$ MJ/kg using an electrode system of “three-points anode – plane” type, the powder mixture contains the following phases: Al, Ti, TiC, Ti_3AlC + Ti_2AlC.

The powder mixture of the initial composition of 85% Ti + 15% Al after processing has an average particle size of about 10 μm, with a peak value of the number of particles with a diameter of 5 μm about 37%. The particle size distribution has a bimodal appearance, approximately 30% of the particles of the mixture retain a size close to the original.

The control sample of cast alloy has a cavity depth of 4 mm. The area of columnar grains is about 10 mm, their width is 2–6 mm. The center of the casting is dominated by grains of 2–8 mm size. The sample that was modified by 0.2% (wt.) AlTiB has a cavity depth of 3 mm. The area of columnar grains is about 1.5 mm, their width is up to 1 mm. The macrostructure is quite homogeneous, the grain size is in range from 1 mm to 2.5 mm. Casting, modified by 0.2% (wt.) HVED processed mixture, has a cavity shell, which reaches 3 mm, subsidence looseness is almost absent, the area of columnar crystals is up to 5 mm, width is from 1.5 to 2 mm, grain size is 1.5–3.5 mm.

The hardness of the control sample was 48 HB, and for modified by AlTiB and HVED treated mixture it was 36 and 48 HB, respectively.

Studies of the change in the tensile strength (σ_b) and yield strength ($\sigma_{0.2}$) of the modified samples show that unlike to the modification by 0.7% (wt.) AlTiB, the addition of 0.2% (wt.) of powder mixture of Al – Ti – C system after HVED treatment does not reduce these characteristics compared to the control sample.

Conclusions.

1. The possibility of using particles of metal powders treated by HVED in hydrocarbon liquid for the modification the structure of welds is shown.

2. It is shown that the addition of the mixture of powders obtained from the initial composition of 15% Al + 85% Ti by HVED treatment in kerosene as a grain refiner allows influencing the structure and properties of the cast aluminum alloy $AK7_{pch}$ (A357).

References:

1. Tashev P., Alexiev N., Manolov V., Cherepanov A.N. Modifying the liquid phase with nanoscale powders in the process of welding and cladding. *The Research of the Science City*. 2017. Vol. 1, No. 1. P. 16–21.

2. Syzonenko O. M. , Prokhorenko S. V., Lypyan E. V., et al. Pulsed discharge preparation of a modifier of Ti–TiC system and its influence on the structure and properties of the metal. *Materials Science*. 2020. Vol. 56, No. 2. P. 232–239. DOI: 10.1007/s11003-020-00421-1.

3. Syzonenko O.M., Prystash M.S., Zaychenko A.D. Vykorystannya vysokokontsentrovanykh potokiv enerhiyi v poroshkoviy metalurhiyi dlya otrymannya karbidostaley [The use of highly concentrated energy flows in powder metallurgy for the production of sintered carbide steel]. Kyiv: Naukova dumka, 2020. 150 p.

4. Hong S.-M., Park J.-J., Park E.-K., et al. Fabrication of titanium carbide nano-powders by a very high speed planetary ball milling with a help of process control agents. *Powder Technology*. 2015. Vol. 274. P. 393-401. DOI: 10.1016/j.powtec.2015.01.047.

5. Sizonenko O., Vovchenko A. Pulsed discharge technologies of processing and obtainment of new materials (Review). Machines. Technologies. Materials. 2014. Vol. 8, No. 12. P. 41–44. URL: https://stumejournals.com/journals/mtm/2014/12/41.

6. Sizonenko O.N., Baglyuk G.A., Raichenko A.I., et al. Variation in the particle size of Fe–Ti–B_4C powders induced by high-voltage electrical discharge. *Powder Metallurgy and Metal Ceramics*. 2012. Vol. 51, No. 3/4. P. 129–136. DOI: 10.1007/s11106-012-9407-4.

7. Sizonenko O. N., Baglyuk G. A., Raichenko A. I., et al. Effect of high-voltage discharge on the particle size of hard alloy powders. *Powder Metallurgy and Metal Ceramics*. 2011. Vol. 49, No. 11/12. P. 630–636. DOI: 10.1007/s11106-011-9280-6.

8. Gumiennya G., Szymczaka T., Pacyniaka T. Effect of modification on characteristic values of TDA curves. *Archives of Foundry Engineering.* 2014. Vol. 14, No. 1/2014. P. 91–96.

9. Sizonenko O., Prokhorenko S., Torpakov A., et al. The metal-matrix composites reinforced by the fullerenes. *AIP Advances*. 2018. 085317. DOI: 10.1063/1.5031195.

10. Sizonenko O.N., Grigoryev E. G., Pristash N. S., et al. Plasma methods of obtainment of multifunctional composite materials, dispersion-hardened by nanoparticles. *High Temperature Materials and Processes*. 2017. Vol. 36, No 9. P. 891–896. DOI: 10.1515/htmp-2016-0049.

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ВПЛИВ ПЕРЕДРЕКРИСТАЛІЗАЦІЙНОЇ ТЕРМІЧНОЇ ОБРОБКИ НА МЕХАНІЧНІ ВЛАСТИВОСТІ ТА ЩІЛЬНІСТЬ ДИСЛОКАЦІЙ СТАЛЕЙ

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Сучасне машинобудування характеризується підвищеною інтенсивністю режимів експлуатації деталей машин і механізмів. Це вимагає постійного вдосконалення вузлів і агрегатів щодо забезпечення достатньої їх надійності та довговічності. Експлуатаційні