INVESTIGATION OF ADDITIVE MANUFACTURING OF PARTS FROM MECHANICALLY ACTIVATED POWDER

Krinitcyn M.G.[1,2,a], *Pribytkov G.A.*[2,b] , *Baranovskiy A.V.*[1,2,c]

[1]National Research Tomsk Polytechnic University, Tomsk, 634050 Russia
[2]Institute of Strength Physics and Materials Science SB RAS, Tomsk, 634055 Russia
[a] krinmax@gmail.com, [b] gapribyt@mail.ru, [c] nigalisha@gmail.com

Composite materials with the structure consisted of disperse solid particles enclosed into a metal matrix (binder) are well-known to have a unique combination of hardness, strength, elasticity and wear resistance under abrasive wear and in tribological conjunctions [1, 2]. A specific example of such materials is tool hard alloys produced by sintering of disperse carbides and metal binder powder mixtures [3]. Moreover, the physical and mechanical properties and durability of composite materials are better-known to be primarily determined by the structure [3-5] (volume fraction, dispersion, and morphology of the strengthening phase).

Additive technologies allow you to create products of complex shape for a single technological cycle. The possibilities of additive technologies are much wider than those of classical technologies, but there is a very small list of materials on a metal base suitable for additive production. Technically, the technology of additive production of metal products is close to the technology of powder cladding or sputtering which are widely used [6-12].

In the present work, the structure of products obtained by Selective laser melting (SLM) and Electron beam melting (EBM) technologies using "TiC - Ti" composite powder has been studied. The composite powder was preliminarily mechanically activated in a high-energy ball mill of the planetary type in order to grind the structure of the powders. In addition, technological features of powder preparation and additive production processes are also described.

The MA process of powders was carried out in the planetary ball mill "Activator-2S". Composition of the initial composite powder "TiC + 50 vol. % Ti", additionally titanium was added to the charge to the total content of the titanium binder of 80 vol. %. The main task was not only to grind the carbide particles in the powder, but also the powder as a whole. The MA process was carried out at a drum rotation frequency of 960 rpm, a powder loading of 50 g, a "powder : ball" ratio was 1 : 1. The MA was carried out for various times in steps of 10 minutes up to 60 minutes, with a study of the fractional composition in each case.

It was found that after 30 minutes of MA the largest amount of fine powder is observed, in the future the powder adheres to powder particles exceeding the original size. A metallographic study of the composite powder was carried out after grinding for 30 minutes. After mechanical activation, it is possible to achieve an even distribution of carbide particles (light) in the titanium matrix (dark). In some particles of the powder, an increased amount of carbide particles is observed in the center and reduced in the periphery, but in general the distribution is uniform. Also, it is possible to effectively reduce the size of the carbide particles in the powder, but the powder particles themselves are not crushed. It should be noted that the shape of the powder after MA is close to spherical, which is important for the use of powder in additive technologies.

The obtained powder was used in laser and electron-beam melting technologies on the equipment of Tomsk Polytechnic University. Laser melting was carried out under the following operating conditions of 3D printer: radiation power is 200 W; scanning speed is 0.03 m/s; typical beam diameter at the sample surface is 200 μm; hatching is 150 μm; powder layer thickness is 100 μm; pressure of an inert gas (argon) in the chamber is 1.5 atm.; working area preheating temperature is 300 ° C. Electron beam melting operating conditions are the same with the exception of the pressure in the chamber and preheating - the EBM process was carried out in vacuum under pressure 5 · 10-3 Pa and preheating was performed using a defocused electron beam to a temperature of 700 - 800 ° C on each powder layer.

These operating conditions were selected in such a way as to ensure high homogeneity of the obtained samples in both technologies, while ensuring the equality of energy contributions to the surface of the powder. For this purpose, the area of high-energy beams, their speed of movement and effective power were the same.

Despite the proximity of energy inputs for the preparation of samples by different methods, the structure of the samples obtained differs. Carbide particles in the samples obtained by SLS have a shallower and disordered structure, whereas in EBM samples a dendritic structure up to the third order is formed in carbides. Presumably, this difference is associated with faster crystallization, which takes place in the process of selective laser melting, since to ensure sintering of the powder in EBM technology, it is assumed that the working region of the sample growth is continuously heated to a temperature of 700 - 800 ° C.

References

1. R.M. Jones, Mechanics of composite materials, Scripta Book Company Washington, DC1975.

2. I.M. Daniel, O. Ishai, I.M. Daniel, I. Daniel, Engineering mechanics of composite materials, Oxford university press New York1994.

3. H. Pastor, Titanium-carbonitride-based hard alloys for cutting tools, Materials Science and Engineering: A, 105 (1988) 401-409.

4. J.-C. Michel, H. Moulinec, P. Suquet, Effective properties of composite materials with periodic microstructure: a computational approach, Computer methods in applied mechanics and engineering, 172 (1999) 109-143.

5. J.P. Watt, G.F. Davies, R.J. O'Connell, The elastic properties of composite materials, Reviews of Geophysics, 14 (1976) 541-563.

6. I. Bataev, A. Bataev, M. Golkovski, D. Krivizhenko, A. Losinskaya, O. Lenivtseva, Structure of surface layers produced by non-vacuum electron beam boriding, Applied Surface Science, 284 (2013) 472-481.

7. I. Bataev, M. Golkovskii, A. Bataev, A. Losinskaya, R. Dostovalov, A. Popelyukh, E. Drobyaz, Surface hardening of steels with carbon by non-vacuum electron-beam processing, Surface and Coatings Technology, 242 (2014) 164-169.

8. M. Golkovski, I. Bataev, A. Bataev, A. Ruktuev, T. Zhuravina, N. Kuksanov, R. Salimov, V. Bataev, Atmospheric electron-beam surface alloying of titanium with tantalum, Materials Science and Engineering: A, 578 (2013) 310-317.

9. D. Hale, The physical properties of composite materials, Journal of Materials Science, 11 (1976) 2105-2141.

10. X.-W. Qiu, C.-G. Liu, Microstructure and properties of Al2CrFeCoCuTiNix high-entropy alloys prepared by laser cladding, Journal of Alloys and Compounds, 553 (2013) 216-220.

11. H. Zhang, Y. Zou, Z. Zou, D. Wu, Microstructure and properties of Fe-based composite coating by laser cladding Fe–Ti–V–Cr–C–CeO2 powder, Optics & Laser Technology, 65 (2015) 119-125.

12. Z. Ulrich, Titan und Titanlegirungen. 1974, Springer-Verlag.