ISSN 1062-8738, Bulletin of the Russian Academy of Sciences: Physics, 2016, Vol. 80, No. 8, pp. 1007–1008. © Allerton Press, Inc., 2016.
Original Russian Text © T.V. Tarasova, A.P. Nazarov, 2016, published in Izvestiya Rossiiskoi Akademii Nauk, Seriya Fizicheskaya, 2016, Vol. 80, No. 8, pp. 1098–1099.

Manufacturing Geometrically Complex Nozzle-Type Parts by Means of Selective Laser Melting

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Abstract—The possibility of manufacturing of such geometrically complex parts as nozzles via the selective laser melting of heat-resistant cobalt alloy is demonstrated. The mechanisms responsible for forming the structure of investigated alloys under the conditions of selective laser melting are characterized. The physicomechanical properties of the resulting parts are determined.

DOI: 10.3103/S1062873816080372

Modern engineering requires the manufacture of geometrically complex parts with robust physicomechanical properties [1]. Examples of such parts are the blades, nozzles, swirlers, seals, rings, inserts, and other parts of turbines and internal combustion engines. The aim of this work was to study the possibility of manufacturing nozzle-type parts by means of selective laser melting (SLM). Heat resistant alloys based on cobalt are promising alloys for engineering applications. In most cases, parts made of cobalt alloys operate at high temperatures and in aggressive environments. Parts manufactured via SLM using powdered materials based on cobalt alloys have high potential for use in engineering, since they combine the unique capabilities of SLM and the physicomechanical properties of cobalt alloys, i.e., the possibility of manufacturing unique geometrically complex parts without the use of five-axis machines and expensive equipment, particularly in the production of nozzle-type parts, and the ability to control the physicomechanical properties of the final product [2–4].

In this work, we selected a powder based on CoCrMo alloy that met the requirements for materials used in selective laser melting. This powder had good flowability (average sphericity, 67.1%; average roughness, 2.4%) allowing us to obtain layers 0.05 mm thick (particle size, 14.5–45.9 μm; average size, 30.5 μm).

The optimum parameters of selective laser melting for the investigated alloy were [5] protective atmosphere, nitrogen; laser radiation power, 200 W; mode of laser operation, continuous; laser wavelength, 1.07–1.06 μm; laser spot diameter, 150 μm; powder layer thickness, 50 μm; scanning rate, 400 mm/s; distance between passes of the laser beam, 100 μm; scanning strategy, two-band with a 90° change in direction from one layer to the next.

The characteristic SLM mechanisms responsible for the formation of the investigated alloy's structure were established. A high rate of cooling produced a nonequilibrium structure consisting of a supersaturated solid solution based on two modifications of cobalt: high temperature cubic and low-temperature hexagonal [6] (Fig. 1).

The physicomechanical properties of prototypes manufactured via SLM at the optimum parameters were density, 8.3 ± 0.1 g/cm^3; hardness, 42 ± 4 *HRC*; precision of linear dimensions, ±0.06 mm; surface roughness, *Ra* 8 ± 2 μm; yield point $\sigma_{0.2}$ = 1000 ± 150 MPa; tensile strength σ_u = 1250 ± 50 MPa; relative elongation, no less than δ = 6%; impact strength, *KCU* 21 ± 1 J/cm^2 [7]. Analysis of our data shows that the mechanical characteristics of samples were quite high, as is typical of alloys obtained as a result of laser processing with surface melting [8–11].

Compared to samples manufactured using traditional means of shaping, the rate of wear of samples

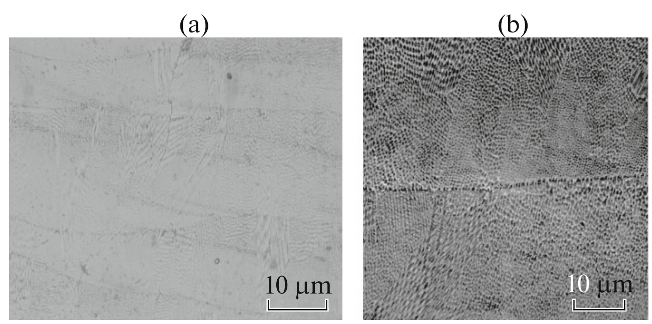

Fig. 1. Microstructure of samples obtained from CoCrMo powder via SLM. Magnification is (a) 500× and (b) 5000×.

(a) (b)

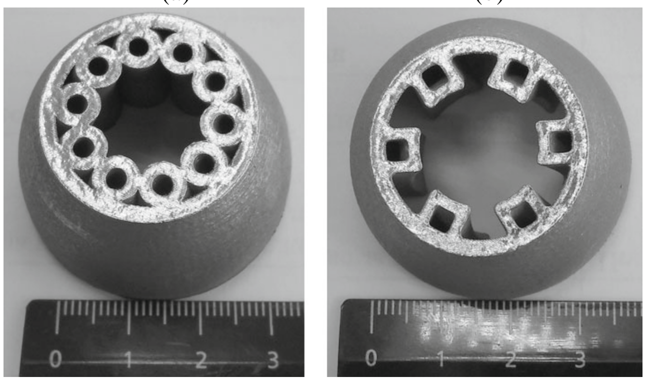

Fig. 2. Examples of nozzles manufactured via the selective laser melting of heat-resistant cobalt alloy.

manufactured via SLM was reduced by a factor of 1.7–1.5 under the conditions of abrasive wear [7].

Figure 2 shows the geometrically complex nozzle-type parts obtained by means of SLM in the proposed modes.

We have thus demonstrated the potential of SLM for manufacturing geometrically complex nozzle-type parts.

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Translated by V. Alekseev