ELECTRON BEAM SURFACE TREATMENT OF 3D-PRINTED TI-6AL-4V PARTS

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There is currently an increasing interest in automated intelligent post processing for metal additive manufacturing. The necessity for carrying out the thermomechanical post-treatment is related to heterogeneous structure of 3D–printed parts, the presence of metastable phases, the emergence of large amount of micropores and flaws induced by fast crystallization, directed solidification and phase transitions, with the latter resulting from repeating thermal cycles.

Continuous electron beam treatment can be successfully applied as post-processing techniques of 3D–printed components. During electron beam surface treatment simultaneous radiation, heat and impact treatment of the surface is accompanied by ultrahigh rates of heating (up to temperatures exceeding melting) and cooling ensure simultaneous roughness reduction, microstructure refinement in surface layers of 3D–printing parts as well as inducing the favorable residual compressive stresses, etc. The aim or this work is to study the effect of electron beam surface treatment on the surface morphology, microstructure and mechanical properties of Ti–6Al–4V parts manufactured by electron beam melting (EBM) process.

Ti–6Al–4V parts were built by EBM of titanium Grade 5 welding wire using an electron beam welding machine 6E400 (Teta, Russia). The electron beam welding machine was also used for the continuous scanning electron beam post-treatment of Ti–6Al–4V parts. A sawtooth signal with a frequency of 100-1000 Hz was used to turn the electron beam into a line of 27 mm length. The accelerating voltage and beam current were 30 kV and 10-60 mA, respectively. The focused electron beam with a spot of 0.5 mm in diameter treated the specimen surface line by line. The electron gun power and the specimen's movement speed were chosen to provide an energy density of 75-450 J/cm^2.

The effect of electron beam treatment on the surface morphology of 3D-printed Ti–6Al–4V parts was studied by a LEO EVO 50 scanning electron microscope and New View 6200 3D optical profiler. It is found that the melted surface layer of the EBM printed parts treated by continuous electron beams becomes more smoother in comparison with the as-build parts.

The phase identification and microstructural characterization of the samples in the plan-view and cross-section geometries were performed by a XRD-6000 diffractometer, a JEM-2100F transmission electron microscope and a LEO EVO 50 scanning electron microscope (SEM) equipped with EBSD and EDS detectors. The three-layer structure are formed in the surface layers of 3D-printed parts subjected to by continuous electron beam post-processing. The thicknesses of the outmost melted surface layer 1, underlying layer 2 and the heat-affected zone (the layer 3) are equal to 50, 60 and 400 μm, respectively. The equiaxial recrystallized grains of 15-20 μm size within layers 1 and 2 are observed. Inside the grains of layer 1, α-Ti and β-Ti fine plates collected in packets and oriented in the different directions. Within the recrystallized grains of layers 2 the bulk fraction of β-phase is lower, wherein the width of the α-Ti plates is higher. The $\alpha \rightarrow \beta \rightarrow \alpha$ phase transformation occurs within the α-grains of the heat-affected zone.

It is shown that the formation of 20 μm size prior β-grains with fine α- and β -lathes within the melted surface layer drastically increases in the surface microhardness of the 3D-printed Ti–6Al–4V parts from 3500 to 6800 MPa. Moreover, the surface hardening increases in tensile strength of the specimens.