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MICROSTRUCTURAL INHOMOGENEITY OF PHASE COMPOSITION AND GRAIN STRUCTURE IN ELECTRON BEAM WIRE-FEED ADDITIVE MANUFACTURED AISI 304 STAINLESS STEEL

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We investigated microstructural peculiarities in specimens of AISI 304 stainless steel fabricated by wire-feed electron beam additive manufacturing (EBAM). The EBAM processing was carried out in vacuum chamber under the following parameters: beam acceleration voltage 30 kV, beam current 16.5 mA, scanning frequency 1 kHz, wire-feed rate 200 mm/min, wire thickness 1 mm, ellipse scan 20 × 20 mm. The AISI 304 steel walls with linear dimensions of 5 × 30 × 100 mm were deposited using layer by layer building principle. A Quanta 200 3D scanning electron microscope equipped with electron back scattered diffraction (EBSD) supply was used to study the microstructure, grain size, and phase composition of the EBAM steel. The magnetophase analysis of the specimens (determination of the volume fraction of ferrite) was carried out using a multifunction vortex-current instrument MVP-2M (Kropus, Russia). Steel specimens were characterized in as-built condition and after post-built heat treatment at a temperature 1050°C for 1 h.

The structure of the as-built steel wall is not uniform in height. A layer structure caused by the deposition method was observed on the etched cross section surfaces of the wall. During the deposition every new layer remelts and solidifies on the top of the previous one. This leads to the formation of heat affect zones between deposited layers. The as-built AISI 304 steel wall exhibits solidified dendritic structure. The direction of the columnar dendrites corresponds with the build direction, which has the highest temperature gradient. The structure is continuous (without interruption at the interface between two deposited layers), but there are misorientations in heat affect zones between deposited layers. The as-built AISI 304 steel wall phase composition is a fine vermicular morphology of δ-ferrite within austenite matrix. The formation of vermicular δ-ferrite is due to the features of cooling rate of the EBAM method and the ratio Cr_{eq}/Ni_{eq}. The vermicular δ-ferrite lamella thickness varies in the range of 0.5–1.5 μm. The volume fraction of ferrite in the as-built wall is 20–25 %. The minimum values of the content of δ-ferrite are observed near the substrate. With an increase in the distance from the substrate, the fraction of δ-ferrite gradually increases, but the changes in the phase composition along the wall height do not exceed 5 %.

The grain structure of as-built AISI 304 steel wall is also heterogeneous. The large columnar grains are oriented along the growth direction and could cross the layers. The grain size varies according to the wall height: in the bottom part (near the substrate) the average grain size is 70 μm, in the top part ≈130 μm. Changes in grain size are due to the characteristics of heat dissipation and cooling rate during the deposition process.

Heat treatment at 1050°C for an 1 h leads to a change in the structure of δ-ferrite. Splitting of δ-ferritic colonies into individual dispersed precipitates is observed. The orientation of the colonies is lost, chaotic misorientations are observed, and the thickness of the δ-ferrite lamellae increases significantly. The volume fraction of δ-ferrite in the post-built heat-treated wall is about 2 times less. After heat treatment, austenitic grains have a more equiaxed form and their size *slightly* increase i*n comparison* with structure of as-built steel wall, but omogenizing effect of heat treatment on grain size, morphology, and orientation was not significant.

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