ADDITIVE MANUFACTURING AND THERMODYNAMICS

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Additive manufacturing technologies are used in various industries, including space, aviation, housing construction, instrument making, and other areas where there is a need for complex-geometry products made from existing and new materials. Functional products are created by layer-by-layer material growth, including direct metal deposition (DMD), surface laser sintering (SLM), and cold spray deposition (Cold Spray) from various materials.

When creating products using additive manufacturing methods, it is necessary to understand the physical, physicochemical, and other processes inherent to materials in various states (solid, liquid, etc.). To model these processes, laws and relationships used in thermodynamics are applied. Integrated modeling of materials based on the CALPHAD method (calculation of phase diagrams, modeling of material crystallization, heat treatment processes, diffusion, etc.) is widely used for additively manufactured products.

Micromodeling of additive manufacturing processes is also used, which involves calculating the distribution of powder particles of the used fraction across the powder bed and melting this layer with a laser at a specified power and pass rate to determine the temperature distribution.

Macromodeling, which calculates residual stresses and warpage of a product of a given shape based on the viscoplastic behavior of the material under specified layer-by-layer growth conditions, is also used. Thanks to comprehensive modeling of additive manufacturing processes occurring during the growth of products, it has become possible to produce products with complex geometries and internal cavities (for example, engine components with a cooling system), as well as to create unique composite and multilayer materials with a unique set of properties.

This paper presents the results of thermodynamic calculations in comparison with experimental data and presents optimization parameters for various materials obtained by additive manufacturing methods. The modeling of nonequilibrium crystallization of materials during double remelting of layers is presented.

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