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Alloy Compositions and Processing Methods to Enable Grain Boundary Engineering (GBE) during Laser Additive Manufacturing (AM)

Novel stainless-steel alloys with tailored compositions and heat treatments enable grain boundary engineering in laser AM parts for enhanced creep and corrosion resistance without deformation.

Researchers at Purdue University have developed a novel metal alloy composition, with accompanying processing methods and post-processing heat treatments, that enable grain boundary engineering (GBE) during laser additive manufacturing (AM) with stainless steel. This innovation marks the creation of a new class of AM alloys that offer unique microstructures and other properties. Conventional stainless steel compositions, including those produced by laser AM, contain connective grain boundary networks that provide easy paths for intergranular cracking, corrosion, and high temperature creep, reducing strength and longevity. This novel alloy composition, paired with laser AM and heat treatment, dramatically decreases grain boundary connectivity. Thus, these alloys are favorable for improving stress corrosion cracking (SCC) and high temperature creep resistance in final products in their use environments. This method has been shown to control abnormal grain growth/critical grain growth while achieving grain boundary engineering without any deformation, thus maintaining the intended additive-manufactured part geometry.

Technology Validation:

The alloy was developed with a novel composition including additive elements such as chromium (Cr), nickel (Ni), etc. with specified percentages by weight. The alloy composition was provided in both low-carbon and high-carbon versions. These were added to the stainless steel using prealloying, ball milling, or powder mixing. The alloy composition was fabricated using laser-based AM processes, including LPBF, Laser DED, laser welding, and laser cladding. Following AM fabrication, a heat treatment process enhanced grain boundary engineering, increasing the fraction of coincidence site lattice (CSL) boundaries. The method was found to achieve grain boundary engineering without deformation, thus maintaining the additive

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manufactured part geometry. The new alloy was found to have a high fraction of CSL boundaries and uniformly distributed precipitates, which are believed to be favorable for improving stress corrosion cracking (SCC) and creep resistance.

Advantages:

-Enables grain boundary engineering

-Controls abnormal grain growth and critical grain growth during additive manufacturing

-No deformation

-Improves SCC and high temperature creep resistance, therefore extending longevity

-Compatible with existing laser additive manufacturing methods (laser powder bed fusion, laser direct energy deposition, laser welding)

Applications:

-Laser additive manufacturing of stainless steel and the applications of those products:

-Nuclear power and reactors

-Human medical devices

-Oil and gas

-Aircraft engines

-Etc.

TRL: 4

Intellectual Property:

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