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NANOPARTICLE-MODIFICATION OF NICU-BASED ALLOY 400 FOR LASER POWDER BED FUSION

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Long Abstract

NiCu-based Alloy 400 is a material being frequently used in corrosive environments wherefore it is applied in several industries like the maritime sector or chemical processing [1]. Numerous functional parts made of this alloy, like heat exchangers or liquid-carrying tubes for instance, may withstand harsh environments to a certain extend but still, at high temperatures and especially in carbon-rich atmospheres, component failure occurs due to poor metal dusting and creep resistance [2–5]. Reinforcing the base alloy system with nanoparticles using gas atomization and subsequent laser powder bed fusion (LPBF) can counteract such material failure [6]. Hence, in this work, titanium was added to Alloy 400 and atomized under nitrogen atmosphere in order to cause TiN nanoparticle formation in the microstructure of printed components.

Nitrogen atomization of the present alloy resulted in spherical, flowable powder with a particle size distribution approx. in between 15 and 53 µm, being considered usable for additive manufacturing. Surface and cross section analysis of powder particles with scanning and scanning transmission electron microscopy (SEM, STEM) revealed the presence of TiN on the nanoscale. Grains, consisting of dislocation-enriched cells, showed Cu segregations on both, grain and cell boundaries as commonly known for NiCu alloys [7]. As a nanoparticle formation was achieved in powders, these were further applied to the LPBF process.

A parameter study varying in laser power, hatch distance and scanning speed was performed. Throughout this, a parameter set leading to a density of ~ 99.8 % was achieved. Test specimens showed multiple layers of scanning tracks resulting from a rotating scanning geometry. Also, no dominant texture could be determined for grains being oriented in build direction. STEM characterization of LPBF parts revealed a higher quantity of TiN nanoparticles than in powders. Also, the dislocation density on cell walls was higher than in single particles. Besides Cu segregations, there were also found Ti segregations in the microstructure. In very low quantity, occasional AlO nanoparticles could be verified as well, not being expected to have any notable effect on mechanical properties.

Ti-enriched Alloy 400 showed the highest engineering strength while still demonstrating an acceptable engineering strain of nearly 30 %. Conventional material had better strain properties but could not reach the ultimate tensile strength of the newly generated LPBF material, which exceeded 600 MPa. Standard LPBF Alloy 400 did by far show the worst strain properties and comparable strength as in conventional material. Considering creep performance, the NiCu-based

alloy strengthened with TiN nanoparticles and the conventionally fabricated part exhibited nearly similar properties, again being significantly more resistant to mechanical load than the unmodified LPBF version. With an approx. ten times longer time to fracture at elevated temperature, the material developed in this study is considered a promising candidate in withstanding the above-described demanding environments.

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