Summary in English

Title:

Material characterization of SLM-printed duplex stainless steel

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This doctoral dissertation examines how laser powder bed fusion (LPBF), deliberate nickel modification, and post-build heat treatment govern the microstructure, mechanical response, and electrochemical behaviour of 2507 super duplex stainless steel (SDSS). The work compares three LPBF-manufactured alloy systems: standard SDSS 2507, SDSS 2507 +3 wt.% Ni, and SDSS 2507 +6 wt.% Ni. These materials are treated as process-specific metallurgical states rather than direct equivalents of conventionally processed duplex stainless steel, because LPBF imposes rapid solidification, cyclic reheating, steep thermal gradients, and a non-equilibrium phase-defect condition.

The central research problem is the restricted formation of austenite during LPBF. In SDSS 2507, rapid cooling can retain a ferrite-rich matrix, while repeated laser reheating, local chemical heterogeneity, residual strain, and defect inheritance can modify subsequent transformation and corrosion behaviour. The thesis therefore evaluates whether nickel addition and selected stress-relief or solution-annealing treatments can provide useful control over ferrite-austenite phase balance, phase morphology, orientation heterogeneity, strength, ductility, impact response, and laboratory electrochemical descriptors.

The experimental programme combines feedstock characterization, LPBF process-window screening, optical and scanning electron microscopy, energy-dispersive X-ray spectroscopy, X-ray diffraction, electron backscatter diffraction, transmission/scanning transmission electron microscopy, hardness testing, tensile testing, unnotched Charpy impact testing, open-circuit potential monitoring, cyclic potentiodynamic polarization, and electrochemical impedance spectroscopy. A bounded machine-learning-assisted corrosion-screening workflow was also used. This workflow organized composition-processing-heat-treatment-electrochemical trends through descriptor-level comparison, but it was not used as a substitute for direct electrochemical testing or as independent proof of localized-corrosion resistance.

The results show that standard SDSS 2507 and the +3 wt.% Ni alloy remained strongly ferrite-rich after LPBF and after the investigated stress-relief treatments. Solution annealing at 1100 °C restored a near-balanced duplex structure in the standard alloy, whereas the +3 wt.% Ni alloy became austenite-rich under the same solution-annealing route. The +6 wt.% Ni alloy showed a substantially higher austenite fraction already in the as-built and stress-relieved states and became strongly austenite-rich after solution annealing at 1150 °C. These results confirm that nickel addition promotes austenite stabilization, but also demonstrate that higher nickel content does not automatically produce an optimally balanced duplex microstructure.

Mechanical testing revealed a clear processing-structure-property trade-off. As-built and selected stress-relieved conditions generally retained higher hardness and tensile strength, consistent with ferrite retention, LPBF-inherited refinement, and orientation heterogeneity. Solution annealing improved ductility and impact response but reduced strength, reflecting a reduction of LPBF-inherited strengthening and increased austenite content. Within the investigated matrix, the SDSS 2507 +3 wt.% Ni alloy stress-relieved at 400-450 °C provided the highest tensile-strength pathway, whereas solution-annealed conditions were more favourable when ductility and impact response were prioritized.

The corrosion-related response was criterion-dependent. Corrosion current density, polarization resistance, charge-transfer resistance, breakdown potential, and repassivation potential did not identify one universally superior material condition. Instead, the ranking changed with the selected descriptor and with the alloy-heat-treatment pathway. The machine-learning-assisted screening results were therefore interpreted only as a supplementary trend-organizing layer, consistent with the measured cyclic polarization and impedance response, rather than as a service-life or localized-corrosion prediction model.

The main contribution of the dissertation is a criterion-specific pathway map linking LPBF processing, nickel modification, post-build heat treatment, phase constitution, crystallographic state, mechanical response, and electrochemical screening descriptors. The thesis demonstrates that LPBF-manufactured SDSS 2507 cannot be assessed by porosity, nickel content, or heat-treatment temperature alone. Its performance must be interpreted through an integrated processing-microstructure-property-corrosion framework, with explicit recognition of trade-offs among phase rebalancing, strength retention, toughness, passivity, and repassivation behaviour.