The role of heat treatment in refining the properties of Laser Powder Bed Fusion fabricated super duplex stainless steel

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Abstract

Statement of the Problem: This study explores the effects of heat treatment processes on the properties of Super Duplex Stainless Steel (SDSS) fabricated through Laser Powder Bed Fusion (LPBF), an additive manufacturing technique. The research begins by examining the microstructure of the as-printed SDSS samples, which is predominantly ferritic due to the rapid cooling rates inherent to LPBF. Through a series of X-ray diffraction and detailed microstructural analyses, the presence of minor austenitic phases within the ferritic matrix is also documented.

The study focuses on exploring different heat treatment strategies, such as stress relieving and solution annealing, to validate its influence on mechanical properties (tensile strength, ductility, and hardness) and corrosion resistance.

Mechanical testing, including tensile and hardness tests, indicates that the strength and ductility of the material change significantly after heat treatment. The material exhibits high mechanical properties and low ductility in the as-printed condition. However, stress relieving and full solution annealing produce a balanced microstructure, resulting in a significant increase in plastic properties. This transition is crucial for enhancing corrosion resistance, but as evidenced by the electrochemical test the stress relieving at 300°C/5h and 400°C for 1 h may enhance corrosion resistance. However, stress relieving at 550°C/5 reduces corrosion resistance due to chromium nitride formation. Notably, a 1-hour treatment at 400°C significantly boosts corrosion resistance, suggesting an effective method to improve LPBF printed SDSS in corrosive settings.

Conclusion & Significance: The research highlights the importance of customized heat treatment in utilizing and improving the inherent potential of LPBF-fabricated SDSS. It provides a detailed understanding of the relationship between heat treatment, microstructure, and material properties, offering valuable insights for optimizing the performance of additively manufactured super duplex stainless steels. Strategic heat treatment processes can refine the mechanical and corrosion resistance properties of the material, allowing for wider applications of LPBF-fabricated SDSS in demanding environments. The results indicate enhanced performance, particularly following specific heat treatment conditions. The study finds that solution annealing and stress relieving at 400°C/1h markedly improve corrosion resistance. However, stress relieving at higher temperatures may compromise corrosion resistance due to undesirable phase transformations

.Recent Publications

1. Mohammad Syahid Mohd Isa, Mohd Ridha Muhamad, Farazila Yusof, Nukman Yusoff, Zbigniew Brytan, et al., (2023), Improved mechanical and electrical properties of copper-aluminum joints with highly aligned graphene reinforcement via friction stir spot welding, Journal of Materials Research and Technology, Volume 24, 9203-9215.
2. Reimann Ł., Brytan Z., Jania G, (2022), Influence of Filler Metal on Electrochemical Characteristics of a Laser-Welded CoCrMoW Alloy Used in Prosthodontics, Materials 15, no. 16: 5721.
3. Brytan Z., Król M., Benedyk M., Pakieła W., Tański T., Dagnaw M.J., Snopiński P., Pagáč M., Czech A., (2022), Microstructur al and Mechanical Properties of Novel Co-Free Maraging Steel M789 Prepared by Additive Manufacturing, Materials, vol. 15 (5), 1734.
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5. Woźniak A., Walke W., Jakóbik-Kolon A., Ziębowicz B., Brytan Z., Adamiak M., (2021), The Influence of ZnO Oxide Layer on the Physicochemical Behavior of Ti6Al4V Titanium Alloy, Materials, vol. 14 (1), 230.

Photograph

Biography

Zbigniew Brytan's work in materials engineering delves into stainless steels, exploring their properties, corrosion resistance, and applications. His extensive research spans the structural and mechanical properties of various stainless steels, their corrosion mechanisms, and surface engineering methods like laser alloying. He also investigates electrochemical techniques to evaluate materials' corrosion resistance and the powder metallurgy processes of duplex stainless steels, focusing on their sintering, mechanical properties, and corrosion resistance. A committed academic and author of "Vademecum of Stainless Steel," Brytan is a recognized expert and advisor to the Polish Stainless Steel Association, dedicated to promoting stainless steel use and understanding corrosion causes through his vast experience and knowledge.

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