Am: Stress, microstructure, performance optimization.

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Introduction

This review comprehensively examines the origins, measurement, and mitigation strategies for residual stress in additively manufactured metals. It delves into how process parameters, material properties, and post-processing treatments influence stress distribution, critically affecting part performance and integrity[1].

This review consolidates understanding of how distinct microstructures, inherent to additive manufacturing processes, dictate the mechanical performance of various alloys. It highlights the impact of process parameters on grain refinement, phase transformations, and defect formation, offering insights into achieving tailored properties for diverse applications[2].

This article thoroughly analyzes the formation mechanisms of residual stress during laser powder bed fusion (LPBF), elucidating its detrimental effects on part quality and performance. It meticulously reviews various mitigation techniques, including process parameter optimization, preheating strategies, and post-processing heat treatments, providing a roadmap for reducing internal stresses[3].

This review focuses on strategies for controlling the microstructure of additively manufactured metallic materials, a critical aspect for optimizing their mechanical and functional properties. It discusses how various processing parameters, alloy design, and post-processing techniques can be manipulated to achieve desired grain structures, phase distributions, and defect characteristics[4].

This article provides a comprehensive overview of various post-processing techniques applied to additively manufactured metallic materials, with a focus on improving their mechanical properties, surface finish, and especially on mitigating residual stresses. It explores thermal, mechanical, and hybrid methods, evaluating their effectiveness in enhancing the overall performance and reliability of AM parts[5].

This review provides a thorough examination of the origins, measurement, and strategies for mitigating residual stress in additively manufactured metallic components. It covers the fundamental mechanisms leading to stress development during various AM processes and evaluates the efficacy of different techniques, from in-situ process control to ex-situ post-processing, in improving part integrity[6].

This review focuses on the advancements in in-situ monitoring and control techniques for tailoring microstructure evolution during metal additive manufacturing. It highlights how real-time data acquisition and feedback loops can enable precise manipulation of solidification pathways and phase transformations, leading to parts with superior and customized microstructural features[7].

This review systematically investigates the influence of various heat treatment regimes on the microstructure and mechanical properties, including the alleviation of residual stresses, in additively manufactured titanium alloys. It details how annealing, hot isostatic pressing, and solution treatments can modify grain structures, phase compositions, and defect densities, ultimately optimizing material performance[8].

This review provides a comprehensive overview of multi-scale modeling approaches used to predict and understand residual stress development in additive manufacturing. It discusses various computational techniques, from atomistic simulations to finite element analysis, and their integration to capture the complex thermal and mechanical phenomena that lead to internal stresses across different length scales[9].

This review explores the fascinating field of high-entropy alloys (HEAs) manufactured via additive processes, detailing how their unique microstructures contribute to exceptional mechanical properties. It discusses the challenges and opportunities in designing and processing HEAs using AM, emphasizing the interplay between process parameters, solidification behavior, and resulting microstructural features[10].

Conclusion

Additive Manufacturing (AM) has emerged as a transformative technology for producing complex metallic components, yet achieving optimal material performance remains a significant challenge due to inherent process complexities. A major concern across the field is residual stress, which profoundly impacts part integrity

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and lifespan. Extensive research examines its origins, measurement, and various mitigation strategies, including process parameter optimization, preheating strategies, and targeted post-processing treatments like heat treatments, crucial for reducing internal stresses and improving overall part quality. Controlling microstructure is another critical aspect for tailoring the mechanical and functional properties of additively manufactured metallic materials. Understanding how process parameters influence grain refinement, phase transformations, and defect formation in various alloys, including novel High-Entropy Alloys (HEAs), is fundamental. Significant advancements in in-situ monitoring and control techniques offer opportunities for real-time manipulation of solidification pathways and phase transformations, leading to parts with superior and customized microstructural features. These efforts aim to overcome challenges associated with microstructural variability and achieve desired mechanical properties. Post-processing techniques, encompassing thermal, mechanical, and hybrid methods, are vital for enhancing mechanical properties, improving surface finish, and effectively alleviating residual stresses. For instance, specific heat treatment regimes are systematically investigated for their influence on microstructure and mechanical properties in materials like titanium alloys. Moreover, multi-scale modeling approaches provide a comprehensive overview of techniques used to predict and understand residual stress development, integrating computational methods from atomistic simulations to finite element analysis. This holistic research collectively advances the understanding and control necessary to optimize the performance and reliability of AM components.

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