**Digital Twin Model of Resonance Ultrasound Spectroscopy Property Assessment Method for Metal Additive Manufacturing**

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**Abstract**

Additive manufacturing (AM) has revolutionized the manufacturing industry by offering flexibility, customization, and rapid prototyping capabilities. However, ensuring the quality and reliability of AM parts remains a significant challenge due to variations in material properties and process parameters. Traditional material property analysis methods, that require experimental testing and computational modeling, are often costly and time-consuming. These challenges are further magnified when repetitive sampling is required. To address these challenges, this paper presents a novel approach that combines experimental findings with Finite Element Modeling (FEM) to construct a digital twin (DT) model of AM parts. The DT model will serve as a virtual representation along with real-time monitoring, simulation, and optimization capabilities. By creating a digital twin model, manufacturers can simulate various scenarios and conditions, allowing them to optimize processes and predict performance outcomes before implementation. In this study, the digital twin model is developed using COMSOL Multiphysics, a finite element analysis software. The CAD model of the sample is imported into COMSOL in .STL file format, and adjustments are made to align with physical samples tested via Resonant Ultrasound Spectroscopy (RUS) and machining processes post-printing. The automated mesh generation in COMSOL, utilizing the physics-controlled mesh option, streamlines the process of creating the digital twin model. Numerical simulations are conducted to correlate the resonance frequency of parts at different process conditions with their material characteristics, represented as RF Z-score values. The correlation is plotted and shows clear isolation and separation of different sample groups based on their RF Z-score values and other material properties. Hence, the results suggest that such an approach provides manufacturers with cost-effective and efficient means of analyzing material properties and optimizing AM processes Moreover, by leveraging digital twin technology, manufacturers can achieve greater process control and quality assurance in additive manufacturing. The findings of this study contribute to advancing the understanding and implementation of digital twin technology in AM; therefore, paving the way for enhanced productivity and reliability in additive manufacturing processes.

**Keywords**

Additive Manufacturing (AM); Nondestructive Testing (NDT); Digital Twin (DT); Finite Element Modeling (FEM); Material Properties Analysis; Resonant Ultrasound Spectroscopy (RUS)