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DIGITAL TWIN-ENABLED REAL-TIME ULTRASONIC ASSESSMENT FOR SPACE STRUCTURES

Abstract

The modern concept of Digital Twin (DT) enables creating a digital model of the manufacturing process, facilitating monitoring throughout the product life-cycle. This concept is commonly viewed as a digital representation that accurately reflects the dynamics of a specific physical process. Its potential in conventional and additive manufacturing is considerable, offering a promising avenue to tackle manufacturing uncertainties. In this study, digital twins for space structures fabricated using a conventional fabrication method and the fused deposition modeling method (FDM) within additive manufacturing (AM) were developed. DT represents a digital replica of the process, based on a validated numerical or analytical model and gathered experimental data. In an alternative approach, the speed of sound is measured by the piezoelectric sensors mounted on satellite panels. In this work, the concept of real-time DT, which is applicable to two different applications is proposed. In the first example, structural condition of metallic satellite panels is evaluated in real time to enable prediction of their structural response and remaining useful life. In the second example, the digital twin is explored for in-process adjustment of printing process parameters. The goal of this development is to prevent the possible formation of defects and to achieve the desired properties of the printed material. DT employs the sound speeds measured by UT sensors located under the printer build plate to assess the elastic properties of the printed material. The foundation of DT's functionality is built upon gathering and analyzing sound speed measurements from PLA samples printed with various combinations of printing process parameters. Based on the measurement results, a response surface that links the elastic properties of the material to the printing process parameters was established. Utilizing information on both the material's speed of sound and printing process parameters, DT provides insights into the elastic properties of the printed part and potential defects, enabling adjustments to achieve desired properties and prevent defect formation. It is suggested that digital twin will find a broad spectrum of application in assessment and maintenance of space systems and structures.