A Machining Digital Twin for Hybrid Manufacturing

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Hybrid manufacturing consisting of metal additively manufactured preforms and computer numerical control (CNC) machining has been established to be an effective method for high material use rates. However, hybrid manufacturing introduces unique challenges. Near-net shape designs are typically selected, which result in a smaller margin for part placement within the stock and stringent requirements for work coordinate system identification. Additionally, less stock material reduces the preform stiffness, which limits the material removal rates during machining. This paper demonstrates a digital twin for CNC machining of a wire arc additively manufactured preform that implements: 1) structured light scanning for stock model identification and tool path generation; 2) a fused filament fabrication apparatus to attach temporary fiducials and scan targets to the preform that enable coordinate system definition for both the CAM and CNC machine; 3) preform and tool tip frequency response function measurements to enable stable milling parameter selection; and 4) post-manufacturing measurements of geometry, surface finish, and structural dynamics to confirm designer intent. These efforts define key components of the machining digital twin for hybrid manufacturing.

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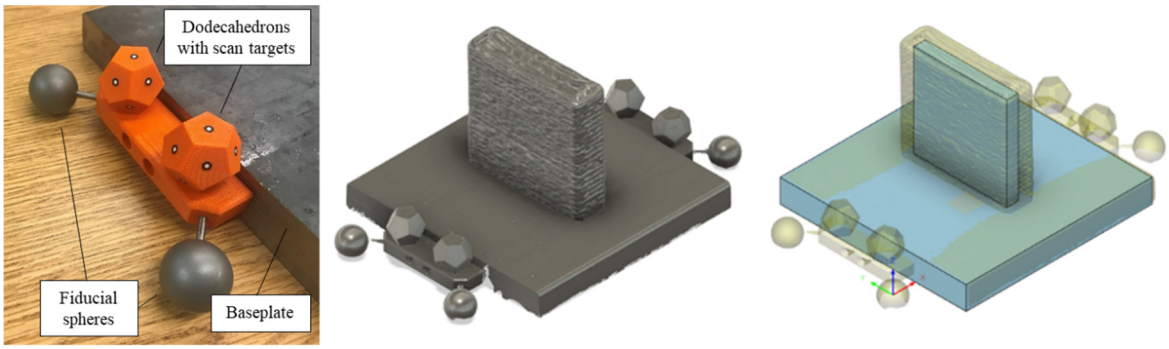

Fig. 1 (Left) fiducials (25.4 mm diameter, satin-finish spheres) and dodecahedrons with scan targets. (Middle) Scan of wall with attached fiducials. (Right) Alignment of wall geometry inside the preform