Experimental and Numerical Investigation on the Formability of SUS304 Stainless Steel Sheets in Multi-Stage Single Point Incremental Forming

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Abstract

Multi-Stage Single Point Incremental Forming (MSPIF) has been proposed as an effective strategy to improve the formability of hard-to-form sheet metals in die-less forming processes. This study presents an integrated experimental and numerical investigation into the formability of SUS304 austenitic stainless steel sheets subjected to MSPIF. Controlled forming experiments are conducted to evaluate the maximum achievable wall angle, thickness distribution, and fracture characteristics under different combinations of process parameters. A three-dimensional finite element (FE) model is developed using the Abaqus/Explicit solver, incorporating large deformation kinematics, nonlinear elastic–plastic material behavior, and frictional contact between the forming tool and the sheet. The numerical predictions are validated against experimental measurements in terms of wall angle, thickness thinning, and final geometry. In addition, a Taguchi based design of experiments is employed to quantitatively assess the effects of forming angle increment, vertical tool step-down, tool diameter, and in-plane tool feed rate on material formability. The results demonstrate that MSPIF effectively enhances the forming capability of SUS304 sheets by promoting gradual strain accumulation and reducing strain localization, thereby delaying fracture initiation. Wall angles of up to approximately 84° are achieved without premature failure. Among the investigated parameters, tool diameter and forming angle increment are identified as the dominant factors governing formability. The proposed experimental numerical framework provides valuable insights for optimizing MSPIF processes applied to stainless steel sheets.

Keywords

Incremental sheet forming, Multi-stage single point incremental forming, SUS304 stainless steel, Formability enhancement, Explicit finite element modeling.