Title: Seam Weld Scrap Reduction in Porthole-Die Extrusion of 6xxx Series Aluminum Alloys Using a Novel Physical Simulation Method

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Abstract:

Seam welds essential for the direct extrusion of hollow aluminum profiles contribute to substantial scrap that must be remelted, cast, and homogenized at high energy costs. These welds form in the solid state along the length of the extrudate, ideally yielding material properties similar to the bulk material by avoiding a heat-affected zone (HAZ) associated with the melting of the material. However, if bonding conditions are not correctly optimized, the seam weld can become a weak point in the extrudate, rendering it unsuitable for structural applications and contributing to scrap. Designing for proper bonding conditions in conjunction with other extrusion parameters presents a unique challenge to process design. While both physical and numerical simulation methods have been developed, they need to be improved in availability and practicality for industry application. To address this challenge, the presented research introduces a novel physical simulation approach to develop criteria for seam welds found in porthole-die extrusion of aluminum alloy 6005A and investigate the effect of varying strain rate and temperature on the microstructure and macroscopic mechanical properties of the weld region. This technique involved using a Gleeble 3500 thermomechanical simulator to compress cylindrical blanks under isothermal conditions at different preheat temperatures and strain rates. Flow stress responses were measured, and mechanical testing of the compressed blanks assessed bonding quality. Numerical simulations of the Gleeble 3500 tests were then performed using DEFORM 2D FEM software to evaluate the flow stress data as a plasticity model for industry-scale simulation. Microstructural assessment (LOM, SEM, EBSD) was used to characterize bond quality and then correlated with the measured flow stress responses and simulation behavior. This correlation successfully validated the flow stress material model for industry-scale numerical simulation and developed a weld criterion relating the bonding quality to the desired process parameters. These findings created an algorithm for aluminum extruders to develop their own seam weld criteria for a given set of process conditions using commercially available equipment.

Additionally, the understanding of microstructural evolution responsible for solid-state bonding of aluminum was advanced. Developing this algorithm and understanding solid-state bonding will enable the aluminum extrusion industry to reduce scrap and energy costs associated with seam weld defects. Future work will integrate this tool with industry-scale numerical simulation using flow stress data from the Gleeble 3500 to model material plasticity under varying process conditions.