Abstract

Bimetallic tubular components are widely used in various engineering applications across automotive, aerospace, and fluid transmission sectors, including bimetallic bushes and bearings, bimetallic flanges, and gear hubs. In these applications, the outer layer serves as a load-bearing and dimensional stability element, while the inner layer provides conformability, weight reduction, and tailored tribological or thermal performance. This combination led to enhanced performance and resource efficiency compared to monolithic designs. The conventional fabrication routes based on fusion and mechanical joining often suffer from poor interfacial integrity, oxidation, permanent material loss, safety concerns, and excessive intermetallic compound (IMC) formation. To overcome these limitations, this thesis presents a novel sustainable solid-state approach for the fabrication of bimetallic tubular components using friction stir backward extrusion (FSBE). A comprehensive literature review is presented to identify the critical challenges associated with existing manufacturing routes and to highlight the need to address research gaps. Firstly, the feasibility of producing defect-free bimetallic tubular components using solid billets was established. The influence of key process parameters on heat generation, IMC formation, and mechanical performance was quantified. It reveals that the optimal IMC layer thickness (~3 to 4 μm) and uniformity result in superior joint performance during deformation. Flattening test on the stainless steel-aluminum tubular component fabricated under the selected process parameters showed no delamination up to 50% compression, confirming the robustness of the joint. A validated thermomechanical finite element model was developed to predict interface temperatures, which were subsequently used in molecular dynamics simulations to investigate atomic-scale diffusion kinetics. Across all temperature ranges, the diffusion coefficient of aluminum is consistently higher than that of iron, exhibiting a systematic increase with increasing temperature, which highlights the temperature-dependent diffusion and intermetallic growth behavior. It also offers an understanding of preferential grain boundary diffusion of aluminum atoms. The sustainability potential of the FSBE process was further demonstrated by consolidating aluminum machining chips to fabricate bimetallic tubular components without the need for external heating. Mechanical testing and X-ray computed tomography confirmed effective chip bonding, elimination of void after extrusion, and strong interfacial *integrity, thereby highlighting the waste-to-wealth capacity of the process. Additionally, a comprehensive numerical investigation of tool end geometries revealed that hemispherical geometry-based tools reduced the plunge force to nearly one-third of the plunge force required in the case of a conventional tapered tool, whereas the further modified pin-based hemispherical tool provides an enhanced material distribution with reduced plunge force. Overall, this research establishes the FSBE process as a scientifically proven, solid-state manufacturing route for bimetallic tubular components. The absence of external heating requirements, single-step processing, minimal material loss, near-net-shape products, and reusable dies and tools makes this process economically viable compared to existing manufacturing routes. The integrated experimental, numerical, and molecular dynamics-based insights presented in this thesis provide a strong foundation for future advancements in bimetallic components.*

Keywords: *Friction Stir Backward Extrusion, Bimetallic, Diffusion, Molecular Dynamics Simulation, Thermo-Mechanical Model, Recycling*