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A highly efficient 'FAST' hot stamping process for complex shaped panel components from titanium alloys

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Abstract

Demand for low density and high strength materials in the aviation sector has expanded greatly due to ambitious carbon emission and fuel consumption targets. In order to meet these targets, manufacturers have focused on weight reduction via the use of lightweight materials. In the aerospace sector, high strength structural components are made from titanium alloys. However, the forming of complex-shaped components from titanium alloys is time, energy and cost intensive. One promising solution to overcome these difficulties proposed in the literature is using the hot stamping process to form complex-shaped components from sheet metal with cold dies, and rapidly quenching the workpiece in the dies simultaneously. The hot stamping process promises to reduce the tool wear commonly found in conventional hot forming processes and be an overall more efficient and economical process when compared to conventionally used isothermal hot forming techniques. A novel hot stamping process for titanium alloys using cold forming tools and a hot blank was studied systematically in this thesis. This work aims to investigate the microstructural evolution and flow behavior of a titanium alloy (Ti6Al4V) under hot stamping conditions experimentally, and to model these parameters using the constitutive equations proposed. The material behavior was modelled using mechanism-based viscoplastic constitutive equations to replicate the material response of a two-phase titanium alloy Ti6Al4V under hot stamping conditions. Finally, the developed model's accuracy was validated by comparing to experimental uniaxial tensile tests and microstructural maps of the deformed alloy. Microstructural analysis revealed that the heating and soaking conditions are vital to the microstructure and post-form strength, whereas the plastic deformation during the hot stamping only has a negligible effect on both recrystallization and phase transformation due to the very short deformation time. The developed material model was implemented into the Finite Element (FE) simulation to study the deformation characteristics during the hot stamping process. The verified simulation data were analysed through a novel hot stamping technique with good agreements achieved between the predicted and experimental results. A complex shaped wing stiffener panel component was successfully formed from TC4 titanium alloy, demonstrating the great potential of investigated technology in forming complex shaped titanium alloys components. Finally, Fast light Alloys Stamping Technology (FAST) was proposed for titanium alloys, where fast heating to a two-phase titanium alloy sheet with equiaxed microstructure is employed. A novel 'FAST' hot stamping process allows to form complex shaped panel components from titanium alloys with an improved forming efficiency by more than 80% in comparison to traditional forming technologies for titanium alloys.