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A coupled finite element/meshfreemoving boundary method for self-piercing riveting simulation

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Abstract. The use of lightweight materials has been steadily increasing in the automotive industry, and presents new challenges to material joining. Among many joining processes, self-piercing riveting (SPR) is particularly promising for joining lightweight materials (such as aluminum alloys) and dissimilar materials (such as steel to Al, and metal to polymer). However, to establish a process window for optimal joint performance, it often requires a long trial-and-error testing of the SPR process. This is because current state of the art in numerical analysis still cannot effectively resolve the problems of severe material distortion and separation in the SPR simulation. This paper presents a coupled meshfree/finite element with a moving boundary algorithm to overcome these numerical difficulties. The simulation results are compared with physical measurements to demonstrate the effectiveness of the present method.

Keywords: meshfree method; element free galerkinmethod; finite element method; moving boundary; self piercingriveting

1.Introduction

Today's vehicle manufacture heavily relies on computer-aided engineering (CAE) analysis. In most scenarios, the CAE analysis provides a quick and cost-effective assessment of the manufacturing process feasibility. Also, the analysis helps improve the design by virtually optimizing process parameters to achieve the design target. With the help of the CAE analysis, the amount of expensive and time-consuming physical tests is greatly reduced. Still, there are scenarios that current CAE technologies cannot comprehend well. Exemplary problems are events and processes involving severe deformation, material separation, fluid-solid interaction, phase changing and other complex physics. The self-piercing riveting (SPR) process addressed in this paper is one of these challenging problems. SPR is a high-speed cold mechanical joining process without fusion or heat input. As illustrated in Fig. 1, a semi-tubular rivet is driven into the materials to be joined between a punch and a die in a press tool. The rivet drives through the toplayers and toward the die, where the die shape causes the rivet skirt to flare within the lower layer and forms a mechanical interlock.

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