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A modified damage model for advanced high strength steel sheets

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ABSTRACT

More often than not, better formability in the simple tension test implies better formability performance in other stretching modes, especially in hole expansion performance since deformation in the hole expansion test is perceived to be in the same simple tension deformation mode. However, when the hole expansion formability is evaluated particularly for the twinning induced plasticity (TWIP) steel, its performance is so poor compared to other automotive steels, even though the TWIP steel has significantly superior formability in the simple tension test. Therefore, hole expansion formability was experimentally and numerically studied for advanced high-strength grade steel sheets, TWIP940 and a transformation induced plasticity (TRIP) 590 steel sheet, as well as a high-strength grade 340R steel sheet, particularly in conjunction with formability in the simple tension test and its surface condition sensitivity. In order to characterize mechanical properties, simple tension tests were performed to determine anisotropic properties and strain rate sensitivities. To account for macro-crack formation, an inverse calibration method based on a damage model utilizing a triaxiality-dependent fracture criterion and hardening behavior with stiffness deterioration was developed. In this approach, the damage model was inversely calibrated by performing numerical simulations and experiments for the simple tension test (with specimens prepared by milling and punching). Then, the damage model was applied to formability study in the hole expansion test. The damage model along with the anisotropic yield function Hill (1948) incorporated into the ABAQUS/Explicit FEM code performed well to predict hole expansion ratios (HER) and their surface condition sensitivity, elucidating the cause of the lukewarm hole expansion performance and strong surface condition sensitivity of the TWIP steel compared to the others.

1. Introduction

As a way to resolve recent environmental and high energy cost issues, automotive companies are exerting major efforts to reduce the weight of vehicles by replacing conventional steels with light weight alloys or advanced high strength steels (AHSS) such as twinning induced plasticity (TWIP) and transformation induced plasticity (TRIP) steels. In particular, the TWIP steel shows significantly improved tensile strength and ductility, especially in the simple tension test, compared to light weight alloys as well as conventional steels. As for ductility, the most simple and common practice to evaluate

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