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ORIGINAL ARTICLE

Microstructure, forming limit diagram, and strain distribution of pre-strained DP-IF steel tailor–welded blank for auto body application

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Abstract

In the present study, tailor-welded blanks (TWBs) of dissimilar material combination were fabricated by laser welding of interstitial-free (IF) and dual-phase (DP) steels using 2.4-kW power and 4 m/min scan speed. Subsequently, TWBs of as-received sheet materials and IF steels were pre-strained up to 20% major strain in the deformed specimens through an equi-biaxial pre-straining setup. It was found that highly non-uniform strain distribution with nearly plane strain deformation mode was induced in the pre-strained TWBs, whereas an equi-biaxial strain was recorded for IF monolithic blank. Microhardness profiles and the effect of weld zone on the microstructural and mechanical properties of the as-received and pre-strained TWBs were studied. Further, the forming limit diagrams (ε-FLDs) of as-received TWB and IF steel were experimentally evaluated. The ε-FLD of pre-strained TWBs was experimentally determined, and ε-FLD of the pre-strained IF material was estimated using the Yld89 anisotropy plasticity model with the Hollomon hardening law. Subsequently, all these respective ε-FLDs were implemented as damage models in the FE simulations for predicting the limiting dome height (LDH) of as-received and pre-strained TWBs. It was observed that the error in LDH prediction of pre-strained TWB domes was within 9.1% when the estimated ε-FLD of the pre-strained IF material was used as a damage model. The FE-predicted strain distributions and weld line movements of TWBs after the second stage of deformation were also successfully validated with the experimental data.

Keywords Tailor-welded blank (TWB) · Pre-straining · Microstructure · Forming limit diagram (FLD) · Strain distribution · Finite element analysis

1 Introduction

The recent implementation of stringent norms regarding fuel economy, tailpipe emission, and greenhouse gas reductions has compelled the automotive researchers to emphasize on the application of lightweight materials for reduction of vehicle weight [1, 2]. One of the promising solutions is the use of tailor-welded blanks (TWBs) [3] which consists of multiple materials of varying strength and/or thicknesses joined together by means of different welding processes such as laser beam welding (LBW) [4], friction stir welding (FSW) [5], electron beam welding (EBW) [6], resistance spot welding (RSW) [7], and gas tungsten arc welding (GTAW) [8]. Among these processes, the CNC-controlled LBW process is generally preferred for the mass production of steel TWBs at very high speeds with narrow weld zone and deeper penetration [9, 10]. These lightweight TWBs are used to fabricate different auto body parts such as bumper, body panels, shock absorbers, wheel cowling, rear door inner panel, and B-pillars [11, 12]. Recently, automotive industries are very much interested in the application of different dual-phase (DP) grade steels, a popular variant of advanced high-strength steels (AHSSs), for fabrication of TWBs due to its superior tensile strength properties [13]. On the contrary, the extra low-carbon

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