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Dynamic Fracture of Ductile Materials

Examination of Mode I loading on resistance spot weld groups in tailored hot stampings

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Abstract

In this work, Mode I fracture of single and grouped resistance spot welds in hot stamped steels for automotive applications were examined. Fully quenched and 400ºC tailored Usibor® 1500-AS samples were used to create flat sheet and hat channel specimens which were resistance spot welded. To characterize the material constituent distribution throughout the parts, hardness measurements were taken. While a large amount of work has been done to characterize tailored hot stampings, spot weld failure is not well understood. The problem is particularly acute for weld failure in structural components where groups of welds may fail in an unstable unzipping mode. To that end, coupon and structural Mode I testing was conducted where force, displacement, and visual data were sampled throughout the test events. While ductility appeared to have little effect on the strength of a single weld, it largely affected the structural response.

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Keywords: hot stamping, boron steel, resistance spot welding, micro-hardness, fracture, fully cooled

1. Introduction

Resistance spot welding is the most common fastening method used for sheet metal in the automotive industry,

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with as many as 5,000 of spot welds in a single vehicle. To maximize the amount of energy absorbed by a Resistance Spot Weld (RSW) during failure, welding parameters are selected such that fracture propagates around the nugget, causing the weld to pull out of the parent material [1]. Typically, the mechanical performance of a joint is characterized by using a variety of welded coupons that induce different loading conditions on a single weld. When analysing several different welding processes, for example, such single-weld coupons are useful because fabrication is straightforward. These testing methods are also used to determine the mechanical strength of the joint so that weld failure may be accounted for in automotive structures. Schieder [2] showed that properly characterizing the energy absorbed by a RSW is crucial to accurately predict structural deformation in numerical simulations. Although there are many tests which characterize the crash performance of various materials, little work has been done to quantify the load bearing capabilities of spot welds structurally.

By using tailored hot stamping, parts can be formed with varying strength and ductility [3]. Eller *et al.* [4] and Burget *et al.* [5] have conducted studies on the mechanical behaviour of spot welded hot stamped steels where the presence of a softened heat affected zone (HAZ) was observed to control the behaviour of the joint. While tailored hot stamping can be utilized to improve the crash response of hot stamped parts, locally adjusting the phase distribution of the welded regions will change the strength difference between base metal, HAZ, and nugget [4]. On a structural level, the softening of the HAZ is of particular interest because of how it effects the load distribution and weld failure in RSW groups.

In this work, resistance spot welded tailored hot stampings were subjected to Mode I loading at a coupon [6] and structural assembly level. To assess the effect of parent metal strength and HAZ softening on the mechanical behaviour of the weld, fully quenched and 400ºC tailored hot stamping conditions were analysed. For coupon testing, Cross-tension tests were conducted on fully quenched and 400ºC tailored specimens extracted from quenched flat sheets. To conduct structural testing, a new test developed dubbed the "Caiman" was performed on spot welded 1.2 mm fully quenched (FQ) and 400ºC tailored flange hat channels. The purpose of these experiments was to observe how the quantity and softening of welds affected the Mode I fracture response.

2. Material

2.1. Summary Mechanical Properties

As described by Omer et al [7], tailored hot stamping can be used to locally adjust the as-formed microstructure by controlling the cooling rate of the austenized blank during die quenching. By increasing the temperature of the die, the cooling rate which the blank experiences during die quenching is reduced and a more ductile material is produced. To highlight this effect, the flow stress curves for various tailored materials is shown in Figure 1.

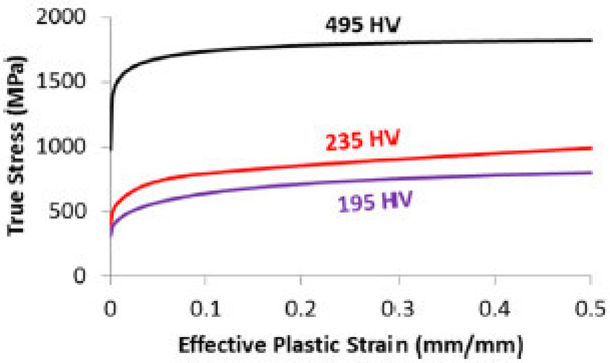

Figure 1: Flow stress curves corresponding to fully quenched (495 HV), 400ºC tailored (235 HV), and 700ºC tailored (195 HV) material [7]

For the single spot weld testing, cross-tension specimens were made from fully quenched and 400ºC tailored