Materials Science & Engineering A 718 (2018) 216–227

Contents lists available at ScienceDirect

Materials Science & Engineering A

journal homepage: www.elsevier.com/locate/msea

Influence of SC-HAZ microstructure on the mechanical behavior of Si-TRIP steel welds

J.J. Guzman-Aguilera[a], C.J. Martinez-Gonzalez[a], V.H. Baltazar-Hernandez[a,*], S. Basak[b], S.K. Panda[b], M.H. Razmpoosh[c], A. Gerlich[c], Y. Zhou[c]

[a] Materials Science and Engineering Department, Autonomous University of Zacatecas, 98000, Mexico
[b] Department of Mechanical Engineering, IIT Kharagpur, Kharagpur 721302, India
[c] Centre for Advanced Materials Joining, University of Waterloo, Canada, N2M 3G1

ARTICLE INFO

Keywords:
Transformation induced plasticity steel
Laser welding
Arc welding
Heat affected zone softening
Carbide precipitation
Formability

ABSTRACT

Transformation induced plasticity (TRIP) steel provides enormous potential for auto-body construction in the automotive sector, owing to its enhanced mechanical behavior. In this work, Si-alloyed TRIP steel is joined by employing laser beam welding (LBW) and by utilizing two arc welding processes: gas tungsten arc welding (GTAW) and gas metal arc welding (GMAW) in order to assess the effect of the net heat input on the microstructure, the uniaxial tensile properties and the forming response. Results indicate that in spite of the Si content in TRIP steel; precipitation and growth of carbides (tempering) are observed in both: the martensite islands and the retained austenite phase, thus leading to the measurable softening at the sub-critical heat affected zone (SC-HAZ) of the arc welded samples. Although the failure location was predominantly found at the sub-critical heat affected zone of the GMAW samples, the maximum stress and elongation was basically controlled by the total extension of the weldment including fusion zone and heat affected zone. While the limiting dome height upon tension-tension (T-T) and tension-compression (T-C) depended primarily on the fusion zone hardness, weld width and geometry of the sample; the fracture location was outside the weld for T-C, whereas the fracture initiated at the weld in T-T samples. LBW specimens showed optimum forming performance.

1. Introduction

Transformation induced plasticity (TRIP) steel belongs to the family of advanced high strength steels (AHSSs) and is composed of a ferrite (α) matrix along with a fraction of retained austenite (γ or RA), dispersed islands of martensite (α´) and some additions of bainite (B) [1]. The relatively high content of Si (i.e. Si-TRIP alloying) and C favors the presence of retained austenite, which in turn promotes an increased hardening rate due to martensite transformation at elevated strains. Such an exceptional structure-property connection is taken into consideration for body-in-white designs where significant stretch forming is required. Furthermore, Si-TRIP steel allows auto makers to meet government regulations concerning both fuel efficiency and passenger safety requirements; thus, making it suitable particularly for crash-worthy behavior in automotive structural components as for example: B-pillar, engine cradle, front and rear rails, among others [1].

In industrial practice, TRIP steel is mainly joined by resistance spot welding (RSW) in the course of assembly [1–8], by laser beam welding (LBW) mostly used in production of tailor-welded blanks [9–12], and by gas metal arc welding (GMAW) in which strength and rigidity is required [13–17]. High fusion zone (FZ) hardness is commonly achieved because of the fast cooling rates encountered by the water-cooling electrodes if employing RSW; however, the joint is prone to fail at the nugget or FZ, in the form of interfacial or partial-interfacial failure mode upon lap-shear tensile testing [2]. The above mentioned failure modes in resistance spot welding of TRIP steel ca n be overcome by employing post-weld heat treatment via a secondary electrode pulse or in-process tempering [3]. On the other hand, penetration, porosity, microstructure, and hardness can be controlled when using LBW in order for the weldment to obtain acceptable mechanical response [9]. For example, a reduction in fusion zone hardness has been obtained when employing twin-spot laser welding [18]. The extent of improvement (once the controlling parameters are set up) has been observed for tailor-welded blanks of dissimilar combinations of advanced high strength steel or mild steel with TRIP steel; for example, excellent fatigue life has been obtained when pairing TRIP steel to mild steel by LBW [10]. Furthermore, the possibility of further controlling the FZ hardness in order to minimize brittleness without losing strength can be

* Correspondence to: Autonomous University of Zacatecas, 801 Ramon Lopez Velarde Ave, 98000 Zacatecas, Mexico.
E-mail address: victor.baltazar@uaz.edu.mx (V.H. Baltazar-Hernandez).

https://doi.org/10.1016/j.msea.2018.01.108
Received 9 October 2017; Received in revised form 25 January 2018; Accepted 25 January 2018