

Patterned ductile-brittle failure mode transition in medium-manganese steel sheets

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Abstract

Steel sheets are extensively used in the automotive industry for their excellent combination of strength and ductility performances at low production costs. However, the ongoing optimization of this set of conflicting properties has brought forward cracking resistance issues in new advanced high strength steel (AHSS) products, leading to fracture toughness concerns. The present work showcases an unusual transition from a ductile to a brittle failure mechanism on Arcan test specimens. The material involved is a 1.35 mm thick sheet of medium-manganese steel with a microstructure comprised of equiaxed grains of ferrite and retained austenite. Arcan specimens were prepared by electro-discharge machining (EDM) with both the loading direction parallel (L) and perpendicular (T) to the rolling direction. The Arcan mechanical tests performed cover two different loading angles: $\theta = 0^\circ$ and $\theta = 45^\circ$, as well as three loading rates: 0.1, 1.0 and 10 mm/min. The transition in failure mode is consistently observed in all test samples, regardless of the loading parameters. Fractography study reveals both dimples (ductile damage) and cleavage facets (brittle failure) organized in well-defined arrow-head markings (AHMs) oriented toward the crack propagation direction. Further geometrical characterization of these chevrons suggests a correlation between the intrinsic energies of both ductile and brittle failure modes involved. The failure transition mechanism is amplified at higher loading rate featuring an increasing number of thinner AHMs. The microstructural and micromechanical parameters triggering the failure mode transition are yet to be identified. Nonetheless, the occurrence of such unusual failure modes emphasizes the need to conduct deeper research in the field.

Keywords: Steel; Fracture; Ductile; Brittle