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Stress intensity factor-based prediction of solidification crack growth during welding of high strength steel

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Abstract: A stress intensity factor (SIF)-based analysis was used to predict solidification crack growth patterns after welding. A coupled thermo-mechanical analysis was conducted to achieve the stresses induced by welding processes, which was used as the initial state in the SIF analysis. The SIF cracked model was established geometrically identical to an uncracked seam element in the thermo-mechanical analysis, based on the Lemaitre strain equivalence principle. Then the prediction of solidification crack growth employed the SIF solutions. The results show that propagation of longitudinal solidification cracks occurs in mode III (at high temperature), as validated by the non-equiaxial and elongated dimple-like crack profile of high-strength steel specimens. Simulations show that the longitudinal cracking switches to mode I as the temperature drops. Transverse orientations are naturally crack-resistant at high-temperature, however, they are prone to the open mode at low-temperature. The comparison of SIFs from different welding speeds shows that high-speed welding increases susceptibility to cracking in the open mode regardless of temperature.

Key words: Weld solidification cracking; cracking mechanism; stress intensity factor; prediction

1 Introduction

Hot cracking, or solidification cracking, remains a challenge in fusion welding because it degrades welding productivity, quality, and material utilization - especially when working with high-strength and high-alloyed steels. The potential of *in situ* crack suppression technology to avoid degradation, has attracted considerable interest and requires a fundamental knowledge of cracking mechanisms (Li et al., 2014; Liu et al., 2015). In fact, solidification cracking is a highly complex phenomenon involving micro-cavities (or voids), inclusions, and the mechanics of crack initiation and growth (Cross and Coniglio, 2008).

Askari and Das (2006) attributed solidification cracking to the metallurgy of the “mushy weld zone” during the last stage of solidification. Ahn et al. (2002) and Ye et al. (2015) investigated solidification cracks in Inconel718 welding, and found that Nb-enriched low-melting-point laves phases formed along grain boundaries