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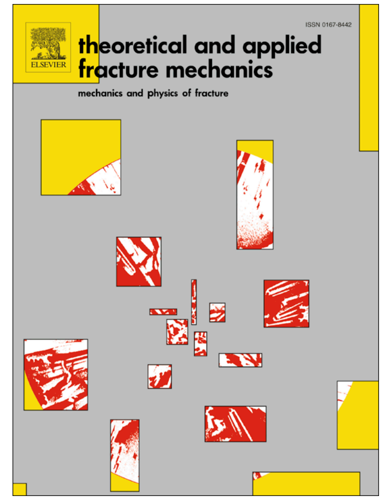

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Indentation for fracture toughness estimation of high-strength rail steels based on a stress triaxiality-dependent ductile damage model

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Abstract

Fracture toughness can be estimated using indentation test (K_{Ind}) based on continuum damage mechanics, usually with the assumption that the critical damage parameter (D_{cr}) of a standard tensile (smooth) specimen is equivalent to that at the crack tip. In view of the effect of stress triaxiality on damage development, K_{Ind} is determined in this work based on the D_{cr} at the crack tip. In addition, an adjusting parameter κ is introduced to reduce the D_{cr} value to reflect the potential difference in damage development between indentation compression and tensile fracture. The above approach is applied to three types of high-strength rail steels to determine their K_{Ind} values. Two types of notch-free (smooth and short-gauge) specimens are used to calibrate a ductile damage model for rail steels, and two additional types of round-notched specimens are used to establish the locus of plastic fracture strain versus stress triaxiality. The damage evolution and D_{cr} at the crack tip are extrapolated for the three rail steels. The so-determined D_{cr} is then applied to the indentation test, with κ as the adjusting parameter, to determine the critical contact depth for calculating K_{Ind}. Results show that D_{cr} is indeed dependent on stress triaxiality, increasing with stress triaxiality under tensile loading. Also, it is found that the change in K_{Ind} based on D_{cr} either at the crack tip or from the smooth specimen is generally consistent with the difference in the measured fracture toughness (K_{Ic}) among the three rail steels, thus, justifying the validity of using D_{cr} from the smooth specimen to estimate K_{Ic} of ductile materials by indentation test.

Keywords: Fracture toughness; Critical damage parameter; Stress triaxiality; Fracture strain