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Fracture Toughness Estimation of Steels from Standard Tensile Properties

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The toughness of a material is a key indicator for preventing unexpected fractures or catastrophic failures. The divided area model was used to validate a simplified approach for determining the modulus of toughness K_f. The square of estimated modulus of toughness was linearly correlated with the Charpy impact energy normalized by the yield stress σ_y, which was also directly proportional to the square of estimated fracture toughness K_{Ic}. The values of fracture toughness of typical structural steels were estimated and predicted using the specification data of mechanical properties in JIS and ASTM standards. This research elucidated the substances as summarized in the following, corresponding to Figs. 1 and 2.

(1) The estimated moduli of toughness using the divided area model demonstrated that for various structural steels, the errors between the estimations and measurements were less than 2.5 percent.

(2) In accordance with the procedure, the lower limits of the modulus of toughness of typical structural steels were calculated using the specification data of the mechanical properties in JIS and ASTM standards for engineering applications.

(3) In one of the steel groups, the square of estimated fracture toughness was proportional to the square of estimated modulus of toughness and linearly correlated with Charpy impact energy normalized by yield stress.

(4) The values of fracture toughness could be predicted from the tensile property data of either a standard specification or measurement, according to a formula that was found to be $\left(K_{Ic}/\sigma_y\right)^2 = \alpha\left(K_f/\sigma_y\right)^2$. This indicates that $(K_f/\sigma_y)^2$ could be seen as a physically equivalent indicator of the plastic zone size.

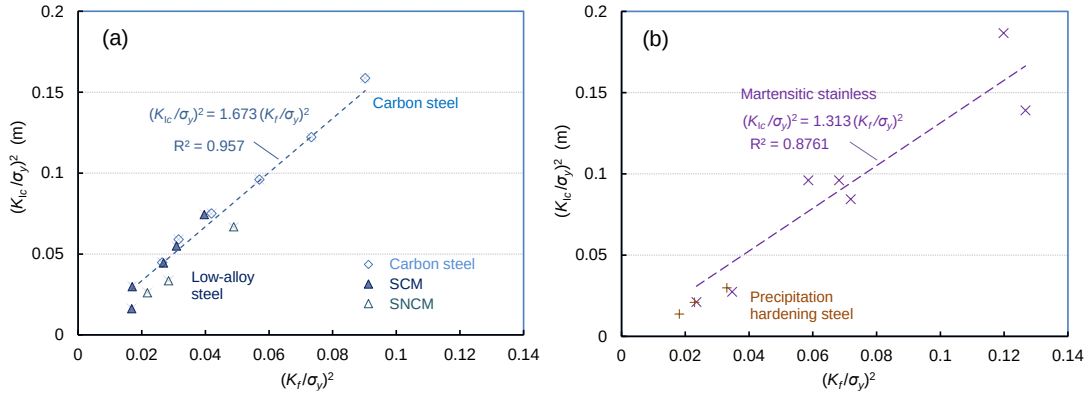

Fig. 1 Relationships between the estimated functions $(K_{Ic}/\sigma_y)^2$ and $(K_f/\sigma_y)^2$ based on JIS standard specification data and the upper shelf Rolfe-Novak-Barson correlation.

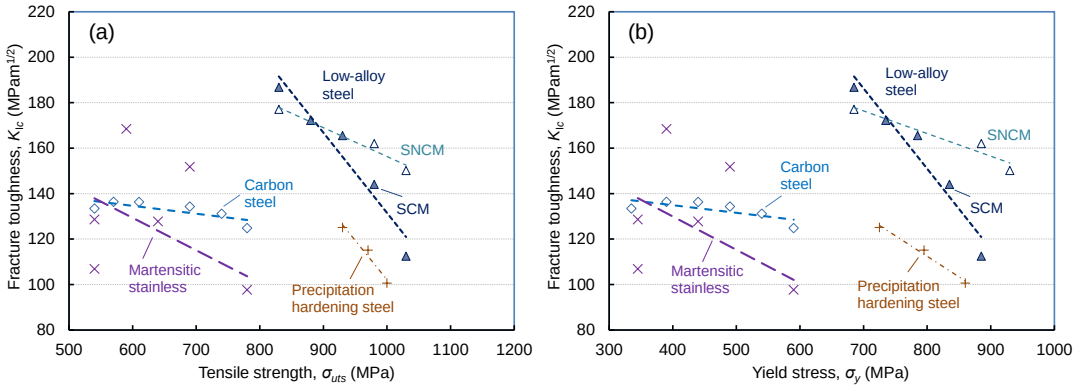

Fig. 2 Estimated fracture toughness as a function of tensile strength in (a) and yield stress in (b), using the specification data of JIS standards.