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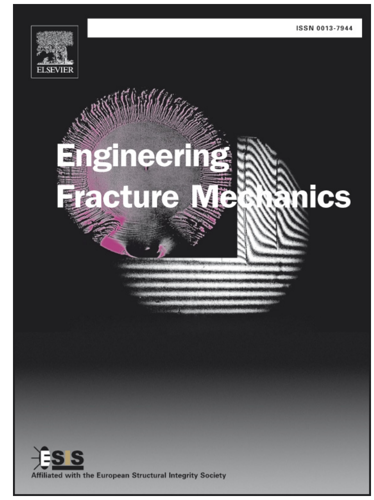

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ACCEPTED MANUSCRIPT

The influence of the out-of- and in-plane constraint on fracture toughness of high strength steel in the ductile to brittle transition temperature range

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Abstract. In the paper the analytical formulae to predict the fracture toughness are proposed. They take into account the influence of in- and out-of-plane constraints. The formula which takes into account the out-of-plane constraint contains the plane strain J_{IC} and Guo's T_z parameter. Alternatively the ratio of the effective to yield stress can be used. The influence of the in-plane constraint can be assessed using J_{IC} and O'Dowd's, and Shih's Q parameter. The theoretical predictions were verified by the results of the experimental program. A good agreement between the theoretical and experimental results is observed.

Keywords: fracture toughness, out-of-plane constraint, in-plane constraint, high-strength steel, transition from ductile to brittle

1. INTRODUCTION

Fracture toughness is a property of a structural or machine member but not a material only. It should essentially not change with an element thickness, provided that the thickness is greater than the value defined in the standards [1], [2]. These standards impose strict restrictions on the sizes and shapes of laboratory specimens. The J_{IC} values measured according to standards, when used in practical applications, may lead to extremely conservative results in the critical state assessment of a structural element. When the thickness of the structural element is smaller than that required by the standards and the crack length is shorter, the fracture toughness can be significantly higher compared to that measured in the laboratory. Moreover, the dimension of a thickness or width may be defined differently depending on the shape and location of a crack within the structural element (Fig. 1). Therefore, it is important to propose theoretical models that allow for actual fracture toughness assessments based on measured J_{IC} values and relatively simple computations.

One of the most important problems in the construction of the theoretical model is the selection of a proper physical quantity that can characterise the influence of the constraints on the fracture toughness. This quantity should be based on the observations of the failure mechanisms at the microscopic level and the characteristics of the strain and stress fields in front of the crack. In this paper, both the out-of-plane constraint and the in-plane constraint are analysed.

So far, in the literature, the out-of-plane constraints are most often characterised directly by the specimen thickness. Using the weakest link concept of fracture analysis of the ferritic steels in the ductile to brittle transition temperature range and for the specimens dominated by plane strain, the relationship between the fracture toughness and the specimen thickness is proposed in the following form [3]: $K \cong (B/B_{ref})^{0.25}$, where B is the specimen thickness, K_{mat} is the fracture toughness in the stress intensity factor units $\mathrm{MPa}\sqrt{\mathrm{m}}$; and B_{ref} is the

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