International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 30, No. 3, September 2020, pp. 375–381; https://doi.org/10.17736/ijope.2020.oa23

http://www.isope.org/publications

Effect of Stress Reflection on Dynamic Stress Intensity Factor in Crack Arrest Toughness Testing

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In a brittle crack arrest toughness test, a brittle crack is initiated by an impact on the side-edge notch of a specimen subjected to a specified static test stress, and the crack arrest behavior is examined. The distance between the loading points of the specimen is one of the important test parameters. When the distance between the loading points is short, a running brittle crack tends to be easily arrested. This may be affected by the stress waves induced by the released stress during crack propagation, as the released stress waves are reflected at the loading points and return to the propagating crack line and can apply compressive stress dynamically to the propagating crack tip. Therefore, for correct evaluation of brittle crack arrest toughness in a brittle crack arrest toughness test, the influence of the reflected stress waves on crack arrest behavior must be eliminated. In the present work, the dynamic stress intensity factors for a running crack in the brittle crack arrest toughness test were calculated by dynamic elastic finite element method (FEM) analysis, and the required condition to avoid the influence of the reflected stress waves was investigated. In practical brittle crack arrest toughness tests, crack arrest toughness, K_{ca}, is calculated by an analytical formula called a tangent formula. The consistency of the stress intensity factor, K, calculated by the analytical formula with the solutions obtained by dynamic elastic FEM was also examined.

INTRODUCTION

Material resistance against a propagating brittle crack as well as brittle crack initiation resistance is often required in steel plates used in important steel structures. It is generally known that the crack propagation resistance in a cleavage-type brittle fracture is smaller than the crack initiation resistance, which can induce unstable behavior of a brittle crack, and for this reason, laboratory tests to evaluate brittle crack arrest toughness are difficult.

Received March 29, 2019; revised manuscript received by the editors June 18, 2019. The original version was submitted directly to the Journal.
KEY WORDS: Brittle fracture, crack arrest, test method for crack arrest toughness, dynamic stress intensity factor, stress reflection.

Brittle crack arrest toughness evaluation by using the stress intensity factor K has been authorized in ASTM E1221-96 (ASTM International, 2002). The test procedure in this standard aims to evaluate arrest toughness K_{Ia} under a plane strain condition, which is assumed as the lower limit of the crack arrest toughness of the material. In welded structures, however, evaluation of crack arrest toughness in the original plate thickness for practical service is required. Historically, the temperature-gradient brittle crack arrest test, or so-called ESSO test, has been used in the steel structure industry (Feely et al., 1955).

In the temperature-gradient-type ESSO test, a brittle crack is initiated by an impact on the side-edge notch of a specimen subjected to a specified static test stress, and the crack arrest behavior is examined. Because the temperature gradient from a low tem-