

Stress Intensity Factors for Three Dimensional Cracks by Applying Slice Synthesis Methodology

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ABSTRACT

Applicability of the slice synthesis methodology with weight function to calculate stress intensity factor for three dimensional cracks is investigated. Although slice synthesis methodology has already been proposed, quantitative investigations of the applicability seem to be insufficient. The authors show the applicable limits of the embedded cracks by comparing conventional formula based on finite element analyses. It is confirmed that the ratio of crack depth to plate thickness effects the accuracy of stress intensity factors by applying the slice synthesis methodology.

KEY WORDS: Slice synthesis methodology; Stress intensity factors; Embedded crack.

INTRODUCTION

In order to improve the structural integrity of ship and offshore structures, fatigue life estimation for three dimensional cracks is important because most fatigue cracks found in these structures are embedded and surface cracks.

The most common method for conventional fatigue life estimation is based on the combination of S-N curves with hot spot stress and cumulative damage rules (Fricke, 2002). However, this method contains some serious weaknesses as follows.

1. S-N curves method cannot give the fatigue crack growth history.
2. The transferability of fatigue life obtained by S-N curves to in-service structures has not established. That is, the relation between fatigue crack length found in in-service structures and fatigue life obtained by S-N curves is not defined clearly.

On the other hand, fatigue life predictions based on fracture mechanics are performed in order to overcome the weaknesses of the conventional S-N curves approaches. Most fatigue life assessments based on fracture mechanics cannot quantitatively evaluate the various transient phenomena under complex loading histories, e.g. retardation and acceleration of crack propagation, because of insufficient consideration of fatigue crack opening / closing behavior caused by crack wake. Toyosada et.al proposed the procedures of fatigue crack growth

simulation for three dimensional crack problems by applying numerical fatigue crack opening / closing simulation for two dimensional crack problems with the equivalent distributed stress method which enables the representation of the stress-strain field at the deepest point of three dimensional cracks for a through thickness crack (Toyosada, Gotoh and Niwa, 2004). Stress intensity factor of analysis objects should be given even though above mentioned method is applied. The goal is to develop direct numerical simulation of three dimensional fatigue crack growth without the application of equivalent distributed stress.

Calculation procedures of stress intensity factor for through thickness cracks under arbitrary stress distributions are generally straight forward, while for three-dimensional cracks such as surface cracks and embedded cracks are more complicated. Because most cracks found in ships and offshore structures show embedded or surface crack morphologies and are located in stress concentration regions, it is important to calculate the stress intensity factor for three-dimensional cracks under arbitrary stress distributions in order to evaluate the fatigue strength in ships and offshore structures.

The slice synthesis methodology with weight function methods to calculate stress intensity factors for cracks in three-dimensional bodies was developed (Zhao, Wu and Yan, 1989a; Zhao, Wu and Yan, 1989b). The applied method has advantages for modeling and CPU time comparing with other numerical calculation method, e.g. finite element analyses. Although the slice synthesis methodology had already been proposed, quantitative investigations of the applicability seem to be insufficient. In this study, the authors make it clear the applicable limits by comparing conventional formulae based on finite element analyses.

THE SLICE SYNTHESIS METHODOLOGY

The slice synthesis methodology with weight function methods to calculate stress intensity factors has potential as a usable calculation method. Calculation procedure for stress intensity factors is explained below. The detail of this methodology was described in the reference (Zhao, Wu and Yan, 1989a).

The analysis object is an embedded elliptical crack shown in Fig.1 and crack surface is divided by two series of orthogonal slices shown in Fig.2. The slice corresponding to $y-z$ plane is called basic slice whose