Prediction of Growth Path of 2D Fatigue Crack

Ki-Seok KIM, Hae Sung LEE

Dept. of Civil, Urban and Geosystem Eng., Seoul National Univ., Seoul 151-742, KOREA

Corresponding Author: Hae Sung LEE, chslee@plaza.snu.ac.kr

ABSTRACT

This paper presents a new incremental formulation to predict the curved crack path of a 2-dimensional elastic body under mixed-mode fatigue loading. The Paris law and the maximum principle stress criterion are adopted for the growth rate and direction, respectively. The displacement and traction boundary integral equations are employed as the governing equations of a linear elastic body with a crack.

INTRODUCTION

Fatigue crack growth is one of the most important factors in the design of the steel structures. A fatigue crack usually does not grow straight due to mixed-mode loadings or asymmetric geometry. Numerous experiments and researches have been performed for the prediction of fatigue crack growth [1]. Most numerical studies are based on incremental simulation such as the tangent approach, in which each segment of crack path is approximated as a straight line [2] or circular arc [3]. Since the growth direction is assumed as the tangent direction at the current crack tip without iterative modification, increments should be very small to describe the curved crack path. Some iterative scheme has been proposed for curved crack growth [4,5,6]. However, in those schemes, the increments were considered as constant during the iterative modification. For a given number of loading cycles, the size of increment is evaluated from the Paris equation along the crack path and that should be modified according to the changes of growth path. This paper presents an incremental formulation to predict the growth path of a fatigue crack, in which both the direction and size of crack increment are iteratively updated for given loading cycles. The validity of the proposed method is demonstrated by a numerical example.

PREDICTION OF GROWTH PATH OF FATIGUE CRACK

The displacement and traction boundary integral equations [2,4] are employed for the elastic analyses of two-dimensional cracked bodies. Paris law and maximum principal stress criterion (MPSC) are adopted for the crack growth rate and tangent direction, respectively. The growth path of fatigue crack is estimated by solving three governing equations, i.e., Paris equation, the equation of MPSC and the dual boundary integral equations (DBIEs), with respect to unknowns, i.e., displacements and tractions of boundary and crack path. Crack growth is simulated by making a crack extension for a given number of fatigue loading. The integral form of the Paris equation is discretized according to the given loading cycles. The growth path for a crack increment is estimated as a parabola satisfying the continuity condition of the crack path given by the MPSC.

In each loading step, each parabola for a crack increment is iteratively updated by using the SIFs obtained at the previous and current crack tip. The mixed-mode stress intensity factors (SIFs) are evaluated by displacement extrapolation method [2]. The direction of crack increment is modified with the MPSC. The size of increment is determined from integration of Paris equation with trapezoidal rule. Each crack path for each loading step is assumed as a parabola, but discretized as a straight line for the simplicity of integration of the DBIEs.

EXAMPLE AND CONCLUSIONS

The proposed method is applied to a rectangular steel plate with single edge-crack under mode II fatigue loading as shown in Fig. 1. Initial geometry of the plate is discretized by 259 nodes and 114 quadratic boundary elements. For two different loading cycles (ΔN =3,000, 6,000) for a crack extension, the growth paths are predicted by the proposed method and tangent approach, and results are depicted in Fig 2. Present study gives more stable and accurate results regardless of the number of loading cycles compared with the tangent approach.

This study provides a rigorous approach for the prediction of the growth path of fatigue crack. Proposed method may be utilized to evaluate the fatigue life for a cracked body.

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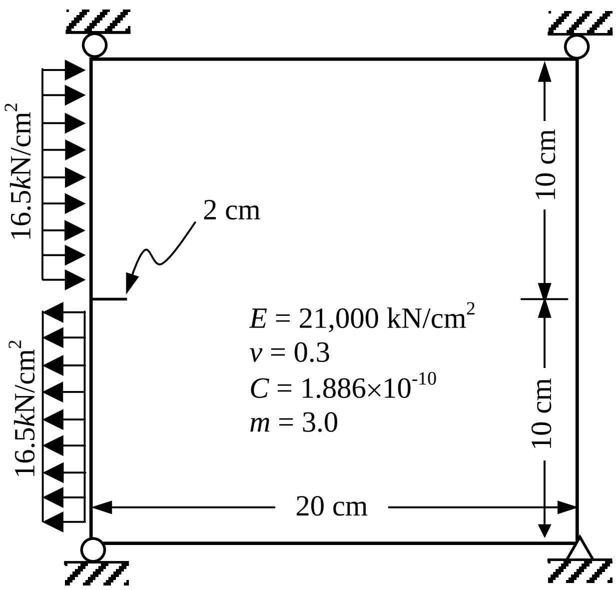

Fig.1. Geometry and boundary conditions of a plate.

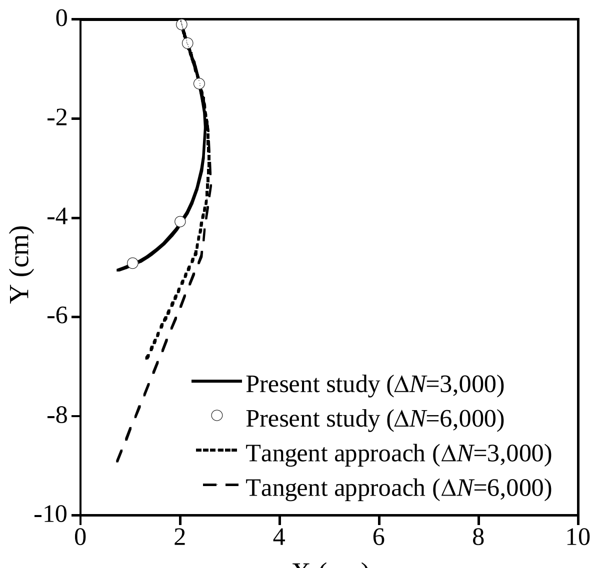

Fig.2. Prediction of growth paths