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Numerical simulation of the crack shape for the thermo-mechanical loaded valve

Hao Wu [a,*], Zheng Zhong [a], Noureddine Benseddiq [b], Abdellatif Imad [b]

[a] School of Aerospace Engineering and Applied Mechanics, Tongji University, Siping Road 1239, 200092 Shanghai, China
[b] Laboratoire de Mécanique de Lille – LML (UMR CNRS 810), Polytech'Lille, USTL, Cité Scientifique, Avenue Paul Langevin, 59655 Villeneuve d'Ascq Cedex, France

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ABSTRACT

In this paper, as a typical example, a valve in a coal-fired thermal power plant with a semi-elliptic crack in its body is presented to illustrate an effective method to predict the surface crack shape under thermo-mechanical loading. The 3D finite element analysis (FEA) is employed to estimate the stress intensity factor (SIF) based on the 3D constraint effect at a set of points along the crack front, and then the evolution of the crack shape is studied according to the SIF. Some numerical techniques were well applied to simulate the real charge condition during the valve operation. It has been assumed that each point in the front of the crack advances in direction perpendicular to such a front, according to the Paris–Erdogan Law. Numerical results of the present method agree fairly well with detective results.

1. Introduction

Laboratory tests usually focus on ideal crack shapes, and based on the experimental fact, it is also wildly accepted that the crack shape of the propagating surface cracks is approximately semi-elliptical [1–3]. The surface fatigue crack growth is normally calculated along both the depth and surface directions through two coupled Paris fatigue crack growth equations. Obviously, the theoretical model contains a crack shape assumption, however some elements for example, initially irregular cracks, interaction between cracks, can modify the following crack shape, which may lead to an uncertain error in the prediction of fatigue crack growth, especially when a complex stress distribution across the plate thickness is involved. Therefore, significant tools to accurately predict crack shape evolution under arbitrary condition are required.

Obviously, the prediction of crack shape is based on the SIF solution. During the last two decades, various methods have been used to obtain SIF distributions for surface cracks and corner cracks in plates. Newman and Raju [4] employed the finite element method (with or without singularity elements) and the boundary integral method, Yan [5] used an empirical formula for stress-intensity factors of cracks emanating from a circular hole in a rectangular plate in tension. Nikishkov and Atluri [6] employed the domain integral method, which was established to evaluate the energy release rate along a 3D crack front in a thermally stressed body.

In this paper, a 3D numerical simulation on the mechanical resistance of a valve in a coal-fired thermal power plant with a semi-elliptic crack in this body has been performed. The displacement field is calculated in the cracked body and employed to predict the SIF at a set of points along the surface crack front instead of its extreme, which enables the crack front of growing cracks to be directly traced so that the crack shape assumption mentioned above can be avoided. In order to create a new crack front, nodal crack advances are defined using the Paris law and the 3D crack closure is considered by introducing the 3D plastic constraint effect.

* Corresponding author.
E-mail address: wuhao@tongji.edu.cn (H. Wu).

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