Theoretical and Applied Fracture Mechanics 54 (2010) 91–97

Contents lists available at ScienceDirect

Theoretical and Applied Fracture Mechanics

journal homepage: www.elsevier.com/locate/tafmec

Edge dislocations generated from blunt crack tip in viscoelastic material under residual stress

C. Xie [a,b], Q.H. Fang [a,b], C.Z. Jiang [a,b,c], Y.W. Liu [a,b,*]

[a] State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body, Hunan University, Changsha 410082, PR China
[b] College of Mechanical and Vehicle Engineering, Hunan University, Changsha 410082, PR China
[c] Department of Physics and Electronic Information Engineering, XiangNan University, Chenzhou 423000, PR China

ARTICLE INFO

Article history:
Available online 13 October 2010

Keywords:
Edge dislocations generation
Viscoelastic material
Blunt crack
Crack tip slide displacement
Number of dislocations

ABSTRACT

The 2D model of edge dislocations generation from blunt crack tip in viscoelastic material under residual stress has been proposed, the solution of stress field and displacement field are solved by using complex potential method, conformal mapping and Laplace inverse transformation. The explicit expressions of stress intensity factor, strain energy density and crack tip slide displacement are obtained in closed form. The principle of compatibility of blunt crack to edge dislocations has been used to evaluate the dislocations number and dimensionless ratio α. Numerical results present that the number of edge dislocations first increases and then decreases with increase of zone size ratio of the dislocations zone and none-dislocations zone, but it can be reduced by higher configurations ratio of semi-minor axis and semi-major axis. In addition, it increases with time and tends to be a constant quickly. The normalized multiplier α first increases and then decreases with increase of zone size ratio. In addition, it decreases with time and the increase of crack configurations ratio. Both normalized micro-volume SED and normalized dislocation-volume SED decrease with increase of distance from crack tip and tend to vanish. But the dislocation-volume SED decreases more quickly than micro-volume SED does, because of its stronger singularity. Moreover, they increase with time and decrease of configurations ratio.
Crown Copyright © 2010 Published by Elsevier Ltd. All rights reserved.

1. Introduction

The analytical researches on the interaction between dislocation and crack are useful and abundant [1–4]. In addition, because the epoxy and metal may creep and relax under high temperature and when we take metal heat treatment, the medium can occur martensitic phase transformation and generate many micro cracks, furthermore, these processes can be explained and described by generation of dislocations and movement of dislocations. The discussion about influence of viscoelastic effect on generation of dislocations is significative. In engineering, viscoelastic medium might also be artificially introduced by design to generate relaxation and damping behavior to the intrinsically brittle piezoelectric devices [5]. Therefore, the viscous effect of medium should be paid more attention. The solution of interaction between a screw dislocation and viscoelastic material [6] was obtained by using integral transform method, and the solution of interaction between a screw dislocation and a viscoelastic piezoelectric bimaterial interface [5] was obtained by using complex variable function, Li and Lee [7] showed facture analysis on a piezoelectric sensor with a viscoelastic interface.

Except the interaction problem, the problems of dislocations emission and dislocations generation were already analyzed by many scholars. Song et al. [8], Huang and Li [9], Taketomi et al. [10], Zhang and Qian [11], Lubarda [12] and Qian et al. [13] studied dislocations emission from crack tip in isotropic elastic medium. Sih and Tang [14,15] proposed the model of dislocations generated from crack tip of self-consistent and self-equilibrated systems. Using the model of self-consistent and self-equilibrated systems, Liu et al. [16] investigated the problem of dislocations generated from interfacial blunt crack tip in bimaterial with viscous interface.

However, as to the knowledge of the authors, the investigation of the influence of viscoelastic effect of material on fracture behavior and generation of dislocations is seldom reported. In present work, this paper gives a model that can estimate the number and type of dislocations for a given external disturbance in viscoelastic medium.

The mechanical 2D model of edge dislocations generation from blunt crack tip in viscoelastic material under residual stress has been proposed, the solution of stress field and displacement field are solved by using complex potential method, conformal mapping

* Corresponding author at: State Key Laboratory of Advanced Design and Manufacturing for Vehicle Body, Hunan University, Changsha 410082, PR China.
E-mail addresses: xiechao1983@yahoo.com.cn (C. Xie), liuyouw8294@sina.com (Y.W. Liu).

0167-8442/$ - see front matter Crown Copyright © 2010 Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.tafmec.2010.10.003

and Laplace inverse transformation. The explicit expressions of stress intensity factor, strain energy density and crack tip slide displacement are obtained in closed form. The principle of compatibility of blunt crack to edge dislocations has been used to evaluate the dislocations number and dimensionless ratio α.

2. Model description

As shown in Fig. 1, let isotropic viscoelastic media occupies the infinite plane, the x-axis divide the region into the upper region I and the lower region II. A blunt crack lies on the x-axis with semi-major axis a and semi-minor axis b, where its center is located at origin. A sharp crack of length $(d-a)$ emanates from the elliptic hole along the positive x-axis. Trapped ahead of the crack is the initial or residual stress over the segment $d-a$.

3. Elastic solution

Consider that the elastic solution for sharp crack (shown in Fig. 2) can be easily solved and the ξ axis in physic plane is mapping onto the x-axis after using method of images [8]. The solution of the model of edge dislocations generated from blunt crack tip in viscoelastic material under residual stress can be obtained by follow steps.

The sharp crack $(-1 \leqslant x \leqslant 1)$in the plane z can be mapping onto blunt crack (elliptic contour $\frac{\xi^2}{a^2}+\frac{\eta^2}{b^2}=1$) in the plane ζ by using the conformal mapping function.

$$\zeta=\omega(z)=\frac{c}{2}\left[Rz\left(1+\sqrt{1-\frac{1}{z^2}}\right)+\frac{1}{Rz\left(1+\sqrt{1-\frac{1}{z^2}}\right)}\right] \tag{1}$$

$$z=G(\zeta)=\frac{1}{2}\left\{\frac{\zeta\left[1+\sqrt{1-\left(\frac{c}{\zeta}\right)^2}\right]}{Rc}+\frac{Rc}{\zeta\left[1+\sqrt{1-\left(\frac{c}{\zeta}\right)^2}\right]}\right\} \tag{2}$$

where

$$R=\sqrt{(a+b)/(a-b)}$$
$$c=\sqrt{a^2-b^2}$$

3.1. The stress solution of sharp crack

Referring to the work [17] and denoting two couple of analytical functions for region I subjected a concentrated load outward the paper and region II subjected a concentrated load inward the paper, respectively.

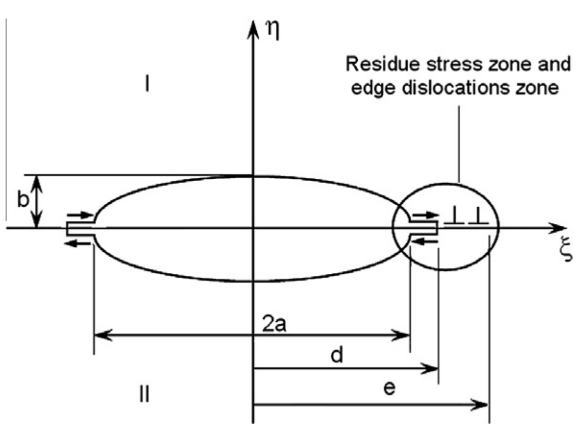

Fig. 1. The model of edge dislocations generated from blunt crack tip in viscoelastic material under residual stress.

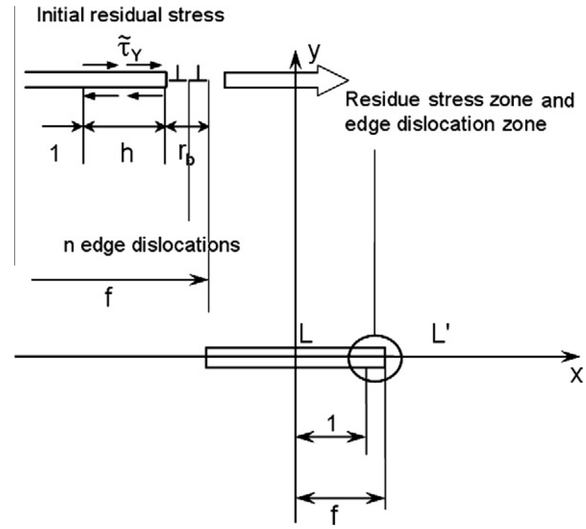

Fig. 2. The model of edge dislocations generated from sharp crack tip in viscoelastic material under residual stress.

$$\Phi_i(z)=\frac{M_i}{z-z_0}+\Phi_{10}(z) \tag{3}$$

$$\Psi_i(z)=\frac{N_i}{z-z_0}+\frac{M_i\overline{z_0}}{(z-z_0)^2}+\Psi_{10}(z) \tag{4}$$

where

$$M_i=-\frac{F_x+iF_y}{2\pi(1+\kappa_i)},\quad N_i=\frac{\kappa_i(F_x-iF_y)}{2\pi(1+\kappa_i)},\quad \kappa_i=3-4\nu_i,$$
$i=1,2,$ z_0 is the point on crack face.

Denoting an auxiliary function

$$\Phi^*(z)=-\bar{\Phi}(z)-z\bar{\Phi}'(z)-\bar{\Psi}(z) \tag{5}$$

thus

$$\Phi^*(\bar{z})=-\overline{\Phi(z)}-\bar{z}\overline{\Phi'(z)}-\overline{\Psi(z)} \tag{6}$$

Referring to the work [13], the stress and displacement components can be expressed by complex potentials

$$\sigma_{yy}-i\sigma_{xy}=\Phi(z)-\Phi^*(\bar{z})+(z-\bar{z})\overline{\Phi'(z)} \tag{7}$$
$$2\mu(u'+iv')=\kappa\Phi(z)+\Phi^*(\bar{z})+(\bar{z}-z)\overline{\Phi'(z)} \tag{8}$$

Boundary conditions can be presented as

$$\sigma_{yy1}-i\sigma_{xy1}=\sigma_{yy2}-i\sigma_{xy2}\quad \text{on } L' \tag{9}$$
$$\sigma_{yy1}-i\sigma_{xy1}=\sigma_{yy2}-i\sigma_{xy2}=0\quad \text{on } L \tag{10}$$
$$u_1'+iv_1'=u_2'+iv_2'\quad \text{on } L' \tag{11}$$

Substituting Eq. (7) into (9), the stress boundary condition can be expressed as

$$[\Phi_1(t)+\Phi_2^*(t)]^+=[\Phi_2(t)+\Phi_1^*(t)]^- \tag{12}$$

Letting

$$g(z)=\begin{cases}\Phi_1(z)+\Phi_2(z)\\ \Phi_2(z)+\Phi_1^*(z)\end{cases} \tag{13}$$

New analytical function $g(z)$ can be written as

$$g(z)=\frac{M_1}{z-z_0}-\frac{\overline{N_1}}{z-\overline{z_0}}-\frac{M_2}{z-\overline{z_0}}+\frac{\overline{N_2}}{z-z_0} \tag{14}$$

Download English Version:

https://daneshyari.com/en/article/807563

Download Persian Version:

https://daneshyari.com/article/807563

Daneshyari.com