A micro-damage analysis of MMCp with equivalent inclusion numerical computation

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Introduction

The pioneer work of inclusion problem was done by J.D.Eselby.[1-2] The elastic field for the region which contains inclusions has also been calculated theoretically or computed numerically[3]. The local region with many inhomogeneities associates with the multiple site damage and plays a very important role in the failure process of solid materials, especially in the composite materials. The main damage forms of MMCp include debonding, cracking of particle, the forming of the voids and the micro cracks in matrix. The purpose of this work is to investigate the interaction of multiple inhomogeneities embedded in an infinite solid and to discuss the incipient damage of MMCp.

Numerical calculation program

The computer program dealing with the interaction among multi-inclusions has been written based on the Eshelby's equivalent inclusion method. The stress fields of one and two cavities under uniaxial applied stress are computed by this program and compared well with the exact results as well as numerical computation results in the literatures[5]. This program can also be used to compute the stress field and analyze the damage evolution of particle reinforced composite material, because the nucleation and growth of cracks in the interface of inclusion and matrix are closely related to the states of stresses in the matrix near the interface. Both the inhomogeneity and the solid are isotropic but have different elastic moduli in the calculation.

Results and discussion

It is assumed that the interface between the inhomogeneity and the matrix is bonded completely in the computation. The ratio of the elastic moduli of inhomogeneity and matrix is 2. The uniaxial tension stress (1000 MPa) is along z-axis. The output of calculation results includes six stress components and two kinds of equivalent stresses. Due to length limitation, the following figures just show the distribution of von Mises equivalent stress.

Figure 1 illustrates the stress distribution of one spheroidal inhomogeneity on the yoz plane. It can be seen that the stress distribution includes three regions, namely, two high stress regions and one low stress region. The maximum equivalent stress locates at the region 45 degree to the loading direction. Figure 2 illustrates the stress distribution for two ellipsoidal inhomogeneities (a_1=1, a_2=0.5 a_3=0.25) on the yoz plane. The longest semi-axis (a_1) of ellipsoid is along loading direction. The figure illustrates that the stress distribution can be divided into two regions, high stress region and low stress region. The maximum stress regions are always close to, but not around the end of longest semi-axis (a_1). The value of the maximum stress is related to the orientation of ellipsoidal inhomogeneity. When the longest semi-axis (a1) is parallel to the direction of applied load, the stress attains maximum value and is larger than that of spheroidal inhomogeneity. There is obvious difference in the stress distribution between the stiff inhomogeneity and the soft inhomogeneity, that is to say, the stiff inhomogeneity has a region on which the stress is smaller than applied stress, the maximum stress location of inhomogeneity corresponds to the minimum stress location of hole. The difference between the maximum stress and the minimum stress of a stiff inhomogeneity is in direct proportion to the modulus' ration of inhomogeneity and matrix.

The stress fields illustrate the interaction between two inhomogeneitie. The amplification effect occurs when the center-connecting line is

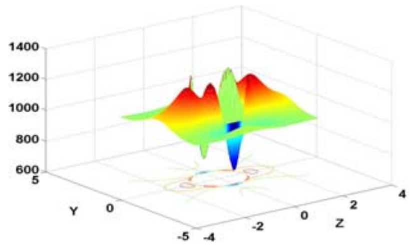

Fig.1 the stress distribution of spheroidal inhomogeneity

parallel to applied stress. On the other hand, the shielding effect occurs when the center-connecting line is vertical to applied stress. The interaction among stiff inhomogeneities is much stronger than that of cracks or holes.

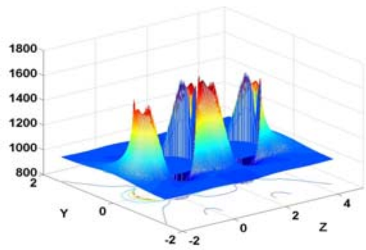

Fig. 2 The stress distribution for two ellipsoidal inhomogeneities (a_1 is along z axis)

In order to analyze the debonding and the propagation of crack, the stress fields for the situations of a spheroid inhomogeneity connecting with a small ellipsoidal void (crack) are illustrated in figure 3 to figure 5. It can be concluded that the debonding will initiate at the top/down region of inhomogeneity, and then will propagate along the interface. The debonding impetus decrease obviously when the debonding propagates to the region of 45 degree to the applied stress direction, and then the debonding will propagate into matrix and form micro crack. The corresponding process of debonding and propagation of crack in MMCp have been observed by us in the experiment.

Acknowledgement

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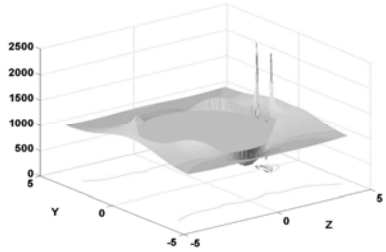

Fig. 3 The stress distribution for the initial debonding at top region of inhomogeneity

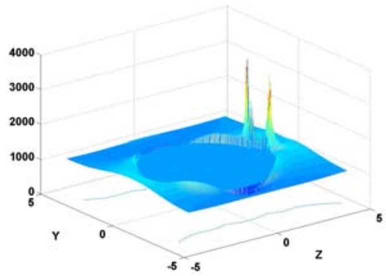

Fig. 4 The stress distribution during debonding propagation along interface

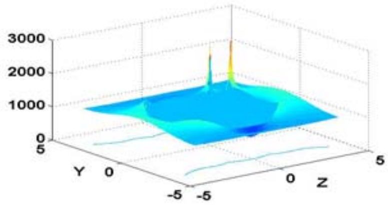

Fig. 5 The stress distribution for the debonding propagation to the region of 45 degree to applied stress direction

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