THE DYNAMIC STRESS INTENSITY FACTOR ANALYSIS OF ADHESIVELY BONDED MATERIAL INTERFACE WITH DAMAGE UNDER NORMAL IMPACT LOADING

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1 Introduction

With developing of high capability adhesive, adhesively bonding technique has become increasingly popular for applications in composites. The adhesively bonded material have become new structural material of spacecraft and gradually instituted the primary structural material by its unique excellent capability, many parts in spacecraft, such as space shuttle, secondary planet, space station and spaceship, having been cemented and sealed in the process of design and manufacture. But when the spacecraft is in service, launching, manned flying and orbit flying, they may undergo complicatedly external environment and further induce damage. For example, vacuum state, high-low temperature alternation, ultraviolet irradiation, atomic oxygen interaction and proton, electron radiation, etc. In addition, the residual stress, caused by mismatching of heat swelling coefficient and difference of physical parameters between different materials, will induce damage near interface, too [1].

Interface is important component of adhesively bonded material, it influences the material intensity by influencing stress transfer; it influences the fracture roughness by controlling damage accumulation process of material; further it influences medium stability and service life. Under impact loading, damage occurring at interface may turn into micro-cracks, and micro-cracks gradually evolve as main crack, with the main crack initiating and growing unstably, the fracture behavior of adhesively bonded material is very complicated by the interaction of interface and crack. Therefore, interface damage is the crucial factor of influencing the properties of material and one of the main failure mode, thus, studying on the interface damage possess important significant, and it had attracted considerable attention and discussion of many domestic and overseas researchers.

Roberta and co-authors investigated the stress intensity factor and interface open displacement of adhesive materials with damage by dual integral equation method [2]. Papanikos et al., adopting three-dimensional parametric finite element model, assessed the stress intensity factor at the crack tip, patch debonding and damage accumulation in the composite patch, further, failure analysis was performed using a set of stress-based polynomial failure criteria [3]. It is shown that the carbon paint method provides a quiet sensitive method for monitoring the crack growth in adhesively bonded joints subjected to creeping loadings, and micro-mechanisms of the crack growth are studied using a scanning electron microscope [4]. But there are much less analysis about the viscoelastic property and dynamic failure of material in the above papers.

The adhesive of adhesively bonded material is constituted by long chain molecules with pliancy property and the molecules movement possessed distinct relaxation character, which determines that damage failure mechanism of adhesively bonded material with viscoelasticity property is much more complicated than the homogeneous material, but there is not profound understanding about the influence of viscoelasticity property of adhesively bonded material on its dynamic response. In addition, for the existence of micro defects and micro damage induced by high stress concentration in macro crack tip region, the crack growing process actually is the damage and deterioration process of materials near crack tip, and the moving process of damage region [5]. Therefore, the study of dynamic stress intensity factor in the dynamic damage interface crack tip of adhesively bonded material with viscoelasticity

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property is important, and it has definite theory and engineering significance for the analysis of adhesively bonded material failure mechanism and toughening design.

Under fracture mechanics framework, considering materials damage, the time response of dynamic stress intensity factor in the interface crack tip of adhesively bonded material under normal impact loading was studied and the influence of physical parameters on dynamic stress intensity factor was discussed.

2 Singular Integral Equations of Adhesively Bonded Material and Numerical Results

Using integral relaxation viscoelastic constitutive equation with damage as the constitutive equation of adhesive and the elastic constitutive equation as the bonded material, and uniting the motion equation and geometric equation under small deformation, the controlling equation of elastic and viscoelastic material with damage expressed by displacement in Laplace and Fourier domain are obtained. By inverse Fourier transform, displacement and stress expressions with unknown coefficients of elastic and viscoelastic material in Laplace domain may be obtained.

Introducing dislocation density functions, combined with the displacement and stress expressions of elastic and viscoelastic material, boundary conditions and interface connection conditions, singular integral equations of adhesively bonded material with Griffith interface crack under normal impact loading are deduced. Adopting Gauss and Gauss-Jacobin integral formula, singular integral equations can be turn into linear algebraic equations about integral dots function, which can be got by collocation dots method.

Under normal impact loading, although the stress state of crack front is complex, but the mode Ⅰ stress state is dominant. Based on this, considering material damage, the time response of mode Ⅰ dynamic stress intensity factor in crack tip are analyzed, and the influence of materials physical parameters on dynamic stress intensity factor are discussed.

Fig.1 shows the time response curves of mode Ⅰ dynamic stress intensity factor at interface crack tip when material near the interface occurs damage under normal impact loading, the dynamic stress intensity factor gradually decreases with the increasing of shear relaxation parameter of viscoelastic material. When material parameters are

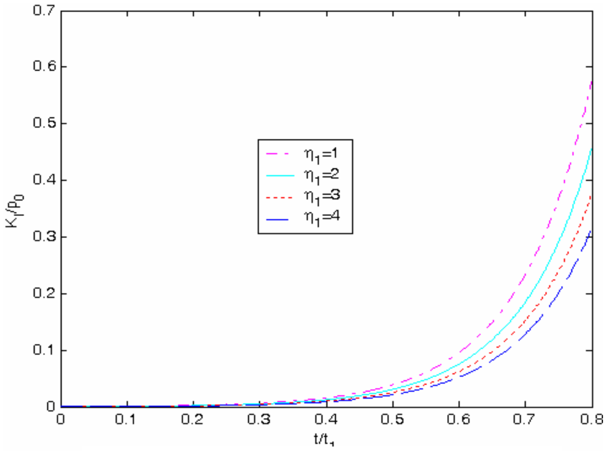

Fig.1. The $K_1 / p_0 - t$ curve in the crack-tip of interface for different η_1

fixed, in the initial stages of crack propagating, the increasing range of dynamic stress intensity factor is very limited; but after reaching certain critical time which can be determined by experiment, the increasing range of dynamic stress intensity factor is very distinct until material failure.

When the crack starts growing, the damage induces the shielding from crack propagating, namely, damage can increase materials toughness, it leads that the increasing range of dynamic stress intensity factor is very small. But with time going, damage will expedite the process of material deterioration; further accelerate the failure of material, and therefore the dynamic stress intensity factor increase significantly.

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