STUDY ON STRESS CONCENTRATIONS IN AN
INTRAPLY HYBRID COMPOSITE SHEET*

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Abstract: A reasonably, simply and accurately modified shear-lag model was proposed.
Based on the model, the stress redistributions due to the failure of some fibers in an intraply
hybrid composite under tension were analyzed. The results show that the present calculating
stress concentration factors very coincide with Fukuda and Chou's results, thus verifying
the reasonableness and correctness of the present model and methods.

Key words: intraply hybrid composite; shear-lag analysis; stress concentration factor

Introduction

The term hybrid is used to describe composites containing two or more types of fibers in a
common matrix. Hybrid composites have several advantages as compared with those fabricated
with a single fiber type. Therefore now they have been widely used in many fields such as
aeronautics and astronautics, communications and transportations, building industry, sport
apparatus, etc. In order to explore the excellent potentialities offered by hybrids and to correctly
design materials, it is at first necessary to understand their failure mechanism and influence
factors. Because of the increase of reinforcements and the synergistic effects, the failure
mechanism of hybrid composites which is closely related to their components, interfaces,
stochastic flaws and geometric arrays is far more complex than single fiber composites. A precise
mechanical model and corresponding synergistic rule have not been proposed as yet. The
longitudinal tensile fracture for unidirectional hybrid composites usually starts from some 'weak'
low-elongation fiber break. When the breakage of one or more of the fibers forms a crack, it will
lead to local stress redistributions (stress concentrations) near the sites of fiber breakage. These
stress concentrations will bring about further fiber breaks, thus causing the failure of the
composites. So stress concentrations are important parameters to reveal the failure mechanism of

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hybrid composites. By using shear-lag analysis, Zweben\textsuperscript{[1]} first examined the stress redistributions in intraply hybrid composites containing both high modulus and low modulus fibers arranged in alternation positions. Owing to the relatively poor approximation of the shear-lag model that he adopted, good results cannot be obtained. Fukuda and Chou\textsuperscript{[2]} investigated the same problem using precise shear-lag analysis. However, the method does not appear applicable to the study of the stress redistributions for the case where interfacial damage between fibers and matrix is taken into account. For this case, based on the shear-lag theory the present paper establishes a modified shear-lag model. The stress redistributions of different failure patterns have been simply and accurately evaluated. The results that remarkably coincide with Fukuda and Chou's can be obtained by using the present model. In addition, it can be further extended to study the stress redistributions with matrix or interfacial damage.

1 Description of the Model

An intraply hybrid composite is modeled as a two-dimensional region, having both high modulus (HM) and low modulus (LM) equally spaced fibers, arranged in alternating positions, as shown in Fig. 1 (a), where a tensile load is applied to fiber direction. Some fibers will break progressively with the increasing load. This will lead to local stress redistributions near the site of breakage. In order to determine the stress redistributions, we draw a shear-lag analysis model from the intraply hybrid composite, as shown in Fig. 1 (b). According to shear-lag assumptions, only the fibers carry the tensile load and the matrix just transfers shear load\textsuperscript{[1, 2]}. The model is symmetrical and consists of \((2r - 1 + 2n + 2N)\) fibers. Now we divide these fibers into three groups. The first group consists of \(r\) HM fibers (containing \(r_1 = r\) broken HM fibers) and \((r - 1)\) LM fibers (containing \(r_2 \leq r - 1\) broken LM fibers), which forms a fracture region.