IS CRACK CLOSURE DUE TO FATIGUE LOADING CAUSING MORE DAMAGE IN CARBON FIBRE REINFORCED EPOXY COMPOSITES?

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0. ABSTRACT

This tension-tension fatigue study on crossplied laminates, revealed that the fatigue stress ratio R has a considerable influence on the fatigue damage development. It has been found that for stress ratios smaller than 0.5 additional damage is introduced due to crack closure. A micromechanical explanation will be presented to model this crack closure phenomenon in \((0^\circ_2, 90^\circ_2)_8\) laminates.

J. Füller et al. (eds.), Developments in the Science and Technology of Composite Materials
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1. INTRODUCTION

The fatigue damage behaviour of carbon fibre reinforced epoxy laminates is characterized by the initiation and growth of specific damage modes: damage in the epoxy matrix, damage of the carbon fibres, damage in between the individual laminae and damage of the interface between the fibre and the matrix.

A fatigue study carried out in tension revealed that beside the fatigue stress amplitude $\sigma_0$, the fatigue stress ratio $R$ has a considerable influence on the damage development in crossply carbon-epoxy laminates.

It was found that a crack closure phenomenon, which is well known for metals but has not yet been recognized for composites, will depend upon the value of the $R$-ratio. The exact value of the stress at which crack closure takes place can be deduced from the hysteresis-curves and the graphs of the acoustic emission activity in function of the stress.

This crack closure phenomenon introduces additional damage at low stress levels i.e. shear fractures of the 90° plies, micro-delaminations between the 0° and 90° plies and initiation of fibre breakage in the 0° plies.

This surplus of damage in crossply carbon-epoxy laminates fatigued with low $R$-ratios, is well documented using the edge replica technique, the X-ray radiography and the deply technique.

2. MATERIAL AND TEST CONDITIONS

Carbon fibre reinforced epoxy (cfre) prepreg layers, Fibredux 920C-TS-5-42 supplied by Ciba Geigy Co., were laminated into a $(0^\circ_2, 90^\circ_2)_5$ stacking sequence and cured in a pressclave resulting in a 1.16 mm thick laminate. Specimens, 19.8 x 128 mm$^2$, were cut from this laminate with a diamond saw. The edges of the laminate were polished up to 1 µm enabling damage studies at the edges with the optical microscope and the replica technique.

The fatigue tests were carried out on a servo hydraulic fatigue testing machine, Schenck Hydropuls 25 kN, in an air conditioned room at 20±2°C and 45±5% relative humidity. The frequency of the sinusoidal fatigue cycle was very low. For a maximum fatigue stress of 70% or 75% of the UTS, test series with different $R=\sigma_{\text{min}}/\sigma_{\text{max}}$ ratios have been carried out.