EFFECT OF MICROSTRUCTURE ON FATIGUE BREAKING OF E GLASS-EPOXY

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INTRODUCTION

The developpement and the improvement of composite materials need a better knowledge of their mechanical properties and lifetime predictions. This is important for industrial structures submitted to a variety of loading and environmental conditions.The question is "How durability can be defined for polymeric reinforced materials ?"

An excellent review of damage in composite materials is given by K.L. REIFSNIDER (1). The author emphasizes that damage is a consequence of a large number of defect accumulation (fiber breakage, matrix cracks, debonding, delamination...) leading to strength, stiffness and lifetime reduction. MANDELL (2) and KIM-EBERT (3) have also pointed out different parameters that can modify the fatigue behaviour, their are : components, process, design and of course the kind of the loading control (stress or strain, frequency, R ratio...). This paper deals with the fatigue damage initiation in bending fatigue test of unidirectional composite structures.

EXPERIMENTAL METHOD AND RESULTS

Recently we developped a method based on flexural fatigue tests to study the behaviour of composite materials (4). The experimental procedure is carried out with a beam specimen tested in 3 point bending under imposed displacement. The stiffness specimen evolution is followed all along the test by recording the maximal load versus number of cycles.

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The different testing parameters are : frequency, span to depth ratio(L/h), R ratio (min/ max), and environmental conditions (temperature, humidity). Several E glass/epoxy materials are considered : pultruded and moulded specimens with different fiber contents (50 % to 60 % v/o). Whöler's curves are plotted using a damage criterion N10 which is the number of cycles corresponding to a ten percent drop in stiffness. Examples of curves are indicated in figure 1 for the same epoxy system. We an notice that the best fatigue bahaviour is obtained for a 50 % volume content. Pultruded materials are characterized by a significant drop in lifetime and a low scattering in results. Overmore static fatigue (R = 1) can give a strongest degradation, particulary for the highest fiber contents (figure 2). Optical observations on the stretchest surfaces enable to enhance two main mechanisms in the early damaging.Table 1 sums them up as fiber or matrix mechanism. this schedule is very important to predict the behaviours of industrial structures (figure 3).

Indeed, it is a thinking scheme to describe parameter influences as different as humidity or R ratio (with an extremun case corresponding to R = 1) and to predict scattering results. For instance, if the very first decays are fiber failures, results will depend upon the interface strength. A weak fiber/matrix interface can lead to debonding and arrest of the cracks : this increases lifetime. Less than 1, R ratio can induce a possible heating effect due to the friction of the broken fiber in the matrix. At last an important parameter is the chemical protection of the fibers (coupling agent,...). If insufficient, this can lead to a static humidity induced fatigue with a subcritic growth of the superficial fiber defects. Of course many failing ways are possible related to the several parameter combinations.

CONCLUSION

The unidirectional E Glass/epoxy in flexural fatigue has been described using stiffness evolutions. Accurate optical observations made the initial damaging mechanism identification possible. These mechanisms soon appear in the fatigue process. Fatigue parameters have then to be considered through a "Safe Crack Growth" approach. Particularly this can modify our needs in the interface properties, as justified by the beneficial effect of weak interfaces and fiber/matrix debonding.

REFERENCES

(1) Reifsnider K.L., ASTM-STP 775, 1982
(2) Mandell J.F., Developments in reinforced plastics 2, G.Pritchard Edit., London-New York, 1984, p.67
(3) Kim H., Ebert L.J., Fibre Science and Technology, 14, 1981, p.3
(4) Fiore L., Vincent L., Composites, 1985, p.61
(5) Fiore L., Puget P., Vincent L., Pluralis Edi., J.N.C., 1985, p715.

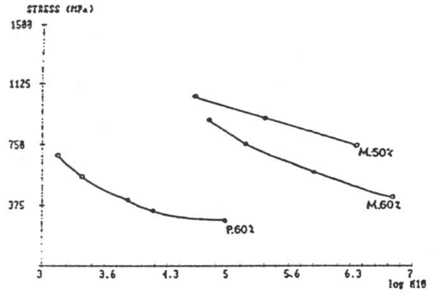

Figure 1 Whöler's curves for the same epoxy system (P:pultruded;M:moulded)

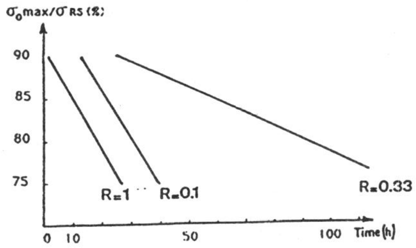

Figure 2 Effects of R ratio in fatigue bending test

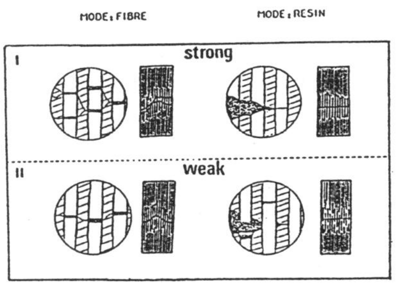

Figure 3 Cracks growth for strong(I) and weak(II) interface

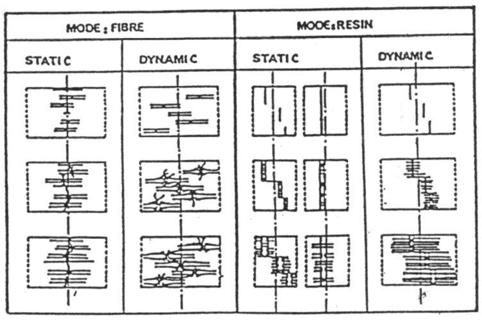

Table1 ways of the two main mechanisms for UD glass/epoxy