Evaluation of experimental techniques for the determination of the shear strength of composite materials

EVALUATION OF EXPERIMENTAL TECHNIQUES FOR THE DETERMINATION OF THE SHEAR STRENGTH OF COMPOSITE MATERIALS

L.E. Govaert, J.M.M. de Kok and A.A.J.M. Peijs

Centre for Polymers and Composites, Eindhoven University of Technology
P.O.Box 513, 5600 MB Eindhoven, The Netherlands

In this study three well-known experimental techniques for the determination of the shear strength of composite materials are evaluated: a) fibre pull-out, b) Interlaminar Shear Strength (ILSS) and c) torsion of pultruded rods. It is shown that the aplied loading in the fibre pull-out and ILSS-test is far from pure shear, resulting in experimental values that deviate markedly from the actual shear strength. However, experimental data of various epoxy based composite materials reveal a linear relationship between the ILSS values and the quantitative shear strengths as obtained in torsion.

Keywords: Composite Materials, Interfacial Shear Strength, Experimental Techniques

INTRODUCTION

The level of adhesion between a reinforcing fibre and the surrounding matrix has a strong influence on the performance of composite materials with respect to faillure mode, fatigue and energy absorbtion upon impact loadings. Consequently, optimization of the level of adhesion between fibre and matrix is still subject of considerable research.
A characteristic parameter to evaluate the level of adhesion on the fibre-matrix interface is the interfacial shear strength. For the experimental determination of this parameter a great variety of test methods is available. Unfortunately, however, the experimental values of the shear strength, as obtained by various techniques, ussually do not compare. An obvious reason for this discrepancy seems to be the inability of several methods to create a pure shear stress situation in the sample. The variety in the resulting 3-dimensional stress situation will inherently affect the faillure of the interface, and consequently the obtained value of the shear strength.
To illustrate the influence of a 3-dimensional loading situation on the experimental values of the shear strength, three well-known experimental techniques were evaluated: a) fibre pull-out, b) interlaminar shear strength (ILSS) and c) torsion of pultruded rods.

3-DIMENSIONAL STRESS SITUATION

The complexity of the loading situation in an ILSS test was already pointed out by Berg et al. [1]. By means of Finite Element Method (F.E.M.) analysis the presence of considerable compressive stresses was demonstrated.

F.E.M. -analysis of a fibre pull-out test (Fig.1) indicates that the applied loading conditon is also far from a pure shear situation, displaying a considerable tensile stresses in radial, tangential and axial direction.
In both cases the deviation of a pure shear loading situation will inevidently influence the obtained value of the interfacial shear strength. As the 3-D loading situation is not identical for both techniques, the obtained values of the shear strength by fibre pull-out and ILSS will inherently not compare.

RELATION TO ACTUAL SHEAR STRENGTH

The discrepancy between the ILSS-test and fibre pull-out has been experimentally verified by Elkink et al. [2]. However, although the experimental values of both methods differ, they are linearly related.
To evaluate the qualitative value of the shear strengths obtained by ILSS, the ILSS values of several epoxy based composite materials were compared with shear strengths obtained in a pure shear geometry, being torsion on pultruded rods.
Although ILSS in general supplies a higher value for the shear strength compared to those obtained in torsion, it is shown in Fig. 2 that both values are linearly related. This linear relation indicates that the ILSS method can very well be used for a qualitative evaluation of the shear strength.

References

1. Berg C.A., Tirosh J., Israeli M. Composite Materials: Testing and Design 2nd Conference ASTM STP 497 (1972) 206-218
2. Elkink, F. in: Integration of fundamental Polymer Science and Technology Part 3 Elsevier Appl. Sci. Publ. (1989) 228-234

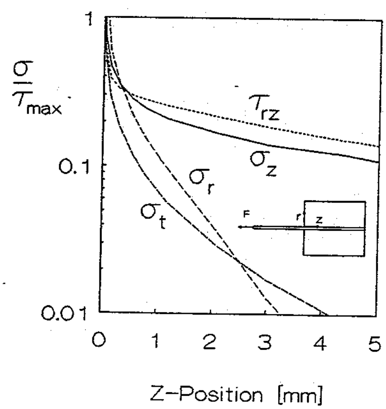

Figure 1.Normal- and shear stresses along the fibre-matrix interface in a fibre pull-out loading geometry

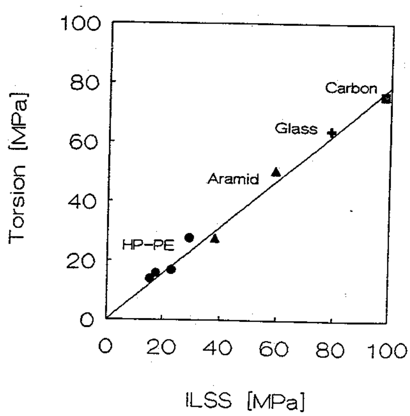

Figure 2. Torsional Shear Strength vs Interlaminar Shear Strength (ILSS) for various epoxy based composite materials