A SIMPLIFIED SOLUTION TO THE THREE-DIMENSIONAL COMPOSITE PROBLEMS

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ABSTRACT

A method is proposed to idealise a three-dimensional composite model to an axisymmetric model which can then be easily analysed using the finite element technique. A comparison is made between the idealised axisymmetric model and the corresponding three-dimensional model. The results show that the proposed method is reasonably accurate for solving three-dimensional composite problems.

INTRODUCTION

Although the application of two-dimensional analysis to the problems of fibre-reinforced composites has provided a good understanding of the behaviour of composite materials, more realistic and accurate predictions can be obtained using the three-dimensional finite element technique. However, both the computer storage and computing time required to carry out a complete three-dimensional analysis of any practical problem are enormous. This is especially so in the study of fibre-reinforced composites because parametric stress analysis is normally necessary. In this paper, a procedure will be proposed to obtain simplified solutions for three-dimensional composite problems.

IDEALISATION OF THREE-DIMENSIONAL COMPOSITES

Figure 1 shows an idealised three-dimensional composite in which the fibres are arranged in a hexagonal array although in reality they are at random. However, the fibre arrangement assumed is capable of predicting the behaviour of real composites (1). The three-dimensional model, which consists of a centre hexagon surrounded by six hexagons, as shown in figure 1, can be used to study the micro-behaviour of the centre hexagon when it is subject to fracture, interface delamination and/or other defects. This model can be idealised to become an axisymmetric model which can then be studied using the finite element technique. The idealisation can be done by assuming that the matrix layer in the centre hexagon is cylindrical and replacing the six surrounding hexagons by a cylindrical composite layer. The cross sectional view of the idealised model is shown in figure 2. The difficulty encountered in this idealisation is the prediction of the mechanical properties of the composite layer which is used to replace the six hexagons. However, it is reasonable to assume that the mechanical properties of this composite layer are similar to those of the hexagonal array shown in figure 1. Thus, the macro behaviour of the composite layer can be predicted by studying the mechanical properties of the whole hexagonal array.

MECHANICAL PROPERTIES OF AN ANISOTROPIC COMPOSITE

The hexagonal array shown in figure 3 consists of repeating elements which are geometrically similar and exhibit the same mechanical behaviour. The repeating elements could be hexagons or rhombi (refer to the hexagon with center at D and the rhombus ABCD with center at O). The latter was used to predict the mechanical properties of the composite layer. It is important to note that the composite being analysed is transversely isotropic and, therefore, there are five independent elastic constants in the stress strain relationships. In order to determine these elastic constants arbitrary composite strains were imposed to a repeating element. By using stress/displacement functions and by imposing the conditions of continuity of stresses and displacements at the boundary between fibre and matrix and between repeating elements, the composite stresses were related to those imposed composite strains. Composite elastic constants were then obtained from these relationships.

APPLICATION OF THE PROPOSED SIMPLIFIED TECHNIQUE

The proposed simplified technique was used for the study of a discontinuous fibre by replacing the fibre in the centre hexagon (refer to figures 1 and 2) by a discontinuous fibre, as shown in figure 4. The end gap between the two broken ends of the discontinuous fibre was assumed to be matrix filled. Axial loads were applied at the two ends of the model in such a manner that uniform strain condition was obtained at the end sections of the model.

Figure 5 shows the distributions of the interfacial shear stress, normalised with respect to the average matrix stress, along the interface between the discontinuous fibre and matrix, obtained by the proposed and the complete three-dimensional finite element methods. It is obvious that the two solutions are in good agreement.

CONCLUSION

The proposed simplified technique was found to be reasonably accurate for solving three-dimensional composite problems. It is important to note that the proposed technique is particularly useful for studying the micro behaviour of a fibre embedded in a layer of matrix.

REFERENCE

1. Pickett, G. Fundamental Aspects of Fibre Reinforced Plastic Composites, Edited by Schwartz, R.T. and Schwartz, H.S., John Wiley, 1968.

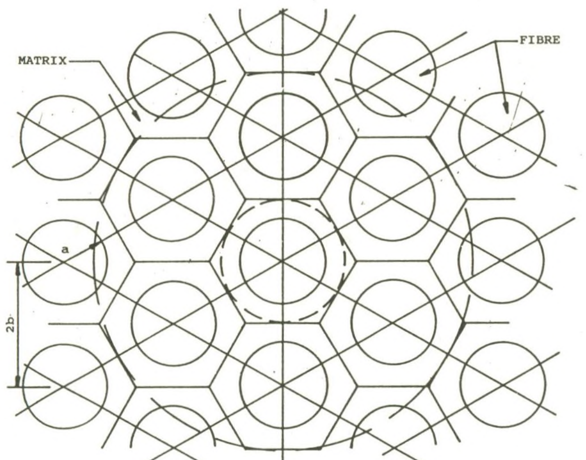

FIG 1 IDEALISATION OF THREE-DIMENSIONAL PROBLEMS

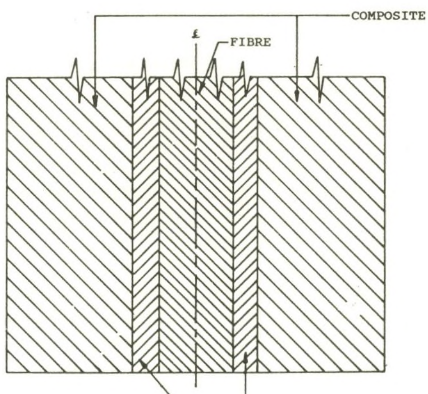

FIG 2 CROSS-SECTIONAL VIEW OF THE IDEALISED MODEL

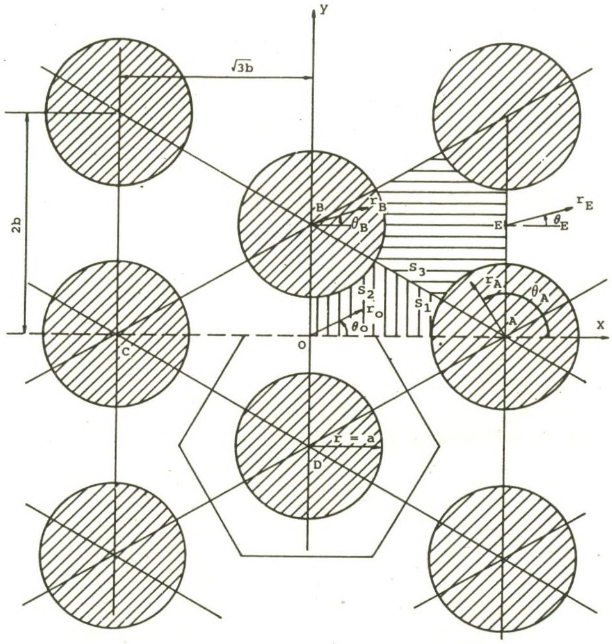

FIG 3 HEXAGONAL ARRAY

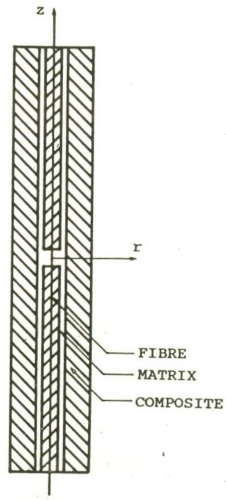

FIG 4 AN AXISYMMETRIC COMPOSITE MODEL

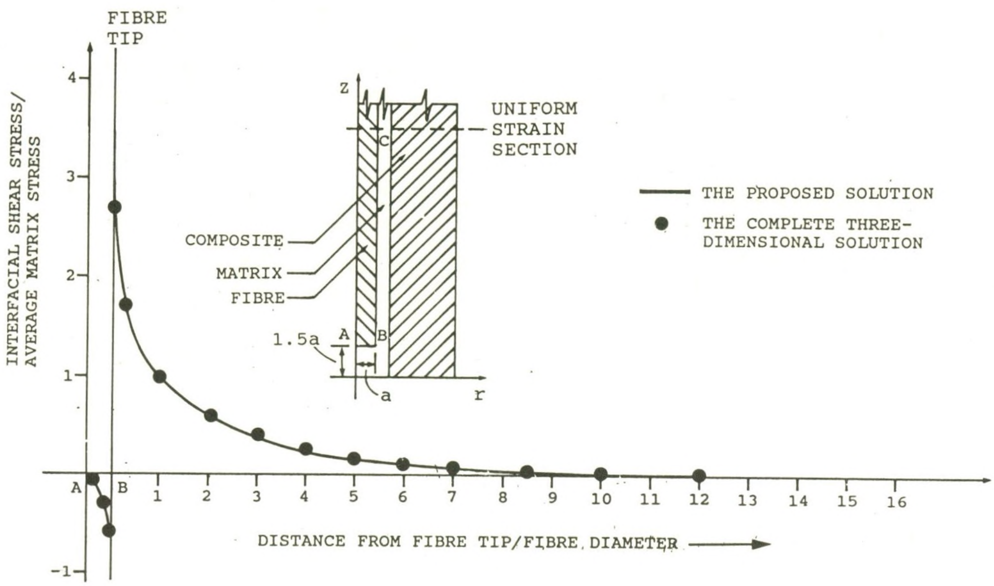

FIG 5 A COMPARISON OF THE INTERFACIAL SHEAR STRESS DISTRIBUTIONS ALONG THE INTERFACE A-B-C OBTAINED BY THE PROPOSED AND THE COMPLETE THREE-DIMENSIONAL TECHNIQUES