TIME DEPENDENT PROPERTIES OF INJECTION MOULDED COMPOSITES

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SUMMARY

The uniaxial tensile creep behaviour of several thermoplastics reinforced with short glass fibres has been studied over a wide range of temperatures using specimens machined from a variety of injection moulded bars, discs and plaques. The samples cover a range of fibre volume fractions from 0.10 to 0.22 and mean fibre aspect ratios from 18.5 to 43.0. A detailed quantitative assessment of fibre orientation distribution (FOD) and fibre length distribution has been carried out for each type of moulding used with each material. This structural information, together with fibre volume fraction, fibre modulus and matrix creep data, has been used in the prediction of composite tensile modulus both parallel and transverse to the major flow direction for each type of moulding. For the theoretical predictions, the FOD was treated using the 'laminate analogy' approach developed by Halpin et al: the properties of a ply containing uniaxially aligned short fibres being calculated using several different theoretical approaches. At low strains, one of these approaches led to remarkably good agreement between theoretical and experimental composite moduli, over most of the very wide range of materials and temperatures studied. An empirical extension of this approach is also shown to give reasonably accurate predictions of composite creep behaviour at finite strains, where both the matrix and the composite exhibit non-linear viscoelastic behaviour.

INTRODUCTION

The relatively low stiffness and strength of plastics can be significantly improved by the incorporation of stiff fibres such as...
glass or carbon into the polymer matrix. For maximum benefit, relatively long fibres are needed, together with the ability to control fibre orientation. These requirements are easily met when using thermosetting resins. However, the production techniques usually employed with fibre reinforced thermosets are not in general suitable for use with thermoplastics and most of the fibre reinforced thermoplastics components produced to date have been made using the conventional thermoplastics injection moulding process. This, and other conventional thermoplastics processing methods do not, at present, permit control of fibre orientation and severely limit the fibre length. There is therefore scope for the development of special processes which offer orientation control of long fibres in thermoplastic matrices. However, full exploitation of fibre reinforced thermoplastics depends on their successful use with the conventional mass production processes.

The usual methods of compounding the fibres and matrix, and the processing of the resulting granules by injection moulding, leads to a broad distribution of fibre lengths in the moulded components. Methods are available for coating continuous fibres with a thermoplastic. However, the 'long' fibres in the resulting granules are usually severely degraded during injection moulding, if good fibre dispersion is required. Fibre lengths in moulded components are typically in the range 0.05 mm to 1.0 mm. The individual fibres are usually fairly well dispersed and, with fibre diameter typically $10^{-3}$ mm, this gives fibre aspect ratios in the range 5:1 to 100:1. Unfortunately this is precisely the range where composite stiffness varies significantly with aspect ratio.

Detailed structural studies on moulded components have shown that, even in simple mouldings, the fibres are oriented in a complex manner; the fibre orientation distribution (FOD) varying both through the thickness and from place to place in the moulding. The resulting anisotropy and inhomogeneity of mechanical properties leads to difficulties in the presentation of suitable stiffness design data and the use of this data in design with these short fibre reinforced thermoplastics (SFRTP).

An extensive programme of work aimed at improving our understanding of these materials and hence simplifying both the generation of relevant engineering data and the associated design procedures is being carried out at Cranfield. An important part of this programme has been the verification of theories for the influence of fibre aspect ratio on composite stiffness for SFRTP materials. Ideally, samples in which the fibres were all of one length, perfectly uniaxially aligned and uniformly dispersed in the thermoplastic matrix would have been preferred in the initial studies. Such samples would also have been extremely useful in studies on the influence of fibre orientation on properties. Unfortunately it is not possible to prepare such samples in the fibre length range...