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Generation of Creep Data for Injection-Moulded Plastics

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ABSTRACT

Tensile creep moduli $E_\theta(t)$ have been determined for thermoplastic strip specimens cut at different angles θ to the flow direction from injection-moulded, anisotropic plates. The materials studied were polypropylene (PP) and poly(butylene terephthalate) (PBT), both in the unreinforced state and reinforced with short glass fibres. The observed patterns of anisotropy are consistent with related studies of crystal lamellar orientation and fibre orientation resulting from the deformation (or flow) and subsequent crystallisation of polymer melts. Short-term creep curves for specimens of different age and for different stress levels have been successfully modelled with a stretched-exponential function. The specification of values of the parameters appearing in such functions can provide a convenient method for presenting creep data and incorporating the data into finite element programmes for the creep of components.

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1 INTRODUCTION

There is now a recognised need for more relevant and user-friendly data on the creep and other properties of plastics for improved product design[1,2]. Tensile creep data have traditionally been presented as plots of the time-dependent strain $\varepsilon(t)$ versus log t for various values of the applied constant stress σ and different temperatures T, together with isochronous and/or isometric cross-sections of the curves at different σ. Alternative methods of graphical presentation have involved plots, against log t, of the compliance function $D(t)=\varepsilon(t)/\sigma$ or its reciprocal, the creep modulus E(t). In order to harmonise the presentation of creep data for plastics, a standard has been issued (ISO 11403-1)[3] that requires the tabulation of $\varepsilon(t)$ values for specified values of creep time, stress and temperature. Moore et al[1,2] have also proposed that a reference value for the creep modulus could be specified together with abbreviated arrays of factors, representing the values of modulus normalised with respect to the reference value, at selected times, strains and temperatures.

The acquisition and presentation of creep data is further complicated by their sensitivity to other variables not yet adequately addressed by existing standards. These variables include the process-induced structural orientation and also the physical age of the material (ie the storage time between processing and load application).

The structures of moulded plastics generally comprise regions of molecular or fibre orientation the direction of which varies from place to place in the material. Structural elements close to material surfaces usually exhibit a high orientation parallel to the flow direction in the mould whereas a transverse or random orientation may exist in the interior regions[4,5]. This often gives rise to 'skin-core' morphologies, where the relative thickness of skin and core layers, and hence the effective material moduli, will depend on the processing conditions and overall material thickness.

Tensile creep data are usually obtained using standard tests (ISO 899-1)[6] that employ end-gated, injection-moulded bars. In the surface layers of such specimens the molecules or fibres may be highly oriented in the flow direction along the length of the bar. Measured moduli of these specimens may thus be considerably higher, and creep rates lower, than values that would be obtained for directions transverse to the flow and are unlikely to be representative of the properties of moulded components. To explore the anisotropy of mechanical properties produced by injection-moulding, workers at the ICI[1,2,7] developed a square plate specimen (150 x 150 mm) using a coathanger-gated mould to produce unidirectional flow parallel to one edge of the plate. Creep moduli could be determined for strips cut from the