JOURNAL OF MATERIALS SCIENCE 5 (1970) 909-915

The Strain-rate, Temperature and Pressure Dependence of yield of Isotropic Poly(methylmethacrylate) and Poly(ethylene terephthalate)*

R. A. DUCKETT, S. RABINOWITZ†, I. M. WARD
Department of Physics, University of Leeds, Leeds 2, UK

The yield behaviour of poly(methylmethacrylate) (PMMA) has been investigated in tension and compression over a range of testing temperatures and strain-rates. Both tensile and compressive yield stresses were found to increase monotonically with increasing strain-rate and decreasing temperatures. Compressive yield stresses were in general found to be more dependent on strain-rate.

The results of this investigation have been correlated with previous published data for the dependence of the torsional yield stress of PMMA on hydrostatic pressure. This was done by a modification of a theory proposed by Robertson which uses the internal viscosity approach to yield in glassy polymers. The modified theory clearly explains the temperature and strain-rate dependence of the yield stress and provides a quantitative explanation of the differences in behaviour between tension and compression in terms of the dependence of yield on the hydrostatic component of the applied stress.

The tensile yield behaviour of isotropic amorphous poly(ethylene terephthalate) (PET) sheets has also been investigated over a wide range of temperatures and strain-rates. No torsion or compressive yield stresses are available because of the sheet form of the PET, but the results obtained in tension are shown to be fully consistent with the above theory, and with other published work.

1. Introduction

Many workers have attempted to extract from the complex non-linear mechanical behaviour of isotropic glassy polymers simple failure criteria which can be used to predict yield behaviour under the combined stresses of constant strain-rate and temperature e.g. [1-3]. These approaches draw on experience obtained in investigations of the yield behaviour of metals and soils. The von Mises criterion, successful for describing the yield of metals [4], has been found to be inadequate for dealing with polymeric materials because of the observed difference in yield stress between tension and compression. The latter has been attributed to a dependence of yield stress on the hydrostatic component of stress, but the limited range of experimental data presently available does not allow a clear distinction to be drawn between a pressure dependent von Mises yield criterion and the Coulomb criterion used widely in soil mechanics [2, 3]. However, a modification of the von Mises criterion proposed by Hill [5] to allow for anisotropy has been used successfully to describe the tensile yield of anisotropic polymers [6-8].

Other papers have concentrated on the dependence of tensile stress on testing temperature and strain-rate. Many of the discussions centre around the problem of establishing time-temperature superposition, e.g. [9-12]. All the polymers investigated show a monotonic increase of yield stress with increasing strain-rate and some authors assert that there is an approximately linear relationship between stress and the logarithm of strain-rate. The yield stress for most glassy polymers decreases linearly with increas-

*Paper presented at Cambridge, April 1970, during conference on "Yield, Deformation and Fracture of Polymers".
†Present address: Ford Motor Co, P.O. Box 2053, Dearborn, Michigan 48121, USA.