STRESS-STRAIN RELATIONSHIPS FOR SOLID POLYMERS UNDER BIAXIAL LOADINGS

By

INDU PRAKASH SINGH

Applied Mechanics Department

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CERTIFICATE

This is to certify that the thesis entitled "Stress-Strain Relationships for Solid Polymers under Biaxial Loadings" being submitted by Mr. I.P. Singh to the Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy is a record of the bonafide research work carried out by him. Mr. I.P. Singh has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard.

The thesis, or any part thereof, has not been submitted to any other University or Institute for the award of any degree or diploma.

(Dr. R.K.Mittal)
Assistant Professor
Deptt. of Applied Mechanics
Indian Institute of Technology, Delhi,
NEW DELHI-110029.

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ABSTRACT

In this investigation the stress-strain relationship of nylon 6, a semicrystalline polymer, and PMMA (perspex), an amorphous glassy polymer, have been studied under uniaxial (tensile and torsional) and biaxial (combined tensile and torsional) loadings. Measures of generalized stress and generalized strain were determined experimentally for these polymers in order to describe their deformation behaviour for all loading paths by the same functional relationship involving these measures.

For conducting the experiments a combined tension-torsion machine was fabricated. This was of the dead weight type, where tensile and torsional loads could be applied independent of each other. Thin walled tubular specimens were subjected to ramp loading through various loading paths, i.e., tension only, torsion only, tension and torsion simultaneously, tension followed by torsion, and torsion followed by tension. They were also subjected to step loadings of tension only, torsion only and combined tension-torsion. The torsional and tensile displacements were monitored independently.

From the experimental observations, it was found that semicrystalline nylon 6 follows a generalized stress-generalized strain behaviour qualitatively similar to that of dead annealed metals as put forward by Bell and generalized by Mittal. The stress-strain relationship is piecewise parabolic and the measures of generalized stress and strain for nylon 6 were found to be

$$\text{generalized stress} = \sqrt{\frac{\sigma^2}{3} + \tau^2}$$

$$\text{generalized strain} = \sqrt{3\,\varepsilon^2 + \gamma^2}$$

where σ and τ are the tensile and shear stresses, and ε and γ are the tensile and shear strains respectively.

On the other hand PMMA, which is an amorphous glassy polymer, exhibits a behaviour that can be compared in a piecewise manner to rubbers. This was further confirmed by the examination of the stress-strain data of others for amorphous polymers (PMMA, PC, unplasticized PVC). The generalized measures of stress and strain for PMMA were found to be

$$\text{generalized stress} = \sqrt{\frac{\sigma^2}{2} + \tau^2}$$

$$\text{generalized strain} = \sqrt{3\,\varepsilon^2 + \gamma^2}$$

The Portevin-le Chatelier effect and the Poynting effect were observed for both the polymers.

Theoretical models based on strain energy functions of Mittal and Mooney-Rivlin have been discussed, to explain the stress-strain behaviour of nylon 6 and PMMA respectively.

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