International Journal of Plasticity 27 (2011) 2085–2102

Contents lists available at SciVerse ScienceDirect

International Journal of Plasticity

journal homepage: www.elsevier.com/locate/ijplas

Sequential evaluation of continuous deformation field of semi-crystalline polymers during tensile deformation accompanied by neck propagation

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ARTICLE INFO

Article history:
Received 22 April 2011
Received in final revised form 27 July 2011
Available online 17 August 2011

Keywords:
B. Polymeric material
C. Mechanical testing
C. Nondestructive evaluation
C. Numerical algorithms

ABSTRACT

The localized deformation field of high density polyethylene and polypropylene during a tensile test accompanied by neck propagation was quantitatively evaluated based on the network digital image correlation method. In the proposed method, the continuity of the deformation field around a point of interest was introduced for accurate evaluation of the displacement. The accuracy of the proposed method was verified through test images. Using the proposed method, the development of a non-uniform displacement field during tensile tests was evaluated from sequential digital images. The local strain rate was almost uniform until the nominal stress reached its maximum value. After the maximum stress was reached, non-uniform deformation developed at a part of the gauge region of the specimen. A decrease in nominal stress induced a reduction of the local strain rate at regions other than the necked zone. In this study, the cross section average local true stress, strain, and strain rate can be evaluated from the local displacement field. Thus, the relationship between these quantities was evaluated during the tensile tests. Using the proposed method, the local response under wide ranges of strain and strain rate can be evaluated from a few test conditions of tensile strain rate and a small range of tensile strain. Finally, the relationships between gradients of stress, strain, and strain rate under uniaxial tension are discussed. These non-local quantities deviated from those predicted by constitutive equations when the domain size used to evaluate the local quantities was large.

1. Introduction

Numerous material tests have been established and performed to evaluate the various mechanical properties of soft materials, such as rubber, film, and plastic polymers with reference to the tests for hard materials. However, soft materials often exhibit high heterogeneity in the deformation field from the early stages of the mechanical test. Therefore, mechanical tests assuming the uniform deformation in the specimen are not appropriate for the determination of the mechanical properties of such materials. Several kinds of polymers exhibit necking in early stage of tensile tests. And the necking continues to propagate along the tensile axis. Those polymers exhibit a sharp drop of nominal stress when a neck is generated in the specimen, and the stress is kept almost constant in the neck propagation stage (Courtney, 1990). Since it is difficult to evaluate the true stress–strain relation of the material from such a load–displacement curve, special procedures have been proposed. Several papers have proposed the sequential monitoring of strain in a very small region, which can be treated as a uniformly

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doi:10.1016/j.ijplas.2011.07.009