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Finite Element Modeling of the Effect of Strain Rate on the Damage of a Biphasic Copolymer

AhlemTahari *[1], Abdel-Nour Zaim[2], Ali Boudjlall Moulai[2], El Bahri Ould Chikh[1]

[1]LSTE Laboratory, University of Mascara, BP 305 Route de Mamounia Mascara, Algeria.
[2]Department of Mechanical Engineering, University of Relizane, Algeria.
*ahlem.tahari@univ-mascara.dz

ABSTRACT

This numerical modeling study explores the relationship between strain rate and damage caused by the coalescence of a spherical cavity in a polymer blend consisting of polybutylene terephthalate (PBT) and Poly (tetramethylene oxide) (PTMO). Damage induced by cavitation in polymers has significant implications for various industrial applications, including material durability and performance. The study focuses on understanding the impact of strain rate on the initiation and damage induced by cavitation phenomenon as well as plastic flow. The uniqueness of this study lies in introducing a unitary axisymmetric model comprising a single spherical cavity (f0=10%, volumetric fraction) subjected to the stress triaxiality. Our objective is to analyze the coalescence rate of the spherical cavity in this polymer blend under three different strain rates.

Keywords: Polymer blend, triaxial loading, homogeneous unit cell, strain rate.

1. Introduction

The phenomenon of cavity coalescence in ductile materials, where plastic deformation is concentrated at the microscopic scale between adjacent cavities, leads to a transition to uniaxial stress. This coalescence starts locally and causes rapid cavity growth until final rupture. The localization of plastic flow, illustrated by the maximum point on the Von-Mises stress/strain curve, is attributed to the necking of the ligament in the matrix, leading to the formation of macroscopic cracks. The study aims to understand the effect of varying strain rate on the maximum stress at the cavity coalescence point. Modeling the growth of cavities in ductile solid materials has led to the development of predictive methods by Needleman and Tvergaard [1,2]. An axisymmetric unit cell model is proposed, where voids are uniformly distributed, allowing for the description of a polymer's microstructure.

2. Experimental

In the initial undeformed configuration, the unit cell is a cylinder characterized by the void volume fraction, void aspect ratio, and cell aspect ratio, with their initial values. Due to the periodicity of the cell network, the cell must maintain its cylindrical shape during deformation, which is achieved by imposing uniform elongation in the axial direction and controlling the radial displacement of the main corner. The "RIKS" algorithm is used by the Abaqus computational code to maintain a constant stress triaxiality. Axisymmetric loadings applied to the model consist of dominant axial traction along the y-axis, as well as constant stress triaxiality. Finite element modeling was performed with Abaqus 6.14 Standard and Explicit, using quadrilateral iso-parametric elements with reduced integration. have been determined experimentally [3]

Table 01: *properties of the copolymer (PBT/PTMO) and obtained results.*

E (MPa)	Y	f_0 (%)	n	T	Strain rate $\dot{\varepsilon}_1$ (s^{-1})	$\Sigma_{eq,\,max}$	$\varepsilon_{eq,\,max}$	$\Sigma_{m,\,max}$
100	0.43	10	0.3	0.6	10^{-1}	0,48552944	0,2134975	1,456113
					10^{-2}	0,49764722	0,2154862	1,492455
					10^{-3}	0,5035397	0,2160638	1,510126

υ : Poisson's ratio, $\mathbf{f_0}$: volumetric fraction, **T**: stress triaxiality, **n**: material hardening coefficient.

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3. Results and Discussion

The results of the cellular model analysis are obtained from stress-strain equivalent curves, varying the strain rate. These results are presented through the evolution of the equivalent stress as a function of the equivalent strain figure.1. To illustrate the results of the numerical modeling, we present the stress distribution isovalves in the RVE at the moment of plastic instability (coalescence) for the three mechanical behaviors at different strain rates. Figure .2 show the distribution of equivalent stresses observed at the moment of cavity coalescence. Given the very large deformations undergone by the cells in this elastomer mixture, they are intentionally presented in their undeformed state to improve the readability of the iso-values. These results show that stresses are concentrated at the equator of the void and decrease as the stress triaxiality increases. Furthermore, the magnitude of the equivalent stress decreases with increasing strain rate. This suggests that an accelerated loading applied to this polymer blend likely has a crucial effect on the extension of macromolecular chains, thus causing the formation of secondary cavities and their coalescence followed by rupture. Additionally, the damage to the RVE is attributed to elastic volumetric deformation and volumetric deformation due to cavitation.

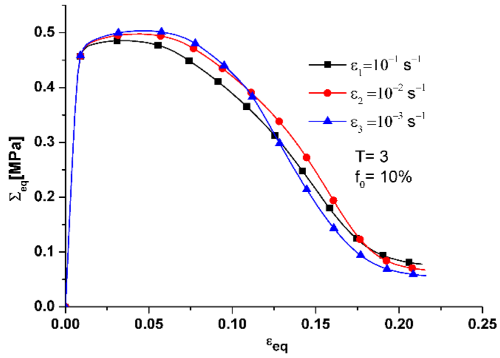

Figure 1: Equivalent stress as a function of equivalent strain at different strain rates.

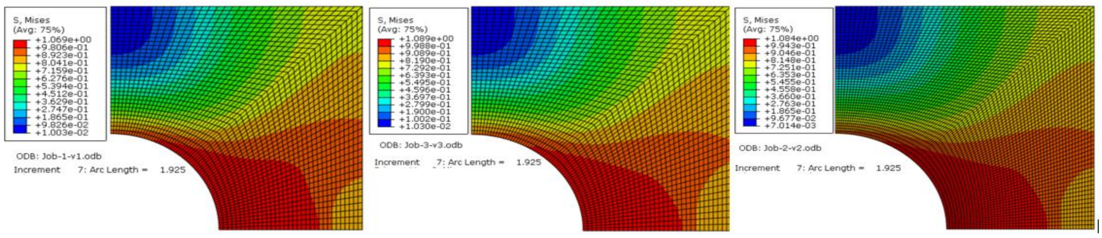

Figure 2: illustrates the Isovalues of maximum equivalent stresses at the cavity coalescence point.

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