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Effect of specimen notch quality on the essential work of fracture of ductile polymer films

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The essential work of fracture approach has been employed to analyse the effect of notch sharpening on the fracture toughness of a semicrystalline multiphase ethylene-propylene block copolymer. Double edge notched tension specimens were sharpened using different techniques: femtolaser ablation, razor blade sliding at room and liquid nitrogen temperatures, saw cutting, plastically deformed saw cutting, and scalpel sliding. The notch sharpening techniques provide notches of different quality in relation to both the notch tip radius and the plastic deformation in front of the crack tip. The best quality notches were produced by the femtolaser ablation technique, which provides very sharp notches without plastic deformation ahead of the crack tip. The effects of the non-collinearity of the notches and tilted specimens on the testing machine grips were also analysed. The shape of the registered stress–displacement curves shows differences, but only in the range comprised between the displacements corresponding to the maximum stress and the onset of crack initiation. A larger crack tip radius and/or larger extent of plastic deformation in front of the notch root leads to larger values of the displacement at the onset of crack initiation, resulting in higher values for the specific essential work of fracture. Yet on the other hand, the values of the slope of the essential work of fracture plot remain unchanged. A lower value for the specific essential work of fracture was obtained for the specimens sharpened using the femtolaser ablation technique.

1. Introduction

Films and thin sheets of polymers, polymer blends, and polymer composites are used in a wide variety of applications such as packaging, agriculture, coating, paint, among others. Their toughness is often a basic requisite to meet some industry needs.

The Linear Elastic Fracture Mechanics (LEFM) approach is used to study fractures occurring at nominal stresses well below the material yield stress. The dissipated energy is confined in a small area near the crack tip and the fracture is brittle. The LEFM approach is not applicable when the plasticity around the crack tip becomes too large; in those cases the Elastic Plastic Fracture Mechanics (EPFM) approach applies. When the crack propagation occurs through a highly deformed and

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Nomenclature

CTOD	crack tip opening displacement
d	displacement
DENT	double edge notched tension specimen
DMTA	dynamic mechanical thermal analysis
E	elastic modulus
EPBC	ethylene-propylene block copolymer
EPFM	elastic plastic fracture mechanics approach
EPR	elastomeric particles
ESIS	European structural integrity society
EWF	essential work of fracture approach
GPC	gel permeation chromatography
IPZ	inner process zone
J	J-integral
L	specimen length
LEFM	linear elastic fracture mechanics approach
MD	machine direction
MFI	melt flow index
NMR	nuclear magnetic resonance
OM	optical microscopy
OPZ	outer process zone
P	load
PET	polyethylene terephthalate
PETG	poly (ethylene terephthalate) modified glycol
PMMA	polymethylmethacrylate
PP	polypropylene
PYFM	post-yield fracture mechanics approach
SEM	scanning electron microscopy
t	specimen thickness
TC4	ESIS technical committee 4
W	specimen width
Z	original distance between clamps
α	propagation contribution to the extension
β	geometrical shape factor related to the OPZ
$CTOD_c$	CTOD value at the onset of crack propagation
d_i	displacement at the onset of crack initiation
d_r	displacement at rupture
$d_{\sigma max}$	displacement at maximum stress
l_o	original ligament length
M_n	average molecular mass in number
M_w	average molecular mass in weight
J_o	J-integral value at the onset of crack initiation
r_p	plastic zone radius
T_g	glass transition temperature
w_e	specific essential work of fracture
W_e	essential work of fracture
w_f	specific work of fracture
W_f	fracture energy
W_p	non-essential work of fracture
βw_p	slope of the $w_f - l_o$ plot
Δa_b	increment of crack length at blunting
σ_i	stress at the onset of crack initiation
σ_{max}	maximum stress
σ_y	uniaxial yield stress

yielded material then Post-Yield Fracture Mechanics (PYFM) can also be applied and the Essential Work of Fracture (EWF) is a suitable method.