DETERMINATION OF THE CRACK INITIATION ENERGY OF FILMS IN PLANE STRESS

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ABSTRACT

The fracture behaviour for a film of an ethylene-propylene block copolymer has been determined applying the essential work of fracture method. Double-edge notched tensile specimens were sharpened by two different techniques. The first technique has used the conventional method of the razor blade. The second one has employed a femtolaser ablation beam. It is studied the influence of the notch sharpening and it is proposed a new way to analyze the results.

KEY WORDS: essential work of fracture, sharpening method, femtolaser ablation.

1. INTRODUCTION

The technique of the essential work of fracture (EWF) is a method appropriate for the fracture toughness measurement in materials where the crack initiation occurs through a highly deformed and yielded material. However, the interpretation of the fracture parameters obtained with the essential work of fracture method is still a subject of discussion and debate [1].

One of the main problems when analyzing the fracture behaviour of a ductile thin polymer sheet is to establish the crack initiation point, which provides the evaluation of the initiation fracture energy of the crack. However, in this work, the data are presented in a novel way, that allows deducing the point of crack initiation. At the same time, the influence of the notch sharpening method is analyzed.

2. EXPERIMENTAL DETAILS

Deeply double edge notched tensile specimens (DDENT) cut out (in MD direction) from extruded films, 0.5 mm-thick, of an ethylene-propylene block copolymer with 8.5 % wt. of ethylene have been employed.

The essential work of fracture method has been applied on DDENT specimens; by one hand in some samples the notches were sharpened with the conventional method by using a razor blade, and by other hand, in some samples the notches were sharpened through an ablation with a femtolaser beam.

The tests have been carried out at room temperature in a universal testing machine, measuring the displacement of the cross-head located at 60 mm over the specimens.

3. RESULTS AND DISCUSSION

In Figure 1 are showed the micrographs obtained by scanning electron microscopy of the notches sharpened by femtolaser (Fig. 1a, 1b) and razor blade (Fig. 1c, 1d) Both notches have a similar tip radius, but the notches sharpened by razor blade display a great plastic deformation, that causes an accumulation of material in the crack tip.

Figure 2 represents in the classic way, the values of the load vs. displacement when the sharpening was made by femtolaser, whereas Figure 3 shows the validation criteria of the obtained data. In Figure 4 is displayed the EWF plot.

The stress vs. displacement plot (Figure 5) can be obtained from Fig. 2, dividing the load by the measured initial ligament section. The shadowed area corresponds with the specific essential work of fracture (w_e) value. In Fig. 5, the curves overlap among themselves up to a displacement value which corresponds with the shadowed area (w_e). From this point, they do not overlap anymore.

The frames shown in Fig. 5 indicate that prior to this point there is not crack propagation and afterwards, the crack growth has already started. Nevertheless, the exact frame where blunting becomes crack initiation is very difficult to determine. Therefore, w_e can be considered as the energy just up to crack initiation.

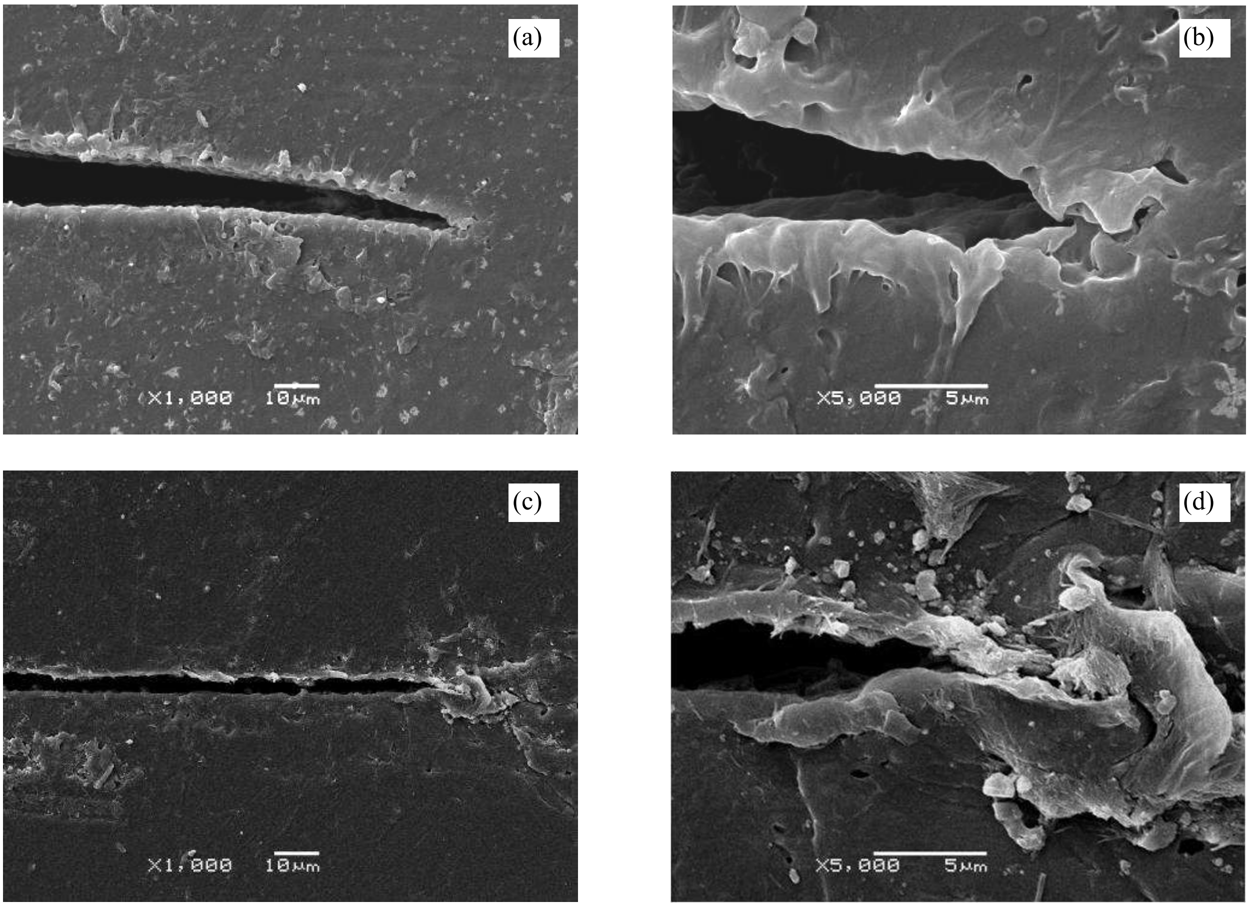

Figure 1. Scanning electron micrographs of notches sharpened by (a,b) femtolaser and (c,d) razor blade.

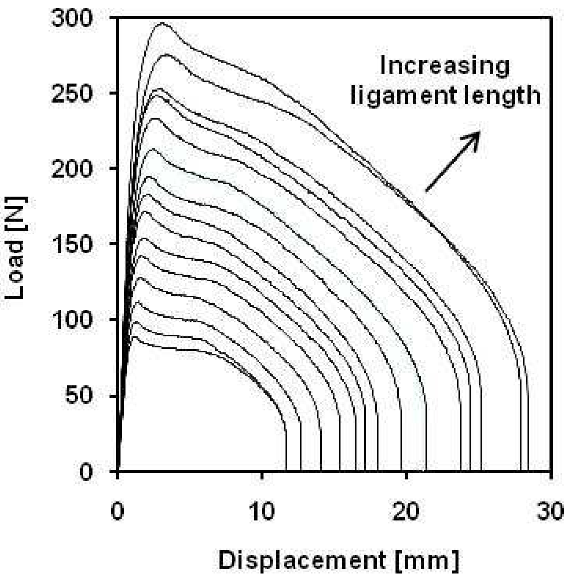

Figure 2. Load vs. displacement plots for DDENT specimens sharpened by femtolaser

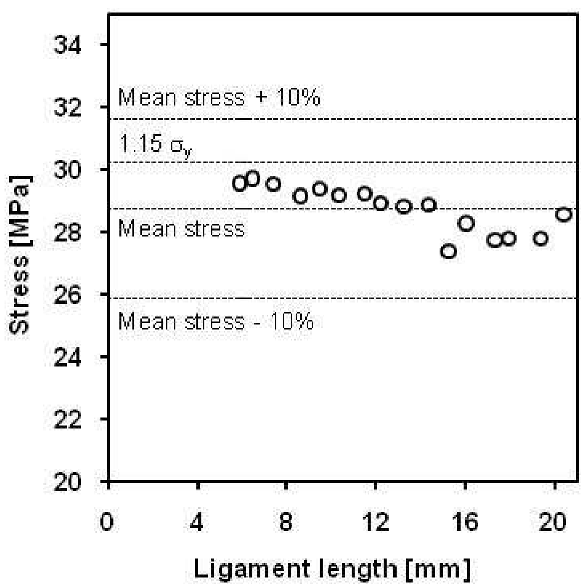

Figure 3. Validation criteria of the experimental points obtained from DDENT specimens sharpened by femtolaser.

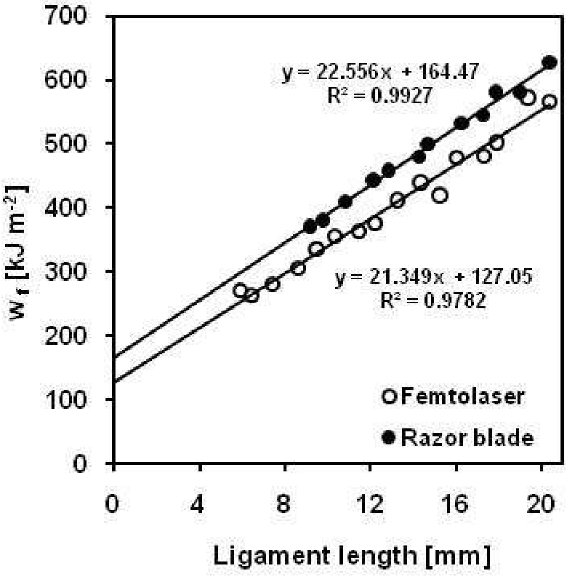

Figure 4. EWF plots obtained from specimens sharpened by femtolaser and razor blade.

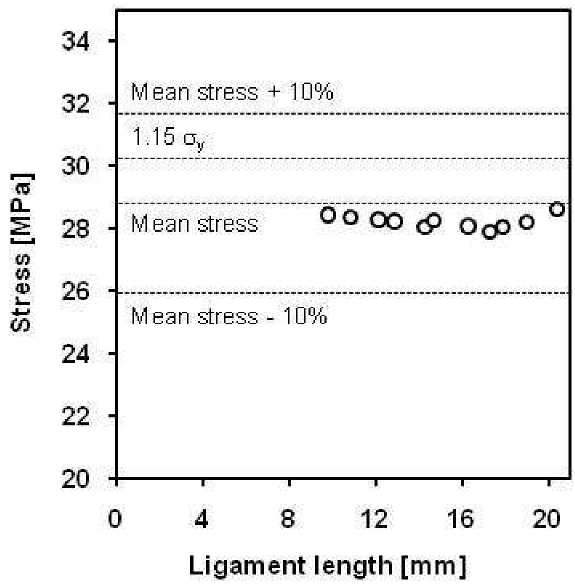

Figure 6. Validation criteria of the experimental points obtained from DDENT specimens sharpened by razor blade.

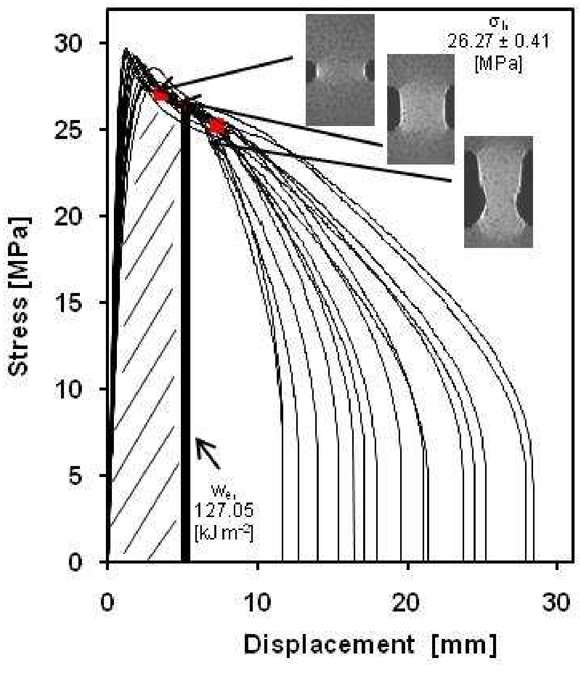

Figure 5. Stress vs. displacement plots for DDENT specimens sharpened by femtolaser.

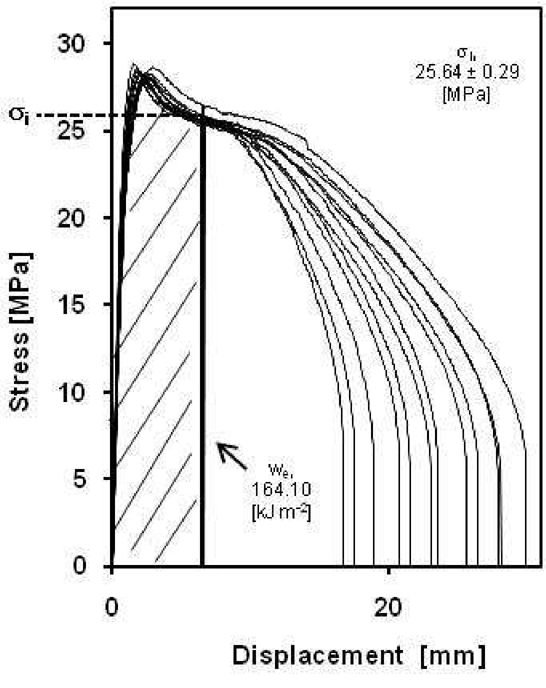

Figure 7. Stress vs. displacement plots for DDENT specimens sharpened by razor blade.

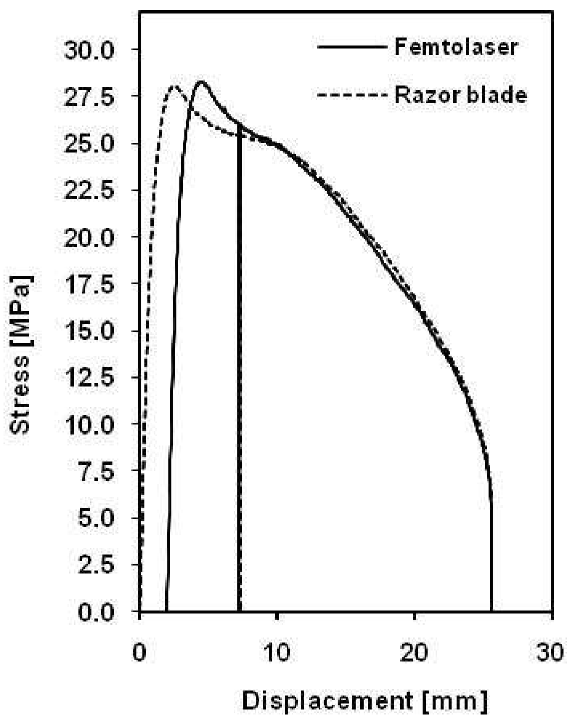

Figure 8. Stress vs. displacement plots for DDENT specimens sharpened by razor blade.

The same procedure has been employed with the specimens with notches sharpened by a razor blade. In Figure 6 is displayed the data validation, in Figure 4 the EWF plot, whereas in Figure 7 is represented the new plot stress vs. displacement.

In the specimens sharpened by a razor blade, sometimes, both notches did not initiate and propagate simultaneously. These specimens have not been taken into account in the analysis of the results, and have been eliminated.

The displacement at which the cracks start to initiate is lower for the femtolaser notched specimens than for the razor blade ones.

The higher displacement needed for razor blade sharpening specimens to start the crack growth can be attributed to the material volume accumulation at the notch tip, whereas femtolaser notch sharpening method do not produce any visible plastic damage.

The crack starts to grow at the same initiation stress, σ_i, regardless to the notch sharpening method.

In Figure 8 the results obtained with two specimens with the same ligament length (one sharpened by femtolaser and the other one by razor blade) are overlapped in the tail. The vertical lines are the values of w_e. It can be observed that from w_e both curves match, what indicates that the propagation does not depend on the sharpening method and explain why in the EWF plots the slopes are very similar when the sharpening methods are very different [2]. By other hand, w_e is not affected by the notch sharpening and the obtained values in the specimens sharpened by femtolaser is lower than in the specimens sharpened by razor blade.

4. CONCLUSIONS

Femtolaser and razor blade sharpening methods give similar notch tip radii.

Razor blade notch sharpening method produces significant plastic deformation ahead of the crack tip, which originates accumulation of deformed material.

The crack starts to initiate at the same initiation stress, σ_i, regardless to the notch sharpening method.

Stress vs. displacement plots are a good method to evaluate self-similarity in the fracture behaviour of series of different ligament length specimens.

In femtolaser sharpened specimens, σ_i is reached at lower crosshead displacements, so the crack requires less energy to initiate than razor blade sharpened specimens.

In EWF plots, the slope is similar for both femtolaser and razor blade sharpened specimens, indicating similar propagation behaviour.

ACKNOWLEDGEMENTS

The authors would like to thank the Education and Science Ministry for the financial support of this work through the MAT2006-13354 project. A. Segovia thanks the National Council of Science and Technology (CONACYT) of Mexico, for the support of a doctoral research scholarship.

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