# EVALUATION OF FRACTURE TOUGHNESS BY EWF METHOD FOR THIN-WALL MOLDINGS

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**ABSTRACT**

Since demand for thin-wall products with high toughness is increasing, the toughened new materials have been developed recently. However, the evaluation method of mechanical properties for such toughened thin-wall products is not standardized yet. As an evaluation method of mechanical properties for thin-wall moldings by means of essential work of fracture theory was proposed in this study. ABS plates fabricated by compression moldings were used, and double edge notched specimens were prepared by introducing the notch by pressing and sliding techniques by which the damage zone generated differently. The effect of notching techniques on the crack propagation and the work of fracture and plastic deformation were discussed. It was observed by optical microscopy that the specimen with the notch introduced by pressing method had larger damage zone and it affected the crack propagation behavior in the case of large ligament length. It resulted in the difference in the EWF plot. It can be concluded that sliding technique is more suitable than pressing for notching, and the specimens with the limited ligament length should be used for obtaining essential work of fracture and non-essential work of fracture.

## 1. INTRODUCTION

Toughening of polymers is one of important issues, because light weight and thin-wall products are highly demanded for mobile phones and lap top computers, and so on. Lots of new toughened polymers have been developed so far. However, there is not a standardized testing method to evaluate toughness of thin-wall products.

Essential work of fracture (EWF) method has been used to evaluate the fracture toughness of plastic materials by e.g. Chen [1-6]., and it enables to evaluate essential work of fracture by a simple method Due to the simplicity of the method, it was proposed as a standardized evaluation of fracture toughness of plastic products..

When the specimens with notch are prepared, there are several choices for notching method. One is the shape of the subjects such as razor, saw, and blade. The others are how to move the razor, saw or blade. It can be easily imaged that they may affect the properties obtained by the testing as reported by Yamakawa [7]. Therefore, in order to obtain accurate the properties, it should be important to select the appropriate notching method. However, the effect of notching on the properties obtained by EWF method was not well understood.

In this study, in order to discuss the effect of notching methods on crack propagation behavior in double edge notched specimens during tensile loading and on experimentally obtained properties by EWF method, compression molding plates of ABS is used.

## 2. EXPERIMENTAL

Material used in this study is ABS (130, Techno Polymer Co. Ltd., Japan). The specimens were fabricated by compression molding at 240°C of molding temperature and 7MPa of molding pressure. Figure 1 shows the geometry of the specimen. The specimens for EWF were cut out from the molded plate in 115mm x 35mm x 1mm. Double edge notched specimens were prepared and ligament lengths were 5, 6.6, 8.2, 6.5, 11.5mm. The nothing techniques were sliding method and pressing method. In the case of sliding method, a razor was fixed on the notching machine, and specimens were moved. On the other hand, specimens were fixed and a razor was pressed into the specimens. The speed of specimen in sliding and razor in pressing were controlled at constant speed. In order to observe the damage zone generated during notching, the areas near the notch were observed by optical microscopy. Tensile load was applied to the specimens at 20mm/min. During loading, crack propagation was observed by CCD camera.

## 3. RESULTS AND DISCUSSION

Figure 2 shows the micrograph by optical microscopy. The damage zone generated near the notch tip appeared in black. In the case of sliding technique, the damage zone appeared just near the notch tip. On the other hand in pressing technique, the damage zone spread widely in transverse direction against the notch. Hence, the difference between the notching techniques was clearly shown.

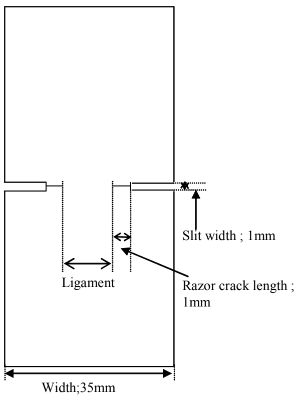
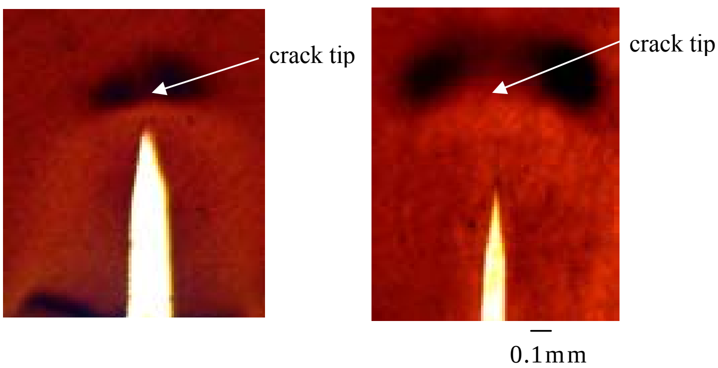



Fig. 1 Geometry of specimen.




(a) Sliding (b) Pressing

Figure 2 Damage zone observed by optical microscopy.

Figure 3 shows the typical load displacement curves at each ligament length and figure 4 is the EWF plots of the specimens prepared by pressing and sliding notching techniques. There were some specimens showing not appropriate crack propagation as reported by Ferrer-Balas [6], such as instability, and they were not included in the EWF plots. Table 1 shows the experimentally obtained properties from figure 4. Small differences between pressing and sliding methods in $w_e$(essential work of fracture), and $\beta w_p$(work of plastic deformation) were found. In order to discuss this point further, the crack propagation behavior was observed by CCD camera.

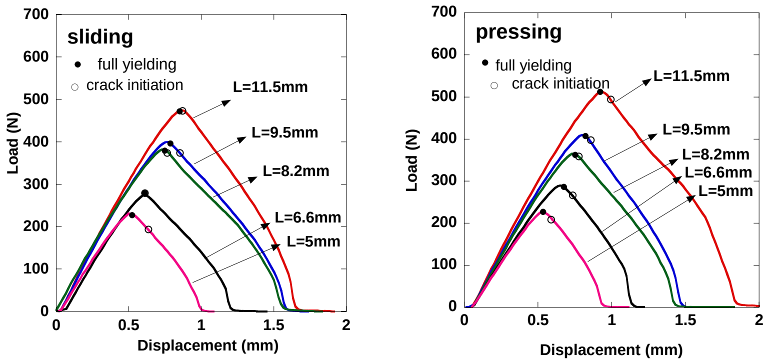



Fig. 3 Load-displacement curves of each ligament length of sliding and pressing method.

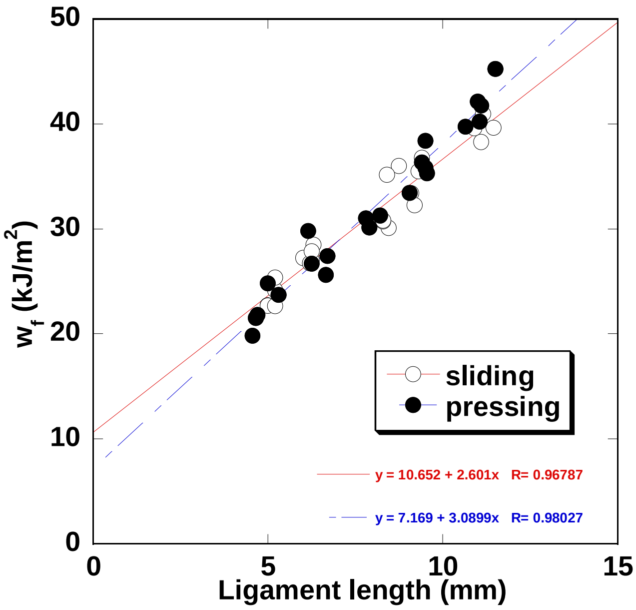



Fig. 4 $w_f$ and ligament length plots.

Table 1. Essential work of fracture and correlation efficient obtained by EWF method.

| Notching technique | $w_e$ (KJ/m$^2$) | $\beta w_p$ (KJ/m$^2$) | R |
|---|---|---|---|
| Sliding | 10.65 | 2.60 | 0.97 |
| Pressing | 7.17 | 3.09 | 0.98 |

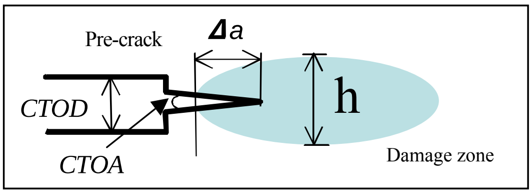



Figure 5 Definition of CTOA, CTOD, h and delta a.

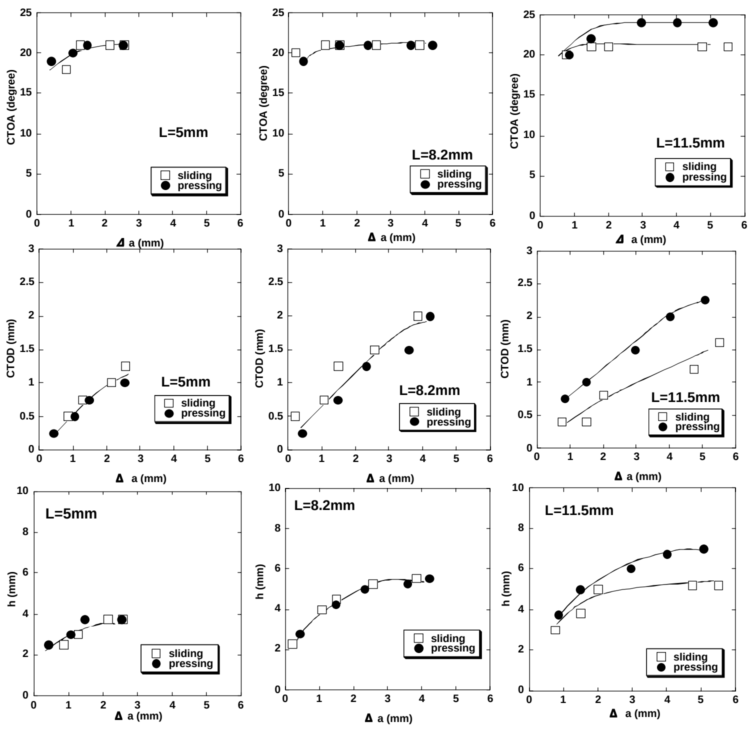



Figure 6 Crack propagation behaviors at each ligament length.

Figure 5 shows the definitions of the parameter, crack tip opening angle (CTOA), crack tip opening displacement (CTOD), crack length(delta a), and height of damage zone (h) which were obtained by means of the images from CCD camera. Figure 6 shows the relationship between COA , CTOD, delta a and crack length. In the case that ligament length of 11.5mm, the COA CTOD, and delta a of pressing method was significantly larger than that of sliding method, while they showed similar tendency in smaller ligament lengths. From the microscopic observation around pre-cracks, it was confirmed that the specimen by pressing method had larger damage zone than by sliding method as mentioned above, and it is the apparent difference between two notching techniques. Therefore, the difference in them as a function of crack length would be related to the damage in notching. Blunting of the crack tip occurred in pressing specimens and it would increase the specific work in the case of larger ligament length. Namely, it can be concluding that the blunting occurred in the case of large ligament length in the specimens prepared by pressing technique. As the effect of damage generated in notching was suggested, the notching method which does not damage the specimen is recommendable for this kind of test. In addition, long ligament length should not be recommended in order to avoid the effect of damage zone generated by notching.

## 4. CONCLUSION

In order to develop the evaluation method for fracture toughness of thin-wall molding, EWF method by using double end notched specimens was a focus. Effect of notching on the damage zone in the specimens and crack propagations were investigated by using the ABS specimens fabricated by compression molding. Crack propagation behaviors were different between pressing and sliding methods, and it is due to the difference in the area of damage zone generated by notching.

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