INSTRUMENTED IMPACT TEST: DETERMINATION OF CRACK RESISTANCE CURVES OF POLYMERS

S. Seidler and W. Grellmann*

The paper shows the advantages and disadvantages of using the known standards and the ESIS TC4 testing protocol for toughness characterization of high impact polymers. Several methods to produce different amounts of stable crack growth where compared. It can be shown that the multiple specimen stop-block technique gives the most conservative results.
The influence of specimen thickness and crack length on the J-Δa curves of ABS (acrylonitrile-butadiene-styrene) and nylon was also investigated. A direct connection between the toughness of the material and the necessary specimen thickness was found.

INTRODUCTION

The questions of a criterion for toughness in fracture of polymer solids have been extensively investigated from both scientific and practical viewpoints. But, the fracture mechanics toughness characterization of polymers has always followed the leads of metals characterization and there are only a few experiencies about the requirements on testing method, specimen geometry and crack geometry especially at higher testing velocities.

EXPERIMENTAL

For the measurements, a Charpy impact tester with 4 J maximum impact energy was used and load-deflection diagrams were recorded (Fig. 1). The dimensions of the SENB specimens were: length L=80 mm, width W=10 mm and thickness B=2-10 mm. The specimens were notched with a razor blade. The notch depth, a, was 4.5 mm and the notch tip radius was 0.2 μm. Stable crack growth, Δa, was quantified on the fracture surface by light microscopy. The value of J for each specimen was determined from the area under its load-deflection curve (1).

* Martin-Luther-University Halle-Wittenberg, Department of Materials Science

RESULTS

Standard comparison

For the determination of J versus Δa curves under static loading, several standards and drafts exist (1-3). Some of them were examined concerning their applicability for polymers under impact loading conditions on example of ABS (Fig.2). In principle, all standards and drafts can be used to describe the crack resistance behaviour of this material. The different J-integral approximation methods and the different validity limits lead to different technical crack initiation values $J_{0.2}$. ASTM 813 (2) recommends fixed offsets for the minimum and maximum crack growth. Since the ligaments can be of any size, the fixed offsets will not always guarantee that the J_R curves are valid. Therefore, only crack growth validity limits which consider the remaining ligament are useful. On the other hand, the ASTM blunting line does not represent the real blunting process (4) and the strain hardening behaviour of polymers under impact conditions is unknown. From this it follows that the ESIS TC4 determination of $J_{0.2}$ is a conservative determination criteria which is in practice very useful.

Comparison of Methods

Figure 3 shows the comparison of the J versus Δa curves of a PP copolymer and a rubber toughned nylon 66 using the stop-block and the low-blow technique. The low-blow technique involved testing velocities in the range $0.5 < v_H < 1.5$ m/s. For the stop-block technique the testing velocity was 1.5 m/s. For the construction of the J_R curves, the ESIS test protocol (1) was used. Data point distribution is very bad for the J_R curves determined with the low-blow technique. Only a few data points are within the validity limits Δa_{min} and Δa_{max}.

In (5) it is shown that there are now differences under static loading between the single specimen method and the multiple specimen method but under dynamic loading there are differences (Fig.4). Especially the slopes of the J_R curves are different. The differences between the J-Δa values increase with increasing Δa. It is possible that the reason for this behaviour is crack tip blunting during unloading. If the crack tip radius after the first loading increases, then the energy must also increase. Another aspect is the possibility of energy dissipative processes occuring during loading. If there are crazes in the material, the energy to start a new crack must increase.

Influence of specimen thickness

The J-integral values are geometry independent if they satisfy equation (1). The constant ε is a material specific parameter and in (6), ε values between 10 and 90 were found.

$$B;\ a;\ (W-a) \geq \varepsilon\ (J/\sigma_y) \qquad (1)$$

Figure 5 shows the influence of specimen thickness on the J_R curves of ABS and nylon. The knowledge of the general J-B connection permits the determination of the critical specimen thickness and the respective ε value. Figure 6 shows the dependence of ε values on the crack initiation values J_{Ic} and J_{Id}. As can be seen, with increasing toughness the ε values decrease. It is possible to use a fit of these data points to get ε values of materials whose specific J versus B connection is unknown.

SYMBOLS USED

v_H = testing velocity (m/s)

Δa = stable crack growth (mm)

σ_y = yield stress (MPa)

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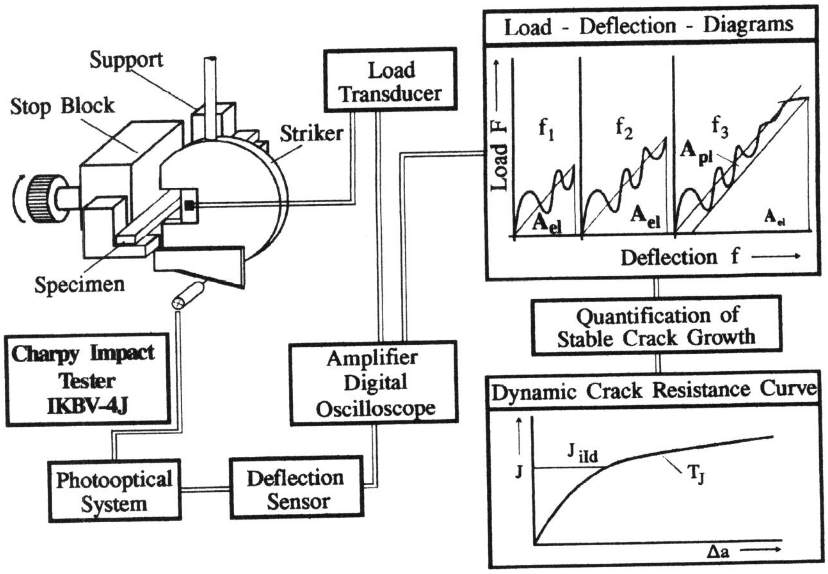

Figure 1 Test arrangement

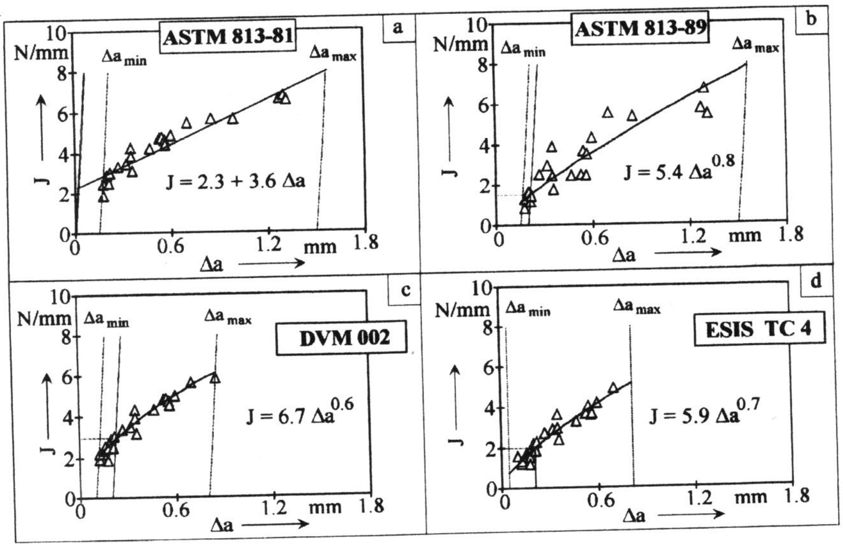

Figure 2 Standard comparison on example of a ABS resin

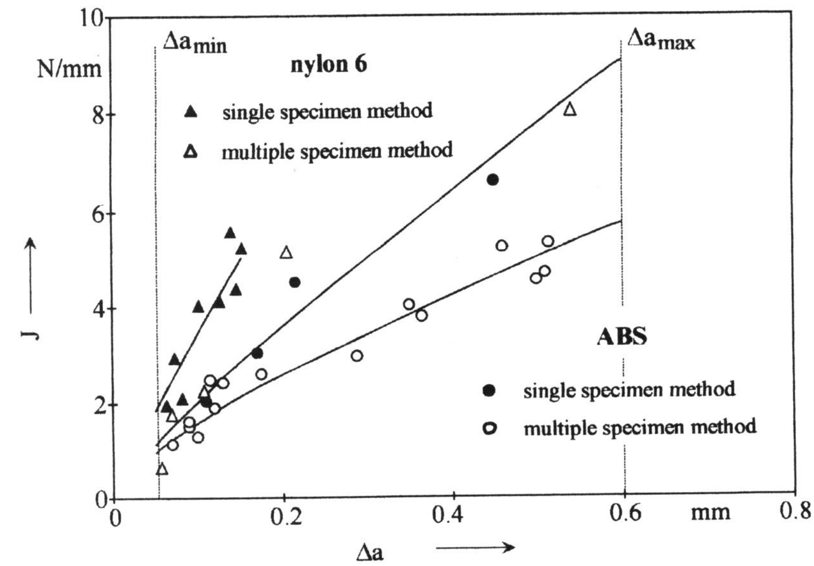

Figure 3 Single specimen method and multiple specimen method

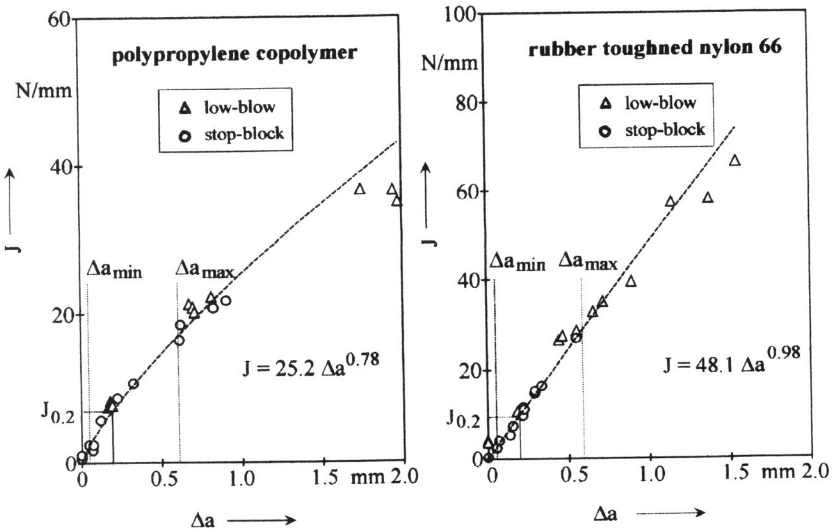

Figure 4 Comparison of the stop-block and the low-blow technique

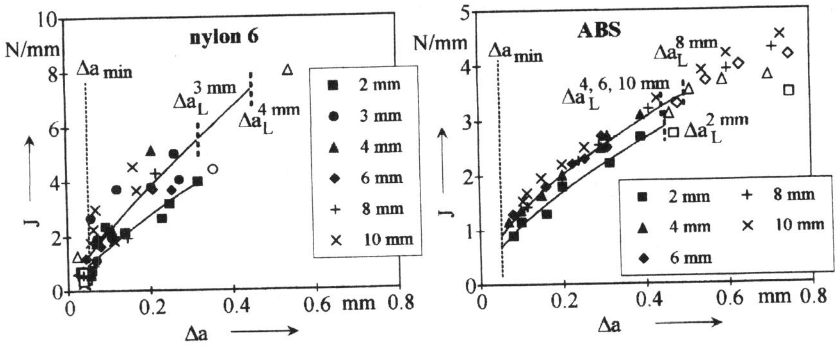

Figure 5 Influence of specimen thickness on the J_R curves of nylon 6 and ABS

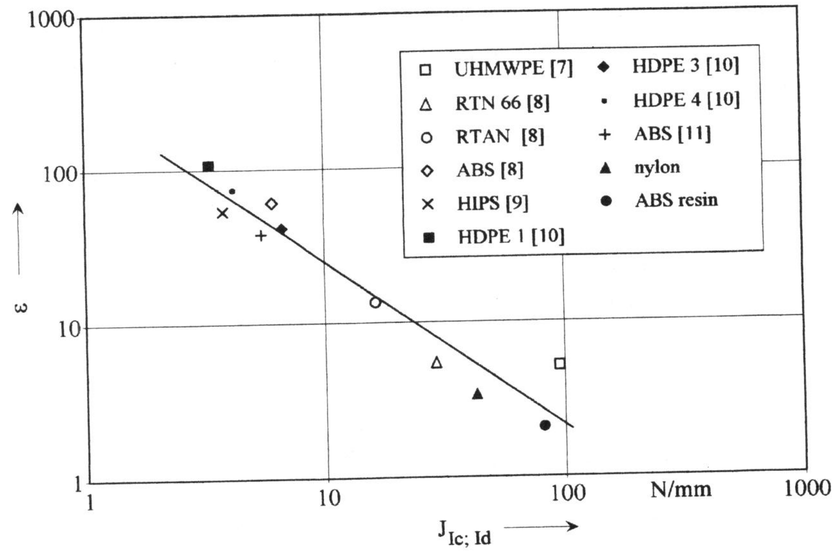

Figure 6 Dependence of ε on crack initiation values