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Testing of Plastics

Instrumented Tensile-Impact Test (ITIT)

Procedure for Determining the Crack Resistance Behaviour Using the Instrumented Tensile-Impact Test

Accredited test laboratory according DIN EN ISO/IEC 17025

MPK-Procedure

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Content

Procedure for Determining the Crack Resistance Behaviour Using the Instrumented Notched Tensile-Impact Test (ITIT)

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1 Application

The instrumented notched tensile-impact test is used for the determination of toughness properties of polymeric materials for which the performance of the instrumented Charpy impact test is not possible because of the specimen thickness and/or low material stiffness. This method should be applied especially within testing of polymeric sheets and elastomers [1–6]. In comparison to the instrumented Charpy impact test [7], instrumented notched tensile-impact tests have been reported in the literature relatively seldom. However, publications [8–14] show, that instrumented notched tensile-impact test is a helpful tool to describe the material properties as a function of structural parameters and/or experimental conditions such as temperature or loading speed.
In some of the cited publications it is described that instrumented tensile-impact tests with unnotched specimens are used to record stress–strain diagrams. These diagrams are the basis of the following determination of stress and strain at break for example. For this reason, it is important to distinguish between notched tensile-impact tests and tensile-impact tests.

In principle, the instrumented notched tensile-impact test is an extension of the conventional notched tensile-impact test according to *ISO 8256* [15] and is performed with specimens with razor-blade notches.
During loading of the specimen, load–time signal is recorded. Resulting material parameters can be used for quality control as well as for research and development.

2 Short Description

Examinations for determination of toughness are performed with the pendulum device Resil Impactor Junior 25 according to *ISO 13802* [16]. This pendulum device has a working capacity of 4 J, 7.5 J, 15 J and 25 J at maximum falling angle (150°). For the test, a specimen is fixed between a stationary clamp and a cross head. In contrast to Charpy impact testing, during notched tensile-impact testing, no direct contact of the pendulum hammer and the specimen takes place. The pendulum hammer hits the cross head which is fixed to the specimen. In this way, the specimen is deformed in direction of its longitudinal axis until fracture occurs. Therefore, a tensile-impact test with unnotched specimens is a uniaxial tensile test with a high deformation speed. The metallic pendulum hammer consists of a tubular pendulum arm and an impact construction with metallic blocks at both sides, which meet the cross head. After release, the pendulum hammer moves in a circle and transfers part of its kinetic energy to the cross head and therefore, indirectly to the specimen, at the lowest point of its trajectory.
For short pendulum hammers (up to 4 J working capacity at maximum falling angle), the testing speed at zero crossing is 2.9 m/s. Larger pendulum hammers have a larger pendulum length and therefore, their velocity at the zero crossing is 3.7 m/s. Specimens have a rectangular cross-section and are double-edge notched.

Recording of the load (*F*)–time (*t*) signal is realised over a piezo load cell, which is integrated in the stationary clamp. Measuring range is 4 kN.
From the *F*-*t* diagrams, the deformation (in this case the extension) can be calculated from Newton's second law. In a first integration step (1), the velocity can be determined, and in a second integration step (2), the extension *l* of the specimen as a function of time:

$$v(t) = v_0 - \frac{1}{m}\int_0^t F(\tau)\mathrm{d}\tau \quad (1)$$

$$l(t) = \int_0^t v(\tau)\mathrm{d}\tau \quad (2)$$

A direct measurement of the extension does not take place. The *F*-*t* signal is transferred to a personal computer over a data acquisition system. By using the belonging software DAS4Win, one is able to display and analyse load–time diagrams. In Figure 1, one can see a schematic *F*–*l* diagram of an elastomer. Analysis of such diagrams is done by determining firstly the maximum load F_{max} and the extension at F_{max} l_{max}. Further, the area under the *F*–*l* diagram is split into two parts: energy up to maximum load A_{max} and a so-called crack propagation energy A_p.

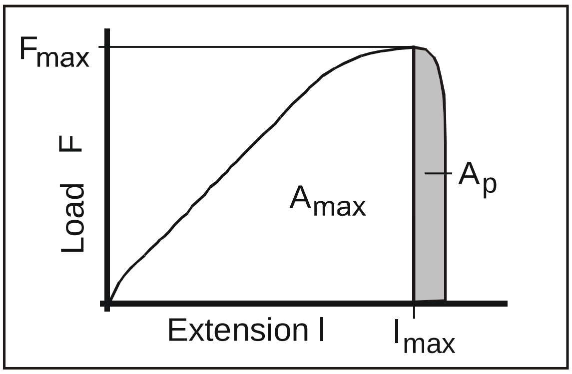

Fig. 1: Characteristic load–extension diagram with crack propagation energy (F_{max} – maximum load; l_{max} – maximum extension; A_{max} – energy up to F_{max}; A_P – crack propagation energy)

3 Determination of Parameters Related to the Resistance Against Unstable Crack Propagation

3.1 Summary of the Test Method

Aim of the tests is the determination of fracture mechanical material parameters. This method is only valid for double-edge-notched tension (DENT) specimens of polymers with a sharp crack. Starting from load–extension diagrams, stress intensity factors K_t and *J* values J_d can be calculated.

3.2 Specimens

According to *ISO 8256* [15], DENT specimens with following dimensions are to prefer:

- Width *W* = 10 mm
- Length *L* = 80 mm and 64 mm, respectively

The notching is carried out preferably with metal blades by a pneumatic notching device on the narrow sides of the specimen up to an initial crack length of 2 mm, this means 1 mm at each side. The surfaces must be free of scratches, craters, depressions and flashes.

Before testing the specimens, the thickness and width must be measured with a precision of 0.01 mm. The results must be recorded. At least 10 specimens should be tested, after storage in the testing room for 12 h.

3.3 Performance

For a material characterization at room temperature, normalisation of the specimens and experiments must be carried out under standard conditions according to ISO 291 [17] with a temperature of 23°C and a relative air humidity of 50 % (referred to as “climate 23/50”) [18]. If deviations occur or if variation from the standard conditions is necessary, this must be reported.

The specimen must be fixed parallel between the stationary clamp and the cross head in that way that the pendulum hammer hits the cross head at the lowest point of the circle motion (see Figure 2). Initial gauge length l_0 is 30 mm, the notches must be in the middle of l_0. Experiments with elastomers should preferably be performed at maximum falling angle. This corresponds to a hammer speed of 2.9 or 3.7 m/s, respectively. When testing thermoplastic sheets, the hammer speed must be 1 m/s or 1,5 m/s (corresponding to a falling angle of 40° or 60°).

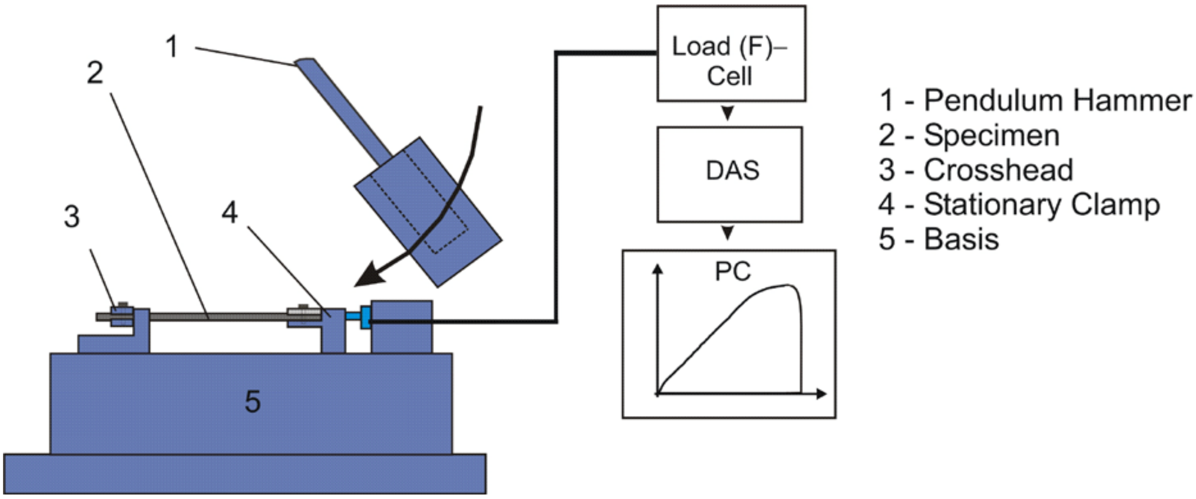

Fig. 2: Schematic representation of fracture mechanics testing device for performance of instrumented notched tensile-impact tests

Recording of load–extension diagrams is carried out according to the service manual of the pendulum device.

3.4 Analysis

3.4.1 General

For analysis, the Ceast software „DAS4WIN extended" should be used. After the test, the recorded load–extension diagram is displayed. As it is shown in Figure 1, at first maximum load F_{max} and extension at maximum load l_{max} must be determined. Furthermore, energy A_{max} (corresponds to the area under the diagram up to F_{max}) and crack propagation energy A_P are to be specified. The software allows to print each F–l diagram and to save it in ASCII data format.
Subsequent changes within settings (for example test duration) or changes of *F-l* diagrams are not possible.

3.4.2 Determination of Fracture Mechanical Parameters

For impact toughness characterization of polymers with thermoplastic and elastomeric matrix according to this procedure, following material parameter J_{Qd} is to prefer [18]:

***J*-Werte *J*Qd**

$$J_{Q_d} = \frac{\eta A_{max}}{B(W-a)} \qquad (3)$$

with

$$\eta = -0{,}06 + 5{,}99\left(\frac{a}{W}\right) - 7{,}42\left(\frac{a}{W}\right)^2 + 3{,}29\left(\frac{a}{W}\right)^3$$

The determination of further characteristic values depends on technical requirements. These values must be reported in the testing protocol.

3.4.3. Validation of the Fracture Mechanical Parameters

3.4.3.1. Validation of Experimental Conditions

For the determination of characteristic fracture mechanics parameters using the notched tensile-impact test, the following experimental conditions must be checked [7,15–18].

- energy absorption (A_{max}+A_P)

Checking of the energy absorption is done according to *ISO 8256*, whereby the absorbed energy **(**A_{max}+A_P**)** must be in the range between 20 and 80% of the maximum energy of the pendulum hammer A_H.

$$0.2A_H \le (A_{max} + A_P) \le 0.8A_H \qquad (4)$$

- speed of the pendulum hammer v_H

Speed of the pendulum hammer should be reduced during the test only by 20 %.

3.4.3.2 Requirements on Specimen Geometry

For the determination of geometry-independent material parameters, a plane strain state must be occurring within the specimen. For this, a certain specimen thickness and a certain notch depth is necessary. When testing very thin specimens (for example from extrusion or blow films), one must assume that because of the small thickness a plane stress state predominates.
In this case, the material parameters from the instrumented notched tensile-impact test can be used to compare materials, for example within a modification series. However, these results cannot be transferred to other geometries. This aspect must be noted within the test report.

4 Literature

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