DETERMINATION OF CARACTERISTIC FRACTURE MECHANICS VALUE AS RESISTANCE USING THE INSTRUMENTED IMPACT TEST

Constantin STANESCU, Professor Dr.eng. “Politechnica” of University Bucharest
e-mail: prof_cstanescu@yahoo.com
Adriana CARSTOIU, Lecturer, Dr.eng. “Valachia” University of Targoviste
e-mail: adriana_cirstoiu@yahoo.com_
Vasile SURCEL, University of Targu Jiu
Cristian BEBE, eng Transport’s College of Bucharest
e-mail:cr_bebe@yahoo.com

ABSTRACT

The instrumented Charpy impact test is used for determining properties of impact strenght of plastics. It is as addition to the pendulum impact test according to ISO and is carried out on razor blade notched specimens. The range for the used plastics is from brittle thermosets up to high impact polymer blends.Both, the load and the deflection signals are registered and the impact energy is divided into an elastic and a plastic part.Considering the requirements for the specimen size and notch geometry independent material parameters are calculated.These parameters can be used for control and protection of quality as well as for research and development.

1.Short description of the procedure

The testing of tough polymers is carried out by a pendulum Charpy impact tester PSW 4 with 4 J work capacity at maximum falling height. Using a Charpy impact device a single edge notched square specimen is broken by the pendulum hammer impact. The striker who has an edge on its impact side is fastened on a tubular pendulum arm. After releasing it moves in a circle and carries a part of its kinetic energy to the specimen at the lowest point of its trajectory.

The measuring device is able to register load(F)-time(t) diagrams and load(F)-deflection(f) diagrams, either. In the case of registered load-time diagrams first of all the deflection can be calculated following Newton’s 2nd axioma. In a first integration step (1) the velocity can be determined and in a second integration step (2) the deflection *f* of the specimen as a function of time.

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

$$f(t) = \int_0^t v(\tau)d\tau \tag{2}$$

An optical device is used for the measurement of the deflection. In the trace of the light rays a diaphragm fastened on the pendulum hammer is shifted by the motion of the pendulum. Depending on the shifting more or less light rays reach a photo transistor. The resulting signal is amplified for further analysis.

Both, the load signal and the deflection signal are carried to a storage oscilloscope. The oscilloscope is used as an analogous digital converter and as a monitor for a first visual interpretation of the load-time curve and the load-deflection curve, replane of the pendulum on the opposite side of the striker edge (Fig. 1). The pendulum velocity should be 1.0 or 1.5 m/s.

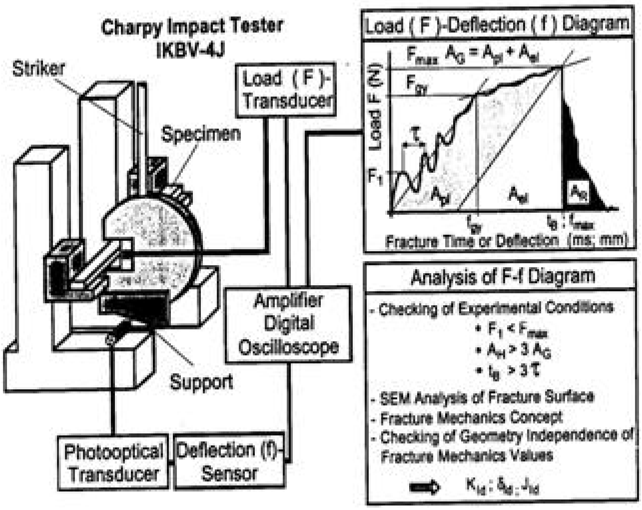

Fig. 1 Fracture mechanics testing device for the instrumented impact test

The registration of the load-deflection curves is carried out as described in the operating instructions.

The determination of the dynamic flexural modulus E_d and the dynamic yield stress σ_y is carried out on at least 5 unnotched specimens.

For that, the linear part of the load-deflection diagram is used, i.e., after fixing the yield point, E_d and σ_y can be calculated following (3) and (4), respectively.

$$E_d = \frac{F_{gy} s^3}{4BW^3 f_{gy}} \tag{3}$$

$$\sigma_y = \frac{3F_{gy} s}{2BW^2} \tag{4}$$

2. Determination of Fracture Mechanics Values

For the impact toughness evaluation of polymers under this procedure the following values are preffered:

Dynamic stress intensity factor K_{Qd}

$$K_{Qd} = \frac{F_{max} s}{BW^{3/2}} f\left(\frac{a}{W}\right) \tag{5}$$

where

$$f\left(\frac{a}{W}\right)=\frac{3}{2}\left(\frac{a}{W}\right)^{1/2}\left[\frac{1.99-\frac{a}{W}\left(1-\frac{a}{W}\right)\left(2.5-3.93\frac{a}{W}+2.7\left(\frac{a}{W}\right)^{2}\right)}{\left(1+2\frac{a}{W}\right)\left(1-\frac{a}{W}\right)^{3/2}}\right] \tag{6}$$

and

$$f\left(\frac{a}{W}\right)=2.9\left(\frac{a}{W}\right)^{\frac{1}{2}}-4.6\left(\frac{a}{W}\right)^{\frac{3}{2}}+21.8\left(\frac{a}{W}\right)^{\frac{5}{2}}-37.6\left(\frac{a}{W}\right)^{\frac{7}{2}}+38.7\left(\frac{a}{W}\right)^{\frac{9}{2}} \tag{7}$$

respectively, is.

J-integral value J_{Qd}

Evaluation method by Sumpter and Turner (ST)- J^{ST}

$$J_{Qd}^{ST}=\eta_{el}\frac{A_{el}}{B(W-a)}+\eta_{pl}\frac{A_{pl}}{B(W-a)}\frac{W-a_{eff}}{W-a} \tag{8}$$

where

$$\eta_{el}=\frac{2F_{gy}s^{2}(W-a)}{f_{gy}E_{d}BW^{3}}f^{2}\left(\frac{a}{W}\right)\left(1-\nu^{2}\right) \tag{9}$$

and

$$\eta_{pl}=2-\frac{\left(1-\frac{a}{W}\right)\left(0.892-4.476\frac{a}{W}\right)}{1.125+0.892\frac{a}{W}-2.238\left(\frac{a}{W}\right)^{2}} \tag{10}$$

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Evaluation method by Merkle and Corten - J^{MC}

$$J_{Qd}^{MC}=G_{1}+\frac{2}{B(W-a)}\left[D_{1}A_{G}+D_{2}A_{K}-\left(D_{1}+D_{2}\right)A_{el}\right] \tag{11}$$

$$G_{1}=\frac{K_{Id}^{2}}{E}\left(1-\nu^{2}\right)$$ for plane strain state (12)

$$D_1 = \frac{1+\gamma}{1+\gamma^2} \qquad (13)$$

$$D_2 = \frac{\gamma\left(1-2\gamma-\gamma^2\right)}{\left(1+\gamma^2\right)^2} \qquad (14)$$

$$\gamma = \frac{1.456(W-a)}{s} \qquad (15)$$

$$A_K = F_{max} f_{max} - A_G \qquad (16)$$

Critical crack opening displacement δ_{Qd}

$$\delta_{Qd} = \frac{1}{n}(W-a)\frac{4f_{max}}{s} \qquad (17)$$

and

$$\delta_{Qdk} = \frac{1}{n}(W-a)\frac{4f_k}{s} \qquad (18)$$

respectively, where

$$f_k = f_{max} - f_b \qquad (19)$$

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

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