Experimentální Analýza Napětí 2009
Experimental Stress Analysis

EVALUATION OF MAXWELL MATERIAL PARAMETERS WITH REGARD TO FEM ANALYSES

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Abstract: This article presents the methodology behind the evaluation of material parameters of element No. 121 from the material elements library of PAM-CRASH software during tension stress-strain experiments. This element material, typically plastic, intended for product manufacture is represented by a generalized Maxwell model. A constant deformation speed of the specimen is supposed. Results obtained from material tests for some constructional plastics indicate significant sensitivity of the stress on strain rate.

1. Introduction

Polymeric materials, whether amorphous or semi-crystalline, show viscous properties during high load speeds. Multi-axial response of the viscous material is given by a constitutive equation

$$s_{ij} = 2\,\mu\,\dot{\epsilon}_{ij}^{v}\,, \tag{1}$$

where

s_{ij}	are components of deviator of stress
$\dot{\epsilon}_{ij}^{v}$	are components of tensor of viscoelastic strain rate, and
μ	is viscosity coefficient.

2. Non-linear response of polymeric material

In case of a non-linear response of polymeric material, the viscosity coefficient is dependent on the speed of viscous deformation [2], i.e.

$$3\mu = \sigma_0\,\frac{\dot{\epsilon}_v^{m-1}}{\epsilon_{v0}^{m}}\,. \tag{2}$$

In the previous relation

σ_0, ϵ_{v0}	is the specific reference state,
$\dot{\epsilon}_v$	is the intensity of viscous strain rate, and
m	is the coefficient of hardening owing to the strain rate

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Coefficient m can be determined as a differential coefficient as below:

$$m = \frac{d \cdot \ln \sigma}{d \cdot \ln \dot{\varepsilon}_{v0}} \quad . \tag{3}$$

For investigating Crash/Forming problems for polymeric materials, PAM-CRASH uses shell element No. 121 as recommended in [1]. This element is defined as the isotropic non-linear viscoelastic shell element of the Maxwell type (see Fig.1).

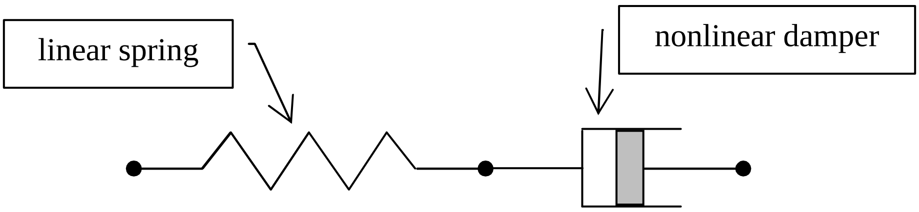

Figure 1: *Maxwell non-linear viscoelastic material*

In cases of a uniaxial tensile test realized for the given polymeric material at a constant clamp speed, the response of the Maxwell material can be described by the following relation:

$$\sigma_0 = k\,[1 - \exp(-w\,\epsilon_{v0})]\,(1 + h_2\epsilon_{v0} + h_1\,\epsilon_{v0}^2). \tag{4}$$

In the previous relation

k	is the material consistency,
h_1	is the first strain hardening coefficient,
h_2	is the second strain hardening coefficient, and
w	is the viscoelastic coefficient.

The five above stated parameters (k, m, h_1, h_2 and w) of the Maxwell non-linear model are defined as material constants dependent only on temperature.

3. Experimental arrangement

For realization of the above-mentioned identification of material dependence, an impact “drop tester tower” device (see Fig.2) has been designed and assembled. The essential mechanical parts of the device are clamps for easy insertion of the test sample (Fig. 3), designed in such a way that the sample of the tested material was loaded and finally torn by simple tension. It should be noted that the test sample fixation was made with regard to the necessity of experiment realization at various temperatures, generally in the range of -40°C to 150°C.

As shown in the displacement-time record (see Fig. 4), with this device it is possible to reach a constant sample strain rate with sufficient precision at various kinetic energies of the impactor (see Tab.1).

The measurement member for recording the force is a piezoelectric dynamometer made by Kistler. Sample elongation is registered by a resistor displacement detector. For future development of the device and related methodology, optical methods for test sample displacement and strain records, respectively, are under consideration.

Table 1: *Kinetic energies of the impactor*

			Mass Example [kg]	
Kinetic parameters			10	40
Drop height [mm]	Velocity [km/h]	Velocity [m/s]	Kinetic energy [J]	
100	5.1	1.4	10	40
250	8.0	2.2	25	100
500	11.4	3.2	50	200
750	13.9	3.9	75	300
1000	16.1	4.5	100	400
1250	18.0	5.0	125	500
1400	19.0	5.3	140	560

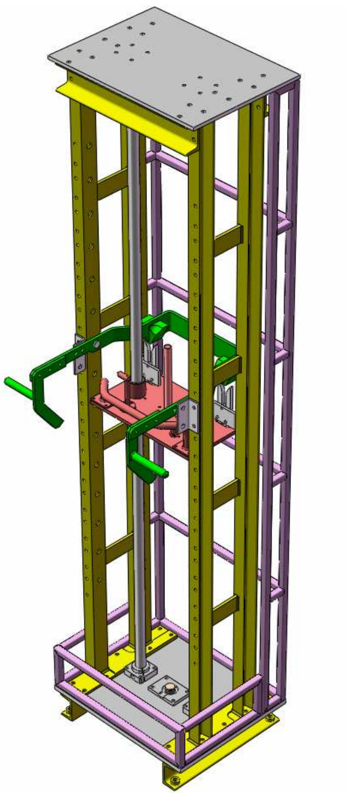

Figure 2: *Drop tester tower*

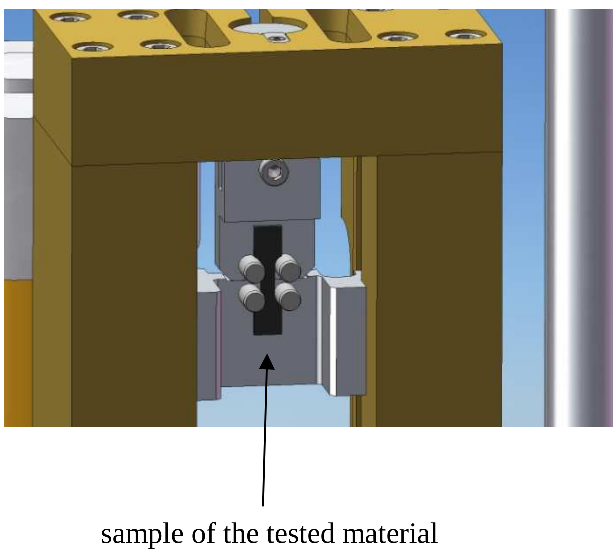

Figure 3: *Clamps for insertion of the test sample*

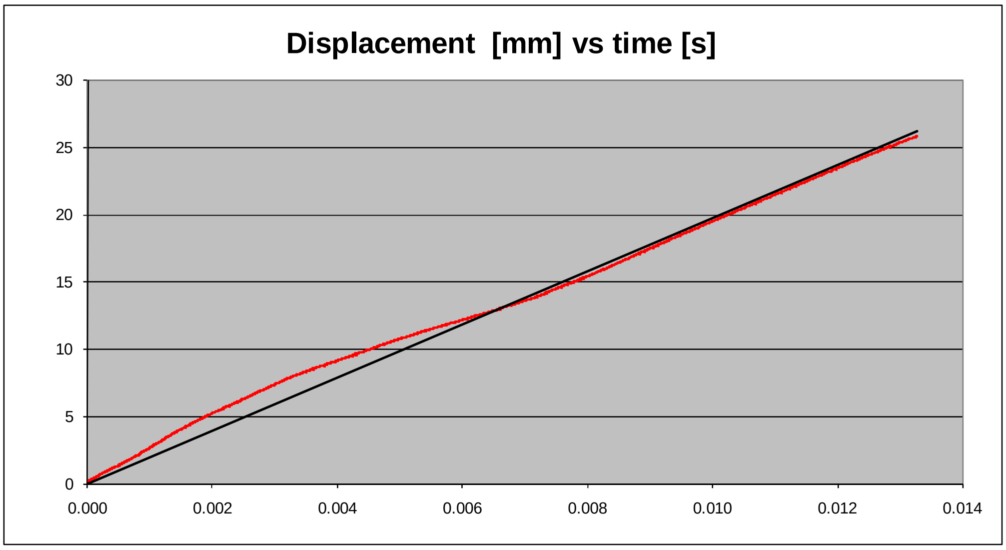

Figure 4: *Displacement vs time record*

4. Example of polymeric material results

The presented methodology was used for identification of material functions of plastics applied in the construction of bumper covers in Cadence Innovation, s.r.o. Examples of the results represented by the above-mentioned five parameters of the non-linear material model of the Maxwell type for the selected material are arranged in Table 2. It should be noted that material model No. 121 is used in PAM-CRASH software in connection with numerical simulations, e.g. collision states during the development of vehicle bumper systems. Comparison of the experimentally measured characteristics (EXP) and the curve created by the material function equation (4) using parameters from Table 2 (Maxwell_121 polyNL) are shown in the Fig. 5.

Table 2: *Parameters of the Maxwell non-linear material model*

Parameter	***k***	h_1	h_2	***w***	***m***
Unit	MPa	1	1	1	1
Material (SAB)	18	1.012e-4	6.675e-4	0.695	0.273

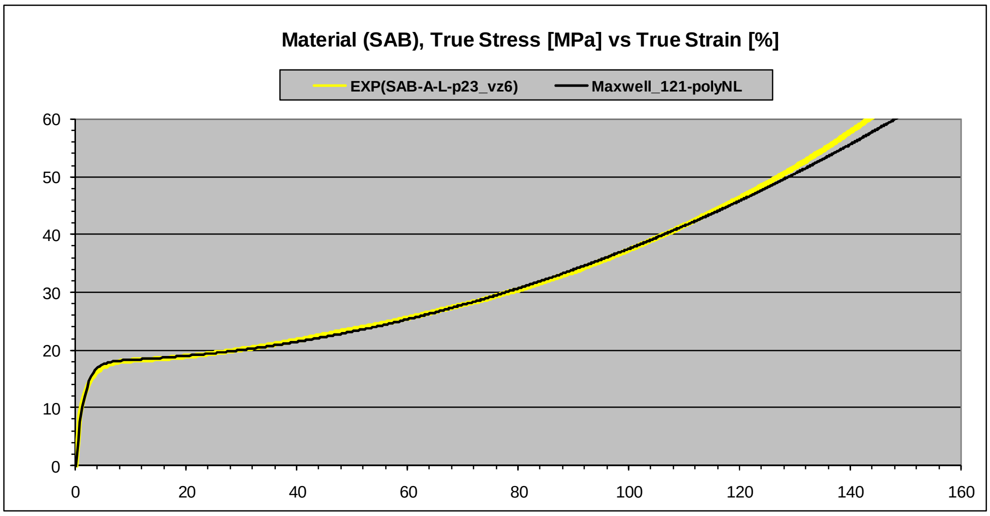

Figure 5: *Comparison of the experimentally measured characteristics and the curve created by the material function equation (4)*

Acknowledgement

The development of the experimental methodology and device are the subject and aim of the request for the subsidised grant project MPO TIP, submitted in February 2009.

References

[1] Explicit solver notes manual, ESI Group, Feb 08, pp. 302-303
[2] DOLTSINIS, I.: Elements of Plasticity Theory and Computation, WITT Press 2000