# IDENTIFICATION AND VALIDATION OF MATERIAL PARAMETERS FOR ISOTROPIC DAMAGE MODEL IN VISCOPLASTIC FLOW CONDITIONS

**P. Kłosowski, Ł. Pyrzowski**
*Gdansk University of Technology, Gdansk, Poland*

## 1. General

Identification of damage material parameters is one of the most important and most contentious aspects of the continuum damage mechanics. The incorrect identification may leads to wrong results, even if a good model is applied.

In this communication, the Lemaitre's isotropic damage model [1], regarding the concept of the damage variable proposed by Kachanov in 1958 [2], is concerned. In the literature different methods of damage material parameters identification for assumed model are applied. The identifications are based on different foundations and use results of different experiments: the uniaxial tensile tests or the uniaxial reversed cyclic tests. In their approaches authors calibrate both $S$ and $s$ damage coefficients or assume $s$ calibrating only $S$. Each of them is applied for different material type, and very seldom researchers tried to conduct these identifications for one material and compare the results with experiment to give the answer which of them is the most suitable.

The authors of this paper have applied all presented identification methods for calibration the damage coefficients for the Al2017 aluminum. Then the results have been compared with the real experiment by numerical modeling, using the elasto-viscoplastic Chaboche [3] model with damage.

## 2. Damage model formulation

The isotropic damage is expressed by the scalar parameter $D$, which is the surface density of the discontinuities in the material. Its evolution, according to Lemaitre [1], is defined by equation:

$$(1) \qquad \dot{D} = \left( -\frac{Y}{S} \right)^s \cdot \dot{p},$$

where $s$ and $S$ are the damage material parameters, $\dot{p}$ is the accumulated plastic strain rate and $Y$ is the damage strain energy release rate, given by:

$$(2) \qquad -Y = \frac{\sigma_{eq}^2}{2(1-D)^2 E} \left[ \frac{2}{3}(1+\nu) + 3(1-2\nu)\left( \frac{\sigma_H}{\sigma_{eq}} \right)^2 \right],$$

where $\nu$ is the Poisson's ratio, $E$ is the Young's modulus of undamaged material, $\sigma_{eq}$ is the Huber-Misses equivalent stress and $\sigma_H$ is the hydrostatic stress.

## 3. Methods of the material parameters identification

The first presented method of the material parameters identification for isotropic damage is proposed by Mashayekhi and Ziaei-Rad [4]. This identification is conducted on the basis of the uniaxial reversed cyclic test and based on the foundation that the damage exponent $s$ is arbitrary assumed. When the damage exponent $s$ is known at the beginning, the damage strength parameter $S$ can be calibrate directly from the equation:

$$(3) \qquad S = \frac{\sigma^2}{2E(1-D)^2 \, dD/d\varepsilon_{pl}},$$

where $\sigma$ is the stress and $\varepsilon_{pl}$ is the inelastic strain, both in uniaxial loading conditions.

The second method is proposed by Daudonnet [5]. It is conducted on the basis of the same experimental tests, but does not introduce the material parameter assumptions, both $s$ and $S$ parameters are calibrate (the last square method approximation):

$$(4) \qquad \frac{dD}{d\varepsilon_{pl}} = \left( \frac{\sigma^2}{2E(1-D)^2 S} \right)^s.$$

The last method is proposed by Ambroziak [6]. This identification does not need to conduct the reversed cyclic tests, it is based on the simple uniaxial tensile test with the constant strain rate but has two disadvantages. The first is, similar to Mashayekhi and Ziaei-Rad approach: the assumption of the damage exponent $s$ at the beginning, the second is the assumption that rupture of the specimen is specified while the damage parameter $D = 1$ (performing the tensile test instead of the reversed cyclic does not allow to identify $D$). The damage strength parameter $S$, in this method, is calibrate from the equation:

$$(5) \qquad S = \frac{(2 \cdot s + 1)^{1/s}}{2 \cdot E} \cdot \left( \int_0^{t_r} \left( \sigma^{2s} \cdot \dot{p} \right) dt \right)^{1/s}.$$

## 4. Identification and validation of material parameters for Al2017 aluminum

The best method to certify, which identification is the most suitable, is to conduct all of them for one material type and compare the results with the real experiment. The authors decided to choose Al2017 aluminum, the selected results are presented in Table 1. For the methods comparison, the numerical simulation of the uniaxial tensile tests with the constant strain rate, has been applied. The detail results and final conclusions will be presented during the conference.

| Method | Exponent $s$ [-] | Strength parameter $S$ [MPa] |
|---|---|---|
| Mashayekhi and Ziaei-Rad | $s = -1$ (assumed) | $S = 2{,}67$ |
| Daudonnet | $s = -0{,}88$ | $S = 2{,}92$ |
| Ambroziak | $s = 1$ (assumed) | $S = 0{,}23$ |

Table 1. Results of the damage material parameters identification

## 6. References

[1] J. Lemaitre (1985). A continuous damage mechanics, *J. Eng. Mater. Technol.*, **107**, 83-89.
[2] L.M. Kachanov (1958). Time of rapture process under creep conditions, *Otd. Tech. Nauk.*, **8**, TVZ Akad. Nauk. S.S.R., 26-31.
[3] J. L. Chaboche and J. Lemaitre (1990). *Mechanics of solid materials*, Cambridge University Press, Cambridge, 253-345.
[4] M. Mashayekhi and S. Ziaei-Rad (2006). Identification and validation of a ductile damage model for A533 steel, *J. Mater. Proces. Techn.*, **177**, 291-295.
[5] B. Daudonet (2006). *Etude numeriqe de la rapture d'elements de structures constituant des reservoirs sous chargement dynamique*, PhD Thesis, Universite d'Orleans, Bourges, 60-63.
[6] A. Ambroziak (2007). Identification and validation of damage parameters for elasto-viscoplastic Chaboche model, *Engng. Trans.*, **55**, 1-28.