21st International Conference **ENGINEERING MECHANICS 2015**
Svratka, Czech Republic, May 11 –14, 2015
Paper **#017**, **pp. 272–273**

# Verification of Ductile Fracture Criteria Based on Selected Calibration Tests

František Šebek[a] *, Petr Kubík[b], Jindřich Petruška[c]

Brno University of Technology, Brno, Technická 2896/2, 616 69 Brno, Czech Republic

[a]sebek@fme.vutbr.cz, [b]m3petr@gmail.com, [c]petruska@fme.vutbr.cz

**Keywords:** ductile fracture, crack initiation and propagation, phenomenological criteria, explicit finite element method, AISI 1045 carbon steel

**Abstract:** Phenomenological ductile fracture criteria represent, among others, one of powerful tools for prediction of ductile fracture. These criteria are based on evaluating damage throughout the solid body as a response to straining. The damage is influenced by plasticity but not vice versa. Therefore, these criteria are often called uncoupled as they do not mutually couple the damage and plasticity. One of immense advantages of such criteria is a possibility not only to predict the crack initiation but also to follow the propagation based on the damage. Moreover, it is not restricted for one specific locus but the damage is evaluated in the entire solid body and one or more cracks can be tracked simultaneously or sequentially. Ductile fracture criteria are calibrated on the basis of several independent calibration tests under various stress states. One way how to verify calibrated model is to simulate numerically an experimental tests and follow the crack initiation and propagation. In the present study, selected phenomenological criteria were calibrated using various calibration tests. Then, selected calibration tests were simulated together with implemented ductile fracture criteria. In our case, the verification is carried out on tensile cylindrical specimens. Finally, computationally obtained results were compared to the experimentally observed ones and the prediction ability and reliability of selected phenomenological criteria is discussed.

The ductile fracture is comprehensive and complex problematics important in many fields of mechanics [1, 2]. It can be applied to vast different engineering applications [3]. Plasticity of AISI 1045 carbon steel was identified at first and two material constants of Hollomon hardening law [4] were calibrated. Three phenomenological ductile fracture criteria were selected and calibrated on the basis of tensile tests of smooth and notched cylindrical specimens and biaxial tests of notched tube specimens. Material constants of model proposed by Bai and Wierzbicki [5], Extended Mohr–Coulomb criterion [6], and model proposed by Lou et al. [7] were found using the non-linear least square method in the software MATLAB.

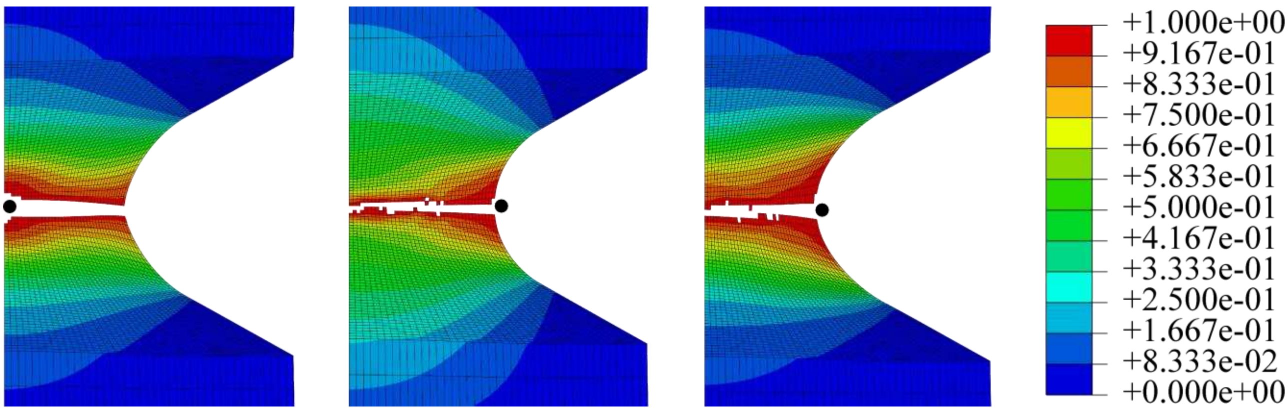


Fig. 1: Field of damage for specimen with notch radius R1.2 from left for model proposed by Bai and Wierzbicki [5], Extended Mohr–Coulomb criterion [6], and model proposed by Lou et al. [7]

Tensile tests of notched cylindrical specimens were simulated to investigate and verify the reliability of selected fracture criteria. The prediction ability was evaluated on the basis of the crack initiation and propagation predicted by each ductile fracture model compared to experimentally observed results. Loci of crack initiation are highlighted by the black circles in Figs. 1 and 2.

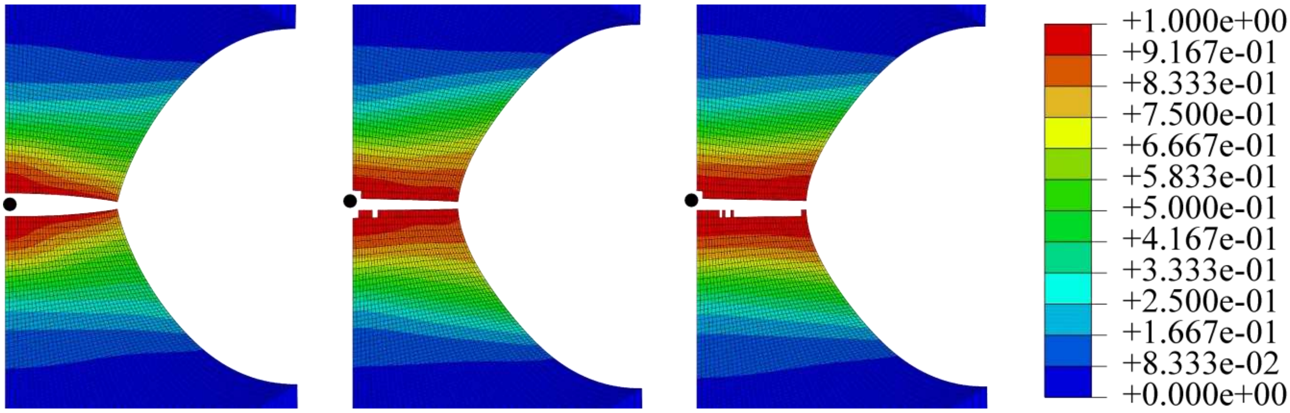


Fig. 2: Field of damage for specimen with notch radius R2.5 from left for model proposed by Bai and Wierzbicki [5], Extended Mohr–Coulomb criterion [6], and model proposed by Lou et al. [7]

The cup and cone fracture was experimentally observed. Fractography revealed [8] that the fracture really initiated in the center of tension cylindrical specimens on the axis of symmetry due to high stress triaxiality. All models predicted the crack initiation well (Figs. 1 and 2) except for the Extended Mohr–Coulomb criterion [6] and model proposed by Lou et al. [7] in case of notched cylindrical specimen with notch radius R1.2 (Fig. 1). Moreover, none of selected models predicted the slant fracture in the final part of the fracture to complete the cup and cone fracture mechanism.

**Acknowledgment:** This work is an output of cooperation between grant project FSI-S-14-2311 and NETME CENTRE PLUS (LO1202) created with financial support from the Ministry of Education, Youth and Sports under the „National Sustainability Programme I“.

## References

[1] J. Petruška, P. Kubík, J. Hůlka, F. Šebek, Ductile Fracture Criteria in Prediction of Chevron Cracks, Adv. Mat. Res. 716 (2013) 653-658.

[2] F. Šebek, J. Hůlka, P. Kubík, J. Petruška. On the Proportionality of Damage Rule in Finite Element Simulations of the Ductile Failure, Adv. Mat. Res. 980 (2014) 189-193.

[3] J. Petruška, T. Návrat, F. Šebek, A new model for fast analysis of leveling process, Adv. Mat. Res. 586 (2012) 389-393.

[4] J. H. Hollomon, Tensile deformation, Trans. AIME 162 (1945) 268-290.

[5] Y. Bai, T. Wierzbicki, A new model of metal plasticity and fracture with pressure and Lode dependence, Int. J. Plast. 24 (2008) 1071-1096.

[6] Y. Bai, T. Wierzbicki, Application of extended Mohr–Coulomb criterion to ductile fracture, Int. J. Frac. 161 (2010) 1-20.

[7] Y. Lou, J.-W. Yoon, H. Huh, Modeling of shear ductile fracture considering a changeable cut-off value for stress triaxiality, Int. J. Plast. 54 (2014) 56-80.

[8] J. Bořkovec, Computer simulation of material separation process, Ph.D. Thesis, Brno University of Technology, 2008 (in Czech).