DANUBIA
ADRIA

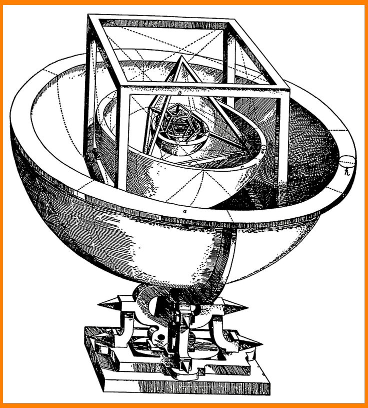
JKU
JOHANNES KEPLER
UNIVERSITY LINZ

Book of Abstracts

37th Danubia Adria Symposium
on
Advances in Experimental Mechanics

September 21st - 24th, 2021

Johannes Kepler University, Linz, Austria



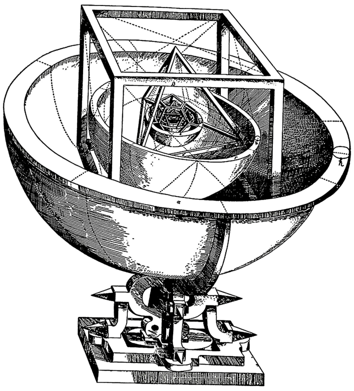
Book of Abstracts

37th Danubia Adria Symposium
on
Advances in Experimental Mechanics

www.jku.at/tmech/das37

September 21st - 24th, 2021

Johannes Kepler University, Linz, Austria



Organized by

Johannes Kepler University, Institute of Technical Mechanics
www.jku.at/tmech

Conference Chair and Local Organizer

Helmut J. Holl
Contact: helmut.holl@jku.at
www.jku.at/tmech/holl

Editor: Helmut J. Holl

ISBN 978-3-9504997-0-4

Preface

The 37^{th} Danubia Adria Symposium was planned for the year 2020 and has been postponed due to the upcoming Covid-19 pandemy. One year later the Danubia Adria Symposium is held in Linz. Some boundaries and restrictions have been changed due to the Covid-19 pandemy. One of these new parts is the necessity of a prevention concept for the symposium, which has been worked out. The personal discussion in the experimental mechanics scientific community is very important for the exchange of knowledge and ideas. This is the one of the reasons to organize a symposium on-site in presence.

The Danubia Adria Society includes 12 countries with representatives of each country in the scientific committee. For the organization of the Danubia Adria Symposium the support of the scientific committee is very helpful and greatful acknowledged.

As a tradition in the Danubia Adria Symposia, a special competition, open to doctoral, graduate and undergraduate students is organized, called the the Young Scientists Award. The scientific committee is the jury that assigns three prizes for the best papers presented by the students.

In this Book of Abstracts a collection of accepted abstracts is included, which are presented and discussed during the symposium. Oral and poster presentations and discussions of the contributions are given. In total there are 16 oral plenary presentations and 78 poster presentations.

The sponsors are important to support the symposium so that it is possible to organize it in an appropriate format. Two industrial oral presentations of latest research results and developed products are given by companies and complete the view to advances in experimental mechanics. The companies are present during the symposium and take part in the symposium booth.

Based on the presentations, the fruitful discussions and the possible publications of selected contributions in the Elsevier journal Materials Today: Proceedings as well as the social and physical coming together hopefully will make the 37^{th} Danubia Adria Symposium an outstanding event.

Helmut J. Holl

September 21^{st}, 2021

Sponsors of the Symposium

voestalpine
ONE STEP AHEAD.

Polytec

distributed by
LB-acoustics

HBK
HOTTINGER BRÜEL & KJÆR

HBM

Brüel & Kjær

MAGNA

salvagnini

LCM
LINZ
CENTER OF
MECHATRONICS
Science becomes reality

MICRO
MEASUREMENTS
A VPG Brand

Co-organized by

Austrian Society of Experimental Strain Analysis (ASESA)
Croatian Society of Mechanics (HDM)
Czech Society for Mechanics (CSM)
German Society of Experimental Structural Analysis (GESA)
Greek Society of Experimental Mechanics of Materials (GSEMM)
Hungarian Scientific Society of Mechanical Engineering (GTE)
Italian Association for Stress Analysis (AIAS)
Polish Committee for Mechanics of the Polish Academy of Sciences (KMPAN)
Romanian Association of Stress Analysis and Materials Testing (ARTENS)
Serbian Society of Mechanics (SSM)
Slovak Society of Mechanics (SSM)
Slovenian Society of Experimental Mechanics (SSEM)

Scientific committee

Austria: Josef Eberhardsteiner (Vienna), Wilfried Eichlseder (Leoben), Bernhard Pichler (Vienna)
Croatia: Lovre Krstulović-Opara (Split), Damir Semenski (Zagreb), Zvonimir Tomičević (Zagreb)
Czech Republic: Milan Ružička (Prague), František Plánička (Plzeň), Robert Zemčík (Plzeň)
Germany: Mathias Bartholmai (Berlin), Thomas Lehmann (Chemnitz)
Greece: Stavros Kourkoulis (Athens), Ermioni Pasiou (Athens)
Hungary: Rita Kiss (Budapest), Attila Kossa (Budapest)
Italy: Francesca Cosmi (Trieste), Mario Guagliano (Milano)
Poland: Zbigniew Kowalewski (Warsaw), Paweł Pyrzanowski (Warsaw)
Romania: Dan Mihai Constantinescu (Bucharest), Adrian Pascu (Sibiu), Ştefan Dan Pastramă (Bucharest)
Serbia: Marko Miloš (Belgrade), Vladimir Milovanović (Kragujevac), Miroslav Živković (Kragujevac)
Slovakia: František Nový (Žilina), Eva Tillová (Žilina)
Slovenia: Igor Emri (Ljubljana), Anatolij Nikonov (Novo mesto)

About the symposium

Each year since 1984, the Danubia-Adria Symposium on Advances in Experimental Mechanics brings together internationally recognized experts and young researchers in an effort to exchange ideas in different topics having as common link EXPERIMENTAL MECHANICS. The symposium acts also as a platform for establishing connections between different research groups that are trying to establish future scientific collaboration.

The symposium is focused on experimental and measuring methods necessary to deepen the knowledge about the mechanical behavior of materials, mechanical structures, and systems, and to provide the physical bases and verification of numerical or analytical methodologies in engineering design.

As a tradition in the Danubia Adria Symposia, a special competition, open to doctoral, graduate and undergraduate students will be organized. The scientific committee will be the jury that will assign three prizes for the best papers presented by the students.

The symposium will consist of oral and poster presentations. Selected contributions presented at the symposium will be recommended for publication in Elsevier journal Materials Today Proceedings.

Main topics at the symposium

The following topics have been selected for the Danubia Adria Symposium:

- Structural analysis: experimental tests, structural health monitoring, system identification, damage assessment, self-adaptive structures
- Materials characterization and testing: smart materials, residual stress, fatigue, fracture, creep
- Instrumentation: new sensors and actuators, advanced measurement systems; Validation and reliability of instrumentation
- Integration of mathematical/numerical methods with experimental mechanics
- Biomechanics: biomaterials, biomechanics, medical and orthopedic devices, biofluid mechanics
- Additive manufacturing: Selective laser sintering, multi-jet modeling, thermoplastic materials injection
- Practical applications and case-studies

Contents

Collection of Abstracts of the DAS37

ISBN 978-3-9504997-0-4

PHASE-FIELD MODELLING OF DAMAGE IN METALLIC MATERIALS

Jelena ŽIVKOVIĆ[1], Vladimir DUNIĆ[1], Vladimir MILOVANOVIĆ[1], Miroslav ŽIVKOVIĆ[1]

[1] University of Kragujevac, Faculty of Engineering, Sestre Janjić 6, 34000 Kragujevac, Serbia, E-mail: jelena.zivkovic@kg.ac.rs, dunic@kg.ac.rs, vladicka@kg.ac.rs, miroslav.zivkovic@kg.ac.rs

1. Introduction

Phase-field damage models (PFDM) are recently used in finite element method (FEM) software combined with plasticity to simulate damage initiation and evolution in structures [1-3]. The fracture of structures results from damage that influences the degradation of material's stiffness, so the proper prediction of damage evolution is valuable. The authors proposed modifications of hardening function and coupling variable to provide more control on the material parameters identification process and more accurate qualitative and quantitative prediction of the metal structures behavior. The staggered iterative scheme is employed for the implementation into the FEM software. The simulation results are compared to the experimental investigation, and an excellent response is obtained. In engineering practice, the proposed modification of PFDM will provide a better understanding of the steel structure's fracture.

2. Phase-field damage model and plasticity

The degradation function d is proposed by Ambati et al. [1, 2] for the phase-field damage modeling of ductile fracture as

$$g(d) = (1-d)^{2p}, \tag{1}$$

where p is the coupling variable. The authors propose the modification because the material is considered to be intact (undamaged) until the equivalent plastic strain achieves the critical value

$$\bar{\varepsilon}_P = \bar{\varepsilon}_P^{crit}, \tag{2}$$

so the coupling variable is $p = 0$, Fig. 1. If

$$\bar{\varepsilon}_P \geq \bar{\varepsilon}_P^{crit}, \tag{3}$$

the coupling variable p is defined as

$$p = \frac{\bar{\varepsilon}_P - \bar{\varepsilon}_P^{crit}}{\bar{\varepsilon}_P^{crit}}. \tag{4}$$

For the simulation of materials (e.g. S355 steel) which exhibits constant stress after yielding occurs, the two-intervals hardening function is necessary to describe the idealized response.

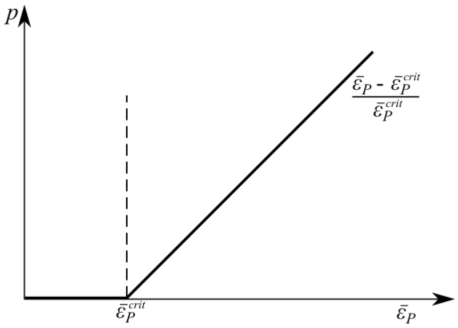


Fig. 1. Coupling variable with respect to equivalent plastic strain

To simulate the described behavior, 'perfect plasticity' is employed for the first interval of loading ($\bar{\varepsilon}_P < \bar{\varepsilon}_{P0}$) until the plastic strain $\bar{\varepsilon}_{P0}$ is achieved. The complete two-interval yield function can be defined by the equation:

$$f_y = \begin{cases} \bar{\sigma}_{eq} - \sigma_{yv} & ;\bar{\varepsilon}_P < \bar{\varepsilon}_{P0} \\ \bar{\sigma}_{eq} - \begin{bmatrix} \sigma_{yv} + \left(\sigma_{y0,\infty} - \sigma_{yv}\right) * \\ * \left(1 - e^{-n\left(\bar{\varepsilon}_P - \bar{\varepsilon}_{P0}\right)}\right) + H\left(\bar{\varepsilon}_P - \bar{\varepsilon}_{P0}\right) \end{bmatrix} & ;\bar{\varepsilon}_P \geq \bar{\varepsilon}_{P0} \end{cases} \tag{5}$$

The detailed algorithm of the von Mises plasticity for large strain problems coupled with PFDM is given in the authors paper [4].

3. Comparison of experimental results and FEM simulation

Three S355 flat specimens are used in uniaxial tensile tests at room temperature, with a strain rate of 10^{-3} s^{-1}. The shape and dimensions of one of the investigated specimens are shown in Fig. 2.

The FE model represents 1/8 test specimen's straight part. The geometrical imperfection is prescribed as 0.01% a linear decrease of the specimen width. The tensile loading is applied to the top surface nodes by displacement increment of 0.02 mm. Calibration of material parameters was done for experimentally obtained results for one of the investigated specimens. The material parameters used for numerical simulations are given in Table 1.

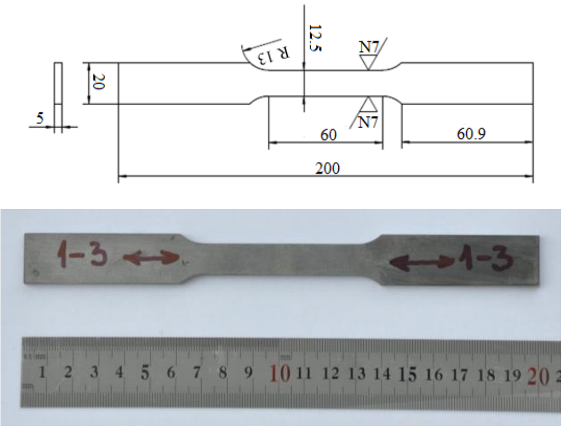


Fig. 2. Shape and dimensions of the investigated flat S355 specimen

Table 1. Material parameters used for PFDM simulation

E [MPa]	ν [−]	σ_{yv} [MPa]	$\sigma_{y0,\infty}$ [MPa]	H [MPa]
190080	0.30	382.86	642.74	0.00001
n [−]	G_V [MPa]	l_c [mm]	$\bar{e}_P^{crit}$ [−]	$\bar{e}_{P0}$ [−]
15.9	9.61	0.01	0.211	0.0051

The equivalent plastic strain field, as well as damage field, obtained by PFDM-plasticity simulation, shown in Fig. 3., are localized in a fracture zone of the experimentally tested specimen.

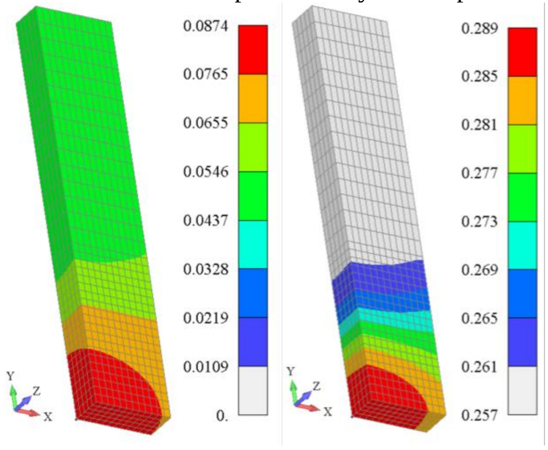


Fig. 3. Damage (left) and effective plastic strain field (right) at the displacement in y-axis of 15.32 mm

It can be noticed that there is a relation between the damage and the equivalent plastic strain, therefore the damage is responsible for the fracture of the specimen. Fig. 4 shows the comparison of the force-displacement relationship between results obtained by experimental test and numerical simulation.

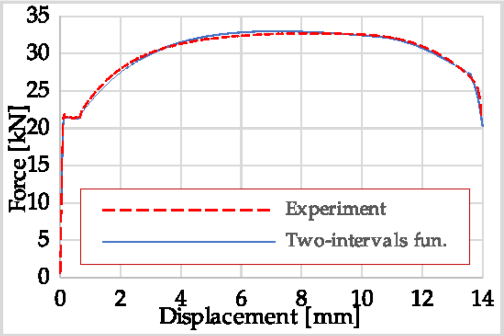


Fig. 4. Comparison of force displacement diagrams obtained by simulation and experiment

4. Conclusions

The two-intervals hardening function extends the use of PFDM to metallic materials which exhibit stress plateau after yielding occurs. In this modification the coupling variable increases after the critical value of the equivalent plastic strain is achieved. The simulation results have been verified by comparing to the experimental results of S355 test specimen. The proposed modifications provide the possibility to control the onset of the damage evolution and crack propagation and to simulate various types of metallic materials in engineering practice.

Acknowledgements

This research was funded by project TR32036 of Ministry of Educations, Science and Technological Development, Republic of Serbia.

References

[1] Ambati, M., Kruse, R., De Lorenzis, L. A phase-field model for ductile fracture at finite strains and its experimental verification. *Comput Mech*, 2016, 57, 149–167.

[2] Ambati, M., Gerasimov, T., De Lorenzis, L. Phase-field modeling of ductile fracture. *Comput Mech*, 2015, 55, 1017–1040.

[3] Miehe, C., Aldakheel, F., Raina, A. Phase field modeling of ductile fracture at finite strains: A variational gradient-extended plasticity-damage theory. *Int J Plast*, 2016, 84, 1–32.

[4] Živković, J., Dunić, V., Milovanović, V., Pavlović, A., Živković, M. A Modified Phase-Field Damage Model for Metal Plasticity at Finite Strains: Numerical Development and Experimental Validation. *Metals*, 2021, 11(1), 47.