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Title:

Modelling of plastic yield surface of materials accounting for initial anisotropy and strength differential effect on the basis of experiments and numerical simulation

Defended by Teresa FRAS : thesis for Docteur de l'Université de Lorraine and Akademia Gorniczo-Hutnicza im. Stanislawa Staszica w Krakowie

Report written by Nadia BAHLOULI, Professeur, Université de Strasbourg, Institut de Mécanique des Fluides et des Solides.

The aim of the thesis presented by Teresa Fras is mainly focused on the modeling of the plastic yield surface of materials dedicated to design of structural applications. A first quick reading highlights the expertise in experimental, modeling and simulation developed by the candidate to address the problem of his study. The document is decomposed in six parts. References are listening after the conclusion. Three appendixes close the document. The general context and the introduction compose the first chapter. The second chapter describes the materials when the third is dedicated to the experimental techniques. Different material families are used to validate the hypothesis of Burzynski: OFHC Cu characterized by a face-centered cubic structure, steel E335, an example of material body-centered cubik structure and two amorphous polymers, a polycarbonate and a PLA. These materials have been chosen in order to demonstrate the versatility of the proposed yield description: amorphous structure and different cubic crystal systems (FCC and BCC). The experimental tests have been performed over a wide range of strain rates from quasi static to dynamic tests. In order to obtain data providing possibility of more accurate description of the yield surface, not only uniaxial tensile and compression tests under quasi static and dynamic loadings have been performed. Double shear test, complex stress state test and biaxial compression tests were carried out. All these tests allow identifying the mechanical behavior in a wide range of strain rates and loading conditions.

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The fourth chapter defines the Burzanski theory. The different hypotheses of the model are described. An important part of this chapter is dedicated to the description and the numerical implementation of the criterion. The isotropic Burzynski hypothesis is implemented in a finite element code ABAQUS using a UMAT. After, the candidate achieves a chapter five in which the different experimental studies are compared to the numerical prediction.

In the whole document, the different figures and pictures are of good quality and well referenced.

In the chapter dedicated to the material description, an important point is the discussion concerning mechanical and micro-structural properties of exemplary materials. Indeed, using a similar model to describe as different as metals and polymeric materials is challenge. The microstructure of metals and polymers are completely different. And the most delicate point is that the mechanisms governing the microstructural changes are of different origin. The sensitivities at the strain rate and temperature are different. This vision is very industrial and limits the models in codes of numerical calculations. Thus, this work is a real challenge. A discussion of this point will be developed during the discussion at the defense. In fig 2.13, perhaps an error exists because just one strain rate is reported. And a particular attention has to be made because in general, the temperature sensitivity is more important for polymers.

In chapter 3, dedicated to the experimental techniques, a focus is made in estimate the inaccuracy between numerical and experimental results. The point concerning the assumption that volume element of the sample before and after the process of deformation remains constant during a quasi-static tensile test would be developed during the defense. Another point has to be analyzed: all the FE analysis has been performed for metals, ductile metals, but is it correct for polymers? In Particular, is there any change in the point concerning the friction effects?

In chapter 4, the main point is the extension of the proposed criterion. This extension is to describe the initial anisotropy. The yield function strain, strain rate and temperature have been introduced. The reviewer has enjoyed the presentation of the different concepts concerning yield criteria. After, an illustrated part leads us to understand why the Burzynski criteria can be applied for a wide range of strain rates and temperatures for different materials. This criteria has been implemented in UMAT ABAQUS and validated with steel E335.

The Burzynski criteria accounting for pressure influence and initial anisotropy are applied in the chapter 5. The proposed criteria are validated for metals and amorphous polymers. An important point of this work is to highlight the low number of parameters necessary to describe yielding state. The large number of validated materials is impressive. In regards of the large number of tested materials, the reviewer would have appreciated a sensitivity analysis of various models parameters for the three classes of materials (FCC, BCC and amorphous polymer) to complete the study.

Concerning the experimental results, why the curves are noisy in figure 5.44 when shear stress shear strain curves are not noisy? But the numerical results concerning the yield surfaces are really interesting.

Conclusion:

The study proposed by Teresa Fras offers an improvement of the material yield modelling. A new methodoloy of biaxial compression test including the elaboration of a model describing friction effect has also been elaborated. In this way, the PhD of Teresa Fras is consistent and provides an improvement in the identification, modeling and simulation of the yield surface for a wide range of strain rates for metals and polymers. In addition, the candidate also showed a control of experimental and numerical aspects. For all of these arguments, the reviewer agrees that Teresa Fras has performed an interesting and scientific work which will improve the design of mechanical structures and the thesis is approved for defense.

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