Indentation based damage quantification methodology revisited

Citation for published version (APA):

Document status and date:
Published: 01/01/2009

Document Version:
Accepted manuscript including changes made at the peer-review stage

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher’s website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

Link to publication

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the “Taverne” license above, please follow below link for the End User Agreement:
www.tue.nl/taverne

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 31. Oct. 2019
Indentation Based Damage Quantification Methodology Revisited

C.C. Tasan∗, J.P.M. Hoefnagels†, M.G.D. Geers†

∗Materials Innovation Institute
Mekelweg 2, P.O. Box 5008, 2600 GA Delft, The Netherlands
c.tasan@tue.nl

†Eindhoven University of Technology
Department of Mechanical Engineering, P.O. Box 513, 5600 MB Eindhoven, The Netherlands
j.p.m.hoefnagels@tue.nl

ABSTRACT

The last decades were marked by the introduction of advanced high-strength steels (AHSS) in the sheet metal forming industry, e.g. the dual-phase and transformation-induced plasticity steels. Although many AHSS grades have superior strength-to-ductility ratios, the industry noticed a reduction in ductility and/or unpredicted failures under some complex loading conditions. Improving the forming simulations to predict such failures requires detailed experimental characterization of the damage evolution in these metals. Lemaitre and Dufailly introduced a number of tools that aim to quantify damage accumulation geometrically (i.e. probing the evolution of area fraction, volume fraction, void density, etc.) or mechanically (i.e. probing the damage induced degradation of hardness, elastic modulus, etc. by indentation) [1].

Recent experimental evidence revealed, however, that the geometrical techniques seem to lack sufficient sensitivity for accurate quantification of the low void fraction (thus large statistical errors) and/or lack a sufficiently high resolution to detect all microscopic voids, crack, etc. in the material (thus additional systematic errors) [2, 3]. Moreover, geometrical methods do not yield information on the correlation between damage morphology/distribution and the resulting mechanical behavior [4, 5].

For the indentation-based mechanical methods, on the other hand, the effect of voids and discontinuities on the mechanical behavior is directly captured by the measured material response. This makes the mechanical methods more promising for damage quantification, especially as Lemaitre and Dufailly observed a sudden drop in both hardness and modulus, which, when attributed to the increase of damage, is a sensitive measure for the damage. Unfortunately, however, we showed recently that for increasing degree of deformation, both the hardness and the elastic modulus not only decrease due to damage, but also increase due to 'hidden' microstructural factors, such as strain hardening, grain shape change, texture development, residual stress, and indentation pile-up, masking the damage-related drop in hardness and modulus completely for some materials (Fig. 1) [6]. This eliminates the indentation-based damage methodology as a reliable method for damage quantification. To overcome this impasse, the present work presents a new indentation-based damage methodology, for which these 'hidden' microstructural factors related to the deformation history are removed by a clever heat treatment to the deformed steel. It was verified that the damage morphology and distribution is not effected from these heat treatments. And the new methodology indeed shows a clear drop e.g.
for DP steel shown in Fig. 2, which prior to the heat treatment showed a continuous increase in hardness and a continuous decrease in modulus. More analysis to scrutinize this technique is underway and will be presented at the conference.

Figure 1: Coupled hardness vs. local strain data for IF steel. An increase in hardness with strain is observed instead of the expected decrease (or sudden drop) in hardness.

Figure 2: Preliminary indentation tests on heat treated dual phase steel samples, showing constant values of hardness (a) and elastic modulus (b) away from the neck-region (no damage), but a clear drop in hardness and modulus in the neck (damage).

References