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Damage Mechanics with GISSMO

Motivation

Crashworthiness simulations are used to optimize structures in the context of passive protection - one of the most critical topics in the automotive industry. The investigation of crack formation and propagation forms an essential aspect in increasing the efficiency of the crashworthiness simulations.

The phenomenological damage and failure model, "Generalized Incremental Stress-State dependent damage MOdel (GISSMO)", to connect the forming and crash imulations. Based on the effective stress concept by Lemaitre (1985), the model is formulated as an incremental continuum damage model in which the damage variable describes the fracture behavior, and the instability represents the damage softening.

Objectives

The primary goal of this thesis is to understand the mechanisms and the physical principles GISSMO is based on. In order to realize the objective, the following tasks are carried out:

- Overview of the literature with a focus on ductile damage.
- GISSMO is explored in LS-DYNA and tested using a tensile test.
- GISSMO is implemented into a finite element simulation in C++.

The GISSMO Damage Model

Path-dependent failure criterion: An incremental formulation which considers the arbitrary strain paths in the failure prediction, has been proposed for damage

$$\mathrm{d}D = \frac{n}{\epsilon_\mathrm{f}^\mathrm{p}} D^{(1-1/n)} \mathrm{d}\epsilon_\mathrm{eq}^\mathrm{p}$$

Path-dependent instability criterion: A similar approach for instability measure is adopted

$$\mathrm{d}F = \frac{n}{\epsilon_\mathrm{l}^\mathrm{p}} F^{(1-1/n)} \mathrm{d}\epsilon_\mathrm{eq}^\mathrm{p}$$

Different weighting functions for damage and instability

- Damage: failure (or fracture) strain $\epsilon_\mathrm{f}^\mathrm{p}$ as a function of triaxiality η.
- Instability: limit strain $\epsilon_\mathrm{l}^\mathrm{p}$ as a function of triaxiality η.

Based on the „Effective Stress“ concept by Lemaitre (1985), the accumulated damage is coupled to the stress tensor

$$\boldsymbol{\sigma} = \boldsymbol{\sigma}^* \left(1 - \left[\frac{D-D_\mathrm{crit}}{1-D_\mathrm{crit}}\right]^m\right) \quad \text{for} \quad D > D_\mathrm{crit}$$

Supervisor: Tobias Willmann

Numerical Example

Implementation in LS-DYNA: GISSMO is explored in LS-DYNA using a tensile test.

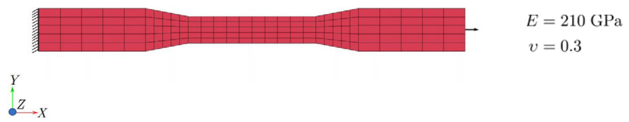

Figure: Tensile test specimen with boundary conditions

Implementation in C++: A one-dimensional system with rate-independent plasticity and linear isotropic hardening is considered.

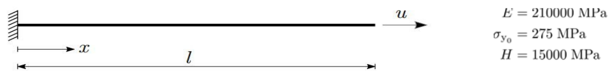

Figure: One-dimensional bar

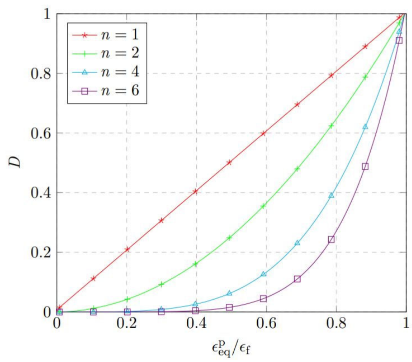

Figure: Comparison of damage accumulations from output of C++

Literature

- Fieder Neukamm: *Lokalisierung und Versagen von Blechstrukturen*, Institut für Baustatik und Baudynamik, Universität Stuttgart, Dissertation, 2018.
- Merdan Basaran: *Stress state dependent damage modeling with a focus on the lode angle influence,* RWTH Aachen, Dissertation, 2011.