Consideration of Damage Accumulated During the Forming Process in Crash Simulations

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Damage accumulated during the forming

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Current Forming / Crash Integration Process

• Formed parts undergo thinning and plastic Deformation

• The method of taking this into account in crash models is well established

Forming simulation: *MAT_36 (Barlat ‘89)

Plastic Residual Strain

Mapping

Thinning distribution

Crash Simulation: *MAT_24 (von Mises)

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Proposed Forming / Crash Integration process with Damage

Forming simulation:
*MAT_36 (Barlat ‘89)
*MAT_ADD_EROSION (GISSMO)

Crash Simulation:
*MAT_24 (Von Mises)
*MAT_ADD_EROSION (GISSMO)

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The Concept of Damage

Damage measures the reduction of the cross section by formation of pores and/or cracks

\[ A \quad = \text{undeformed cross section} \]
\[ A_0 \quad = \text{deformed or current cross section} \]
\[ A_{eff} = A(1 - D) \quad = \text{effective cross section} \]

If \( D=1 \) the material has failed as a macrocrack has developed

In a so-called coupled damage formulation the stress is computed as follows:

\[ \sigma = \frac{F}{A} \quad = \text{true stress relates to true cross section} \]
\[ \sigma_{eff} = \frac{F}{A_{eff}} = \frac{\sigma}{1 - D} \quad = \text{effective stress relates to effective cross section (undamaged material)} \]

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Damage is computed based on a failure criterion and a damage evolution law calibrated using coupon testing:

Damage starts post necking
Approaches for Damage Assessment

Damage accumulated during the forming process can be determined by:

1) Performing incremental stamping simulation using GISSMO to extract accumulated damage.

2) Perform incremental stamping simulation without GISSMO and generate damage through a automated subroutine ST2CR.
T-Shape Stamping at AK Steel

Interlaken Servo Hydraulic Press Double Motion

T-Shape Die

3 Camera DIC System

Evolution of Major Strain Distribution Determined by ex situ DIC

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1.2 mm Thickness
Test Part Fabrication

- Fabricate stamped T-section parts at different draw depths to represent safe, marginal and unacceptable parts for DP-980 material. The binder gap was kept as a constant, 110% of the blank thickness.

Evolution of Major Strain Distribution Determined by ex situ DIC
Validation of Forming Simulation - Thinning comparison to scanned values

- Incremental stamping and scanned part shows close correlation on thickness variation
Test Set-Up

- Conduct test to deform the part at damage location induced during forming.
- Perform forming and crash simulation to duplicate test and demonstrate effect of damage by comparing failure with and without damage.
Project Steps Flow Chart

1. Fabricate part at safe and marginal draw depths
2. Conduct test to break part at high damage area
3. Simulation and test comparison
Post Test – Simulation Comparison

Test

Finite Element Model
Load – Deflection Comparison

Draw Depth 10.6 mm – Minimally damaged

Draw Depth 13 mm – Marginally damaged
Post Forming Simulation Estimate of Damage

- Sometimes the damage values will not be available from the forming simulation.
- A program Stamping to Crash (ST2CR) was developed to estimate the damage from the final results of the stamping simulation.

Crash Simulation:
*MAT_24 (von Mises)
*MAT_ADD_EROSION (GISSMO)

Forming simulation:
*MAT_36 (Barlat ‘89)
Damage accumulated during the forming process

- Comparison between computed and estimated (ST2CR) damage:

  - From incremental simulation
  - From automation script
Damage accumulated during the forming process

- Comparison between computed and estimated (ST2CR) damage:

  From incremental simulation

  From automation script
Thank You
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