Parametric Identification of Damage Parameters of LS-DYNA Gurson Material Model

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   Karthik Chittepu

Tata Motors
   Ganesh Gadekar
   Kedar Joshi
Importance of crash simulation?
- Safety

Why simulating?
- Compression of development cycles
- Cost reduction

Why optiSLang?
- Unknown sensitivities
- Many parameters
Why Gurson Material Model?

- Increasing requirement on crash safety of automotive components
- Also increasing demand of light weight and cost efficient components
- Accurate prediction and numerical simulation of fracture and material failure
Methodology

- **Boundary Conditions**
- **Mesh**
- **Uniaxial Tensile test**
- **Effective Plastic Strain & Effective Stress**
- **Damage Parameter (EN, FC, FF0, F0, SN, and FN)**

**Input Parameters**

- **CAD Model**
- **LSDYNA Pre Processing**
- **LSDYNA Gurson Material Model**
- **LSDYNA (Batch-Run)**
- **LSDYNA Post processing**
- **optiSLang**
- **Post processing in optiSLang**

**Output Parameters**

- **Plasticity Area**
- **Failure Strain**

**New Parameter set**

**Uniaxial Tensile test**

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Uniaxial Tensile Test & Simulation Model

- Tensile test is carried with one end fixed and constant rate of motion on the other end
- Force and displacement are measured
- Engineering stress-strain curves is plotted based on the measurements
- FE model is developed based on test specifications
Methodology

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optiSLang

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Calibration of Effective Plastic strain and stress

- Besides Young’s Modulus and Poisson’s ratio, the input of a **uniaxial true stress-strain** function is required
- Usually determined by the **ASTM method**
- At material specific max. stress, **necking** of sample begins
- Stress **changes** gradually from the simple uniaxial tension to a complicated condition of biaxial stress
- After necking, **weighted average method** is used.

Where \( w = \) is the weight constant

\[
\sigma = \sigma_u [w (1 + \varepsilon - \varepsilon_u) + (1 - w) \left( \frac{\varepsilon}{\varepsilon_u} \right)]
\]
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Gurson Material Model

- In metals and metallic alloys ductile fracture is linked to the micromechanical process of micro-voids growth to coalescence.
- Gurson Model adopts this void growth and nucleation approach.
- Under plastic deformation, the material strain hardens, and voids nucleate and grow, and subsequently lead fracture.

Ductile fracture process which consist of void nucleation, growth and coalescence.

- This behaviour is governed by the damage parameters.
Damage Parameters

- In this parametric identification process the following damage parameters in the Gurson model has to be identified:

  - FC: which is the critical void volume fraction, where voids begin to aggregate.
  - EN: which is the mean nucleation
  - FF: which is the failure void volume fraction
  - F0: which is the initial void ratio
  - SN: which is standard deviation of EN
  - FN: which is void fraction of nucleation particles
  - FF0: which is failure void fraction

<table>
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<tr>
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Workflow

Boundary Conditions
Mesh
Uniaxial Tensile test
Effective Plastic Strain & Effective Stress

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Post Processing

• After the simulation the force and displacement are estimated.
• Based on these value Stress-strain plot is plotted.
• For the parametric identification following parameters are calculated from the stress-strain curve
  
  – Area Under Plastic Region
  – Maximum stress
  – Failure Strain

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Uniaxial Tensile test

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CAD Model
Basic Criteria

1. Difference of area under plastic region between Test and Simulation
   Target: 0

2. Difference of maximum stress between Test and Simulation
   Target: 0

3. Difference of failure strain between Test and Simulation
   Target: 0
Sensitivity Analysis

- Sensitivity analysis is used to scan the design space by varying design optimization parameters within upper and lower bounds
- **Global Sensitivity** of responses with respect to design variables variation
- Identification of important input parameters and possible reduction of the design space dimension for optimization
- **Understanding and verification** of the optimization problem
- Choosing a start design for optimization
- Proof of numerical robustness
- Preparation of the optimization problem and reduction of the problem dimension

Latin Hypercube Sampling
• EN, FN, SN and FF0 have major influence on maximum stress value of the curve

• EN, FF0 and FN have major influence on the failure strain and area under plasticity region.

• All design parameters are considered for optimization
Optimization - Evolutionary Algorithm

- Evolutionary algorithm is used. It's a metaheuristic algorithm. This algorithm is selected due to the low computation time of each design in this project.

- Evolutionary algorithm usually features
  - Robust
  - Can handle any complexity
  - Takes time to converge
Optimization - Evolutionary Algorithm

Objective History  

Best Design Data  

Output Data of Best Design

Damage parameters of the optimized Gurson material are shown in figure above (Best Design Data)
Summary

- In Crash simulation, numerical simulation of fracture and material failure is important.
- **Gurson Material model** can define the material failure using the void growth and nucleation approach.
- Identification of the *damage parameters* of the Gurson Material model through tests in expensive.
- Material identification task is completed automated using **optiSLang**.
- **Sensitivity analysis** is carried out to find out most influential design parameters and also start design for optimization.
- All design parameters are considered for optimization.
- **Evolutionary algorithm** is used due to low simulation time for each design.
- More research has to be done to understand the Gurson model behavior.
Thank You