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

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Acknowledgement

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CADFEM India

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Crash Application

Importance of crash simulation?

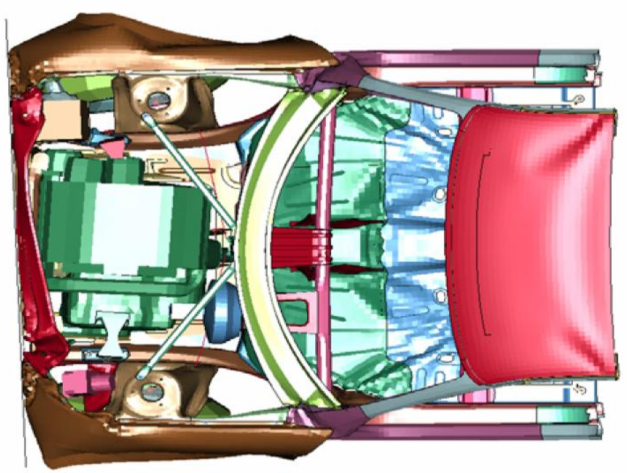
- Safety

Why simulating?

- Compression of development cycles
- Cost reduction

Why optiSLang?

- Unknown sensitivities
- Many parameters



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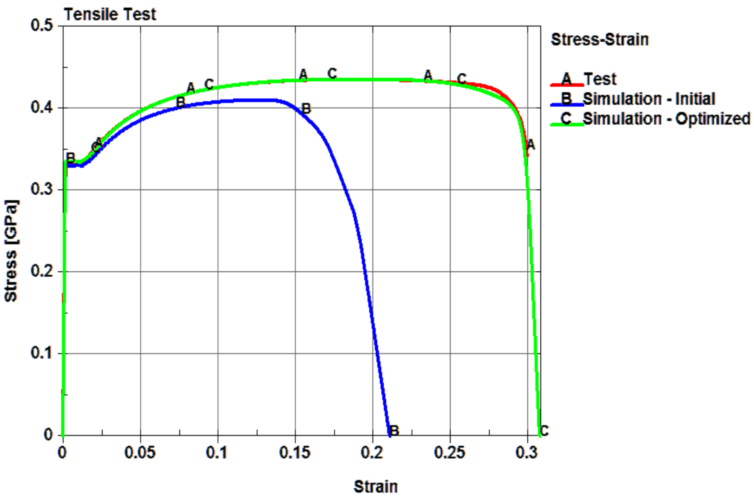
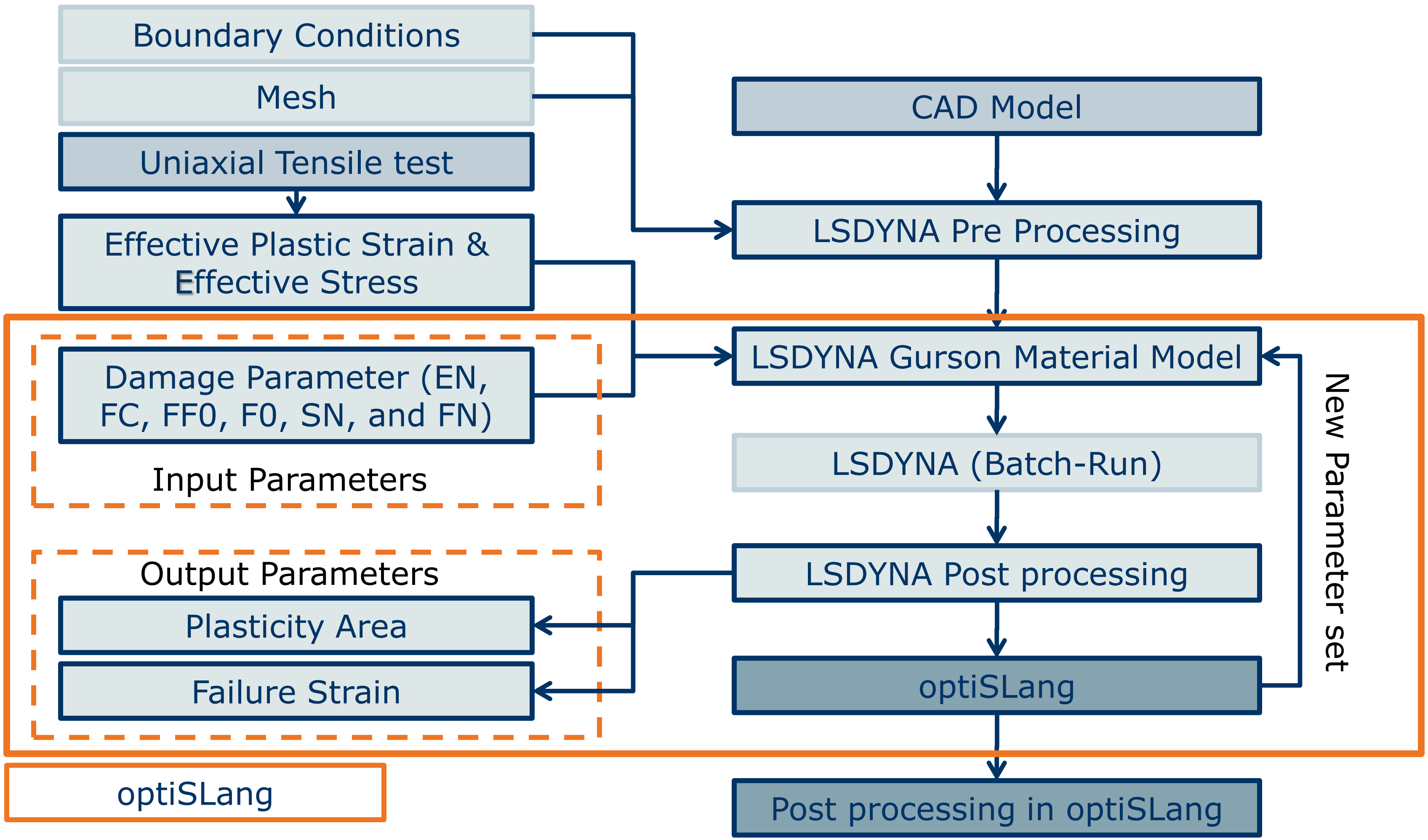
Why Gurson Material Model?

- 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



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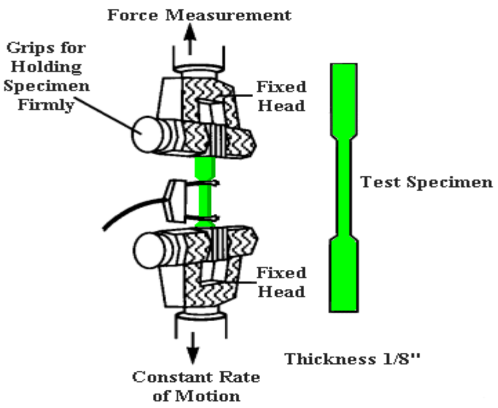
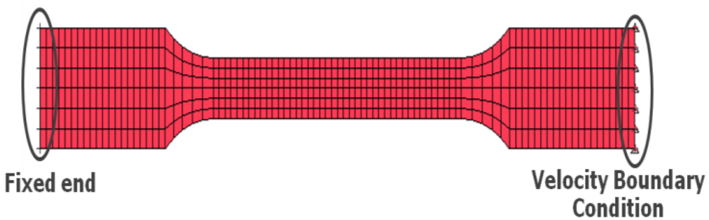
Uniaxial Tensile Test & Simulation Model

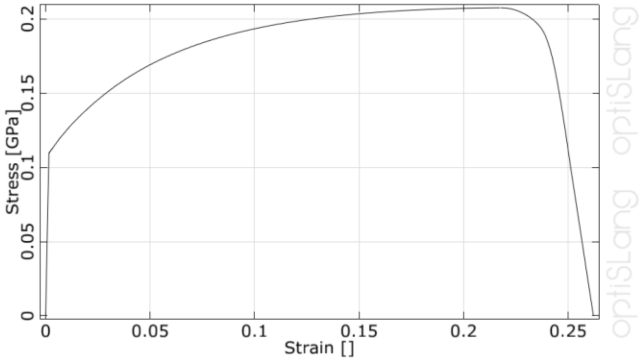
- Tensile test is carried with one end fixed and constant rate of motion on the other end
- Force and displacement are measured
- Engineering stress-strain curves is plotted based on the measurements
- FE model is developed based on test specifications



Uniaxial Tensile Test



FE Model



Stress-strain curve

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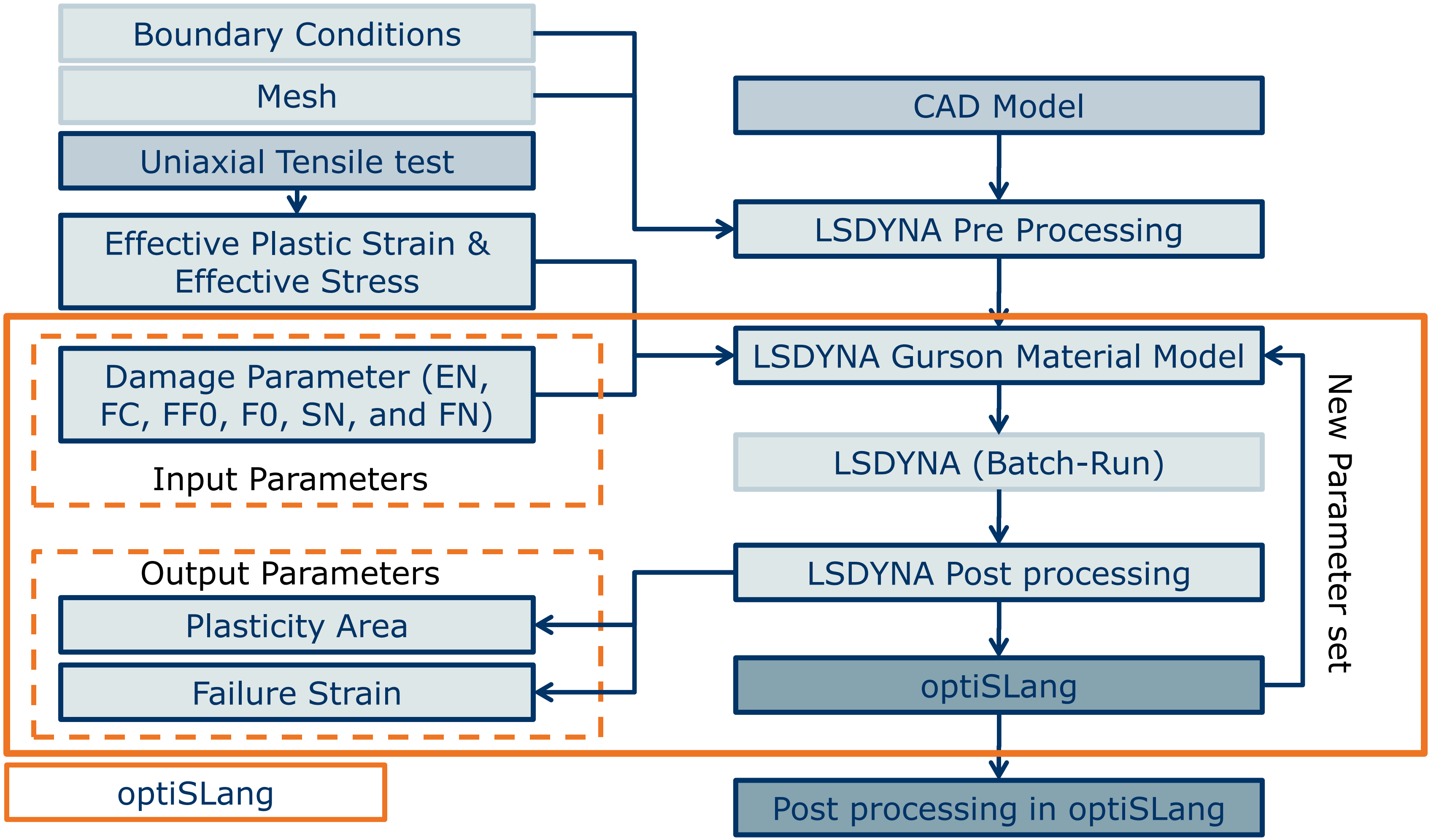
Methodology



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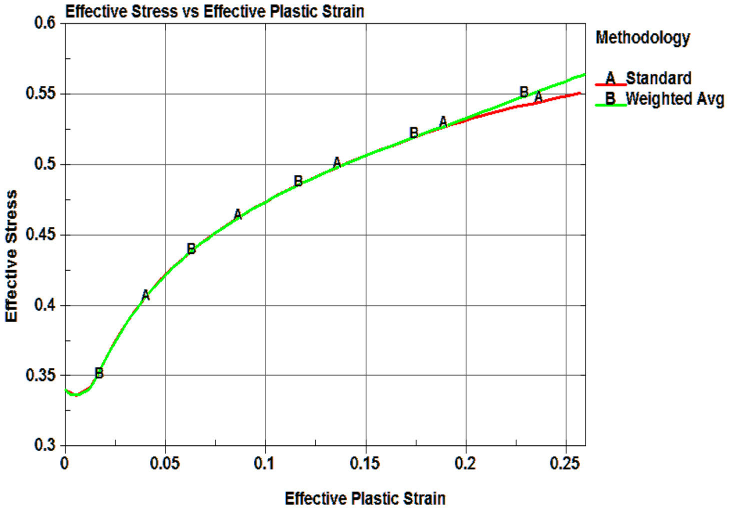
Calibration of Effective Plastic strain and stress

- 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

$$\sigma = \sigma_u \left[w\,(1+\varepsilon-\varepsilon_u) + (1-w)\left(\frac{\varepsilon^{\varepsilon_u}}{\varepsilon_u{}^{\varepsilon_u}}\right)\right]$$



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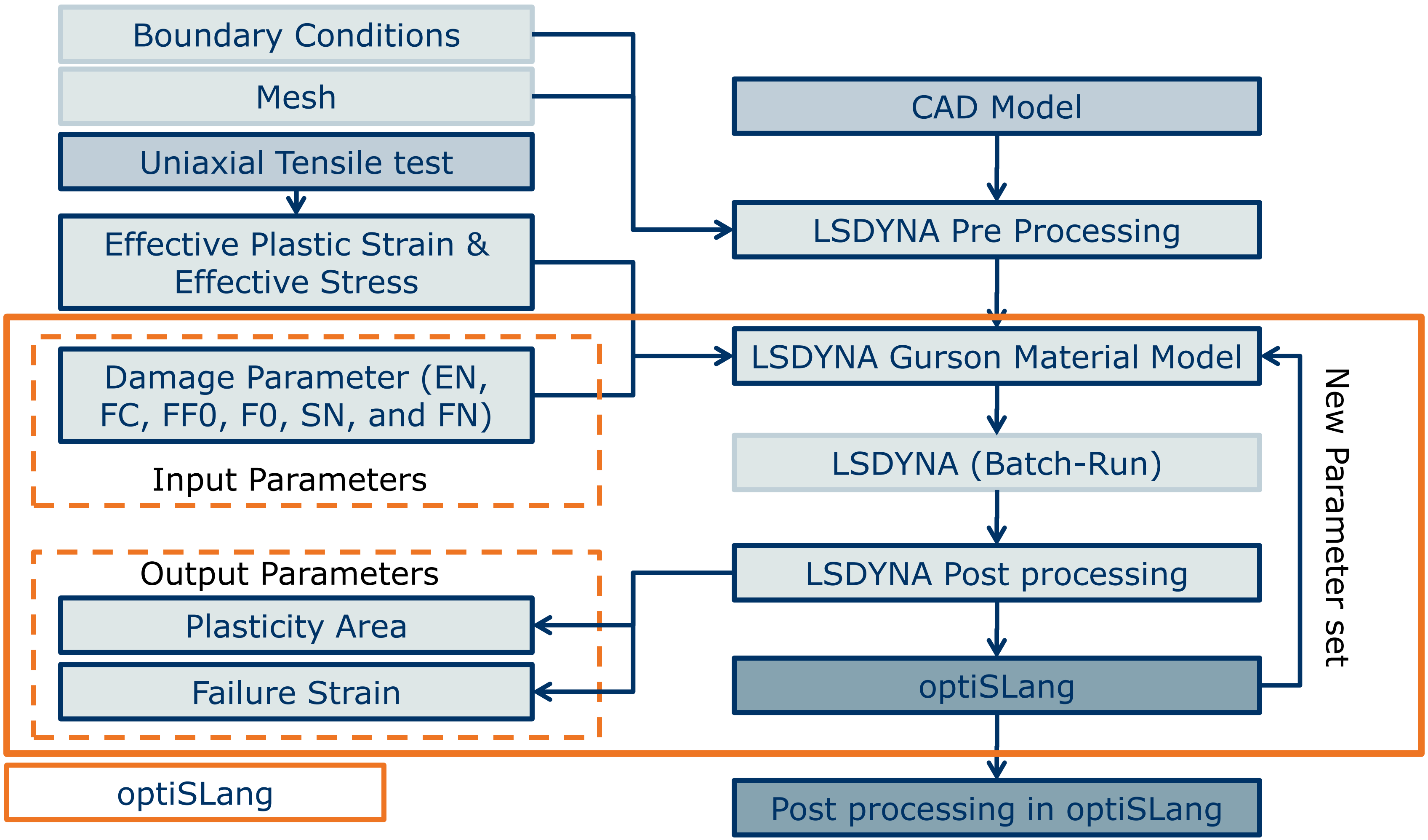
Methodology



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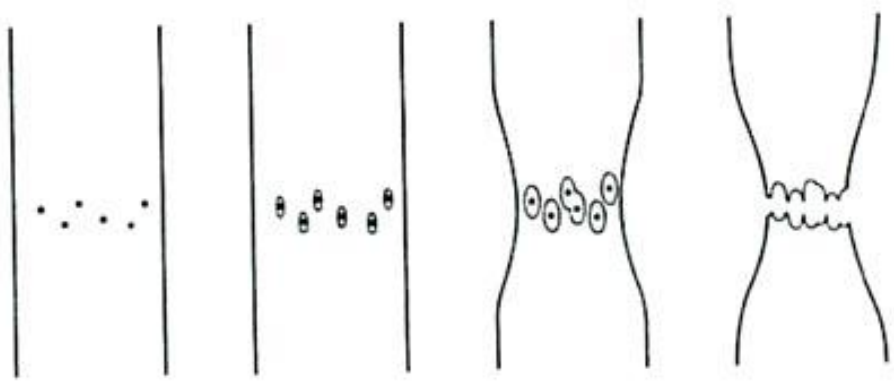
Gurson Material Model

- 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.

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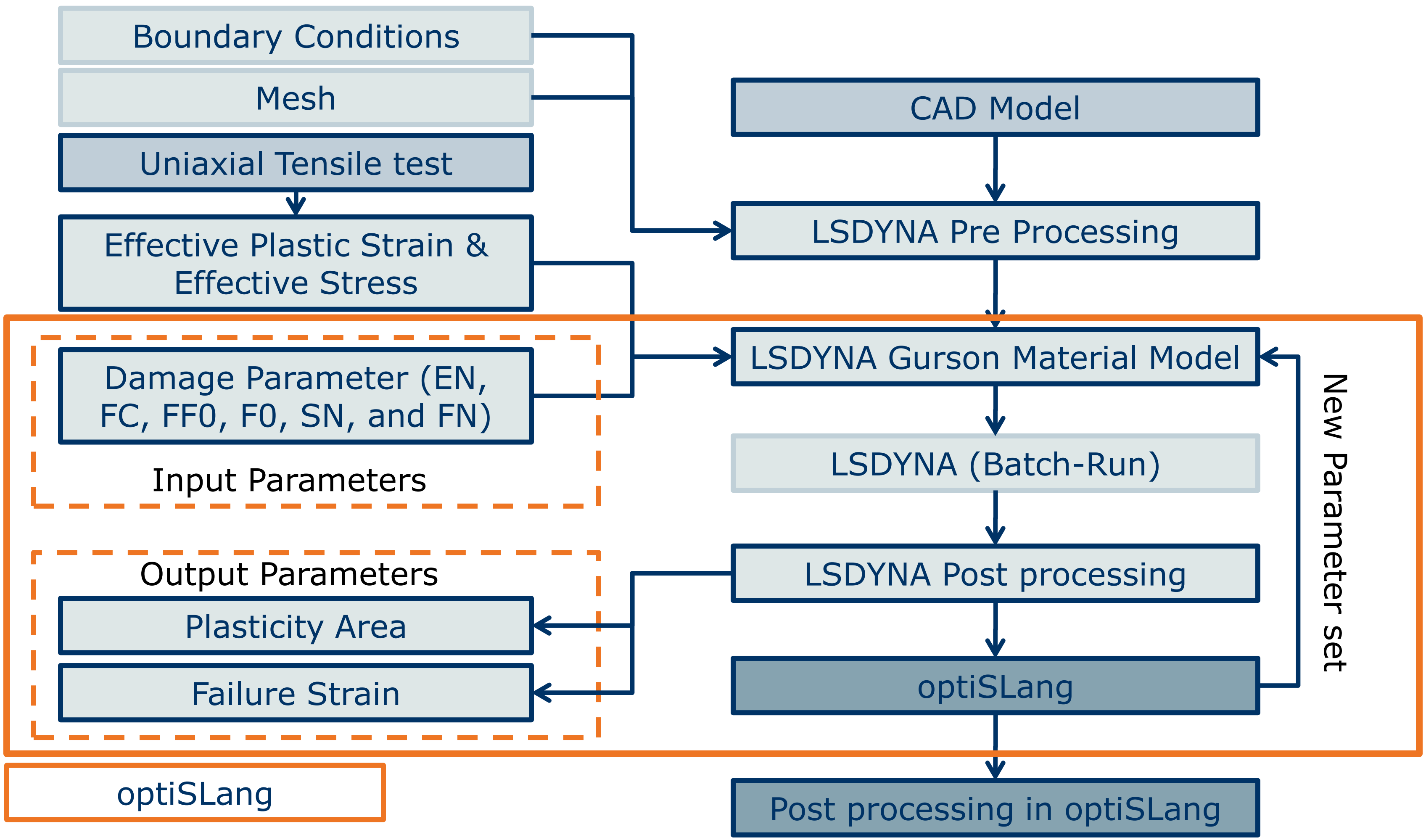
Damage Parameters

- 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

Parameters	Reference Value	Lower Bound	Upper Bound
F0	0.01	0.0001	0.03
FC	0.15	0.03	0.15
FF0	0.25	0.1	0.9
FN	0.04	0.001	0.2
EN	0.1	0.1	1
SN	0.1	0.05	0.15

Workflow



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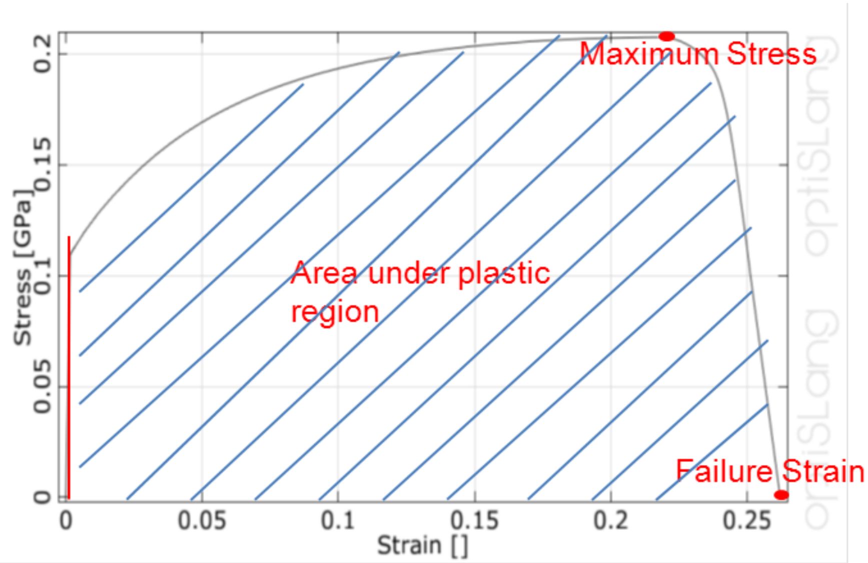
Post Processing

- 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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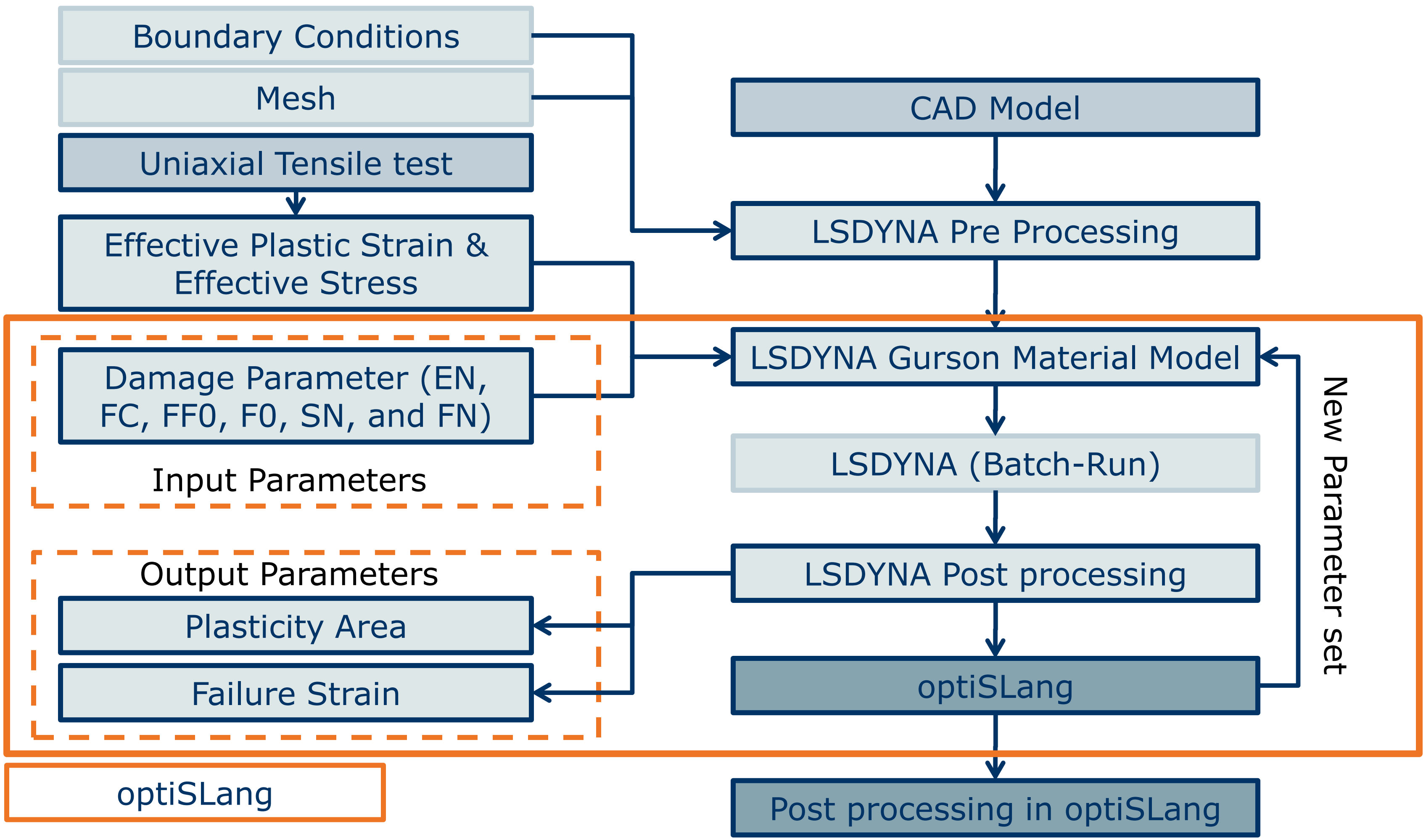
Workflow



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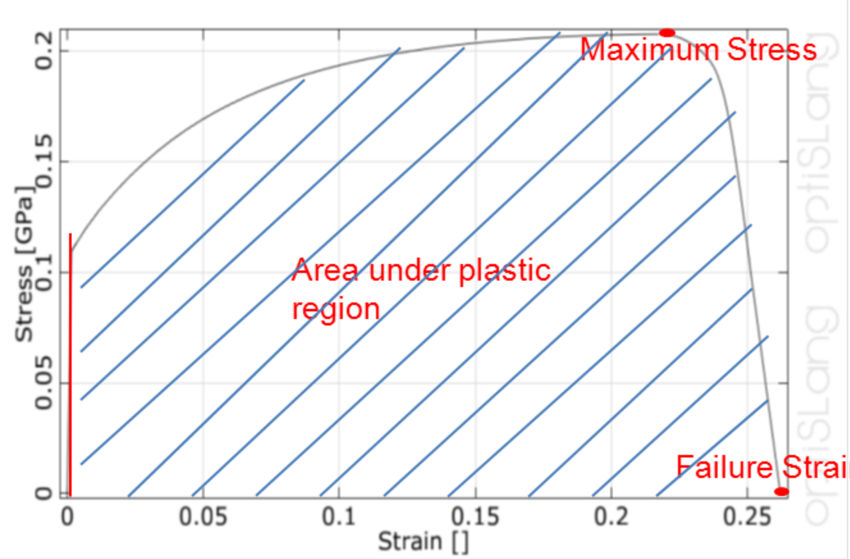
Basic Criteria

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



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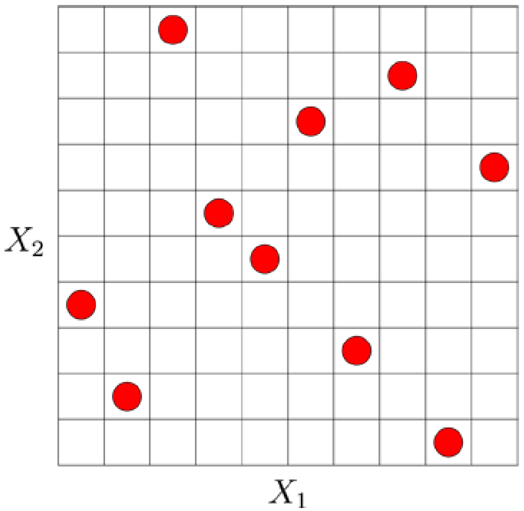
Sensitivity Analysis

- 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

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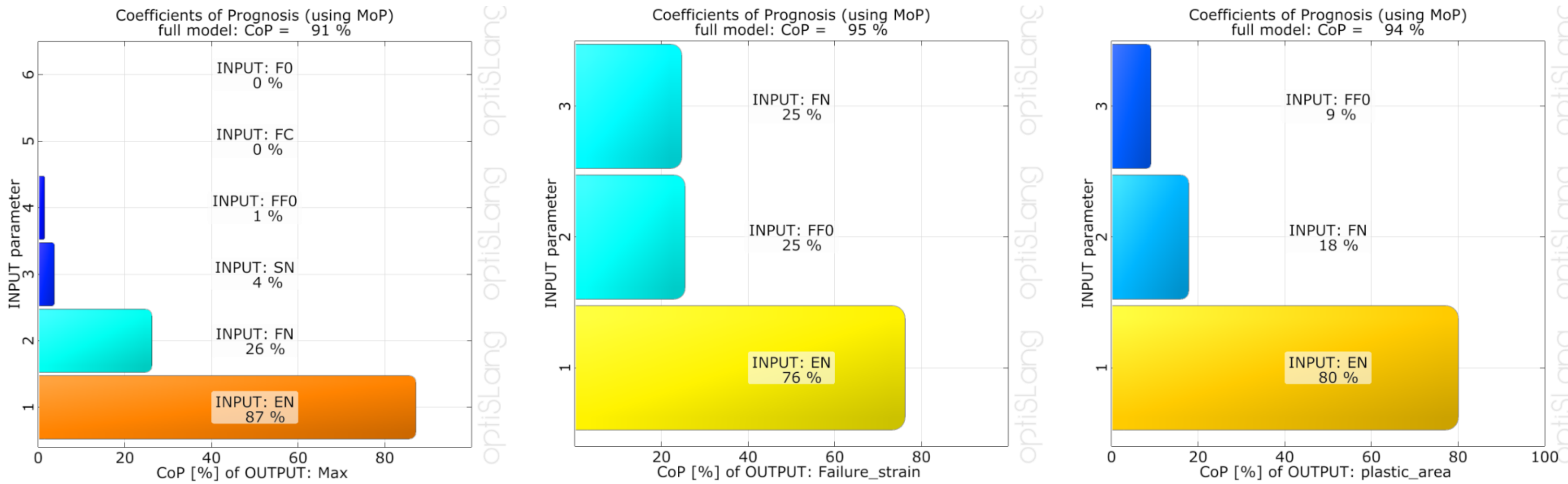
Sensitivity Analysis

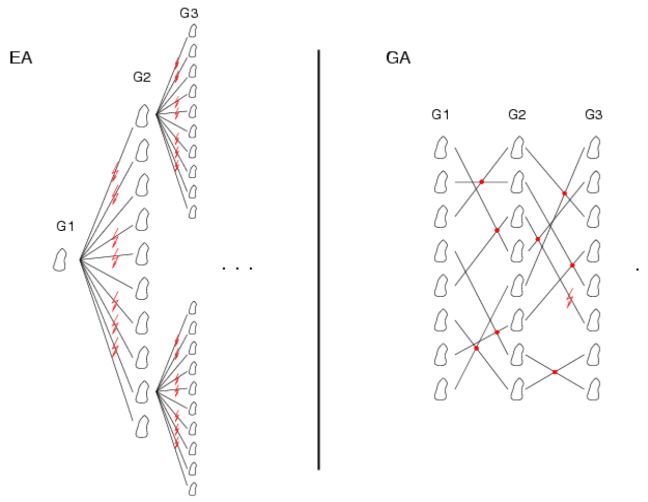


- EN, FN, SN and FF0 have major influence on maximum stress value of the curve
- EN, FF0 and FN have major influence on the failure strain and area under plasticity region.
- All design parameters are considered for optimization

Optimization - Evolutionary Algorithm

- Evolutionary algorithm is used. Its 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



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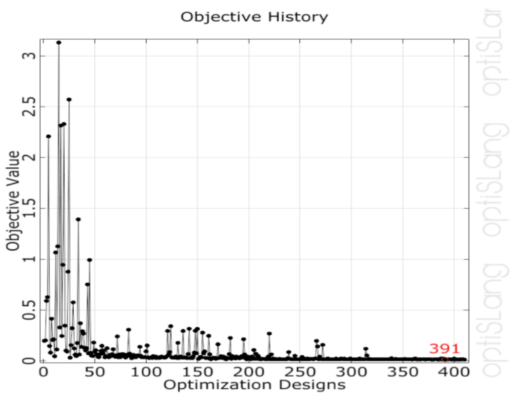
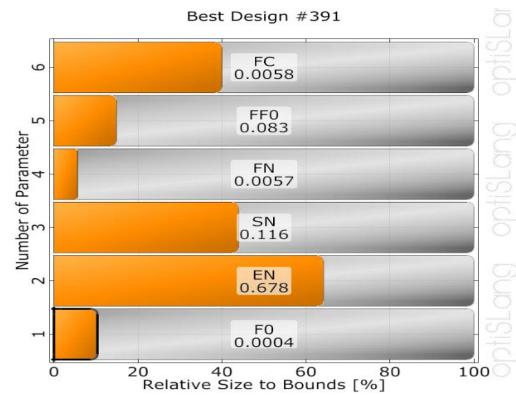
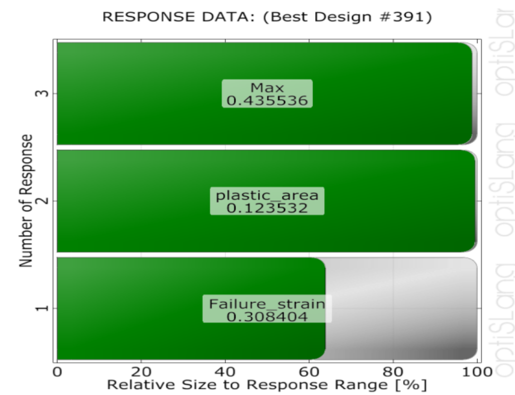
Optimization - Evolutionary Algorithm



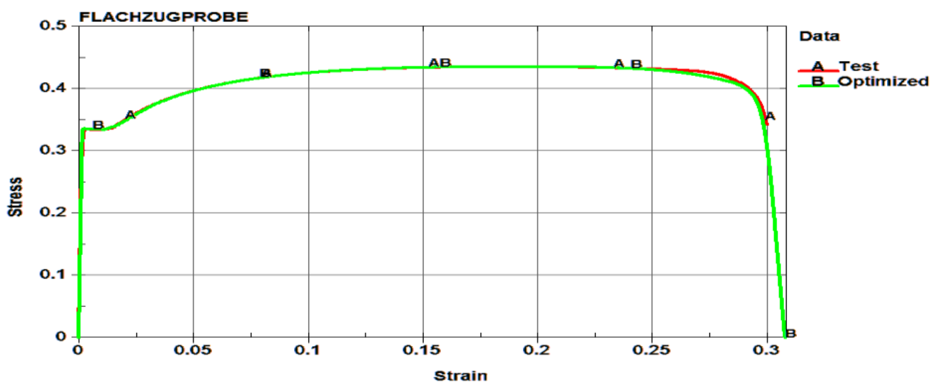
Objective History



Best Design Data



Output Data of Best Design



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

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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