Prediction of damage and fracture during forming simulations in Alloy 718

Lluís Pérez Caro, Mikael Schill, Stefan Marth, Eva-Lis Odenberger, Mats Oldenburg

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Lluís Pérez Caro
Researcher / Industrial PhD student, lluis.perez.caro@swerea.se

GKN AEROSPACE

LULEÅ UNIVERSITY OF TECHNOLOGY

Contents

1. Motivation

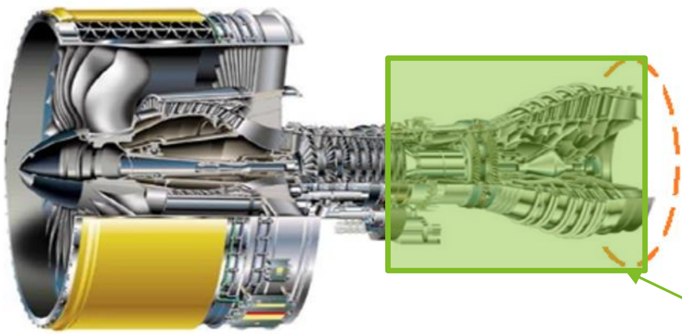
NFFP6 SME project

Project: Virtual process chain for superalloy sheet metal aero engine structures – Validation and demonstrator

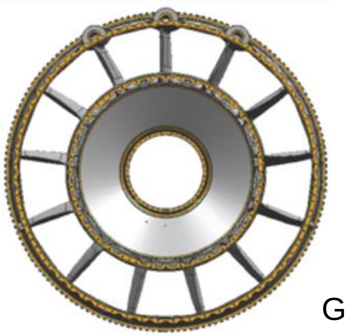
1. Motivation

Fabrication → Flexible designs

- Sheet metal
- Cast parts
- Forgings



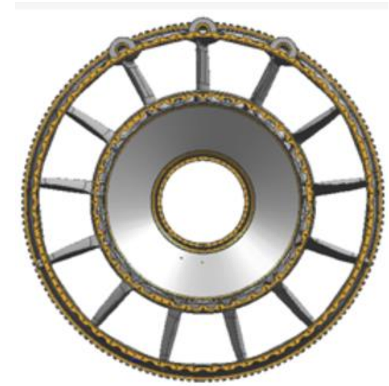
Ni-based superalloys
Working temp. up to 650°C



GKN TEC, GP7000

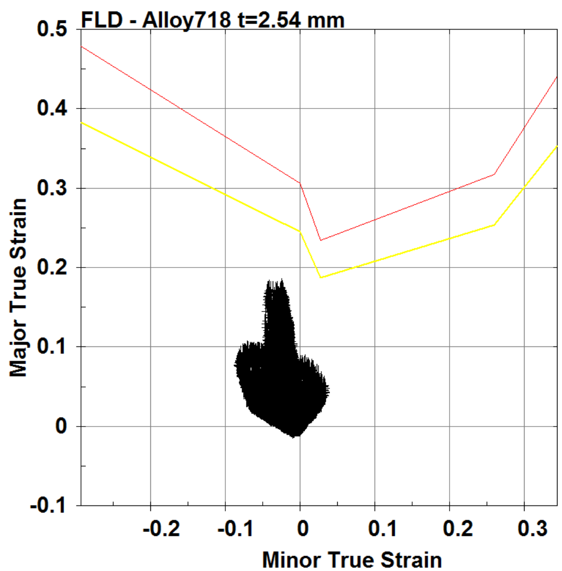
1. Motivation

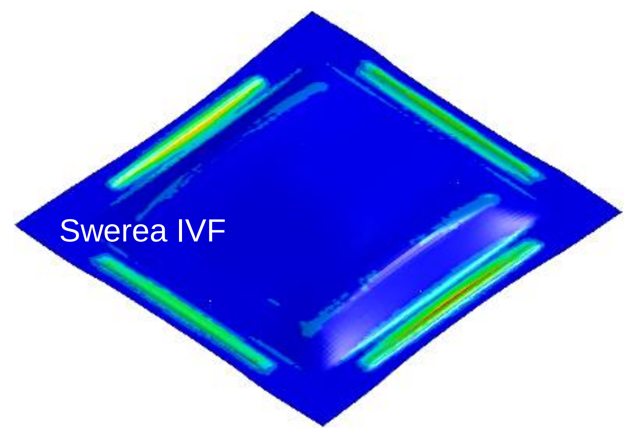
Forming → Trimming → Welding → Heat treatment



GKN Turbine Exhaust Case

Small cracks on one of the drawbeads after forming





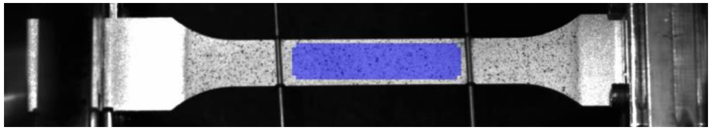
Forming simulation showing high strains (in red) on the same drawbead. No risk of cracks

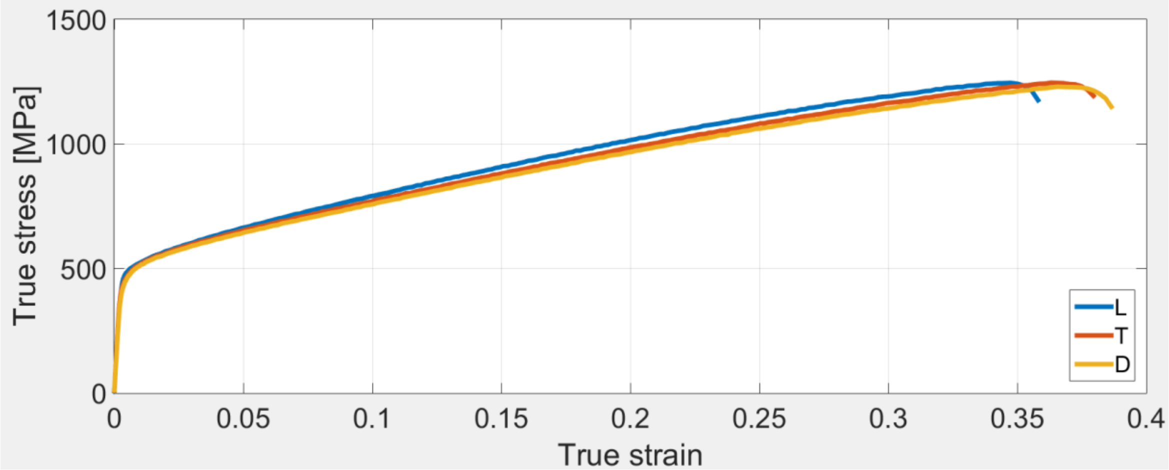
2. Aim and scope

- Use the GISSMO damage model in order to accurately predict risk of cracks in the drawbeads after forming an Alloy 718 sheet
  - Calibrate the GISSMO damage model
  - Compare forming simulations with experimental forming tests at room temperature

3. Material

- Alloy 718
  - Precipitation hardened nickel-chromium superalloy
  - Solution annealed condition
  - Nominal thickness of 2.54 mm





Roll. Dir.	r(10)	r(15)
0° (L)	0.66	0.62
90° (T)	0.88	1.04
45° (D)	1.07	1.26

Hardening curves and r-values for Alloy 718 at room temperature

3. Material

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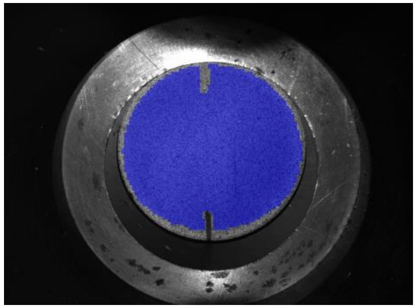
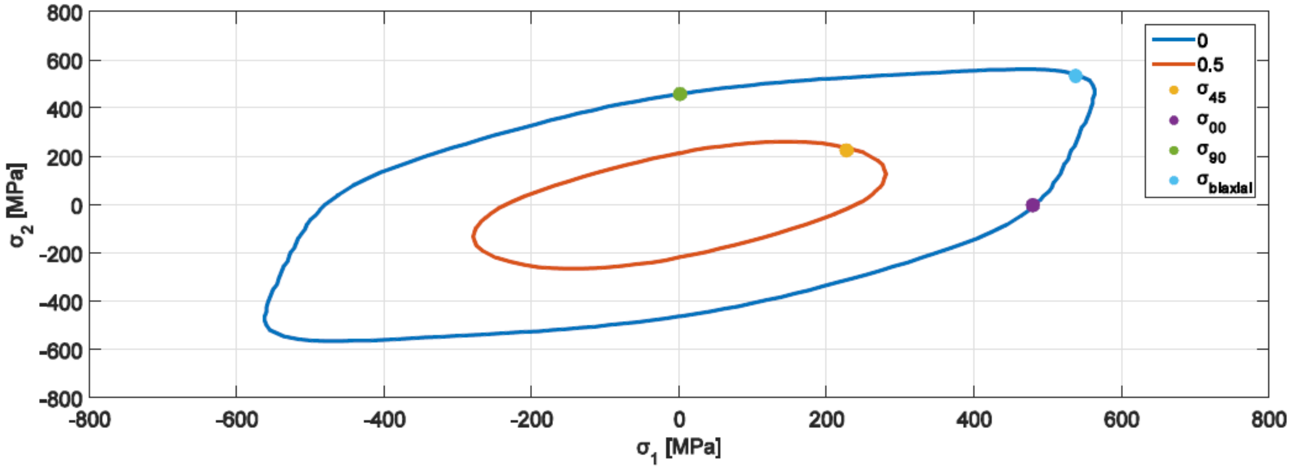
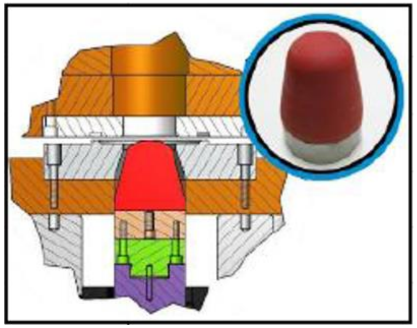






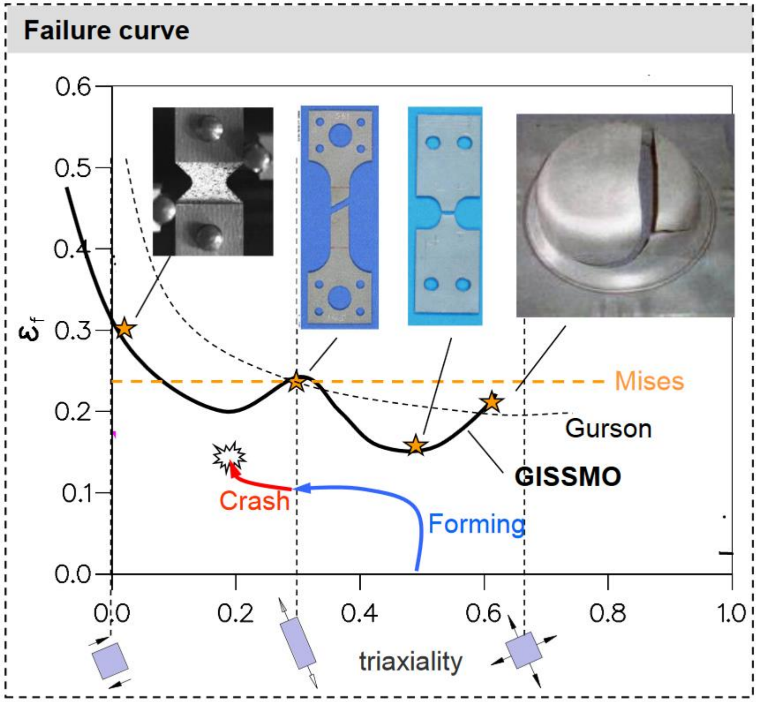
Calibrated yield surface of Alloy 718 and Bulge test setup at room temperature

4. GISSMO damage model

- **G**eneralized **I**ncremental **S**tress **S**tate dependent damage **Mo**del
- Prediction of ductile damage
- Failure occurs when D = 1
- Implemented into LS-DYNA and coupled with *MAT_133 (Barlat Yld2000)
- Parameter determination directly from experimental tests

4. GISSMO damage model - Implementation

- Cards 3 and 4 of the LS-DYNA keyword *MAT_ADD_EROSION
- IDAM = 1
- DMGTYP = 1
- Main inputs
  - LCSDG: failure strain vs. triaxiality
  - ECRIT: instability strain vs. triaxiality
  - LCREGD: element size regularisation



Neukamm, Feucht, DuBois & Haufe (2008-2010)

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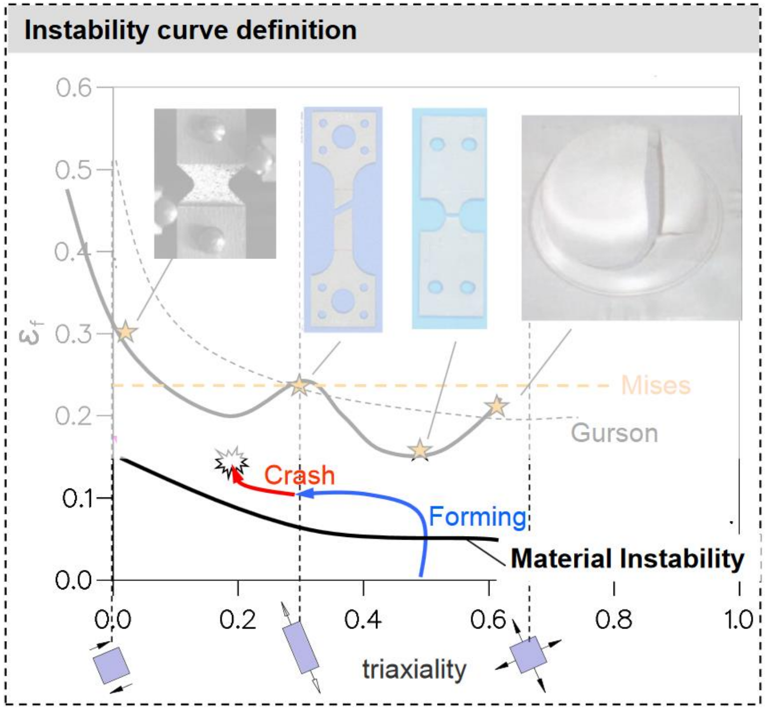

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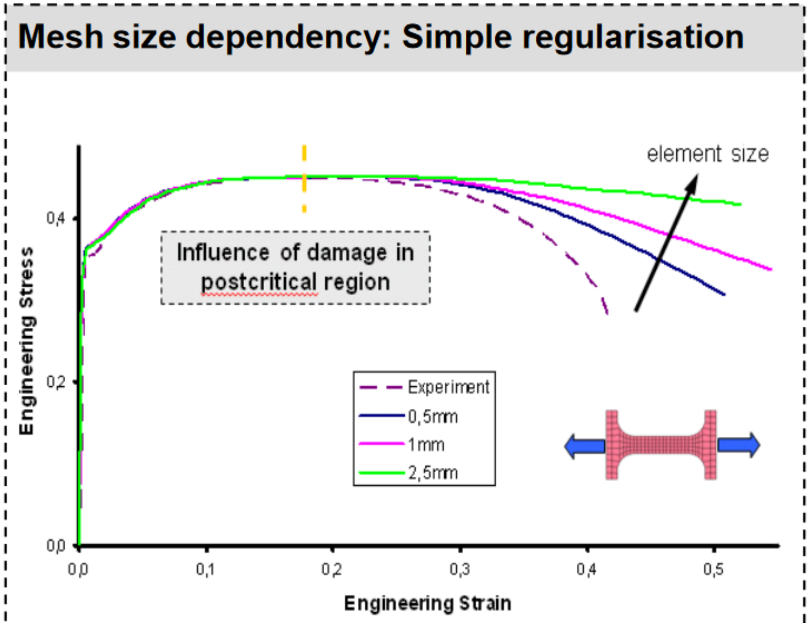
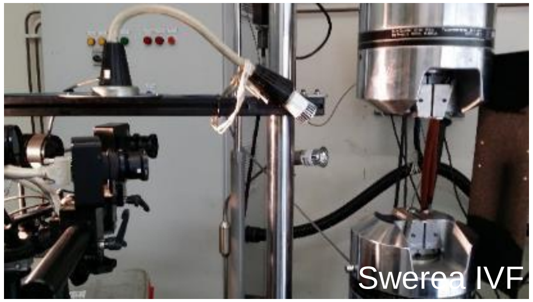


Haufe, DuBois, Neukamm, Feucht. LS-Dyna Developer Forum 2011, DYNAmore, Stuttgart

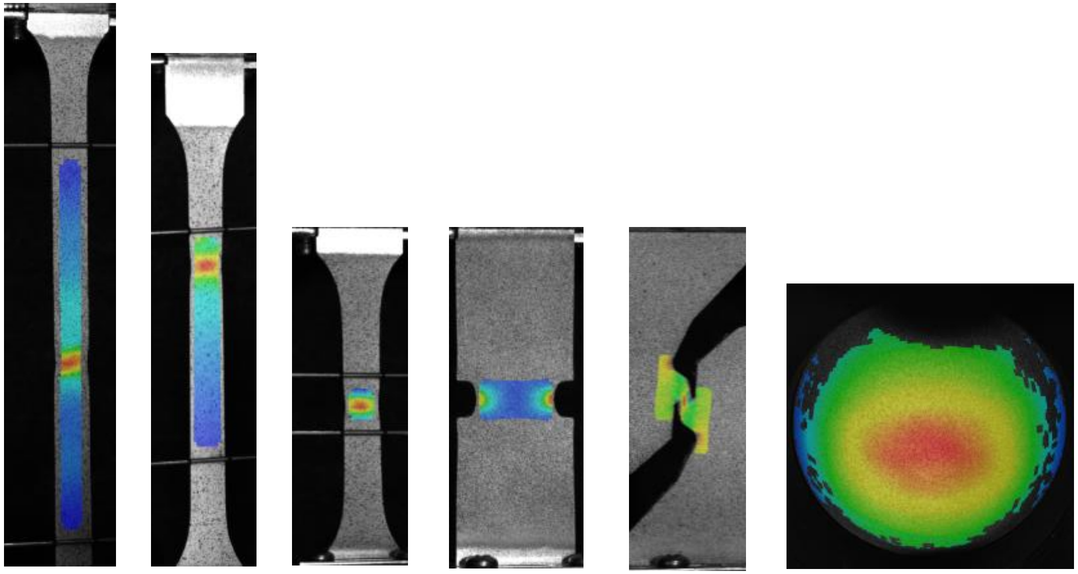
4. GISSMO damage model - Calibration

- 6 different geometries tested
- ARAMIS™ optical strain measuring system

Hydraulic press 1,300 t



MTS 100 kN



A80 A50 A10 Plane Strain Shear 15° Biaxial

ARAMIS™ strain field before fracture of GISSMO specimens

4. GISSMO damage model - Calibration

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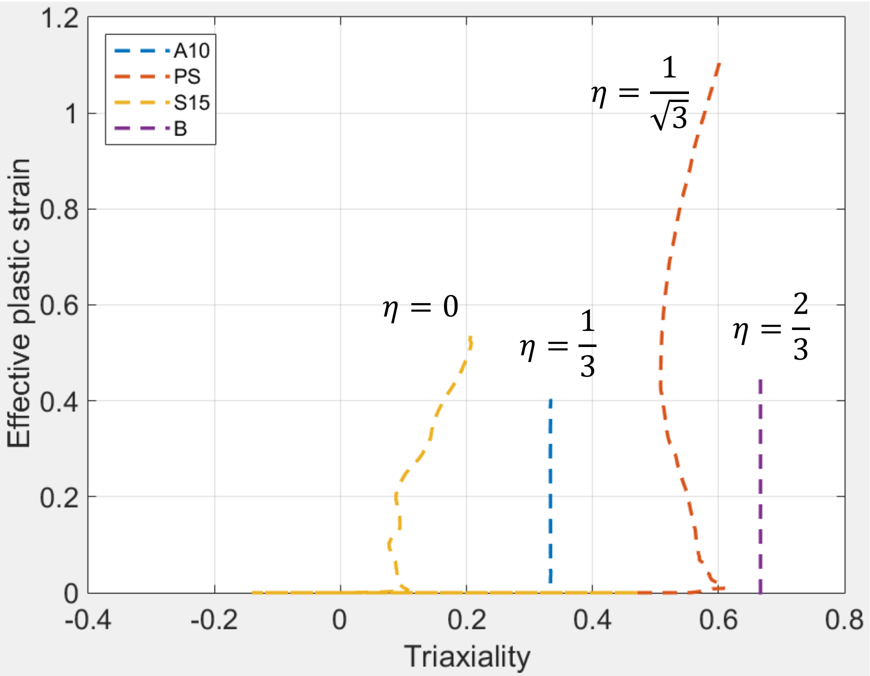
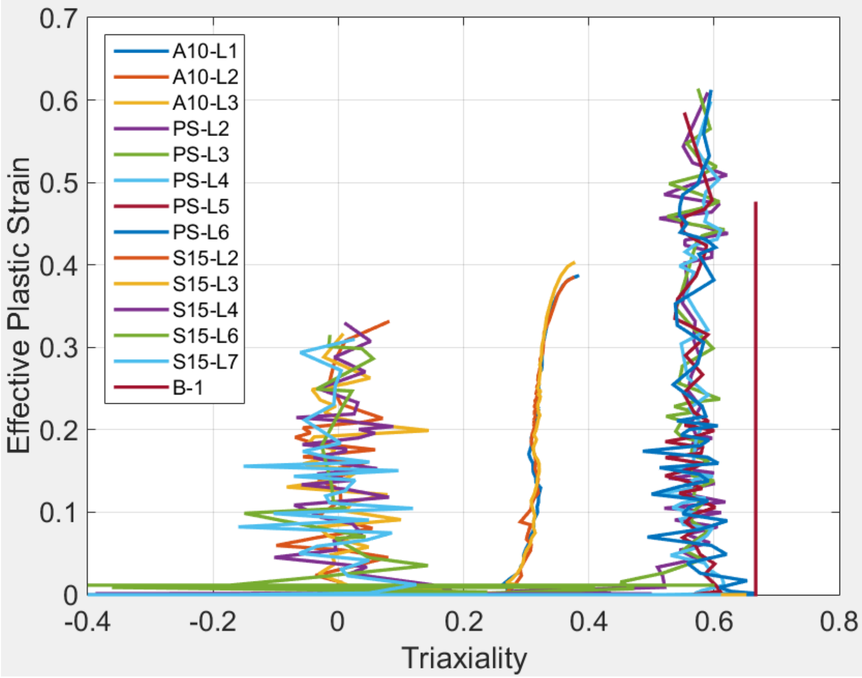
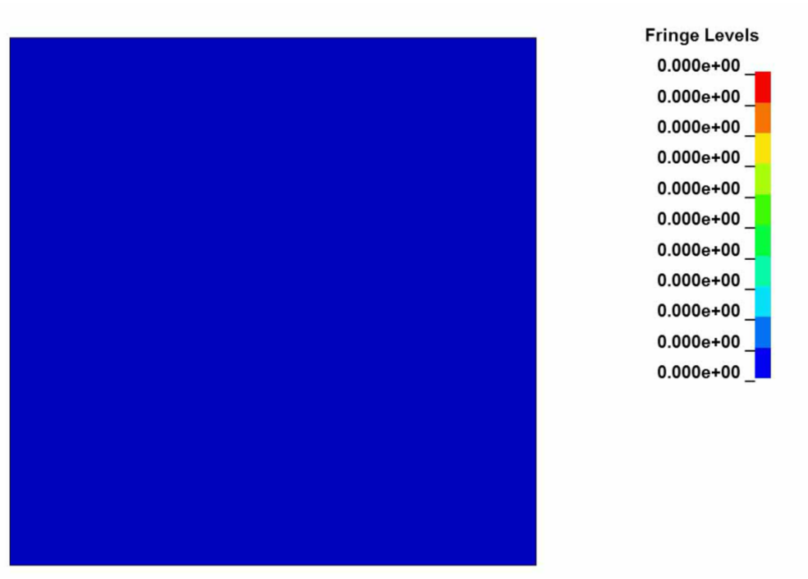


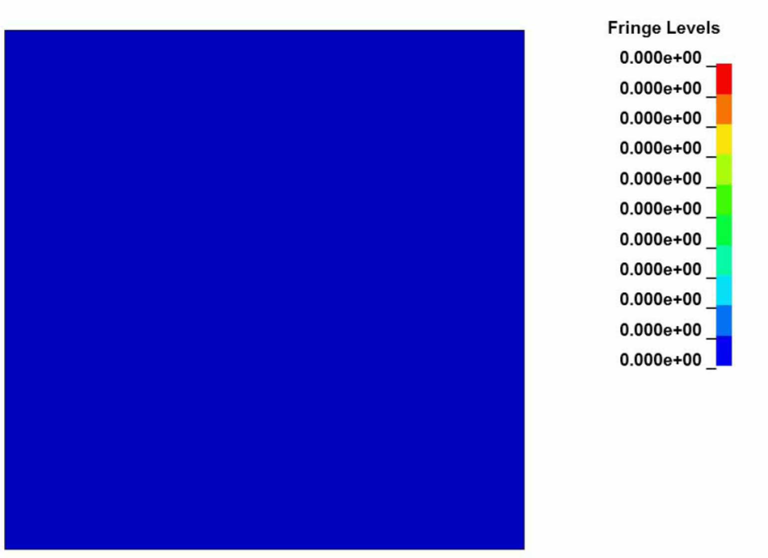


5. Forming simulation coupled with damage

- The damage in the material is accumulated. Element failure occurs for D = 1. Then, the element is deleted



Forming simulation. High strains (in read) on one of the drawbeads



Forming simulation + GISSMO. Elements deleted on the drawbeads

6. Summary and conclusions

- An initial calibration of the GISSMO damage model for an Alloy 718 sheet at room temperature is performed
- Experimental stress triaxiality values have a good agreement with simulations for six different specimen geometries
- A forming simulation including the GISSMO damage model can predict failure in the same areas where cracks were observed from forming tests at room temperature

7. Acknowledgements

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