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Audi

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Numerical modelling of aluminium die-castings using a probabilistic approach

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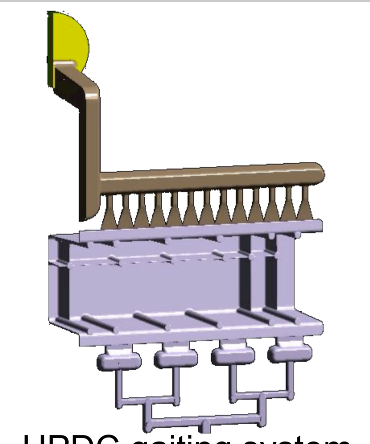
Introduction:

- The High Pressure Die Casting (HPDC) process allows to produce thin-walled components.
- Here, internal defects (porosity, oxide films, cold flow areas) influence the structural behaviour. Especially the fracture behaviour is dominated by these cast defects. [1]

Objectives:

- Weight reduction and crash requirements of HPDC components
- Evaluation concerning fracture in HPDC components - place and time of fracture initiation

[1] R. Treitler, PhD Thesis, Institute for Reliability of Components and Systems, University Karlsruhe, Germany (2005)

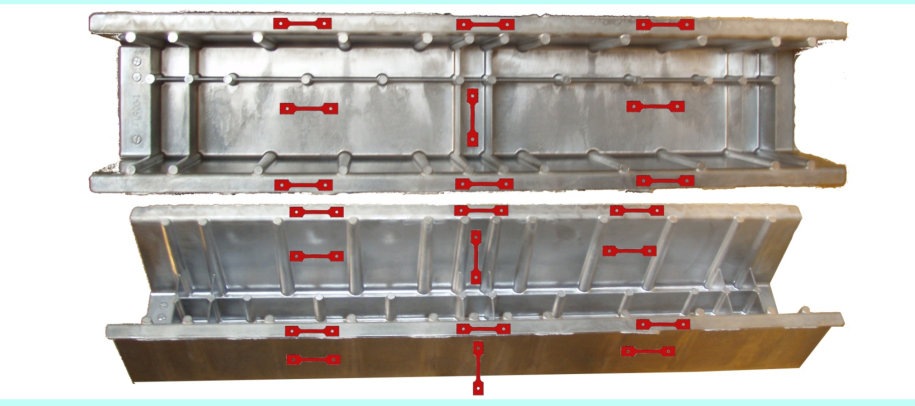


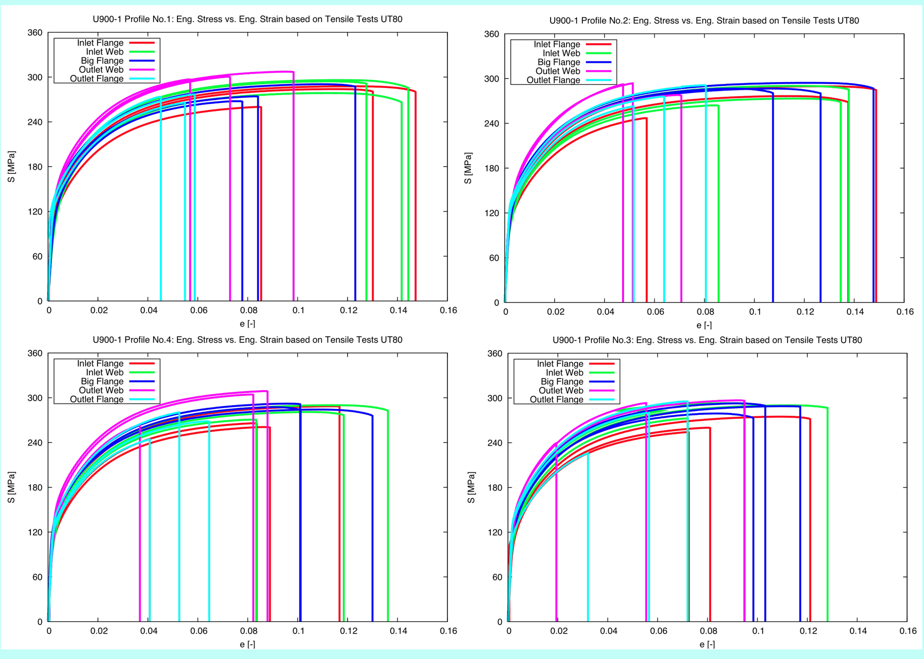
HPDC gaiting system

AUDI A8 Space Frame (ASF): Application of HPDC components (red)

Material Characterization:

- Aluminium alloy *Castasil-37*
- Analysing:
  - Elastic-plastic behaviour
  - Fracture behaviour
  - Influence of the process chain
- Quasi-static tensile tests with specimens cut from a generic HPDC component (F condition)





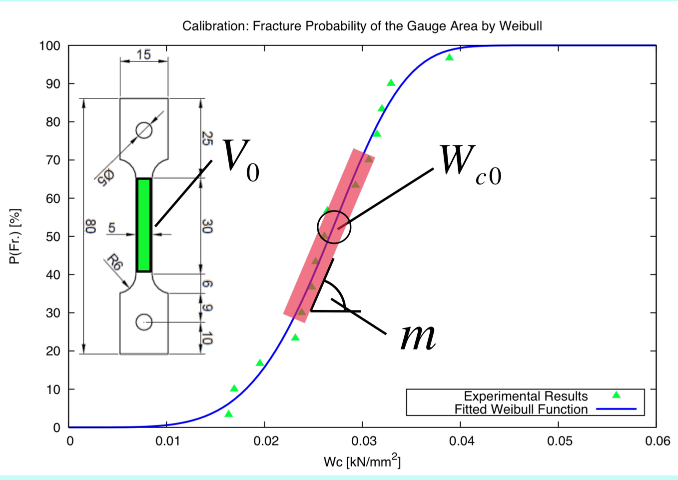
Results from uniaxial tension tests cut from 4 HPDC components (engineering stress vs. engineering strain)

Probabilistic approach in fracture modelling [2]:

- Background:
  - It is assumed that properties entering a fracture criterion are given in terms of probability distributions.
  - Probabilistic models lead to statements about fracture risks.
- Deterministic fracture criterion:
  - Ductile fracture criterion by *Cockcroft-Latham* (CL)
- Approach by *W. Weibull*:
  - “The probability for the occurrence of a critical defect increases with the volume under consideration.”
  - Size effects are included.
  - The approach can be referred to finite element modelling.
- Fracture Probability of a large Volume:
  - Large Volume composed of material (element) volumes.

$$W=\int_0^{\bar{\varepsilon}^{pl}} \max(\sigma_1,0)\,d\bar{\varepsilon} \le W_c$$

$$P(W_c)=1-\exp\left[-\left(\frac{V}{V_0}\right)\cdot\left(\frac{W_c}{W_{c0}}\right)^m\right]$$



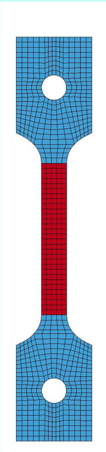
$$V^e:\quad W_c^e \quad P^e(W_c^e)$$

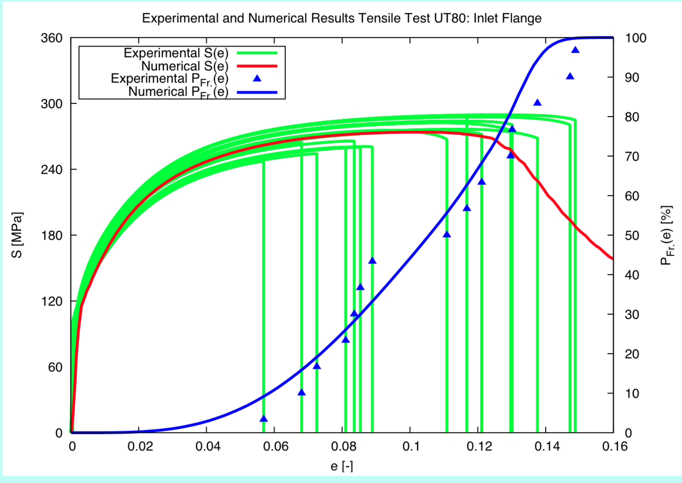
$$V=\bigcup_{e=1}^{n_e} V_e:\quad P=1-\prod_{e=1}^{n_e}\left(1-P^e\right)$$

[2] C. Dørum, O.S. Hopperstad, T. Berstad, D. Dispinar, Engineering Fracture Mechanics 76 (2009) 2232-2248

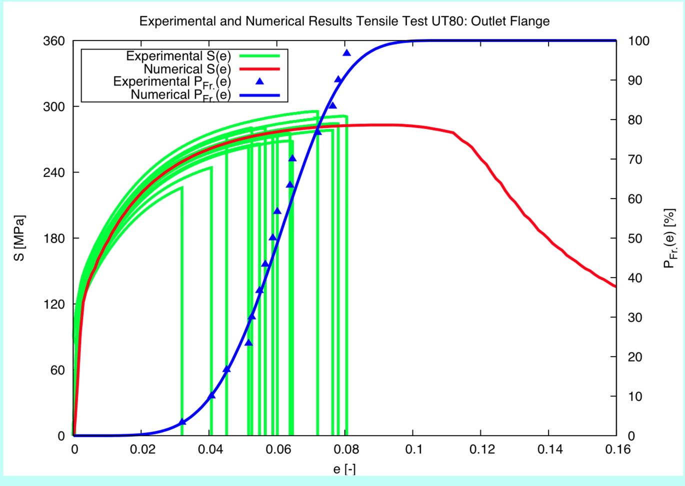
Numerical simulations of the tensile tests (LS-Dyna):

- Material modelling:
  - Isotropic yield criterion
  - Associated flow rule
  - Isotropic hardening
- Fracture modelling
  - CL criterion
  - Approach by *Weibull*
- Finite element model:
  - 800 shell elements





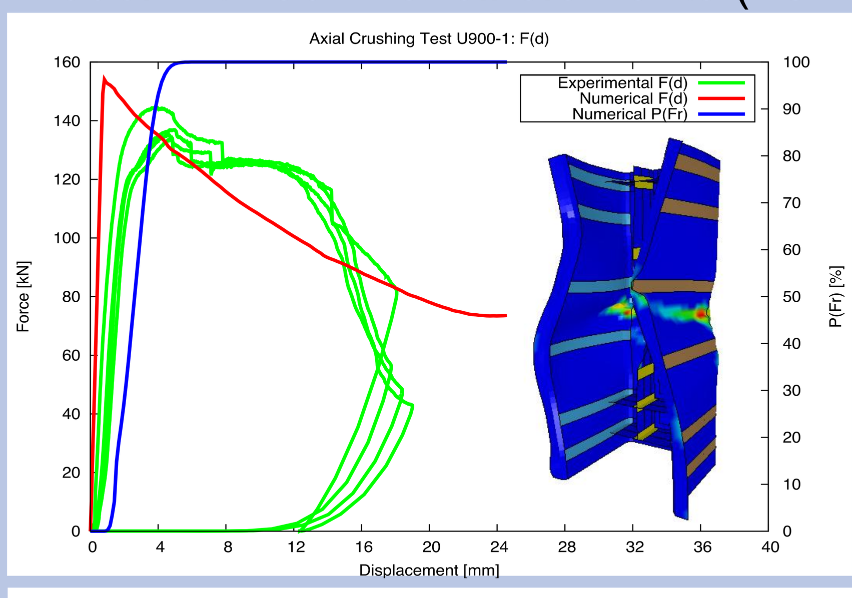
Results gating side (stress vs. strain and probability of fracture vs. strain)

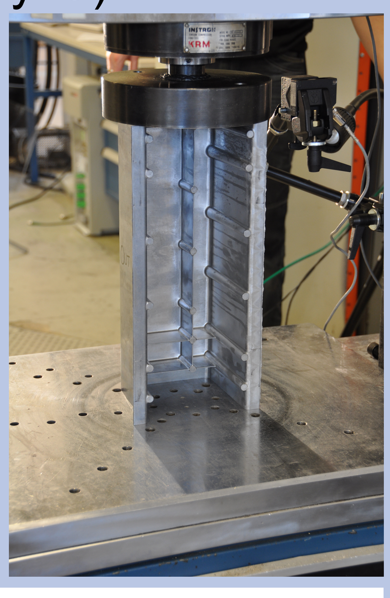


Results vacuum side (stress vs. strain and probability of fracture vs. strain)

Structural behaviour: Axial crushing test

- Quasi-static loading (3 mm/min)
- FE model with 5621 shell elements (LS-Dyna)

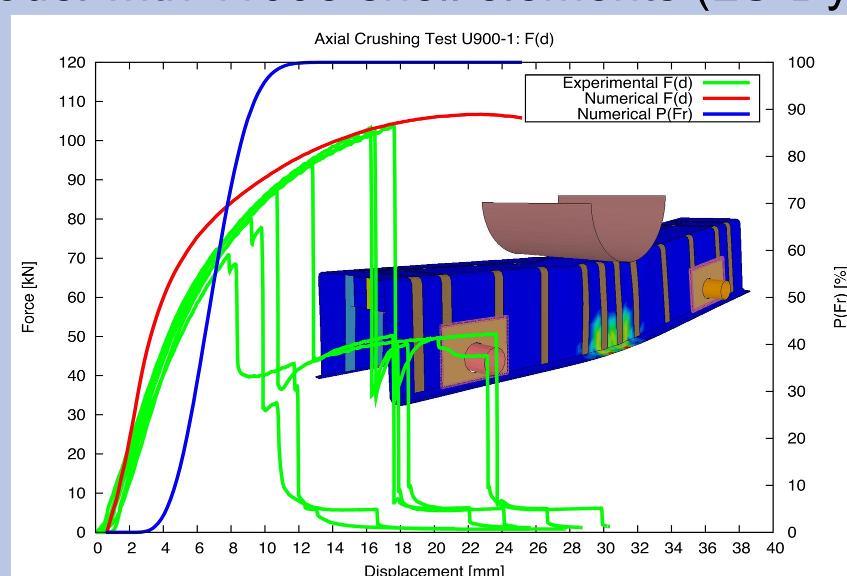


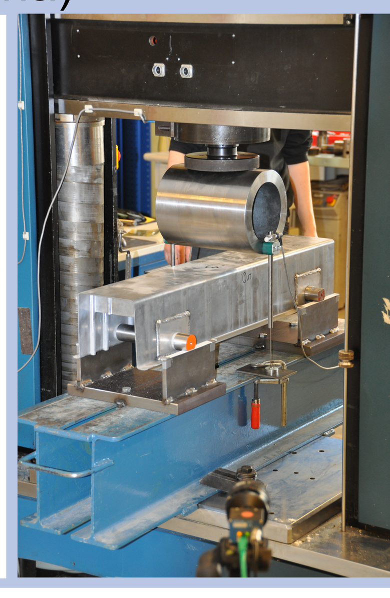


Experimentally measured and numerically predicted force-displacement behaviour together with the fracture probability (HPDC component, AlSi9Mn F)

Structural behaviour: 3 point bending test

- Quasi-static loading (3 mm/min)
- FE model with 11098 shell elements (LS-Dyna)





Experimentally measured and numerically predicted force-displacement behaviour together with the fracture probability (HPDC component, AlSi9Mn F)

Conclusions:

- A probabilistic methodology is presented to analyze aluminium HPDC components concerning the probability of fracture.
- The numerical results of the tension tests as well as the prediction of the fracture probability fit well to experimental data.
- The discretization of internal ribs and ejector domes influences the numerical results tremendous. Here, further investigation are necessary.