3rd EMMC International Workshop

EMMC

New Modelling Approach for Edge Cracking Simulations

FORM PLANET

ArcelorMittal

CRF CENTRO RICERCHE FIAT

LULEÅ TEKNISKA UNIVERSITET

eurecat Centre Tecnològic de Catalunya

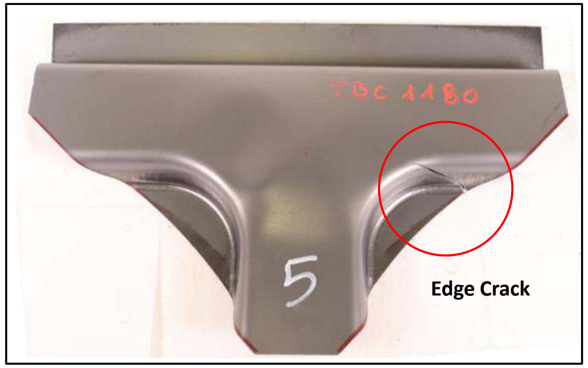
FORMPLANET PROJECT

Boosting the sheet metal forming industry

FormPlanet project aims to develop and demonstrate, and **integrated ecosystem** (open innovation test bed) offering **novel testing methodologies to characterize sheet metal properties, predict part performance and prevent production loses** to the sheet metal forming industries, tackling the upcoming challenges in formability and part quality assessment.

The project will promote a wide usage of high strength sheet materials while reducing production costs and time-to-market for sheet products in different industrial end-use sectors.

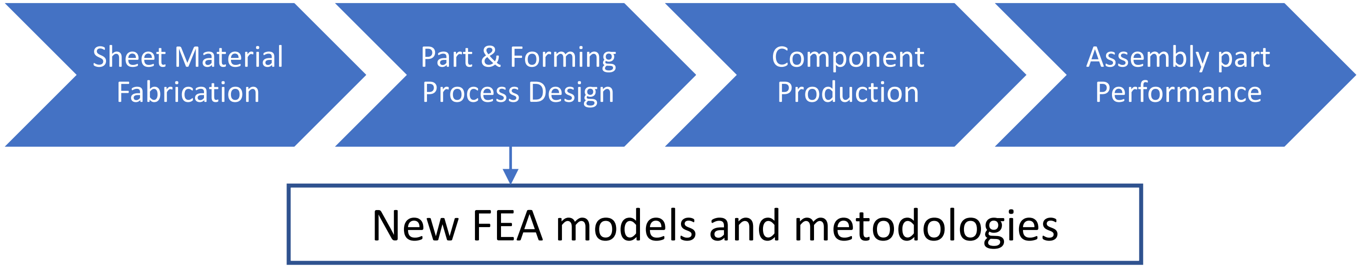
- New multi-scale characterisation techniques
- Novel tests to predict part performance and formability
- Quality control and material integrity by novel non-destructive techniques
- Novel finite element modelling to predict part manufacturing and performance, and to shorten part design phase
- Creation & analysis of a complete material database
- Contribution to the setting of future standards
- Creation of a certification methodology to ensure quality levels



The Edge Carcking Problem

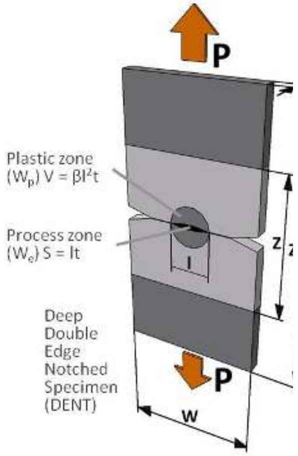
The use of new high strength sheet materials still represents a challenge to the manufacturing sector. It faces serious industrial problems to reach defect-free production as well as productivity losses due to the unpredictable occurrence of edge cracking and lack of overall formability during forming.

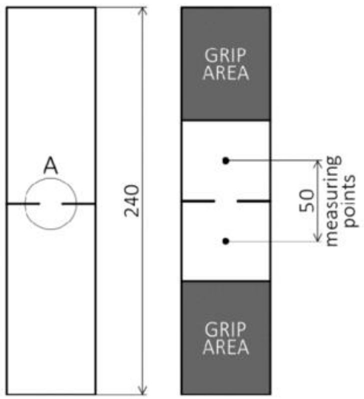
In most of the cases, the contour or even the tool itself must be modified and sometimes, the sheet material has to be changed. This results in high additional costs and delays in part delivery programs or can even impede the manufacture of parts with high-strength materials. Traditionally, sheet formability has been addressed through tensile tests and forming limit curves (FLC), with good enough results. However, such tests do not allow understanding crack-related problems, which remain as still unsolved issues in the sector and hamper the use of new materials and the development of high-performance parts at reduced costs. Accordingly, FormPlanet addresses the urgent need for accurate material characterization tests and new modelling approaches to predict defect generation at an early design state, as well as to prevent and to solve it during industrial manufacturing, covering the whole value chain.

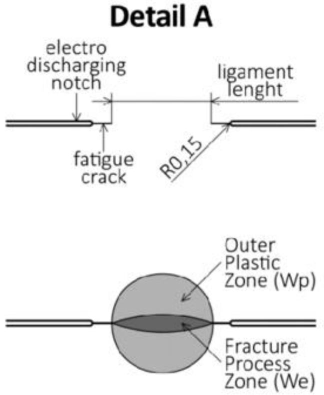


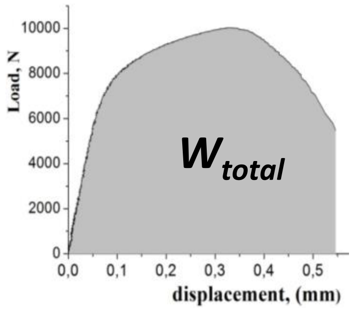
New Modelling Approach for Edge Cracking Simulations

Toughness Measurements
Essential Work of Fracture (EWF)
Dobble Edge Notch Tensíon Test (DENT)







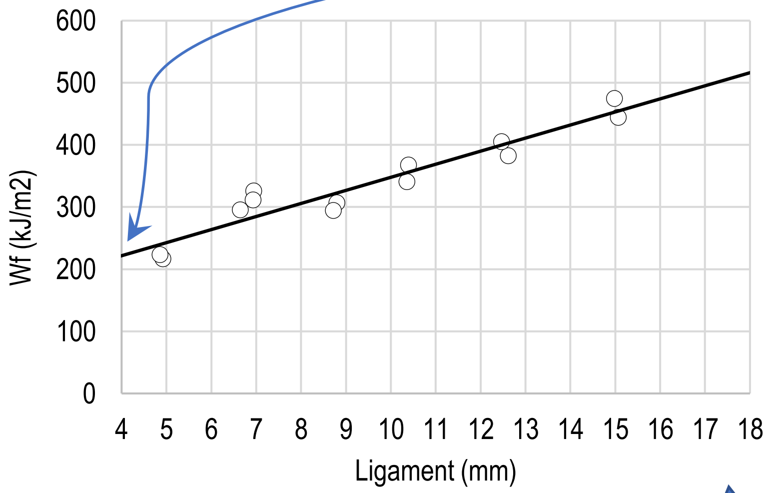


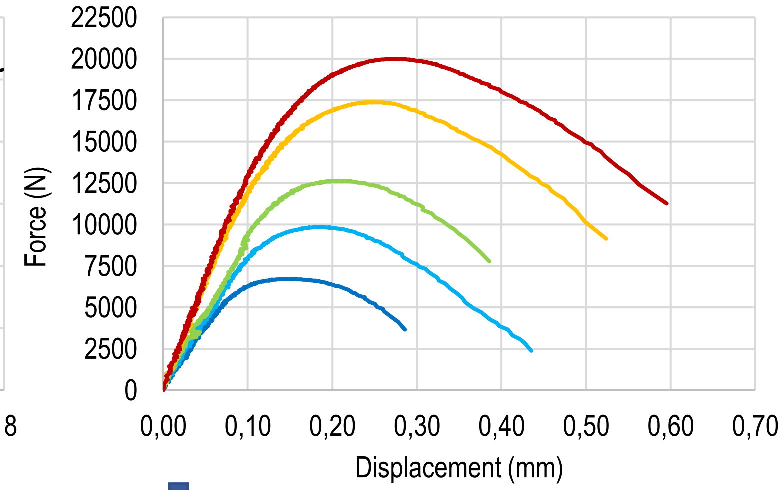
Total Work Plastic Work

$$W = w_p \beta l^2 t + w_e l t$$

$$W/lt = w_p \beta l + w_e$$

Essential Work of Fracture





DENT Especimens with Different Ligament Length

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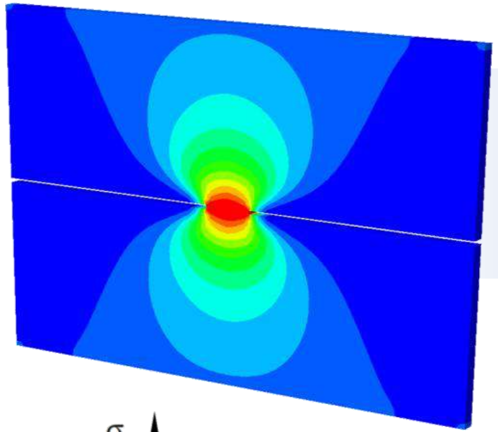
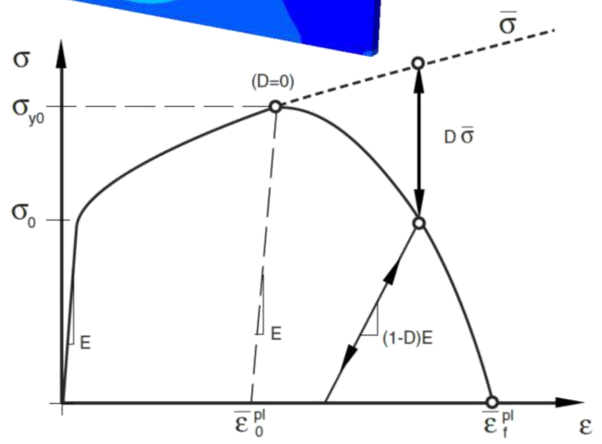
DENT Simulation



Ductile Damage:
- Damage Initiation
- Damage Evolution

SIMULIA ABAQUS



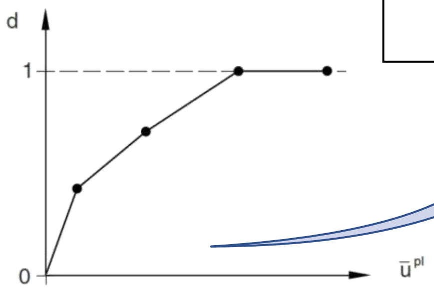
Criterion for damage initiation:

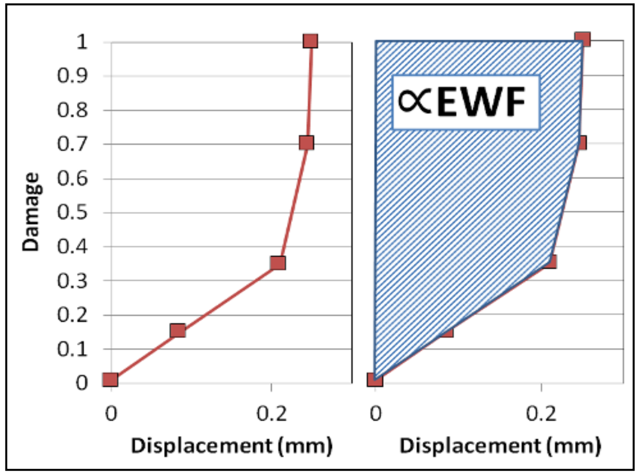
$$\omega_D = \int \frac{d\varepsilon^p}{\varepsilon^p_D} = 1$$

Criterion for damage evolution:

$$D = \frac{L \cdot \dot{\varepsilon}^p}{U_{pf}} = \frac{\dot{u}^p}{U_{pf}}$$

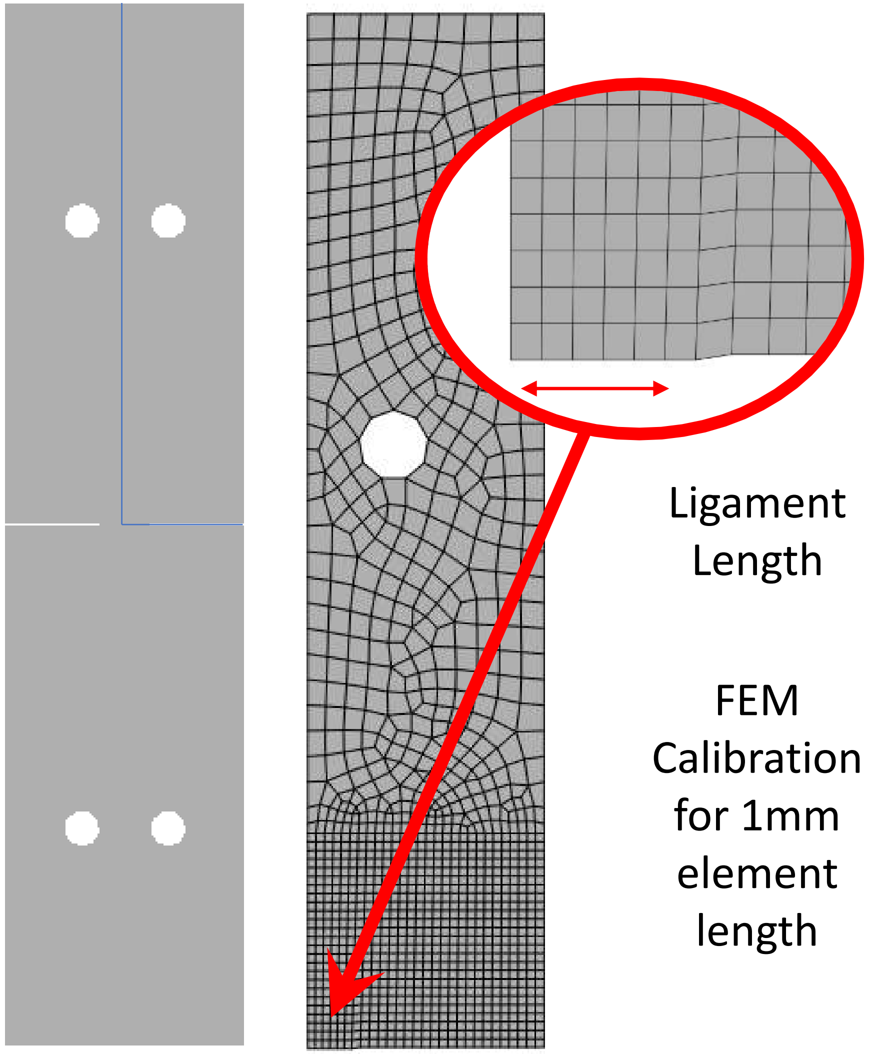
L Characteristic length





Damage Evolution

neither linear
nor exponential



Ligament Length

FEM Calibration for 1mm element length

Symmetry → a quarter of model

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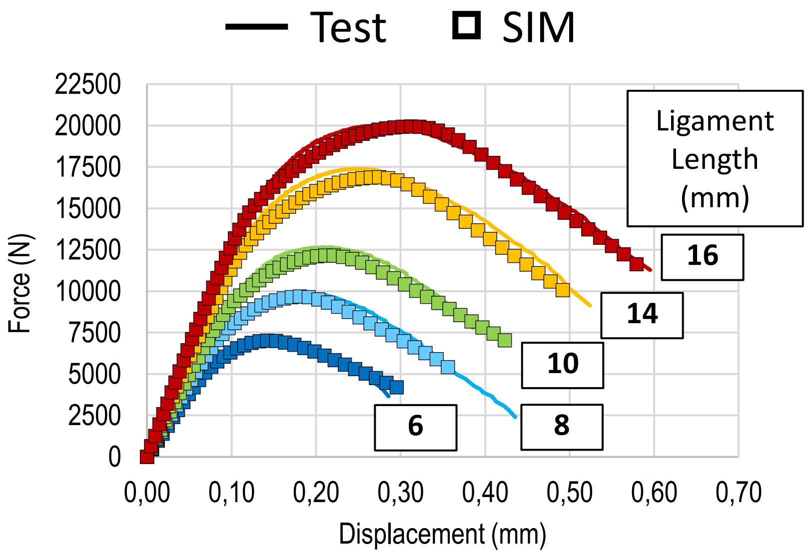
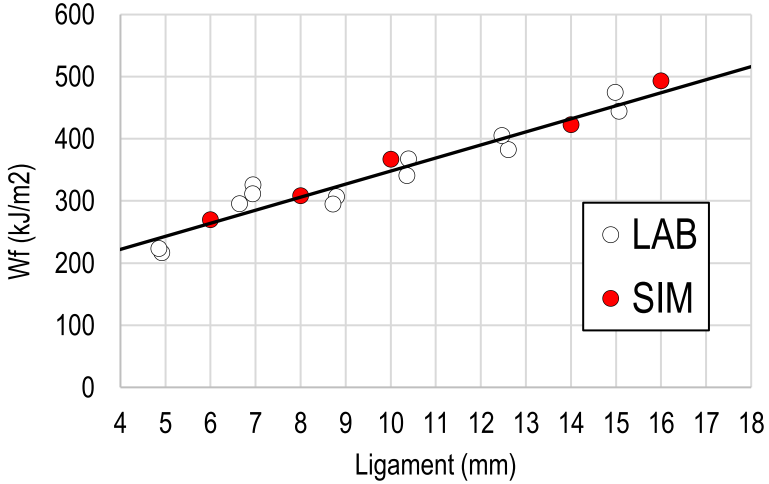
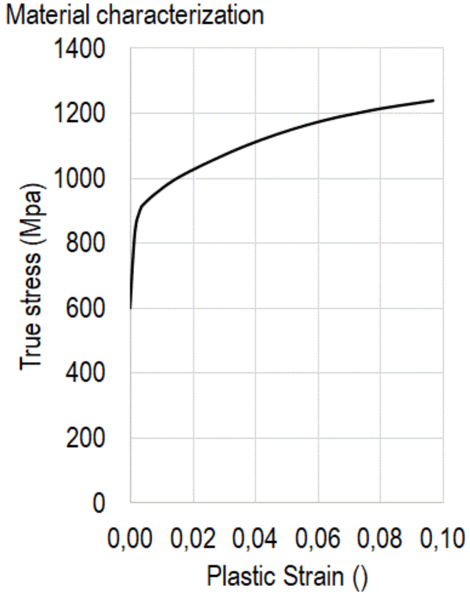
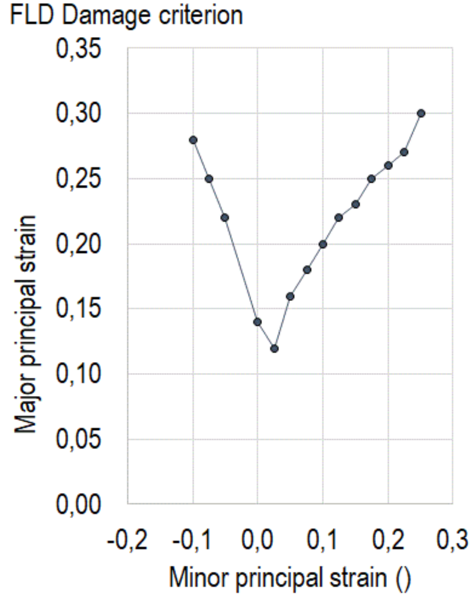
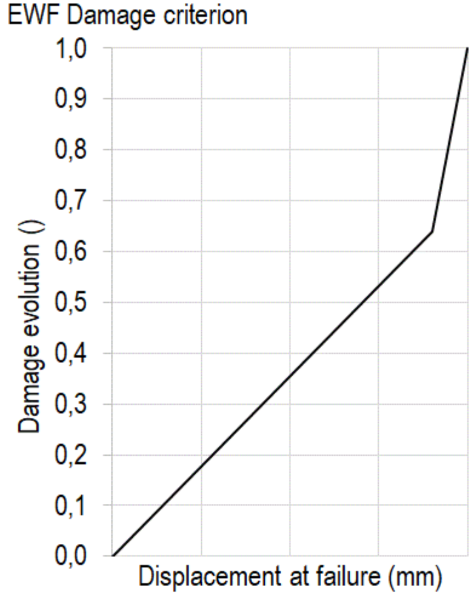
DENT Simulation









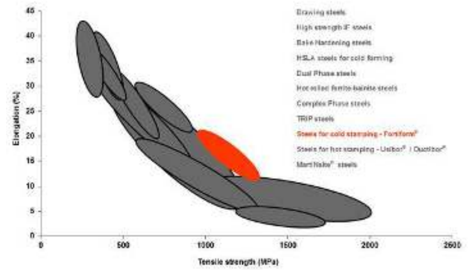


Full Empirical Aproach

Obtained by reverse engineering through an iterative process

ArcelorMittal

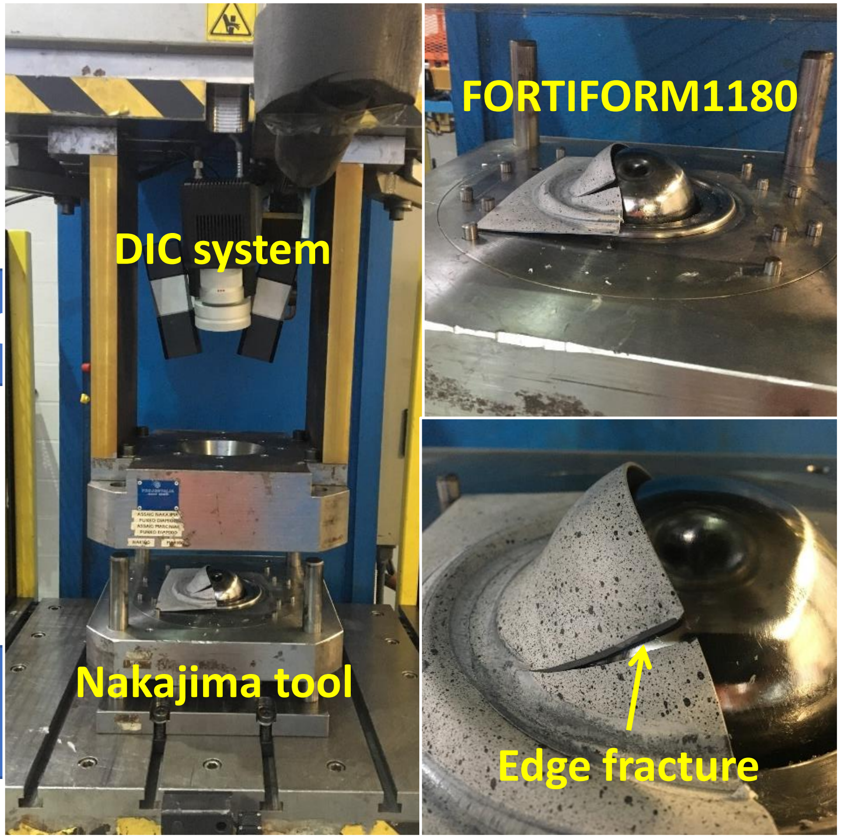
Exemple of AHS steel grade

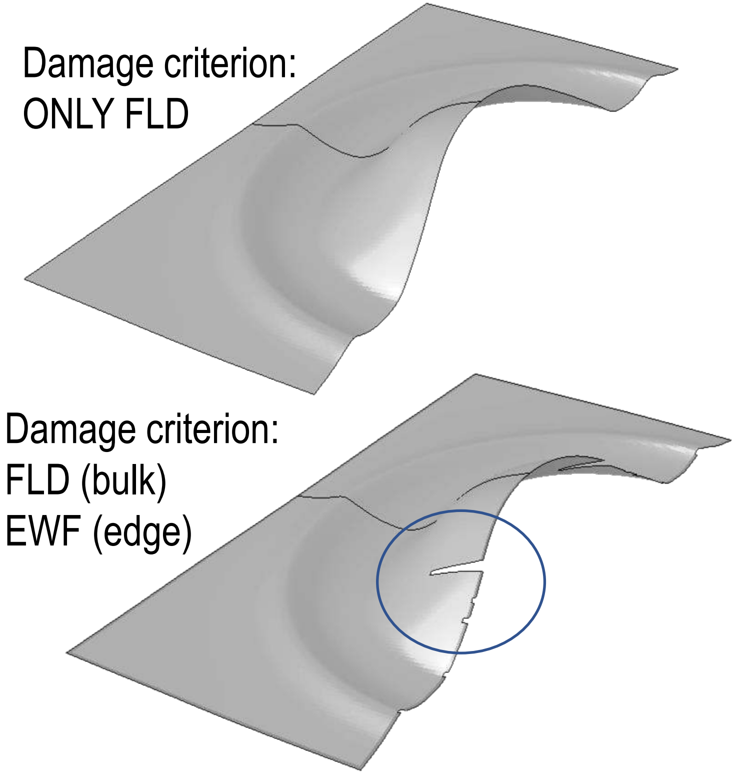


Fortiform® 1180 (HF1180) thickness 1,4 mm

Failure criterion validation

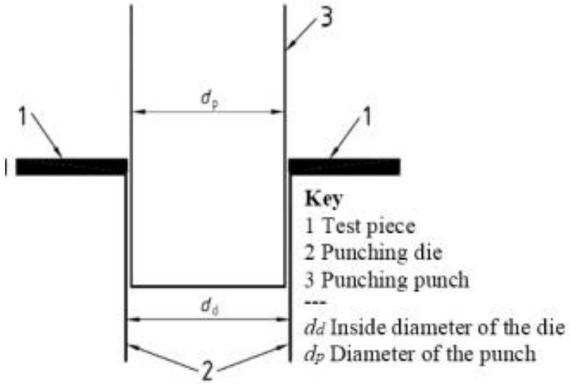
Half specimen dome test (HSDT)

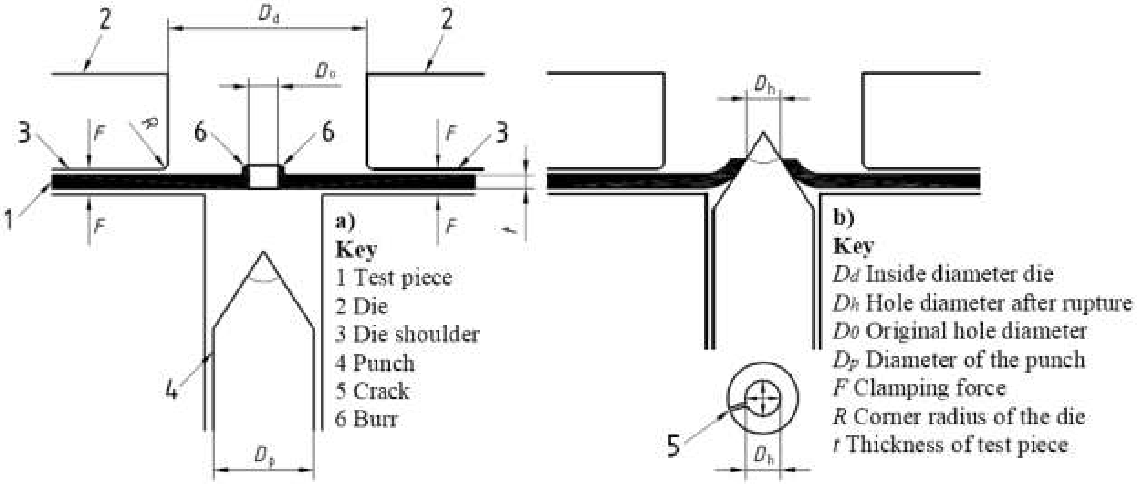




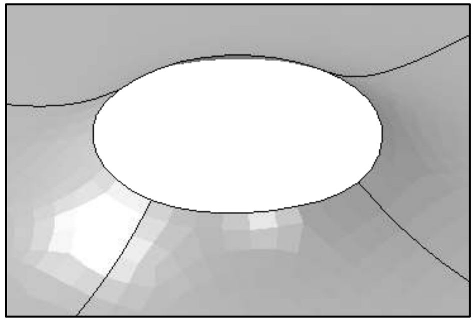
Failure criterion validation

Hole Expantion Test (HET)

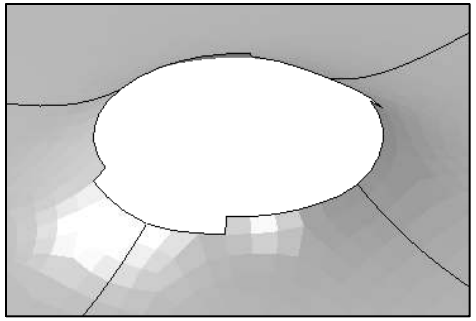




Some preliminary result of HET simulations



FLD No failure



Edge cracking with EWF criterion

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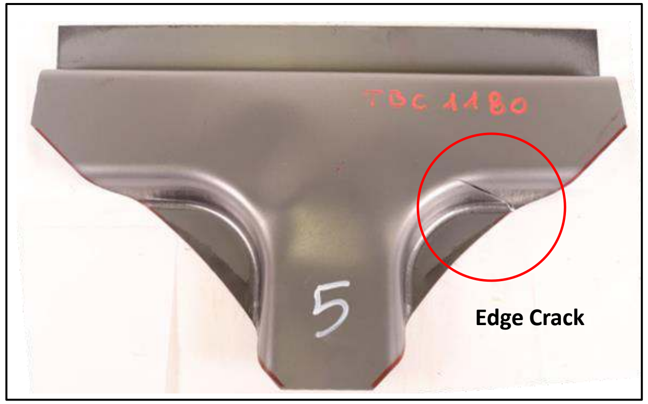
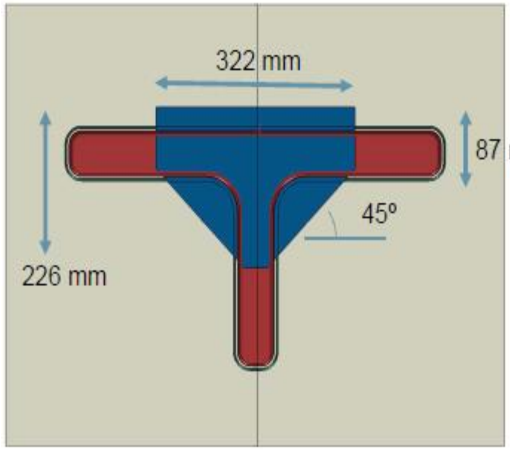
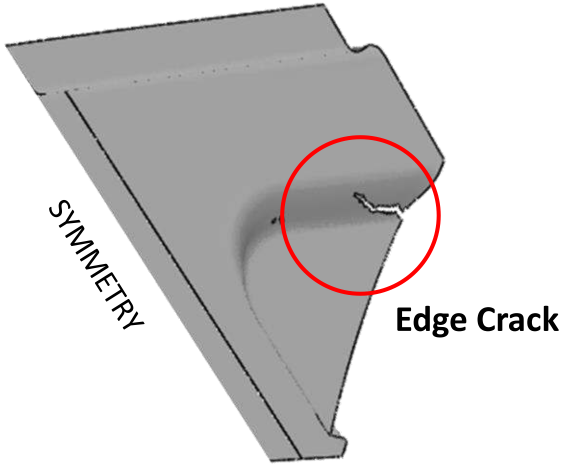
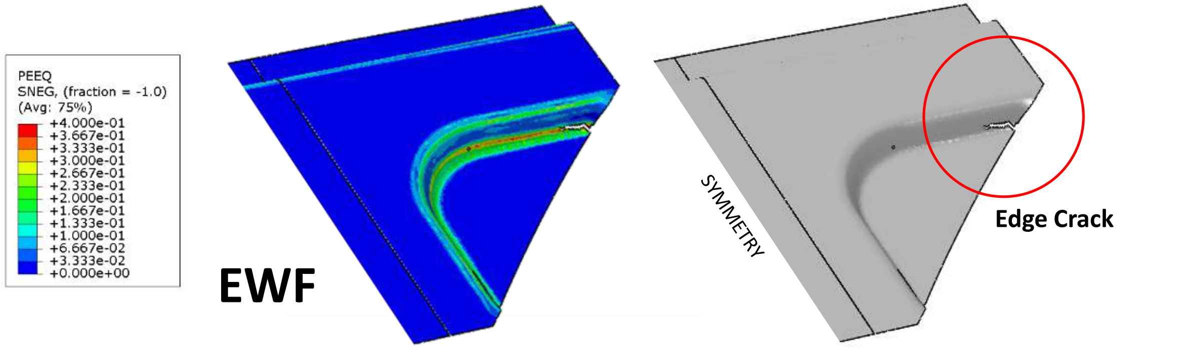
Failure criterion validation

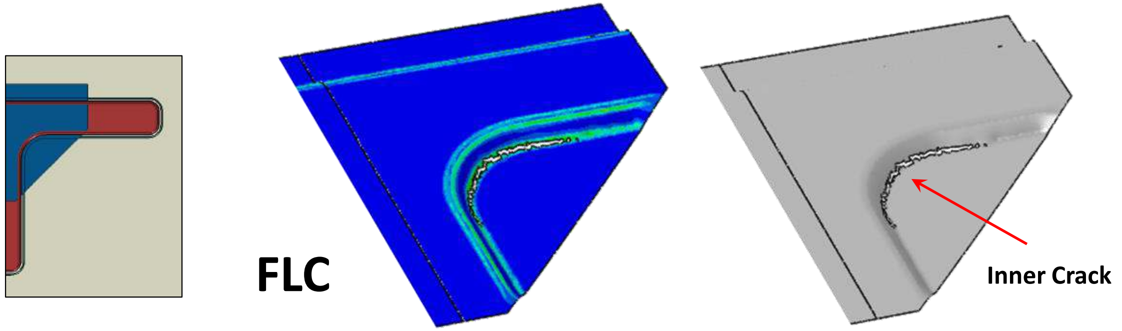
Real component – T Node







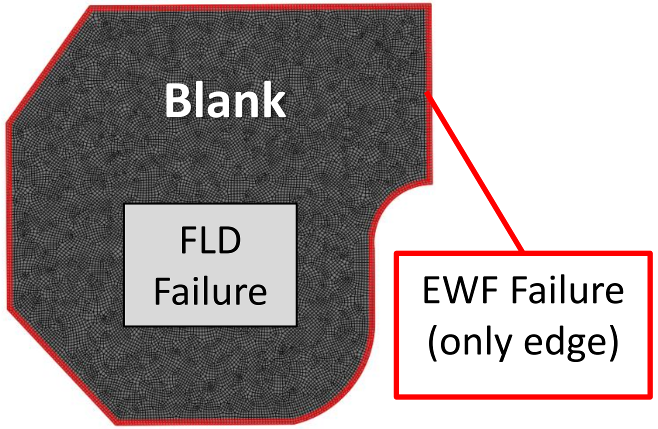




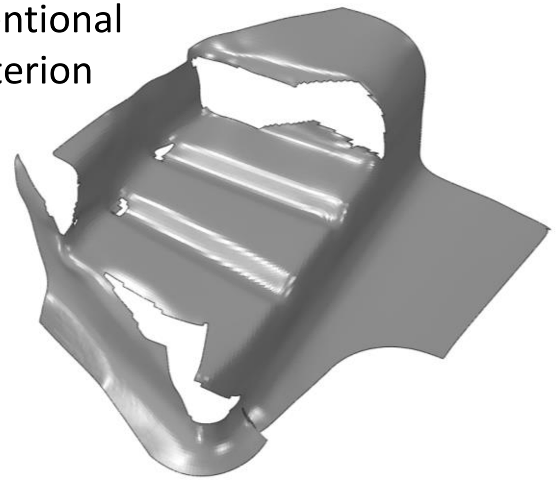
New Modelling Approach for Edge Cracking Simulations

Failure criterion validation

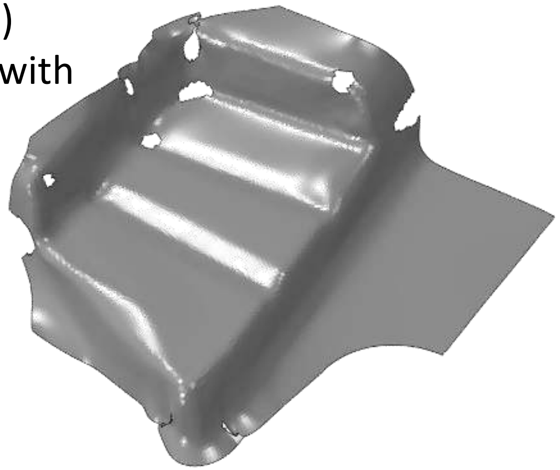
Real component



FLD conventional failure criterion



EWF (edge) combined with FLD

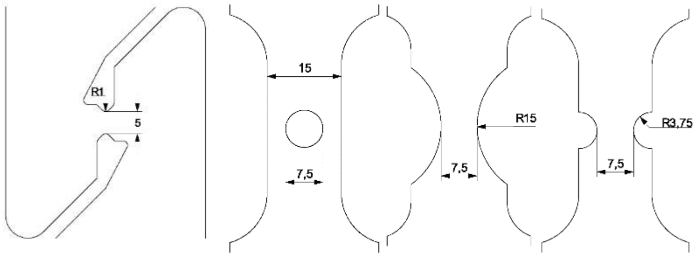


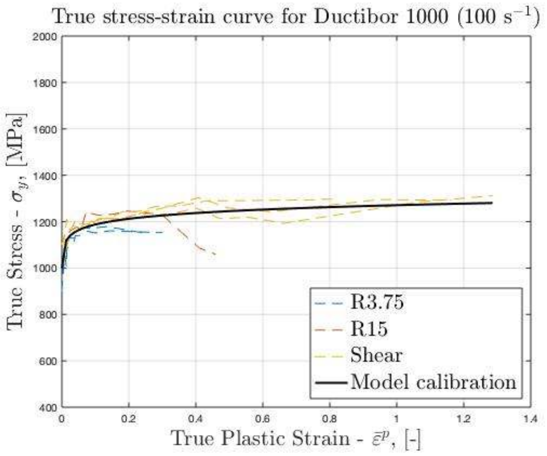
New Modelling Approach for Edge Cracking Simulations

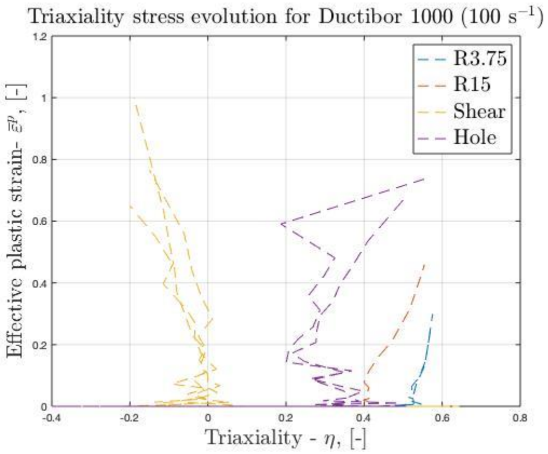
Crash worthiness improvements

- Stepwise Modelling Method used at high strain rates and various stress states to obtain
  - Flow stress curves
  - Fracture strains

Specimen geometries

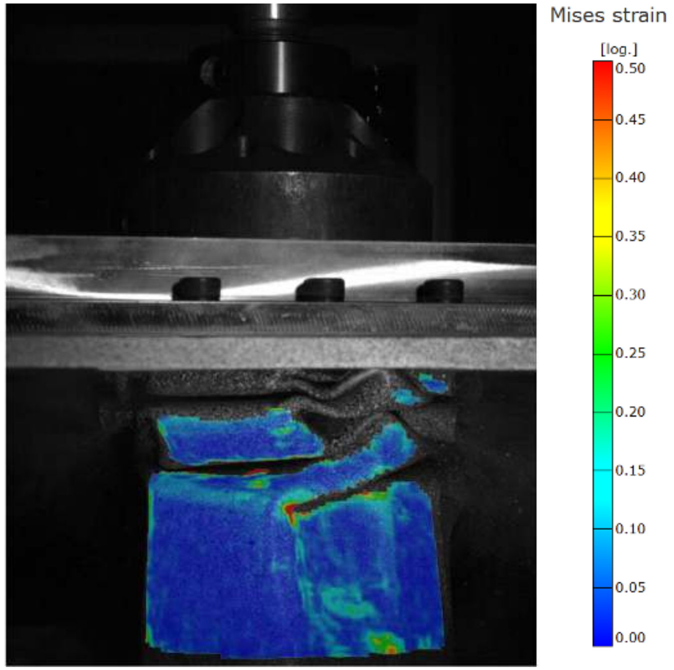






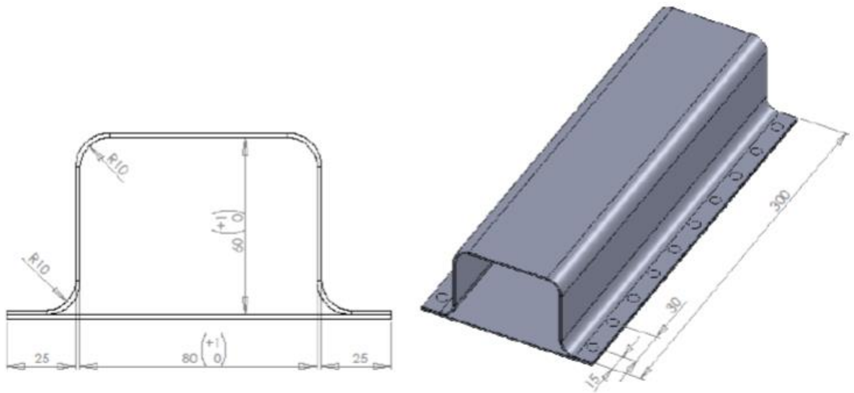
Material data for evaluation of energy absorbtion and crashworthiness Crashbox testing at 20 m/s.

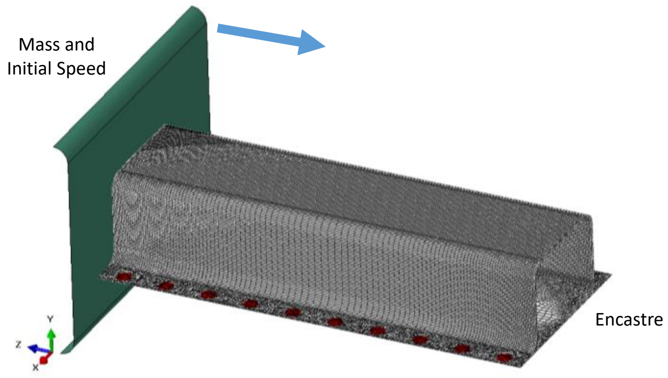
Stereo DIC using two high-speed cameras to obtain strain field and to detect cracks



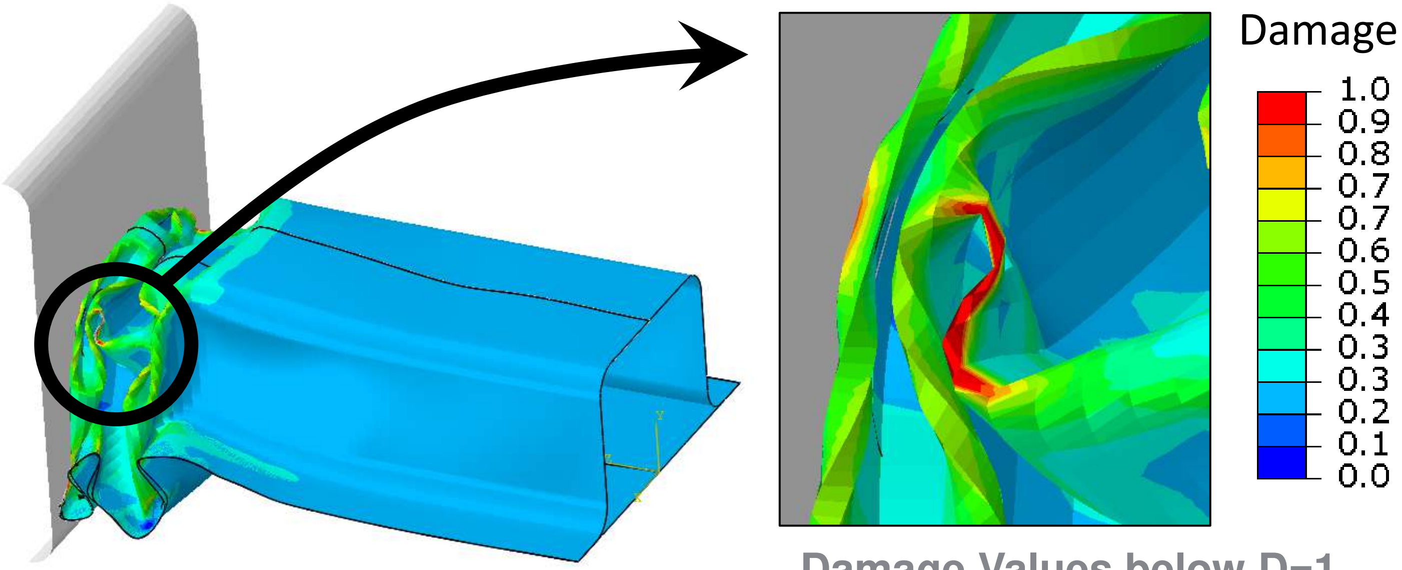
New Modelling Approach for Edge Cracking Simulations

Crash worthiness improvements





ArcelorMittal **Fortiform® 1180**



Damage Values below D=1
No reach element deletion

NO CRACKS

Experimental crash test

Conclusions

- A new approach to define the ductile damage model based on EWF by DENT test is presented showing a good edge cracking prediction on forming operations of AHSS.
- It can be used in conjunction with FLC to analyze forming processes of complex part, including small operations like hole expansions.
- The model follow an empirical methodology and require an inverse engineering iteration process to define the material chart.
- Thinking about industrial approach, the failure characterization was adapted to square shell elements with 1mm side length. This type of mesh can be used easily on complex part FEA.
- The use of high-speed material characterization allow the crash simulation improvement taking account of triaxiality sensitivity.