NORDIC 2010 NAFEMS CONFERENCE

Simulation of Side Impact on a Hydroformed B-Pillar Considering the Forming Process

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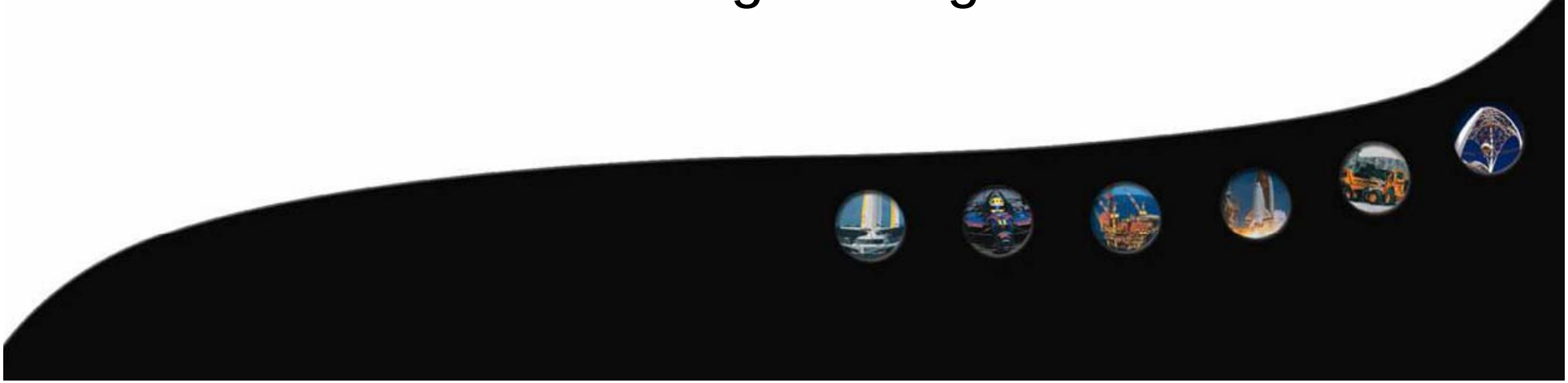


Background – NGV Project

- Next Generation Vehicle (NGV) Project
  - Joint project between Stainless steel producers
    - Outkumpu Oyj
    - ArcelorMittal Stainless
    - ThyssenKrupp Nirosta GmbH
  - OEMs
    - BMW AG, AUDI, Daimler AG, Saab Automobile, Volvo Cars, Centro Ricerche Fiat
  - Courtesy of NGV Project consortium
- Aim
  - Demonstrate Stainless Steel in Automotive Applications.
  - Show the world, that stainless steel is an attractive material for lightweight constructions.

Background - ERAB

- Distributor of LS-DYNA in the Nordic Countries and the Baltic states.
- Part in NGV-project
  - Virtual technologies for processing and testing
  - Virtual evaluation of crash behaviour.

LSTC Livermore Software Technology Corp.

BETA CAE Systems SA

FORMING TECHNOLOGIES INCORPORATED

Stainless TRIP steels

- TRIP – Transformation induced plasticity
  - Austenite to Martensite transformation during deformation
- Provides a combination of strength and formability
- The TRIP effect is temperature dependent
  - Thermo-mechanical simulations needed
  - Material model and procedures has to be developed which applies to both forming and crash simulations.
  - Since the crash behaviour of the finished part is highly influenced from the previous forming, the results have to transfered from the forming to the crash simulation.

Hänsel Model

- The constitutive model used in the simulations is the Hänsel model[1]

Martensite evolution

$$\frac{\partial V_m}{\partial \bar{\varepsilon}^p} = \begin{cases} 0, \text{if } \varepsilon < E_{0(mart)} \\ \\ \dfrac{B}{A}\exp\left(\dfrac{Q}{T}\right)\left(\dfrac{1\text{-}V_m}{V_m}\right)^{(B+1)/B} {V_m}^p \dfrac{1}{2}(1-\tanh(C+D\cdot T)), \text{if } \bar{\varepsilon}^p \geq E_{0(mart)} \end{cases}$$

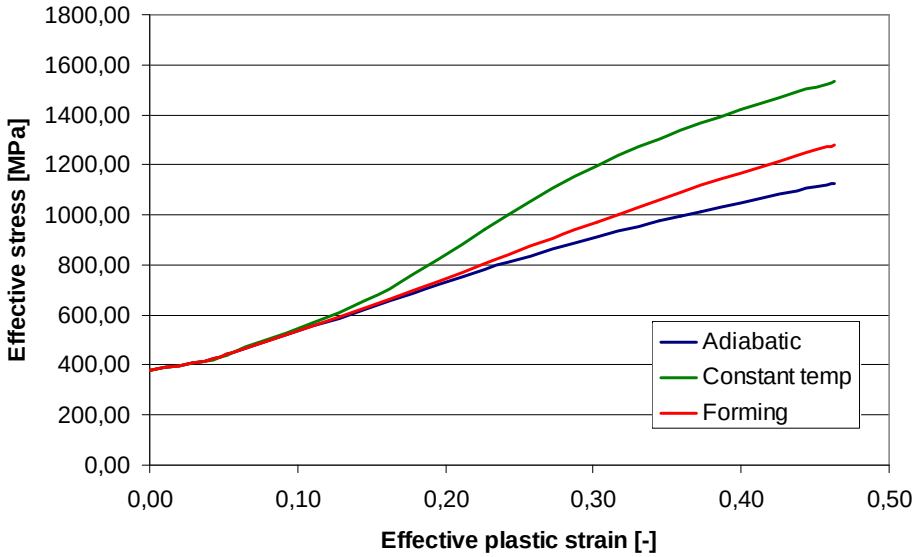
$$V_m = \int_0^{\varepsilon} \frac{\partial V_m}{\partial \bar{\varepsilon}^p} d\bar{\varepsilon}^p$$

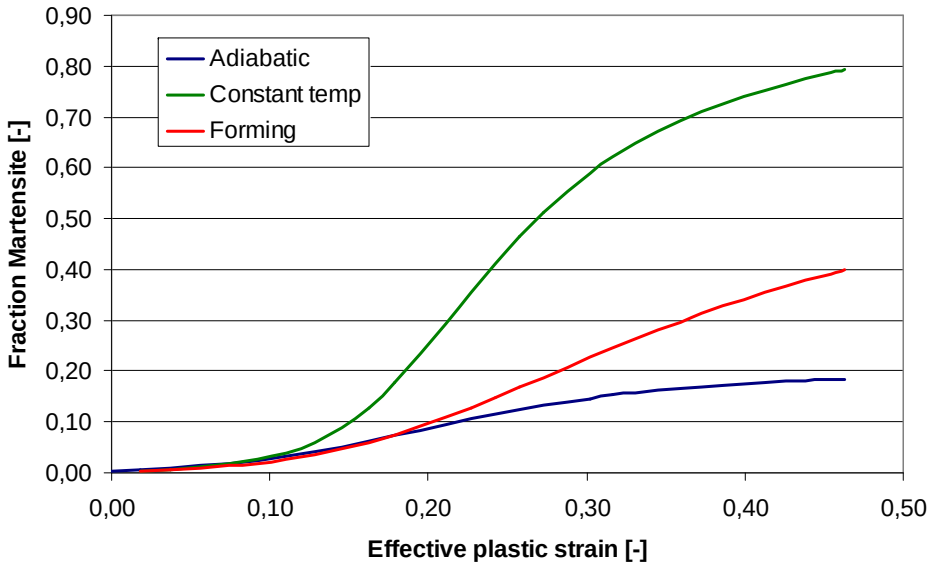
Yield stress

$$\sigma_y = \left\{B_{HS}\text{-}(B_{HS}\text{-}A_{HS})\exp\left(-m\left[\bar{\varepsilon}^p + \varepsilon_0\right]^n\right)\right\}(K_1 + K_2 T) + \Delta H_{\gamma\rightarrow\alpha'} V_m$$

1 A.H.C Hänsel et. al., Simulation of Materials Processing: Theory, Methods and Applications, Balkema, Rotterdam, 1998

1.4310 Temperature dependence

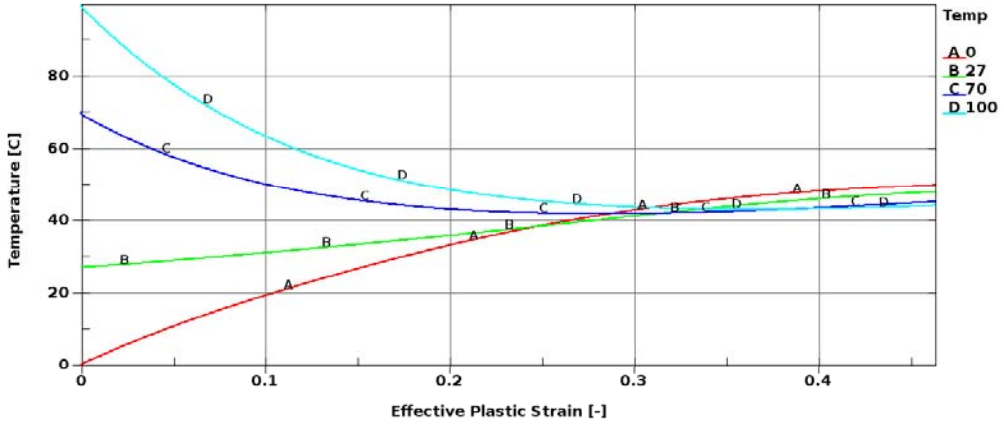


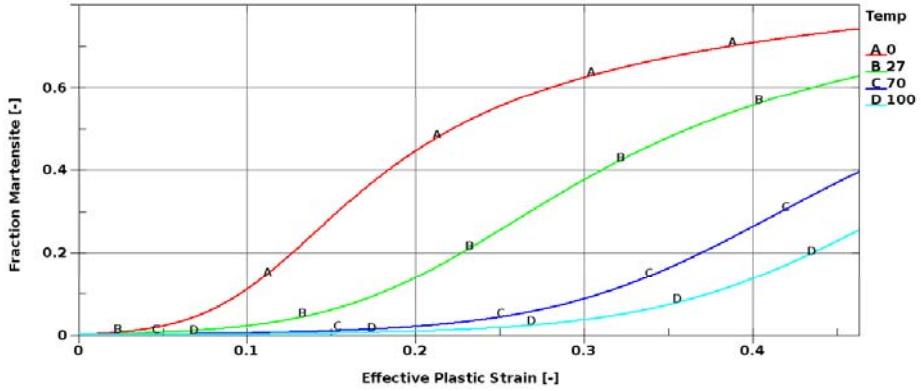


- The Forming case corresponds to a case where the material is in contact with one tool surface and 3s forming time.
- The temperature is around 100^{o} C in the adiabatic case and 67^{o} C in the forming case.

Material characterization

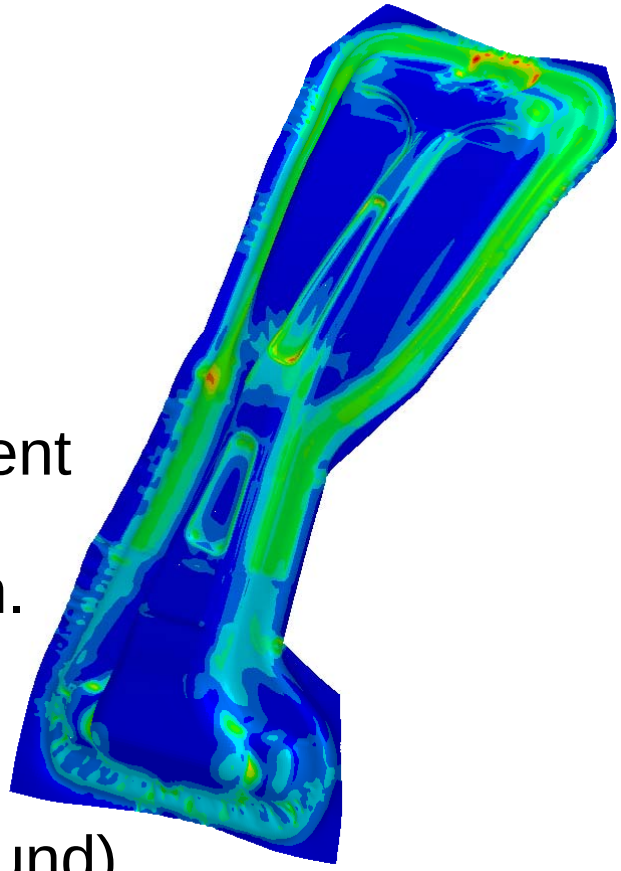
- Material characterization was done using uniaxial tensile tests originating from different temperatures.
- The stress, strain, temperature and Martensite content were countinously monitored and recorded.





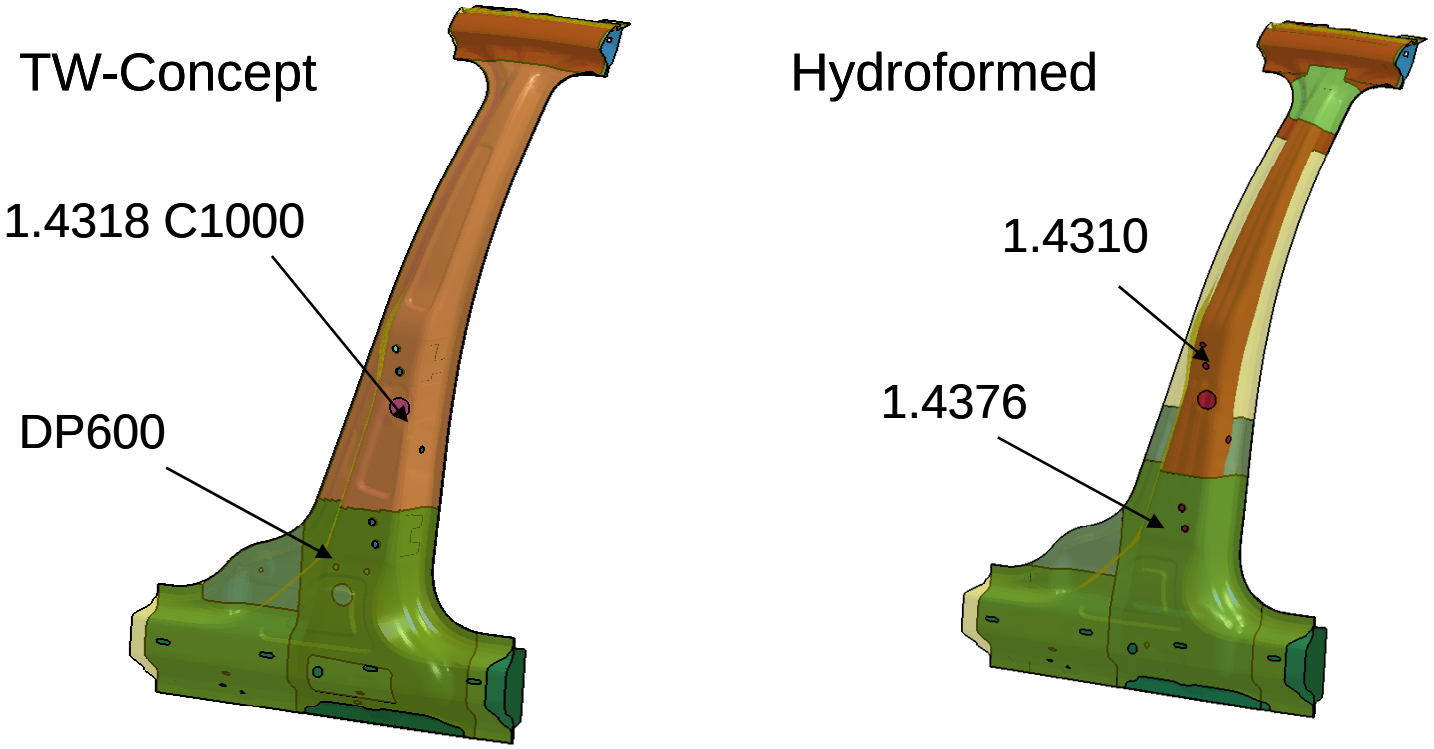
Coupled thermo-mechanical simulations

- Requirements for solver
  - Coupled thermo-mechanical solver
  - Thermomechanical material models
  - Thermal contacts
  - The functionality above has to be present in a production-friendly environment, i.e. one-code strategy and mpp version.
- Requirements for simulation
  - Thermal properties
  - Heat transfer coefficients (not easily found)
  - Time is a factor



B-Pillar Concepts

- The Volvo S40 B-Pillar was chosen as a reference



- Both concepts were simulated, produced and crash tested.

Simulation procedure

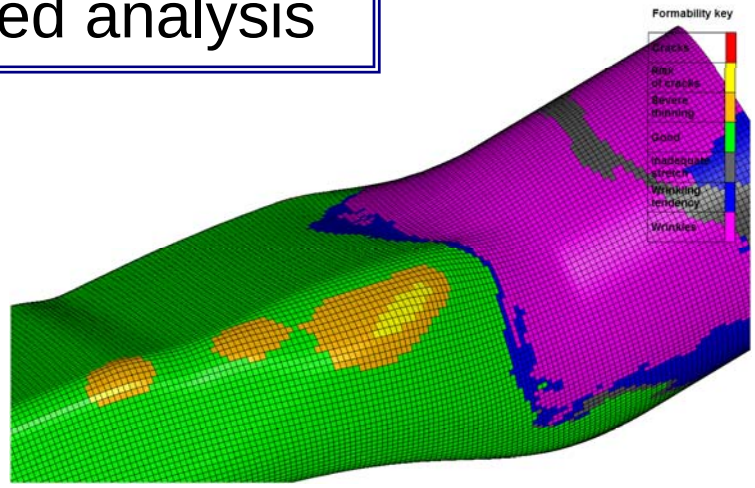
Forming Simulation

LS-DYNA

Material data
Outokumpu

Rigid Tools
Constant Temperature
Conical Tube

Hänsel model
Coupled analysis

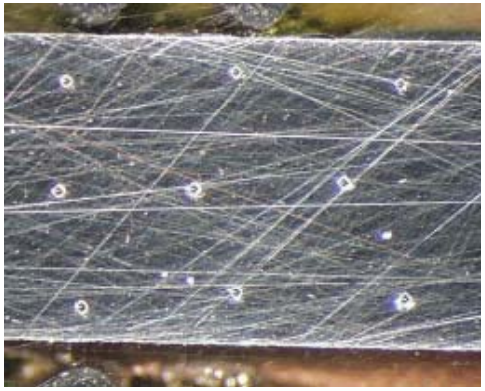


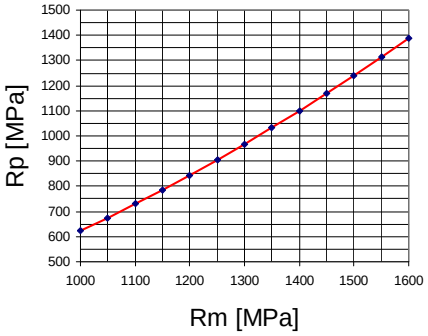
Simulation procedure

Forming Simulation

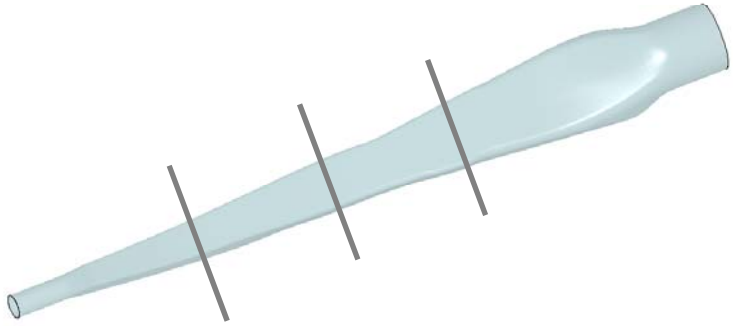
LS-DYNA

Thickness
Yield stress
Evaluation





Hänsel model
T_{Room}



Simulation procedure

Forming Simulation

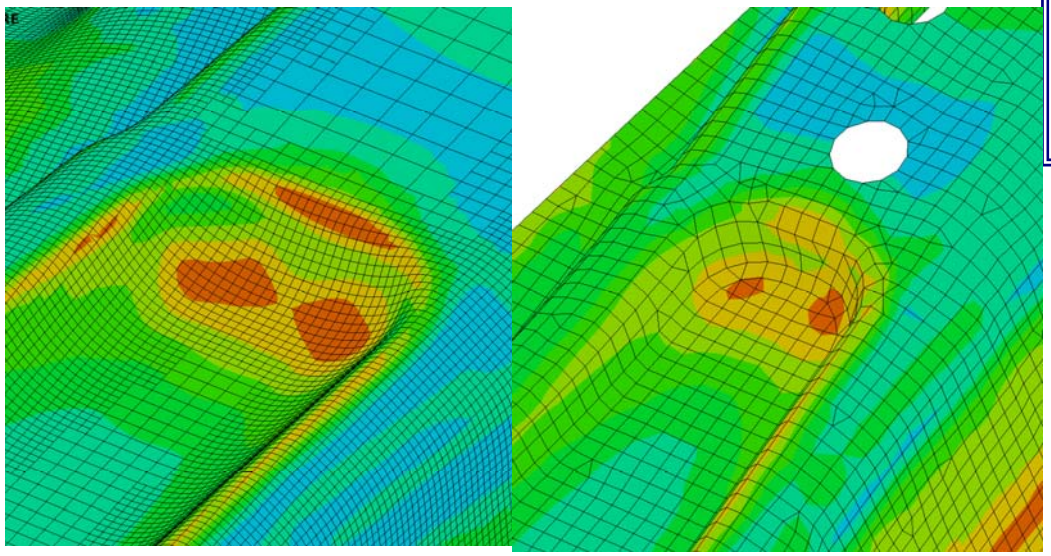
LS-DYNA

Thickness
Yield stress
Evaluation

$V_m, \bar{\varepsilon}_p$

Thickness

Mapping of results



Simulation procedure

Forming Simulation

LS-DYNA

Thickness
Yield stress
Evaluation

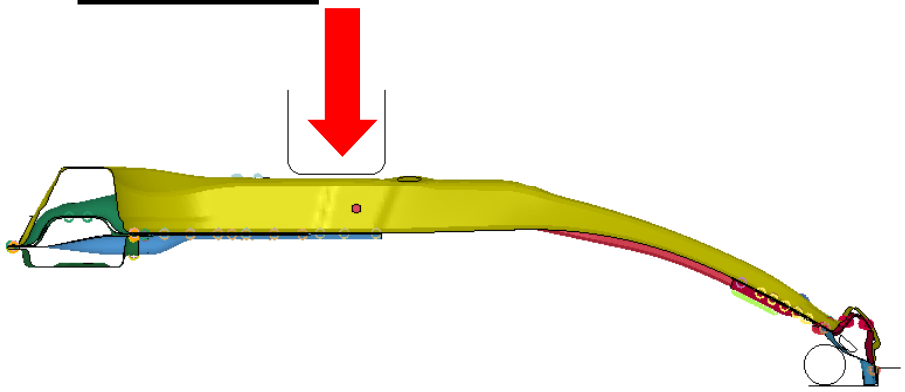
Hänsel model
Adiabatic

Mapping of results

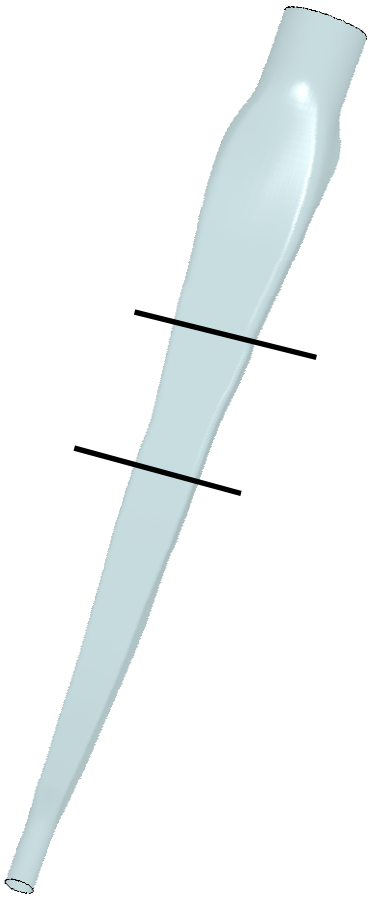
Crash

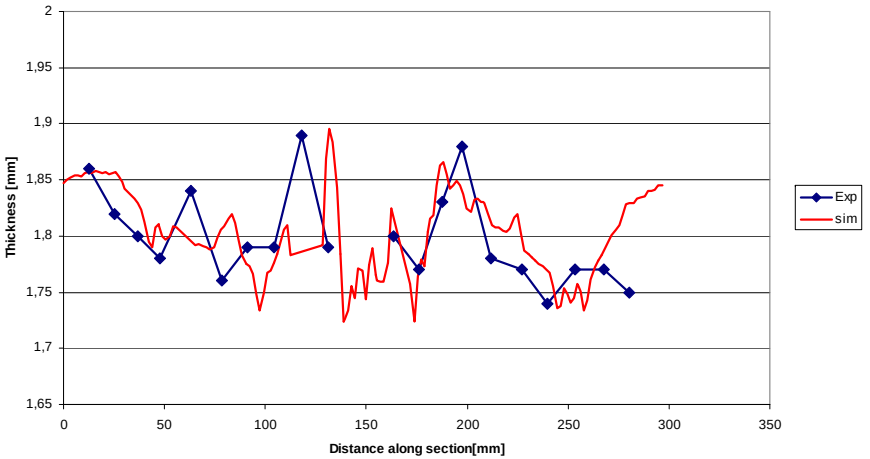
LS-DYNA

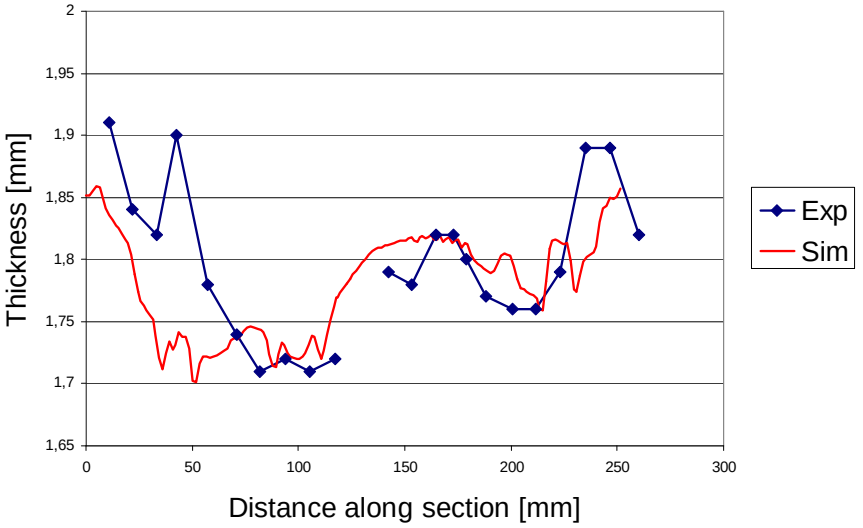
230 kg
7.17 m/s



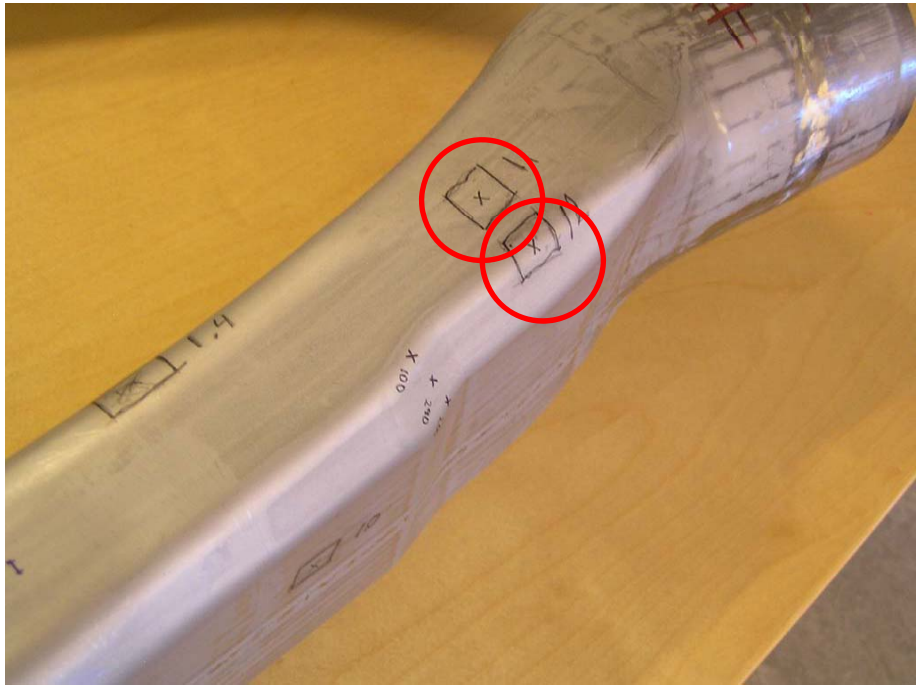
Results Forming Simulation

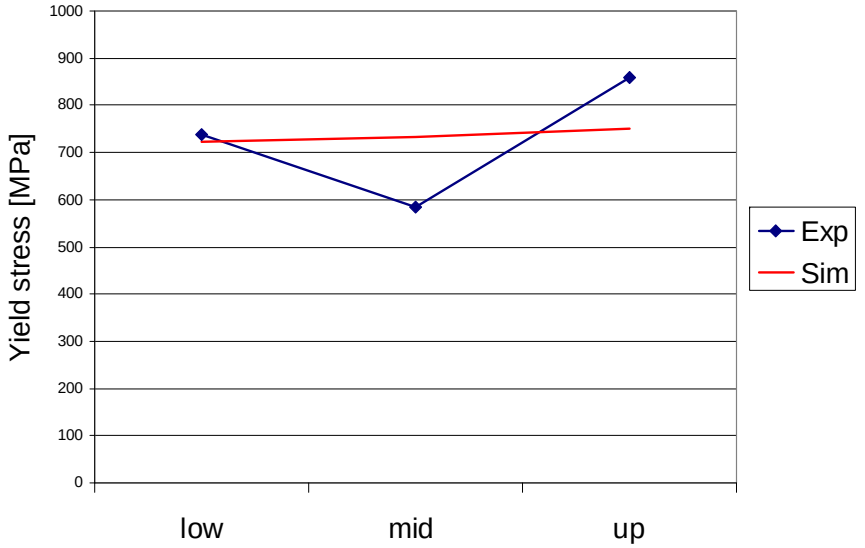


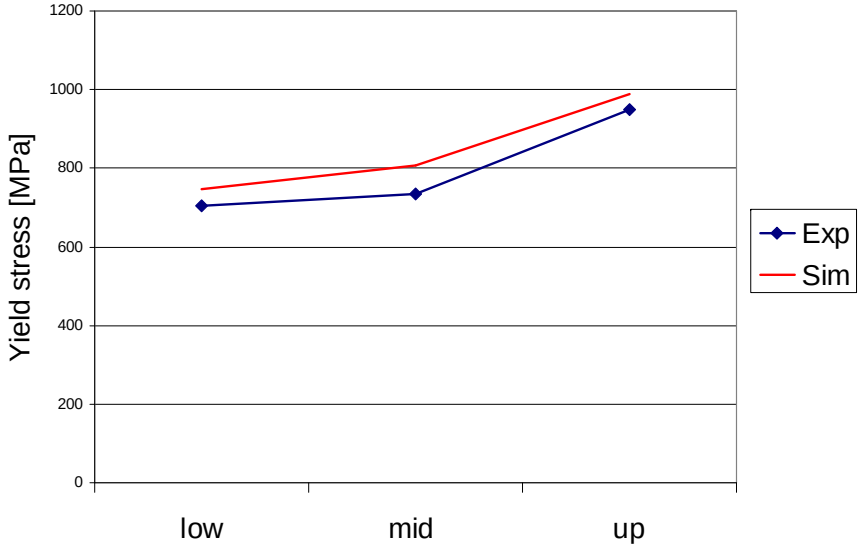




Results Forming Simulation







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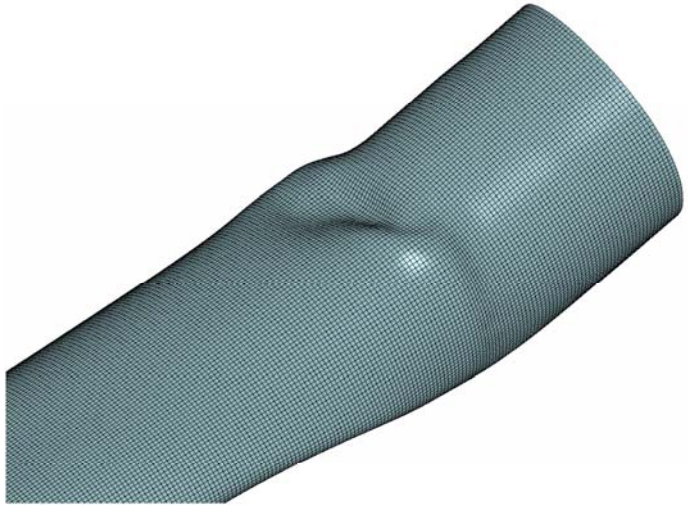
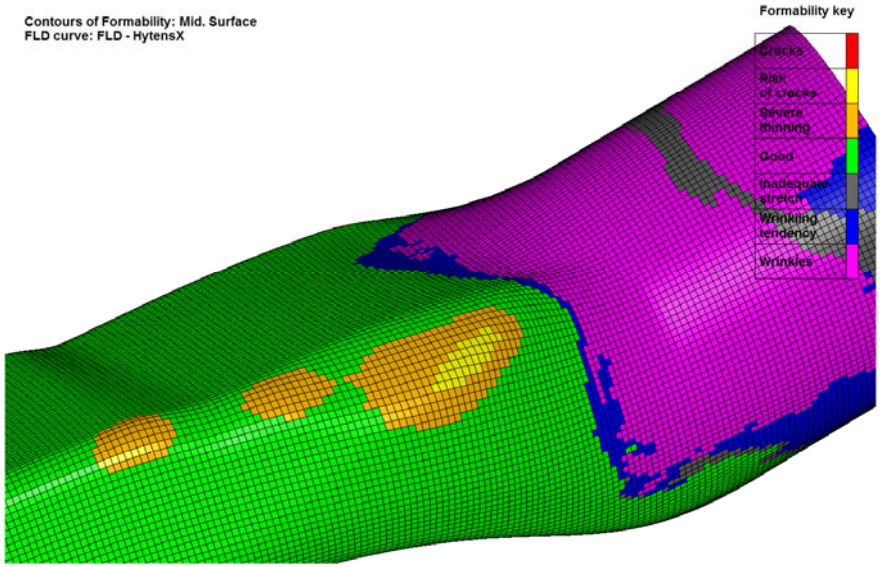
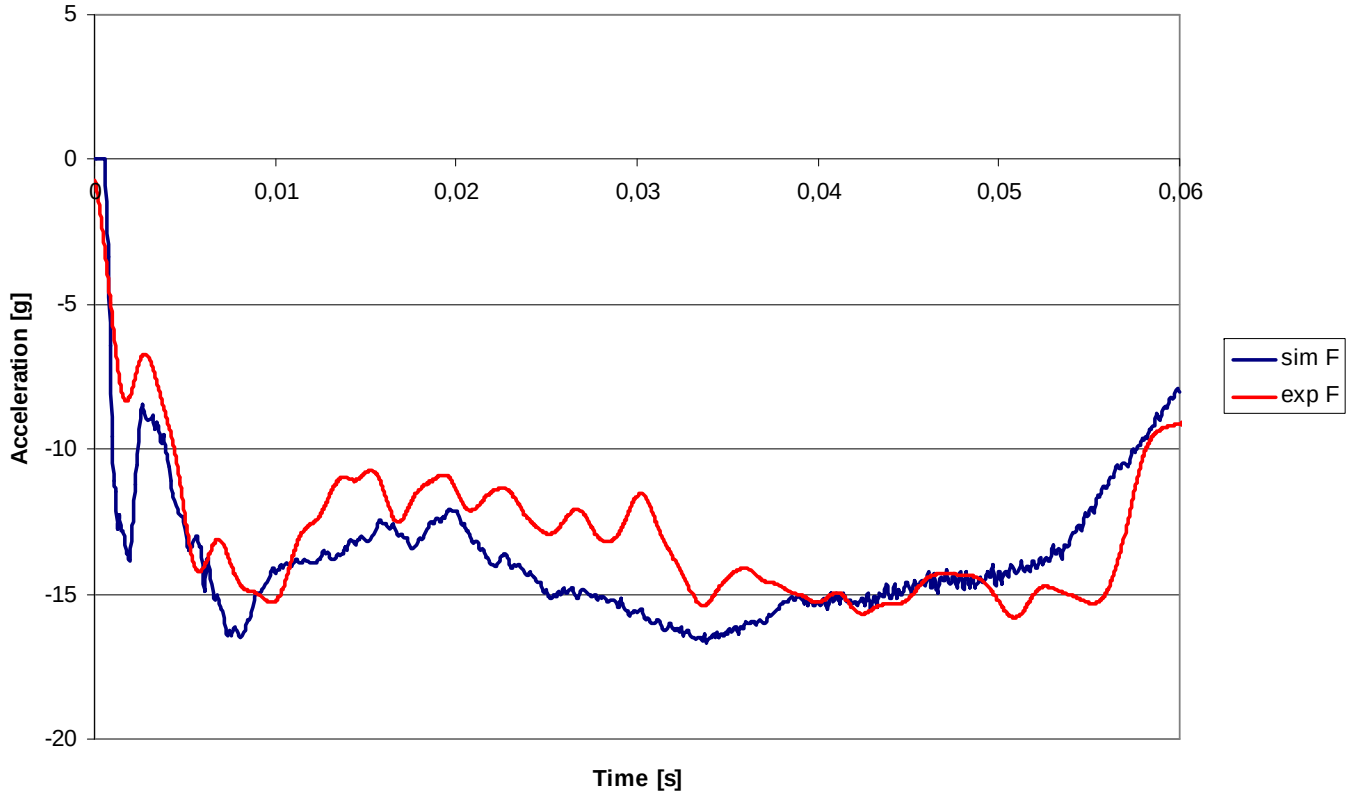


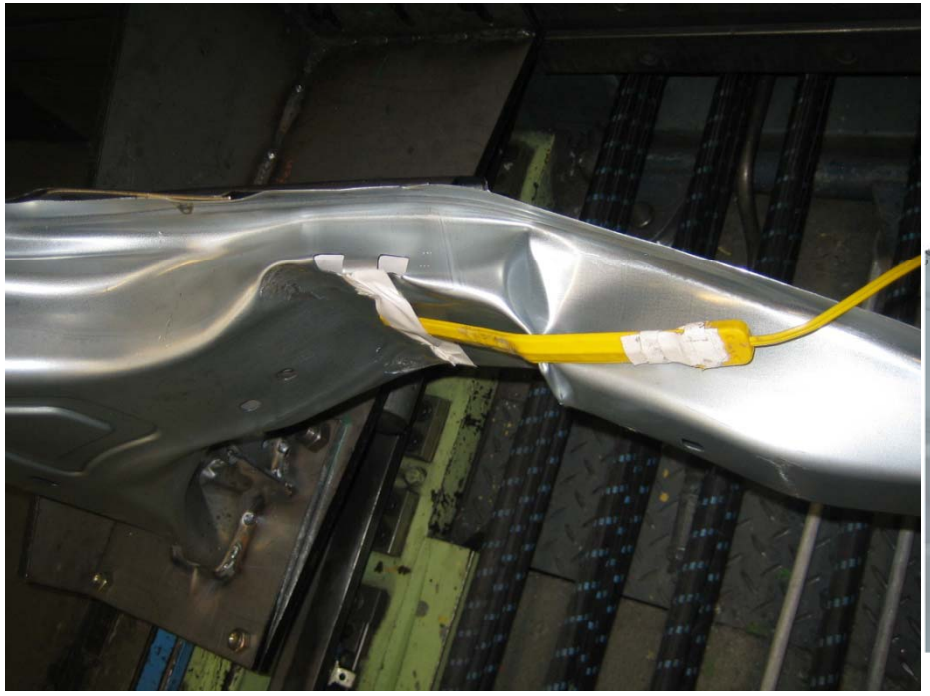


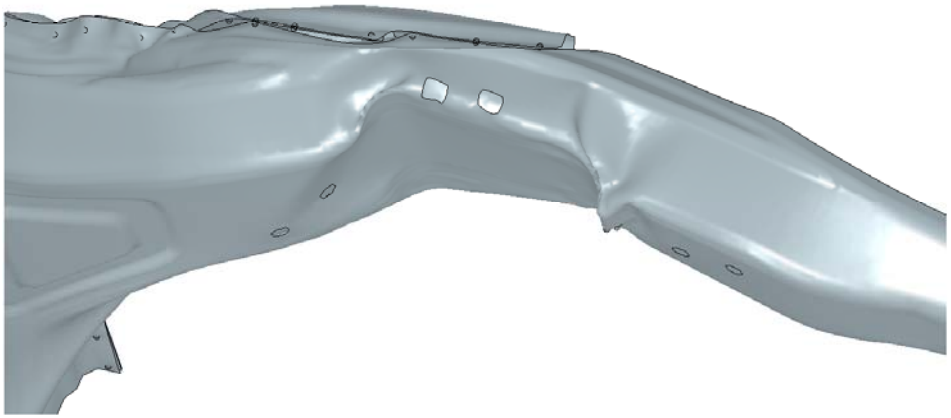
Results Crash simulation



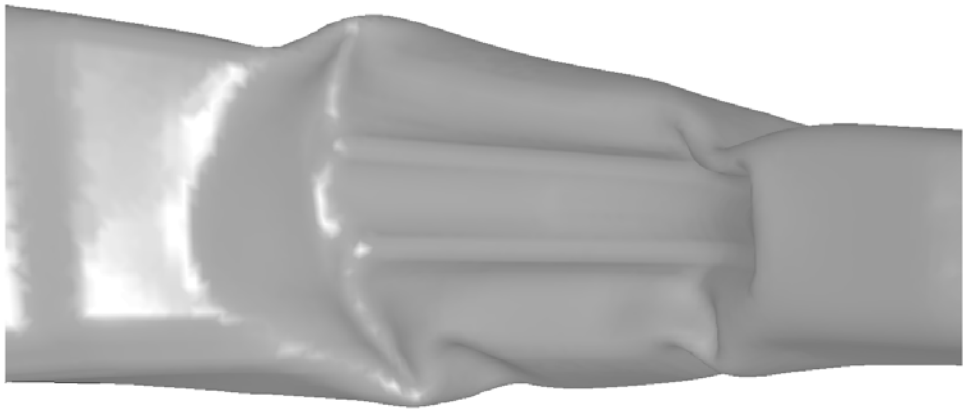
- The behaviour of the virtual B-Pillar is slightly stiffer compared to experiments

Results Crash simulation





Results Crash simulation



Conclusion

- The decrease in weight for the TW and hydroformed concept was 9 % and 11 %, respectively.

- Coupled FE-simulations with the TRIP material model were successfully used in the development of the B-Pillar designs. By using virtual models continuously through the design process it was possible to:
  - Estimate formability, resulting strength and process parameters
  - Modify the process and part geometry prior to making tools and testing.
  - Predicting crash response with increased accuracy

- This leads to that parts can be produced almost directly and avoids having to spend a lot of time on tool and process adjustment and tuning.

Thank You!