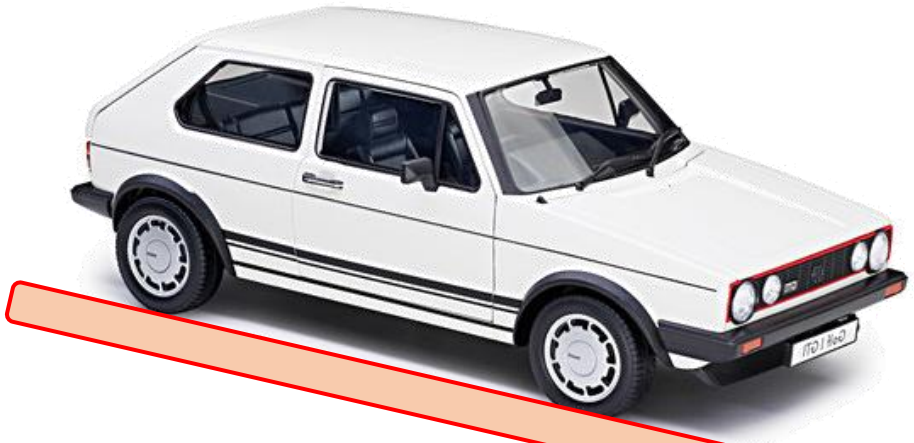
From Third-Generation to Green-Generation Steels: Impact-Dynamic Performance, Lightweighting and Future Design Directions

Prof Patricia Verleysen

DyMaLab

Background – Weight, weight, weight…



Volkswagen Golf 1
Curb weight 750kg

Rimac Nevera
Curb weight 2150kg

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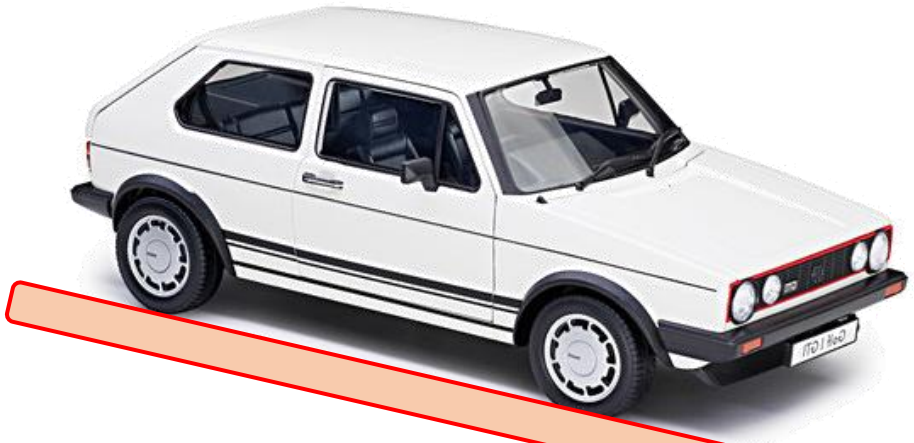

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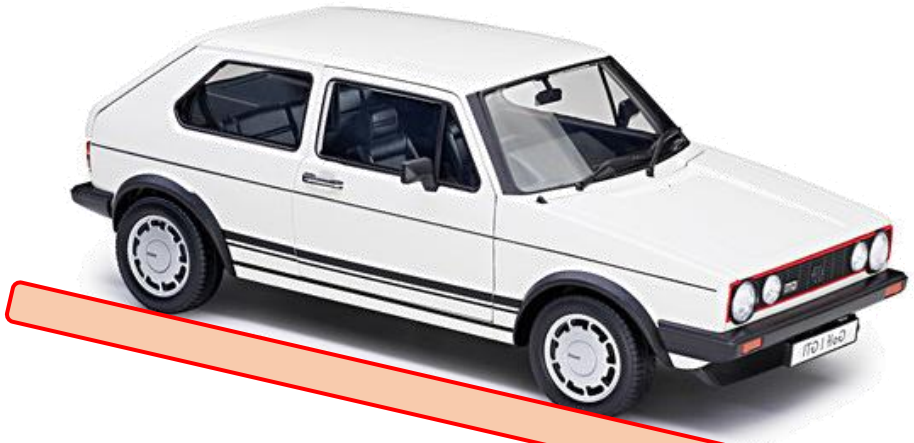

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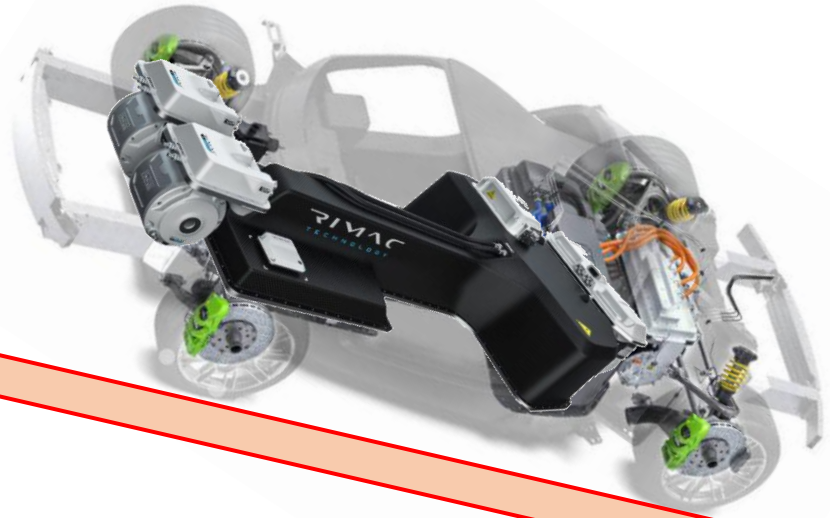
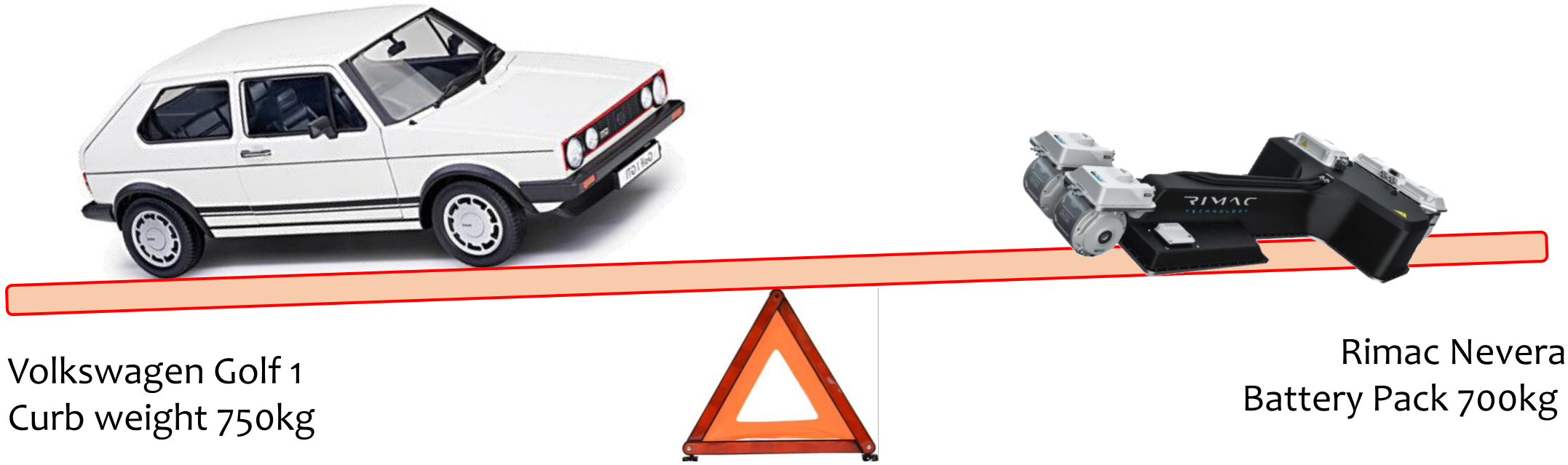


Rimac Nevera
Battery Pack 700kg

Background – Weight, weight, weight…



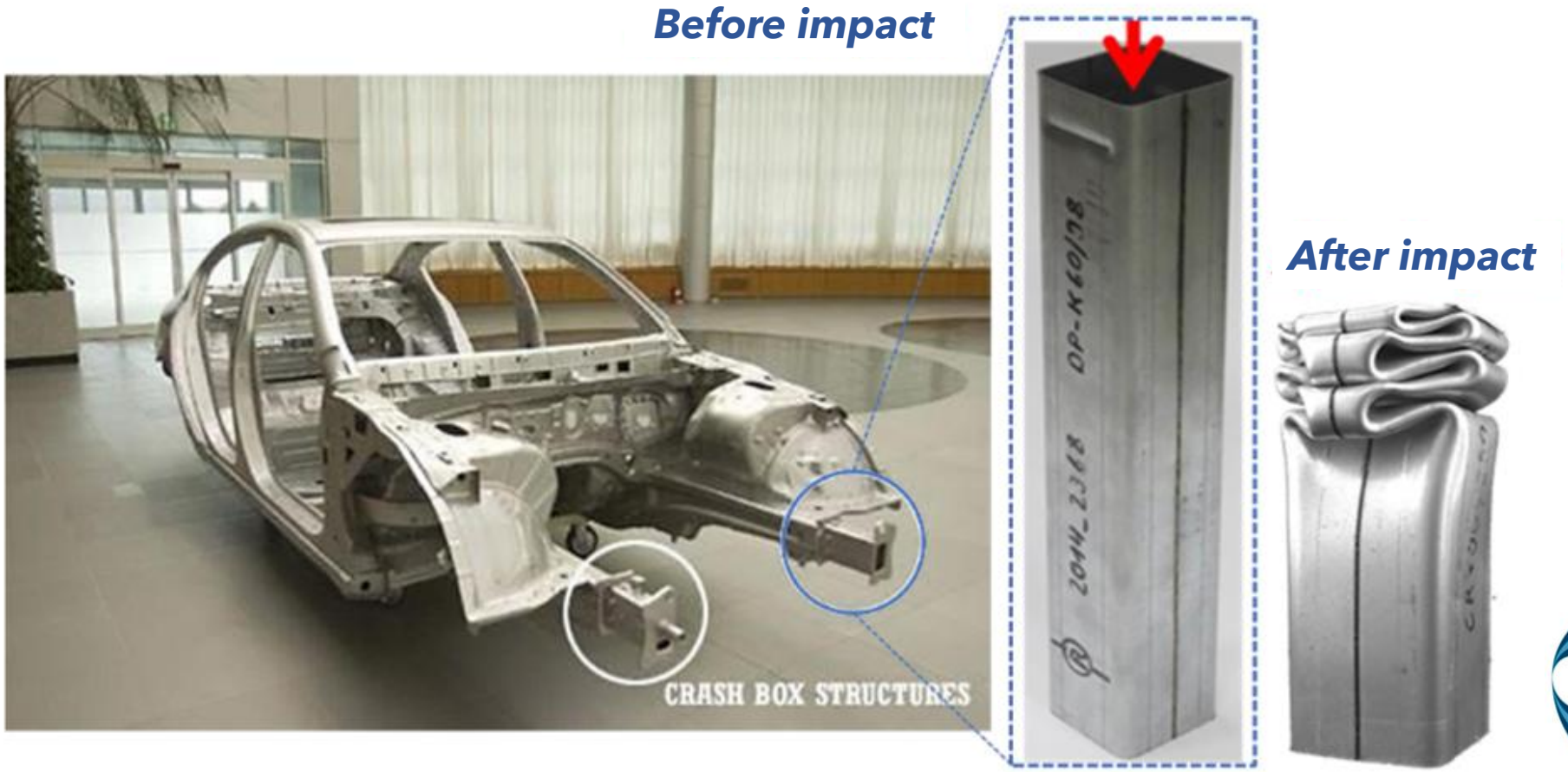
Volkswagen Golf 1
Curb weight 750kg

Rimac Nevera
Battery Pack 700kg

TOOLKIT - Toolkit for the design of damage tolerant microstructures

Crash Box (dual phase automotive steel)

- **Objective |** Maximize energy absorption through optimised microstructure/composition/processing



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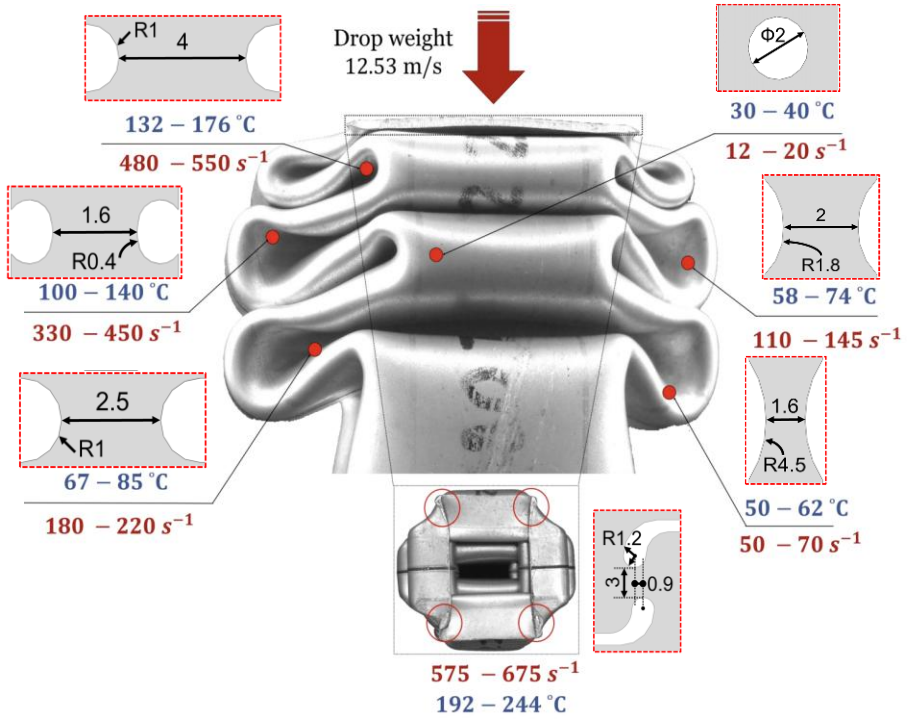
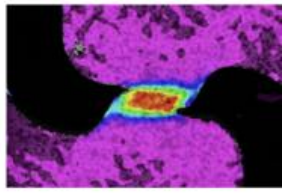
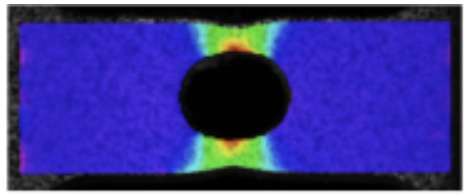
DyMaLab Focus – Impact-Dynamic Response AHSS & Crash Box

Tailored Experimental Characterization



- Full-field deformation measurements





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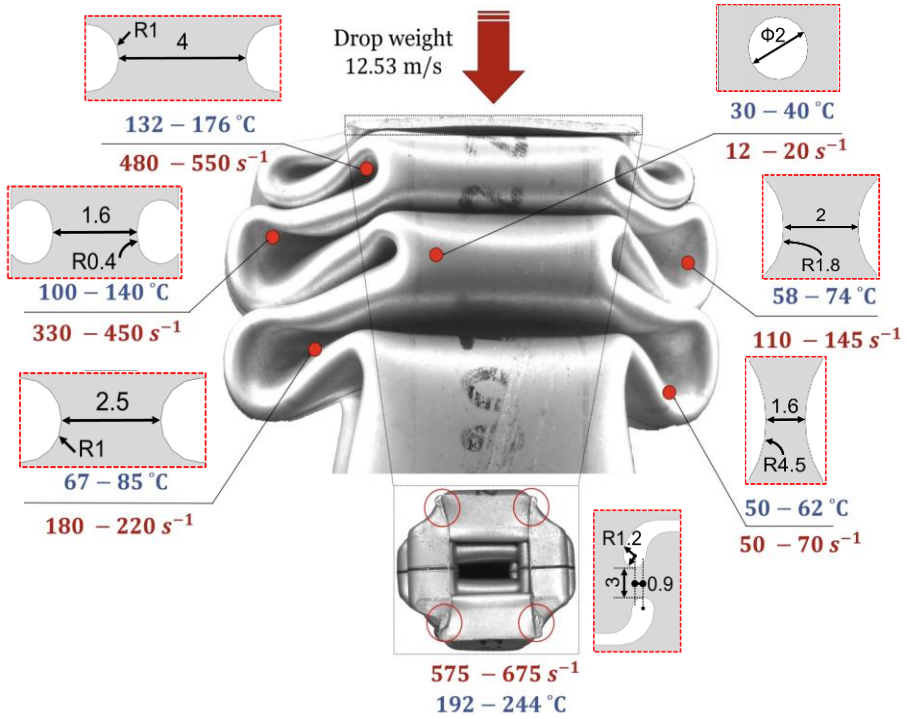

Full-field deformation measurements

Material model identification

- **Plasticity**: Influence of strain hardening, strain rate, temperature, and stress-state
- **Damage**: Initiation and evolution criterion

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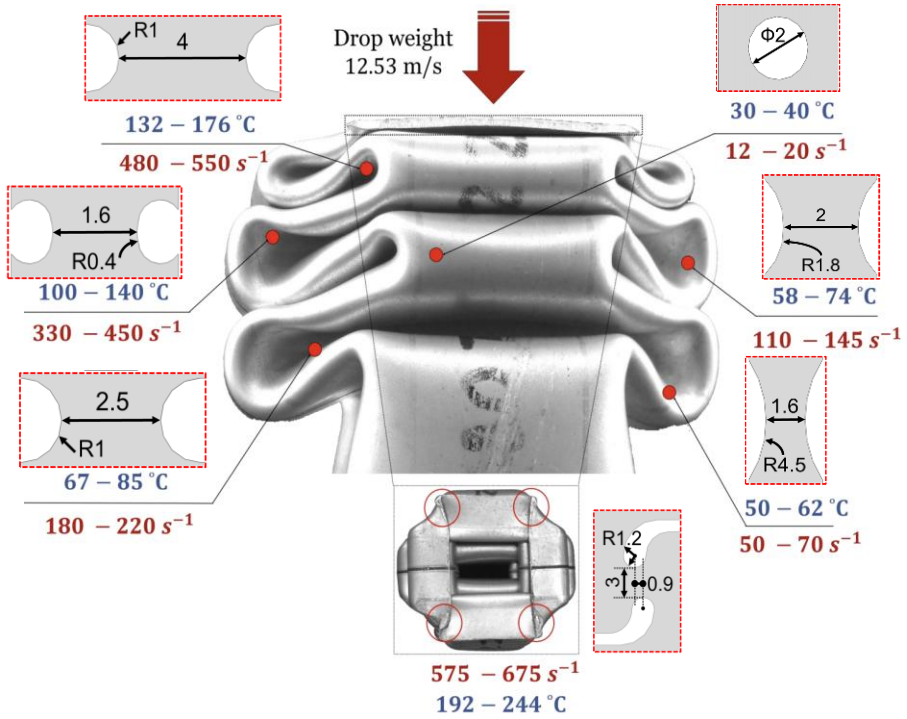
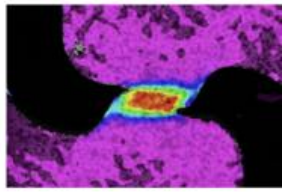
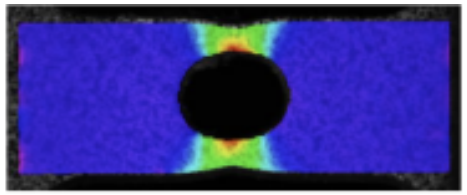
DyMaLab Focus – Impact-Dynamic Response AHSS & Crash Box

Tailored Experimental Characterization



- **Full-field deformation measurements**





Material model identification

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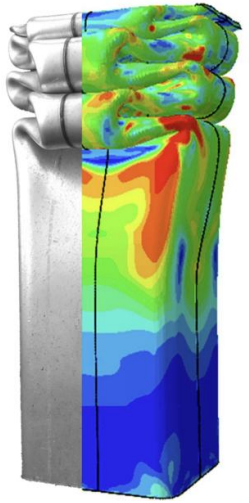
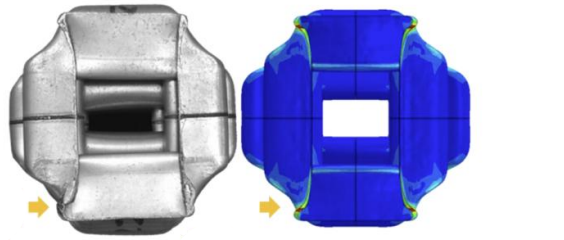
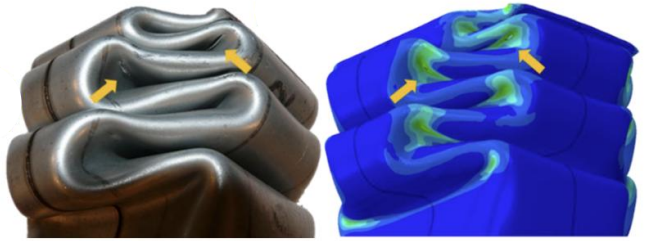
Impact phenomenon prediction





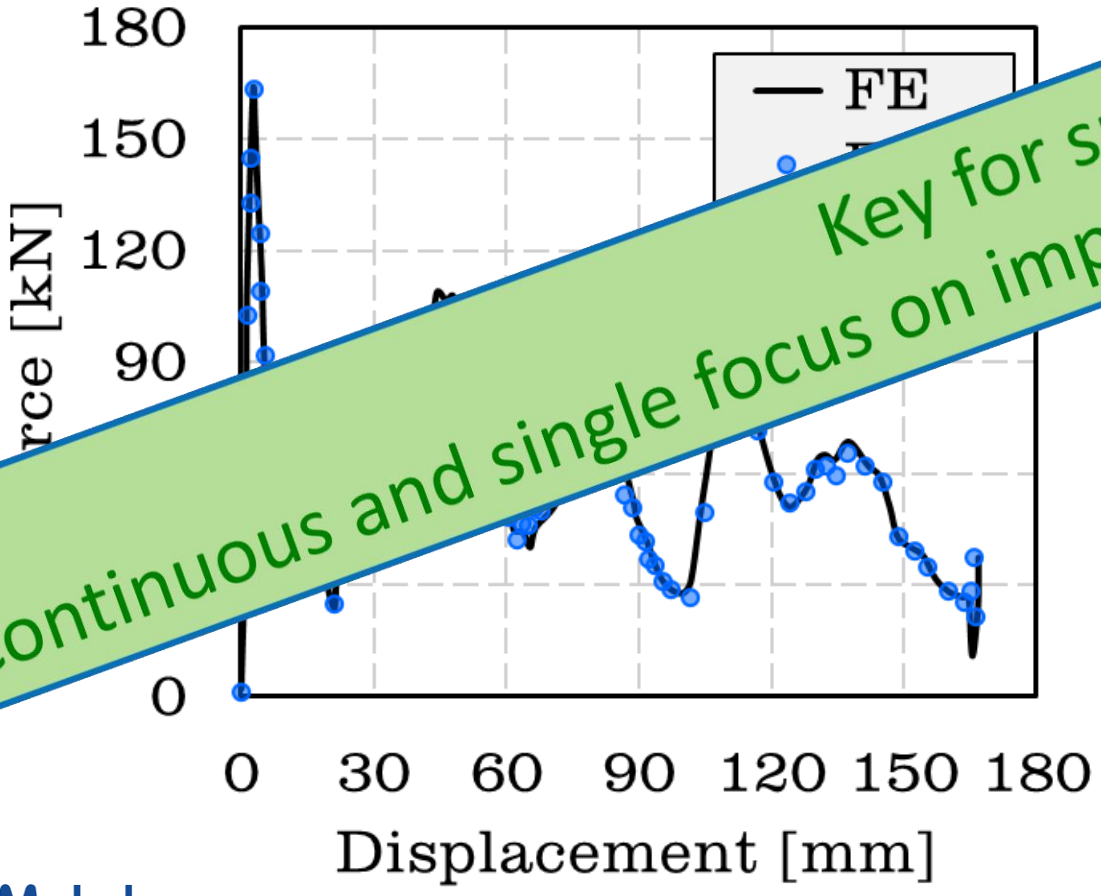


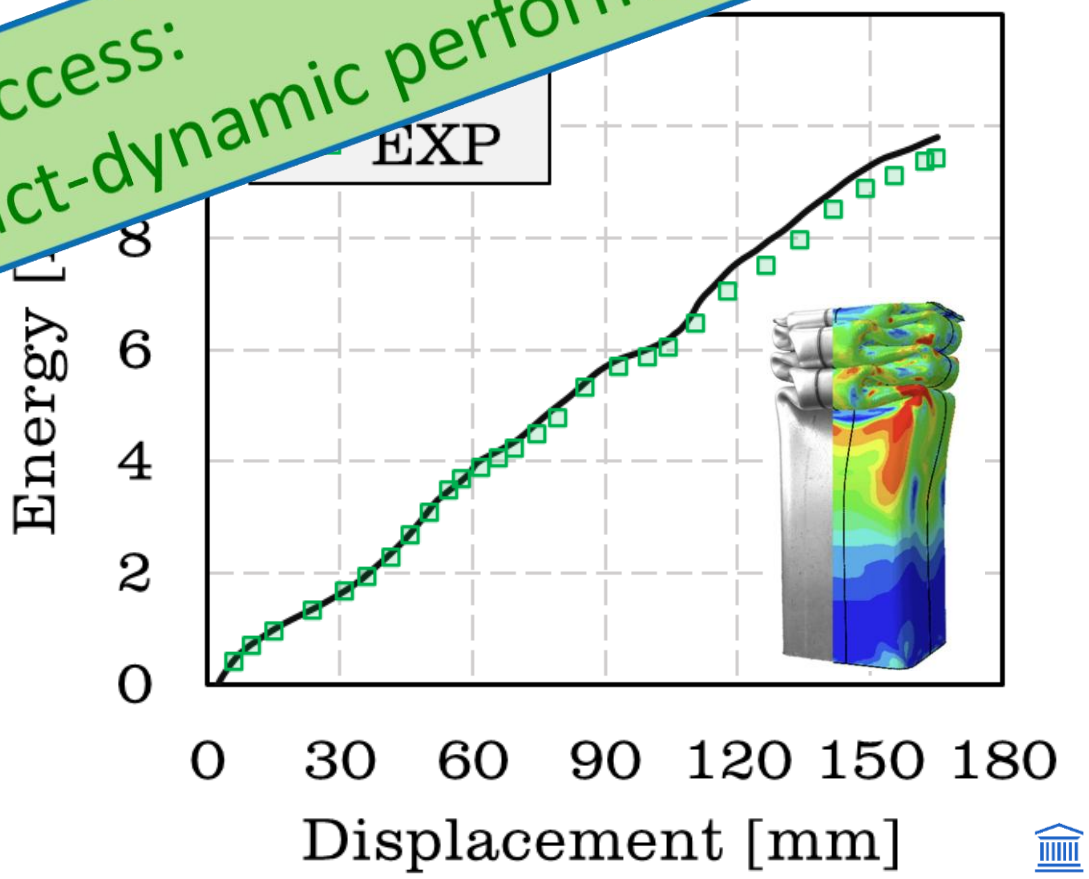
DyMaLab Focus – Impact-Dynamic Response AHSS & Crash Box

Results

- ☑ Energy absorption predicted, and main features captured
- ☑ Identification of relevant material properties

Key for success:
Continuous and single focus on impact-dynamic performance crashbox





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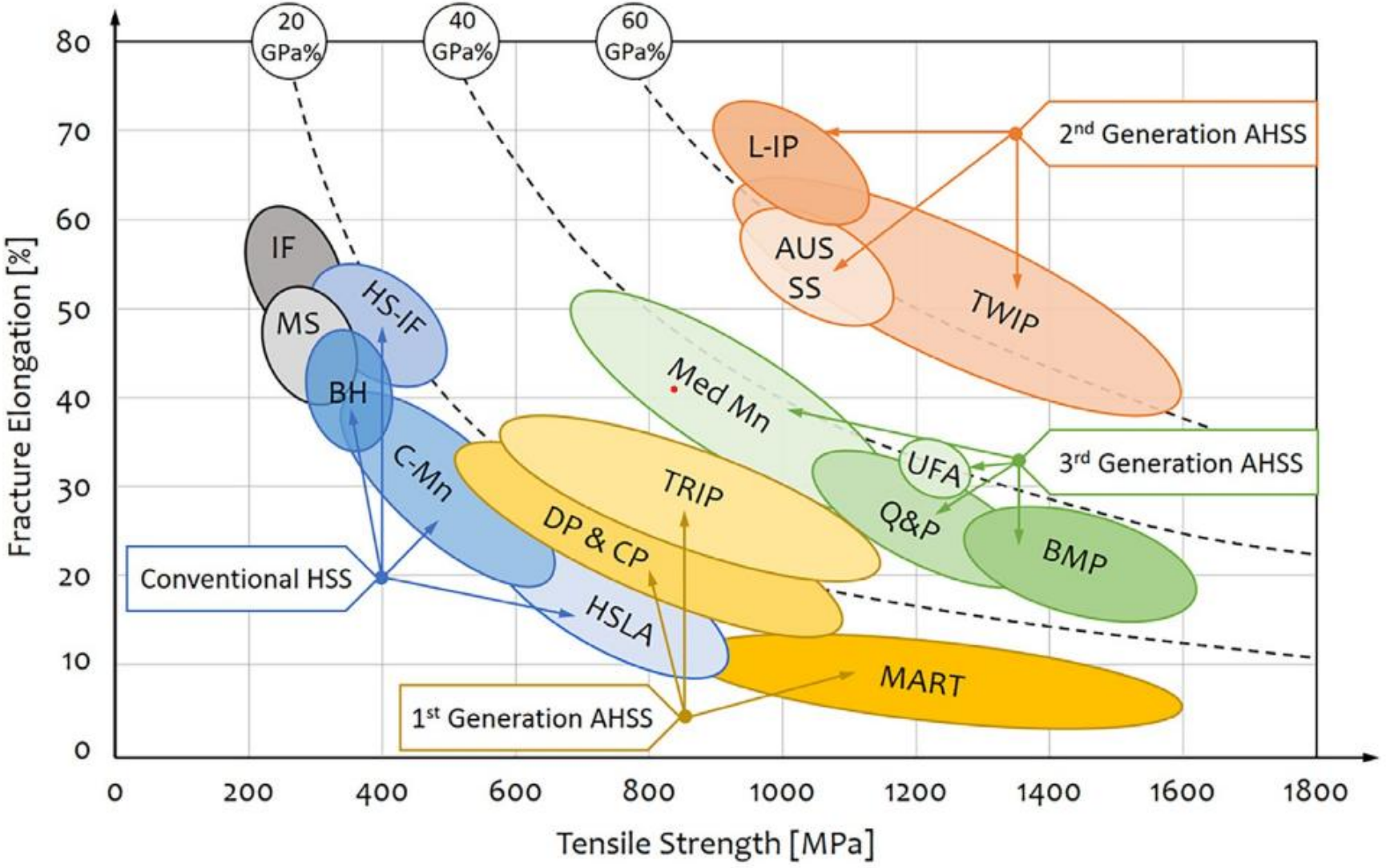
Third-Generation Advanced High Strength Steels

Verleysen P. (2023): Dynamic Behavior of Materials: Fundamentals, Material Models, and Microstructure Effects – Chapter: Dynamic behavior of high-strength steels for automotive applications.



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Third-Generation Advanced High Strength Steels

RFCS projects with focus on dynamic properties

- **OptiQPap**: Optimisation of QP steels designed for industrial applications
- **DYNAUSTAB**: Austenite stability under dynamic loading

→ Q&P, ultrafast annealed, medium-manganese, carbide-free bainitic steels

→ Focus on application-related properties, incl. impact-dynamic performance and forming

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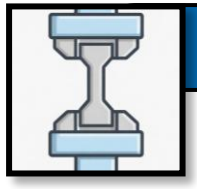
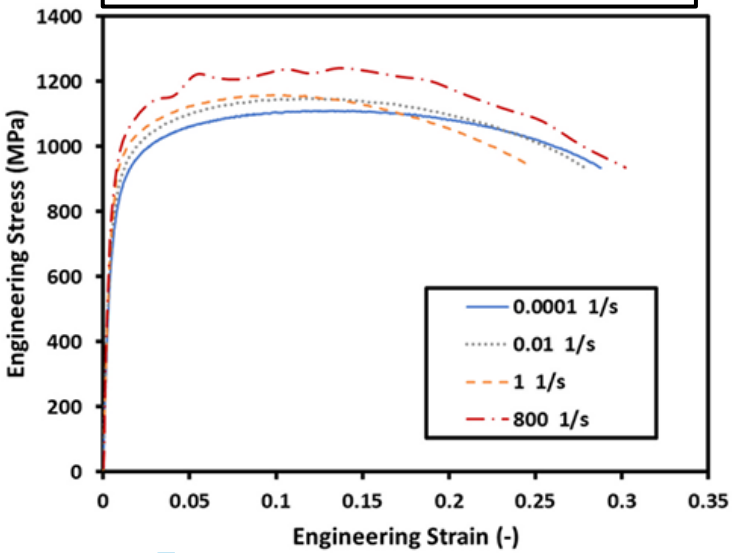
Third-Generation AHSS – Strengths & Challenges



Dynamic mechanical performance

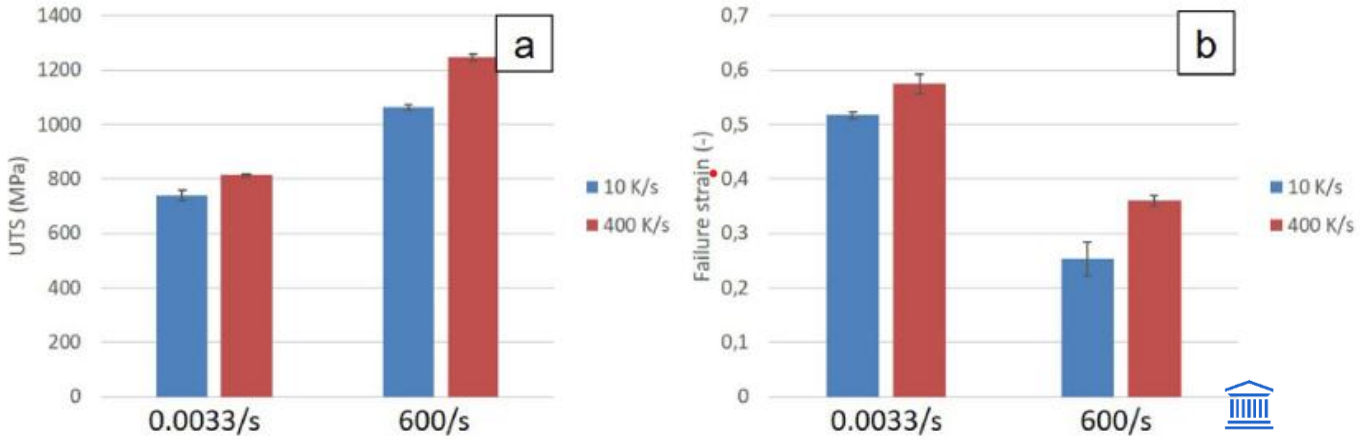
Strong performance under dynamic loading

Carbide-free bainitic steel



Carreno-Saavedra et al. (2025) JMRT

Ultra-fast annealed steel



Vercruysse et al. (2020) MSEA

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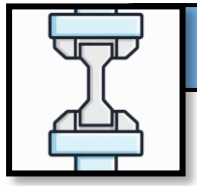
Third-Generation AHSS – Strengths & Challenges



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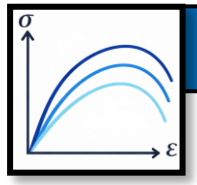
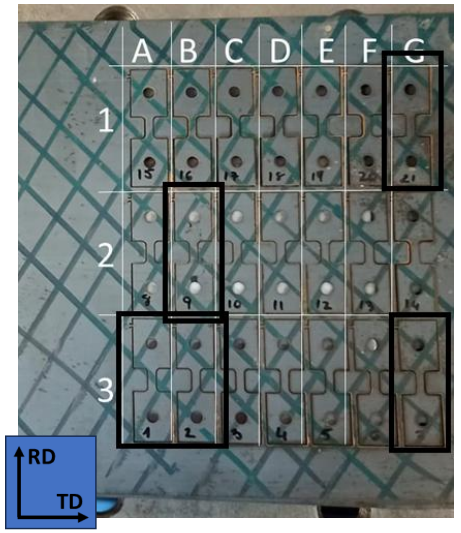


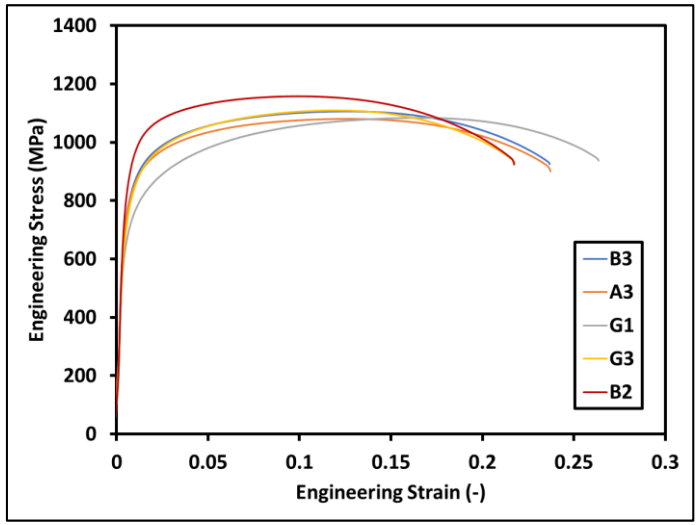
Mechanical properties variability

Mechanical response not uniform across the plate/sheet

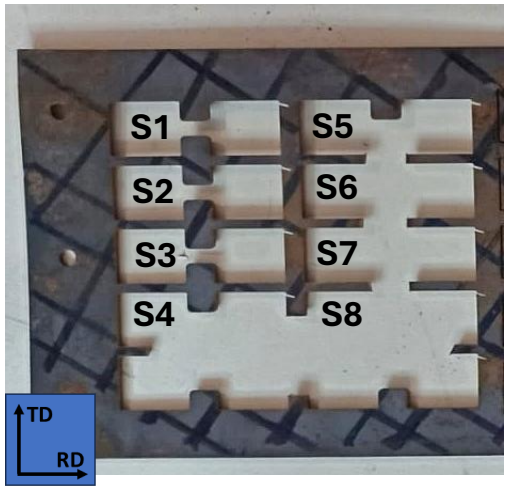
CFB steel



0.0001 s^{-1}



MedMn steel



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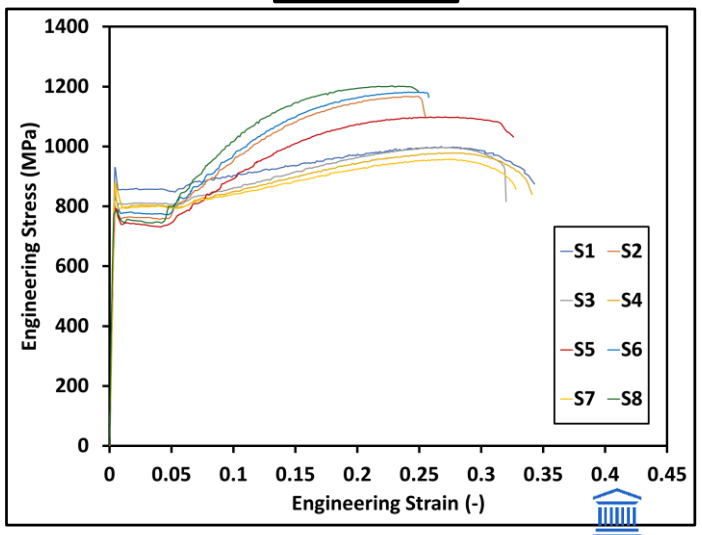

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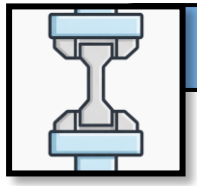
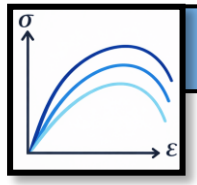
Third-Generation AHSS – Strengths & Challenges



Dynamic mechanical performance

Strong performance under dynamic loading



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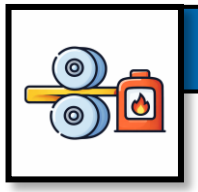


Processing challenges

Achieving uniform microstructure requires tight thermal control

Homogenisation requirement

1200°C for 30h

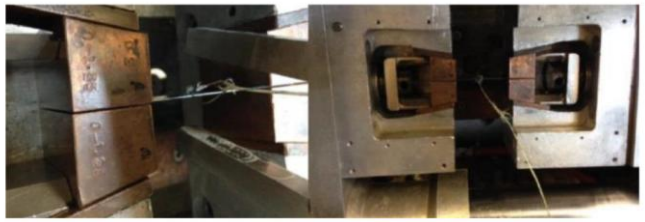
Mn segregation

Salth bath furnace

www.phase-trans.msm.cam.ac.uk

Dynamic annealing simulator

Gleeble thermal simulator



Induction heating setup

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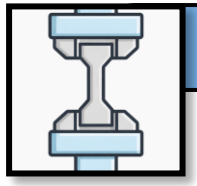
Third-Generation AHSS – Strengths & Challenges



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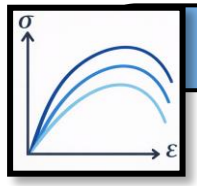

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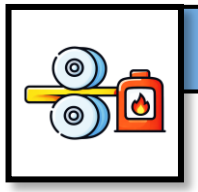

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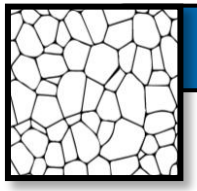
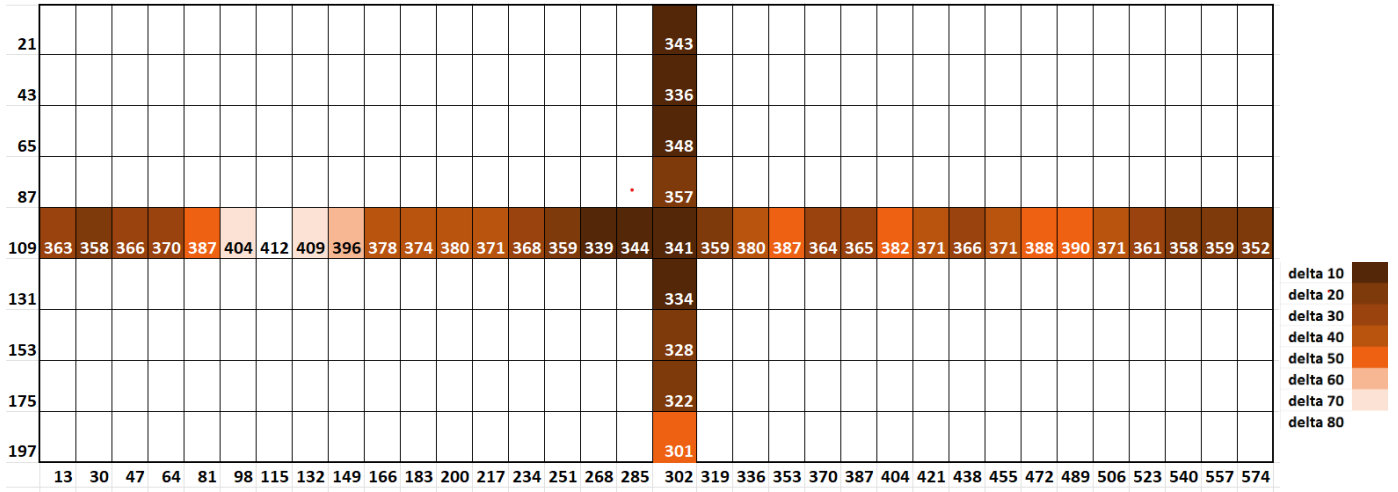


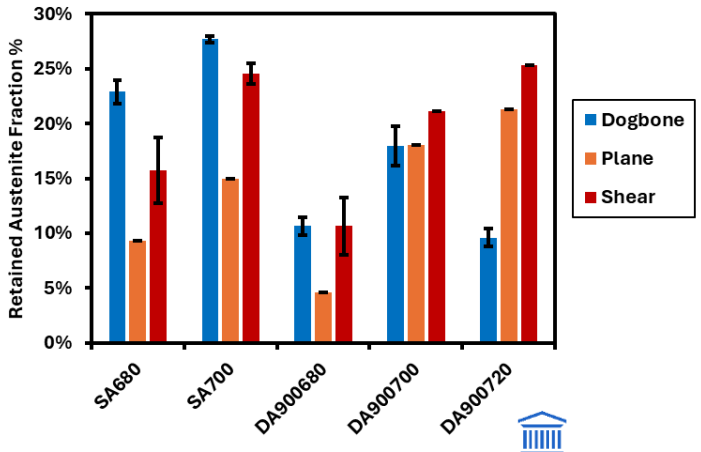
Microstructure sensitivity

Chemical heterogeneity & small temperature variations → changes in retained austenite content/stability and properties

Q&P steel – Vickers hardness profile



MedMn steels – Retained austenite content



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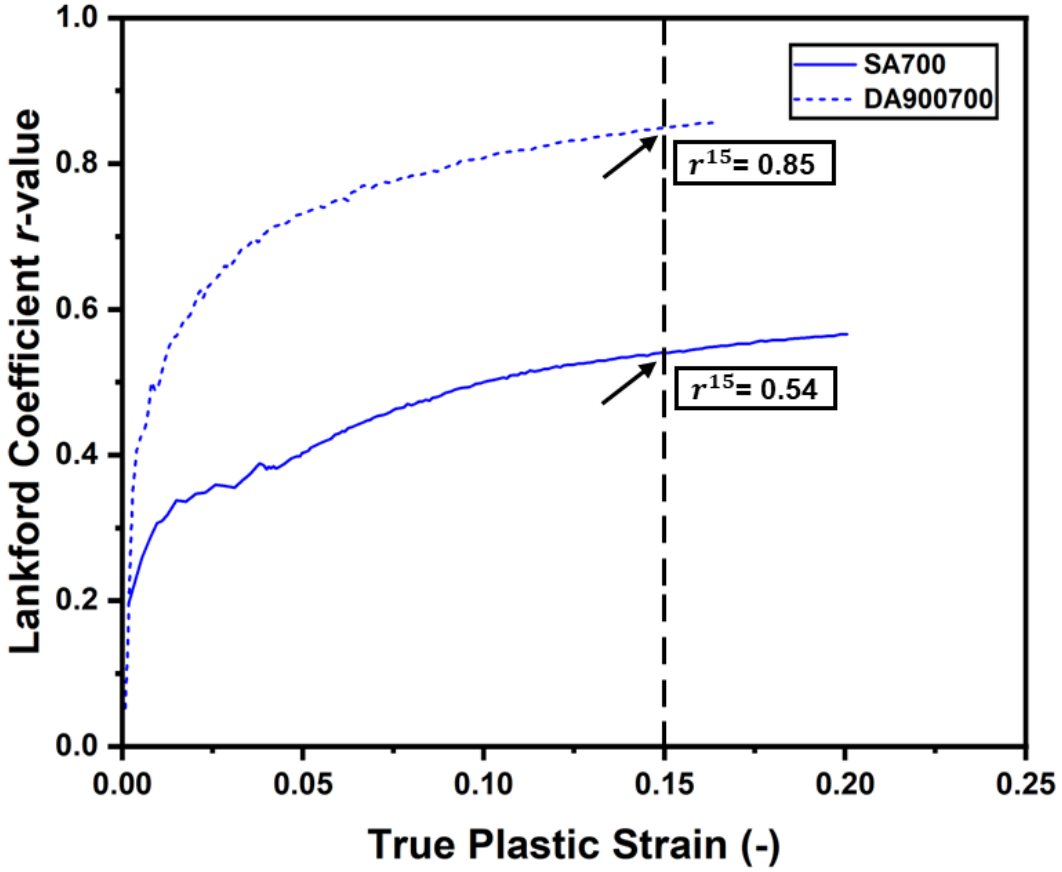
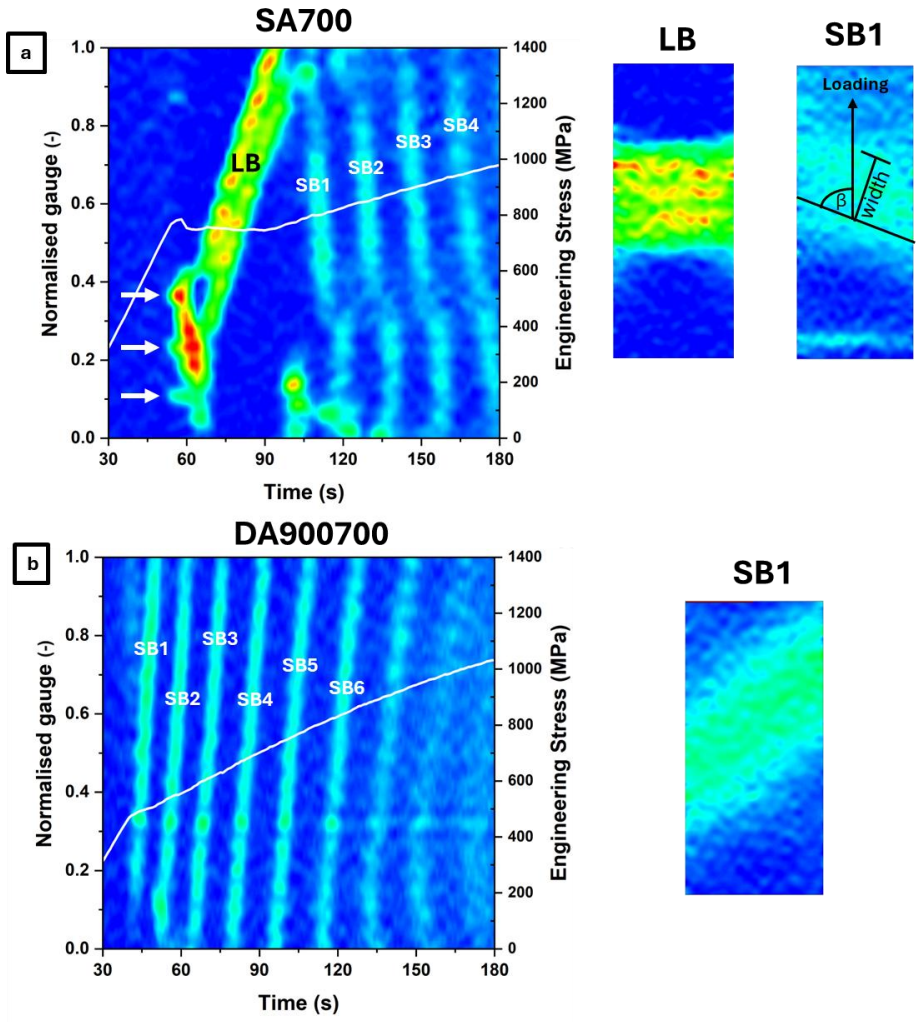
Third-Generation AHSS – Key Bottlenecks in Application Performance

Forming properties

Need optimisation



Medium Mn steel



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Carreno Saavedra et al. (2026) Metals

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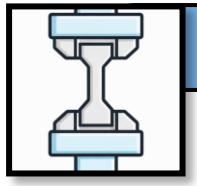
Third-Generation Advanced High Strength Steels



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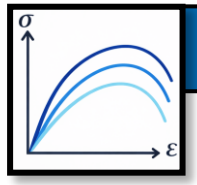


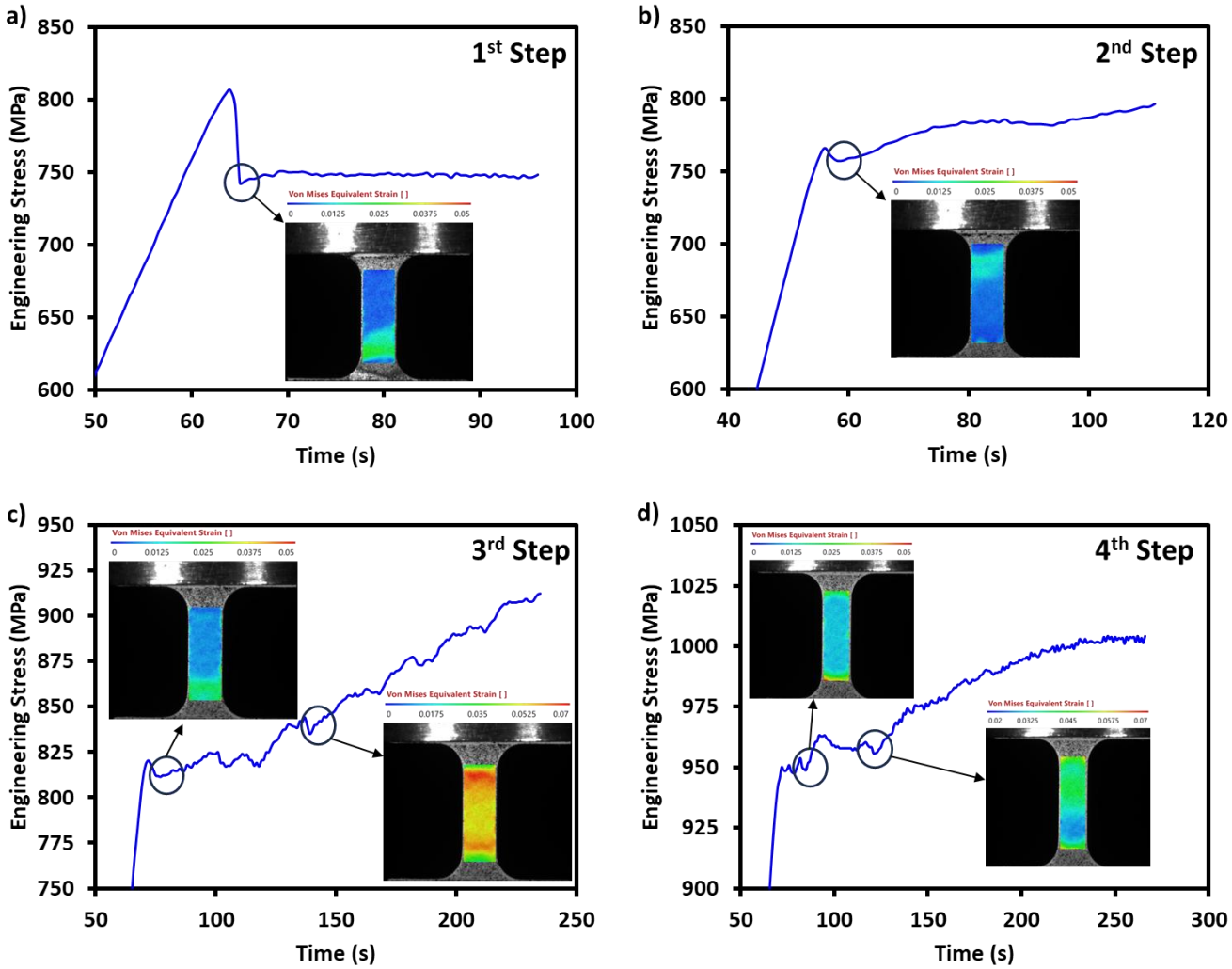
Strain localisation phenomena

Static and dynamic strain aging strongly affect mechanical response in medium-Mn steels

Promising properties
Challenging production
Application properties
requiring further research
Critical alloying elements

Med Mn steel

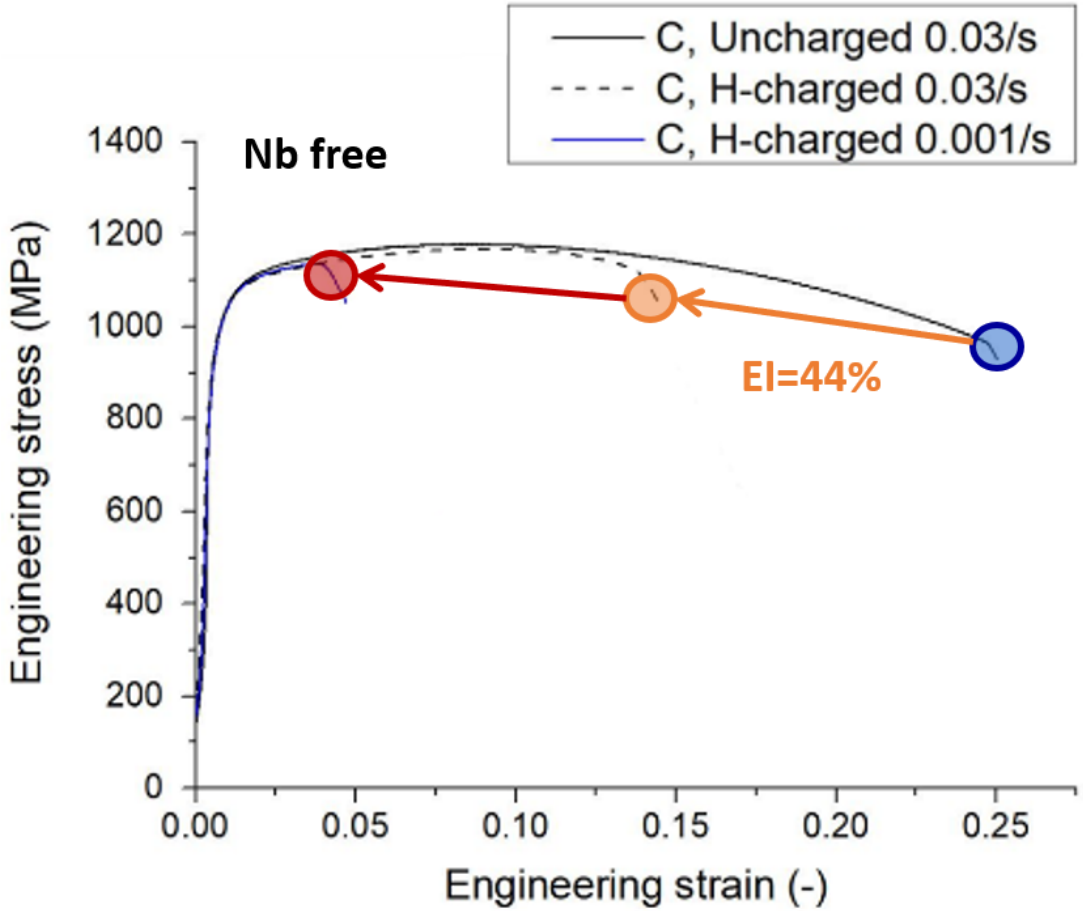
Interrupted tests – Uniaxial stress state

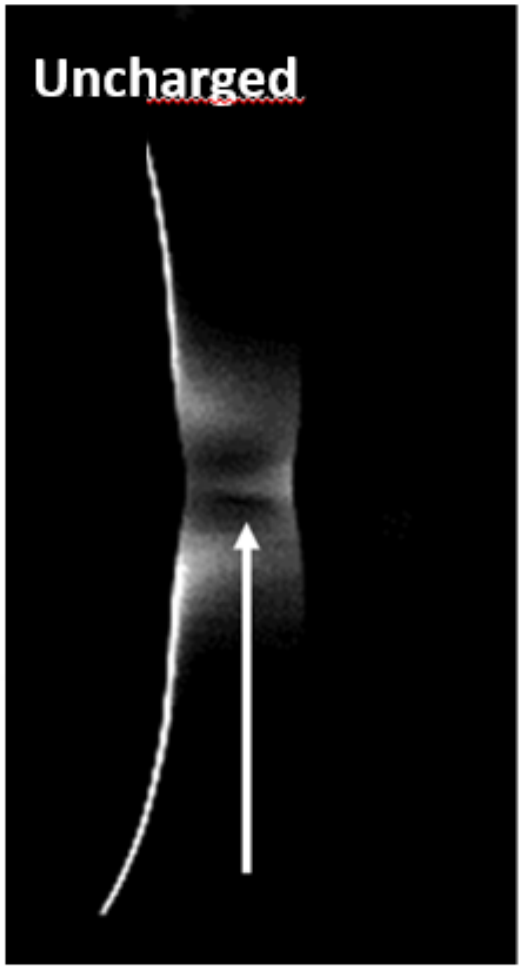


Third Generation - What's Next? New Challenges!

Energy transition

- **Challenge |** Increased use of hydrogen might result in embrittlement of steels used





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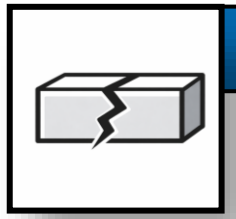
Third Generation – What's Next? Green Generation?

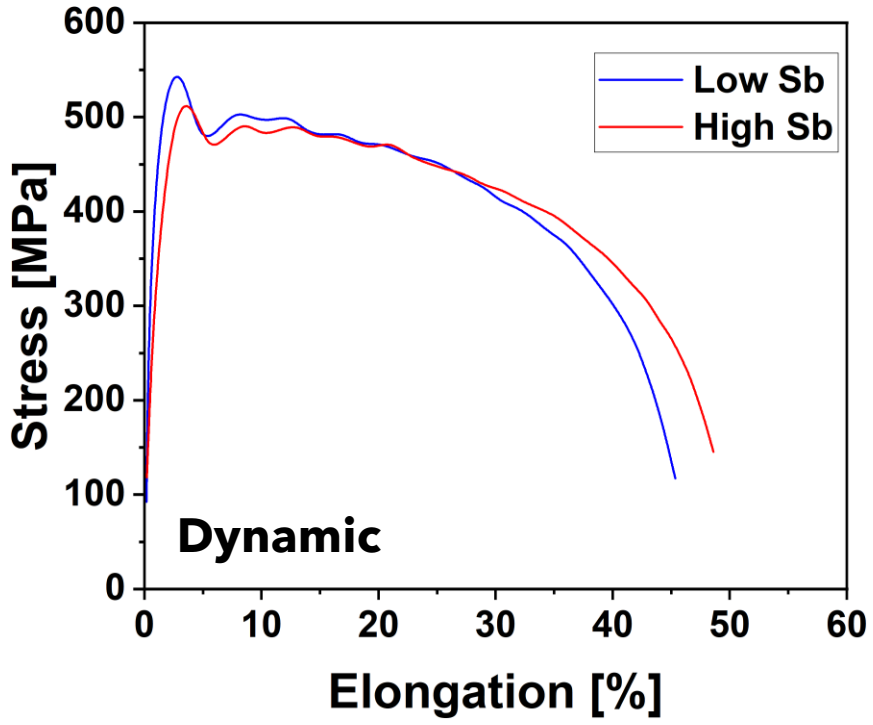
CO_2 reduction steel making process

- **Challenge |** Increased use of scrap might affect mechanical properties



Embrittlement – Impact-dynamic behaviour

14 1,8 Si 28		15 2,1 P 31	
32 1,8 Ge 72,5		33 2,0 As 75	
50 1,8 Sn 118,5		51 1,9 Sb 122	



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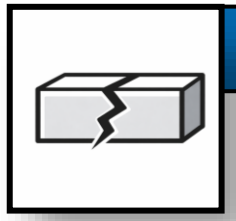

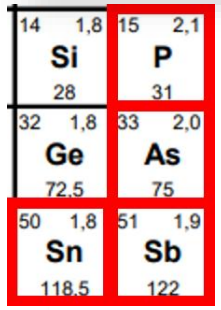

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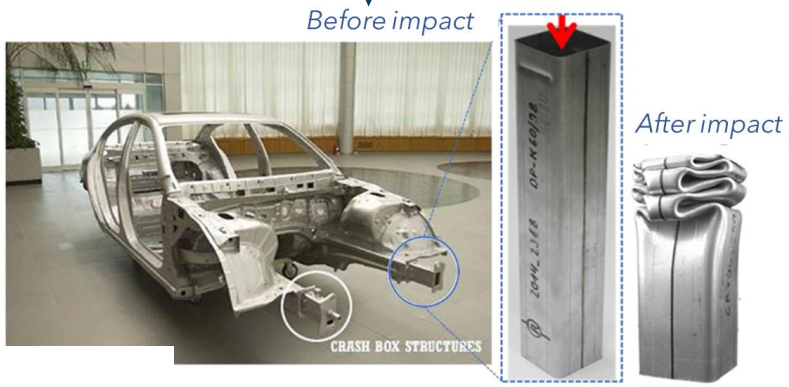

Embrittlement – Impact-dynamic behaviour

Green-generation steels might

- Rely on **well-established high-performance steel concepts**
- Designed with explicit consideration of **life-cycle efficiency, circularity and resource optimisation**, while fully preserving mechanical performance and safety

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Conclusions – Challenges and Opportunities for European Steel

- **HSS & AHHS** unequalled in performance and cost-efficiency
  - high-performance, **durable and circular material** for applications where **safety and reliability** is key
  - built on decades of **research and experience**
  - designed based on **performance & societal needs**

Conclusions – Challenges and Opportunities for European Steel

- **HSS & AHHS** unequalled in performance and cost-efficiency
- Renewed **strategic momentum** for European steel

worden. 'Mensen moeten begrijpen wat hierbinnen gebeurt. Zonder deze tekeningetjes hadden ze me in Europa nog steeds niet begrepen. Mensen van de Commissie zeiden me recht in het gezicht dat ze niet zeker waren dat we de industrie nodig hebben, gewoon, blunt, boem. Ze geloofden ons niet als we zeiden wat we nodig hadden. 'Jullie gaan wegtrekken uit Europa', bleven ze zeggen.'

'… People from the Commission told me straight to my face that **they weren't sure we needed the industry, just like that, bluntly, boom.** They didn't believe us when we told them what we needed. 'You're going to leave Europe,' they kept saying.'

Geert Van Poelvoorde, CEO of ArcelorMittal Europe
Source: De Tijd, 14 February 2026

Conclusions – Challenges and Opportunities for European Steel

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boven 80 procent brengen. Dat is cruciaal om rendabel te draaien. Is alles opgelost? Nee. Er zitten nog gaten in het systeem en de energieprijs blijft een probleem. Maar de richting is veranderd. Europa erkent opnieuw dat staal een strategische industrie is. Ik praat niet meer tegen een muur.'

'… Has everything been resolved? No. There are still gaps in the system and energy prices remain a problem. But **the direction has changed. Europe once again recognizes that steel is a strategic industry.** I am no longer talking to a brick wall.'

Geert Van Poelvoorde – De Tijd, 14 February 2026

DyMaLab

GHENT UNIVERSITY

Conclusions – Challenges and Opportunities for European Steel

- **HSS & AHHS** unequalled in performance and cost-efficiency
- Renewed **strategic momentum** for European steel
- Europe positioned to lead through its **focus on sustainability**
  - our work focusses on **performance-preserving lightweighting & greener production routes**, and **damage-tolerant design**

Launch of the Clean Steel Partnership paves the way for further research and deployment of ground-breaking technology

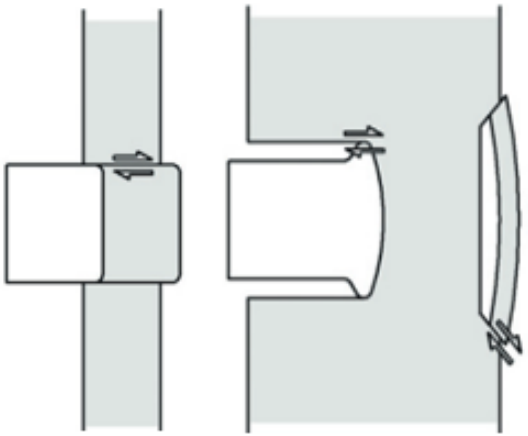
The Clean Steel Partnership was formally launched today and the Memorandum of Understanding will be 'e-signed' by representatives of the European Commission and the European Steel Technology Platform (ESTEP) in the coming weeks.

Conclusions – Challenges and Opportunities for European Steel

- **HSS & AHHS** unequalled in performance and cost-efficiency
- Renewed **strategic momentum** for European steel
- Europe positioned to lead through its **focus on sustainability**
- Existing unique and mature **collaboration ecosystem**
  - **RFCS & Horizon Europe funding key enablers**
  - Strong European steel sector organisations, including **EUROFER & ESTEP**

Conclusions – Challenges and Opportunities for European Steel

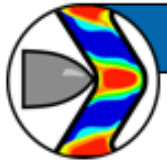
- **HSS & AHHS** unequalled in performance and cost-efficiency
- Renewed **strategic momentum** for European steel
- Europe positioned to lead through its **focus on sustainability**
- Existing unique and mature **collaboration ecosystem**
- **Dual-use applications**: demanding, though stimulating innovation



B. Dodd and Y. Bai, Book 2012

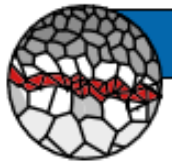
Extreme high strain rate

10^3-10^6 /s



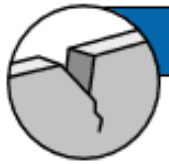
Complex stress-state

Heterogeneous stress-state and extreme hydrostatic stress



Adiabatic Heating

Onset of Adiabatic Shear Bands (ASBs)



Complex failure modes

Plugging, petalling, spall on the back face, delamination (in laminates).

Conclusions – Challenges and Opportunities for European Steel

‘I am optimistic, very hopeful. Europe has woken up. … We don't want to leave here: **Europe is our cradle, our R&D is here, our best factories are here, the best people are here. Europe will always remain Europe. It wants to go green and it will go green. And it has to succeed.**
I do not rule out – and I am going out on a limb here – that the **steel industry in Europe will grow again**. Other continents will inevitably also embark on the path to greening within a few years**. Climate problems are not going away. … And who will be leading the way? Europe!** We will then have a ten-year head start with technologies for electric furnaces, CO2 capture and reuse... No one else in the world is producing **top-quality steel for cars using electric furnaces**. We are now going to do that.’

Geert Van Poelvoorde – De Tijd, 14 February 2026

Questions? Remarks?

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Research Fund for Coal & Steel

FACULTY OF ENGINEERING AND ARCHITECTURE