technische universität dortmund

Institute of Forming Technology and Lightweight Components




# Prediction of adiabatic blanking process properties with temperature dependent fracture criterion

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ICHSF21 INTERNATIONAL CONFERENCE ON HIGH SPEED FORMING

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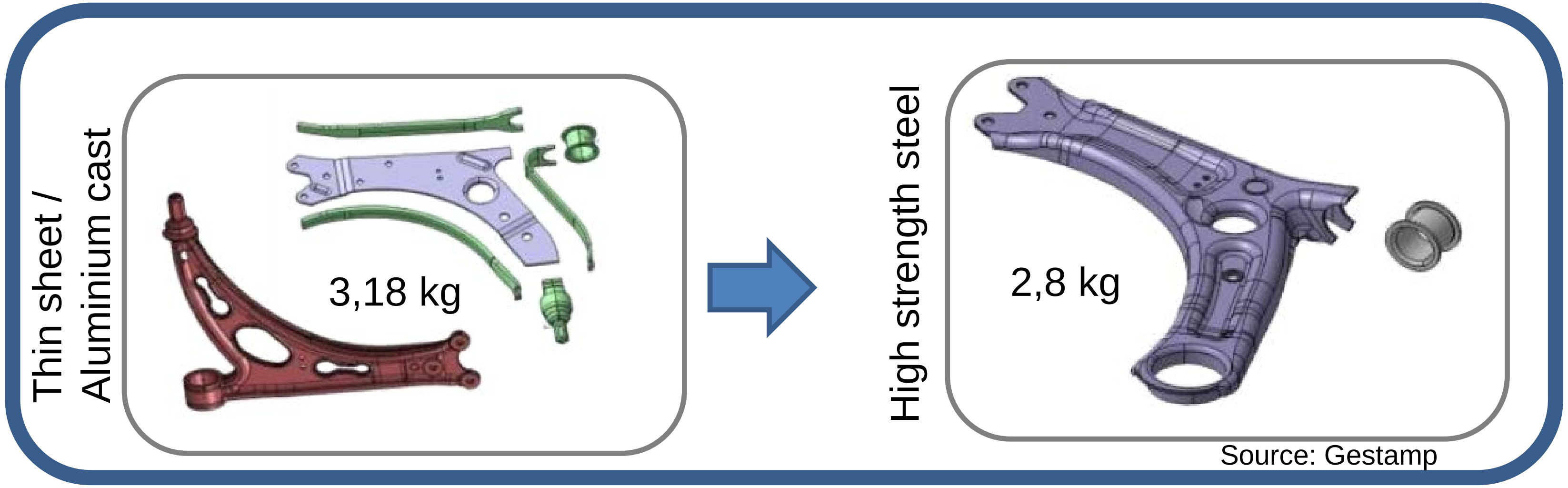
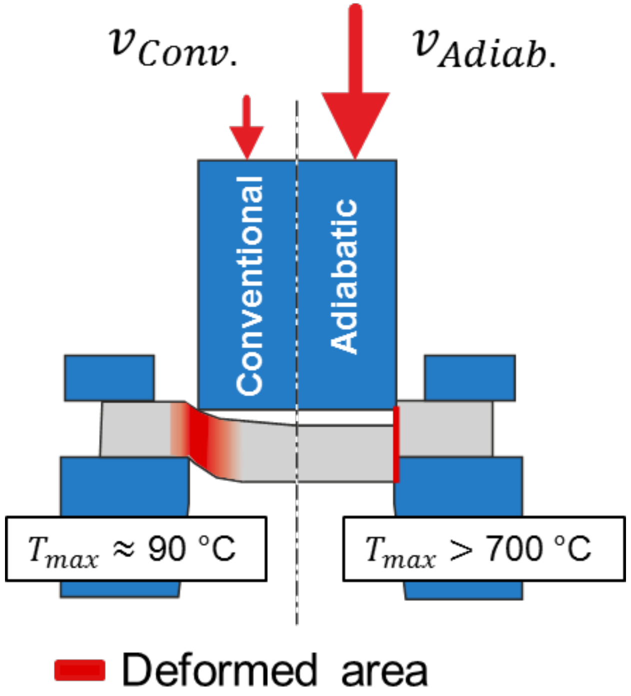
15.10.2021

# Motivation / Vision




## Challenges

### Blanking of sheets

- Influence of sheared edge on process chain

### Trimming of formed parts

- Inhomogeneous mechanical properties (hardening)
- Damage

Collaboration:


**Knowledge and prediction of adiabatic shear bands and their properties is necessary for process design**



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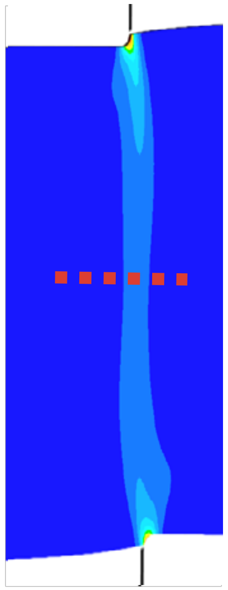
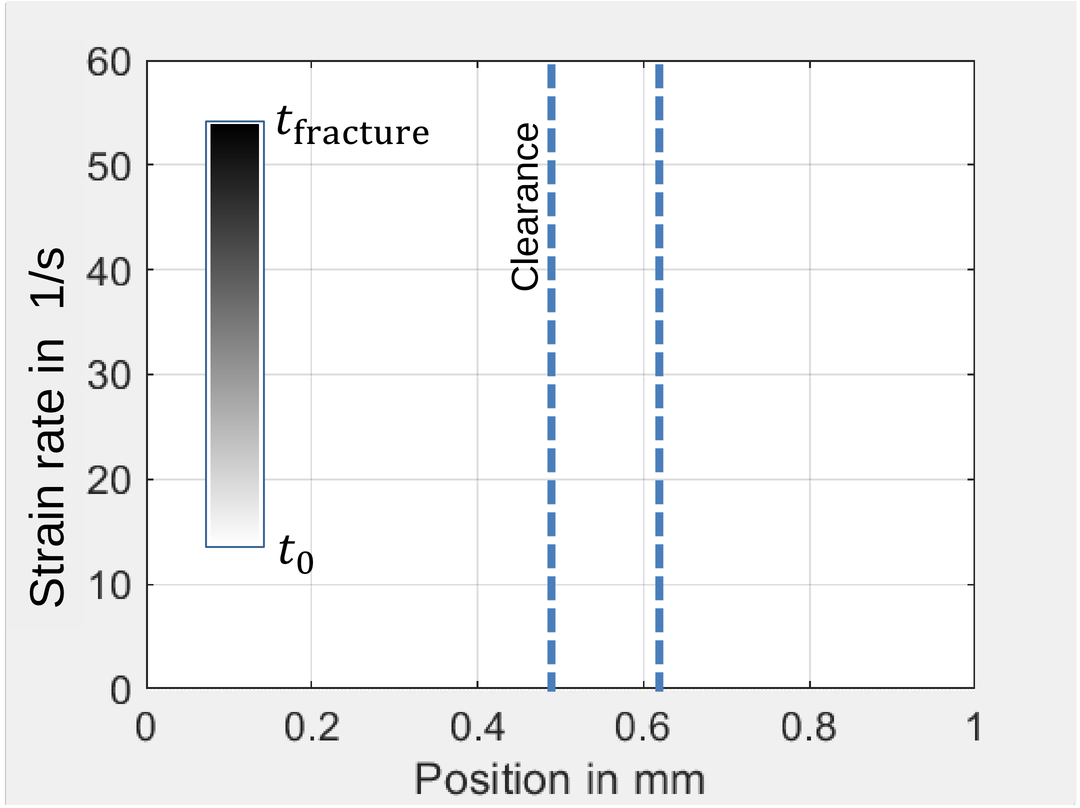
# Local deformation rate in blanking

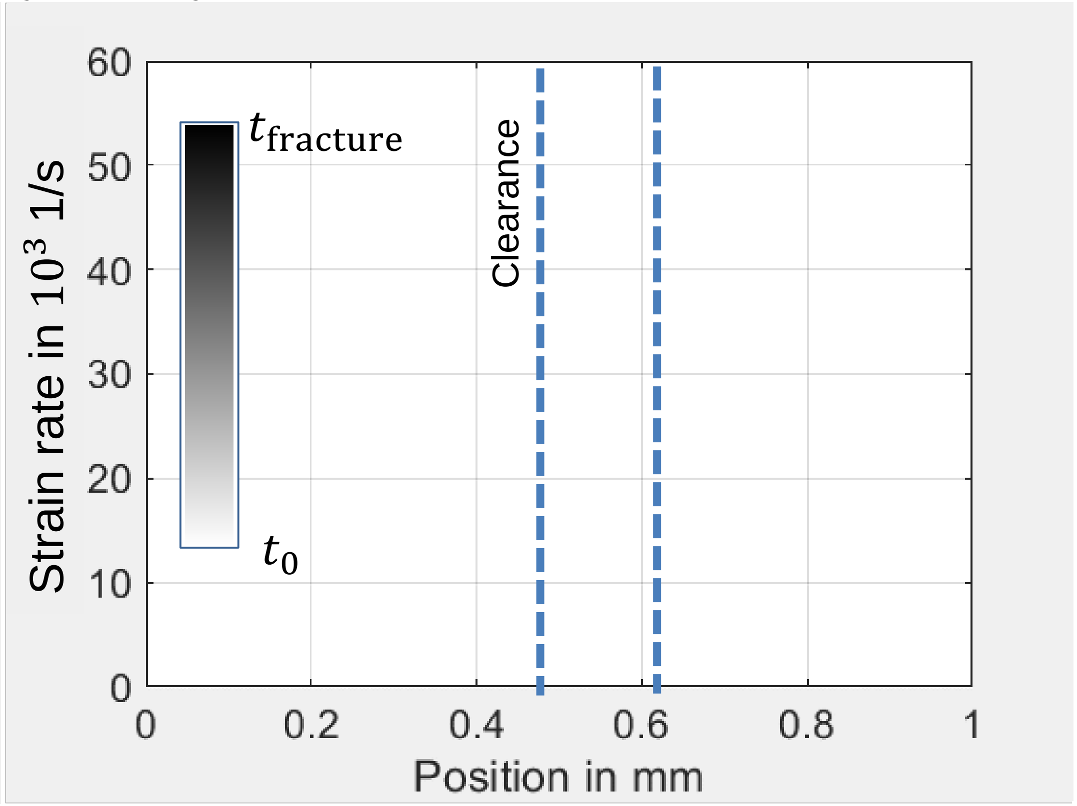
Strain rate in 1/s



Conventional blanking
(0.1 m/s)




High speed blanking
(5.3 m/s)



# Adiabatic Blanking: Overview

## Experiment

Known:
- Energy
- Velocity
- Affected area

Unknown:
- Local strain(rate)
- Temperature

**Plasticity** →

$\sigma_f(\dot{\varepsilon}, \varepsilon, T)$

## Simulation

BC from Experiments

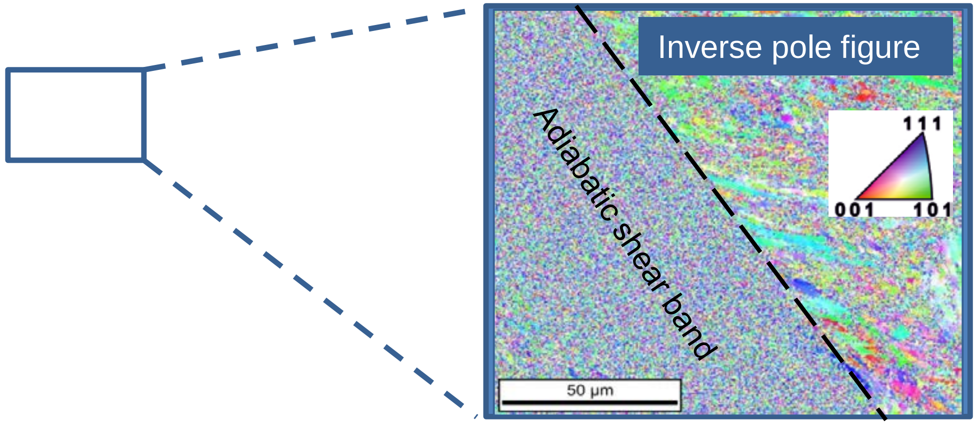
Fracture modeling

# Effects of adiabatic blanking

No in-situ meassurements of $T$ and $\dot{\varepsilon}$ possible ← Post mortem determination

Material:
20MnB5

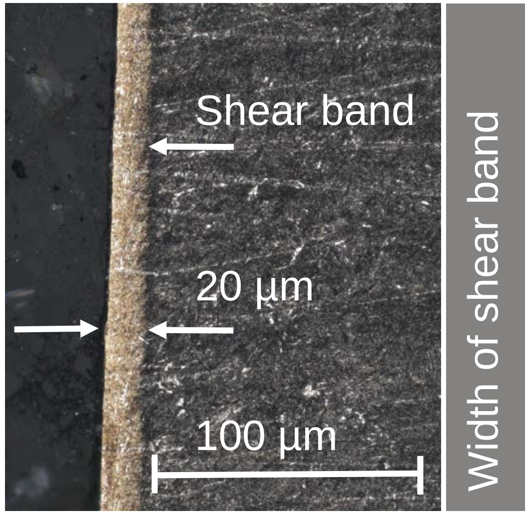
## Material science




## Technological aspects

Sheared surface


Microstructure




### Highly localized strains

- Dynamic recrystallization
- Local properties (hardness)

### Material modeling

- JMatPro ($E(T), c_{\mathrm{p}}(T), \ldots$)
- Flow curves ($T, \dot{\varepsilon}, \varepsilon$)

Modeling of adiabatic blanking in FORGE

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# Strain rate sensitivity

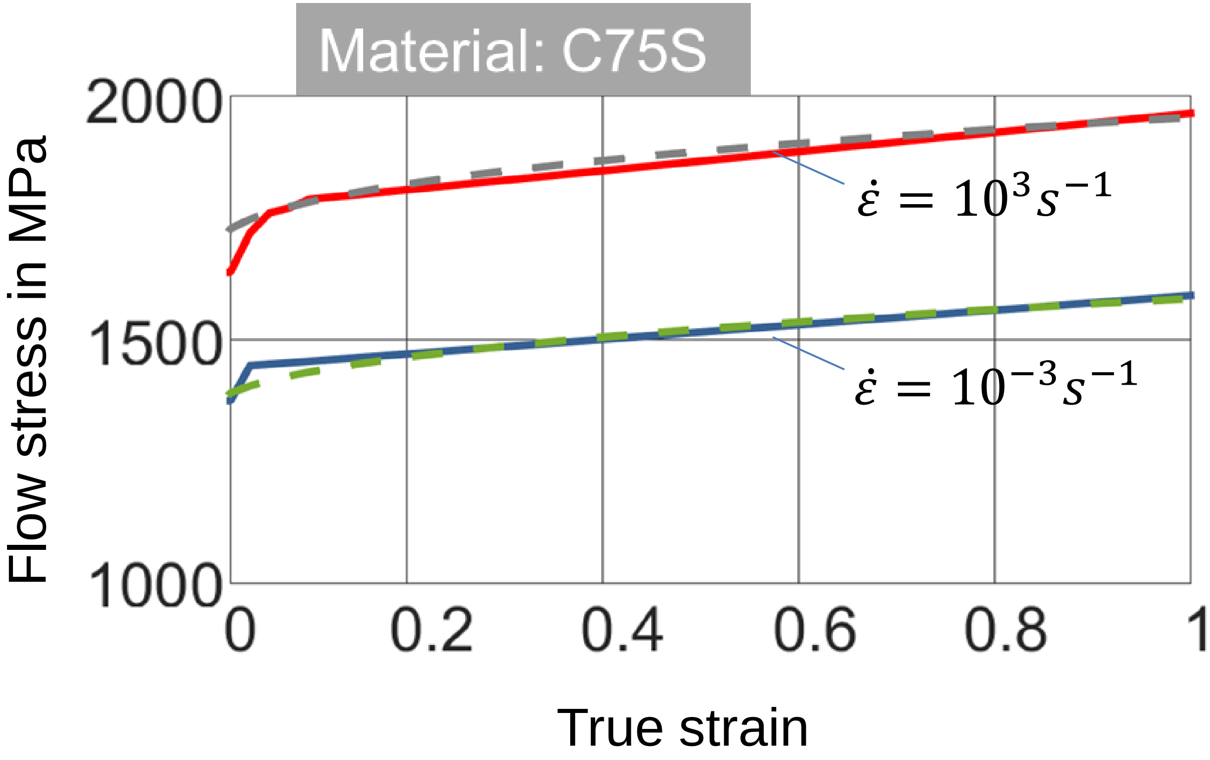
Johnson-Cook (J-C) Model

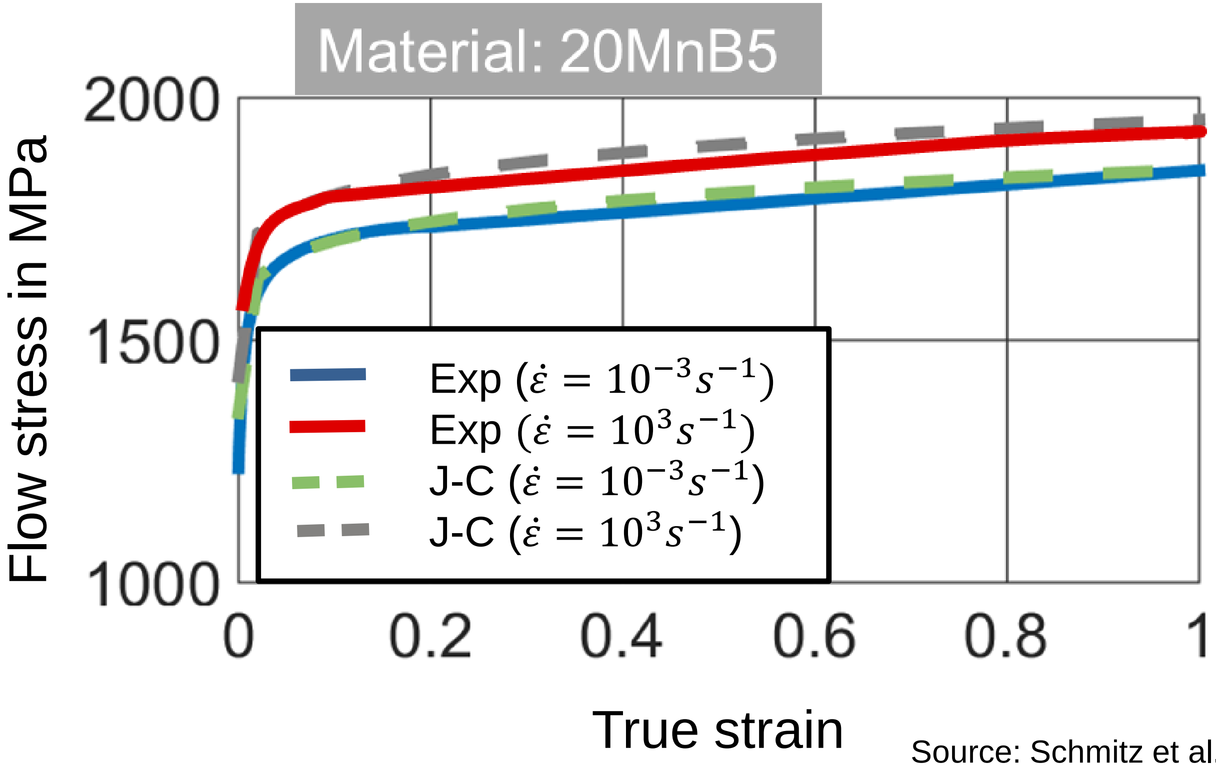
$$\sigma_f = (\varepsilon, \dot{\varepsilon}, T) = [A + B\varepsilon^n] * \left(1 + C * \ln\left(\frac{\dot{\varepsilon}}{\dot{\varepsilon}_0}\right)\right) * \left(1 - \left(\frac{T - T_{room}}{T_{melt} - T_{room}}\right)^n\right)$$

Elasto-plastic term | Viscosity term | Thermal softening term

Strain rate sensitivity:

$$m = \frac{dk_f}{d\dot{\varphi}}$$



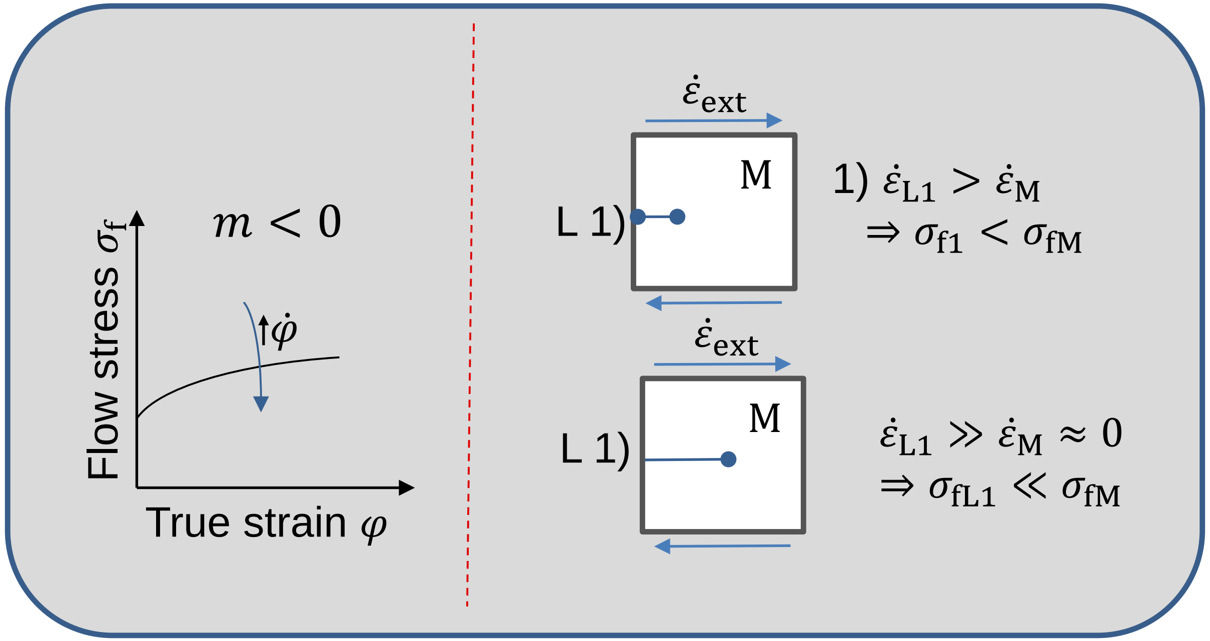



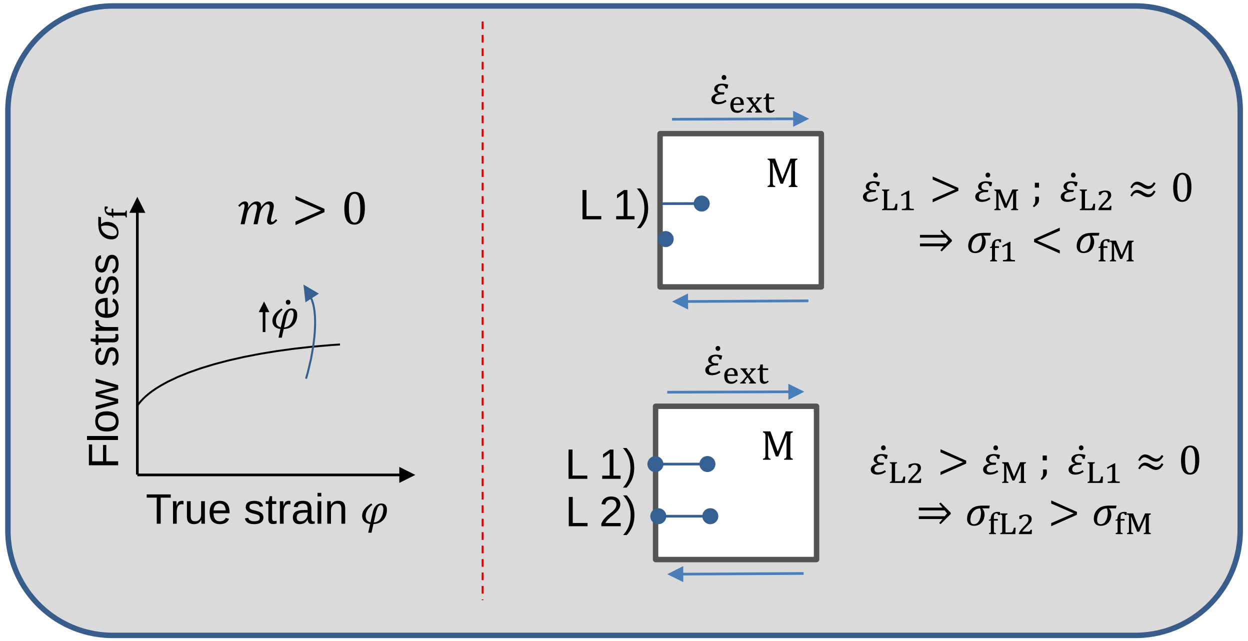

Source: Schmitz et al., 2020, CIRP Annals.

# Shear band initialisation

$$m = \frac{dk_f}{d\dot{\varphi}}$$

Room temperature




**Smaller shear bands, higher energy density**

↳ Acceleration of localization

**Bands wider, less localized deformation**

↳ Localization slowed down

20MnB5 $m = 0.0033$

C75S $m = 0.0068$

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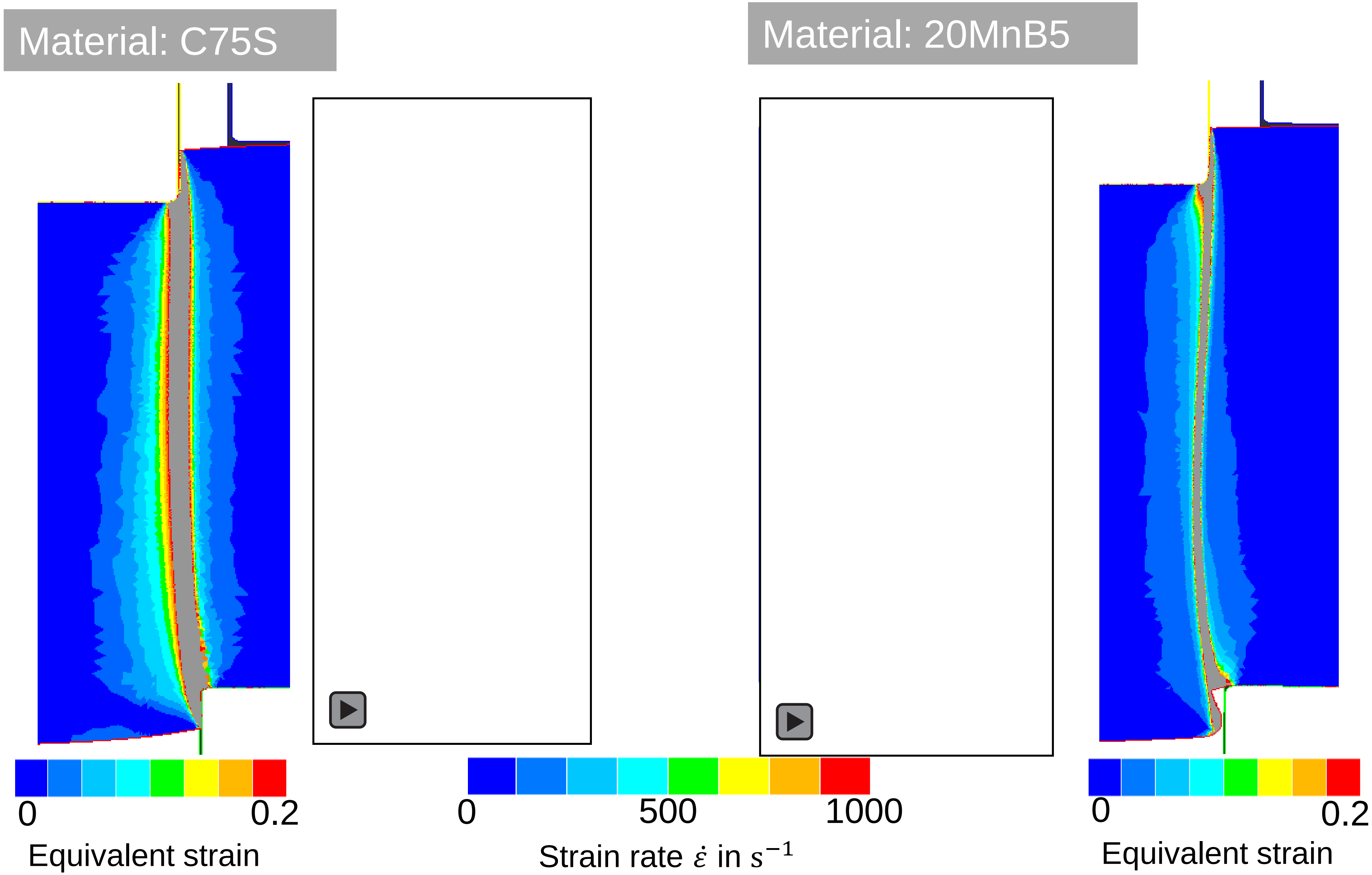
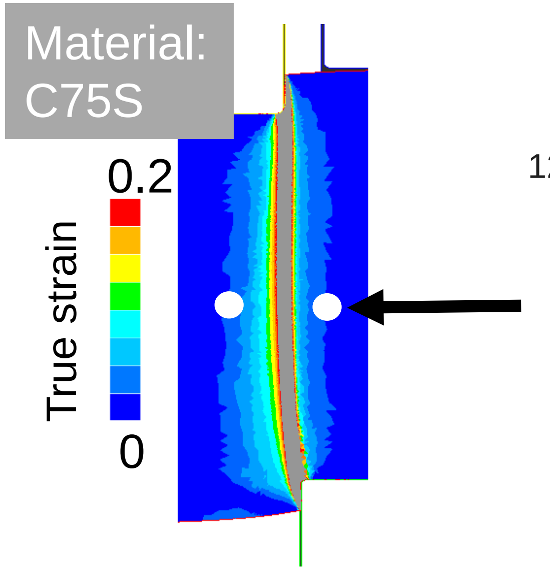
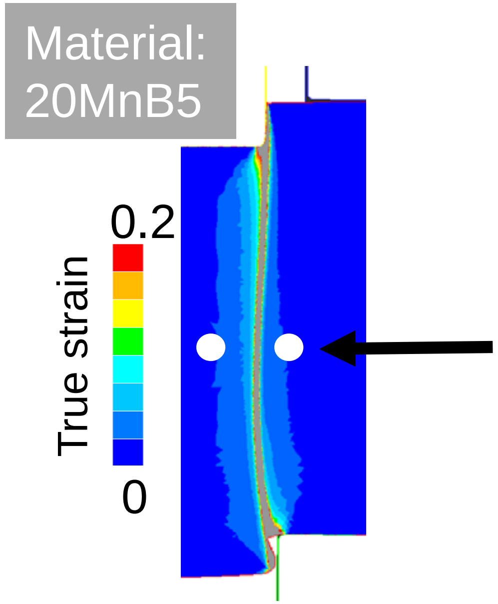
# Shear band initialisation

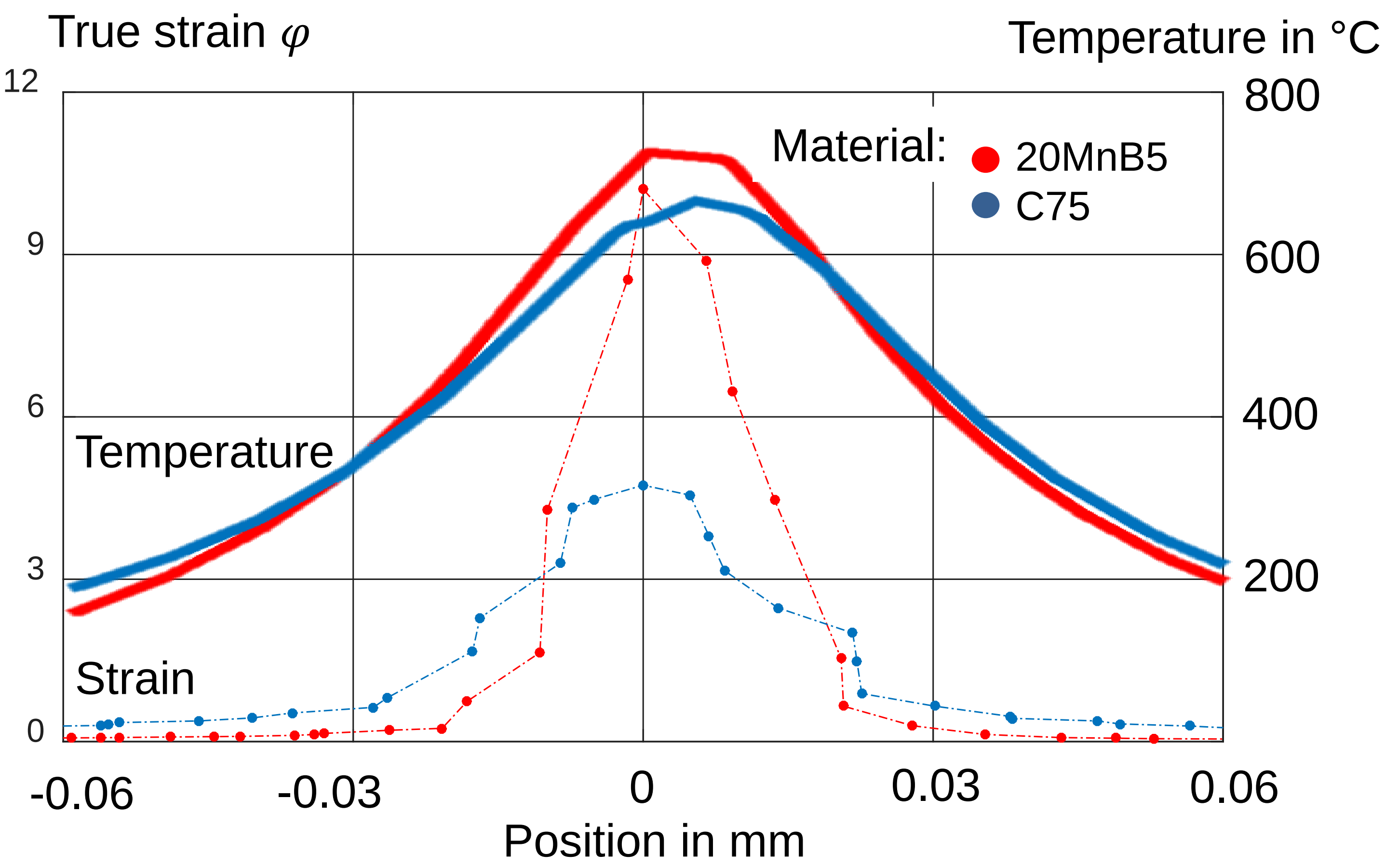



Source: CIRP Annals
Schmitz et al.

# Shear band properties




Converged mesh

Local strains of $\varepsilon \geq 9$ feasible?

- High local strains for 20MnB5

  → Higher gradients of temperature



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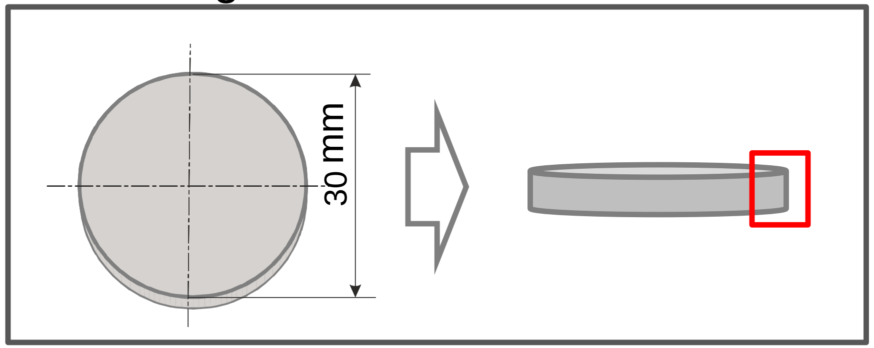
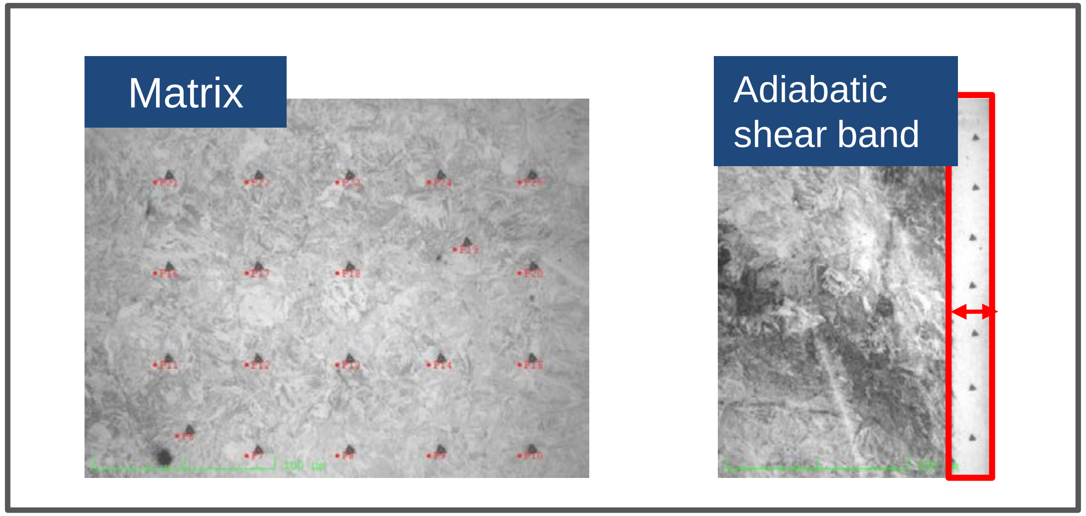
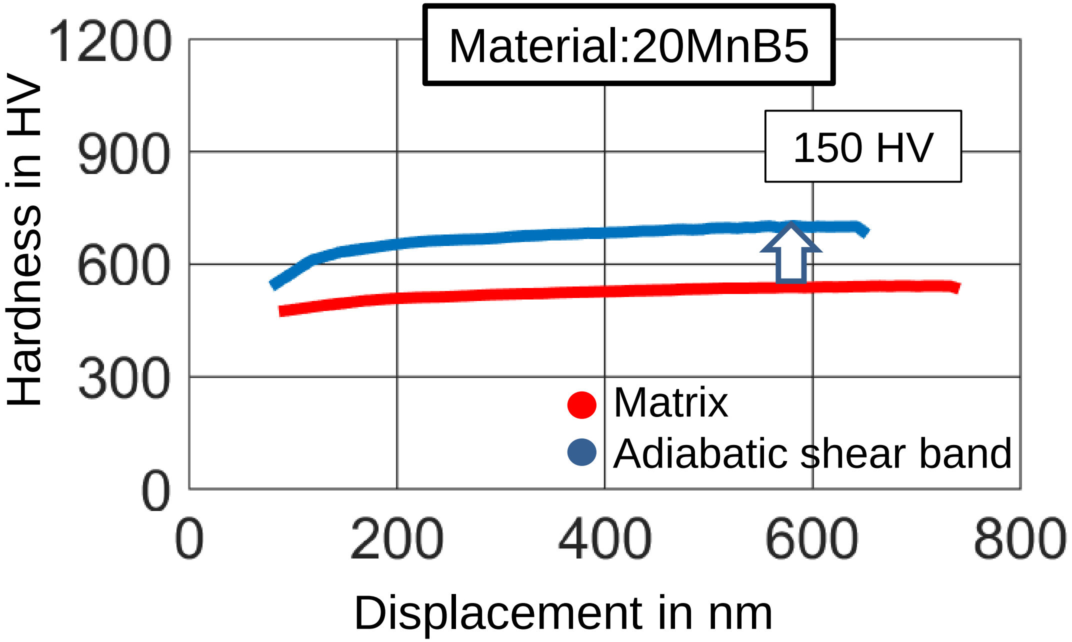
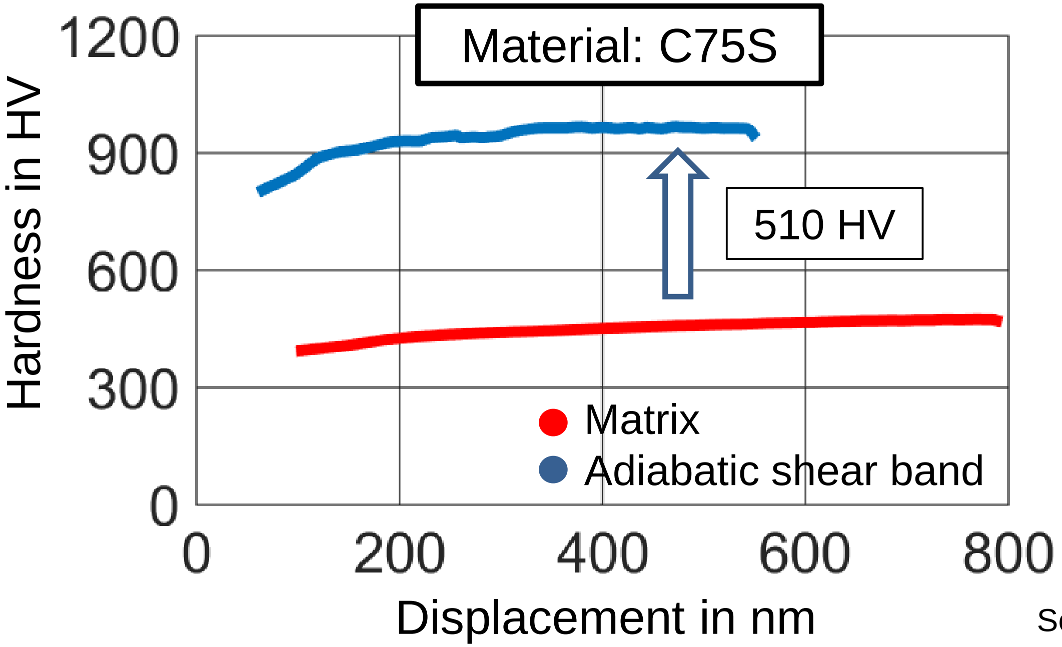
# Shear band properties (Nanoindentation)

Investigation of demonstrator




Source: Schmitz et al., 2020, CIRP Annals.

# Temperature dependent fracture criterion

## Normalized Cockcroft-Latham criterion

$$\int_0^{\bar{\varepsilon}_p} \frac{\sigma_1}{\bar{\sigma}} \, d\bar{\varepsilon}_p < C_0$$

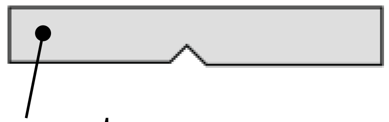
Modification

$$\int_0^{\bar{\varepsilon}_p} f(T) \frac{\sigma_1}{\bar{\sigma}} \, d\bar{\varepsilon}_p \leftarrow \; C_T(T) = C_0 * g^*(T)$$

Charpy impact test

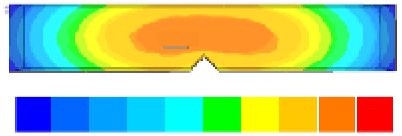
## Correction of temperature

Charpy specimen

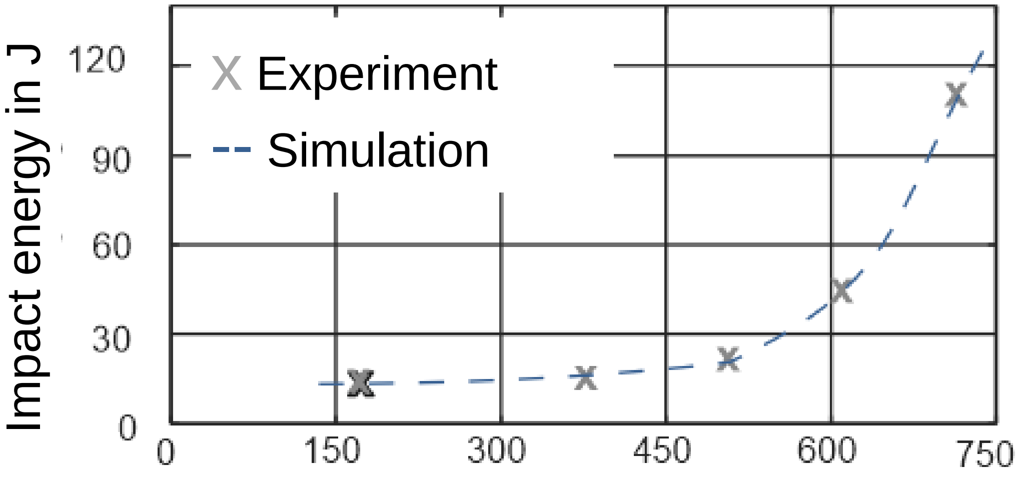


Temperature measurement

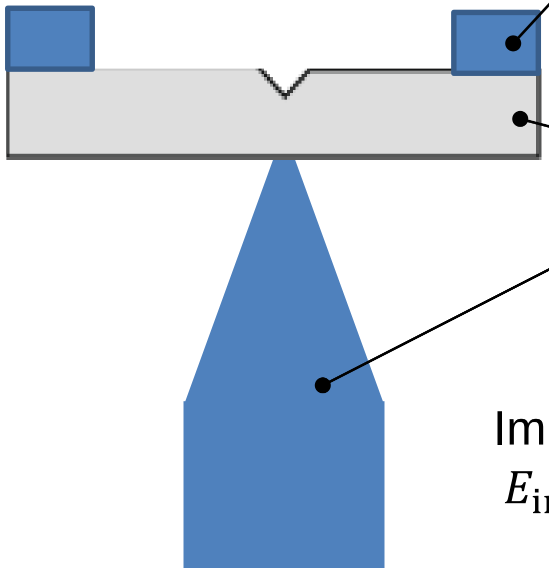
Temperature distribution




Material: C75



# Temperature dependent fracture criterion

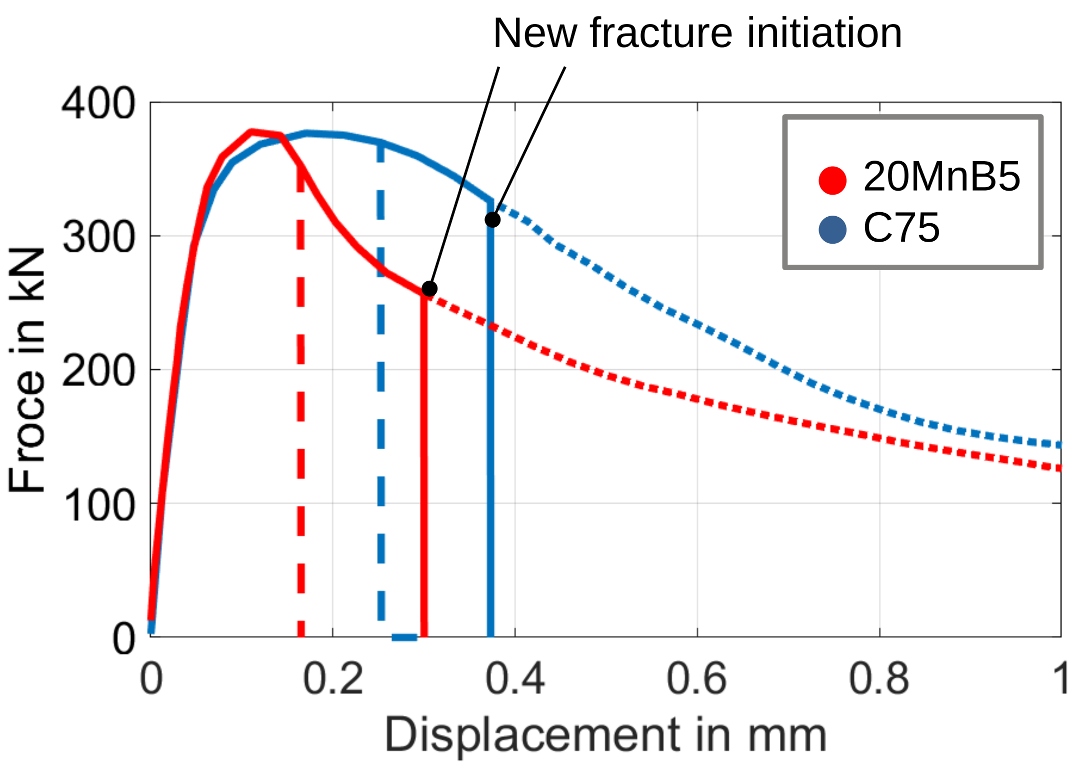



Impact energy:

$$E_{\mathrm{imp}} = 0.5 * m_{\mathrm{h}} * (v_0^2 - v_1^2)$$

$$C_{\mathrm{T}}^{\mathrm{Exp}} \overset{!}{=} C_{\mathrm{T}}^{\mathrm{Sim}}(T) = \int_0^{\bar{\varepsilon}_{\mathrm{p}}} f(T) \frac{\sigma_1}{\bar{\sigma}} d\bar{\varepsilon}_{\mathrm{p}}$$

Simulation: Adiabatic blanking

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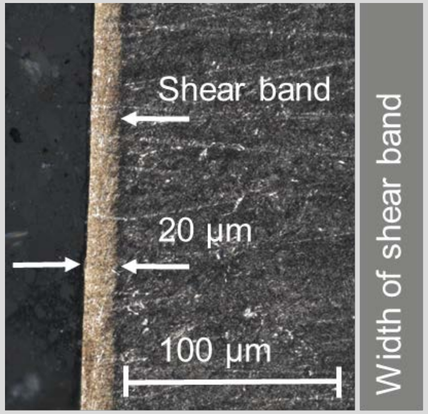
## Experiment




Higher speed leads to localization and adiabatic shear band formation

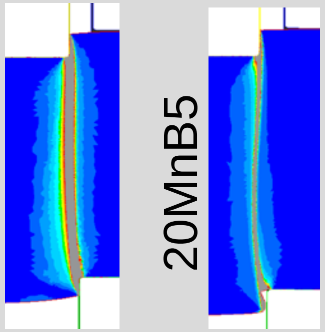
## Plasticity

Strain rate sensitivity

## Simulation

Prediction of adiabatic shear bands

C75S



20MnB5

Prediction of separation

**Excellent prediction of product properties needs**

- Material characterization
- Process knowledge
- Advanced modeling



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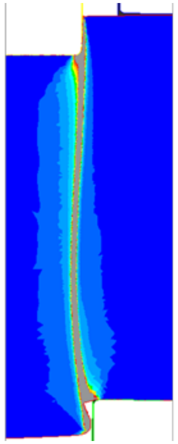
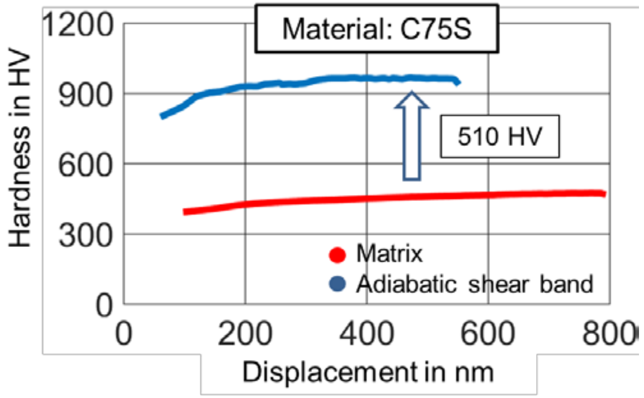
$$\int_0^{\bar{\varepsilon}_p} f(T)\,\frac{\sigma_1}{\bar{\sigma}}\,d\bar{\varepsilon}_p$$






Partner:

WERKSTOFF WISSENSCHAFT

# Thank you for your attention.

Deutsche Forschungsgesellschaft
(German Research Foundation)

**DFG Project:**
Effect of pre deformation on adiabatic blanking and their properties (edge crack sensitivity)

DFG number:
TE 508/84-1