ViRalForge

Virtual Reality for the Training and Development of Employees in Open-Die Forging

Moritz Gouverneur[1], Nikhil Jagtap[1], Christoph Klameth[2] and Boris Kantzow[3]

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[1] IBF, RWTH Aachen University

[2] Edelstahl Rosswag

[3] Weltenmacher GmbH

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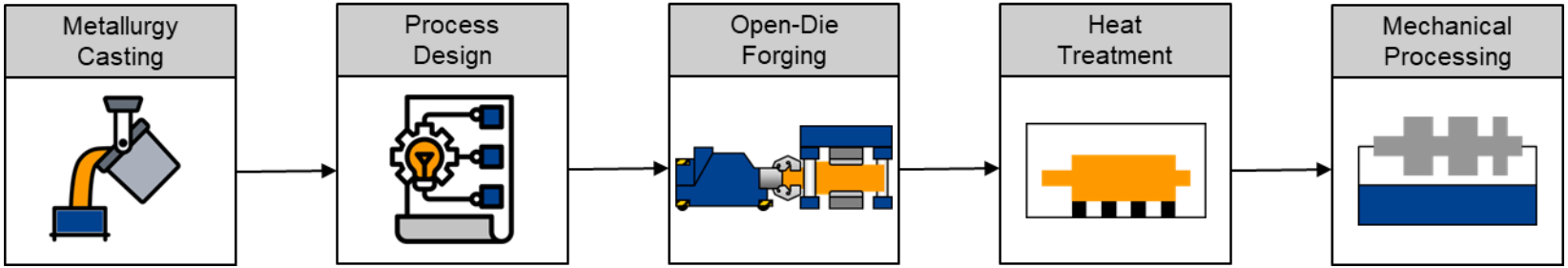
Open-Die Forging



Open-Die Forging

- The workpiece is heated to forming temperature (~1200 °C) in the furnace
- Positioning is performed using a manipulator
  - Press and manipulator are controlled using joysticks
- Stroke wise forming
  - Forging over a length is called a pass
  - Free material flow leads to complex deformation states
- Forging process results from several passes with a large number of strokes

Motivation

- Incremental forming process to produce highly loaded components with excellent material properties

- Process route defines product quality, energy requirements and material costs

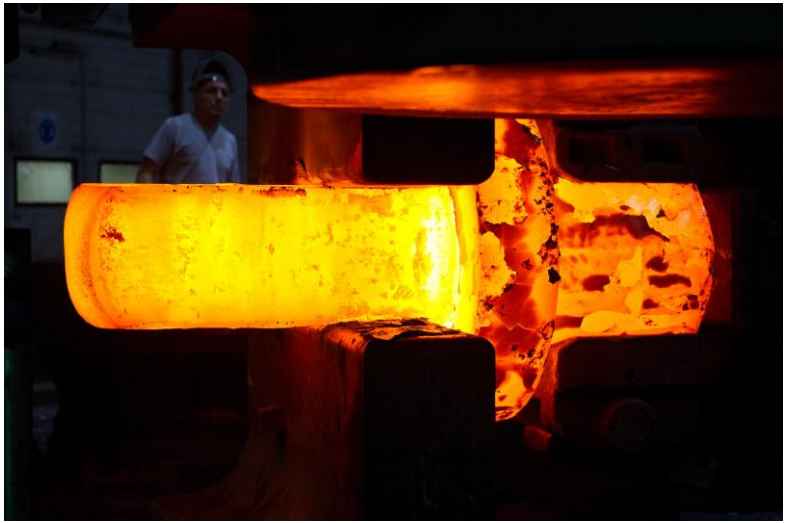
- Process design and execution is often reliant on experience

→ Machine operators and their training plays a key role in open-die forging!

- But: Today (new) employees can only be trained at the real forging plant

→ Production can be disturbed

→ Learning through trial and error not possible



Source: Rosswag

Training of Employees in Virtual Reality

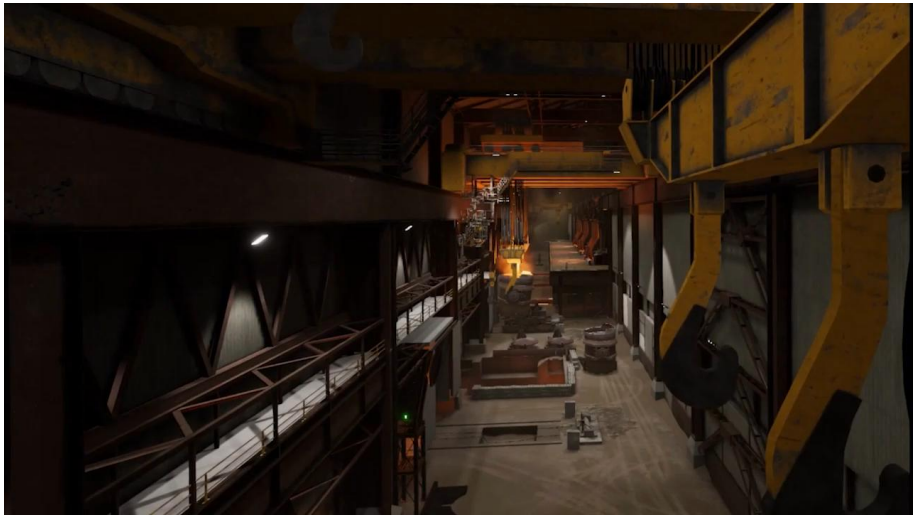
- Number of companies training employees in VR is growing

- Example from the steel industry: Seel Sim VR
  - crane driver training
  - Used by: Acelor Mittal & Tata Steel & Algoma Steel

- Users immerse into the virtual world

- Strong interaction between user and surroundings

→ Big positive impact on the learning process



Quelle: Steel Sim VR

Training of Employees in Virtual Reality

VR training is especially useful

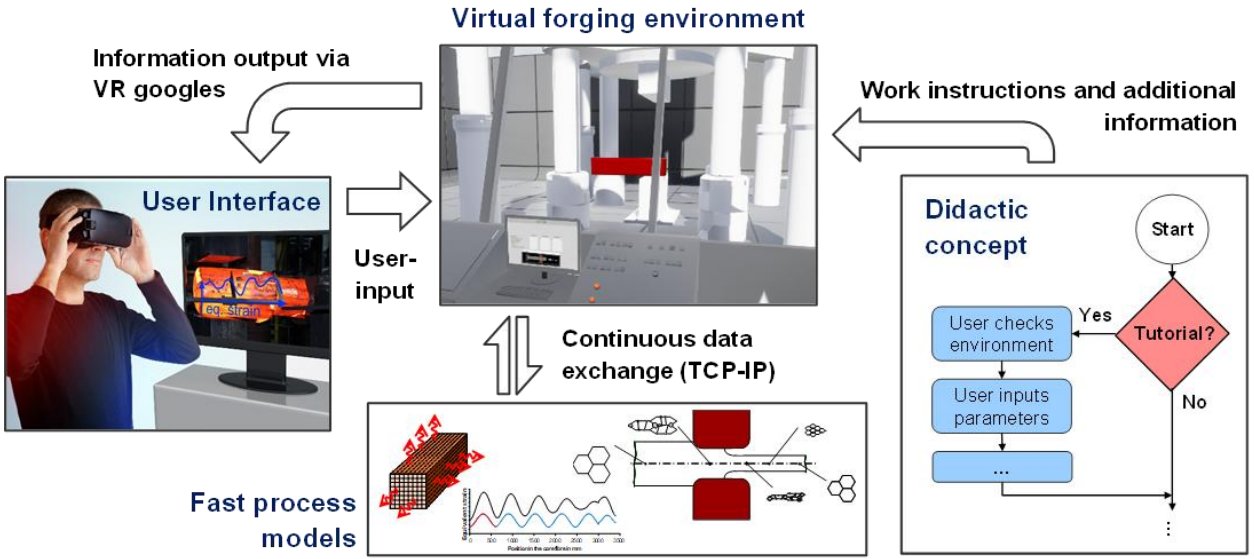
- for applications with high risk for humans or machines in use
- for applications with high costs
- whenever machines or equipment are not sufficiently present
- for situations that are improbable or cannot be physically recreated

→ **For open-die forging!**

Concept for virtual open-die forging

- Combination of fast process models, a virtual forging environment and a didactic concept
  - Realistic representation of visuals & acoustics for immersion
  - Fast process models ensure realistic representation of the physics
  - Training tool for employees in open-die forging!

  → **ViRalForge**



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Virtual Forging Environment

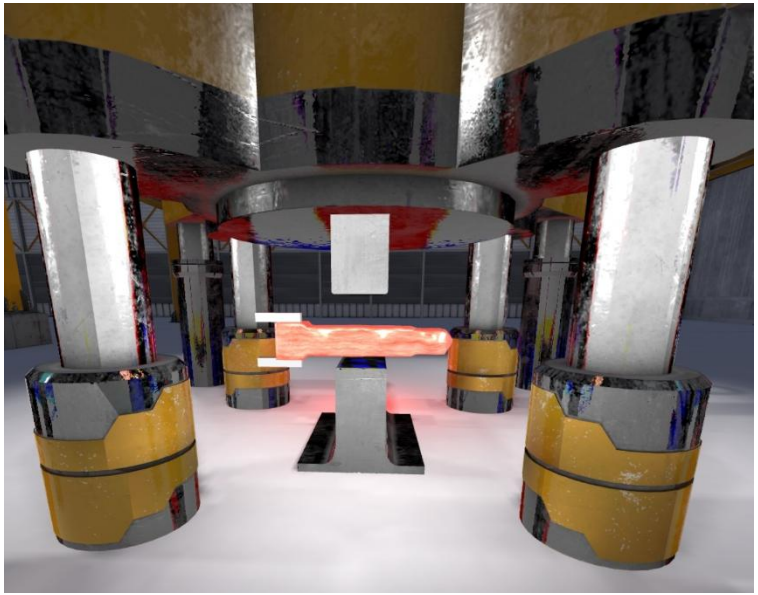
- Reproduction of the forging environment including:
  - Control panel with levers and buttons

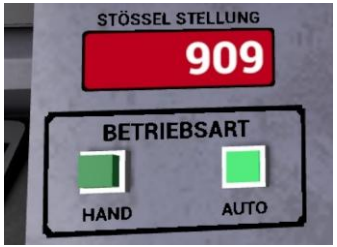
Original at Rosswag GmbH

Control panel in ViRalForge

Virtual Forging Environment

- Reproduction of the forging environment including:
  - Control panel with levers and buttons
  - Forging Press with a set of flat dies
  - Different operating modes (automatic vs. manual)

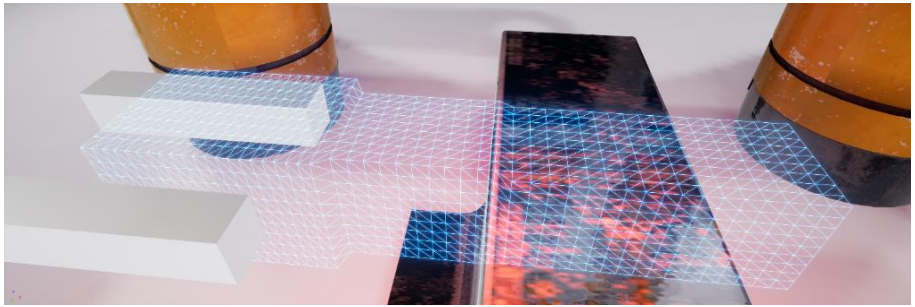




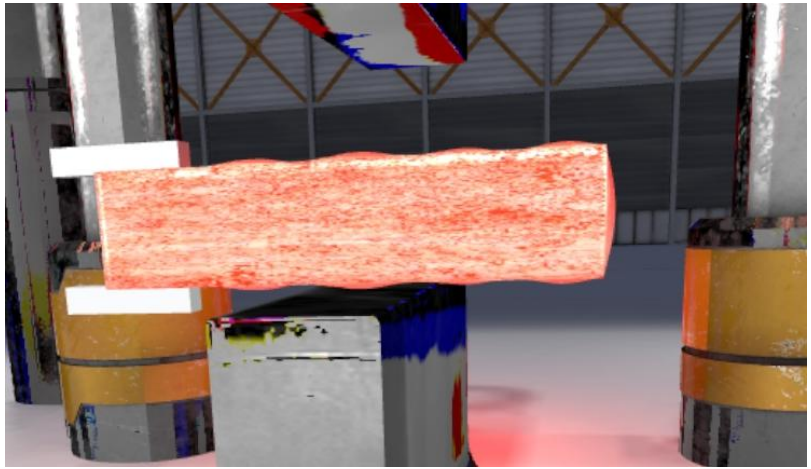
Forging Press
in ViRalForge

Virtual Forging Environment

- Reproduction of the forging environment including:
  - Control panel with levers and buttons
  - Forging Press with a set of flat dies
  - Different operating modes (automatic vs. manual)
  - Material flow using a 3D mesh and a spread model



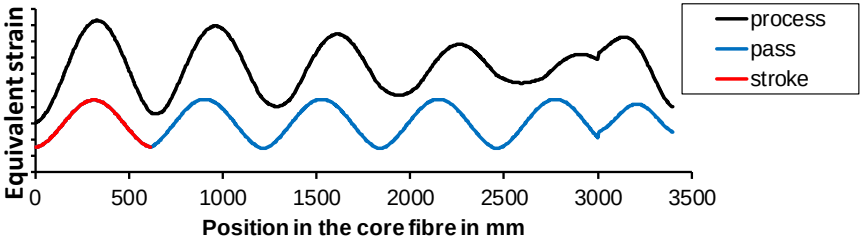
3D-Mesh for calculation of the geometry



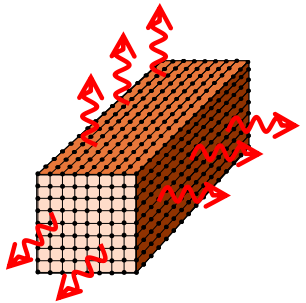
Virtual workpiece with spread contour

Fast Process Models for Open-Die Forging

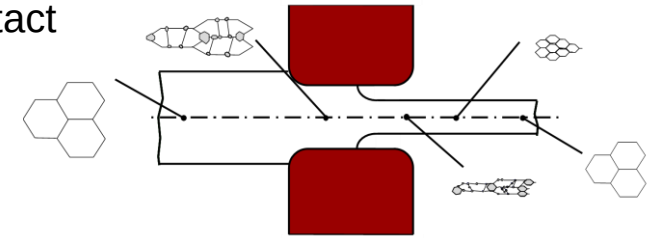
- Spread model by Tomlinson and Stringer
  - Adaption to indicate bulging or retraction on component surfaces



- Model for equivalent strain (core fiber)
  - $\sin^2$-function for each stroke
  - Superposition of the equivalent strain of single strokes over the whole forging process



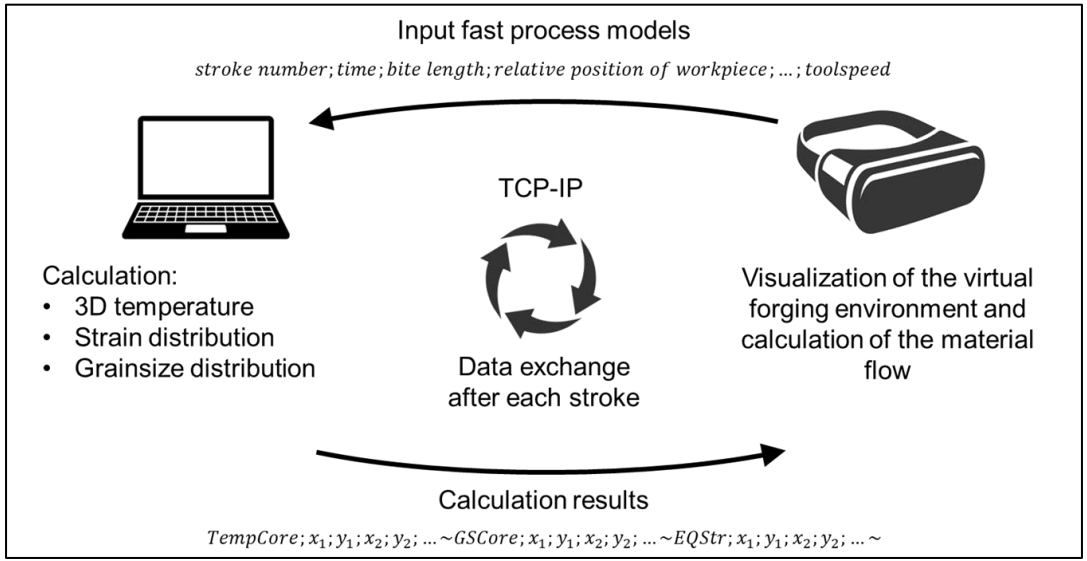
- 3D-Model for temperature
  - Based on finite difference method
  - Includes conduction, convection, radiation and tool contact



- Model for microstructure: StrucSim
  - Based on JMAK equations and Substructure modeling
  - Calculation of recrystallized fraction and grain size

Interface between Fast Process Models and VR Headset

- Motion sickness: Minimum speed of 60-90 FPS is required
- Fast models adapted and accelerated for VR applications (e.g., idle state)
- Reduce the calculation load on VR headset by calculating the fast process models on a separate PC
- Necessary communication between PC and VR headset via TCP/IP interface:



→ Successful connection of the fast process models to the virtual forging environment

Prototype ViRalForge

- Impressions from the control panel of the ViRalForge prototype:
  - General view

Prototype ViRalForge

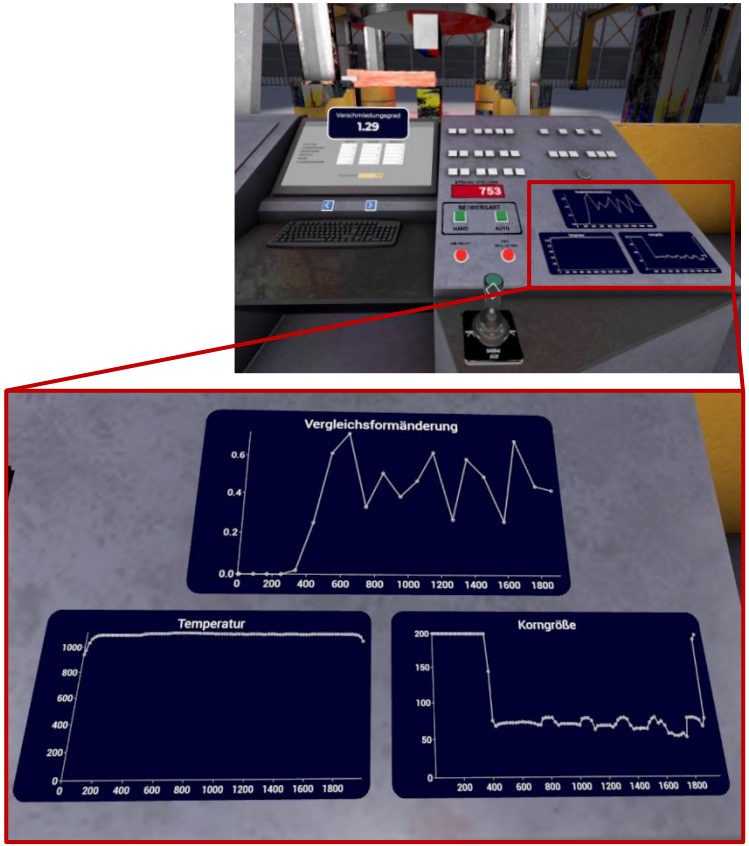
- Impressions from the control panel of the ViRalForge prototype:
  - General view
  - Operating the press

Prototype ViRalForge

- Impressions from the control panel of the ViRalForge prototype:
  - General view
  - Operating the press
  - Moving the workpiece

Prototype ViRalForge

- Impressions from the control panel of the ViRalForge prototype:
  - General view
  - Operating the press
  - Moving the workpiece
  - Forging with assistance system



Prototype ViRalForge

- Impressions from the control panel of the ViRalForge prototype:
  - General view
  - Operating the press
  - Moving the workpiece
  - Forging with assistance system

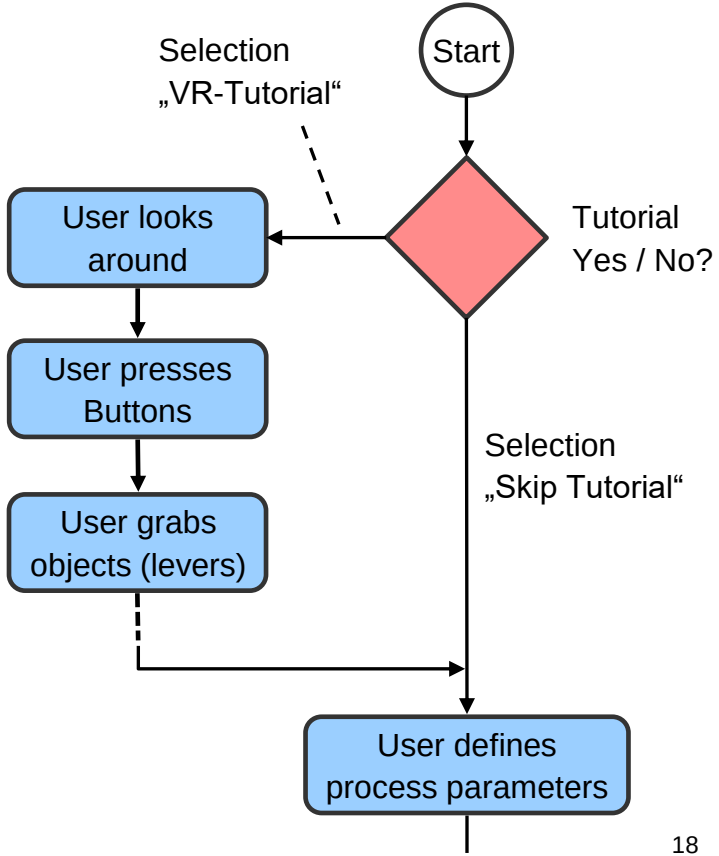
Didactic concept

- “sandbox mode” alone does not lead to consistent learning progress

→ A didactic concept is needed to guide the user through the virtual forging environment

- A didactic concept describes:
  - What is being learned?
  - When is what being learned?
  - How is something learned or taught?

- Close cooperation between Rosswag, Weltenmacher and the IBF for the development and preparation of
  - learning objectives
  - step-by-step work instructions
  - and additional information.



Didactic concept

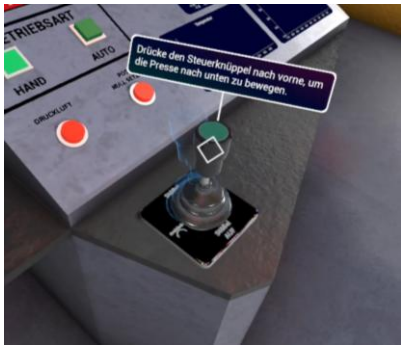
User passes through 3 levels:

Level 1: Operating the forging press

- Explanation of all buttons and levers

- What are the functions of the press?
  - Hand- vs. Automatic mode
  - Compressed air
  - Setting the reference point for press height
  - …

- How is a forging plan executed?



Quelle: Rosswag GmbH

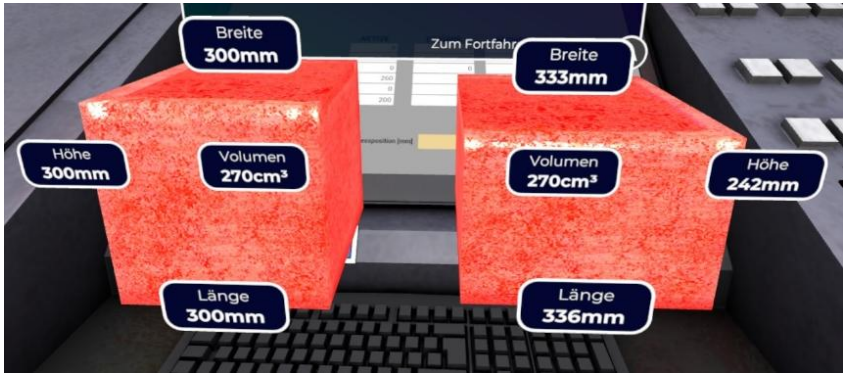
Didactic concept

User passes through 3 levels:

Level 2: General process knowledge and fundamental process parameters

- Fundamentals such as:
  - Material flow
  - Volume consistency
  - Shape change
- Important process parameters:
  - Bite ratio
  - Height reduction
  - Bite offset
- Influencing factors Press force

Volume constancy



Inhomogeneous material flow due to friction

Didactic concept

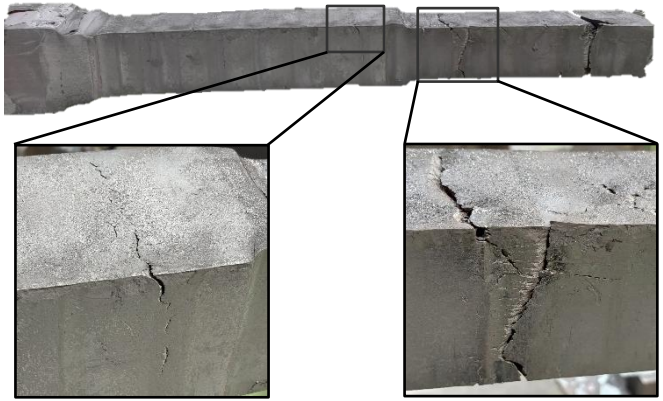
User passes through 3 levels:

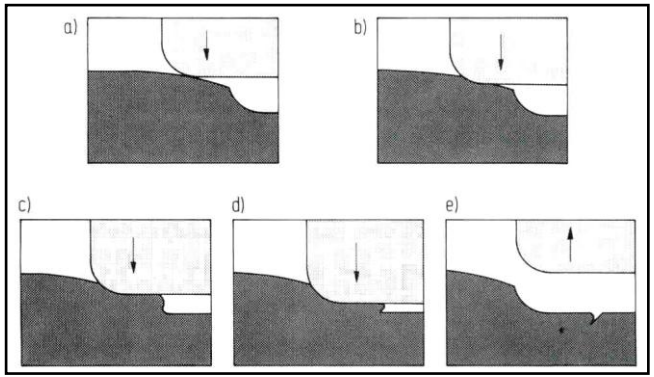
Level 3: In-depth process and material knowledge

- Strain distribution in the volume of the workpiece

- Forging strategies for special materials:
  - Titanium
  - Ni-based alloys
  - High-alloy steels

- Reasons and countermeasures for various forging defects:
  - Edge cracks
  - Overlaps



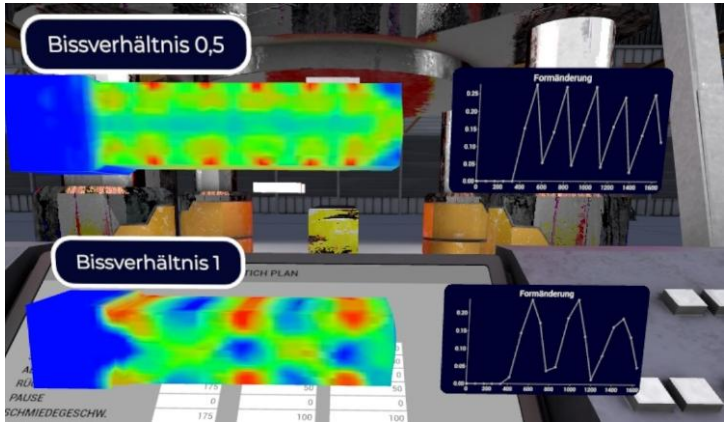


Quelle: Dahl, Kopp, Pawelski

Didactic concept

- Level 1 – fully implemented
- Level 2 – three lessons implemented:
  - Lesson 2.1: Material flow
  - Lesson 2.2: Shape change
  - Lesson 2.3: Bite ratio
- Level 3 – not implemented

- Instructional texts and images are supplemented by:
  - Virtual assistance system
  - 3D graphics/displays of various workpieces
  - Deliberately built-in “traps” such as an incorrectly zeroed press



Validation of VR training

- Evaluation with 30 volunteer participants
  - Brief introduction to the hardware
  - Completion of the four implemented lessons
  - Evaluation using a questionnaire

- Lots of positive and constructive feedback:
  - High recommendation rate
  - No cases of motion sickness

- People with no prior knowledge achieved an average of 6.5/9 points in the quantitative part
  - Expected value “pure guessing” = 2/9 points

→ Successful proof of initial learning success!

Summary

ViRalForge cooperation project successfully completed.

- Virtual forging environment established
  - Realistic graphics and acoustics
  - Design and function identical to real forging press
- Fast models ensure accurate representation of the process
  - Real-time connection via TCP-IP interface
- Three-level teaching concept developed
  - Learning objectives and work applications developed
  - Levels 1 and 2 (Lessons 1–3) implemented

→ Functional prototype developed and validated
Try it out!

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Outlook

- The project partners (Weltenmacher, Rosswag, IBF) intend to continue developing the virtual forging environment ViRalForge
  - Many open questions and potential for development
  - Not yet a finished product, but...
  - ...great overall potential for modern employee training in open-die forging

- Therefore, two parallel approaches:
  - Aim for further research project
  - Bring prototypes into industrial application

→ If you are interested in using ViRalForge, please feel free to contact us!

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Thank you for your attention!

Contactperson at IBF:
Nikhil Jagtap
Email: nikhil.jagtap@ibf.rwth-aachen.de
Tel.-Nr.: +49 241 8095943

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