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Abstract

Abstract refers to the topic:

Digitalisation and Artificial Intelligence in Forging

Transforming Forging Industry Practices with Advanced Material Simulation

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The forging industry is on the cusp of transformation due to the need to reduce energy consumption, carbon emissions, and dependence on critical raw materials. To overcome these challenges, it is necessary to reevaluate processing methods and develop new materials. This task can be costly and time-consuming. The trial-and-error approach in material and process development is prevalent. However, this approach generates excessive waste and contributes significantly to additional emissions. The energy sector, which heavily relies on turbines for gas, steam, and wind power generation, faces a similar challenge. The manufacturing of turbine shafts involves intricate processes, from casting and forging to a complex heat treatment regimen. These activities consume substantial materials and energy resources. Furthermore, the alloys used in such applications often include critical raw materials like Mo, Nb, and Ni, which are characterized by limited availability and high supply risks.

To address these concerns, the new Horizon Europe project *AID4GREENEST* is spearheading the development of sophisticated simulation tools. These tools are tailored to precisely forecast material behaviors, which is crucial in bolstering the steel sector. One of the project's key use cases is the development of a computational framework capable of predicting microstructure evolution during open die forging of large turbine shafts. At the heart of this simulation workflow is a mean-field model that combines microstructure evolution with thermo-mechanical material behaviors. The model is derived from a comprehensive thermodynamic framework and includes work hardening, recovery, recrystallization, and grain growth. It incorporates numerous coupling phenomena through a robust physics-based approach.

By integrating this material model with finite element software, the methodology enables precise prediction of local microstructures within forged shafts based on varying process parameters. This methodology significantly reduces time and resource consumption in process design through numerical simulations, revolutionizing conventional approaches in the forging industry. This promises to be an innovative stride in the manufacturing and alloy design paradigm of the sector.

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Brief biographies of the authors

- Dr. Lukas Kertsch

Lukas Kertsch joined the Fraunhofer IWM in 2014. He received his PhD in Mechanical Engineering from the Karlsruhe Institute of Technology KIT in 2022. His research focuses on the development of models for the thermo-chemo-mechanical behaviour and microstructure evolution of metallic materials. As a member of the research team “Forging” in the business unit “Manufacturing Processes”, he has worked on several projects related to the microstructure evolution of steels, copper, aluminum, and nickel-based alloys during hot forging, extrusion, and heat treatment.

- Dr. Maxim Zapara

Maxim Zapara joined the Fraunhofer IWM in 2012. He received his PhD in Mechanical Engineering from Tula State University in 2004 with a focus on damage mechanics of metals subjected to large plastic deformations. He is currently leading the research team “Forging” in the business unit “Manufacturing Processes”. The team's activities are focused on characterizing, modelling and simulating material behaviour and microstructure evolution in cold and hot forging processes.

- Dr. Dirk Helm

Dirk Helm joined the Fraunhofer IWM in 2006. He received his PhD in Mechanical Engineering from the University of Kassel in 2001. Since 2014, he heads the business unit “Manufacturing Processes” at the Fraunhofer IWM. His scientific focus is on the experimental investigation, modelling and simulation of materials, processes, and components within the framework of thermodynamics. Continuum mechanics and materials theory combined with data science and machine learning are his main research areas.