MM 20: Topical Session: Fundamentals of Fracture – Microstructure Impact on Fracture (Experiments)

Time: Tuesday 14:15–15:30 Location: SCH A 216

MM 20.1 Tue 14:15 SCH A 216

Fatigue damage prediction using graph neural networks on microstructure representations — •Ali Riza Durmaz[1,2,3], Akhil Thomas[1,2], Chris Eberl[1,2], and Peter Gumbsch[1,3] — [1]Fraunhofer Institute for Mechanics of Materials IWM, Freiburg im Breisgau, Germany — [2]University of Freiburg, Freiburg im Breisgau, Germany — [3]Karlsruhe Institute of Technology, Karlsruhe, Germany

Crack initiation governs high-cycle fatigue (HCF) life and makes HCF very susceptible to microstructural details. Predicting microscopic cyclic plasticity in polycrystals requires thorough microstructure representations.

In this work, we compare phenomenological crystal plasticity models with graph machine learning models on the task of predicting local cyclic plasticity in ferritic steel (EN1.4003). A workflow is presented which consists of a combined experimental and data post-processing pipeline to establish fatigue damage/crack initiation and short crack propagation data sets efficiently. It evolves around fatigue testing of mesoscale specimens to increase damage detection sensitivity, data fusion through multi-modal registration to address data heterogeneity, and image-based data-driven damage localization. The resulting data fuels both crystal plasticity and graph machine learning efforts. For the latter, the pixel data is transcribed into graph representations of the microstructure before being fed to different graph neural network variants. Interpretability techniques are applied to the machine learning models to learn about driving forces for the formation of extrusions and protrusions in individual grains.

MM 20.2 Tue 14:30 SCH A 216

analysis of plasticity in cyclic compression precracking — •mohamed amine faham, nathalie limodin, jean françois witz, and jérôme hosdez — Univ. Lille, CNRS, Centrale Lille, UMR 9013 - LaMcube - Laboratoire de Mécanique, Multiphysique, Multiéchelle, F-59000 Lille, France

Determining whether a defect will grow or not is of outmost importance particularly for railway axles. In this context, compressive precracking is an interesting procedure to get fatigue crack growth threshold. Using this method, specimens are precracked with both maximum and minimum compressive loads. This study uses fracture mechanics analysis, digital image correlation (DIC) and finite element method (FEM) to assess compressive plastic zone and precrack length ahead of a SENT specimen notch.

The DIC strain field in the direction of loading shows the evolution of the monotonic compressive zone ahead of the notch with increasing load. Other techniques were used to assess the plasticity ahead of the notch and to verify DIC vertical strain field results. One technique consists of projecting (in the least squares sense) the measured DIC displacement fields on Williams' basis. The difference between the DIC vertical displacement field and the analytical one highlights the plasticity in the notch region. A coupled DIC-FEM simulation with boundary conditions issued from DIC displacement fields applied on a numerical model of the specimen with inelastic material behavior was done in order to verify the extent of the compressive plastic zone and to estimate the compressive precrack length.

MM 20.3 Tue 14:45 SCH A 216

Microstructural damage analysis in a DP800 steel subjected to complex strain paths — •Maximilian A. Wollenweber, Luiz R. Guimarães, Nicole Lohrey, Setareh Medghalchi, Talal Al-Samman, and Sandra Korte-Kerzel — RWTH Aachen, Aachen, Germany

During forming processes, initiation and evolution of microstructural damage sites have a strong negative influence on the mechanical properties of the finished product. It is therefore important to investigate the damage behavior during deformation and unravel its relationship with the strain path. The current work investigates the microscopic damage evolution in a dual-phase steel DP800 subjected to different loading scenarios in tension and bending. The aim is to elucidate how the strain path influences the initiation and growth of microstructural damage in order to design more damage-tolerant industrial forming processes. The methods used comprise machine-learning algorithms and in-situ testing in a scanning electron microscope to observe and classify damage sites in the deformed samples. The results show that strain hardening inhibits damage formation, while pre-existing damage sites tend to facilitate further damage formation.

MM 20.4 Tue 15:00 SCH A 216

Three-dimensional characterization of damage sites and strain dependence in dual phase steel — •Setareh Medghalchi[1], Binbin Lin[2], Joscha Kortmann[1], Bai-Xiang Xu[2], Ulrich Kerzel[3], and Sandra Korte-Kerzel[1] — [1]Institute for Physical Metallurgy and Materials Physics, RWTH Aachen University, Aachen, Germany — [2]Mechanics of Functional Materials Division, Institute of Materials Science, Technische Universität Darmstadt, Darmstadt, Germany — [3]Fakultät für Georessourcen und Materialtechnik, RWTH Aachen University, Aachen, Germany

High performance materials like dual phase steels possess a heterogeneous microstructure resulting in the unique interplay between the two phases. High resolution scanning electron microscopy serves as a tool to unravel many of the microscale properties related to the deformation and mechanical properties of these materials. Damage sites in the microstructure serve as the main controlling feature during deformation. There are two fronts to tackle for a deeper understanding of the global damage accumulation: First, bringing high resolution analysis to large scales, and second, moving from two dimensional to three-dimensional characterization. We approach this challenge by employing slice-and-view SEM sectioning in combination with automated convolutional neural networks. With the knowledge of the damage occurring in different positions with various local conditions, we combine some related parameters to capture not only the trajectory of the damage sites inside the volume of the sample, but also the relative local stress-strain distribution condition.

MM 20.5 Tue 15:15 SCH A 216

Experimental and computational crack growth analysis under in-phase and out-of-phase thermo-mechanical fatigue — •Valery Shlyannikov, Aleksandr Sulamanidze, and Dmitry Kosov — Kazan, Russia

This study presents interpretation and evaluation of non-isothermal experimental crack growth data generated by tests carrying out by stress-controlled in-phase (IP) and out-of-phase (OOP) thermo-mechanical fatigue (TMF) conditions. A crack growth testing method has been developed utilizing inductive heating and direct the crack tip opening displacement (CTOD) techniques for polycrystalline XH73M nickel-based alloy. The crack growth experimental results interpretation is based on finite element analyses of the mechanical stress-strain rate fields at the crack tip and new fracture resistance parameters. To this end, an algorithm for multi-physics numerical calculations was developed and implemented by incorporating Maxwell 3D, Fluent, and the transient structural modules of ANSYS 2021R1, to understand the mechanics of crack tip deformation under thermo-mechanical loading conditions. Fatigue fracture diagrams build in terms of new crack growth parameters have shown that in-phase testing produces accelerated crack growth rates compared with out-of-phase due to increased temperature at peak stress and therefore increased time dependent crack growth.