Influence of applied stress on dynamic strain ageing – experiments and enhanced model formulation

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Dynamic strain ageing (DSA) and the associated Portevin–Le Chatelier (PLC) effect continue to present significant challenges for constitutive modelling, particularly when deformation paths depart from simple monotonic loading. Many established modelling approaches, including those based on the Estrin–McCormick framework, employ an ageing-time variable to represent the diffusion-controlled interaction between solute atoms and dislocations. Although this concept enables the reproduction of key features of DSA, the classical evolution equation proposed by McCormick does not clearly define the mechanical conditions under which the ageing time should accumulate. Consequently, ageing-time evolution is commonly assumed to proceed continuously, which can introduce non-physical hardening contributions in simulations involving holding times, unload–reload sequences, or other non-monotonic loading scenarios.

The aim of this talk is to address this limitation by combining experimental observations with modelling considerations. To this end, tensile tests with prescribed waiting times are conducted on the aluminium alloy AW5083. These experiments are designed to quantify strain ageing during distinct stages of deformation and to evaluate the influence of the applied stress level during short waiting intervals on the subsequent material response.

On the basis of these experimental findings, a modified evolution equation for the ageing time is proposed. The formulation preserves the fundamental structure of the Estrin–McCormick approach but introduces a stress-dependent criterion that restricts ageing-time accumulation, in accordance with the experimental observations. This modification suppresses the unintended growth of DSA-related hardening that can arise in the classical formulation, without adding complexity to the constitutive model.

Comparisons between simulations using the classical and the modified approaches show that both capture the general characteristics of the PLC effect. However, the enhanced model provides more consistent predictions for non-monotonic loading paths and exhibits improved agreement with the experimental results for AW5083. The proposed refinement thus offers a practical improvement for the application of DSA models in finite element simulations that must represent realistic loading histories.

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