

Thermo-mechanical analysis of propagating instabilities in metals – from experiments to reliable numerical prediction

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Unstable behaviour of materials involves localized deformation modes, in which deformation concentrates in narrow bands of the material while the rest of the specimen undergoes unloading. Material instabilities significantly affect material properties such as ductility, strength and fatigue resistance and can eventually lead to failure of the structure. In this project special attention is paid to the observation and prediction of propagative instabilities, so-called Lueders bands and Portevin–Le Châtelier (PLC) effect, which occur in plastic flow processes. This requires large strain thermo-mechanical models that capture the initiation and evolution of these bands at different loading rates and temperature levels (from room temperature up to 200°C), and advanced experimental investigations in the context of model parameter identification.

As an example, the response involving Lueders bands is presented below in the results of a pilot experiment and simulation of an aluminium dog-bone shape specimen under tension in room temperature. The numerical results on the right differ from the respective experimental deformation patterns obtained using so-called Digital Image Correlation (DIC) technique. This shows the simulation model should be improved and its parameters should be identified.

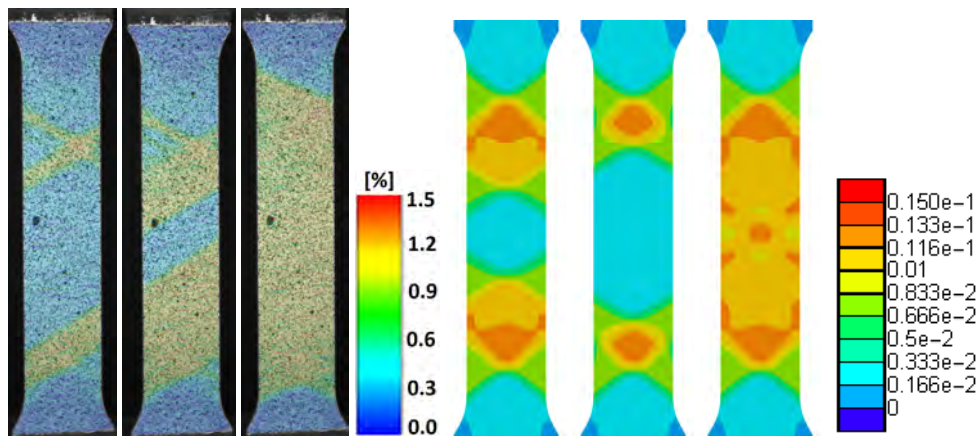


Figure 1: Uniaxial tension of aluminium specimen – experimental and simulated distributions of engineering strain for a sequence of time moments.

The goal of this project is to elaborate a complex simulation model that enables a reliable prediction of Lueders bands and the PLC effect, and which is identified on the basis of full field displacement and temperature data (thermography is the second observation technique used in addition to DIC). The research is divided into three work packages: 1) laboratory experiments to be performed at TU Dortmund University, 2) advanced thermo-visco-plastic modelling framework to be developed at Cracow University of Technology, 3) formulation and application of parameter identification strategy, leading to satisfactory agreement between experimental and simulation results, to be worked out by both cooperating teams.

The outcome of this research has important implications for mechanical and civil engineering. Deeper understanding and expansion of knowledge on instability phenomena, as well as the formulation of the reliable numerical models capable of reproducing unstable behaviour of materials and their progressive failure, lead to a safer design of structures in extreme loading conditions. Moreover, the research results are of key importance for a resource-efficient design of structural components made of materials exhibiting these phenomena, in particular metal alloys.