DFG project "Experimental and numerical determination of correlations between process variables of thermo-mechanical treatment and mechanical properties in graded mixed structures with bimodal grain size distribution".

The ILH members - Prof. Dr.-Ing. Habil. Mirko Schaper (Chair of Materials Science) und Prof. Dr.-Ing. habil. Rolf Mahnken (Chair of Engineering Mechanics) - have been granted a three-year extension of a project at the German Research Foundation (DFG) on June 23, 2022. The aim of the project is the simulation-based determination of the relationships between process variables of thermo-mechanical processing and the resulting graded microstructure with bimodal grain size distribution.

To reduce CO2 emissions in the transport sector, the approach of load-adapted components is increasingly being pursued to reduce the overall vehicle weight. By applying graded thermo-mechanical processing, components with mixed microstructures and grain sizes can be produced, which are specifically tailored towards specific load or crash case. The simulation-based process design of such multi-stage thermo-mechanical treatment enables a reduction of the experimental effort and a targeted adjustment of the properties.

During thermo-mechanical treatment, a variety of micromechanical phenomena occur that strongly affect the macroscopic properties of steels. The process for generating bimodal microstructures is divided into three subprocesses. The sub-processes are intercritical annealing (I), work hardening (II) and recrystallization annealing (III). The process temperature and the applied deformation are shown schematically.

The evolution of the phase fractions is described by internal variables and is shown on the mesoscale in Figure 1. During intercritical annealing (I), the purely ferritic microstructure partially transforms into austenite and forms a mixed ferritic/austenitic microstructure. Subsequent quenching converts the austenitic portion of the mixed microstructure into martensite. During cold forming, dislocations are formed, caused by plastic deformation. This eventually leads to an increase in dislocation density and stored energy. During recrystallization annealing after cold working, static recrystallization and precipitation of carbides occurs, allowing nucleation and grain growth restricted by the finely dispersed carbides to relax the martensitic microstructure fraction and form fine ferritic grains. The combination of large grains and newly formed small grains constitutes a bimodal ferritic microstructure. This allows desired properties, such as high fatigue strength or better corrosion resistance, to be set. Within the scope of the project, graded mixed microstructures are generated to produce simulation-based components, which possess the desired bimodal grain size distribution.

The main objective in the field of materials science is the experimental determination of the formation of mixed microstructures with bimodal grain size distribution and the development of a model for the description of the process-microstructure-property correlations.

The main objective in the field of engineering mechanics is the simulation of the process chain using microscopic material models.

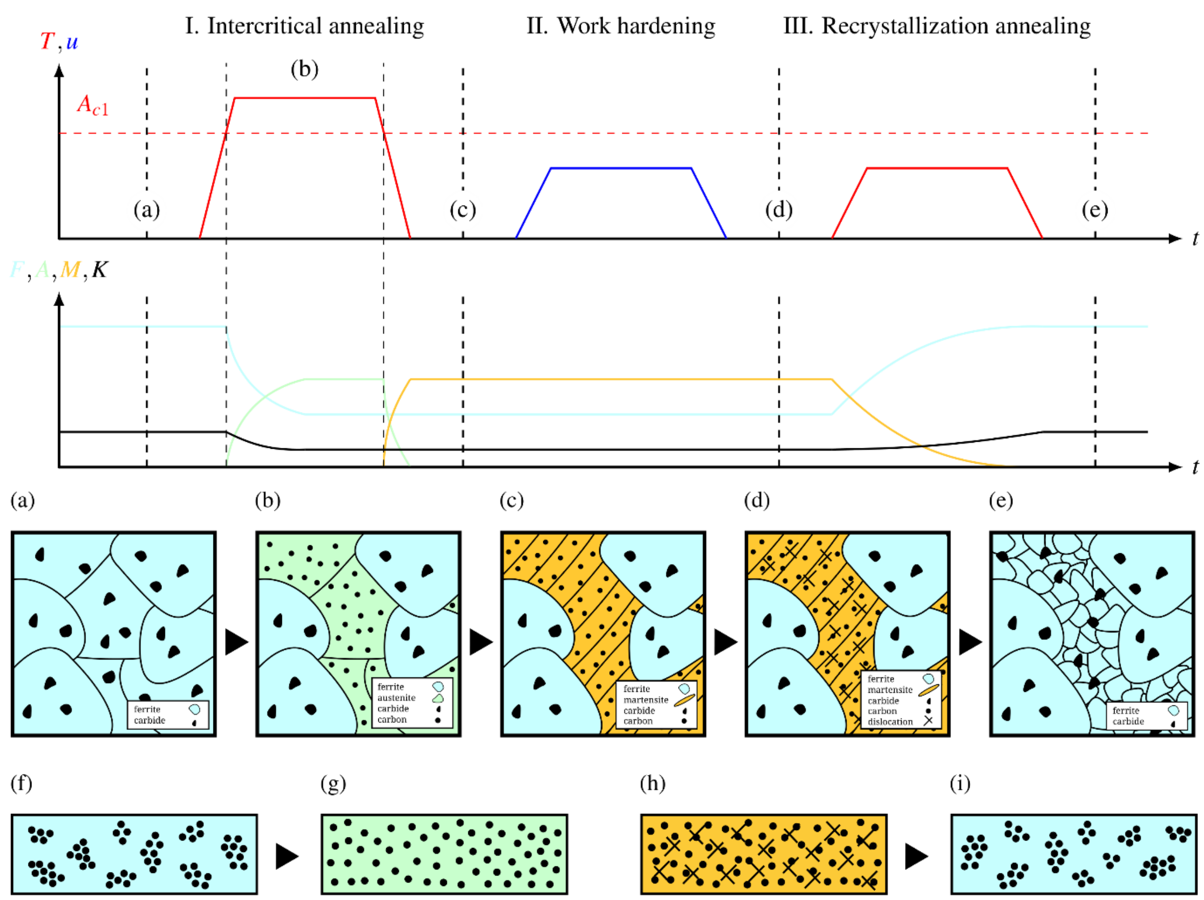

Figure 1: Microkinetics: (a)-(b) Transformation from ferrite to ferrite/austenite, (b)-(c) Transformation from ferrite/austenite to ferrite/martensite, (c)-(d) Work hardening to raise dislocations, (d)-(e) Transformation from ferrite/martensite to bimodal ferrite, (f)-(g) Carbon equalization within a phase, (h)-(i) Carbon accumulation within a phase.