DEEP-LEARNING ASSISTED DAMAGE OBSERVATIONS ON THE MICROSCALE – A NEW VIEWPOINT ON MICROSTRUCTURAL DEFORMATION, FRACTURE AND DECOHESION PROCESSES

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In recent years, state-of-the-art micromechanical systems have given researchers the ability to observe deformation processes in-situ. While this technology enables a site-specific observation, this very achievement can turn into a major limitation: To deduct conclusions about the relevance of specific processes for the bulk material, a larger field of view than typically possible in microscale observations is often required.

Starting with the fundamental microstructural damage mechanisms in multi-phase microstructures - typically the fracture of brittle constituents and the ductile decohesion of various types of interfaces - a framework for recognition and automated classification of damage sites has been developed. This system enables the microscale observation of a significantly enlarged area up to the order of 1 mm², in-situ or post-mortem.

We applied high-resolution SEM panoramic imaging on in-situ deformed, miniaturized specimens under uni- and biaxial tension. Deep neural networks act as a tool for the automated recognition, tracking and classification of damage sites, according to the prevailing micromechanical mechanisms of local damage formation. Classifying thousands of relevant sites in seconds helps unravelling new insights about damage intensity, dominance of specific mechanisms as well as microstructural preferences for void initiation by introducing a statistically relevant data set.

The proposed method has been developed and tested on dual-phase steels as a study material and expanded for other materials with high mechanical contrast. Thus, the proposed framework delivers a powerful tool to couple highly-resolved in-situ observations of micromechanical processes to statistically and technologically relevant, large-scale observations, yielding a deeper understanding of the interplay of microscale deformation, damage initiation and evolution processes.

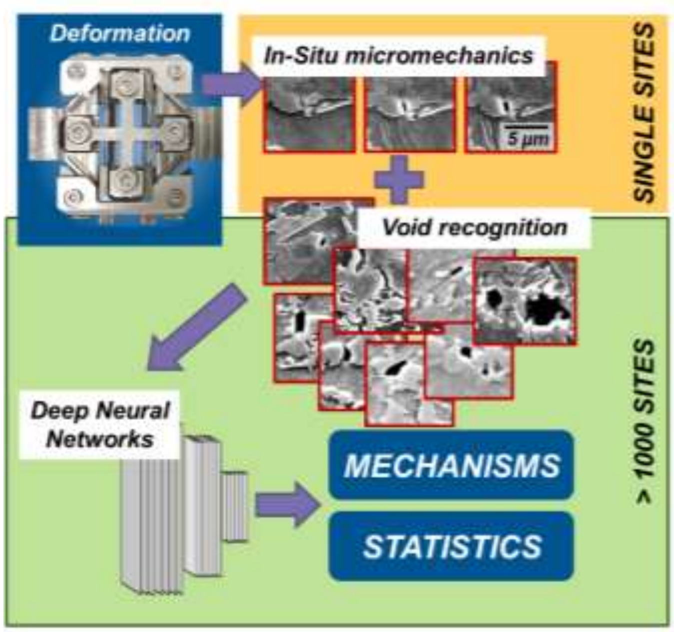

Figure 1: Automated recognition and classification approach for observed micromechanical processes on the example of in-situ damage formation