Impact of micro-scale residual stress on in-situ tensile testing of ductile cast iron: Digital volume correlation vs. model with fully resolved microstructure vs. periodic unit cell

The understanding of the mechanisms controlling deformation of ductile iron at the micro-scale and their coupling to the manufacturing conditions is still far from complete. In this respect, recent synchrotron-based studies have demonstrated that the thermal contraction mismatch between the graphite particles and the matrix during solid-state cooling leads to a complex residual stress state in the microstructure. To investigate its impact on the room-temperature tensile deformation, a computational-experimental analysis extendable to other similar composite materials is presented in this paper. First, a miniaturized specimen is loaded and imaged in-situ with X-ray tomography. Then, the microscale displacement is reconstructed using digital volume correlation (DVC) and used to prescribe the boundary conditions in a finite element model of the full microstructure between two cross-sections. The model predictions at both the macroscale – tensile force and lateral contraction – and the microscale – strain field – are compared to the corresponding experimental and DVC-based data for several choices of the initial stress state, particles’ mechanical behavior and strength of the particles-matrix interface. It is proved that the micro-scale residual stress and a low interface strength are the key to explain the early stages of the tensile deformation of ductile iron. Finally, it is shown that a simple unit cell model of the microstructure would lead to significantly different results, thus demonstrating the superior accuracy and robustness of the present approach.

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