A Machine Learning based Framework to Predict Local Strain Distribution and the Evolution of Plastic Anisotropy & Fracture in Additively Manufactured Alloys

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Abstract
In the present work, an ML based framework is proposed to predict the evolution of local strain distribution, plastic anisotropy and failure during tensile deformation of AlSi10Mg aluminum alloy produced by selective laser melting (SLM). The framework combines the procedures involved in additive manufacturing (AM) and artificial intelligence (AI) including printing of test specimens using laser powder bed fusion (LPBF), x-ray computed tomography (CT) scanning to measure internal defects distribution, mechanical testing with digital image correlation (DIC) to get local strain evolution, extraction and coupling of CT and DIC data, and the development, validation and evaluation of an artificial neural network (ANN) model. The experimental data from CT and DIC measurements are used to train, validate and evaluate the proposed ANN model. Microstructural features such as the size, shape, volume fraction and distribution of porosity are used as an input to ANN. The proposed ANN model successfully predicts the evolution of local strains, plastic anisotropy and failure during tensile deformation. The intensity and location of strain hotspots as well as the shape of shear bands and the location of crack initiation are well predicted. The current research demonstrates the applicability of an ML based ANN approach to predict microstructure – property – performance relationships for engineering materials with intricate heterogeneous microstructures such as those produced additively by SLM. The success of the present approach motivates further use of ML techniques, as a mean for accelerated development of new alloys, AM process optimization and its wide scale applicability.