Failure Prediction in Additive Manufacturing Processes

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Failure prediction is a challenge in manufacturing processes in general, and it is more so in additive manufacturing (AM). The melting of a few microns deposited in a layer-by-layer approach in AM processes results in a severe thermal gradient that causes thermal stresses which can lead to significant deformation of the part being built and lead to cracking of the part and support structure during the build process. Failure due to cracking of the part or the support can account for over 50% of the cost associated with developing complex parts in AM and can result in a significant loss of time for parts that takes days and weeks to build.

Currently, there is no criterion for predicting when a crack is likely to initiate during the build process or during further post-processing heat treatments. Moreover, most of the metal alloys currently being used in AM are taken directly from casting or wrought alloys with no special adaptation to the microstructural challenges (re-crystallization, precipitate distribution, metastable phases, etc.) that AM presents. Efforts are underway to develop alloys specifically adapted to AM in the literature but one of the main challenges is the characterization of the susceptibility of the new alloys to cracking. Consequently, our talk will focus on numerical simulations and experiments for use in predicting failure initiation in additive manufacturing. Specifically, we shall be discussing: (i) specimen geometries that can be used to determine the susceptibility of different alloys to cracking and (ii) the development of a criterion including triaxiality effect that could be applied across the different stages of the AM process for predicting crack initiation. These will lead to a better understanding of what features in a part design are likely to lead to failure for possible re-design before the part is built.

Several tools are available in the literature (GeonX, Netfabb, Simufact, Amphyon, Atlas3D, ANSYS, ABAQUS, etc.) specifically targeted at predicting distortion and re-coater interference during the build process for powder bed AM processes. These tools either use pure elastic or elastoplastic models in their simulations. The effect of these modeling assumptions will be examined to determine their suitability for predicting crack initiation using the criterion and specimen geometries discussed above.

Keywords: Additive manufacturing, failure modeling, crack initiation, failure criterion, triaxiality effect