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Analytical pretraining of artificial neural network models to mitigate limited experiment data availability in the L-PBF melt pool dimensions and densities predictions.

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ABSTRACT

Integrating new metals or metallic alloys into the portfolio of Laser Powder Bed Fusion (L-PBF)-ready materials is a non-trivial problem requiring expensive and time-consuming developments. Numerical tools are used to help in this development, but they are not without drawbacks. Using simplified models reduces the applicability of simulations results, while more complex and accurate models require extensive development and parametrization to work properly. Machine learning algorithms, and in particular deep learning techniques, hold considerable promise in addressing the challenges associated with material development. However, one of the main difficulties in the implementation of these models consists in a sparse quantity of data available for their training.

This study aims to assess the performances of a novel method for training the Artificial Neural Network (ANN) deep learning model of the L-PBF process capable of predicting the melt pool dimensions and the density of produced parts, which are representative of print quality. The proposed approach is to generate a basic version of this model using an extensive database generated by numerical simulations, which do not require significant resources. The basic model is then refined using less numerous but more precise experimental data. At each step, the model performances are evaluated using experimental data excluded from the training.

For this case study, numerical data were generated using the Ansys Additive 2022 “Single Bead” and “Porosity” modules. These modules were used to calculate 7340 sets of melt pool dimensions and 2336 printed densities for 8 different materials, as functions of the laser power and beam diameter, scanning speed and layer thickness. For the printed density calculations, hatching distance values were added. The experimental data for validation were generated for 7 different materials using an EOS M280 L-PBF system. The melt pool dimensions (width and depth) were measured on the produced single tracks, using optical microscopy, while the printed density was measured using computed tomography and microscopy.

This study showed that artificial neural networks are promising to help in the development of new alloys for additive manufacturing, and can be used to reduce the quantity of data necessary to develop powerful deep learning models. These models can be used as pre-trained models to be personalized in other labs with locally obtained data, thus taking into account the specificities of printing infrastructures.