MULTISCALE IMPREGNATION MODELING USING DEEP LEARNING

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Abstract

Fiber-reinforced composites (FRCs) manufacturing with liquid composite molding processes, such as resin transfer molding (RTM), involves impregnating a fabric with a polymer resin. Achieving high-quality production requires complete and fast mold filling at the macroscale and simultaneously impregnating the meso- and micro-scale pores within the preforms. Numerical methods are being increasingly used for addressing flow-related issues ranging from prediction of the permeability tensor of fabric unit cells to optimization of the process conditions to minimize the void formation and transport or to optimization of the mold design for fill time, weld lines, waste resin, etc. while taking into account the variable nature of fabrics. However, multiscale simulations to address the aforementioned processing issues are computationally expensive and this is mainly addressed by modeling the homogenized behavior at larger scales to maintain reasonable computational times at the expense of the phenomena at the smaller scales. Simulation performance degrades significantly when such phenomena are prominent, for instance in the presence of geometrical variability (e.g., corners, over/under-compaction areas) or material variability (e.g., ply drop-off, multi-material layups). To address this limitation, we are working towards bridging the scales through a computationally efficient framework accelerated using machine learning accelerated.

Figure 1 summarizes the typical processing issues we are addressing at all relevant scales. Previously, we have demonstrated that the prediction of microscale permeability is possible through the use of convolutional neural networks [1]. However, predicting the permeability of mesostructures in the presence of strong scale separation at the yarn boundaries or due to variation in fiber volume fraction (i.e., in the presence of resin-rich areas) has proven challenging. We hypothesize that this limitation calls for predicting the flow field instead of the permeability; and once trained using an appropriate database, a surrogate for steady-state flow shall provide improved results in the presence of scale separation. We are developing a machine learning-based surrogate for microscale steady-state velocity prediction using a model inspired by the U-Net architecture [2]. Results presented in Figure 2 highlight that there is an excellent match between the ground truth and the predicted flow fields, and post-processing of the network outputs through Darcy's law leads to improved permeability prediction accuracy compared to our previous work [1].

Based on these, our talk will detail the complete pipeline starting from the generation of the ground truth data using OpenFOAM to optimization of the U-Net architecture and our investigation for the use of our model in large domains that contain resin-rich areas.

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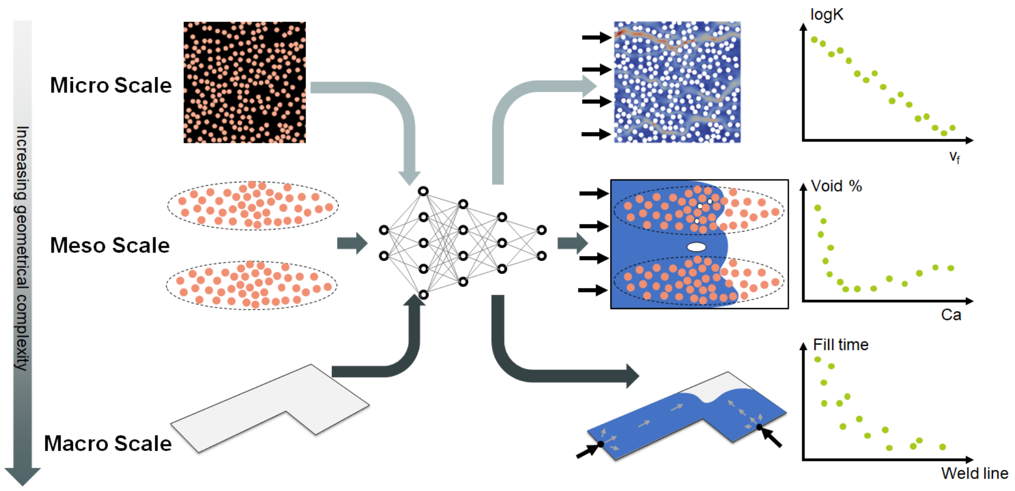

Figure 1. *An overview of our activities for modelling of multiscale flow phenomena using AI algorithms*

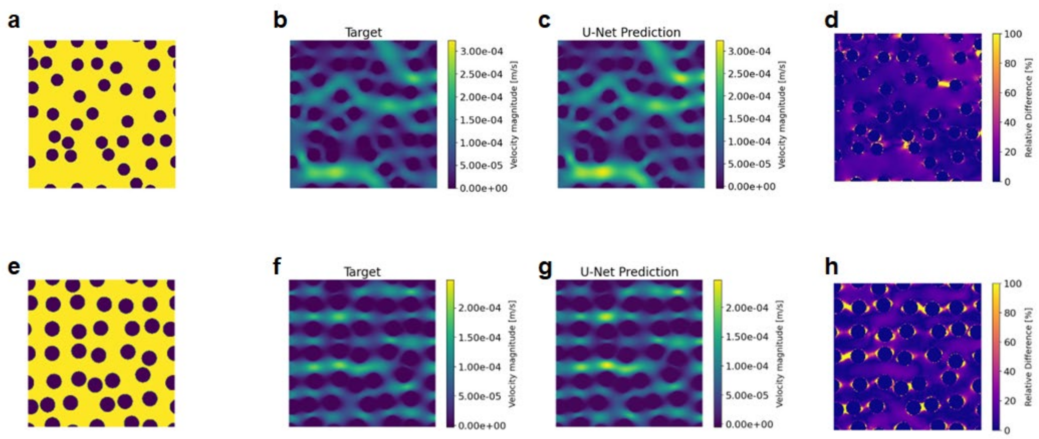

Figure 2. Two examples (a-d training set, e-h validation set) demonstrating the microstructures, and corresponding flow fields: b&f ground truth and c&g U-net prediction, and d&h the deviation of the U-net prediction from the ground truth.

References

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