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OPTIMIZATION OF GRIPPER TRAJECTORIES IN AUTOMATED COMPOSITE DRAPING

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Abstract: “FlexDraper” is being developed as an automated solution for the draping of woven carbon fiber prepregs. The “FlexDraper” system is comprised of an array of actuated grippers mounted on an industrial robot. This robotic system cando a one-by-one ply placement (draping) of a set of fabrics onto a mold surface to provide a repeatable and automated composite manufacturing process. A major challenge for this automated draping is to determine the respective movements for each of the grippers such that the draped configuration matches a prescribed boundary and does not induce any out-of-plane wrinkles. In a previous research effort, an advanced nonlinear, rate-dependent Finite Element (FE) model was created and used to study the problem with simple gripper movements. It was found in that study that the placement of the ply is highly dependent on the path taken by the grippers and that wrinkles can easily form during draping. Thus, it was concluded that a concerted effort should be put into determining the optimal gripper trajectories. While the FE model agrees well with experimental results, it is also computationally expensive. Thus, it is not suitable for completing optimization analyses and a faster, approximate model must be developed. In the present study, the fiber ply is modelled by a series of catenaries, i.e. curves that represent the behavior of cables supported at the end points. To match the experimentally measured behavior of the fiber ply, a catenary model with added bending stiffness is employed. An optimization framework is set up such that the respective movements of the grippers from the initial configuration with the ply suspended above the mold, to the final draped configuration, can be determined. The movement of the grippers is divided into steps, where in each step, an optimization problem is solved with move limits imposed on the grippers. In this way, the trajectories of the grippers can be mapped. Before mold contact, the objective is – in addition to minimizing the mold-ply distance – to position the ply such that it will match the prescribed boundary at the end of the placement process. After mold contact, the objective is to minimize the difference between the slopes of the ply and the mold at the contact point. In this manner, the ply will be rolled onto the mold and wrinkling will be mitigated. Ultimately, the generated gripper movements are used in the FE model and compared to experimental results.