Computer Graphics-based Method for efficient generation of 3D Microstructure of CFRPs via Blender Rigid/Soft-Body Simulation: Investigating Modelling of Compaction-Induced Fiber Misalignment During Nip-Roller Impregnation

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Introduction

The current generation engine resolves fiber–fiber overlaps using an iterative Projected Gradient Step (PGS) algorithm, a purely geometric packer enforcing a customized surface-to-surface clearance at each depth slice. While validated against CT data, this approach cannot represent how manufacturing processes (consolidation pressure, roller compaction, tow flattening) actually redistribute fibers and shape the misalignment field, and its runtime scales quadratically with fiber count, making large-volume (12,000+ fiber) generation expensive even on the HPC cluster.

In nip-roller impregnation, opposing rollers apply a transverse compaction pressure to consolidate the tow and drive resin impregnation. As the tow is squeezed, fibers locally become wavy and shift from their nominal path, producing misalignment fields that current statistical models capture only empirically, with no mechanistic link to the roller pressure, speed, or temperature that produced them.

Aim: Develop a parametric Blender soft-body compaction simulation of a single UD fiber tow through a nip-roller stage, modelling fibers as flexible bodies, to study how compaction pressure, line speed, temperature, and tow count govern the resulting misalignment statistics.

Research Question: How do nip-roller process parameters (pressure, speed, temperature, tow count) quantitatively influence within-tow fiber misalignment, and can a Blender soft-body simulation reproduce misalignment signatures observed in CT data from known process conditions?

Activities & Expectations

1. Soft-body simulation setup: Build a parametric Blender scene of a single UD tow (200–500 flexible fiber rods, ~7 µm diameter) passing between two counter-rotating rigid rollers, using Blender's soft-body solver to represent fiber flexural rigidity under prescribed transverse compaction pressure.
2. Process parameter study: Run a DoE over pressure, speed, temperature (as a friction/stiffness proxy), and tow count; export deformed fiber centerlines per point..
3. Validation: Compare Blender-generated misalignment statistics against CT data from known nip-roller conditions (TU Delft TapeLab, if available), assessing whether the simulation reproduces the correct statistical fingerprint.

Expected outcome: A documented, mechanistic relationship between nip-roller process parameters and the misalignment-distribution inputs of the statistical model. This enables the pipeline to be seeded not just from CT scans but from engineering process specifications, a significant step toward predictive, process-aware virtual microstructure generation.

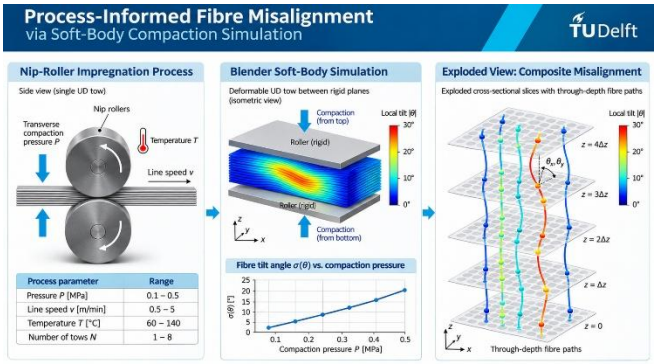


Figure 1.Proposed pipeline schematic [fig made by ChatGPT].

This work is suitable for Master/Bachelor students.
Sounds interesting? Please get in touch!

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