Influence of Material Behaviour and Relative Velocity on Cascaded Width Control During Mechanical Bar Spreading of UD Carbon Fibre Tapes

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Abstract

Unidirectional (UD) reinforcement fibre tapes are thin, low areal weight fibre strips consisting of highly oriented multifilaments produced by spreading dense fibre bundles. The fibres are subsequently fixed using a polymer binder or fully impregnated with a matrix material. These tapes are mostly processed using Automated Tape Laying (ATL) or Automated Fibre Placement (AFP) systems, enabling highly load-optimised component designs.
However, material defects frequently limit these advantages. Tapes often exhibit significant width variations exceeding standard ATL tolerances (0.1 - 0.5 mm), causing defects like gaps or overlaps. These flaws can reduce local strength and stiffness by up to 27% (1,2). Manual inspection and rework account for up to 63% of the total process time (3), while automated detection systems only reduce cycle times by around 20% without fully solving the underlying issue (4).

To address this, an active control system was developed at the ITA to dynamically respond to material fluctuations during spreading. This setup reduced width variance from 16.38% to 1.28%. An expanded sensor configuration allows individual width measurements at each spreading bar. Consequently, a dedicated control loop was formulated for each bar. The resulting PID cascade controller maintains specific target widths by adjusting the relative velocity between the individually driven bars and the fibre material. To determine these target widths, the parameter space of roller velocities was explored using superimposed sine functions, establishing a model that allows the selection of the optimal target value from a global minimum of the expected variance.

The relationship between control deviation (MAE) and the controller parameters (KP,KI,KD) is a black-box function approximated via Bayesian optimisation with a Matérn kernel. From 25 candidates, the optimisation selected the parameter combination with the lowest mean error. The resulting optimised controller reduces the standard deviation from the target tape width to < 0.3 mm. Using this new controller, 96.6% of all tape segments fall within the 0.5 mm tolerance threshold, a substantial improvement over the 12.9% of uncontrolled systems.

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