STRETCH-STEERING OF ALIGNED DISCONTINUOUS FIBER TAPES ON HIGHLY CURVED PATHS USING AUTOMATED FIBER PLACEMENT

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Introduction
TuFF is a novel material with highly-aligned short fibers. The discontinuous microstructure allows deformation in all directions allowing forming of complex geometries and elongation of up to 40%. During tape placement, TuFF tapes can be stretched to mitigate buckling, improving steering radii by a factor of ~10 compared to continuous fiber tape material.

Motivation
• TuFF tape steering enables:
  • Variable angle tow laminate designs optimizing weight vs. performance
  • Use of wider tapes for complex geometries increasing throughput
  • The material deformation during TuFF steering is unknown and has to be understood to optimize process conditions

Objective
Evaluate the material deformation by developing a methodology to measure strain during tape steering of TuFF/PEI tapes using Photogrammetry and minimize the path deviation
• Deformation occurs continuously in the heating and placement zone
• Induced strains offset the compression strains resulting in buckling free steering of the tape

Methodology
Automated Tape Placement:
• Tapes are cut from TuFF/PEI blanks and fed into the ATP head alignment channels
• All tapes are placed at 450°C laser set-point temperature, 15 mm/s lay-up speed, 400 N consolidation force using a 1 in consolidation roller
• Kinematic strain is applied due to a difference in the speed of the feed roller and the compaction roller
• The tape is stretched in the heated zone and placed onto the substrate in a straight line or a curved path with different radii

Photogrammetry and Path Deviation:
Photogrammetry measures the location of dots on the measuring surface by taking multiple images of the measuring object from different positions. Based on the initial distance between the dots a strain field can be generated
• Patterns are applied to the tape with high temperature paint and pressed in at 330°C with 300 psi to embed the pattern into the blanks
• Tapes are placed on a substrate, and pictures are acquired. Photogrammetry method is applied to measure final strain in the coupons
• The path deviation can be minimized by offsetting the Tool Center Point (TCP) to the nip-point of the consolidation roller

Photogrammetry and Path Deviation

Validation of Longitudinal Strain Gradient
• The strain is computed with a series of sections across the tape width
• The strain gradient closely follows the predicted gradient

Summary and Conclusion
A concept for the measurement of strains for tapes placed at processing conditions was developed
• The predicted longitudinal strain gradient across the tape width was validated

A methodology to quantify and minimize the path deviation was implemented:
• Optimal TCP can be found with few experiments
• Improved path following reduces defects and enables smaller steering radii
• Steering of 0.5 in TuFF/PEI tape was demonstrated

Minimum Steering Radius 0.5 in TuFF/PEI
• Applied strains were chosen based on the predicted strain gradient and set at 18% for the 50 mm steering radius and 32% for the 25 mm radius
• The tape placed at 50 mm steering radius showed no defects, whereas the tape at 25 mm steering radius showed slight folding on the inside and fraying on the outside edge
• The path deviation for both tapes is within the tolerance

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