PERFORMANCE OF STRETCH-STEERED ALIGNED DISCONTINUOUS FIBER TAPE WITH AUTOMATED FIBER PLACEMENT

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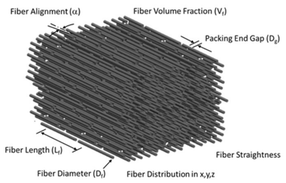
Introduction

Tailored composite design by steering of tapes with Automated Fiber Placement (AFP) can reduce weight and increase performance in composite parts by orienting fibers to optimize for a load case. Tape steering introduces compressive strains which produce defects like wrinkles upon placement. With continuous tape, there exists a minimum steering radius where paths are restricted based on course geometry.

TuFF is an aligned discontinuous fiber material which can be stretched during processing in improve manufacturability.



***TuFF* Diagram**

Thermoplastic TuFF has been shown to increase minimum steering radius by in-situ stretching the tape during placement to offset the compression and manufacture aligned fiber composite laminates without defect.

¼" continuous tape steered at 1000 mm radius

1" TuFF tape steered at 100 mm radius

The objective of this work is to develop the process control for stretch steering thermo-set matrix TuFF and determine the material mechanical properties after processing as a function of this stretching.

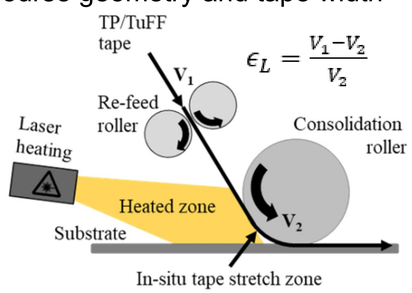
This work utilizes the Laser-Assisted Mikrosam AFP to process epoxy matrix (Axiom) TuFF with 3mm IM7 fibers constructed to 47% fiber volume fraction.

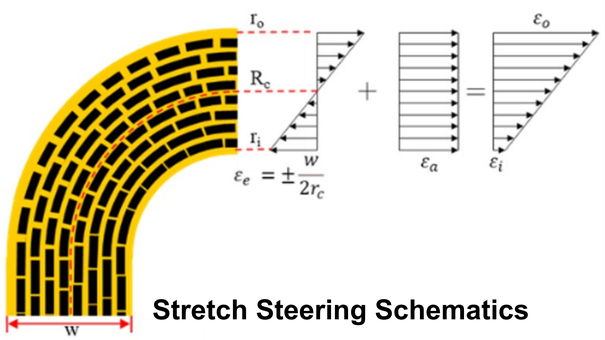
Placement Process

- A PWM heating method was implemented to the 3.2 kW laser to allow for low power usage
- The nip point temperature was targeted to ~50 °C
- This temperature reduces the resin viscosity to 300 Pa*s which is necessary to optimize stretching, allowing fibers to slide in the matrix
- A cycle of 4 ms laser on and 12 ms off for a 5% set power resulted in an actual power output of ~1% (~32W output power)

In-situ Stretching

- TuFF tape is kinematically stretched in the fiber direction by differentiating the speeds of the feeding rollers
- The applied strain can offset the compressive strain from steering to avoid defects like wrinkles
- Setting an applied strain results in a strain gradient across the tape based on course geometry and tape width

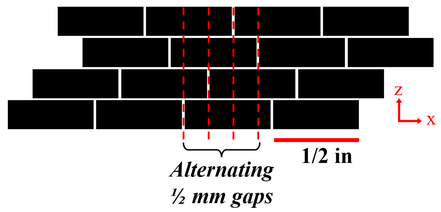




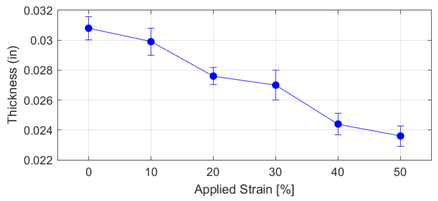
Stretch Steering Schematics

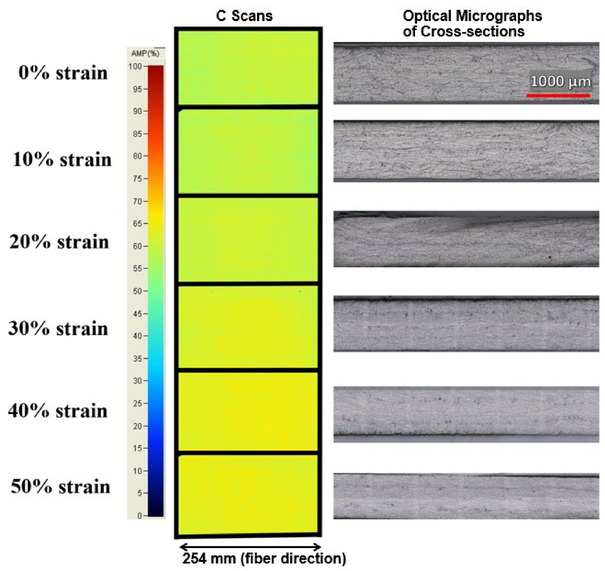
Test Panel Fabrication

- Mechanical testing panels were fabricated at strain levels of 0-50% stretched along straight paths
- Tapes were staggered ply to ply to avoid alignment of gaps between tows



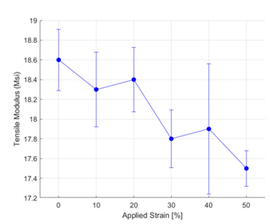
- Panels were consolidated and cured in the autoclave at 250 °F and 300 psi for 2 hours
- Ultrasonic c-scans and micrographs were taken from each sample
- Materials inspection showed uniform spatial distributions and no significant porosity
- **Linear decrease in thickness with strain**

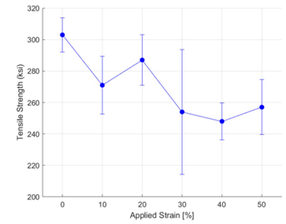




Mechanical Property vs. Stretch

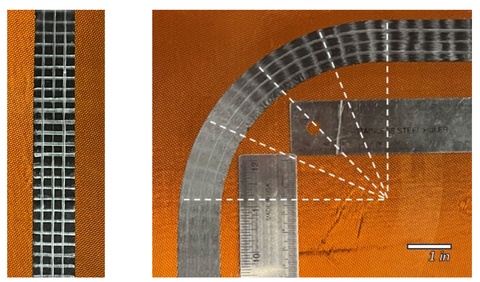
- Mechanical testing followed ASTM D3039 for calculation of tensile properties
- Property retention was measured comparing strength and modulus of the 0% strain sample to the 50% strain
  - **Tensile Modulus: 94% retention**
  - **Tensile Strength: 85% retention**





Conclusions

- A method was developed to produce and test coupons for material properties as a function of applied forming strain
- No material defects were shown however strength reduced to 85% at 50% strain
- This work allows mapping of local mechanical properties with respect to the strain gradients across the tape width during stretch steered tape placement



Strain Map

Acknowledgements

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