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.

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.

The objective of this work is to develop the process control for stretch steering thermoset 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

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

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