EFFECTS OF THE WEAVING PROCESS ON TENSILE STRENGTH DISTRIBUTION OF S2 GLASS FIBER TOWS EXTRACTED FROM DIFFERENT 3D-WOVEN FABRICS

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- **Motivations and Concerns**
  - 3D fabrics advantages over 2D fabrics, such as:
    - High interlaminar fracture toughness
    - Tailored 3-D properties (hybridization)
  - Tow Damage can occur during weaving process (curvature and abrasion mechanisms)

- **Objectives**
  - Evaluate strength properties of S2-glass fiber tows extracted from different sub-layers of 3D fabrics
  - Identify the degradation mechanisms due to weaving process

- **Materials and Specimen Preparation**
  - **Control Samples**
    - S2-glass 1250 (6,104 den)
    - S2-glass 250 (18,040 den)
    - S2-glass 750 (3,614 den)
  - **3D S2-Glass Fabrics**
    - 28oz/yd²
    - 50/50oz/yd²
    - 100oz/yd²

- **Experimental**
  - **Tensile Test**
    - Applying ASTM standard D 2256-02
    - 10-inch gauge length
    - Crosshead speed of 12 inches/minute (304.8 mm/min)
    - Specimens were wrapped around the cylindrical fixture
    - At least 30 samples were tested

- **Tow cylindrical fixture**

- **Sample during tensile testing**

- **Data Reduction**
  - **Tensile Strength**
    - From load-displacement data obtained for each product, the strength was calculated as:
      \[ \text{Strength} = \frac{\text{Failure Load (F)}}{LD (\text{den})} \]
      (Where LD is the average linear density of the tow. Linear density was averaged over 15 specimens)
  - **Tensile Strength Distribution**
    - MINTAB software was used to reduced the data:
      - Strength distribution
      - Failure probability
      - Retention based on mean strength (Rm)
      - Retention value at 10% and 90% failure probability.

- **Strength Distribution Results for Weft Sub-layer Tows from 100 oz Fabric**
  - With respect to control samples, the peak of the distribution in weft tows from 100 oz fabric show shift to lower strength by 24% (for middle sub-layer) and 9% (for top sub-layer)

- **Failure Probability Curves for Weft Sub-layer Tows from 100 oz Fabric**
  - Weft-top tows exhibit the highest failure probabilities for a given strength among all sub-layers
  - For tows from weft sub-layers (middle and bottom), the effect of weaving is to narrow the distribution and rotate the probability curve counter clockwise
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(Continued)

- Warp tows exhibit shifts to lower strength levels, with respect to control samples, extracted tows exhibit shift in the peak locations to lower strength levels by 48%, 26% and 73% for the tows extracted from 28, 50 and 100 oz fabric.
- Z-tows from 100oz-fabric show significantly narrower distribution than others.

Mechanisms of Strength Degradation in Z-Tows:
- Measured Strength Degradation due to the Effects:
  - Curvature
  - Broken fibers
  - Abrasion
  - Other mechanisms and interactions

- D(Total) = D(broken fibers due to curvature & abrasion) + D(abrasion & other mechanisms)
- Degradation due to broken fibers was evaluated from elastic modulus measurements on extracted Z-tows.
- Fiber breakage is due to curvature and abrasion.
- Degradation due to curvature of control tows was quantified.
- D: Degradation in Strength = 1 - Rm

Failure Probability Curves for Z-Tows Extracted from 100 oz Fabric

- Z-tows from 100 oz fabric show the greatest shifts to lower strengths, with respect to control.
- Z-tows from 50 oz fabric show the smallest shifts to lower strength levels, with respect to control.
- A significant increase in the slope can be obtained for Z-tows from 100 oz fabric.

Conclusions
- Weaving can degrade dry tow strength (3-D fabrics).
- Highest degradation in strength was observed in the S2-glass Z tows. Z-tows extracted from 28, 50 and 100oz fabric strength loss of 44%, 31% and 71%, respectively.
- Abrasion and fiber breakage mechanisms are the major factors for strength degradation for Z-tows.
- The strength retention for impregnated Z tows (66-75%) is significantly higher compared to that measured for dry tows (29-35%).
- Hybridization of 3-D weaves offers opportunity to reduce Z-tow strength reduction.

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