EFFECTS OF 2D AND 3D-WEAVING PROCESS ON TENSILE PROPERTIES OF SYNTHETIC FIBERS

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OBJECTIVE

- To study the effects on the reduction in tensile properties of fabrics due to the weaving process which incorporates abrasion and fiber curvature.

MATERIALS

- 2D Plain Weave Vectran Fabric - HT0150P1 and VE5050
  - HT0150P1
    - Two Sublayers - Weft Tows (Type HT110/20)
    - Two Sublayers – Warp Tows (Type HT110/20)
  - VE5050
    - Two Sublayers - Weft Tows (Type HT1670/600)
    - Two Sublayers - Warp Tows (Type HT1670/600)
- 3D Fabric-100 oz S2 Glass Fabric (HX19) with Dyneema Z-tows
  - Three Sublayers - Weft Tows (Type 750)
  - Two Sublayers - Warp Tows (Type 250)
  - Z tow -Dyneema Tows (Type SK75)
- Control Tows
  - 2D Fabric
    - Vectran HT1670/600 for weft and warp tows
  - 3D Fabric
    - Warp – AGY 250
    - Weft – AGY 750
    - Z tow – Dyneema SK75

SPECIMEN PREPARATION

- The Baseline Tows were carefully cut from the spool.
- The warp and weft directions (and z-direction in the 100 oz S2-glass Fabric) were carefully extracted from the fabric, ensuring that no damage was induced on the microfibers of each individual tow being pulled.
- After the tows were successfully cut from the spools and removed from the Fabric, they were cut to 15 inches and weighed to find their linear densities.
- The tows were then end-tabbed using rigid poster board cut into 1”X1” squares and room temperature adhesive with a gage length of 10 inches.

TENSILE TESTING

- The prepared specimens were tested using an Instron Test Frame.
- Following ASTM Standard D 2256-02.
- All of the tests were conducted at a crosshead speed of 12 inch/min.

Data Reduction

- From load-displacement data obtained for each product, the strength was calculated as:

$$Strength = \frac{Failure\ Load\ (g)}{LD(den)}$$

  - Where LD is the average linear density of the tow.

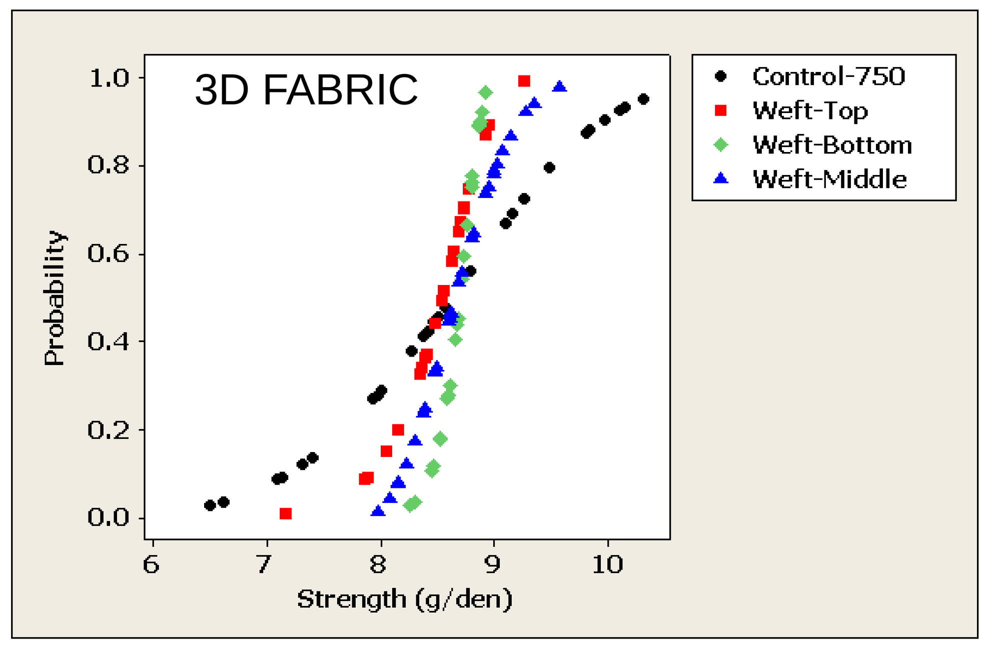
- The percentage of broken fibers within the Z-tow was calculated from the Elastic Modulus of the control tow (E_C) and extracted tow (E_{ext}), By the following equation.

$$\frac{\Delta E}{E_C} = \frac{E_C - E_{ext}}{E_C} = \frac{N_b}{N}$$

  - N_b: Number of broken fibers
  - N: Total number of fibers within the tow

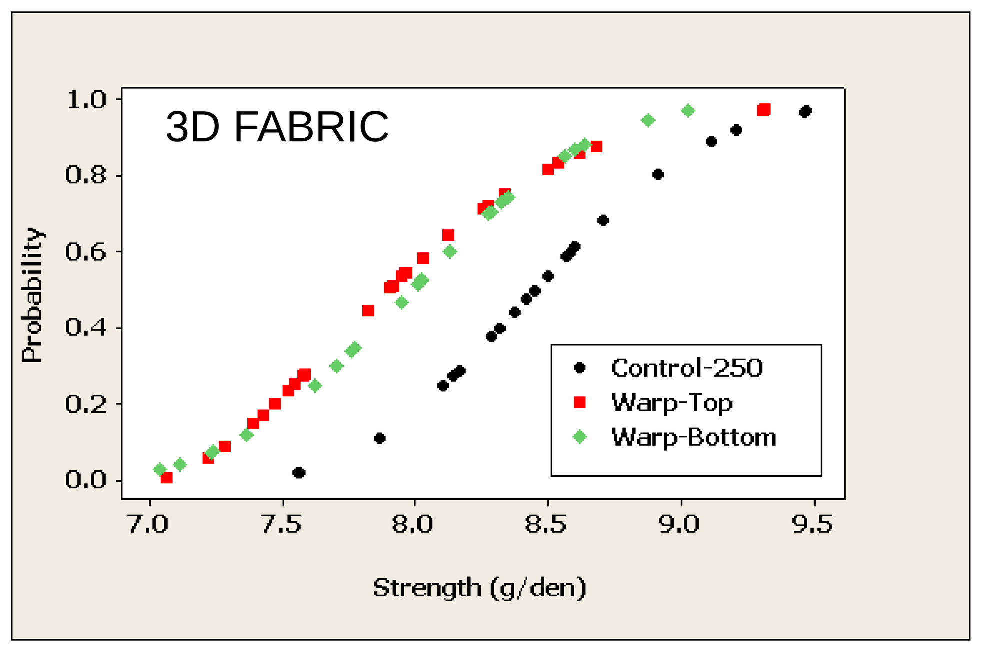
- Failure probability curves were calculated using Minitab Software.
- The effects that curvature has on the tensile properties of fibers was found by using a wrapping technique where control tows were wrapped around nominal radius sizes that match the radius of curvature in the corresponding fabrics.
  - The samples were then tested following the same specimen preparation and testing methods

FAILURE PROBABILITY CURVES FOR WEFT S2-GLASS TOWS



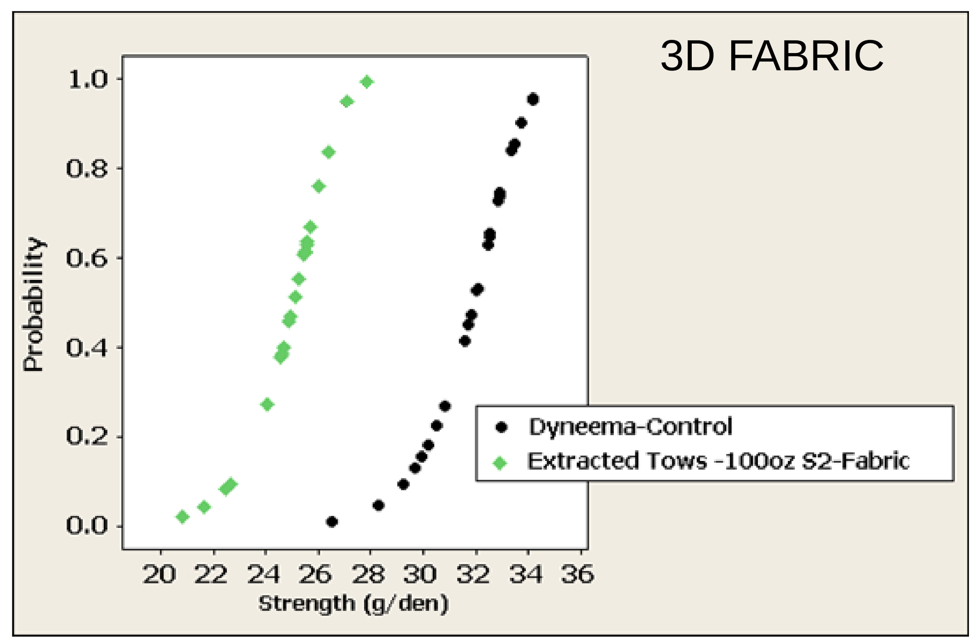
- With respect to control, weft tows exhibit higher failure probabilities for a given strength above 8.6 g/den level and lower failure probabilities below 8.6 g/den level.

FAILURE PROBABILITY CURVES FOR WARP S2-GLASSTOWS



- Curves for both warp tows exhibit significant shifts to lower strength levels, compared to control tows.
- Insignificant differences in the failure probability behavior between the warp-top and the warp-bottom tows.

FAILURE PROBABILITY CURVES FOR DYNEEMA Z-TOWS



- There is a noticeable shift in the extracted Dyneema Z-tows strength, with respect to control tows.

SUMMARIZED STRENGTH RETENTION VALUES

	Retention Based on Mean value	(R-10%) (R-90%)*
Dyneema Z-Tows	78%	(73%)(79%)
Warp-Bottom (S2-glass)	94%	(93%)(94%)
Warp-Top (S2-glass)	94%	(93%)(95%)
Weft-Top (S2-glass)	98%	(100%)(90%)
Weft-Middle (S2-glass)	100%	(114%)(90%)
Weft-Bottom (S2-glass)	100%	(100%)(88%)

*: R-10% and R-90% are retention values calculated based on 10% and 90% failure probabilities, respectively.

- Dyneema Z-tows exhibit the lowest strength retention values.
- Insignificant effects of weaving on strength properties of weft tows and a slight degradation of strength properties for the warp tows.

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(Continued)

DEGRADATION MECHANISM IN DYNEEMA Z-TOWS

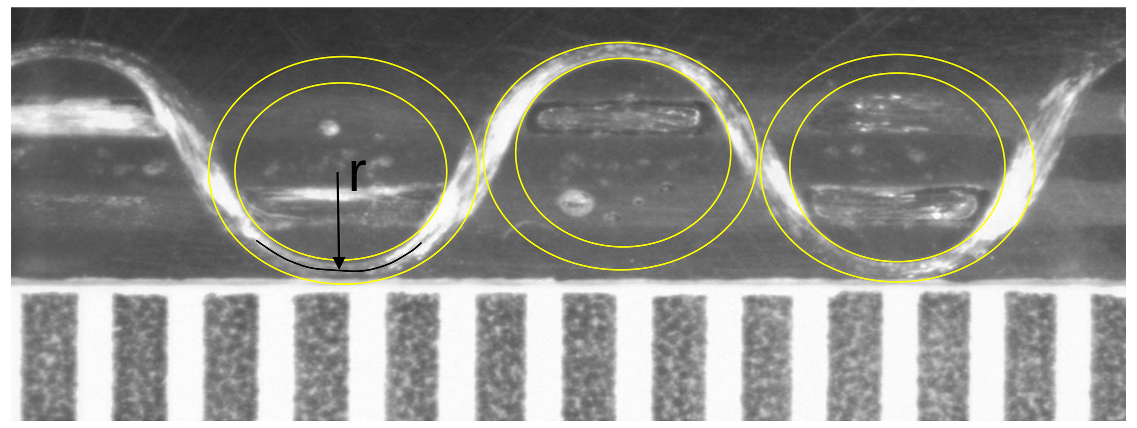
Z-Tows	Total Degradation	N_b/N Curvature-Control	N_b/N - In Situ (Due to Curvature & Abrasion)	Abrasion/Other Interactions - In Situ (Reduced Strength)
Dyneema *	22%	~0%	8%	14%
S2-Glass **	71%	15%	38%	33%

*: Extracted from Hybrid 3D Fabric (HX19) – 100 oz
**: Extracted from 100 oz 3D S2-Glass fabric

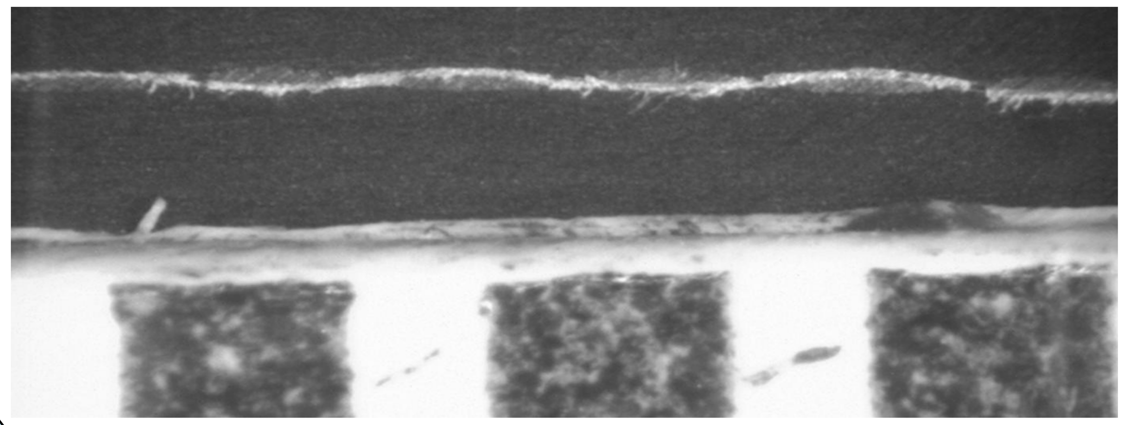
- The filament breakage due to curvature is negligible in Dyneema Z-tows.
- It can be seen that abrasion is the major source for reduction in strength of Dyneema Z-tows.
- Dyneema Z-tows have significantly higher resistance to the effects of 3D weaving than S2-Glass.

CURVATURE BASED STRENGTH DEGRADATION OF FIBER

- Sections of fabric were cut in the warp and weft direction and placed into vinyl ester and allowed to cure.
- Cross sections were polished and viewed at low magnification to measure the radius of curvature of the tows in the fabric.



*:Cross section of Dyneema Z-tow



*:Cross section of HT0150P1-Fine

- Knowing the radius values for each fabric, we could mimic the curvature of the fiber, separating the effects of curvature from the effects of abrasion.

TENSILE STRENGTH OF VECTRAN TOWS EXTRACTED FROM 2D FABRICS

Fabric	Warp Tows	Weft Tows	Control Tows*	Retention in strength (Warp), (Weft)
Vectran HT0150P1	25.05±2.33	25.56±1.65	26.44±1.70	(0.95), (0.97)
Vectran VE5050	25.04±1.17	25.81±1.51	26.17±0.89	(0.96), (0.99)

*: Vectran HT-110/20, Vectran HT-1670/600 are control tows for 2D fabrics of HT0150P1 and VE5050, respectively.

- Curvature and abrasion under certain tension/velocity values are major sources for the degradation of mechanical properties of the fibers.
- From this Table, it can be seen that both types of Vectran tows show low levels of degradation in strength ranging from 0% to 4% due to curvature.

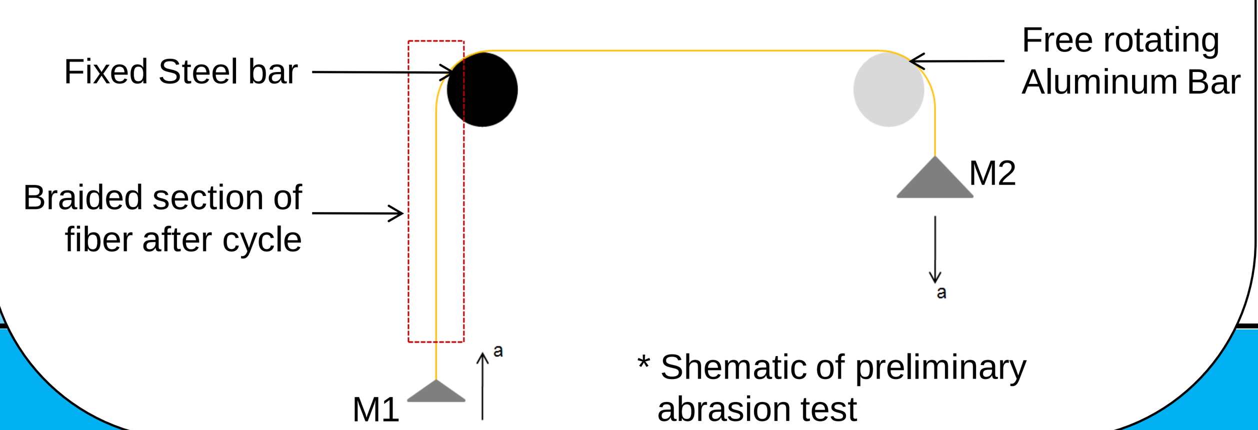
EFFECTS OF CURVATURE ON TENSILE STRENGTH OF VECTRAN TOWS

Radius of Curvature (mm)	Vectran 1670/600 Strength (g/den)	Retention
Control	26.17±0.89	-
0.25	21.92± 1.54	84%
0.4	21.67±1.84	83%
1	24.10±1.54	92%
2	24.88±1.52	95%
3	25.87±0.83	99%
5	25.0±0.33	95%

- At lower radius of curvature levels, Vectran tows tend to show lower retention in strength values.

PRELIMINARY ABRASION RESULTS

Sample Set	Weight (Kg) M1	Weight (Kg) M2	Cycles	Vectran 1670/600 Strength (g/den)	Vectran 1670/600 Retention
Control	-	-	0	26.17±0.89	-
1	2.15	4.60	10	22.98±0.46	88%
2	0.45	1.02	10	25.27±1.25	96%
3	0.34	0.68	10	25.64±0.75	98%
4	1.02	2.15	10	23.88±0.74	91%



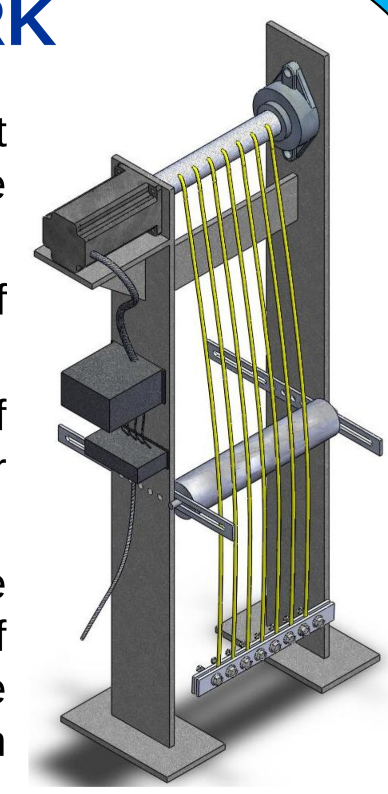
* Shematic of preliminary abrasion test

CONCLUSION

- In 3D weaving, the Z-tows show higher strength degradation than the warp or weft tows. Z-tows of Dyneema have higher damage resistance to 3D weaving compared to S2-Glass.
- For Dyneema tows, abrasion is the main source of strength degradation.
- Vectran tows from 2D fabric exhibit insignificant reduction in strength with respect to control tows.
- Degradation mechanisms due to weaving such as fiber breakage, abrasion, and curvature were addressed. Preliminary testing on abrasion of Vectran fiber shows that the maximum reduction in tenacity of 12% was observed. Design of an abrasion test machine is proposed for future work.

FUTURE WORK

- Further Study the effects that abrasive forces have on tensile properties.
- We are currently in the process of building an abrasion test machine.
- The machine will be capable of oscillatory rotation to cycle the fiber continuously.
- Control fibers found in fabrics will be braided over various types of materials to better understand the role abrasion has in the strength degradation of the fibers.



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