Development of Laboratory Tests for the Physical Durability of LLINs

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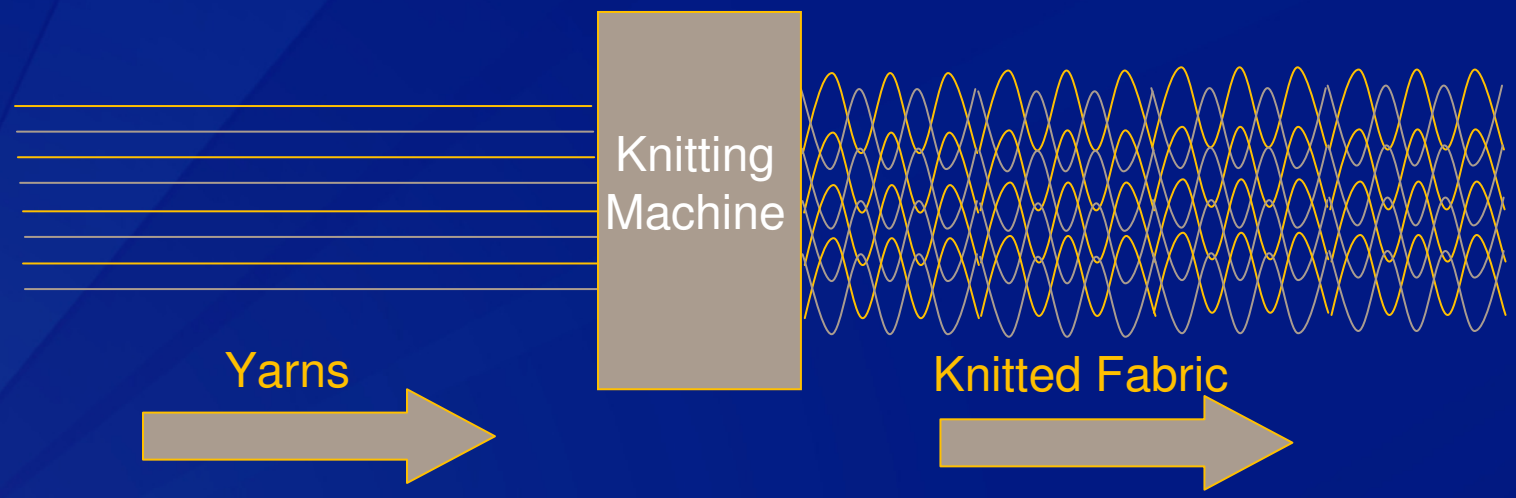
How Textile Structure Influences Durability

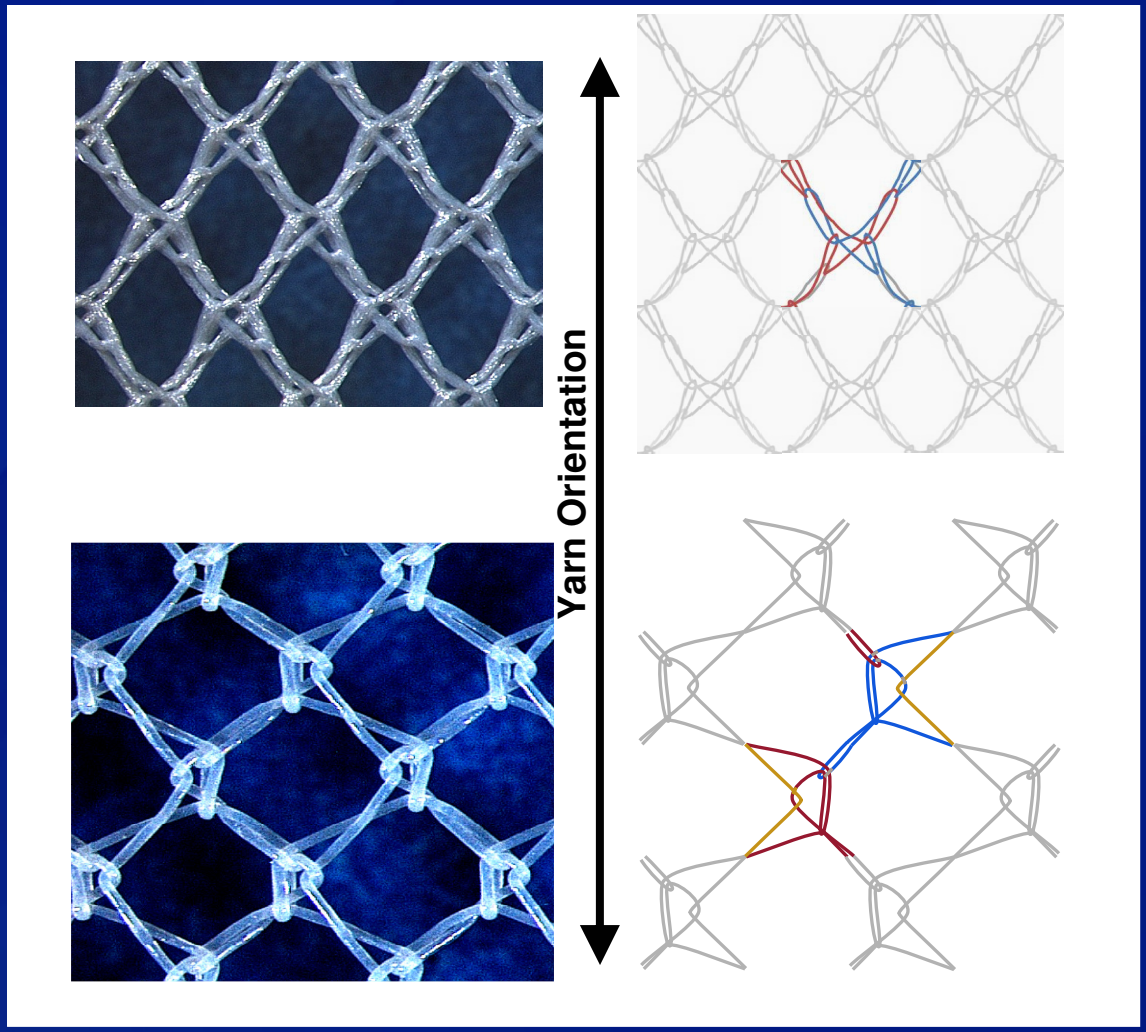
- LLINs are made by warp knitting.
- Yarns oriented lengthwise through the fabric.
  - Analogous to "grain" in wood.
- Strength and tearing properties are directional.
  - Tears tend to run parallel to yarn orientation.



Current LLIN Yarn Patterns

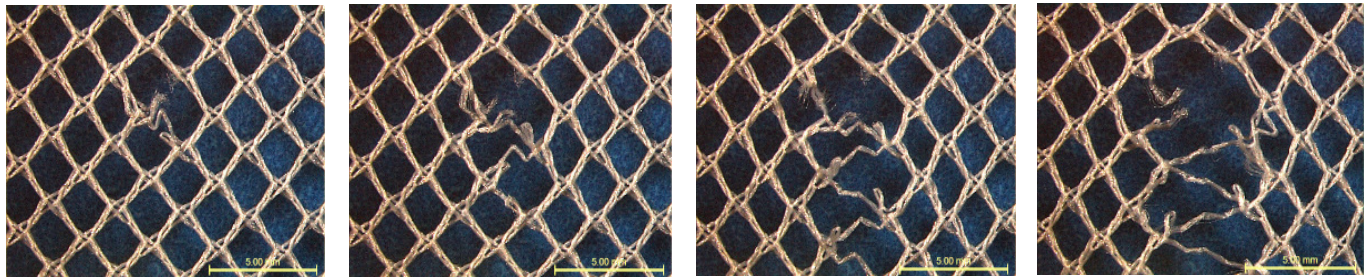
Polyester and Polypropylene (multifilament yarns)

Polyethylene (monofilament yarns)



Raveling

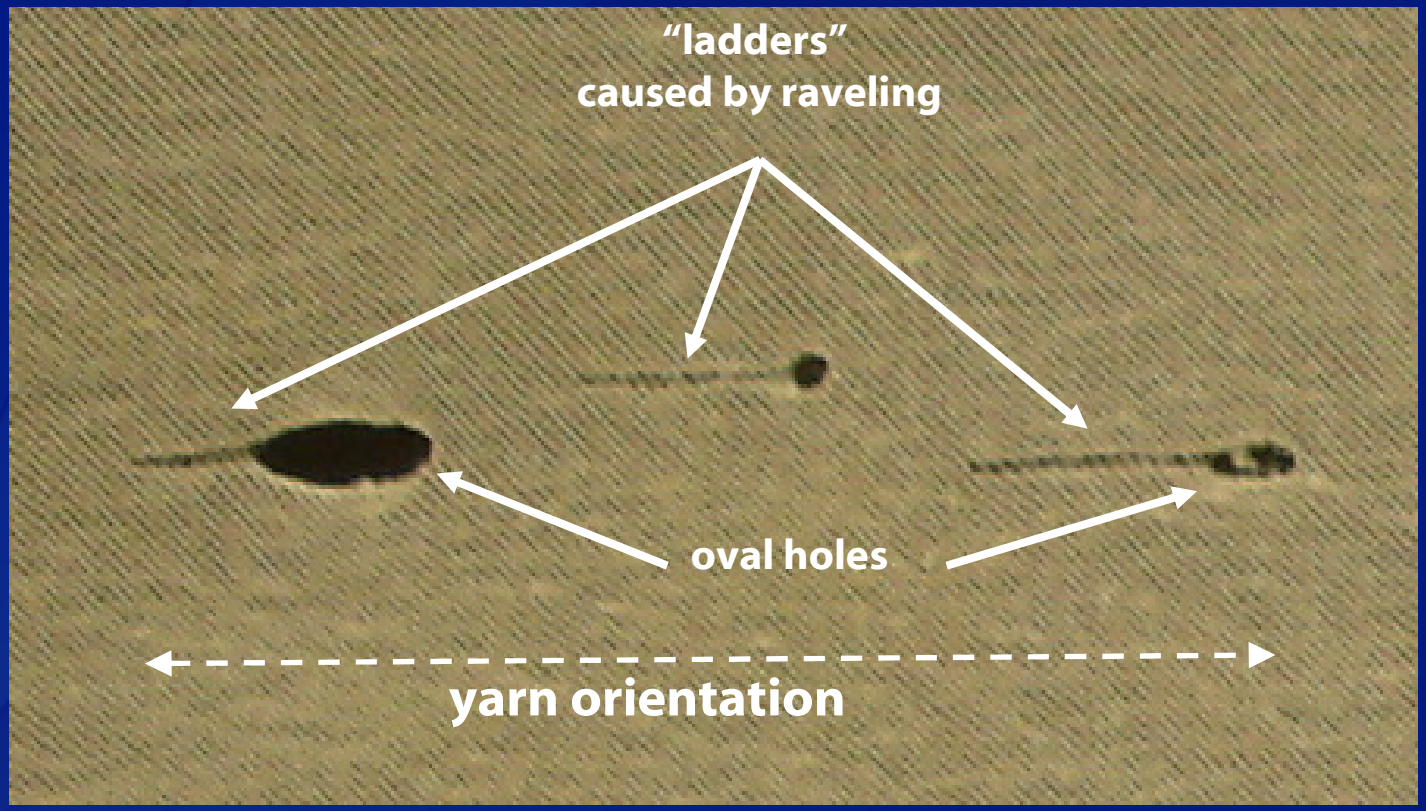
- Severing one or more yarns can lead to a process of sequential loop disengagement.
  - Small holes get larger.
  - Hole enlargement occurs in one direction.
  - No additional fiber breaks.



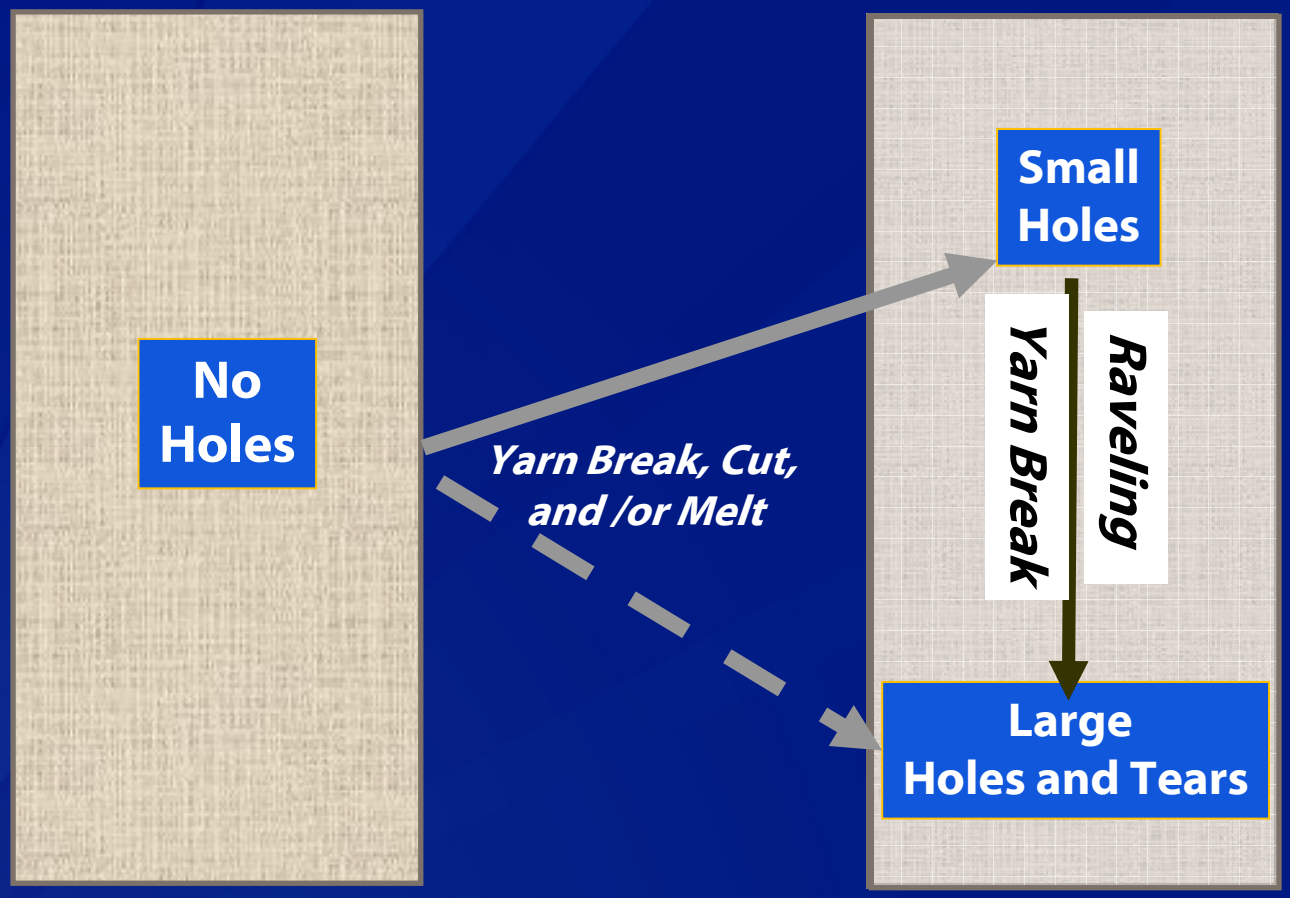
process of raveling after a single yarn cut

Typical LLIN Damage

Typical LLIN Damage



Hypothetical Deterioration Pathways



Intact Net

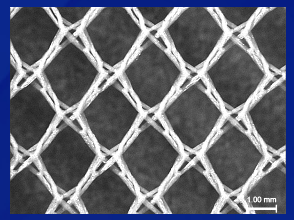
Damaged Net

Potentially Useful Tests

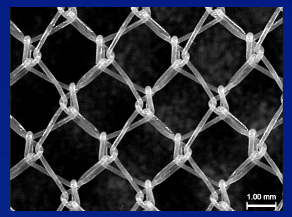
- Susceptibility to initial hole formation.
  - Snagging (tensile breaks)
  - ~~Cutting~~
  - ~~Melting~~
- Strength loss after hole formation.
- Resistance to raveling.

NETS INVESTIGATED

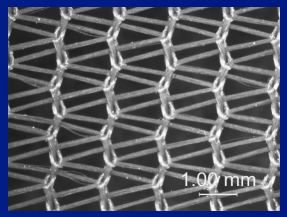
	NET	YARN			FABRIC			
		POLYMER	FILAMENT	DENIER (reported)	WEIGHT (g/m^2)	KNITTING PATTERN	UNIT CELL WARP (mm)	UNIT CELL WEFT (mm)
LLINs	DawaPlus	PET	multi	100	42.80	A	2.84	2.84
	Interceptor	PET	multi	75	28.94	A	2.70	2.88
	PermaNet 2.0	PET	multi	100	41.84	A	3.33	2.53
	LifeNet	PP	multi	100	41.27	A	2.20	2.30
	PermaNet 3.0 (upper side)	PET	multi	75	32.46	A	1.95	2.50
	PermaNet 3.0 (roof)	PE	mono	100	39.00	B	2.48	1.90
	DuraNet	PE	mono	145	48.03	B	3.44	2.77
	NetProtect	PE	mono	118	37.62	B	3.65	2.39
	Olyset Net	PE	mono	150	46.89	B	5.88	3.16
non-LLINs	Iguana Net (military)	PET	multi		55.65	C	1.34	1.48
	Marquisette Net (retail)	PET	multi	75	63.27	D	3.70	1.31
	Noseeum Net (retail)	PET	multi	75	69.49	A	1.19	1.47



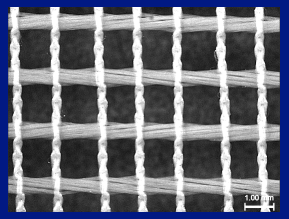
Pattern A



Pattern B



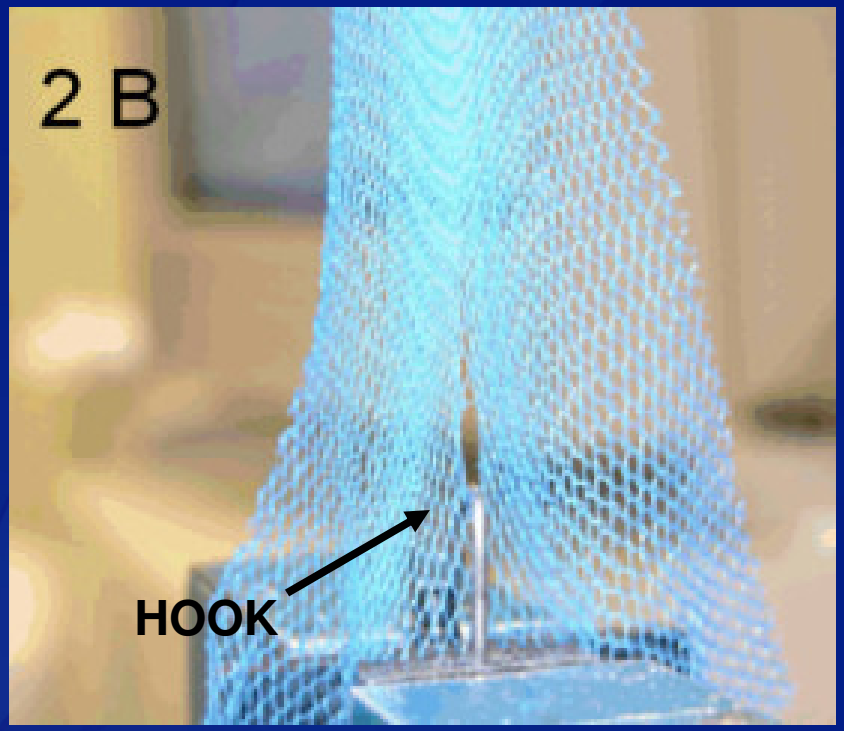
Pattern C

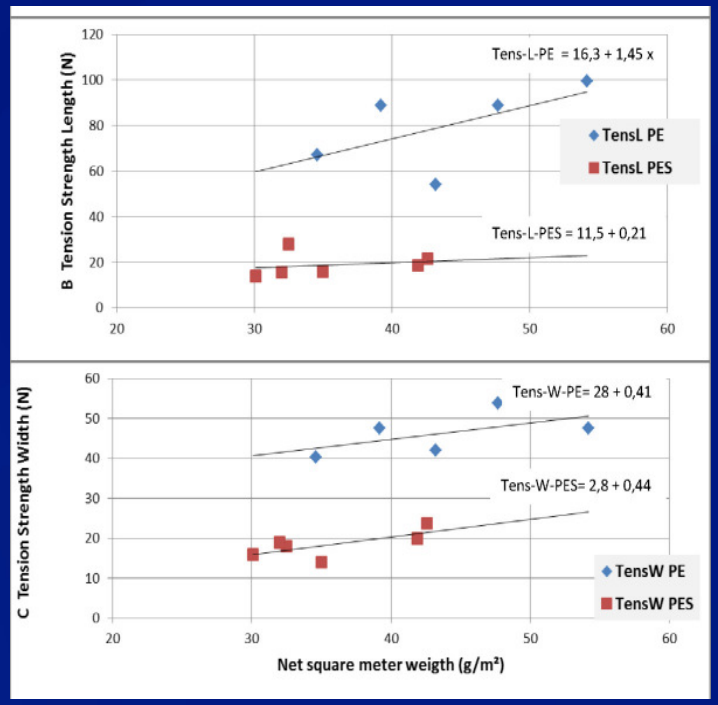


Pattern D

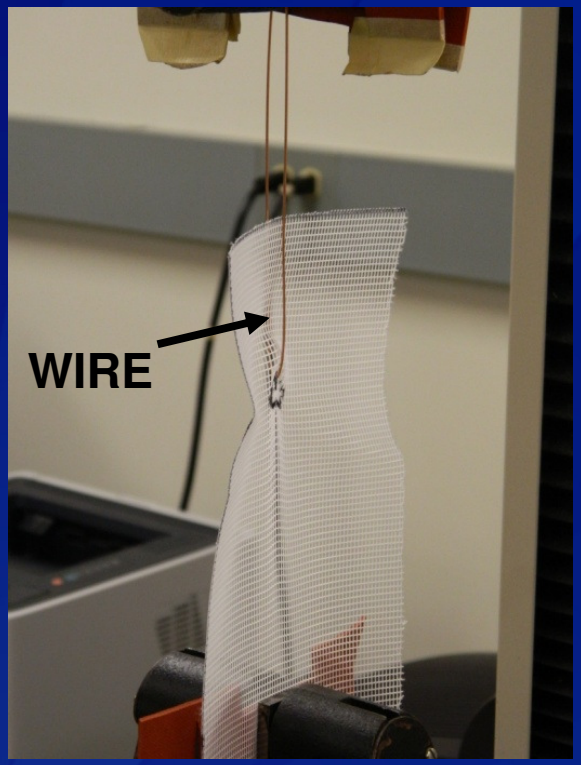
Resistance to tearing by snagging (Skovmand and Bosselmann, 2011)

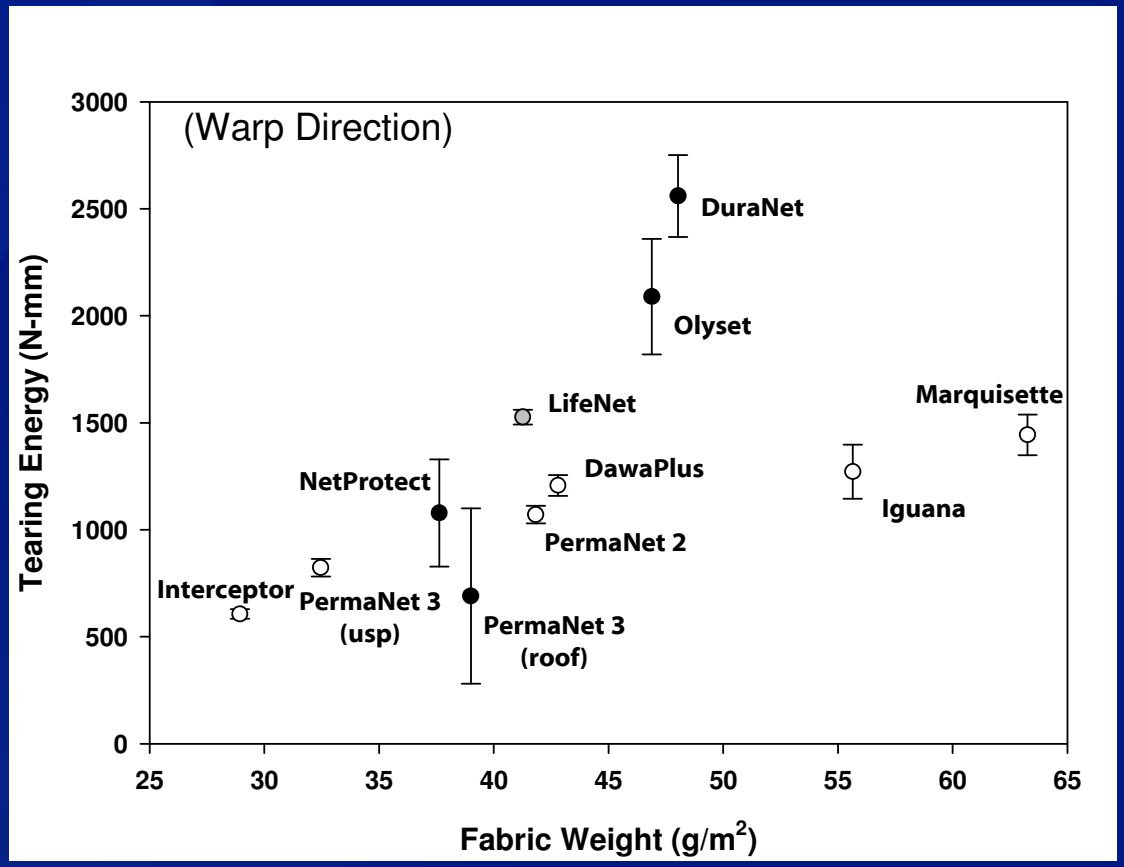
Skovmand, O. and R. Bosselmann (2011). "Strength of bed nets as a function of denier, knitting pattern, texturizing and polymer," *Malaria Journal*, 10(87).





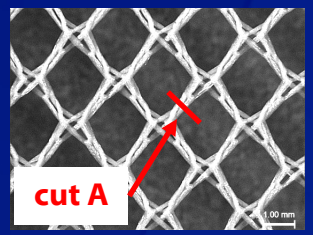
Resistance to tearing by snagging (CDC/NCState)

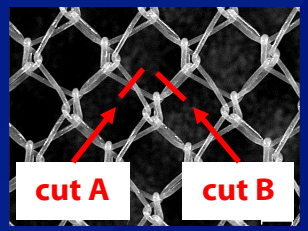


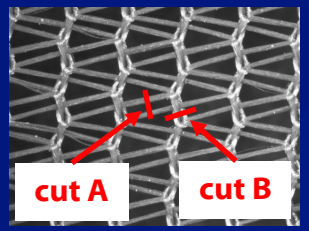


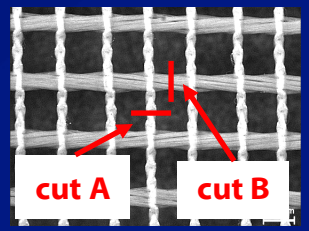
DuraNet and Olyset are best performers in this test

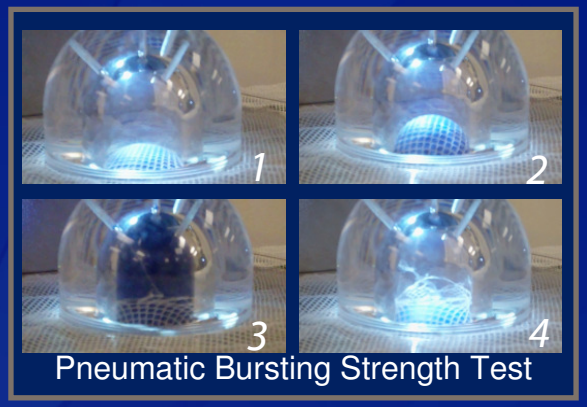
Strength loss after yarn severing

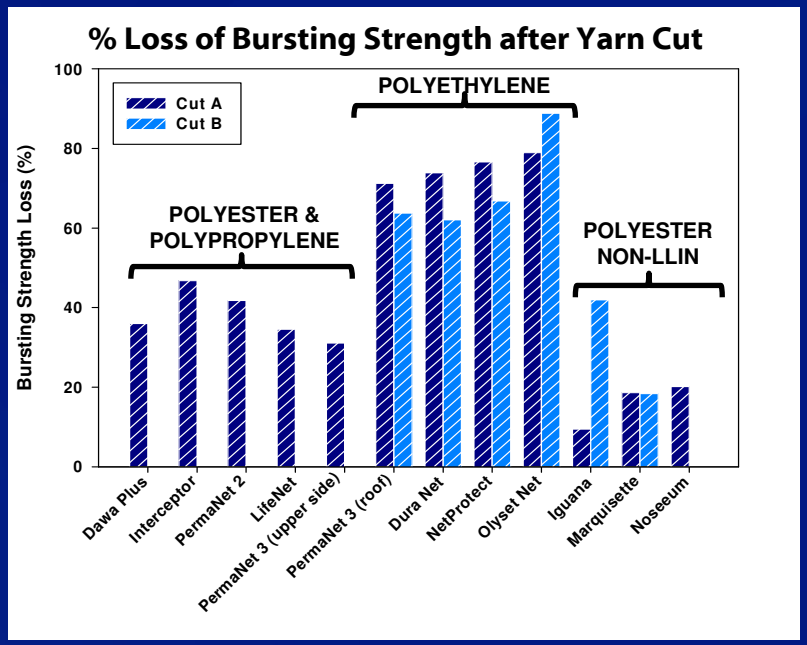












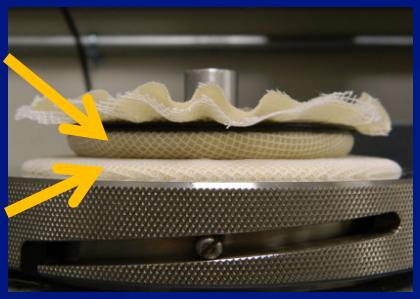
Polyester/Polypropylene nets perform best in this test.

Raveling resistance

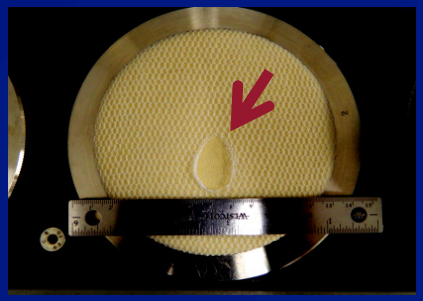
Martindale Abrasion Tester

Top platen
Oscillates
Specimen uncut

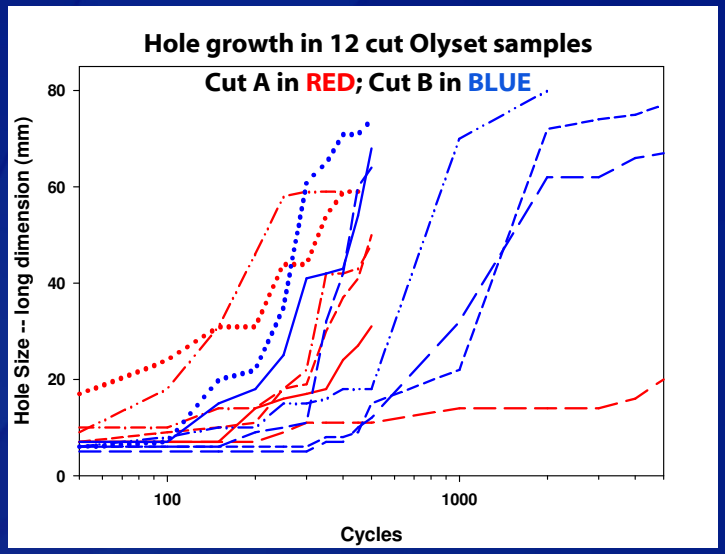
Bottom platen
Stationary
Specimen cut



Side view of test platens showing net specimens in place.



Specimen showing enlarged hole due to raveling.



- Only Olyset Nets showed tendency to ravel in this test.
- Rate of hole enlargement was inconsistent.
- Further test development is needed.

Consequences

- Hole formation and enlargement likely involves ***multiple mechanisms***.
- Its unlikely that a single test will be able to predict durability. Instead, a ***combination of tests*** will be needed.
  - Net performance depends on the conditions the net is exposed to.
- Nets <u>will</u> get holes: designing more durable LLINs should focus on ***resisting hole enlargement***.
- Users should be encouraged to ***repair even small holes*** and not wait for holes to get large.
- ***Correlation with field results*** is needed.

COLLEGE OF Textiles NC STATE UNIVERSITY

CDC