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## INTRODUCTION

### Motivation

- >The process of weaving fibers into a fabric damages the fibers, making them weaker
- >We want to understand how much of that damage is caused by the crimping/buckling of the fibers rather than the abrasion.



### Materials list

- >Rolls of each fiber (Armos, Kevlar KM2, and Zylon HM)
- >9mm and 6mm rods
- >1.12mm wire
- >Scanning Electron Microscope
- >1" Cardboard Squares (end tabs for testing)
- >Epoxy

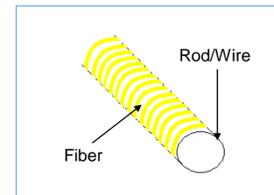


### Applications

- >These fibers are most well known for their use in military applications
  - >Body Composite Hybrid Structures
  - >Composite Hybrid Vehicles
- >Because of their high resistance to heat and low flammability, fibers like these are often found in heat/flame resistant clothing

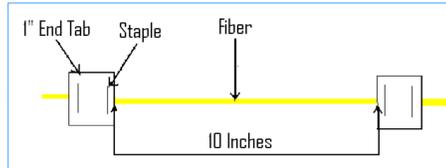
## EXPERIMENT

- >Three different fibers will be tested
- >Comparisons will be done with fibers that were not wrapped at all and fibers wrapped at 9mm, 6mm, and 1.12mm diameters.
- >The three fibers will be looked at under a scanning electron microscope to determine why any loss of strength may have occurred
- >The percentage of strength lost in each different fiber will be compared and analyzed.



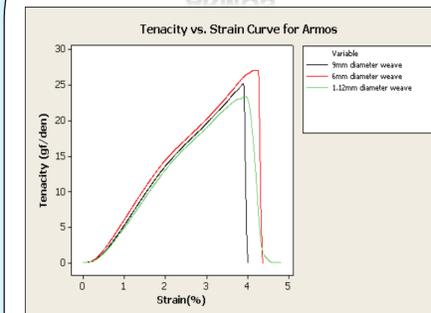
## METHOD

- A fiber ~14" in length is taken from a large spool and wrapped around the rod/wire of the desired diameter
- Fiber measure on a ruler in inches and recorded
- A knot is tied at the end of the fiber
- Fiber is weighed in milligrams (Accuracy to 1/100<sup>th</sup> mg) and recorded
- Linear density is calculated in deniers
  - $LD = (9 * m) / (.0254 * L)$  where LD is Linear Density, m is mass in mg, and L is length in inches.
- 1" Square end tabs are stapled to each end, making a 10" gauge length
- Epoxy is placed on each end tab on top of the fiber
- Another end tab is placed on the epoxy and stapled to hold it in place while the epoxy dries
- Wait at least one day, then the fiber is ready for testing
- Testing Procedure
  - Set up Instron 5567 with 500N load cell
  - Use 0-.25" grips
  - Pre-load the fiber to ~1.8N then down to ~.35N
  - Reset Gauge Length of Start Test
  - Plug in Linear Density into Bluehill program and Gauge length(254mm)

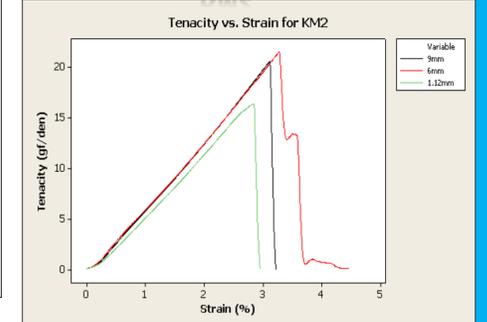


## RESULTS

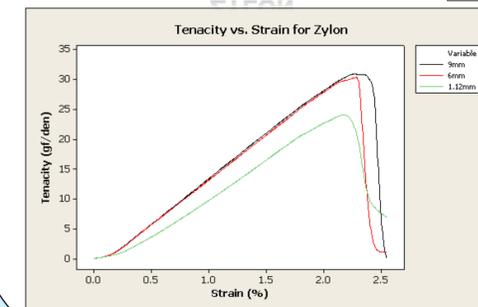
### ARMOS



### KM2



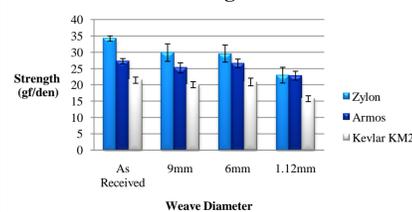
### ZYLON



>These three graphs show the differences in Tenacity-Strain curves for each material at each different wrap diameter.

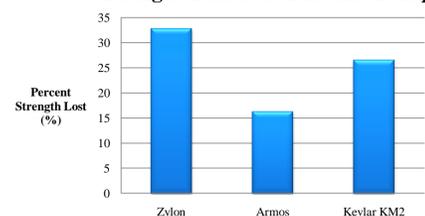
## ANALYSIS

### Weave Diameter vs. Tensile Strength



>This graph displays the tensile strength of each different fiber at all four conditions tested. "As received" came straight from the roll of fiber, and the 9mm, 6mm, and 1.12mm represent the diameter of the wrap

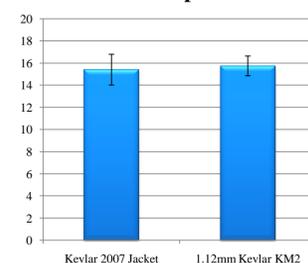
### Strength Loss after 1.12 mm Crimp



>This graph shows the percentage of strength lost from the original fiber for each material at the 1.12mm wrap diameter. Zylon shows a much greater strength loss compared to KM2 and Armos

## WARP WEAVE

### 2007 Vest vs. 1.12mm Wrap

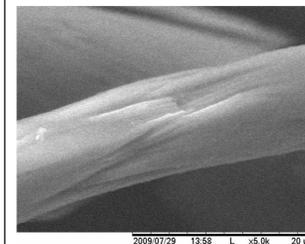


>This graph compares the average tensile strength of fibers pulled from a Kevlar vest from 2007 to the average tensile strength of the Kevlar KM2 fiber wrapped at a 1.12mm diameter.

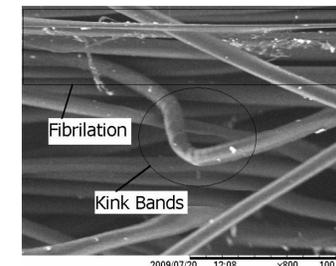
- >The 1.12mm diameter wire was chosen because the radius of curvature of Kevlar KM2 fiber in a warp weave is .56mm
- >We wanted to compare the strength of a fiber that had a warp weave and the strength of a fiber that underwent that same crimping effect, without the abrasion

## MICROSCOPY

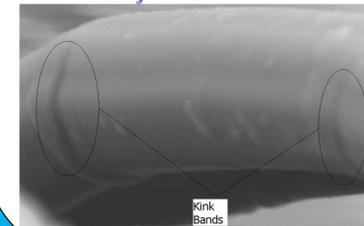
### Armos SEM Photo



### KM2 SEM Photo



### Zylon SEM Photo



- >Zylon-Failure mode Classic kinkband
- >Kevlar-Failure modes Kinkband and fibrillation
- >Armos-Atypical failure mode for fibers.

## CONCLUSION

- >Not much difference between 9mm and 6mm
- >All fibers showed significant strength degradation for 1.12 mm diameter wrapping which was comparable to radius of curve for single tow in a warp weave.
- >For 1.12 mm diameter wire:
  - >Zylon HM showed the greatest percentage loss in tensile strength. This is likely because Zylon is lacking the inter-molecular hydrogen bonds that are found in Kevlar and Armos. These hydrogen bonds act as glue for the fiber strands, preventing them from slipping. Since Zylon has no hydrogen bonding, it experiences the greatest amount of slippage.
  - >The strength of the Kevlar KM2 is very close to the average strength found in the 2007 jacket. This is because the 1.12mm diameter replicates the .56mm radius of curvature found in the warp weave which the 2007 jacket probably experienced.
  - >Armos shows unusual failure mode

## ACKNOWLEDGEMENTS

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