Bullet Proof Helmet

Kashish Kanodia

220103062

Various Ballistic Materials

TRADITIONAL MATERIALS

- Wood
- Fiberglass and Polycarbonate
- Compressed Fibers
- Steel

NOVEL MATERIALS

- Aramid
- Aluminum Oxide
- UHMWPE
- Ceramic Fibers

“Innovations in material science drive advancements in durability, adaptability, and cost-effective solutions”

Comparison

FIBERGLASS AND POLYCARBONATE
Pros: Frontal durability, High strength.
Cons: Brittleness, High Density, Manufacturing cost.

CERAMIC FIBERS
Pros: High strength, High modulus.
Cons: Very high production cost.

ARAMID (KEVLAR)
Pros: High tenacity, High modulus, High energy absorption, good Performance/weight ratio, High V50 rating.
Cons: Poor compressive strength.

STEEL
Pros: Moderate protection, cost Friendly.
Cons: Need high thickness steel, Heavy.

UHMWPE
Pros: Lightweight, Durable, High Impact Strength.
Cons: Lower V50 rating than Aramid.

Aramid Vs UHMWPE

Table 1. Mechanical properties of different fibers.

Fiber	ρ (g/cm^3)	E (GPa)	E/ρ (kJg^{-1})	σ_f (GPa)	σ_f/ρ (kJg^{-1})	ε_f (%)	c^* ms^{-1}
Aramid							
Kevlar 29 [15]	1.44	70–91	49–63	2.9–3.0	2.0–2.1	3.0–4.2	595[a]-703[a]
Kevlar 49 [15]	1.44	113–120	78–83	3.0	2.1	1.2–2.6	480[a]-621[a]
Kevlar 129 [15]	1.44	96–99	67–69	2.9–3.4	2.0–2.4	3.3–3.5	647[a]-700[a]
Kevlar 149 [15]	1.47	185	126	3.4	2.3	2.0	638
Kevlar KM2 [15]	1.44	70–85	49–59	3.3–3.9	2.3–2.7	3.8–4.5	672[a]-776
Twaron standard [13]	1.44	60–80	42[a]-56[a]	2.4–2.5	1.7[a]	3.0–4.4	544–658
Twaron high modulus [13]	1.44	100–120	69[a]-83[a]	3.0–3.6	2.1[a]–2.5[a]	2.2–3.0	576–700
Twaron high tenacity [13]	1.44	85–95	59[a]-66[a]	3.4–3.6	2.4[a]–2.5[a]	3.2–4.0	662–741

Table 1. Mechanical properties of different fibers.

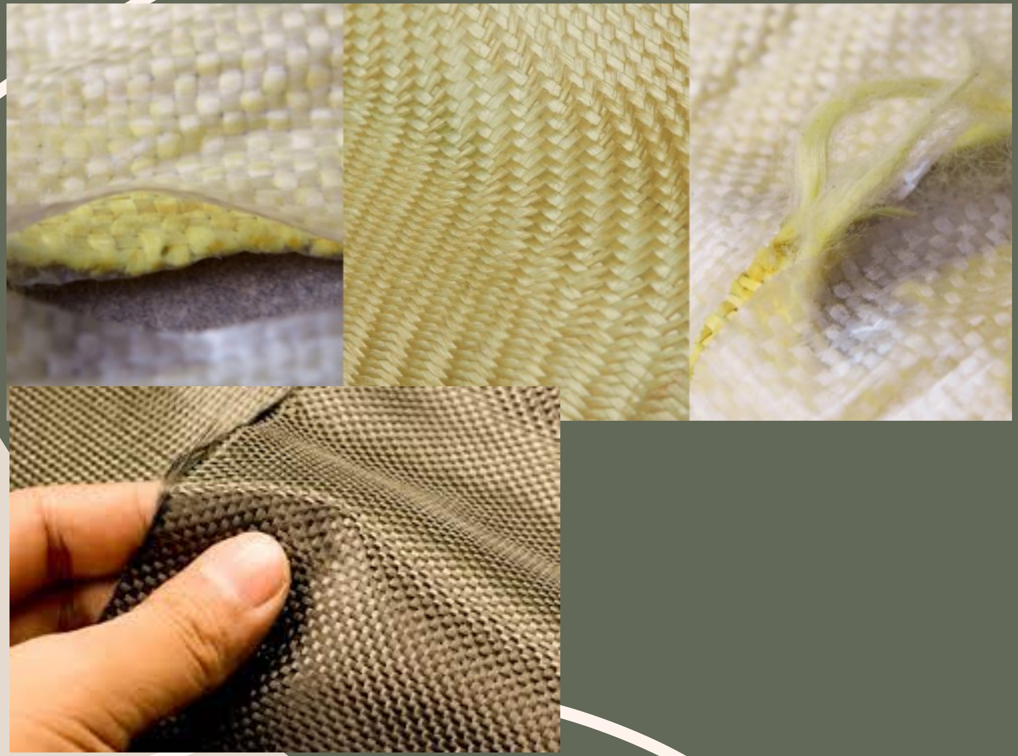
Fiber	ρ (g/cm^3)	E (GPa)	E/ρ (kJg^{-1})	σ_f (GPa)	σ_f/ρ (kJg^{-1})	ε_f (%)	c^* ms^{-1}
UHMWPE							
Dyneema® SK60 [15]	0.97	89	92	2.7	2.8	3.5	776
Dyneema® SK65 [15]	0.97	95	98	3.0	3.1	3.6	820
Dyneema® SK75 [15]	0.97	107	110	3.4	3.5	3.8	888
Dyneema® SK76 [15]	0.97	116	120	3.6	3.7	3.8	917
Spectra 900 [15]	0.97	73–79	75–81	2.3–2.6	2.4–2.7	2.8–3.9	660[a]-778[a]
Spectra 1000 [15]	0.97	97–120	100–124	2.6–3.3	2.7–3.4	2.8–3.5	721[a]-872[a]
Spectra 2000 [15]	0.97	116–124	120–128	3.2–3.3	3.3–3.4	2.9–3.0	806[a]-833[a]
Spectra 3000 [15]	0.97	115–122	119[a]–126[a]	3.2–3.4	3.4–3.5	3.3	840[a]-866[a]
Zylon AS [15]	1.54	180	117	5.8	3.8[a]	3.5	893
Zylon HM [15]	1.56	270	173	5.8	3.7[a]	2.5	849
M5-AS [35]	1.70	150	88[a]	2.5	1.5[a]	2.7	571[a]
M5-HT [35]	1.70	330	194[a]	5.5	3.2[a]	1.7	726[a]

Source: https://www.sciencedirect.com/science/article/pii/S1359836822002694

Most Suitable Material

After analyzing all the materials and their properties we observe that Kevlar is the most suitable material to make bullet proof helmets.

- ➢ High strength
- ➢ Proven effectiveness
- ➢ Excellent performance/weight ratio
- ➢ Cost-Efficient
- ➢ Versatile
- ➢ Lightweight
- ➢ Flexible
- ➢ High V50 rating
- ➢ Chemical Stability



https://www.sciencedirect.com/topics/materials-science/kevlar#:~:text=It%27s%20good%20in%20tension%20applications,Deepak%20and%20Subbaya%2C%202020

KEVLAR

Mechanical Properties

Following research paper shows experimental results of various tests (Tensile Test, Flexure test etc.) conducted on Kevlar :

[Jayakumar-Vijayarangan/publication/331496092_Evaluation_of_Mechanical_Properties_of_Kevlar_Fibre_Epoxy_Composites_An_Experimental_Study]

Fiber	k29	k49
Structural Properties		
Crystallization	0.52	0.58
Skin Thickness	1.2 um	0.7 um
Misorientation angle	4.0°	2.5°
Pleat Width	17.7 nm	18.7 nm
Pleat Length	250 nm	250 nm
Modeling Results (this paper)		
Strength	3.07 GPa	2.59 GPa
Ultimate Strain	0.041	0.021
Young's modulus	76.66 GPa	140.16 GPa
Literature Results [21], [22], [36], [39], [41]		
Strength	2.8–3.6 GPa	2.2–3.0 GPa
Ultimate Strain	0.038–0.042	0.022–0.028
Young's modulus	65–80 GPa	GPa

Table 3: Flexural result

Test parameters	Observed values (N/mm^2)
Aluminum	216.28
Kevlar epoxy	330.38

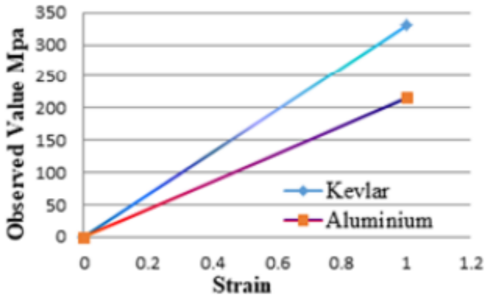


Fig. 7: Flexural results over aluminium

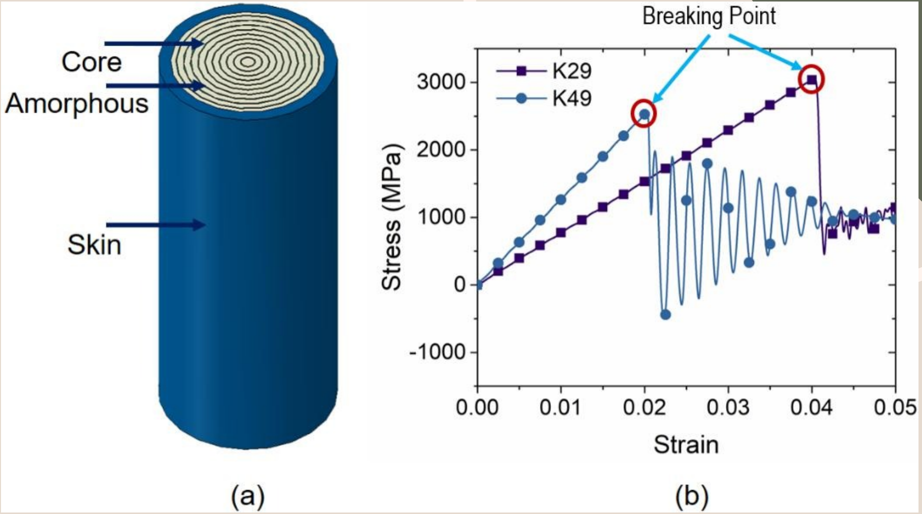
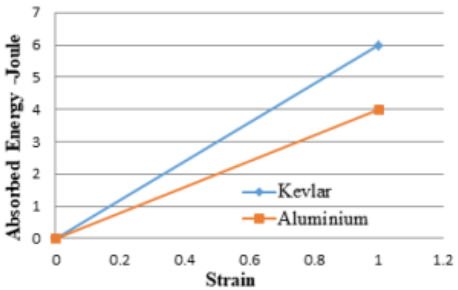


Table 4: Impact test results

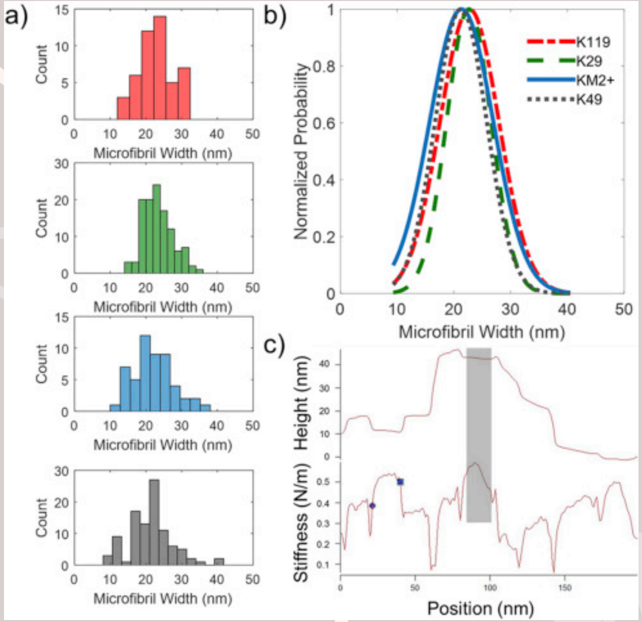
Test specimen	Specimen size (mm)	Notch type	Test temperature	Absorbed energy J
Aluminium	2.5×10×55	"V"	24°C	03
Kevlar Epoxy	2×16.85×130	Unnotched	24°C	06



MICROSTRUCTURE OF KEVLER

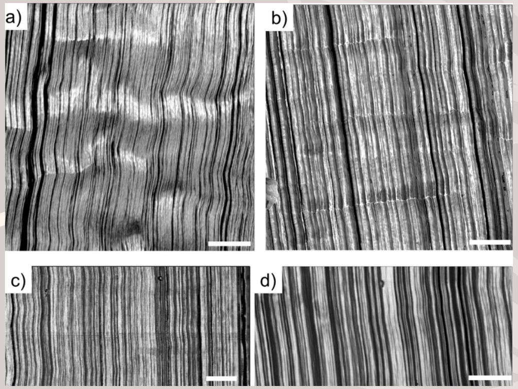
MOLECULAR COMPOSITION

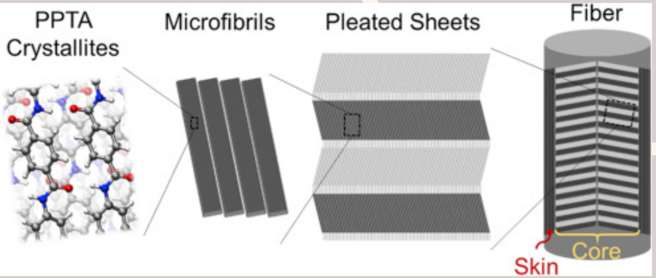
- Composed of PPTA molecules
- Strong intermolecular Hydrogen bonding
- Anisotropic unit cell

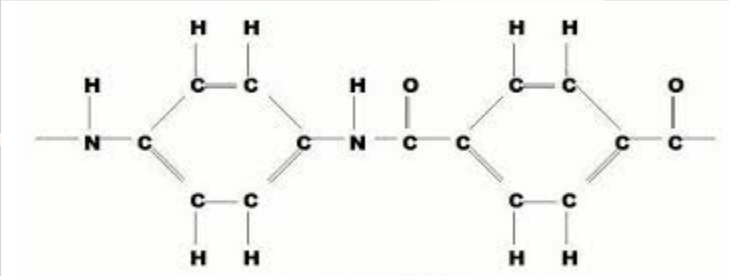


MICROFIBRILS

- 22 nm wide tape-like microfibrils
- Pleated sheet conformation







Source : https://www.sciencedirect.com/science/article/pii/S0032386117309126

RELATIONSHIP WITH MECHANICAL PROPERTIES

- Thicker skins are associated with higher **tensile strength**.
- Pleated sheet structures are **consistent**.
- Heat-treated fibers show less apparent **banding.**
- **Crystallite Orientation**.
- Thicker skins are associated with lower **elastic moduli** and higher **tensile strengths**.
- **Molecular rotation** within microfibrils.

APPLICATION

- **Ballistic Protection (Bulletproof Vests and Helmet)** – Due to high tensile strength, resistant to penetration.
- **Cut-Resistant Gloves and Clothing** : Strong fibers enhance the durability.
- **Aerospace Components :** High strength-to-weight ratio.
- **Sports Equipment (e.g., Bicycle Tires, Racing Sails):** Due to its strength and flexibility.

REFERENCES

Research Papers

- https://www.sciencedirect.com/science/article/pii/S1359836822002694
  (Analysis of different materials for making bullet proof helmet. Refer section 2.1.1 up to 2.1.4)

- https://www.sciencedirect.com/topics/materials-science/kevlar#:~:text=It%27s%20good%20in%20tension%20applications,Deepak%20and%20Subbaya%2C%202020
  (Study of Kevlar fiber and its mechanical and physical properties. Refer section 2.2)

- https://www.sciencedirect.com/science/article/pii/S0032386117309126
  (Internal Structure of Kevlar Refer section 1, 2.1, 2.2, 3.1 , 3.2)

- Evaluation-of-Mechanical-Properties-of-Kevlar-Fibre-Epoxy-Composites-An-Experimental-Study
  (Refer Section 3)

Website

- https://uarmprotection.com/what-materials-are-used-to-make-vests-bulletproof/

(Various materials used for ballistic application)