

## Composites Reinforcement Fibers: II - The Aramid and Polyethylene Families

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Blast mitigation, damage tolerance, ballistic vests and clothing – we hear these words a lot when it comes to the aramid and polyethylene fiber family per se. Two companies have generally pursued the aramid fiber products (Teijin Aramid USA and DuPont Advanced Fiber) with a variety of high performance fibers suitable for both the aerospace and commercial marketplace. Teijin’s products are the Twaron® and Technora® line while DuPont provides the Kevlar® line of aramids. Table 1 shows the typical mechanical and physical properties of the current major fiber systems within this group of aramids.

The Twaron®, Technora® T-200 and Kevlar® 29 aramid fibers are typically used in commercial applications. The Twaron® HM and Kevlar® 49 were developed at higher modulus and higher strength properties for aerospace applications. These fibers have excellent tensile strength at very low densities, making them very attractive in structural composites which rely primarily upon tensile loading conditions. However, they do have significantly lower shear and compression material allowables which often requires a significant “over-design” in which additional material layers must be added to compensate for the low mechanical strength in those applications. They are also susceptible to ultra-violet (UV) degradation unless they are protected by the resin system. Aramids require different machining, drilling, cutting, grinding and finishing operations and tools (see DuPont Kevlar web site for recommendations) to produce quality finished surfaces. Moisture weight gain for the fiber itself is often on the order of 7-8 wt% and adequate fiber or fabric drying is required to assure good cured composite parts. However, having said all of the above, these materials offer perhaps the best damage tolerance properties of all the available fibers. Consequently they are used extensively for impact damage mitigation, ballistic performance enhancement, and projectile penetration reduction in many armor situations.

**Table 1.** Typical mechanical and physical properties of primary aramid fibers (Teijin Aramid, DuPont).

| <b>Fiber Property</b>                           | <b>Teijin Aramid USA</b> |                  |                       | <b>DuPont Advanced Fiber</b> |                  |
|---|--------------------------|------------------|-----------------------|------------------------------|------------------|
|   | <b>Twaron</b>            | <b>Twaron HM</b> | <b>Technora T-200</b> | <b>Kevlar 29</b>             | <b>Kevlar 49</b> |
| Density (gm/cm <sup>3</sup> )                   | 1.44                     | 1.45             | 1.39                  | 1.44                         | 1.45             |
| Tensile Modulus (Tow/Impregnated Strand) (Msi)  | 11.6                     | 18.0             | 10.1                  | 10.2-12.0                    | 16.3-18.0        |
| Tensile Strength (Tow/Impregnated Strand) (ksi) | 406-457                  | 406-456          | 440-N/A               | 400-525                      | 400-525          |
| Elongation (%)                                  | 3.3                      | 2.0              | 4.4                   | 3.6                          | 2.4              |
| Thermal Expansion (10 <sup>-6</sup> in/in/°F)   | -1.94                    | -0.19            | N/A                   | -2.20                        | -1.10            |
| Fiber Diameter (micron)                         | 12                       | 12               | 12                    | 12                           | 12               |

Polyethylene fibers are based upon chemically and mechanically enhanced polyethylene into a series of ultra-high molecular weight polyethylene fibers (UHMWPE) that are drastically different from conventional polyethylene materials. The inherent internal orientation of the fiber structure provides for a very strong reinforcement fiber. Although one of the limiting factors of both Spectra® (Honeywell) and Dyneema® (DSM Dyneema) fibers is its low melting temperature (150°C/300°F), its attributes are its toughness and extremely low density.

Table 2 shows the mechanical and physical properties of the dominant polyethylene fibers in use today. Because it has excellent viscoelastic properties, it also is known for its high strain rate mechanical properties and damping characteristics. It also has excellent low dielectric constants which make polyethylene fiber composites virtually transparent to radar. Bonding to these fibers often presents a problem, but that problem also seems to be one of the primary reasons for its great impact damage tolerance behavior. Under an impact loading condition the lack of good bonding provides a mechanism for energy absorption and fracture containment over larger areas of dispersion.

**Table 2.** Typical mechanical and physical properties of primary polyethylene fibers (Honeywell, DSM Dyneema).

| <b>Fiber Property</b>                         | <b>Honeywell Advanced Fibers</b> |                     |                     | <b>DSM Dyneema</b>  |
|---|----------------------------------|---------------------|---------------------|---------------------|
|   | <b>Spectra 900</b>               | <b>Spectra 1000</b> | <b>Spectra 2000</b> | <b>Dyneema SK60</b> |
| Density (gm/cm <sup>3</sup> )                 | 0.97                             | 0.97                | 0.97                | 0.97                |
| Tensile Modulus (Msi)                         | 17.0                             | 25.0                | 18.0                | 12.6                |
| Tensile Strength (ksi)                        | 384                              | 448                 | 484                 | 391                 |
| Elongation (%)                                | 3.5                              | 2.7                 | 2.9                 | 3.5                 |
| Thermal Expansion (10 <sup>-6</sup> in/in/°F) | -5.0                             | -5.6                | N/A                 | N/A                 |
| Fiber Diameter (micron)                       | 38                               | 27                  | N/A                 | N/A                 |

### References

1. *Handbook of Composites, 2<sup>nd</sup> Edition*, Edited by S.T. Peters, Chapman & Hall, 1998
2. *Composites Design Manual*, J.A. Quinn, Technomic Publishing, 1999
3. *Fundamentals of Composites Manufacturing: Materials, Methods and Applications, 2<sup>nd</sup> Edition*, A.B. Strong, Society of Manufacturing Engineers, 2008.
4. *Carbon and High Performance Fibres: Directory and Databook, 6<sup>th</sup> Edition*, Edited by T.F. Starr, Chapman & Hall, 1995.
5. Fiber Web Sites:
  - a. Teijen Aramid USA (aramid): <http://www.teijinaramid.com>
  - b. DuPont Advanced Fiber Systems (aramid): <http://www2.dupont.com/Kevlar>
  - c. Honeywell Advanced Fibers (polyethylene): <http://www51.honeywell.com/sm/afc/products-details/fiber.html>
  - d. DMS Dyneema (polyethylene): [http://www.dsm.com/en\\_US/html/hpf/home\\_dyneema.htm](http://www.dsm.com/en_US/html/hpf/home_dyneema.htm)