Filament Winding vs. Fiber Placement Manufacturing Technologies

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The question frequently comes up as to what the primary differences are between "filament winding" and "fiber placement". Its not a question that is asked often amongst aerospace manufacturers, but it is asked frequently by students and those entering the composites manufacturing world for the first time. Or from an industry that is more commercial where fiber placement technology has yet to make a large entry.

Filament winding has been around for well over 50 years. It is frequently used in aerospace, industrial, commercial and sports and recreational areas. Pressure vessels, tubes, pipe, tanks, ski poles, golf shafts, launch tubes, booms, masts, drive shafts and numerous other structures are made using this process. Fiber placement, on the other hand, is a relatively new kid on the block. Tape laying and tape placement technology grew rapidly in the 1970's and 1980's as a better means of laying up prepreg materials in widths that were both precise and faster. Somewhere along the way folks figured out that perhaps tape laying machines and filament winding machine technologies could be married to achieve the best of both worlds. The 1980's through present time saw considerable growth in the use of fiber placement technology. While still used primarily for aerospace and high performance applications, fiber placement technology is growing.

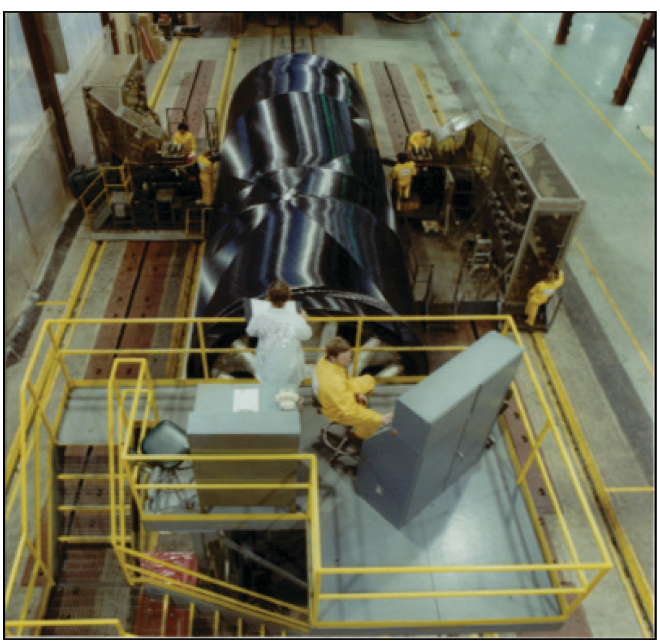

Figure 1. Filament winding machine producing a carbon fiber/epoxy composite segmented pressure vessel (with dual winders on both sides). (Photo courtesy of ATK)

The number of fiber placement machines have grown from a few half dozen in the 1980's to numbers in the 40-50 range today. Some are very small while others are large enough to make commercial aircraft structures and wind energy blades that have significant dimensions on the order of 40-60 meters (~120-180 feet). As a result of this question and its frequency, Table 1 was created to focus on some of the key areas where there are differences between the processes. As can be seen in the table, even the terminology may be slightly variable when it comes to fiber placement.

Fiber placement is often used for high performance structures where the fiber path within a given layer is designed to more precisely be laid down to be in conformance to the major local load conditions. Consequently it often is desired to "steer" the fiber tow or band into various angles that better optimize the load-carrying capability of the structure. Fiber placement also allows one to cut material and add material as necessary for tapering, expanding, crossing open areas (windows, doors, complex spaces, etc.) more efficiently. Consequently fiber placement scrap rates are much lower than filament winding or tape laying processes because materials are used much more efficiently.

Fiber placement technology has been rapidly expanding across several resin families. Most work currently has been with prepreg epoxy systems although BMI's are being pursued for high temperature appli-

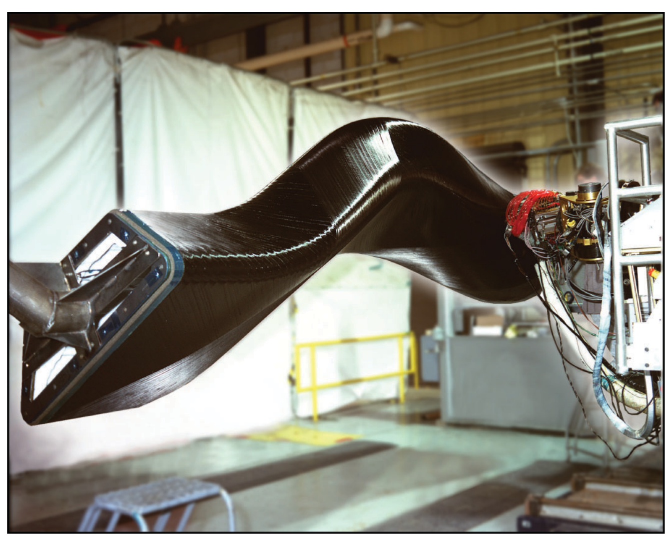

Figure 2. Fiber placement machine building a complex, high performance carbon fiber aircraft engine duct (FP machine on right side). (Photo courtesy of ATK)

Table 1. Comparison of "Filament Winding" and "Fiber Placement" similarities and differences for key manufacturing parameters.

Parameter	***Filament Winding*** (see Figure 1)	***Fiber Placement*** (see Figure 2)
General Terminology	Most commonly called Filament Winding (FW)	Sometimes called differently within the industry: • Fiber Placement (FP) • Automated Tow Placement (ATP) • Automated Fiber Placement (AFP)
Mandrel	Requires forming mandrel of some sort (usually does ***not*** go into an autoclave for final cure processing later)	Requires forming mandrel of some sort (often built for subsequent entry into an autoclave; typically for aerospace applications)
Resin Application State	Resin form may be: • Wet resin bath or wet resin bath with drum • Prepreg resin/fiber form • Dry fiber only – no resin	Resin ***must be*** a prepreg resin/fiber form (thermosets) or in a thermoplastic form
Fiber Forms	Fiber in various possible dry or prepreg forms: • Individual rovings (glass fiber designation) • Individual tows (carbon fiber designation) • May be any number of rovings or tows (typically anywhere from 1 to >60, depending on the width desired for winding) • "Tape" may also be selected form	Fiber comes ***only*** in prepreg form: • Width developed by number of rovings, or tows, must be manageable • Width typically on order of 0.10-inch to 0.50-inch in band (may be slightly wider) • Aerospace uses narrower widths than commercial applications
Fiber Tension	Fiber rovings or tows are ***continuously*** under tension (pulling) during winding process and are not "cut" until winding typically completed	Fiber rovings or tows are ***not*** under tension, but are "placed" onto the surface and compacted in place using "normal" pressure applied via a roller following the prepreg fiber width. Relies on "tack" to stick.
Cutting, Adding Fibers	Fibers are ***not*** cut during the process and are ***not*** added during the winding process – cut fibers lose tension and slip out of designated position (angle, location, pre-tension) on mandrel	Fiber roving and tow bands may often be cut, or added, during the placement process at any point in time using software to designate "when" and "which" tows
Fiber or Tow Cutting Mechanism	Not applicable – fibers are ***not*** cut	Mechanical knives (aerospace) or laser (commercial) mechanisms
Fiber or Tow "Steering"	Fibers are tensioned and take up a path of least resistance unless they are trapped in position mechanically (end fittings, mandrel rotation, pin rings, etc.)	Fiber tows and bands may be "steered" along different paths and angles on the surface since they are not tensioned like those used in filament winding
Resin/Fiber Temperature	Prepreg fiber is warmed up (to room temperature) prior to winding; resin baths for "wet" winding approach usually are at room temperature but often may be heated to obtain certain desired viscosity level; some applications may even cool the resin material	Fiber is in prepreg form – and is usually in "chilled" state. Fiber is preheated just before mandrel lay-down so it flows and compacts onto the mandrel.
Applicable Resin Systems	***Large variety*** of resin systems available: • Polyesters, vinyl esters • Polyurethanes • Phenolics • Epoxies • Cyanate esters • Bismaleimides (BMI) • Polyimides • Various exotic systems • Various thermoplastic matrices	Resins often limited to ***proven*** prepreg systems: • Epoxies (predominantly) • Limited Bismaleimides (BMI) work • A number of thermoplastic matrices

cations. Thermoplastics technology started with smaller machines but has gradually moved toward higher production machine technology and high performance aerospace and oilfield markets. One machine using large tow carbon fiber/epoxy (140K+ tow) has been installed for manufacturing very long wind turbine blades as a first ever entry into the commercial market with very high fiber lay-down rates. Initially FP lay-down rates were typically on the order of only 2-4 pounds per hour unless the orientation was very simple and no tow-cut/tow-add stops were required. Newer machines have significantly increased that lay-down rate with the optimization of what is termed "on-the-fly" tow cut and add programming features.

Figure 1 shows a typical filament winding machine and part while Figure 2 shows a high performance fiber placement machine in operation.