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FILAMENT WOUND PREFORMS FOR RTM

D. DeWayne Howell and Frank E. Roundy
StorageTek Composites
One StorageTek Drive, MS-0091
Louisville, Colorado 80028

ABSTRACT

A method has been developed for creating a Resin Transfer Molded (RTM) preform using the filament winding process. The preform fabrication process is applicable to the production of tubular composite products (see Figure 1). A low cost preform can be created by winding dry fiber tow over a mandrel and holding it in place using a tackifier. By using filament winding, one can accurately control the winding angle in the preform. Filament winding the preform onto the mandrel and resin transfer molding the preform, while still on the mandrel, results in a low cost, high quality composite component.

KEY WORDS: Filament Winding, RTM, Preform, Tackifier, Fabric, Braid, Tow

1. INTRODUCTION

Figure 1:
Filament Wound Preforms

There are several methods which can be used to create preforms on a mandrel for use in the RTM manufacturing process. The most common is to use a *fabric* that has a slight amount of tackifying binder applied to the fabric. The fabric is cut to size and wrapped, piece by piece, around the mandrel. When this method is employed, it can be difficult to maintain consistent fiber orientation and uniform wall thicknesses due to overlaps in the cloth. Furthermore, the cutting of the fabric results in a loss in benefits provided by continuous fibers.

An alternate method is to use a *braided sock*. This process involves a weaver braiding the sock in the shape of a long tube. The braided material is cut to length and placed over the mandrel and secured in place. An inherent problem with this method is that as the sock is stretched into place it can twist and compact. This in turn effects the fiber orientation and fiber volume of the finished composite part.

For both of these methods, the fiber is woven or braided on a machine and then placed on the mandrel. Neither method offers consistent, accurate fiber placement, and fiber orientation. A third method is to *filament wind* the preform onto the mandrel and RTM the preform on the mandrel. This method provides benefits preforming for RTM by providing a low cost, high fiber volume, controlled fiber angle, continuous fiber, on mandrel composite preform.

2. BENEFITS OF THE DRY FIBER TOW FILAMENT WOUND RTM PREFORM

2.1 Reduced Cost.
The most inexpensive composite material available is dry tow. There is very little supplier handling of this material and as such the price of the tow is low. In order to make a low cost composite tube, dry tow must be used. The use of a woven fabric, or a braided sock, adds considerable cost to the preform because a weaver or braider must be compensated for their costs and profit in producing the material. Fabric and braid are more expensive than tow on a pound for pound basis. By filament winding the preform onto the mandrel it is possible to use the least expensive fiber available, dry tow.

2.2 High Fiber Content Composites.
Unlike weaving or braiding, a filament wound preform has a lower “bulk factor”. The bulk factor is related to how well the fibers in a preform nest together. The lower the bulk factor , the better the fiber nesting. Since bulk factor and fiber content are inversely related to each other, filament winding gives a higher fiber content in RTM parts. High fiber content leads to parts which are stiffer and stronger.

2.3 Repeatable and Accurate Fiber Placement.
Most RTM applications use fabric or braid to make a preform. When fabric or braid is used, the weave can become distorted as it is wrapped around the mandrel and the fiber angle will change. It is extremely difficult to produce a tube with uniform wall thickness and fiber volume using fabric. In addition, the fabric may have a tackifier added to the fiber to help stabilize the weave pattern. This material can reduce the overall strength of the part. The most accurate method to control the fiber angle on a tube is to use the filament winding process. This method of fiber placement uses a computer controlled machine to wind the fiber on a mandrel at precise angles.

2.4 Unlimited Fiber Angles.
Filament winding offers the unique advantage of being able to place fiber angles from almost 0° to 90° onto a mandrel. This can be quite advantageous when a structural design requires angles other than the 0°/90°/±45° possible with cloth and the 0°/±θ°, where θ is limited to the same angle in the entire structure, for braids. Unlike braiding or fabric preforms, an infinite number of filament winding angles can be used to produce a preform with diverse and custom fiber orientations.

2.5 On Mandrel Preform Fabrication.
Many fabric or braided preforms must be placed onto the mandrel as a secondary step in the process of preparing an RTM preform. Filament winding the preform directly onto the mandrel

eliminates the need to transfer the preform onto the mandrel, thereby reducing fiber distortion and fabrication time. The on-mandrel preform is ready for insertion into the RTM mold soon after the winding is completed.

2.6 Limited use of Tackifirers.

Dry tow winding, per this method of preform fabrication, is very difficult to accomplish because the tow moves when cut, since the only element keeping it in place on the mandrel is the winding tension latent in the tows. A method has been developed to wind the dry tow around a mandrel and secure it in place. This method uses a limited amount of polyester scrim cloth to secure only the cut areas of the preform. The polyester scrim is heated and melts into the fiber. When it cools the material is secured and the excess is cut off. There is no movement of the dry tow and the preform contains only a small amount of tackifier at the ends only.

3. FABRICATING THE FILAMENT WOUND PREFORM

3.1 Winding.

The preform fabrication begins with the filament winding of the dry fiber (See Figure 2.) Much like wet filament winding, the tows are wound onto a mandrel at pre-determined fiber angles. Since the fiber is dry, it is quite slippery and tends to be easily distorted at the ends of the mandrel where the fiber reverses direction on the mandrel. To compensate for this tendency, dome shaped fixtures are located at both ends of the mandrel which allow for a smooth transition from one direction of the winding to the other. Sliding delivery redirects are used between the tensioning creel and the delivery head. The delivery head itself consists of a series of three rollers used to position each of the six tows into a band and to flatten the band (see Figure 3.) Sliding rather than rolling components were initially used on the delivery head, but were quickly replaced with rollers because the sliders caused the band to "rope" or "bunch-up," resulting in a gapped preform winding. The delivery head also is allowed to pivot so that the fiber band is deposited without roping and turns around evenly on the ends of the mandrel.

Figure 2:
Filament Winding Dry Tow

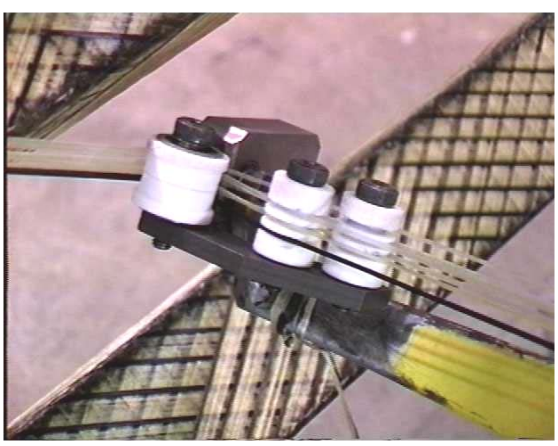

Figure 3:
Delivery Head

3.2 Tackifier Application.

Tackifying a preform typically involves impregnating the entire preform material with a low volume content of some sort of epoxy, polyester or some other binder material. Since the product under discussion here is a tube and the preform remains on the mandrel through the RTM process, complete tacification of the preform is not necessary. In order to get the mandrel to seal inside of the RTM mold, it is necessary to expose the mandrel surface beneath the filament wound preform and create a seal. In Figure 1 the exposed mandrel can be seen in the foreground ends of the preform and mandrel. To do this, the turn around ends of the preform must be removed from the preform/mandrel combination. Since the latent tension in the fiber due to filament winding is all that holds the preform onto the mandrel, as soon as the ends of the preform are cut the entire preform will unravel. To address this issue, a light polyester scrim is wrapped in a 5 cm (2 in.) wide band around the mandrel near the turn around ends of the preform (see Figure 4.) The polyester scrim is applied several times between various layers of the preform winding. This insures that the preform will be saturated with the polyester scrim material through the complete thickness of the preform. The important item to note here is that the tackifier is applied only to the areas where the preform will be cut, and not to the entire preform.

Figure 4:
Tacifier Scrim Application

3.3 Tackifier Consolidation.
Once the winding of the preform is completed and the tackifier scrim cloth has been inserted between various layers in the preform, a final wrap of tackifier scrim is applied to the OD of the preform. In its current state, the tackifier is nothing more than a group of polyester fibers imbedded between layers of the preform. For the tackifier to do its job of holding the preform together, the polyester fibers must be melted and forced into the fibers of each layer. To do this, electric heater blanket strips are wrapped around the preform in the areas of the tackifier. Aluminum clamps are then placed around the heater blankets and the preform is compressed through its thickness (see Figure 5.) The heater blankets are activated for a period of about 20 minutes. At the end of the 20 minute heat/consolidation cycle, the clamps and heater blankets are removed to reveal a compressed, tackified region of the preform.

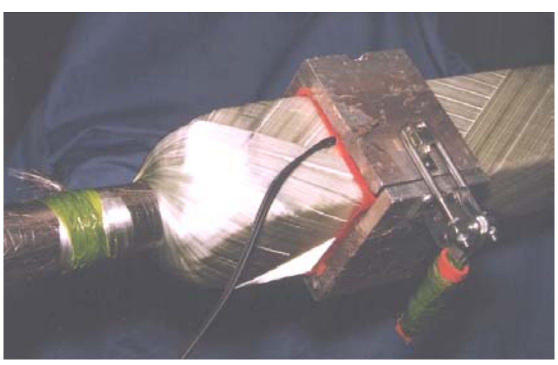

Figure 5:
Tacifier Melting & Consolidation

3.4 End Trim.

The final step in the preparation of the filament wound preform is to trim the end turn around regions from the preform. The tackifier consolidation step has stabilized the preform and the ends are cut using a rotary blade cutting system (see Figure 6.) The rotary blade cuter is more effective than cutting with a razor blade knife because the blade "rolls" rather than "drags" across the preform. This helps to minimize any distortion which may occur due to the unlikely event of poor tackifier consolidation. As shown in Figure 6, the mandrel is spun on its axis as the rotary cutter is rolled around the circumference of the preform. The cut is located on the tackified region of the preform near the turn around side of the region. Once the cut is made, most of the tackified area of the preform remains with the preform and the outboard (turn around end) of the preform is discarded. The tackifier holds the windings tightly in place and prevents distortion of the fiber during the cutting operation.

Figure 6:
End Trim of Preform

3.5 Resin Transfer Molding.

Now that the ends have been trimmed from the preform, the mandrel is exposed at the ends of the preform so that it can sealed. The preform/mandrel combination is now placed into the RTM mold as shown in Figure 7. The exposed area of the mandrel can be easily seen in the bottom left corner of Figure 7. It is also notable that for this particular RTM operation, a light carbon veil is wrapped around the preform as it is placed into the mold. The carbon veil serves two purposes. First, it gives the finished part a black color. Black pigments in the resin were tried early on in the development process, but the fiber content in the part was so high that the pigment was filtered by the preform during the injection process. Fiber contents in the finished fiberglass resin transfer molded part are around 57% by volume. Second, the carbon veil aids in preventing fiber splintering and breakout during the machining process performed on the molded part after cure.

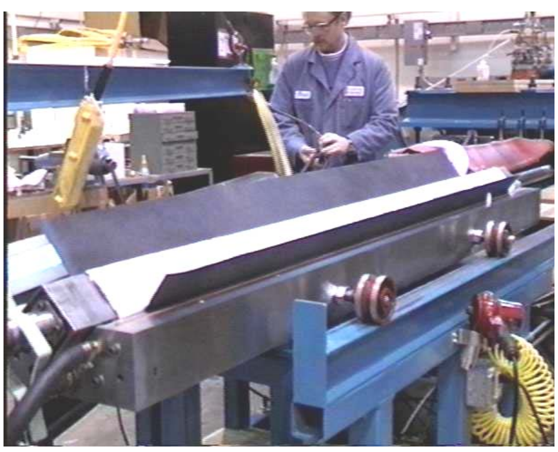

Figure 7:
Place Preform In Mold

Figure 8 shows the end seal in place against the mandrel at the trimmed end of the preform. The longitudinal seal can also be seen in the middle right side of the picture. Once the mold is closed, resin is injected to flow around the part circumferencially rather than down the length of the part axially. Figure 9 displays the final RTM part as it is removed from the mold still on the mandrel. Once removed from the mandrel, the tackified end regions of the RTM part are trimmed off of the part as it is trimmed to final length.

Figure 8:
RTM Mold End Seal & Preform

Figure 9:
RTM Tube Out of the Mold

4. CONCLUSIONS

The filament wound preform fabrication method for tubular RTM products has several advantages. Advantages include: high fiber content, accurate and repeatable fiber angle placement, unlimited possibilities of fiber angles using continuous filament wound fibers in the preform, and the limited use of tackifiers resulting is 0% tackifier content in the finished part. For operations which already have filament winding equipment in place, the filament wound preform method can also offer on-mandrel preform fabrication resulting in reduced cost preforms and finished products.

5. BIOGRAPHY

D. DeWayne Howell is a graduate of the University of Cincinnati, with a BS in Aerospace Engineering. He is a Senior Development Engineer for the StorageTek Composites Group and has worked in the composites industry continuously for 14 years.

Frank E. Roundy is a graduate of the Brigham Young University, with a BS in Manufacturing Technology. He is a Senior Development Engineer for the StorageTek Composites Group and has worked in the composites industry continuously for 15 years.