Advancements in Composite Tape Placement Manufacturing

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MEEG453
HW#7
11/14/2011

Summary

Composite manufacturing has produced some of the most versatile objects to date. Being able to reduce the weight of an object while still maintaining the properties of said object has been a striving goal of composite scientists. There are numerous manufacturing processes that are currently in use to create finished composites that have specific properties and weigh less than there isotropic counterparts. A unique composite manufacturing process is tape placement which involves precisely laying individual fiber tows on a mold. Research and engineering in tape placement has improved over the years for higher accuracy, faster production, and reducing cost. The advancements in tape placement are a great example of how composite manufacturing has progressed.

Discussion

Since composites were first introduced, the need for fast, efficient, consistent and customizable production methods has been the driving force in innovation. Tape placement is one method that is able to meet these requirements but the process involves more advanced machinery and computer control systems than ever before. Tape placement entails laying fiber tows on a mandrel or mold in a precise manner until the part is completed (Figure 1). It evolved as prepreg fabrics became more available, as the use of prepreg is vital to modern tape placement methods. Tape placement machines are able to produce parts with complex curves and structures with very precise fiber directions in order to produce the desired properties.

Early tape placement operations' main limiting factor was the rate at which fiber and matrix could be laid up. Early marks were set at only a few lbs/hr through hand lay-up and early machines, but current machines are able to place 12 inch wide tows and can lay down over 100 lbs/hr greatly improving production rates [3]. The aerospace industry is pushing tape placement methods further and further by requiring complex parts to be produced at a large scale, such as the nose of the Boeing 787 (Figure 2) and large aircraft engine ducts (Figure 3). As the technology behind the actual machinery and the computer control systems evolves, tape placement may prove to be the best way to create the planes and spaceships of the future.

Tape laying and tape placement's technology improved in the 1970 and 1980's as being a better, more precise, and faster manufacturing process for laying up pre impregnated composites fibers. There has been some research in using different resins depending on the application. However, the newest advancements in this field have been improvements on the automated tape placement machines and software and building these machines at a lower cost for a wider customer base. These machines range in size from small applications to making sections of aircraft frames and wind energy turbine blades [1].

Over the past few years, research has focused on the effects of using other resin/epoxies. Fibers come in spools only in the prepreg form, using a thermoset and thermoplastic resin, and are usually between 0.1 to 0.5 inches wide [1]. Bismaleimide (BMI) resin is one example of an addition type polyimide typically used in high performance structural composites that require high temperatures and high toughness. Blends of BMI have proved to function at temperatures of 205°C to 290°C [2].

Developed from the traditional computer numerically controlled (CNC) machinery is the automated tape laying and fiber placement machinery. The latest models in this field can handle up to 190,000 lb mandrels [3]. The machines control the feed, clamp, and cuts the fibers all independent of one another. This allows for automated adjustments of fiber band width, controlled steering of the fiber for changes in curvature and angles, and precise configuration for complex parts. The tool that applies the fiber to the mold is the head. This head includes a spool of fiber, a roller with guides, a shoe for compaction, a position sensor, and a cutter blade. The head can be positioned on a multi-axis robot that either moves around the mandrel to apply the fiber, or the head is suspended on a gantry frame and the mandrel rotates for correct fiber placement [3]. Fiber placement heads are very complex as they allow "on-the-fly" cutting, clamping, and repeating for each fiber tow. Those tasks are performed while maintaining the proper temperature on the deposition surface as well as inside the head. The fiber tows are kept cold and the roller makes them stick to the surface by controlling the heat right before placement. Fiber placement on a surface is done using a special roller capable of fiber steering, which is where fiber tows are precisely laid on a surface next to one another and can be done at various angles and radii (Figure 4). The last yet most crucial step is the compaction force that is applying the fibers to the previous layers. This is important because the layers need to properly homogenize to their designed structure [4].

Fiber placement heads are being engineered to provide easy and low cost solutions to the operator. Heads are designed to have access to internal components for cleaning, repairs, or replacing parts to minimize down time. Automated Dynamics, a manufacturer of fiber placement machinery, has a new "right-sized" automated tape laying (ATL) head targeted at manufacturers who make thermoset composite parts without much curvature in moderate to high rate production (Figure 5). This head has many benefits such as being able to be installed on different machine platforms, tailorable to any part size, and is affordable because of its simplicity. One component that has been simplified is the cutting system which makes one cut perpendicular to feed direction with a guillotine style instead of complex cutting system to make edge-of-ply or change-of-path angle cuts. The roller offers flexibility to minimize axes, but is limited by the curvature of the part's surface. Another advantage is that the cutting blade is two inches away from the roller allowing for short strips to be laid down at a time by the machine which aides in flexibility for building complex part [5].

The most state of the art technology in tape placement is using a laser to heat the fiber tow before surface application (Figure 6). The laser technology efficiently produces a high energy density beam precisely in the welding zone. The laser, with response times of a couple milliseconds, gives accurate control without overheating the fiber by taking local temperatures at the laser output [6].

Programming and analysis software is also becoming more sophisticated and flexible. Traditionally, design software allows the composite engineer to create composite structures using the automated fiber placement techniques which can then be imported as a CAD file to the AFP machine for production (Figure 7). With newer software, such as Mikrosam's MikroPlace, one can analyze and fix production problems and even do custom post-processing modifications for the final layup. MikroAutomate is another software program, except this is a control and data acquisition system that allows the user to run a production program, override a set of parameters, and give complete tracking of data points. The data can then be generated to a report and inspect previous production runs [4].

Economic Aspect

Designers are making automated tape placement machines with customers in mind by selling them a product with lowered cost, higher production, more reliable and user friendly machinery. The machines use standard parts for reduced purchase cost as well as maintenance cost. Since tape laying has become automated, a major focus has been to increase the production rate, such as by widening the fiber tow. These higher production rates allow composite manufacturers to build complex parts with quick changeover time, enabling the company to earn money faster. Fiber placement heads are complex, with many components, and for that reason much can go wrong. Designing the machinery to be reliable with low maintenance reduces down time, which results in less loss of productivity and less revenue. Reliability and low maintenance are accomplished by making the head out of higher quality parts with exposed components for quicker and easier cleaning and repairs. The tape laying process is becoming more user friendly because of the easy-to-use software that is incorporated into the machinery. The ease of equipment and software use gives companies the flexibility to hire less experienced engineers or machine operators, thereby reducing training time and overall wage rate, leading to lowered overhead and higher profits.

Relevance for Engineers

The advancements in tape placement composite manufacturing provide direct benefits to engineers, regardless of experience level. Composites are becoming more and more popular because it allows engineers to design the material for an application instead of trying to pick out of a set of materials. The significance of automated tape placement for beginning engineers is that it allows endless flexibility for composite manufacturing. Virtually any part, regardless of curvature or complexity, can be made with high precision. This endless flexibility can be daunting for beginning engineers, but improvements in software facilitate the research development and trouble-shoot during the design process. The significance of tape placement for experienced engineers is giving them an opportunity to find new ways to lower the cost and make the equipment more affordable for a larger customer base. If machinery and material costs for tape laying can be further lowered, then more companies would adopt this process for manufacturing intense engineered parts, such as an airplane fuselage, with high strength, low weight, and low corrosion.

Learning

I learned that tape placement involves much engineering but more specifically, heat transfer to keep the proper temperature of the fiber inside and out of the head, and mechanics to apply the perfect amount of pressure at the deposition surface. My background knowledge in tape placement included only the process and not the intricacy and details of the components. First I researched the history of tape placement and found that it originated from hand layup. Then, in researching the manufacturing process I learned the details, capabilities, and difficulties or issues with the process. Finally, I researched the advancements of this process and found that companies are designing fiber placement heads and their software to be more accurate, faster at producing parts, and more economical for wider customer base.

Figures

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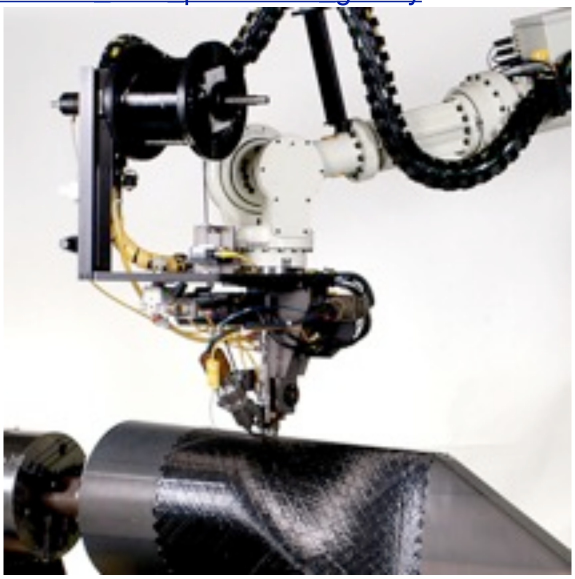

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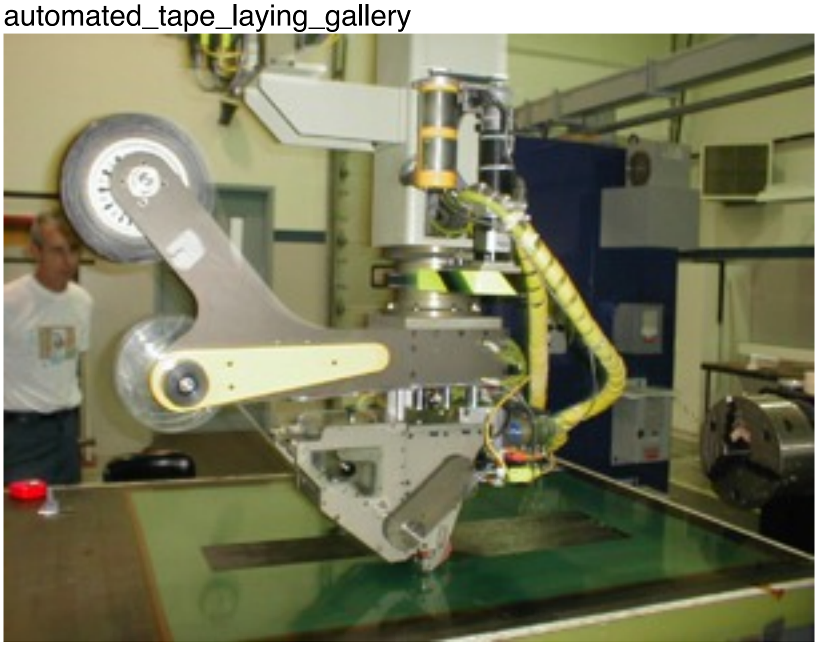

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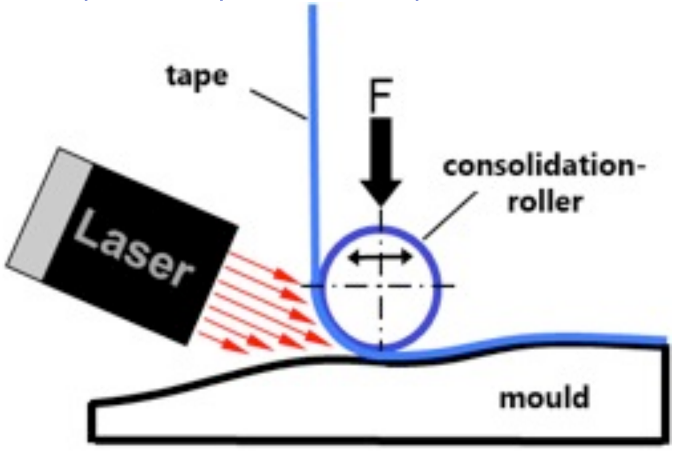

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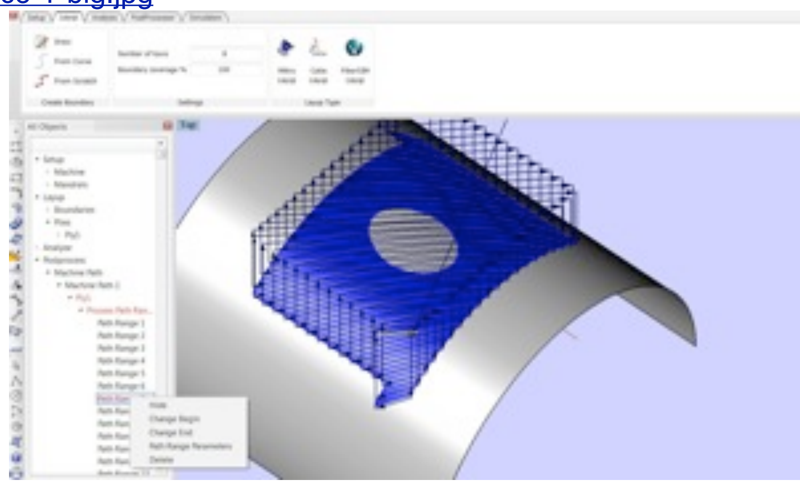

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