RECENT DEVELOPMENTS ON AUTOMATED COMPOSITE MANUFACTURING (ACM)
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1 General Introduction
The availability of automated tape layup (ATL) and automated fiber placement (AFP) machines has facilitated many advances in the automation of the manufacturing of composite structures. ACM of composite structures can provide many benefits such as increased speed of material deposition, good compaction of the laminate, reduction of wastage of materials, more precise control of the fiber orientation, better repeatability in the architecture of the materials, the ability to manufacture large structures, and the ability to make unique structures that are not possible by any of the current manufacturing techniques. Over the past few years, there have been increased activities on automated composites manufacturing in many centers around the world. The first international symposium on automated composites manufacturing (Montreal April 11-12, 2013) provided a snapshot of many of these activities. This paper provides a summary of the work presented at this symposium. The paper also presents a summary of the work on the development of a few unique structures at Concordia Center for Composites.

2 Highlights of work presented at the First International Symposium on Automated Composites Manufacturing.
One of the main reasons many composites manufacturers get into ACM is to increase the speed of materials deposition. While the rate of material deposition using Hand Lay Up is about 2.5 lbs/hr, this rate is about 10 lbs/hr using either ATL or AFP. The rate varies depending on the type of machine, how many heads it has and how elaborate is the mechanism for deposition. While the speed of deposition is important, the ability of manufacture structures with complex geometry is also very relevant. To assist in the handling of the complex shapes, many organizations have specialized in the development of software for the simulation of the process. There were also materials issues such as the ease or difficulty in slitting the prepreg, the effect of the tackiness of the thermoset prepreg on the manufacturing process, or the effect of the quality of the thermoplastic preforms on the quality of the final part. The existence of laps and gaps in the manufacturing of complex structures such as cones, or due to the steering of fibers can have significant effect on the property of the final product. On the other hand, the steer-ability of the fibers can provide many benefits such as the augmentation of buckling properties of plates or cylinders made using the steered fibers. Laser heating has been introduced for the manufacturing of parts using thermoplastic composites.

3 Comparison of the performance of laminates made using out of autoclave prepregs and ACM
Some preliminary work on the use of ACM to process out-of-autoclave prepregs have been performed at Concordia. Four types of laminates were manufactured, all using out-of-autoclave prepregs. These types of laminates are: AFP + autoclave (pressure), AFP + Oven (vacuum only), Hand Lay UP + autoclave (pressure), Hand Lay Up + Oven (vacuum only). These laminates were then characterized for mechanical properties using the following tests: Tensile test along 0° and 90° directions, compression tests along 0° direction, and in-plane shear test.

It can be seen that samples made using AFP exhibit higher stiffness and strength than those made by HLU. This can be due to better compaction of the laminate during the
deposition process. More information on this work can be found in reference 1.

Figure 1: Comparison of tensile stress-strain curves for OOA samples made by AFP and HLU

4. Fabrication of thermoplastic composite tubes.

AFP has unique advantages over other techniques for the manufacturing of composite tubes, particularly thermoplastic composite tubes. This is because the wrapping of composite fibers around a tube requires good fiber tension to avoid wrinkling. The ability to heat and fuse the thermoplastic composite layers together allows the elimination of the second step in autoclave, such as required if thermoset composites were to be used. The only drawback is the existence of a large amount of voids in the thermoplastic laminates, if improper processing conditions are used. Figure 2 shows a SEM image of the cross section of a tube with voids. The use of appropriate pressure and temperature is essential for the production of good quality laminates. Apart from the thermal and pressure management, the use of repeated passes can also provide structure of good quality. Some work has been done at Concordia in this direction [2]. Figure 3 shows the SEM picture of a cross section of a tube made of thermoplastic composites using different number of passes.

It can be seen the number of passes can provide composite with very good quality.

References:


Figure 2: SEM picture of a tube section made by thermoplastic composites and AFP (carbon/PEEK, 825 C, 40 lbf, 2.75 in/minute)

Figure 3: SEM picture of a tube section made by thermoplastic composites and AFP (carbon/PEEK, 850 C, 75 lbf, 2.75 in/minute) a) 1 pass, b) 3 passes