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Robot Driven Automatic Tapehead for Complex Composite Lay-ups

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ABSTRACT

A compact automatic tape layer head is constructed to place two unidirectional carbon fiber tows for lay-up of small complex composite components. A mechanism is employed to direct the tows to either side of the compaction rollers, allowing bi-directional operation without head rotation. Small diameter compaction rollers and a toolpoint with 90 degrees of clearance enable lay-up of interior corners. The head is positioned with a 6-axis robot. Current work focused on robot accuracy is envisioned as integral to devoloping the head and robot for production purposes.

Figure 1 – Twin Tow Head & Robot & Tool

INTRODUCTION

The twin-tow head is intended to automate the layup of small and complex composite parts with unidirectional tow – many of which are currently made by hand with woven fabric. The head is a modular design with onboard creels and a toolchanger. Bi-directional lay-down reduces machine motion and speeds short course lay-ups. A very low profile toolpoint can deposit tow in all orientations on complex shapes such as internal corners with small radii. Independent compaction axes for each tow allow off-normal lay-down laterally (camber), and the low-profile toolpoint allows an equal degree of tangential (caster) off-normal lay-down. A robot provides a very economical and flexible motion platform. Current robot techonology will soon match the high speed and medium accuracy requirements of composite lay-ups. Combining small, agile, modular heads with fast robots presents an attractive solution for production of certain composite components

MAIN SECTION

This section is divided into three sub-sections:

- Unidirectional carbon fiber tow lay-up process
- Head Arrangement
- Future Applications

UNIDIRECTIONAL CARBON FIBER TOW LAY-UP PROCESS

The layup process can be summarized as follows:

1. Head approaches tool with tow ready, compaction rollers contact tool
2. Tow is fed towards nip point and lay-down starts
3. Tow is cut to finish course lay-up
4. Head is shifted to next course
5. Repeat

The head provides the following functionality:

- Low profile toolpoint is capable of 90 degree internal corner lay-ups with corner radii as small as 12mm and facilitates tangential off-normal lay-down.
- Bi-directional lay-down reduces head rotation between courses and saves significant time on short course lay-ups.
- Non-normal lay-down reduces machine movement
- Independent compaction axes allows lateral off-normal lay-down
- Modular head is self contained

Currently many large composite components are manufactured with automatic lay-up machines. These

components tend to be relatively flat (locally) and are well suited to high tow count (16+) heads with large compaction rollers and very high surface speeds. Examples include aircraft wing skins and fuselage barrels. More complex shaped components such as stringers and frames are not possible to lay up with these heads. Accessing complex geometry dictates a lower tow count.

Traditionally the machine maintains head normality with the part. This simplifies part programming but, depending on part geometry, machine geometry, and surface speed, can impose extreme demands on the machine. Laying up complex parts fast greatly benefits from off-normal operation. Tangential non-normality (caster) simply requires toolpoint clearance above and below the compaction roller. Lateral non-normality (camber) is achieved with independent compaction axes for each compaction roller. This is possible with two tows, but it is not clear whether it can be expanded.

A good example of off-normal caster benefit is negotiating a corner. The head can approach the corner at an angle (equal to half of the corner angle), negotiate the radius and finish at the same angle. During the course the machine can slowly angle the head before and after the corner. This dramatically reduces the machine accelerations compared to maintaining instantaneous head normality. The same applies for camber when laying a 45deg ply around a corner. The two modes are combined to reduce machine accelerations.

Typically automatic tapeheads dispense tow or tape on one side of the compaction roller. This limits operation of the head to one direction and the machine must rotate the head 180 degrees between courses. This is not critical on long course parts but on smaller parts with short courses the added time to rotate becomes more significant. It can also drive up the requirements on the relevant machine rotation axis. Adding a small mechanism that directs the tow to either side of the compaction roller enables bi-directional operation.

HEAD ARRANGEMENT

The apparatus is discussed in five sections:

- Modular head
- Independent compaction axes
- Toolpoint
- Bi-directional tow flipper
- Drives & Controls
- Robot Motion Platform

Modular Head

Comprising the head are a main backplate, two compaction tower/sled assemblies and two creels (see Figure 3). The backplate provides a common surface on which to mount the aforementioned components. Additionally there is a group of pneumatic servo valves and a servo drive for each feed motor.

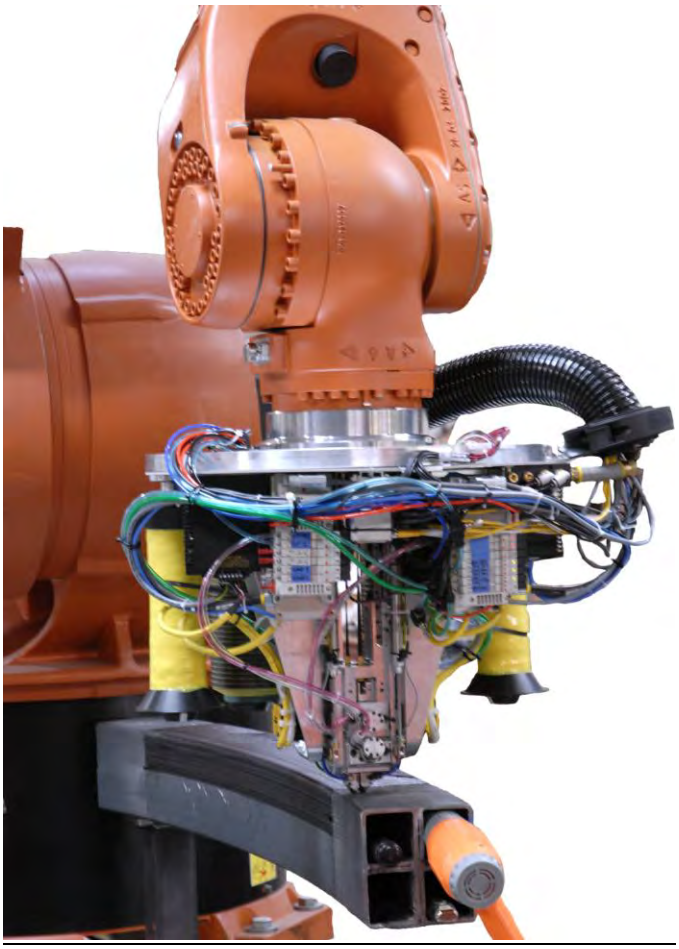

Figure 2 – Head normal on part

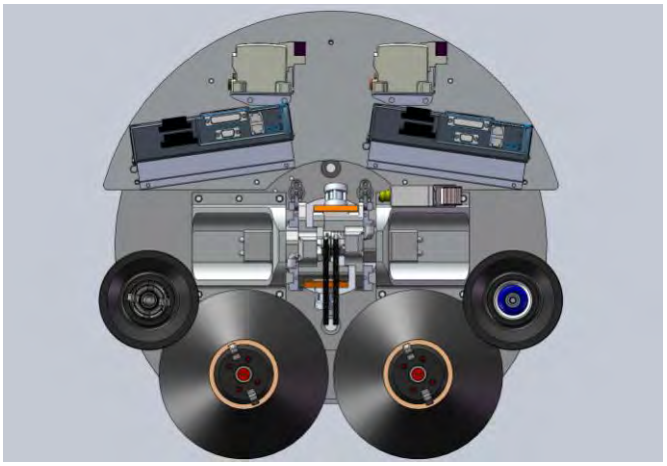

Figure 3 – Modular Head

Figure 4 – 45deg Course with Caster & Camber

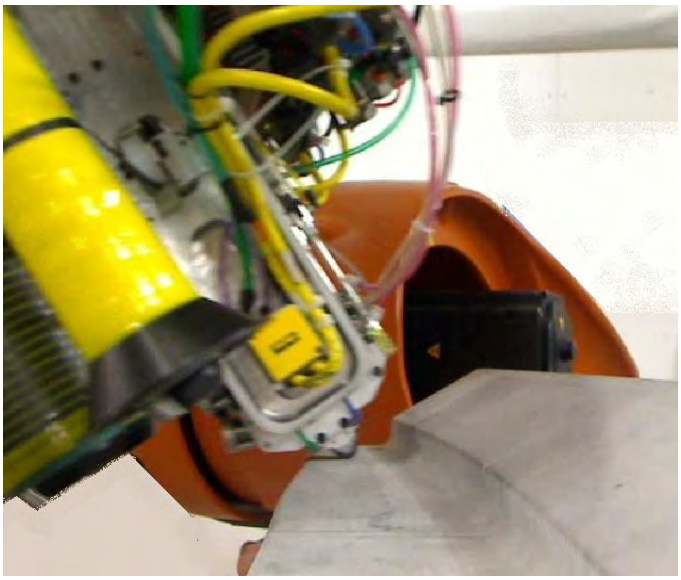

Figure 5 - 90deg Course with Caster

Independent Compaction Axes

Each compaction axis assembly is essentially a single tow tapehead and allows for off-normal camber lay-down (see Figures 4 and 8). It comprises a tower bolted to the backplate supporting a pair of linear rails on which slides the sled. The sled supports all the process tools which includes the feed motor and roller clamp module, the knife module, the flipper, and finally the compaction roller. The two assemblies are nearly identical and nest together in such a way as to position the two ¼" tows exactly ¼" apart. This leaves limited space in which to contain a variety of components.

Toolpoint

The toolpoint is a pair of ¾" x ¼" diameter x width polyurethane compaction roller supported on small ball bearings. The tow guides – one on each side of the rollers – extend just beyond the centerline of the rollers. This is sufficient to start the course while maintaining necessary clearance.

Bi-Directional Tow Flipper

The minimum piece length of a tapehead is an important concern. This is especially true when making small complex parts with inherently short courses. Adding the flipper mechanism (See Figures 6 and 7) between the knife and the compaction roller has a direct impact on the minimum piece length, however the design is such that this is minimal. The flipper is a very small pneumatically actuated gate which, when open, allows the tow to follow an uninterrupted path tangent to the compaction roller. When closed, the flipper directs the tow down to the other side of the compaction roller. This interuppted path necessitates an additional idler roller just beyond the knife.

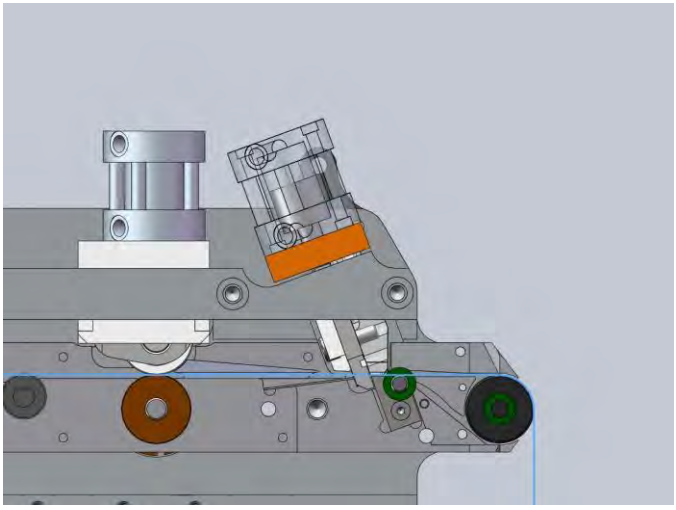

Figure 6 - Forward Tow Path

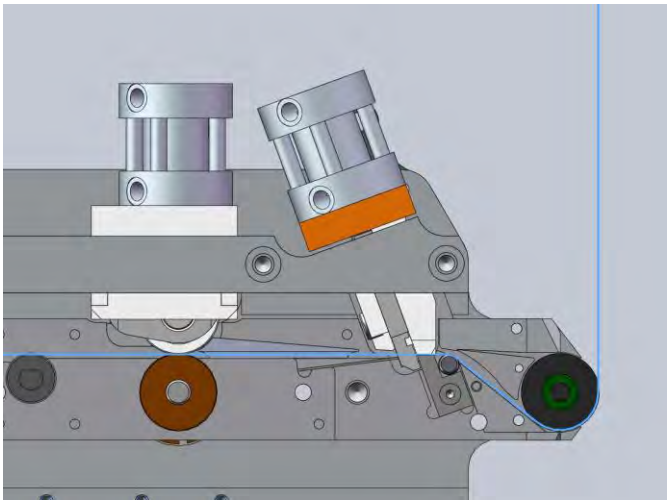

Figure 7 - Reverse Tow Path

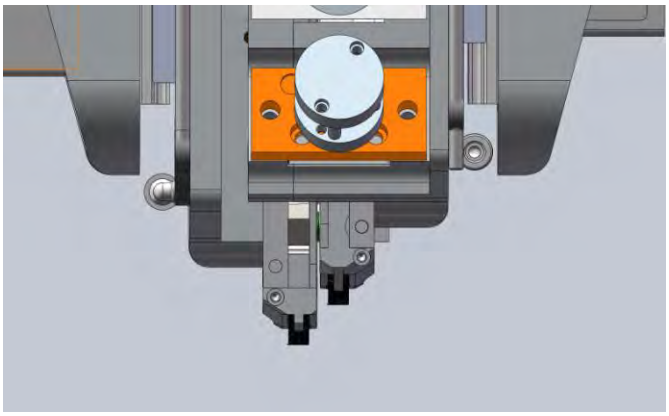

Figure 8 - Camber with Independent Compaction

Drives & Controls

Each feed roller is driven directly by a small servo motor. This head syncronously accelerates the tows from zero to surface speed during the lead-in portion of the tow path. Other tapeheads have employed a more discreet on/off type of feed which uses a clamp roller to engage or disengage the tow with the feed roller. This method is very practical however it becomes unreliable at high speeds when the acceleration demands overcome the available friction.

Robot Motion Platform

For this demonstration a KUKA KR360 six axis robot was used to position the tapehead. While adequate to demonstrate head functionality it is not appropriate for a production system. It lacks acceleration and path accuracy. However the latest robots and control systems are very promising for this application of automatic lay-up.

FUTURE APPLICATIONS

Further head development is needed to improve reliability and feed and cut speeds. Some of this is possible on the current robot. The next step is to upgrade to a faster robot and bring the system up to a production-ready level of development. There is a variety of parts currently being made manually of fabric that would greatly benefit from the use of automation and unidirectional tow. This warrants further development of an agile low profile tapehead driven by a robot. The system is very modular, scalable, and relatively economical.

CONCLUSION

A small manuevorable modular tapehead with off-normal lay-up and bi-direction capabilities, paired with a high performance robot, has great potential to automate the lay-up of complex composite parts using unidirectional slit tow.

ACKNOWLEDGMENTS

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REFERENCES

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CONTACT

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ADDITIONAL SOURCES

High-quality components used on this apparatus include:

Bosch-Rexroth Linear Products www.boschrexroth.com

Parker Automation & Pneumatics www.parker.com

Siemens Control Systems www.siemens.com

Kuka Robots www.kuka.com

Baumer Sensors www.baumerelectric.com