Constant cross-section: Sigmatex offers novel 3D structures for high volume production

Taking textiles to the next dimension

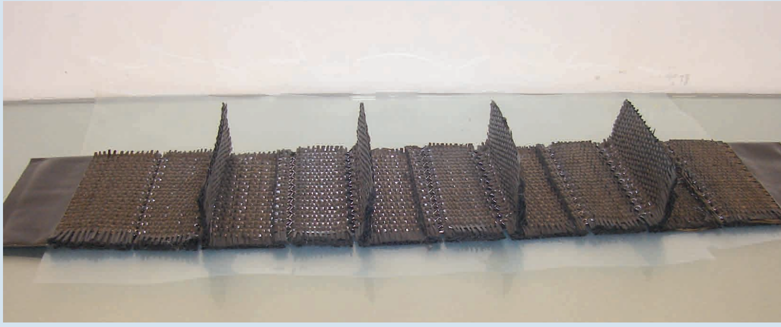
3D woven structures are beginning to cause a stir in manufacturing, allowing for structurally strong, complex shapes to be produced in relatively short timescales. **Chris McHugh**, lead development engineer 3D structures at Sigmatex explains how.

While at an early stage, the use of 3D woven structures in aerospace manufacturing is currently seeing an increase in activity. Constant cross-section 3D Pi structures have been developed over the last decade and are being used in current developments around the world. Solid 3D woven structures are being considered and developed for more technical aerospace applications where their interlaminar sheer properties are expected to improve composite performance further. The following is an overview of the current 3D woven structures which are finding a niche in aero-composites manufacturing.

Sigmatex uses current state-of-the-art weaving capabilities with machinery from Staubli and Dornier to develop and manufacture novel 3D structures. The flexibility of the machinery allows a range of materials to be created which can be characterised as: solid, expandable, constant cross-section profiles and one piece woven components. Although solid 3D woven structures and profiles form the majority of interest, the creation of expandable and one piece woven structures also offer a wide range of benefits to the aerospace industry. By interweaving and having control over the position of each thread in a 3D structure, the position of the fibre can be designed to offer the performance where needed.

Solid woven 3D structures are constructed using multiple layers of stuffer warps and wefts, combined with a through thickness binder. The way by which the through thickness binder links the layers within the structure determines the definition of the weave design. More complex solid structures are possible by using a ply drop-off method, where the solid structure is tapered by reducing the amount of layers of warp and weft. Although it is possible to weave these structures on single sided weft insertion systems, excess threads need to be removed to achieve the taper. Examples of solid structures are shown below, with various weave styles available each offering their own benefits. The orthogonal version shown in Figure 1 has more through thickness reinforcement than the angle interlock structure in Figure 2 with a greater amount of binding in the Z direction.

Expandable structures can take the form of honeycombs in warp, weft or both directions. The distance between the outer structure surfaces is determined by the combination of fabric sett and internal structure weave repeat size. When creating expandable structures, the distance between the outer layers can be changed by altering the length of the internal tethers.



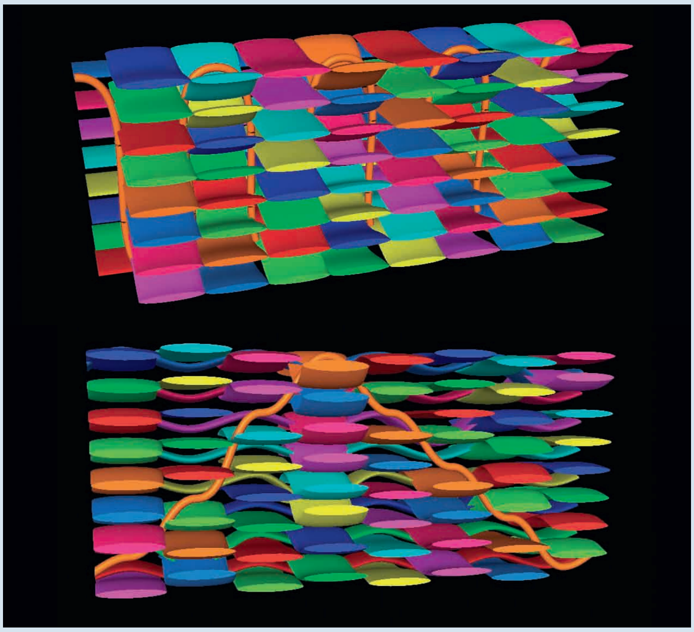
Driving down costs: Multiple T profiles produced by high volume weaving technology

The contoured effect will be achieved by combining multiple layers of hexagonal elements and by reducing the tether length to reduce depth or increase length to increase outer profile distance. This method of designing a tapered honeycomb also allows for novel tapering if required.

Another area where advances are being made is in the production of high volume constant cross-section profile components. Current profiles are expensive and have constraints in manufacture, limiting production output. Although improvements can be made, processing limitations in narrow fabric weaving will always restrict output rates. Narrow fabric looms are used to manufacture constant cross section profiles with multiple profiles being manufactured simultaneously using multiple heads. By using wider weaving looms there is the opportunity to manufacture many profiles of different sizes enabling a substantial increase in production rates for popular T and Pi section structures.

Sigmatex is developing its high production rate profiles to drive down the cost and improve output of T and Pi profiles that are not constrained by shuttle weft insertion limitations. Again by using the capabilities of new weaving machinery developments, additional features can be designed into the profiles. The ability to control thread position throughout a structure means that complex geometries and weave styles can be utilised.

One example of current profile developments is the orthogonal Pi profile, which is entirely woven. Fibre is woven through the thickness of the multiple layer structure and at the base section during the weaving process. The failure mode of the orthogonal Pi differs from conventional jointing technology. As can be seen in Figure 3, the through thickness binding is pulled out during the tensile tests, causing the fibres to protrude from the failure location. Given that the ultimate strength is provided by the strength of the 'Z' binders there is opportunity to increase strength in a number of ways. Introducing higher strength 'Z' fibres, increasing the density of 'Z' binders and increasing the footprint size will all contribute to higher maximum pullout loads.



Figures 1 and 2: Orthagonal and angle interlock weave structures

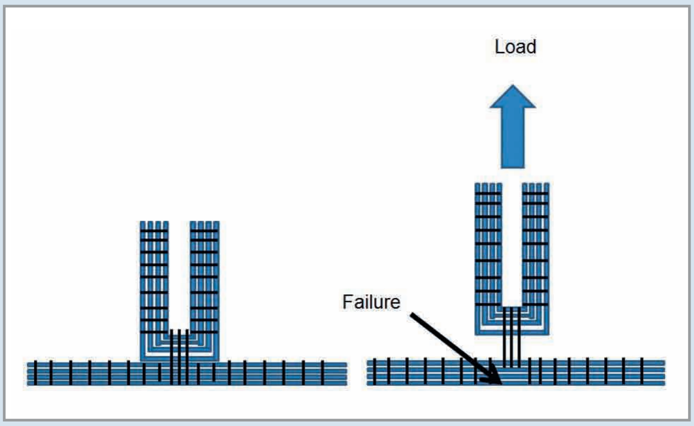


Figure 3: The failure mode of orthogonal Pi joints differs from conventional technology

There is no doubt that there are benefits to be achieved through the use of 3D woven structures. Interest from a broad range of global OEMs and tier one suppliers is growing with the possibilities of improved functionality and weight/cost reduction. As stated, Pi joining technology is gaining a great deal of interest as are solid woven structures with integrated through thickness woven binders. Currently the use of woven carbon fibre forms the majority of the 3D materials, however structures are being looked at which have integrated structural health monitoring woven into the architecture of the materials. The drive towards the adoption of the technology is a result of reducing labour costs and integrating functionality into the component by manipulating threads and use of alternative continuous fibre materials.

Another aspect being examined in conjunction with materials development is the use of modelling techniques, and this is currently looked at in several Technology Strategy Board co-funded projects including Intertex, i-Composites and 3DSimComs.

The future of 3D woven structures is very positive, with an endless array of capabilities to be exploited. As more and more complex shapes are requested, the major barrier to exploitation is predicting the properties of the structures. The need to integrate the weaving design process with FEA tools is apparent and work continues in various collaborative projects to ensure 3D weaving is adopted into mainstream composites engineering.

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