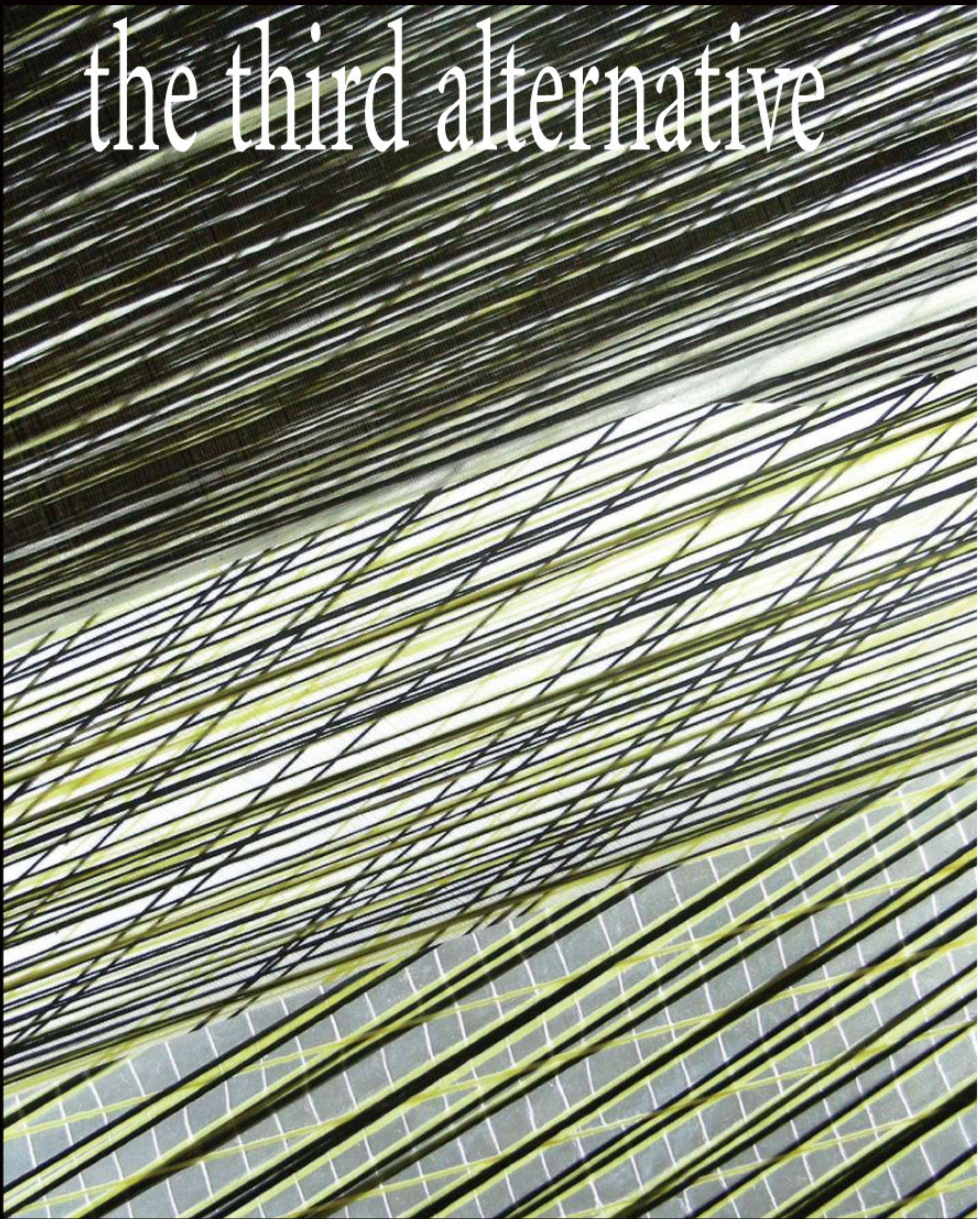
TRILAM

the third alternative

Since high modulus carbon fibres were used in the eighties to make racing sails, the manufacturing techniques and the way the composite membranes are made has been evolving constantly. After the «Air Frame» and «Genesis» developed by Sobstad sailmakers, which gave rise to North's 3DL and Dimension Polyant's D4, a third system has been perfected by the Frenchman Pascal Rossignol in the CLM company: Trilam. A new way of arranging the fibres to suit the strains of sailing.



Trilam up, D4 down: the difference in appearance is due to the external skin, in Mylar for D4, in Utex for Trilam.

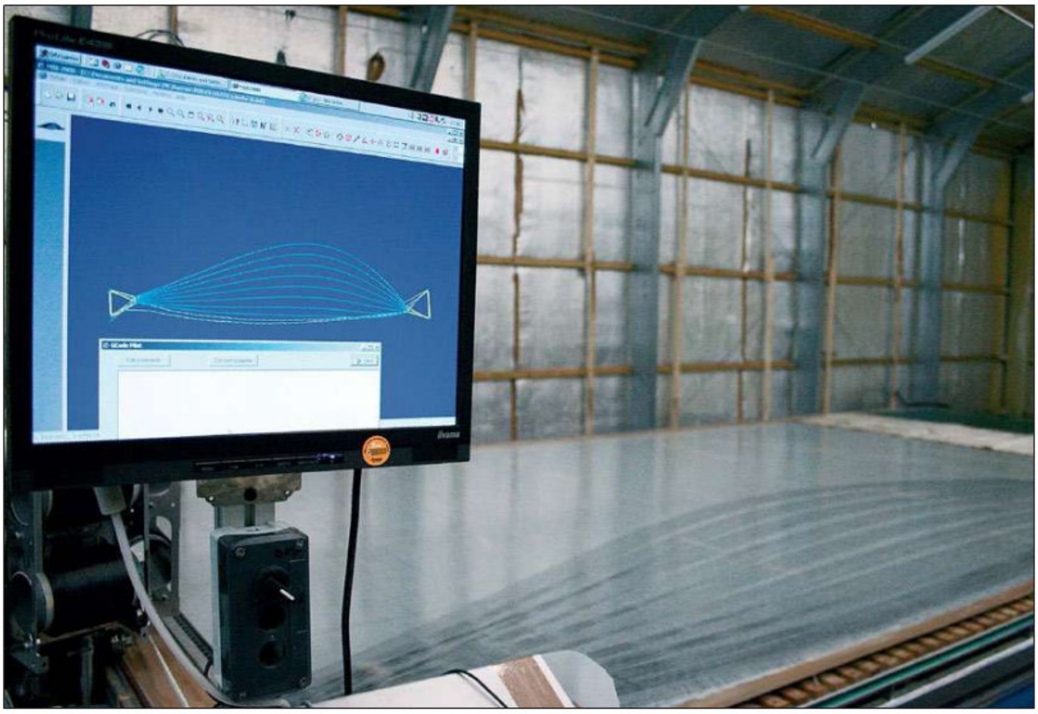
Back in the seventies, sails were still an assembly of cloth fibres manufactured by weavers, usually using Dacron. Then for the 1980 America's Cup the first laminated cloth appeared with Kevlar. The advantage of this aramid comes from the fact that it does not stretch when pulled, which allows the profile of the sails to remain fixed. They were in fact woven fibres squeezed and stuck between two Mylar films. This new technology came originally from the aircraft industry, which used weather balloons made of Nylon and Mylar, and some specialist gear, which used laminating. However, stitches could not be applied directly, because they slid off and tore the plastic film, so it was necessary to stick strips of Dacron on the joins to assemble the parts. Glues were not yet really perfected and it was common to see the cloth delaminating. In 1983, under the direction of Tom Schnackenberg, who was in charge of sails for Australia II for the America's Cup, the «leech-cut» appeared on mainsails: instead of the fibres being perpendicular to the leech, they were placed in a parallel direction from the head to clew. In the same way, genoa sails were « spider-cut » (a forerunner of the triradial sail). Engineers were able to use the first computers to simulate the strains on a sail and so draw up the most favourable direction to give to the fibres to offer resistance. New cloths were specially created, more or less reinforced in the warp or weft, according to the various areas of the sail and the strains imposed. The method remained empirical, but sails lost their shape less and were lighter, two key factors to improve the performance of 12m Jls. As computing developed and the financial capabilities of America's Cup syndicates grew, business increased for the sailmakers, who were asked to make special cloth and laminates. The use of Kevlar fibres was in any case the first step towards the technological revolution of composite materials.

Photos D. Bourgeois

There are many fine threads to share the stresses throughout a large area by favouring the direction of the maximum strains, in particular on the clew, head and tack.

The second revolution

In the nineties, the American Peter Conrad at Sobstad sailmakers developed the concept of laying down fibres all the way in the direction of the strain from the clew to the head, for example, on any type of surface such as a flat or curved Mylar membrane. He patented the concept under the name of «Air Frame» in 1985, then «Genesis» in 1986, which was based on the same principle, but on a cut-out support base using juxtaposed strips, meaning the fibre strips stopped at each join. The first patent was therefore the forerunner of North's 3DL and the second is currently being developed under the name of D4 by Dimension Polyant. At the time, Peter Conrad stuck strips of unidirectional fibre by curving them empirically, as there was still no efficient calculating soft-



The software directs the arm, which positions the fibres on the Utex-Mylar backing.

ware. He was forced to use lots of small panels. As this type of patent lasts in the U.S. and Europe for twenty years, there were some legal proceedings before other sailmakers could use the same principles, with their own methods of production. Thus 3DL (imagined by North sails in 1992) is based on a flexible mould, which adopts the final shape of the sail: a film is applied to the mould and stuck, then the fibres are laid down and arranged using a machine driven by a computer, another film is stuck on top, and finally, a vacuum is applied using a lamp heated cover. The sail therefore is all in one piece. The D4 imagined by the Australian master sailmaker Frazer in 1999, is made of large panels of pre-impregnated or pre-glued film, which are laid out flat and heat treated: the curved and straight fibres are squeezed between two films in a vacuum and then pressed. The sail is therefore a patchwork of large panels, with the shape being given by the squeeze. In terms of sail performance, it is in fact more interesting having large panels to reduce the number of joins. The 3DL enables a one-piece membrane to be made and the D4 reduces significantly the number of panels in comparison to a traditional cloth sail. Thus the range of strains are defined when trimming the sail, with the forces acting on the fibres and the way the fibres are laid down incorporates the various effects the trimmer is looking for. The strains depend in fact on the clew adjustment, the tension on the halyard, the wear of the leech, the strength of the wind... The pressure fields vary all the time and do not act continually on the same points. It tends to be multidirectional in the middle of the sail and unidirectional nearer the tension points (sheet, halyard, tack).

A third approach

Trilam, invented by Pascal Rossignol, offers another alternative by considering that the Mylar film should not play a role in the resistance of the membrane, but act as a support to stick all the various fibres together. Trilam was created out of the idea that modern sails contained less and less thread, thanks to efficient high modulus fibres, and therefore more and more Mylar. However, the plastic film is heavy and up to 800 times less effective than carbon fibre or PBO! The current trend for all makers is therefore to increase the number of threads and to spread them over the sail. By crossing the threads, the membrane becomes more stable, with greater homogeneity, which makes it a sturdier support. Trilam tries to cross the fibres as much as possible, which then support each other, as they are stuck together to form a mesh, which remains in place. This process allows more threads to be used with a smaller diameter, which is the contrary to D4 or 3DL, which requires thicker thread for technical and financial reasons. In Trilam, the plastic film is very thin and very light, as it is simply a backing for the fibres and an anti-porous surface. This concept is based around two types of technology: thread is placed in a particular direction and curved where there are few strains (foot, reef), straight and stretched out, where there are strains (leech, clew, head and tack), and are stuck together not between two plastic films, but on a very fine cloth specially made of polyester (Utex), which has the advantage of being a resistant weave without any weight drawbacks. The single layer of very fine Mylar film in the middle is essentially used to make it watertight during the gluing and no longer has a mechanical role. In fact, Trilam following a request from sailmakers re-establishes the idea of a cloth with fibres laid down in a particular direction, and the laminating allows all sorts of possible combinations thanks to the way the fibres are placed, their type and the diameter of the thread, the thickness of the Mylar, and the weight of the Utex…

A special machine

The Trilam manufacturing process begins with the manufacture of Utex, which will make up the external skins: polyester threads are woven, then go into a weaving machine with 5000, 7000, 10,000 threads… on a width of 3.40 metres. The Utex is made in the Najac factory, as no weaver wants to manufacture this type of product in small quantities. The CLM company buys different sorts of thread to make Trilam and polyester thread to weave the Utex on their own machines, which offers them total autonomy concerning the supply and allows them to manufacture various weights of cloth. Utex has a structural role by stabilising the weave and blocking the fibres together. It is even possible to carry out dying on a mass scale. The weight of Utex varies according to the use, size, and strains on the sail. Then, this various thickness of cloth is stuck by the main laminating machine on to the plastic film to build up the first external skin. It then goes back through the laminating machine to be covered in glue before the automatic arms directed by the computer place the directional fibres (straight or curved). A heated rolling press squeezes the fibres onto the first skin, then another Utex layer is applied and glued to create the second external skin. This process is used for standard Trilam manufacturing, but it is also possible to adjust the symmetry by using several layers of weaving or leaving out the Utex on the first external skin, which will thus have a Mylar side and a Utex side for lightweight sails. The process on the same production equipment is similar, but it is also possible to vary the number of fibres, the number of layers, the thickness of the plastic film, the number and weight of the cloth layers, how they are built up… The various combinations make it possible too to turn the whole thing upside down with for example: directional fibres, plastic film, Utex, film and directional fibres. Anything is possible to satisfy the requirement for more or less flexible panels, which can vary in thickness, be more or less resistant, lighter or heavier… The sailmaker supplies a paper giving the specifications of the sail with the joins they have made, the volumes, the different mixture of fibres chosen by the computerised system (Sail Pack, Fabric). The CLM software lays down the fibres in two dimensions and the laminating machine makes the panel, which is then cut out digitally and sent to the sailmaker to be pieced together and finished off. Each panel is thus one single piece.

The huge laminating machine carries out all the work to apply Utex to the Mylar film, positions the threads, sticks them together and heats it up

Price per square metre

The laminating machine produces panels between 2.80 and 3.10 m of any length. It is possible to make several different sails in one go, to mix the panels for different sails to make the most of the machine's use. The machine can make a large sized panel (gennaker with 30-m luff) in several goes without interrupting the process. The sail now requires very little reinforcement, as there are more directional fibres in the area where there is the greatest strain. The additional reinforcement is used to ensure that the webbing or eyelets are held in place and bear the strain between the fibres and the webbing. The digitally cut panels are stored flat for a few days. The master sailmaker receives the panels and carries out the finishing touches by adding reinforcement, batten holders, and luff. He saves on assembling the panels with for example an A-35 sail in five panels instead of fourty used in the manufacture of a triradial cut with bobbin cloth: weight gain, time saving, fewer stitches and fewer mistakes in the assembly process. According to the designer, for the same characteristic of cloth, Trilam means a weight saving of 10% to 30% in the sail through the use of directional fibres and less plastic film. The machine can make up to 40m_ of panels per hour. The price of Trilam panels is fixed per square metre and the denier (quantity of fibres per centimetre or per inch), the quantity (diameter of thread, more or less high modulus) and the type of fibres (polyester, Pentex, Tawron, Kevlar, PBO, carbon, Black Technora, Vectran, Spectra…).

Dominic Bourgeois

Pascal Rossignol

Pascal Rossignol who started out with studies in mechanical engineering applied to aeronautics (Toulouse), did his military service as a scientist at the French National Space Centre (CNES) in 1989, where he worked on the gluing of weather balloons, then on the sails for Marc Pajot's Défi. They needed to overcome the gluing problems that were frequent with plastic film to heat seal the panels of weather balloons on a 300-metre long table. At the same time, he worked on the development of lightweight materials for asymmetrical spinnakers, gennakers and light genoas. At that moment, it was in general sticky tape and primers applied with a brush that were used to carry out the gluing. In 1995, Pascal Rossignol began to develop stretched radial fibre reinforcers, stuck in the middle of a sandwich of two films, which was not restricted by Conrad's patent (Genesis). He manufactured all sorts of shapes and sizes of reinforcements, which were to be used by sailmakers around the world (Incidences, Quantum, Doyle...) for a range of technical specifications on the tack, head and clew, for reefing points, for the tips of the battens... He thus designed special machines, which were capable of making reinforcements up to three metres by two. Working for the French team in the 1995 Cup, he found an industrial glue to stick Cuben fibre together, a glue that was heat activated by using a heating press to ensure a firm bond. He worked on special machines to get as close as possible to the laminating machines used industrially for cloth, so that the internal glues and those used for assembling the panels were compatible.