

## Flat knitting machine: the 3<sup>rd</sup> dimension

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For many years, composite fibre has appeared in applications requiring low weight for large areas. Composite fibre was first used in the aeronautics and space industry due to its mechanical properties. Currently, it is used in many competition sports such as Formula 1 and sailing boats, where every gram counts. All these applications have several points in common: limited editions, lower price pressure when compared to other fields, implementation of the fibre on relatively simple and generally two-dimensional shapes. The purpose of the Mapicc 3D project is to develop a comprehensive process for manufacturing three-dimensional parts. We want to combine the use of composite fibre on a demanding industrial scale, such as the automotive industry, with more complex shapes and reduced production costs. Fifteen partners integrated into the “7th framework project” of the European community have combined their expertise to analyse the best methods to implement these fibres and create a complete production chain. The goal is to provide tools ranging from finite element simulation of the final product to the characterisation of the piece and the performance of mechanical tests, all the way to the production of technical textiles, shaping and solidification through a mould.

The European Community has clearly defined the purpose of the project as the development of an industrial tool, which justifies the presence of a machine manufacturer. Steiger was chosen as partner given its long association with universities related to the textile industry and the unique characteristics of its machines.

Key features of these machines include:

- Motorized yarn guides positioned with an accuracy of 0.5 mm
- Performing take-down allowing traction suitable for the most delicate fabrics with complex shapes
- Through an open carriage, the possibility of feeding the yarn directly to the needle with reduced tension and minimum friction

These technical specifications provide a unique tool for the development of new technologies.

The Mapicc 3D project is an alliance of partners specialising in the field of textiles including universities, laboratories, specialists in finite element simulation, machine manufacturers, automotive or aerospace industry suppliers, and transportation related end users. Main partners of Steiger include ENSAIT, MECACORP, Technische Universität Dresden, Riga Technical University, ALSTOM, TEN CATE and VOLVO.

Some of the project’s detailed objectives include the development of a production system for 3D geometries based on multilayer composite fibres that are shaped by a unique process of thermoplastic solidification. The different production stages should allow the use of preform, foam injection, and integration of sensors in the final piece. In parallel with the production process, Mapicc 3D will develop simulation tools of physical and mechanical properties of semi-finished and finished products.

Different production technologies of fibre preform are analysed in order to find the less expensive, less polluting, fastest and most energy-saving solution. Reducing waste by formatting the piece

during the preparation of the textile preform is essential. The traditional method—weaving—is in competition with flat knitting. Weaving of carbon fibres is very fast and economical for large surfaces. This method is currently used by all major aircraft manufacturers for new aircraft fuselages. By cons for complex parts, the process of cutting the carbon fibre plate generates a large amount of waste. Within the framework of the Mapicc 3D project, flat knitting brings one of its greatest assets: 3D shaping of the piece at the exit of the knitting machine. Preform is finished and can go directly to the thermal solidification phase. This offers three main advantages: the elimination of a production stage, waste reduction, and exceptional strength. Until now, cutting required optimisation of shape implementation on the plate to minimise waste. Nevertheless, a significant portion of the plate was unused and had to be discarded. Flat knitting allows the knitting of the final piece and saves a large amount of carbon fibre.

In order to validate the whole production chain, a prototype linked to the automotive industry was chosen. Volvo proposed to replace the driver's seat retaining plate of its vehicle with a piece of knitted fiberglass. The choice of this piece relates to its dimensional complexity and the mechanical resistance. At the end of the validation, the piece will undergo the same tests as a metal piece, including a vehicle crash test. The weight of the driver attached to the seat will apply extreme force on the 4 attachment points between the seat and the fiberglass plate.

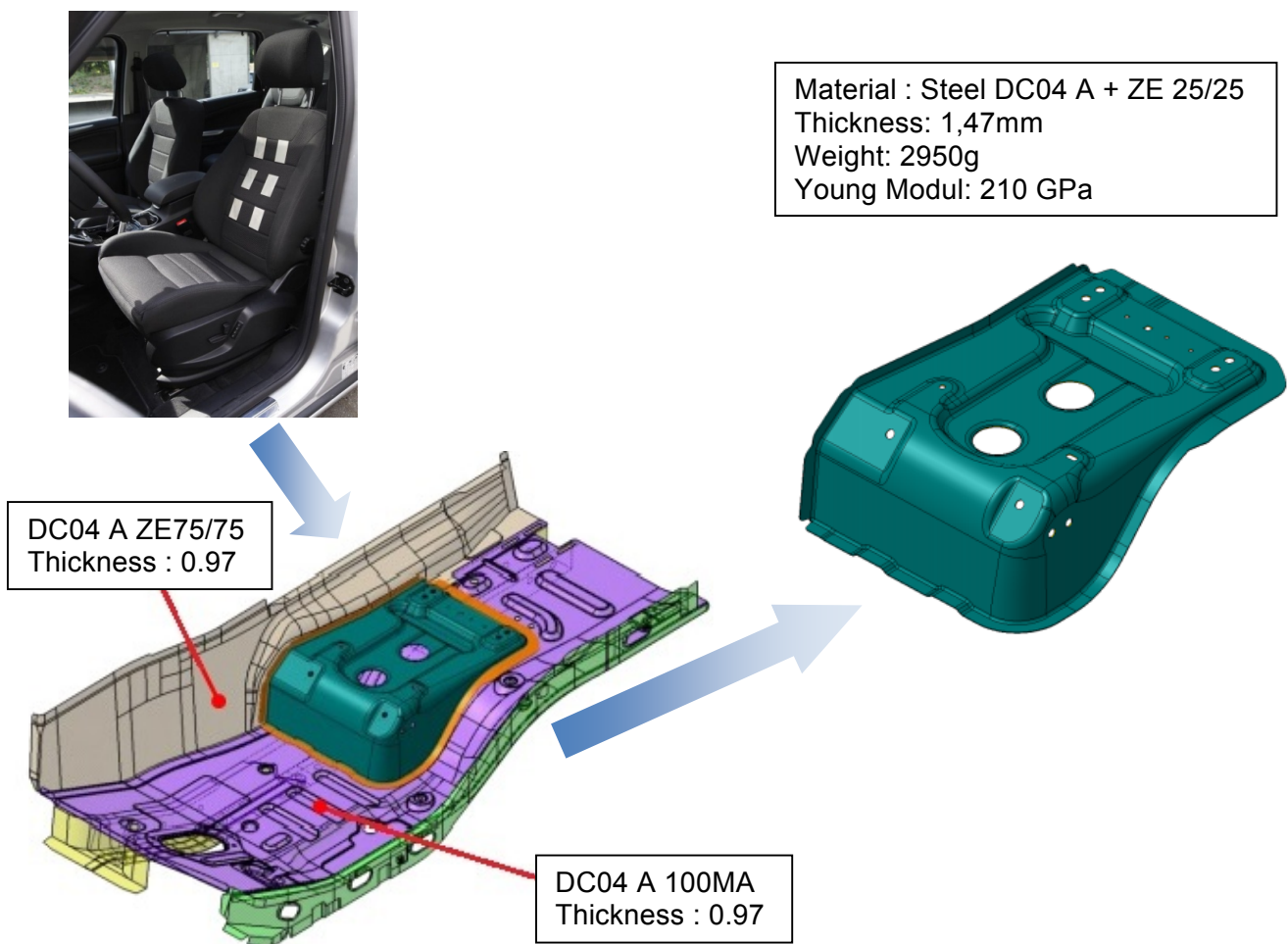


Figure 1: Driver's seat support prototype (source: VOLVO Group Truck)

The first stage consists of finite element simulation of the mechanical stresses the plate undergoes upon impact in the different XYZ axes. Based on these simulations, preform should be reinforced at points suffering the most severe stress, as shown below in red. The fixing of the plate on the chassis will also be adapted. Electric spot welding will be replaced with adhesive glue that will bind the entire perimeter of the composite piece to the chassis.

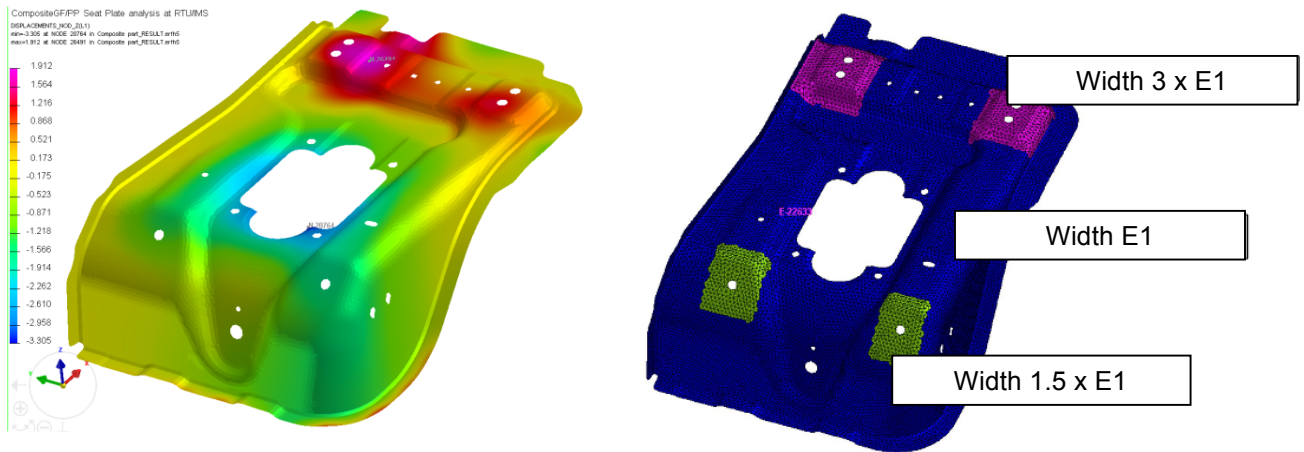


Figure 2: Simulation of maximum stress on the Z-axis and determining the thicknesses of the zones requiring reinforcements (source: Riga Technical University, Institute for Materials and Structures)

Once the geometry of the glass fibre preform is determined by simulation, the next step is the design of the preform itself. The objective is to determine a knitting technique to knit the piece three-dimensionally with different thicknesses. This part requires specialised expertise in the performance of a knitting machine and knowledge of available knitting techniques. Preliminary tests were used to test methods to mechanically reinforce a section of the piece or thick knitting in highly stressed areas:

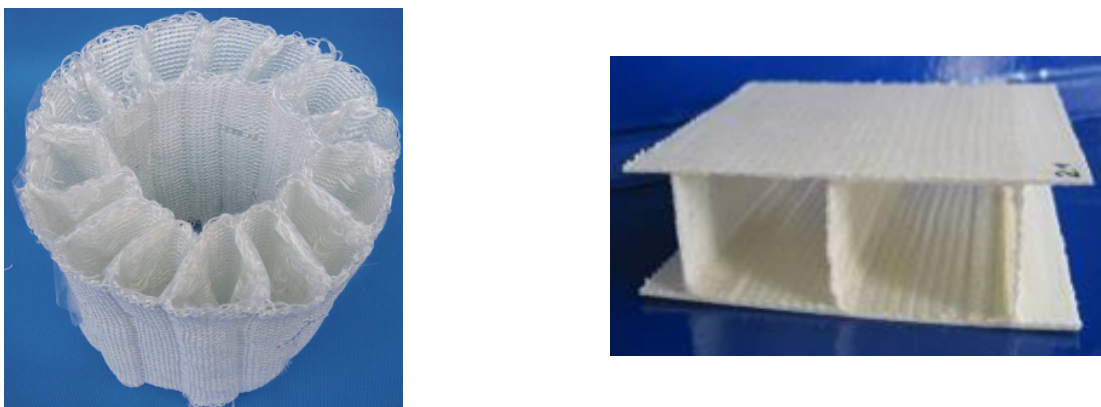


Figure 3: Examples of 3D knitting techniques (source: Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden)

All of these techniques were then combined and programmed in the machine to achieve the required geometry.

After the manufacture of the glass fibre preform, the next step is to solidify the preform. The glass fibre is coated with a thermoplastic PP that will react with temperature. Within the project, a craft mould will be made to validate the technology. The PP-coated glass fibre preform is vacuum plated to fit to the mould. The whole piece is gradually heated to 190°C above the melting temperature of the PP and cooled gradually over a few hours. The final product is available for analysis. A series of stress testing, as well as dynamic and vibration tests will be performed in order to qualify the piece for its final use. In addition, values found will be compared to values expected by finite element simulations. Basic assumptions of the simulation will be reviewed and corrected to be even closer to the final result. In our driver's seat support example, we need to obtain a piece 2.4 times lighter than the piece made of steel.

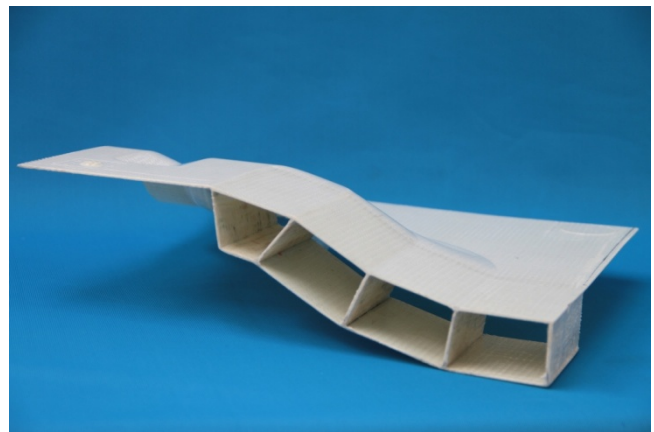


Figure 4: Example of moulding and finished structure (source: Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden)

In order to achieve an industrial production tool of the knitted preform, we are required to push knitting to its maximum limits. The machine developed and built for the project inherits the successful experience with two modified Aries 3-type machines installed at the Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden since 2006. During these years, researchers at the institute have developed multilayer fabrics. They have validated techniques to mechanically reinforce the knitted fabric by adding weft yarn and warp yarn.

Fabric reinforced in two axes  
by weft yarn and warp yarn

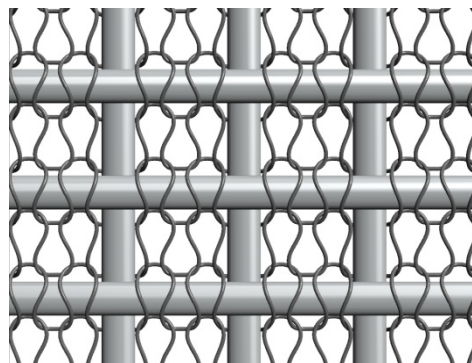


Figure 5: Structure of mechanically reinforced stitch (source: Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden)

Through this experience, the institute was able to demonstrate the benefits of knitting in the field of composite fibres. Weft and warp yarn ensure stress resistance in two axes, and stitches bind the whole piece, providing a substantially final geometry in the preform by using the fully fashion technique.

This successful experience has resulted in the transition to 3D. It has guided the specifications for a new machine necessary for this technological leap. A view of a reinforced wall shows the complexity of combining 3 different textile technologies on a single machine:

1. Weft yarn
2. Warp yarn
3. Knitted yarn
4. Needles

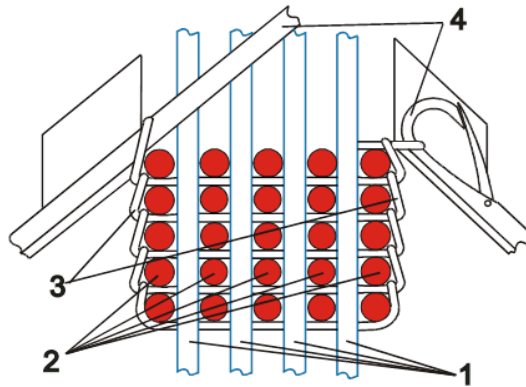


Figure 6: Example of thick walls knitting (source: Institute of Textile Machinery and High Performance Material Technology, Technische Universität Dresden)

To achieve this, a specification of the 3D Mapicc machine was discussed to consider the benefits and limitations of current technology while trying to improve them.

Specifications:

- E7 gauge with E6 needles
- Minimum needle bed length (100 [cm])
- Distance between two needle beds: 16-20 [mm] to allow introduction of weft and warp yarn
- 8-10 motorised yarn guide equipped with yarn feeders



Figure 7: View of the 3D machine knitting area (source: Steiger)

For this project, engineers must continually innovate, since 3D is not part of the standard knitting universe. Fortunately, the basic structure of the machines is adapted to the technological requirements of volume and thickness. In fact, the open carriage that allows the introduction of weft yarn, the motorised yarn guide that deposit warp yarn, and the take-down set up very high for precise management of forms are technologies necessary for the transition to 3D.

Steiger's has improved his efficiency to respond rapidly to the new demands of the market. The effectiveness of its development team and production flexibility is a success factor for this ambitious project. Mapicc 3D allows us to demonstrate the enormous potential of composite textile knitting, on which we have been working for years. Through this project, knitting becomes a tool of economic output for tech industries. The goal is to make it leave hyper-specialised workshops and become a competitive solution, as compared to other technologies that are heavier, more polluting and wasteful. The partners, involved in this project will achieve the goal of designing a composite fibre structure, simulating its behaviour, programming its production, knitting the defined program, testing the results, and bringing the piece to a final user. Mapicc 3D will provide a channel for reliable manufacturing. After 4 years of work, this ambitious goal will be achieved in 2015, thanks to a successful collaboration of a group of academic and industrial partners.

Steiger is a renowned flat knitting machine manufacturer based in Vionnaz, Switzerland. Founded in 1947, the company is part of CiXing group since 2010 and employs approximately 100 people worldwide. It is the technology leader for industrial knitting machines used for technical and medical products. In the fashion world, it is recognised for the quality of its stitch and for its Intarsia machines. Steiger delivers its products worldwide through a sales and extended service network. A corporate culture based on innovation and a partnership with CiXing group has allowed Steiger to remain the technology leader in the flat knitting industry.

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