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DEVELOPMENTS OF 3D KNITTED FABRICS

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Abstract: The 3D knitted fabrics have a large applicability in technical applications. Their main advantage refers to their excellent formability, the possibilities of obtaining fabrics with complex architectures during the knitting process. The object of this research is to obtain knitted fabric with three-dimensional effects using weft knitting technology on an electronic flat-bed knitting machine.

1 INTRODUCTION

The potential and the use of knitted fabrics for technical applications are documented throughout literature [1-4]. Knitted fabrics have a good potential for the production such complex shapes due to:

- Their high formability, determined mainly by their high elasticity;
- The high level of complexity for the shapes that can be knitted;
- The existing machinery can be used without significant modifications;
- The control of fabric behaviour through structure and structural parameters.

Both weft and warp knitted fabrics are used in technical applications, from reinforcement for composite materials to medical products, industrial applications such as tanks and hoses, sport and leisure items, etc.

2 WEFT KNITTED FABRICS WITH SPATIAL GEOMETRY

The shape of textile fabrics/products is an important factor in the design stage, because it influences the selection of raw material, structure and technology. The need for products with complex shape required the adaptation of the textile fabrics and led to the concept of 3D fabrics and 3D architecture.

The idea of 3D shape of a textile product is not new, but at first it implied the use of assembling technologies. The production of three dimensional fabrics eliminates the ulterior assembling operations (with implications regarding the production time and costs), as well as it offers the possibility of controlling the final product shape from the fabric design stage. The technological developments of the last decades and the introduction of the CAD/CAM systems made possible the production of 3D fabrics with increasing complex shape.

The 3D fabrics are found in different applications, many times a certain destination imposing the shape of the fabric/product. The field of technical textiles is the one where the complex shape fabrics had the most significant development, due to the high level of the applications, the restrictions imposed by the specific requirements, the process of the high performance raw materials and the need to simplify the subsequent processing. Most known example is the advanced composite materials, for which the reinforcement (preform) is produced with the final shape of the composite [1].

A classification of the 3D knitted fabrics includes the following types:

1. **Multiaxial fabrics**, characterised by the presence of successive layers of yarns within the fabric structure. The most important are the warp multiaxial fabrics (see Figure 1), with layers

of yarns inclined at preset angles, from 0^0 (weft yarns) to 90^0 (warp yarns). Such fabrics are characterised by very high thickness and the reinforcement on preset directions. Their main destination is as reinforcement for composite materials, the yarns used to make the layers being glass and carbon.

The multiaxial weft knitted fabrics are still in laboratory phase, requiring new types of machines. The main problem is the complicated process of yarn feeding.

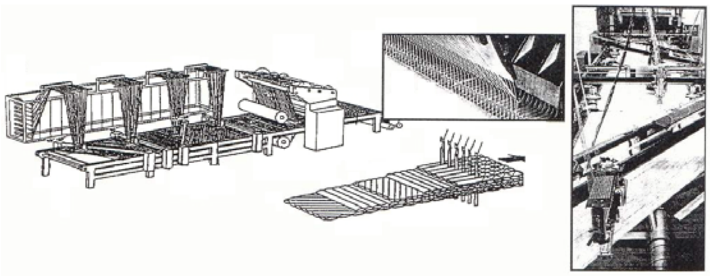

Figure 1: Multiaxial warp knitting technology (Liba)

2. **Sandwich/spacer knitted fabrics** are made of two independent fabrics connected through yarns or knitted layers.

The warp knitted fabrics with such a structure are known as spacer fabrics the connection being made only with yarns. The warp knitting technology is suited for the production of spacer fabrics with open and/or closed structure for the external fabrics, as exemplified in Figure 2. The fabric thickness depends on the trickplate distance, going over 5 cm. If special monofilament yarns are used the connection, the spacer fabrics present an excellent bending recovery that recommends them for end-uses such as backpacks, shoes, mattresses, etc.

In case of weft knitting, the sandwich fabrics are connected using yarns or knitted layer. The connection through yarns offer limited possibilities of structural diversification, while the fabric thickness is limited. The sandwich fabrics with connection through knitted layers (single or double) are characterised by a complex geometry, for which the shape and dimensions of the cross section depend on the connecting layer. The length of this layer can reach 10 cm, while the shape can be different, from rectangular to elliptic, V shaped, trapeze, etc.

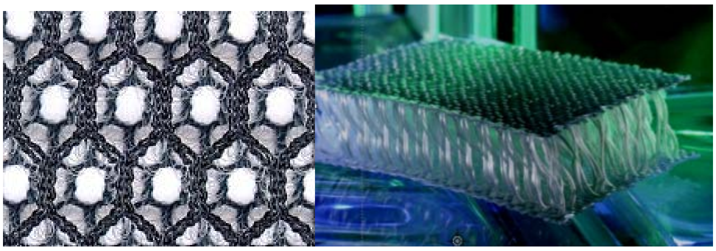

Figure 2: Examples of spacer fabrics with closed and open structure

The main destination for these structures is preforms for advanced composites, produced with glass/carbon fibres. An important aspect is the volume fraction due to the structure of the knitted layers (produced on selected needles 1x1).

3. **Spatial fashioned fabrics** are fabrics where the 3D geometry is obtained through fashioning, when the knitting is carried out on a variable number of needles. The 3D geometry is generated by the different amount of rows knitted along the panel width, the

surplus stitches being placed spatially. These fabrics are produced on electronic flat knitting machines for which the carrier course is variable. The paper focuses on this type of fabrics.

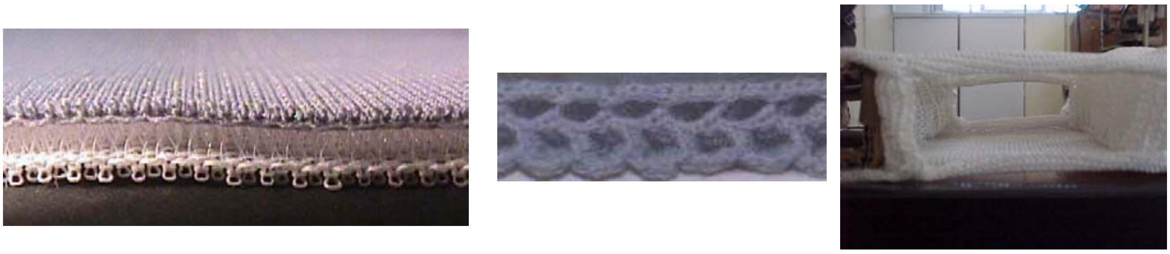

Figure 3: Examples of sandwich fabrics with connection through yarn and knitted layer

The spatial fashioning of the knitted fabrics is based on the need to produce fabrics with complex shapes that are similar to the shape of the final product. Even if a certain degree of spatial geometry can be obtained by using modules of structures with different patterns or by dynamic stitch length, the technique of spatial fashioning is the only one that has no limitations with regard to the shape complexity and dimensions. This technique (also known as ‘flechage’) is based on knitting courses on all working needles and courses on a variable number of needles, determining zones with different amount of stitches [2]. The zones with the highest amount of stitches will have in the end a spatial geometry.

A classification of the spatial fashioned fabrics must take into consideration the 3D shape of the product. There are fabrics with different shape, such as: hemispherical and spherical fabrics; frustum of a cone and hyperboloid fabrics; tubular shaped fabrics – straight (T shape) or bent; parallelepiped and pyramid fabrics; discoid fabrics; fabrics with other shapes, derived from the ones mentioned above [3].

3. EXPERIMENTAL WORK

The experimental work focused on the production of weft knitted fabrics with spatial geometry and complex shape. The 3D fabrics were produced on electronic flat knitting machines (CMS 530 E6.2, Stoll Italy) using acrylic yarns count Nm 28/2. Different types of regular shapes were considered – (hemi) spherical, tubular/cylindrical.

The fabrics use jersey evolutions and the spatial geometry is obtained based on knitting on variable number of needles technique. The fabrics were programmed on a M1 station and the technological parameters, especially take-down were adjusted accordingly in order to avoid problems during the knitting of fashioning lines. The fashioning lines define where the knitting will be carried out on a variable number of needles, these zones generating the spatial geometry. The lines have two components, corresponding to decreasing the number of working needles and the other to increasing them.

Figs. 4, 5 and 6 present three examples of 3 D knitted fabrics produced on the Stoll 530 E6.2 machine. The examples cover different types of geometrical shapes, illustrating the technical possibilities of the flat knitting machines.

In Figure 4, the 3D shape is placed in the middle of the fabric surface, not at its edge, as it is usually done. There are two zones with 3D geometry. The spatial fashioning is obtained by stopping the knitting on all needles but the ones involved in the fashioning. The knitting technique is similar to the one used for sock heels, as it is presented in Figure 4.

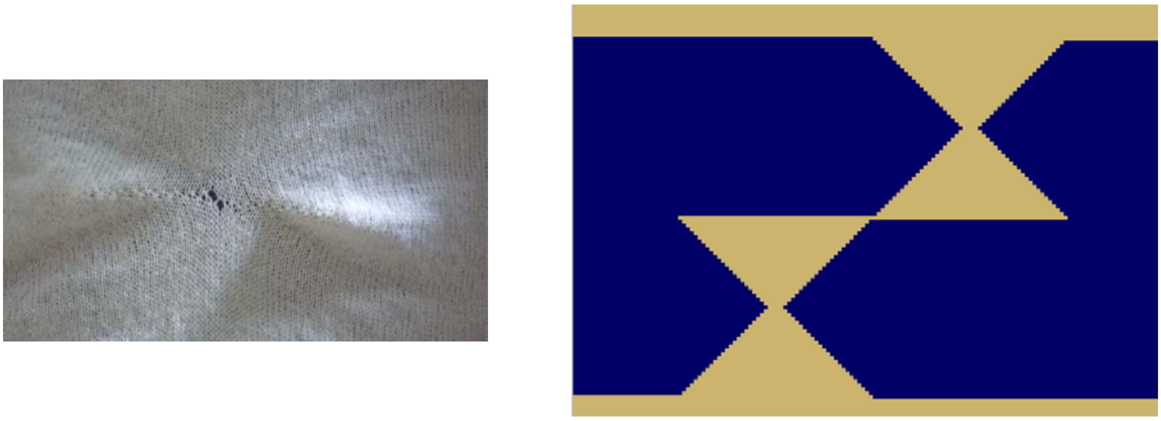

Figure 4: Spatial fashioned fabric, with spatial shape placed in the fabric – fabric aspect and knitting programme

To obtain the 3D shape that is presented in Figure 5 is used the same technique that was exemplified previously in the 3D shape from Figure 4. The 3D shape is amplified by using a compound fashioning line.

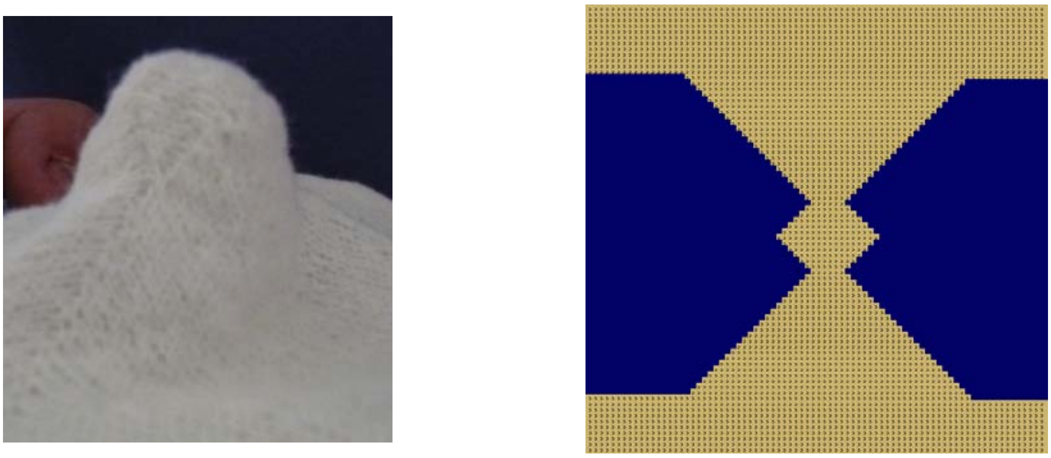

Figure 5: Spatial fashioned fabric – fabric aspect and knitting programme

The spherical shape that is present in Figure 6 is using a fashioning line with variable increment. The shape is obtained by repeating several times the fashioning line.

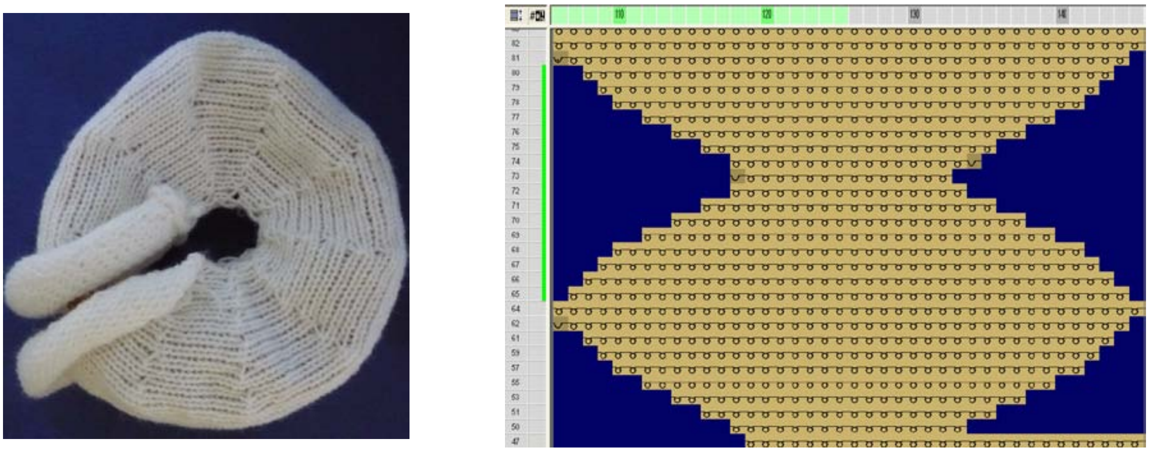

Figure 6: 3D spherical shape – fabric aspect and knitting programme

4. CONCLUSIONS

Knitted fabrics present the best potential for complex spatial architecture in comparison with the other types of textile materials. The final shape of the fabric is obtained by creating a supplement of stitches that are forced out of the fabric plan.

The position of the fashioning lines within the 2D fabric plan generates the three dimensional shape. By controlling this position and the dimensions of the fashioning lines it is easy to diversify the fabric shapes.

The paper exemplifies some of the possible shapes that can be obtained.

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Acknowledgements

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