Parametric modelling design applied to weft knitted surfaces and its effects in their physical properties

N P Oliveira¹ ², L Maciel¹ ³, A P Catarino² and A M Rocha²

¹ IFRS, Instituto Federal Rio Grande do Sul, Rua Domingos Zanella, 104, Bairro Três Vendas, Erechim, Rio Grande do Sul, Brasil
² University of Minho, Center of Textile Science and Technology, Campus de Azurém, Guimarães, Portugal
³ Heriot-Watt University - Scottish Borders Campus Research Wing, Galashiels, Selkirkshire TD1 3HF, United Kingdom

Email: whiteman@2c2t.uminho.pt

Abstract. This work proposes the creation of models of surfaces using a parametric computer modelling software to obtain three-dimensional structures in weft knitted fabrics produced on single needle system machines. Digital prototyping, another feature of digital modelling software, was also explored in three-dimensional drawings generated using the Rhinoceros software. With this approach, different 3D structures were developed and produced. Physical characterization tests were then performed on the resulting 3D weft knitted structures to assess their ability to promote comfort. From the obtained results, it is apparent that the developed structures have potential for application in different market segments, such as clothing and interior textiles.

1. Introduction

Computational modeling programs are part of innovative and fundamental technologies to engineer complex geometric shapes and designs which extend the control and the interaction of functions and processes in a project to the designers [1]. Since an object can comprise many elements, where mutual relations influence and continuously determine the whole structure functioning, three-dimensional complex systems can be designed and engineered beyond the surface expressions or the object’s structure [2].

In the textiles area, where innovation is paramount and the development of higher added-value products fulcral to remain competitive and compensate the pace of business and markets decline due to the global economic environment, such creative resources can promote the generation of novel structures and surfaces [3].

In this context, the parametric tool can be, not only a creative solution to problems encountered in the field of product design and architecture, but also, a projectual tool in the area of textile and fashion design.

In this paper, the digital modeling tool is used to support the parametric design of knitted fabric patterns development. The purpose is to emphasize the three-dimensionality of surfaces, which can influence fabrics comfort-related properties resulting in textile products that can be used in different application areas.
2. State of the art

Three-dimensional (3D) surface design represents an important area in textile design, since it will produce an effect in the aesthetic appearance of the fabrics, but it also may influence their physical properties and thus, alter its performance.

According to Ujiie [4], the first computer system specific to textile design was introduced in 1967 by IBM and was developed for Jacquard knitting and textile printing machines. Only in the 1980s textile designers had access to personal computer systems equipped with design software for creative product development [4]. Nevertheless, for Lamar [5], a CAD system is basically a tool that allows a fashion designer to perform and visualize her/his work in an optimized and appealing style to the market.

Parametric design implies representing the design intent through a series of associative operations, controlled by parameters [6]. The basis of parametric design is the generation of geometric shapes combined to each other and the establishment of the formal relation they maintain with each other. Associated with parametric design in building structures is an important process - generative design - which can be considered a methodological component of parametric design [2,7,8]. Through generative design, the designer is not concerned on solving a particular problem in a specific context, but on defining a method that allows solving similar problems in different contexts and with slightly different characteristics [7]. Conceptually, parametric design includes the generative design and the designer's approach or intention, since it uses parameters to define results and differentiates concepts [9].

These capabilities enable the use of parametric design as a projectual tool to automatically generate novel textile structures and surfaces, making it possible to overcome the present limitations of machines' CAD systems.

3. Materials and Methods

The variety of structures that can be obtained with weft knitting, just considering single needle system machines, is quite considerable and the present CAD systems do not offer the possibility of automatically generate new structures. Therefore, to explore parametric design in the generation of 3D surface shapes, knitted structures were considered as a case study. Besides aesthetic aspects, the change in some parameters, which lead to different shapes and surfaces, will also influence the functional behaviour of the knitted fabrics associated to comfort. Therefore, this work involved the following steps: use of a specific software – Rhinoceros and Grasshopper – to generate the simulated shapes; translation of the shapes into 3D knitted shapes, using the proprietary CAD software of the knitting machine (Merz seamless machine); production of samples, and characterization of comfort-related physical properties, namely thermal properties, air and water vapour permeability and compressibility. The following paragraphs will briefly describe each one of the above mentioned steps and section 4 will present and discuss the characterization results.

Rhinoceros 3D © V5 is a three-dimensional modelling software which was used in conjunction with the Grasshopper plug-in, a generative creation tool for Rhinoceros. The software and plug-in work together, and the structure is created in Grasshopper and viewed in the Rhinoceros interface. Initially, a geometric solid is created at the Rhinoceros interface. The first solid is generated using three-dimensional square shapes that are joined into a single geometry, forming a new complex geometric figure. This geometric solid is the pattern motif (or structural cell in the knitted structure) that will be repeated to virtually form the fabric surface. Keeping the Rhinoceros interface, a base surface for virtual representation of a fabric section is developed. The first structure created is applied on this surface and by changing the parameters in the Grasshopper plug-in, the surface of that section is changed. Figure 1 briefly illustrates the method described.
Figure 1. Method for obtaining the surface structures to be transformed in weft knitted fabric with two variations based on H2.

The next step consists in translating these surfaces to weft knitted structures. By combining the basic weft knit loops – knit, miss and tuck loops, it was possible to replicate the 3D shapes obtained with parametric modelling. In particular, knit and miss loops in alternate columns were used to obtain a raised effect in the weft knitted surface. Since integration of the Rhinoceros software with the Merz’s Multi Pattern Editor software was not possible, the simulated drawings were inserted in the knitting machine through the reproduction of the planned design in the structural cell of the machine software. The areas with volume in the 3D simulation were identified as alternating columns of knit and miss loops (black and grey) and the areas without volume were identified by plain knit (solid grey). Figures 2, 3 and 4 illustrate the three selected structures for production and the resulting fabrics.

To transfer this pattern motif or structural cell to the Merz’s Multi Pattern Editor software it was necessary to split this pattern motif into four parts, resulting in squared spaces that would be filled with four parts of the pattern motif (figure 2). The visual result obtained in the fabric (figure 2.D) was very similar to the digitally simulated image in the Rhinoceros 3D software. The weft knitted fabric developed in the circular knitting machine with knit and miss loops achieved the intended three-dimensionality.

To produce the fabrics, a full jacquard seamless weft knitting machine MERZ model MBS was used, with a E28 gauge, diameter of 13” and 1152 latch needles. The yarn used was a polyamide 78 dtex multifilament yarn and a bare elastane 44 dtex monofilament using plating technique. The loop length was 0.28 cm. It is important to note that the 3D surface effect on jersey based structures appears on the technical back of the knitted fabric.

Figure 2. A - Rhinoceros 3D simulation of H2 weft fabric; B - Design transferred to knitting machine’s representation; C - pattern motif repetition; D - 3D effect on H2 (technical back); E – technical front of H2.
In the last step the 3D fabrics produced were characterized in terms of comfort-related properties to better assess their potential applicability. Thermal properties, compressibility, air permeability and water vapour permeability were selected as the most relevant comfort factors. Thermal properties were evaluated using the Alambeta instrument, according to ISO EN 31092:1994 standard procedure. Air permeability was evaluated according to NP EN ISO 9237:1997 using the Textest FX 3300 instrument. The water vapour permeability was assessed under ISO 11092:2014 standard and with a Shirley Water Vapour Permeability Tester M261. Knitted fabrics thickness (NP EN ISO 5084:1996 using a Thickness Gauge M034A) and mass per unit area (NP EN 12127:1999) were also characterized.

4. Results and Discussion
The functional performance, in terms of comfort-related properties, of the three-dimensional fabric samples produced H2 and variations H2A and H2B is presented in table 1 and figure 5.

| Fabric | Mass per Unit area (g/m²) | Thickness (mm) | Air Permeability (l/m²/s) | Water Vapour Permeability (WVP) index (%) | Thermal Conductivity (W/m.K) | Thermal Diffusivity (m²/s) | Thermal Absorptivity (Ws/s.m.K) | Thermal Resistivity (m².K/W) | Thermal Flux (W/m²) |
|--------|--------------------------|----------------|--------------------------|------------------------------------------|-----------------------------|---------------------------|-------------------------------|----------------------------|------------------|
| H2     | 373                      | 3.80           | 440                      | 91.8                                     | 49.72                       | 0.24                      | 101.54                        | 64.76                     | 0.36             |
| H2A    | 567                      | 3.58           | 389                      | 81.0                                     | 53.98                       | 0.30                      | 98.10                         | 67.10                     | 0.28             |
| H2B    | 425                      | 3.34           | 303                      | 91.3                                     | 53.86                       | 0.15                      | 142.20                        | 49.42                     | 0.49             |

From the results depicted in table 1, it is apparent that the changes produced in the fabrics due to parametric variations resulted in differences in the basic characteristics of the knitted fabrics and on some of the comfort-related physical properties. In general, changes in the structure greatly increased the mass per unit area. The WVP index, thermal conductivity and air permeability were the comfort parameters that demonstrated the slightest differences. In what concerns compressibility, figure 5, it is clear that the compression behavior largely depends on the structure design.
5. Conclusions

Digital modeling is a tool that enables the creation and visualization of a product before being physically processed. Through the parametric and generative design, small variations in the parameters lead to the generation of a diversity of products. Although the surfaces developed for this work were created in the software Rhinoceros 3D to be applied directly in the knitting software, it was necessary to adapt the designs developed to the software of the weft knitting machine. For that, the drawing was inserted by recreating it in this software, splitting in four parts the pattern motifs or structural cell. The case study showed structures with significant changes in some physical properties, just by slightly changing some design parameters. Thus, it is possible to state that parametric computer modelling can be a valuable tool for proposing new 3D structures, since it can generate several possibilities which can then be selected according to the application needs. The measurement of some physical properties helped to elucidate the possible uses of the fabrics. The yarn characteristics and loop length have not been varied, but the different structures created have variations in thickness and surface design, which are responsible for the difference in results. In conclusion, the development of three-dimensional fabrics in the weft knitting machine through the generation of surfaces in the digital modeling software proved to be of great value, since the time spent to create surfaces was decreased and the design options were easier to improve.

Acknowledgments

This work is financed by FEDER funds through the Competitiveness Factors Operational Programme - COMPETE and by national funds through FCT – Foundation for Science and Technology within the scope of the project POCI-01-0145-FEDER-007136 and the IFRS-Brazil under the administrative process nº23364.000466.2013-12.

References

[1] Palma D, 2014, Master's thesis, Processos paramétricos na exploração da arquitectura sacra reconfigurável, Lisboa: Recip p 66
[2] Nobre A X M Alencar M H V Machado L M A 2014 A abordagem sistêmica do processo generativo da forma aplicada ao projeto em Design Proc. XVIII Conference of the Iberoamerican Society of Digital Graphics - SIGraDi: Design in Freedom (Florianopolis) Vol 1 Number 8 (Blucher Design) pp 413-417
[3] Ferreira A J S Ferreira F B N Oliveira F R 2014 Têxteis Inteligentes: uma breve revisão da literatura. Revista de Design, Inovação e Gestão Estratégica (Rio de Janeiro: REDIGE) Vol 5, Number 01 pp 01-21
[4] Ujiie H 2011 Computer technology from a textile designer's perspective Computer Technology for Textiles and apparel (Cambridge: Woodhead Publishing); chapter 11 pp 245-258
[5] Lamar T A M 2011 Integrated digital processes for design and development of apparel *Computer technology for textiles and apparel* ed J Hu (Cambridge: Woodhead Publishing); 2011. pp 326-350

[6] Malé-Alemany M Sousa J P 2003 Parametric Design as a Technique of Convergence. *Proc. 8th Computer Aided Architectural Design Research in Asia* (Bangkok: CAADRIA) pp 1-5

[7] Pinto Y A Pupo R 2015 Explorando a ferramenta de programação em design: um estudo sobre grasshoper. *XIX Congresso Ibero-Americano de Design Gráfico Blucher Design Proceedings* vol 2 number 3 pp. 686-690

[8] Fischer T Herr C R 2001 Teaching Generative Design. *Proc. of the 4th Conference on Generative Art*

[9] Vieira A K 2014 Design Generativo - Estudo exploratório sobre o uso de programação no Design