

Virtual prototyping as an evaluation method for functional clothing

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Abstract. In the process of developing new products, validation through prototypes is of fundamental importance. This traditional task accelerates the process, allowing detection of errors, identification of changes in the styles, turning possible the observation of new potential solutions. CAD 3D software for textile-based products contributes to the aesthetic and constructive visualization of new products. This paper has as objective the evaluation of the contributions of the virtual prototyping systems in the aid of the ergonomic validation of functional garments, related to the compression and the tension produced on the body of the user. The research procedure of this study lies within the exploratory field of qualitative character. Through the experimental process, it was possible to identify the characteristics and differentials between the traditional and virtual procedure in the ergonomic validation of clothing. Finally, it is possible to conclude that the virtual simulation offers significant gains in the development process for new products. Nevertheless, this technique does not eliminate the need to produce the physical pilot garment as a final evaluation of the development process. Keywords. Anthropometrics, Ergonomics, Functional clothing, Virtual prototyping.

1. Introduction

The process of developing functional clothing has different methodological characteristics in relation to conventional garment project design. The importance of fashion runway trends and the elaboration of collections based on seasons, branding and aesthetics, essences for the fashion market, are less significant in the environment where specific needs must be met.

The functional garment project the premise of, understanding the context of its use, considering all aspects of the situation of its use, as well as possible, direct and indirect, interactions of the garment with the system where it will be inserted. [1]

During the development process of clothing, taking as a case study the functional clothing specific of workwear, we can highlight the importance of the freedom of movements and comfort to the users, to carry out their work tasks safely and efficiently. Thus, it is important to study the interaction between the user, the elements surrounding him and the context of his actions, with the goal of improving his well-being, achieving better performance. [2] The ergonomic factors are the ones with the greatest impact in the flat pattern design process, fundamental for the performance of the garments. Similarly, the physical constitution of the user and their postural dynamics, interfere in the garment design process and consequently in the performance of the garment. [3]

The verification of the functionality proposal and its validation through prototype development allows strategic gains in the development of the new product. It enables an acceleration of the process, allowing detection of errors, identification of changes in the styles, turning possible the observation of



new potential solutions. According to Baxter [4], during the construction of a product prototype, the designer will be able to validate or not, the ideas proposed in the project and continue its development. In the clothing universe, the prototype, besides checking the style aesthetics, has the function of verifying its functional aspects, such as the adequate garment construction, fit, patterns, draping of the used materials, ability to dress, and the various aspects of comfort related to its use. [5]

The traditional prototyping process can be time-consuming and expensive for companies, especially considering the increasing need of the fashion industry to present regularly new products to market, each time with shorter development times. With the physical prototype, it is possible to identify possible defects in the pattern design process. Therefore, basic patterns must be updated and new prototypes made until their final approval. [6]

The use of CAD 3D systems as a prototyping tool is widely used in engineering projects, namely in mechanical engineering, and in some segments of product design development, such as furniture, electronics and others. [7]

An example is *SolidWorks* software. It enables the virtual prototyping from the simulation of design, strength and mechanical operation of the product during the design stage, in addition to other specific features. For virtual prototyping, the properties of the materials applied in the manufacturing stage are considered in the function of the shape of the product. Thus, making possible the visualization of the performance of the project, through a colour chart, showing the points of greater and lesser fragility of the project. Figure 1 represents an example of a resistance simulation in *SolidWorks*.

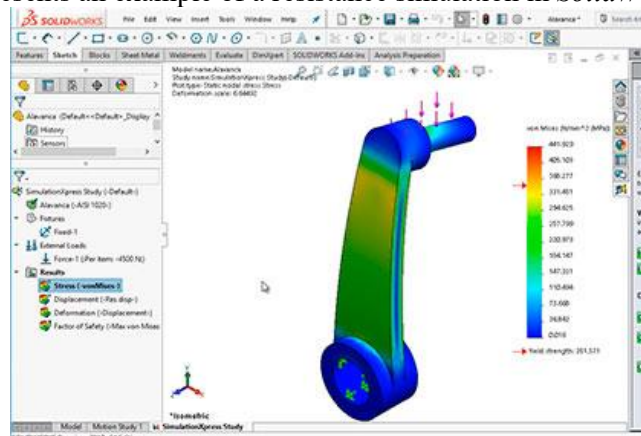


Fig. 1. SolidWorks interface and resistance simulation.

However, the use of CAD 3D in the textile and garment industry is recent, aiming mainly textile materials simulation and virtual prototyping in the clothing universe. There is also a high contribution potential in the development of fashion products, due to its flexibility and speed, resulting in important cost reductions in the process of products validation.

According to Sayem, Kennon, and Clarke [8], there are currently available different software programs responding to the demand of virtual prototyping in the fashion industry. Being the main ones: *Vstitcher*TM from the Israelis of *Browzwear*; *3D Runway* from *OptiTex International*; *Accumark 3D* from the North American *Gerber*; *TUKA3D* from *Tukatech*; *Modaris 3D* from the French *Lectra*; *Vidya* from the Germans of *Assyst*. In an updated review Pires [9] mentions the potential of other solutions with similar proposals, adding two solutions from *Clo Virtual Fashion*, *Clo 3D*, and *Marvelous Designer systems*.

The different companies that supply CAD 3D systems promise greater agility in the process of creation, validation, and production. In other words, "CAD systems used in the textile industry are, in general, so-called specific systems, whose ultimate function is to replace the manual process". [10] Analogously, they have similar interfaces, which combines the 2D and 3D universes into independent windows. Figures 2, 3 and 4 represent examples of some of the existing solutions in the market.

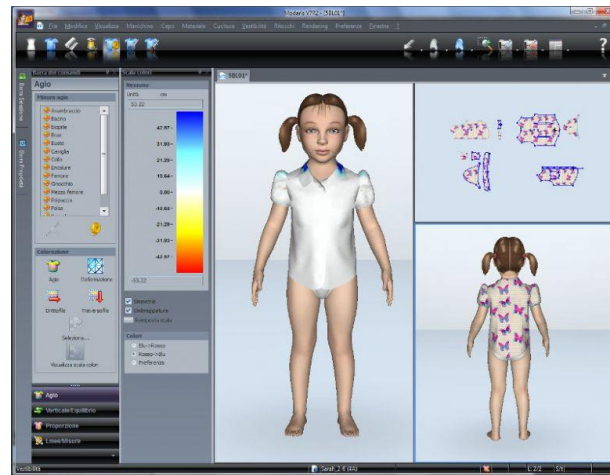


Fig. 2. Lectra - Modaris 3D interface.

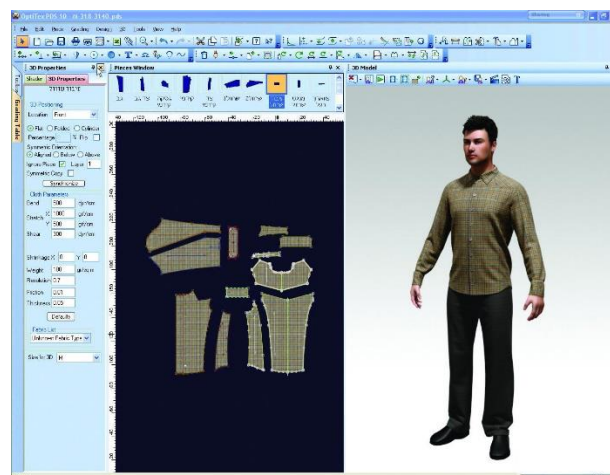


Fig. 3. OptiTex International - 3D Runway interface.

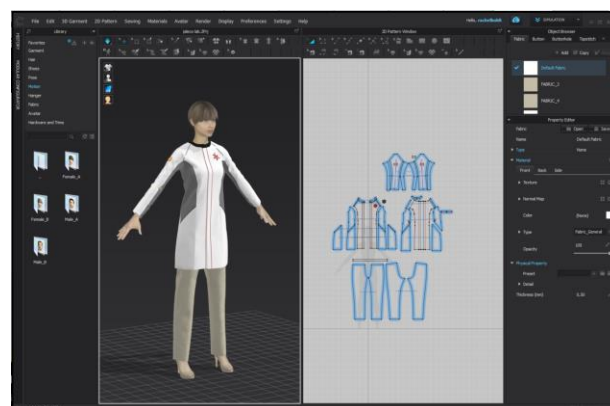


Fig. 4. Clo Virtual Fashion – Clo 3D interface.

Equally similar is the simulation feedback proposal. The software proposes similar assembly features and three-dimensionalization of the flat patterns; relative representation to the fit of the garment, as a

function of the virtual proof body and effect of the trim of the fabric, related to the characteristics of the used fabric.

2. Methodology

The article presented here is classified as an exploratory research of qualitative approach, according to its study objectives. Its rationale is based on "providing greater familiarity with the problem, with a view to making it more explicit" [11]. The main objective of this study was the evaluation of 3D CAD system capacity as a methodological tool to analyze problems related to the ergonomic aspects in the design of functional work clothes.

For this, in the first moment of the research, the bibliographic survey was adopted as a technical procedure of data collection and analysis. Its objective was to contextualize and provide bases for the evaluation of problems such as those related to the development of functional workwear, the limits of the traditional methods of verification of clothing functionality and the technological availability of Cad 3D systems intended for the textile and of clothing.

In the second moment, experimental procedures were performed with the objective of producing situations that promoted the analysis of examples that stimulated the understanding of the research problem [12]. The results obtained were directly documented, mainly through images taken from the interface of the software and compared with the experience of evaluation of the traditional method of validation of clothing modelling.

As a methodology for the preparation of the experiment were developed design proposals for functional work clothing. These had the purpose of acting as pre-existing variables of the experiment [13], that is, previously established bases of comparison of results for different scenarios

Clo 3D system version 4.0 was used in order to identify the ergonomic analysis capability promoted through virtual prototypes. The software served as a constructive platform in 3D models and provided model behaviour data based on the shape of the flat patterns, applied fabric physics, and the test body.

The project simulation and evaluation procedure cover the work steps, from the prototype preparation to the final model, as shown in the diagram in Figure 5.

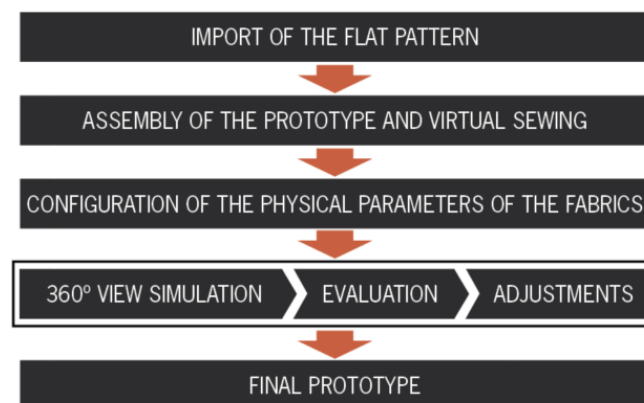


Fig. 5. Stages of work.

The steps characteristics will be exposed and discussed on the following topic.

3. Results and discussion

The first stage was characterized by the export of the flat patterns files, developed in the 2D CAD system, and then imported into the 3D CAD system. This way, the technical characteristics of the flat patterns were preserved and can be manipulated directly in the 3D software.

In the assembly stage of the prototype, it was possible to visualize dynamically the three-dimensionalization of the developed flat patterns. Through seam simulation, it was better understood

the construction lines of the developed flat patterns, and, how to fit all parts into the final product. Figure 6 represents the prototype assembly process and flat patterns visualization.



Fig. 6. Prototype assembly process and flat patterns visualization.

With the purpose to obtain greater simulation fidelity, it was developed the physical parameters configuration of the fabric in a virtual environment. For this, it was requested preliminary tests of the real fabrics sample. Checking material physical aspects of toughness, elasticity, hardness, draping, etc.

The materials physical characterization can be easily defined in laboratory tests. However, in the context of development in apparel companies, this step is seen as an obstacle. The CAD 3D software's offer a diverse range of pre-programmed materials. This facilitates the operation, but do not guarantee a simulation compatible with the actual result.

3.1. Simulation, Analysis, and adjustments

For the ergonomic evaluation of the project, images were extracted from the virtual environment for analysis. Three typologies of images were analysed, namely: simulation sketch; realistic; and tension map. Figure 7 represents the three typologies of images.

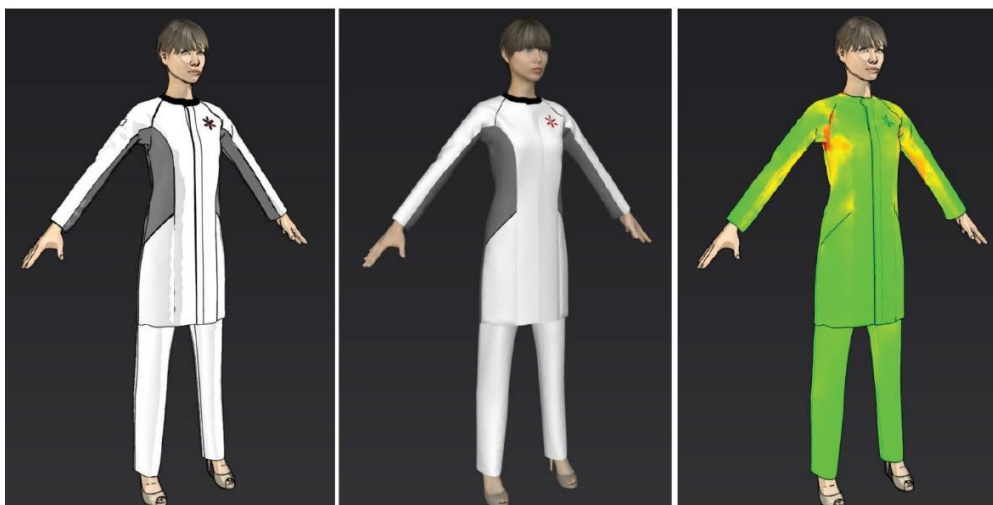


Fig. 7. Images extracted from the software: sketch simulation, realistic and tension map.

The typologies with sketch and realistic effect show the aspects of aesthetic order, namely the fall and volume of the fabrics, constructive details of the cut-outs and aesthetic elements such as colours,

textures, etc. The simulation with effect sketch allows to evidence the constructive lines, seams, and folds, through the prominence of black lines.

The stress simulations are subdivided into three new types of representation: Stress Map, Strain Map and Fit Map. The simulations using a voltage graph show the aspects related to the ergonomics of the parts. They indicate, through colour diagrams, the areas of greater and lesser tension in the simulated fabric. The simulations differ from each other and complement the understanding of the behaviour of clothing during use.



Fig. 8. Typologies of images extracted from the Clo 3D software: Stress Map, Strain Map and Fit Map.

The *Stress Map* shows the external stress causing garment distortion per area of the fabric, appears in the range of colour and numbers. Stress Map appears in total eight colours: With the red colour indicating the strongest stress (100kPa) while the blue colour indicates zero distortion (0.00kPa). Other numbers in between are expressed as the gradation of two colours.

The *Strain Map* represents the rate of distortion of clothing due to external stress. This stress is quantified in percentage form and is represented by a colour diagram. Being a total of eight colours: Red indicates 120% of the distortion rate while blue indicates 100% (no distortion). The numbers between them are expressed as two-colour gradation.

The *Fit Map* shows how tight clothes are on the user's body. It is shown in the colour diagram, where red indicates the impossibility of wearing; orange indicates as very tight area; yellow as a slightly tight area and white indicates that the area is loose.

From the observation of the simulation images with sketch effect, it was possible to identify some project aspects able to be improved: small adjustments in tweezers and heights; positioning of aesthetic details, such as the chest-height logo; and evaluation of the proposed aesthetic-ergonomic attributes.

On the other hand, the evaluation from the ergonomic perspective was based on the observation of the images of tension graphs with the test body in a work situation, in a static and dynamic position. It was possible to observe the clothing's behaviour and the tension generated in a simulation of use. Figure 9 represents the static and dynamic positions used.

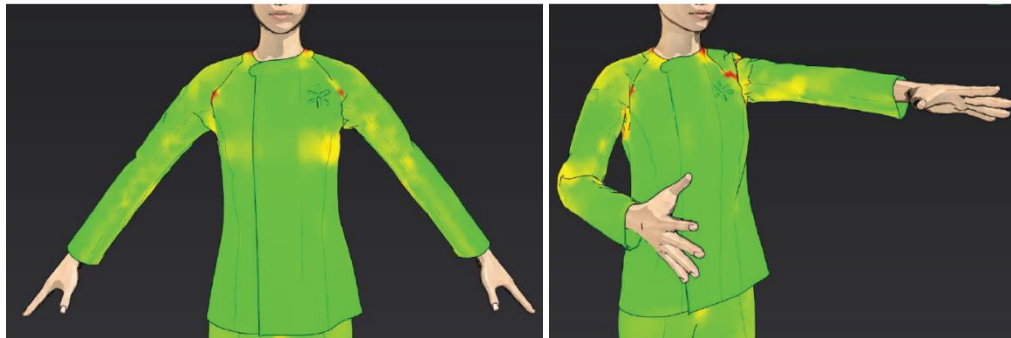


Fig. 9. Bodywork situation, in a static and dynamic position

In Figure 10 it is possible to observe the garment's behaviour in two different design proposals, one using a fold in the middle of the back panel and one a simple seam in the centre back, without fold or extension capacity. This simulation provides relevant data to compare both designs effectiveness, where it was possible to conclude that the use of the fold supported the user's movements.



Fig. 10. Comparative evaluation of ergonomic attributes. Proposal with a fold in the centre back (left) and proposal with a regular seam in the centre back

The simulation, evaluation and adjustment process was repeated until the desired effect was reached, resulting in the final virtual prototype, without producing any physical prototype, wasting time and material.

4. Conclusion

The results obtained show relevant gains in relation to the product traditional development process, regarding the evaluation of the ergonomic effectiveness, the gain in flexibility of execution of small adjustments and the aesthetic variations in the product. The CAD 3D software used contributed to the evaluation of the various modifications and proposals for improvement, without the need to produce the final product, and, in a lower extent, use the software test models, since it was possible to evaluate the products on virtual manikins in conventional positions and in working positions.

The results were presented graphically. The compression forces are visualized by the representation of tension from the variation of colours between green, yellow and red, with the cold tones representing a lower tension and the hot tones representing the greater strain.

It is also possible to make a pre-evaluation of the materials draping in the body, since the virtual representation demonstrates the formation of roughness, volume, and deformation, according to the cut of the pattern and the physical characteristics of the simulated material. However, for a more effective simulation of the draping, it is necessary to adjust parameters of physical simulation of the fabrics having the actual fabric as a comparative.

Finally, it was possible to conclude that the virtual simulation offers significant gains in the development process. Nevertheless, this technique does not eliminate the need to produce the physical pilot garment as a final evaluation of the development process, largely increasing its success in its first development.

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