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System of Material and Construction Parameters for a Reliable Simulation of Textile Surfaces in the Clothing Industry †

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Abstract: Garment simulation enables the reduction of physical prototypes saving time, material and costs. Complete elimination of physical prototypes is not yet possible because simulation is not reliable enough for a robust fit analysis. In addition, predictions of the textile-physical behaviour of virtually available materials would be useful. A new approach is being developed to represent the material and construction properties of textile surfaces, their correlations and their influence on the simulation. Based on the material parameters, conditions for a reliable simulation and prediction of the material behaviour can be derived. This paper first focuses on the distinction between material properties of the fibres and construction properties of yarn and surface.

Keywords: 3D simulation, virtual prototype, fit analysis, quality assurance, material parameters, material and construction properties

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1. Introduction

In the clothing and textile industry, the goal of research and development is to create continuous digital process chains from the product idea to production and quality control [1]. In particular, virtual product development and thus the 3D simulation of textile surfaces and clothing products plays a central role.

The implementation of 3D simulations in product development processes means minimizing costs and time, savings resources and optimizing communication between customers, suppliers and producers [2,3]. Accordingly, 3D simulation opens up economic potentials in terms of sustainability and resource efficiency and means added value for companies and end users. This essentially corresponds to the concept of Industry 4.0, which is characterised by

- Product individualization;
- Flexible and efficient production down to batch size 1;
- The involvement of customers and business partners in the value creation processes and
- The combination of production and high-quality services [4].

In the current product development cycle, simulation is primarily used to generate idealised and promotional representations. For fit analysis, an initial assessment can be made of the silhouette, proportions and design in terms of colours and surface texture. This allows the reduction of physical prototypes. The complete elimination of physical prototypes, as required by the end-to-end digital product development process mentioned above, requires reliable virtual fit analysis and optimisation. However, this is not possible if the simulation does not represent the material behaviour realistically enough.

Surveys regularly confirm that the fit of clothing is the most important purchase criterion for customers [5–8]. Therefore, virtual fit analysis and optimisation must be considered when implementing a consistent digital product development process. Predictions about the behaviour of materials that do not yet physically exist should also be targeted. In both cases, in addition to a realistic representation of the material behaviour, the numerical description of the material behaviour is essential. In the authors' opinion, this can only be achieved by optimising the integration of the material parameters of the textile surface into the simulation algorithms.

This paper gives an insight into the research field of the new approach for the determination of simulation-related textile-physical material parameters.

2. State of the Art

The software for 3D simulation of clothing that are used in practice can be divided into two categories [3,9]:

1. Construction of garments on the avatar and subsequent unwinding of the shape into the plane (3D to 2D);
2. 2D construction of a cut, which is then virtually sewn and placed around the avatar (2D to 3D).
3. The first principle is very well suited for the implementation of products that are close to the body, such as clothing in the sports and medical sectors, but also in the automotive industry. The second principle has gained acceptance for clothing, as it can be used to visualise both close-to-body and far-from-body clothing. It has been implemented in numerous programmes over the years.
4. Normally, research focuses on questions of the reliability of the simulation and the correlation of the virtual representation of the simulation with reality.
5. According to Morlock [10], three steps are defined for a reliable simulation:
6. the digitally available 2D sectional construction;
7. the avatar, which reflects the human body in terms of its dimensions and proportions;
8. the material parameters that describe the surface appearance and the deformation behaviour of the textile.
9. This project focuses exclusively on the textile-physical deformation behaviour of the material. It will therefore be discussed in more detail below:
10. The deformation behaviour of textile surfaces can be divided into two application cases [11]. While the simulation of technical textiles mainly considers the drapability, i.e., the textile-physical behaviour under forced deformation, the behaviour under free deformation under the effect of gravity is decisive in the simulation of clothing. Therefore, different modelling models can be used for both applications. In the case of technical textiles, which are used e.g., for fibre composites, the simulation is mainly carried out with the help of FEM models [12]. This method is relatively computationally and time consuming [13]. For clothing, on the other hand, the so-called particle model is used, which allows simulations to be carried out in real time, taking into account the relatively short development cycles in the clothing industry. Among other things, the complex processes of wrinkle formation and the collisions of different surface levels are realised in a balanced relationship between computing time and computer capacity [13].
11. The work of Pierce, Cusick and Kawabata is particularly noteworthy in the study of clothing simulation and its fundamentals. Pierce laid the foundations for textile materialsimulation of in the 1930s when he studied the relationship between stiffness and weight and the drapability of textile surfaces. Cusick followed in the 1960s with his investigation of the influence of shear stiffness and bending length on the drape coefficient and developed the method still used today to determine the textile drop [14]. Kawabata and Niwa developed a system for objective handle identification and

associated measuring systems and devices, thus making a considerable contribution to the objectification of subjectively perceived textile properties. This makes correlative comparisons with mechanical properties possible. In turn, it is thus possible to draw conclusions from the mechanical properties to the subjectively perceived, haptic properties of the material [11]. This is particularly important because materials cannot be assessed haptically as long as they are only depicted digitally. This is a major challenge for product developers when dealing with simulated clothing, as they have to learn to evaluate a textile material based on its digital representation and parameters.

12. As already mentioned, the main objective of the research work mentioned above, as well as others, was to describe the fall behaviour of textiles objectively and numerically. Thus, they are considered the cornerstone for the simulation of textile surfaces. On this basis, Breen, House and Wozny developed the particle-based model for the simulation of textile surfaces [15] in 1994, which for the reasons described above, is most suitable for the simulation of clothing. In addition, alternative approaches to simulation algorithms, especially for technical textiles, have been presented [16–20].

3. Problems and Objectives

3.1. Textiles vs. Compact Materials

Compact materials, such as steel, are mechanically resistant to bending and are characterised by a continuum-mechanically coherent structure whose bonding ratios can be defined at the atomic-molecular level. As compact materials, they predominantly exhibit linear-elastic deformation behaviour, which can be derived from the physical properties of the material or material in conjunction with the workpiece geometry and described by means of material constants.

Textile materials, however, are not compact materials, but represent complex, anisotropic and flexible structures made of individual elements. They are composed of fibres or filaments that are joined together during processing, first to form yarns and then to form surfaces. Within these structures, the fibres come into contact with each other and are exposed to frictional forces under load. In order to describe the deformation behaviour of textile surfaces, it is necessary to take into account the material or fibre properties, the construction properties of the yarns and the surfaces, and the textile-physical properties of the textile surface. Furthermore, it should also be noted that textiles hardly exhibit linear-elastic deformation behaviour, which means that no material constants are available and can be used to describe the deformation behaviour.

3.2. Challenges in the Application of the Simulation Programmes

The commercially available clothing simulation programmes for different material parameters in relation to the surface to be simulated. Common to all programmes is the query for thickness, weight, elongation and bending stiffness. For the latter two properties, loads in the warp, weft and diagonal directions are taken into account in order to take into account for the anisotropic material behaviour of textile surfaces. It can be concluded that these material parameters play a significant role in the simulation algorithms, but the value of each individual parameters in relation to the simulation remains open and undefined. Therefore, it is not clear which parameters are included in the simulation calculations and with which share. Similarly, the way in which parameters are integrated into the simulation algorithms can only be guessed at. Unfortunately, there is limited information available on this, as software manufacturers are reluctant to disclose the underlying algorithms. Furthermore, no evaluation of the various simulation programmes is possible, even with regard to quality assurance of textile products, which considerably limits the use of the software in quality assurance.

Studies show that different programs deliver different simulation results even when the framework conditions (2D section, avatar, material parameters) are identical [3,21–23].

On the other hand, very similar simulation results can be obtained despite the implementation of different material parameters [3]. The comparison of the physical with the virtual fitting shows that the simulation quality for a reliable fit analysis and optimisation is still insufficient, especially if physical prototypes are to be largely eliminated in the future or completely omitted for economic reasons. Significant discrepancies are existing between the physical and the simulated drape tests. These results lead to the conclusion that the physical material parameters are not implemented sufficiently well in the calculation algorithms. In particular, the anisotropy of the material appears not to be taken into account in the calculations, despite the fact that the bending stiffness and the elongation in the warp, weft and diagonal directions have been entered. So far, it is therefore not recognisable according to which criteria material parameters are selected and taken into account in the programmes.

It can be concluded from this that there is still a considerable need for basic research with regard to the simulation-relevant material parameters. From the authors' point of view, future work must concentrate on the definition and determination of simulation-relevant material parameters and the optimization of the calculation algorithms.

3.3. Objectives

Therefore, a new approach to describe the deformation behaviour of textile surfaces in the context of clothing simulation is being developed. This involves investigating the correlations between fibre, yarn and surface properties. The aim is to clearly distinguish between fibre and construction properties. Initially, only the textile case is considered for deformation behaviour, i.e., the free deformation due to the effect of gravity. By comparing the relative properties of fibre, yarn and surface, it is possible to show the property changes over the process stages and to represent the values of properties in terms of their influence on the simulation.

4. Methodology an Implementation

Previous research has mainly focused on the influence of yarn and surface properties on the textile case. From the authors' point of view, the material properties have not been sufficiently considered so far. In the current project, the importance of the material properties for the simulation is being investigated. At the same time, the connection between the material properties and the yarn and surface properties is considered. Therefore, the investigation of the textile case as a function of the fibre, yarn and surface properties is carried out by means of tests on the deformation behaviour of the material and corresponding correlation calculations. From the results, reasonable approaches for simulation optimisation can be derived.

The following considerations are decisive for the selection of the material to be investigated:

- the parameters influencing the investigation should be kept as manageable as possible;
- the fibre material used should show as little plastic deformation behaviour as possible;
- The constructions of yarns and surfaces should correspond to the respective basic constructions, i.e., single yarns and basic weaves.

Therefore, a surface made of untreated cotton was selected as the model material. The yarns used in the surface are single yarns in z-twist. The construction of the surface is characterised by a simple plain weave, the yarn systems of which have identical yarn constructions and have been processed with approximately the same yarn density.

The selected surface has been tested for material and construction properties according to relevant standards. The subsequent comparison between fibre, yarn and surface properties includes correlation calculations and graphical evaluations.

5. Conclusion and Outlook

Initial results allow conclusions to be drawn about the value of material and construction properties in relation to deformation behaviour.

The investigation for one model material will be extended to other materials in order to test the transferability to other textile surfaces.

Furthermore, the results of the work will allow conclusions to be drawn for the modelling of forced deformation behaviour. This is necessary for the simulation of clothing taking into account the human movement process and for the simulation of technical textiles.

This work will contribute to the further objectification of fit analysis and optimisation using garment simulation. This makes it possible to streamline product development processes in the apparel industry. In addition to the above-mentioned resource savings, an exclusively digital product development without physical prototypes makes it possible to involve the customer in the product development process at an early stage and thus meet the growing trend of product individualisation. Not only are design wishes taken into account, but the fit is also analysed and individually adapted to the customer's wishes. As a result, returns are avoided and the current aspect of sustainability in terms of resource efficiency and avoidance of overproduction is met. This creates an essential prerequisite for incorporating the simulation of textile structures into quality management systems and opening up quality assurance as part of a quality system for garment-specific concerns as well.

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