Virtual Fit vs. Physical Fit – How Well Does 3D Simulation Represent the Physical Reality

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Abstract

The popularization of new technologies, such as 3D Simulation programs is an important factor to help speed up the development chain and save resources within the clothing industry. Proper fit to help size conformity, company loyalty and to decrease return rates is becoming an increasing requirement. This study aimed to investigate the effectiveness of 3D virtual fitting technologies of garments and analyzing the similarities as well as differences between real and virtual fit.

Within this study different garments on the upper and lower body were analyzed and compared, by evaluating the whole development chain. The first step was to scan different test subjects with individual body shapes and figure types in the Vitus Smart XXL 3D Scanner and to generate according avatars for each size analyzed (a small, middle and large size). Then patterns were created for each garment and simulated virtually on the according avatar within three different 3D Simulation programs: CLO 3D, Vidya Assyst, and V-Stitcher Browzwear. These same garments were also sewn physically and fitted on the same test subjects to evaluate the similarities and differences between the virtual fit and physical fit.

The analysis showed that for both the virtual fit testing and physical fit testing in-depth fit knowledge was essential to evaluate the results properly. Sufficient ease and proper fit was given virtually in the example of this male jacket German size 50, which was simulated in CLO 3D. However, the ease was not sufficient enough when creating the physical garment and could not be closed, or small movements such as lifting arms could not be made, resulting in a too tight real jacket. Folds and tension will show on the physical garment, but not within the 3D software. An important insight was to simulate with base layers, as it would be worn in real life, since without base layers the fit was not shown accurately within the 3D system.

The investigations revealed that there are various factors that affect the success of virtual fit testing, This is an important research effort for the clothing industry, as it demonstrates which parameters need to be taken into consideration for a realistic and accurate virtual fit testing with the help of 3D technologies.

Keywords: 3D simulation, virtual fit, physical fit, avatar, material parameters

1. Introduction

Since the beginning of the 1980s, the simulation of clothing has been of scientific interest. Technology is developing rapidly. Therefore, the processing power of computers have been growing exponentially, thus advancing the technological progress of simulations. This process has been accelerated in the past years and the simulation of clothing has not only been an issue in science but has also reached industry. [1-4] The advantages are obvious. Garment simulations allow better planning in terms of design and fit. Production can be adapted accordingly without the need for several physical prototypes. [5-7] Digital preparation of the garment saves time and money. The three-dimensional drawing is more realistic and simplifies communication between departments in the production chain. Saving on transport and prototype costs also means that the entire production chain has a smaller environmental footprint compared to the traditional analog process, making it more sustainable. The digital twins of fit models don't change during time, can be shown in all sizes and are available at any time. [8] In order to be able to judge the fit qualitatively on the basis of a simulation it is necessary to prepare material and avatar according to the simulation system. [7] It is also important to know how to use the system and at the same time to have a background in garment technology for the correct fit assessment in the various simulation software. The aim of this study was to transfer the real, proven process of fitting evaluation at Hohenstein into a digital environment and to highlight the potential and the challenges. Influencing factors on virtual fit were identified and the user role in the 3D fitting process investigated.

2. Method

To investigate how well 3D simulation represents the physical reality, different virtual and real garments on the upper and lower body were analysed and compared, by evaluating the whole development chain. In the virtual fitting workflow three different 3D simulation systems (CLO 3D, V-Stitcher, Vidya) were utilized by three different users. The physical fit assessments were performed by three fitting experts The virtual and physical fittings on the one hand and on the other hand the results of the different users were compared. In this paper the process of fitting a jacket is shown as an example. By considering the individual steps of a fit test and the digital counterpart. It is important for the fit test to follow a protocol which is tested and validated. Therefore, the Hohenstein fit test was taken as a model. The relevant parameters for a realistic fit simulation were worked out.

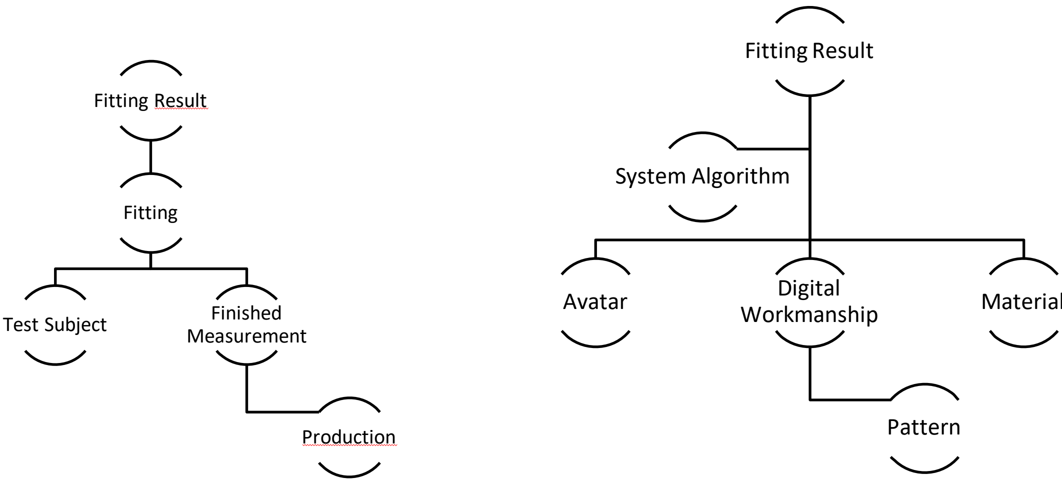

Figure 1: Left: Fit assessment process of physical products
Right: Fit assessment process of digital products,

Figure 1 shows the proven Hohenstein real fitting assessment on the left side and the digital assessment workflow on the right. Whereas, in the traditional fit test two parameters were assessed (finished measurements and fitting on real test subjects) the digital fit test included six parameters. These were pattern, material, digital workmanship, avatar, system algorithms and the final fitting result.

2.1. Prototype Production

Before the garment can be tested both real and virtually, it was sampled. For a comparison, a suit pattern for men was created, in different sizes, this design was then sewn as prototype and comparison for the simulation. For the real production, a technical package with processing instructions was created. The information from the technical description was adapted for the creation of the simulation.

2.2. Material parameters

To check the virtual fit, the outer fabrics used in the prototype were tested according to the standards. Before the simulation was started, the materials used were tested for their textile physical properties. For this purpose, the main parameters were tested in the laboratory according to DIN Standard. The basis weight according to DIN EN 12 127[9], The bending stiffness according to DIN 53362: 2003-10[10], The maximum tensile force according to DIN EN ISO 13934-1[11], The Drapemetertest according to DIN 54306[12]. These values were then calculated for the software systems Clo3D, Vidya and Vstitcher.

2.3. Digital Workmanship

The processing instructions from technical production were precisely analysed and transferred to the simulations. Definitions for digital processing were established for the real processes.

2.4. Avatar

To check the fit, a male avatar of SizeGERMANY size 50, with a chest circumference of 100cm, and a fit dummy was created. These Geometries were then imported to the simulation systems.

2.5. Real Fitting and Digital Fitting

The tests defined from the real fit test were determined and transferred to the digital fit test. The fit of the garments was tested virtually on the avatar and on the dummy. These were checked visually, and the internal system analysis tools were used. In addition, the finished measurements from the product description were compared with those in the simulation and the circumference measurements of the avatar.

3. Results

Findings show that 3D simulation can represent the physical fit well. Yet, to achieve reliable fit assessment results a fundamental understanding of the utilized system and the garment production process is necessary. Analyzing the 3D simulation of different products requires the assessment of more parameters than in the physical assessment. Therefore, a protocol for the digital fit test was developed. According to this the simulation was created and the fit tests were performed. This was the basis for the comparison between the physical and virtual garment as well as between the users.

Comparing the real fitting assessment with the digital counterpart revealed that the technical description which is the foundation of the physical production process can only be applied to the simulation to a limited extent and must therefore be converted to the parameters and setting options of each simulation systems. A realistic simulation is made up of several factors. These are the algorithms used to calculate the material drape, on which the user can only have a limited influence. The calculations are based on the measured data of the textile-physical parameters, which must be checked by the user. The pattern is of course also the basis for a simulation, but the fit is checked on this one, so it has not been closer examined. Fitting models are available for the real fit test, these also have been prepared for the digital fit test in the systems. In figure 1 parameters as avatar, digital workmanship and material are shown and their influence on the results have been closer examined in more detail. Digital fit almost has the same requirements of physical fit. Once the product description, the avatar and the material are prepared the 3D garment can be sewn. The virtual workmanship should be as close as possible to reality. Therefore, some knowledge about clothing technology is required to be able to put the pattern pieces together properly. Once the 3D garment is sewn, it can be positioned on the avatar as described on the product description. It is recommended to choose a minimalistic optic, without prints and colors for the fit evaluation. Garments should be combined the way they are worn in real life: a shirt under a jacket, trousers under a top. Those different layers have a huge influence on the optic and the virtual fit assessment.

3.1. Digital Production

In the technical package for the producer there is a detailed technical instruction for the workmanship. The producer must comply with this product description and set up a production line over several stations. Many of these stations are equipped with special machines that have accelerated and optimised the work process or to achieve certain effects. Digital production can be done in several steps, but the automatic process performed by the machines must be adapted by the user. In digital production, the seams created by the special machines must be described by simulation parameters. Here the angle can be set how two cut pieces are sewn together, for example left to left or right to right folding. The seam width can be specified by adjusting the value.

3.2. System parameters

Each system has different possibilities to simulate seams and processing. Besides the processing, the simulation parameters also have a high influence on the simulation. The density of the generated grid structure can be adjusted and also the collision parameters can be adjusted. The finer the grid structure, the more precisely the material fall can be calculated. The maximum fineness of the grid structure depends on the system. The smallest grid size in Vidya is 18, which corresponds to an edge length of 5.5mm. In Clo3D it is possible to set the edge length down to 1mm. The collision parameters are particularly important for layer separation. The separation of layers works via the normal direction of the geometries, which makes it difficult to translate traditional processing into digital.

As mentioned above, the translation of the technical specifications for the physical prototype into digital production is relevant for a realistic representation.

3.3. Material Parameters

A material can be precisely described by its physical characteristics. With these the fall of the material is calculated in algorithms stored in the simulation programs. The way in which this is measured and the extent to which it is measured is not uniform in the systems. According to the system in which the material values must be inserted, different parameters are required. In the case of the elongation test, the values for all systems could be checked in one test and then calculated for each system. The difference between the standard settings of the material and those measured is very large.

3.4. Fitting Categories

Simulating and analyzing the various products it was particularly noticeable that the result of the fit also depends on whether a hole outfit or a single part was simulated.

Figure 2: Simulation differences

Figure 6 shows how different the optical fit check is. The pictures on the outside show a jacket on an avatar without clothing underneath. The jacket was also smoothed with virtual pins. There are no wrinkles and the optical impression of a good fit is created. A complete simulation of the same jacket with additional clothing and without pins shows that the excess width is too small. This is confirmed by comparing avatar body measurements with finished measurements (see Table 1)

Table 1: Ease assessment

Measurements [cm]	Garment	Avatar	Difference	Ease Recommendation	
½ Chest girth / chest width	**51.5**	**50.0**	**1.5**	**7.0**	**10.0**
½ Waist girth / waist width	**48.0**	**44.0**	**4.0**	**6.0**	**8.0**
½ Hip girth / hip width	**56.0**	**51.0**	**5.0**	**6.0**	**9.0**

Even with a desired slim fit, the values are well below Hohenstein's ease recommendations. These are based on over 25 years of expertise and fitting knowledge within Hohenstein

The cross-section analysis through the jacket and avatar on hip level underlines this finding. The inner space of the jacket does not leave enough room for undergarments, e.g. shirt and pants (see Figure 3).

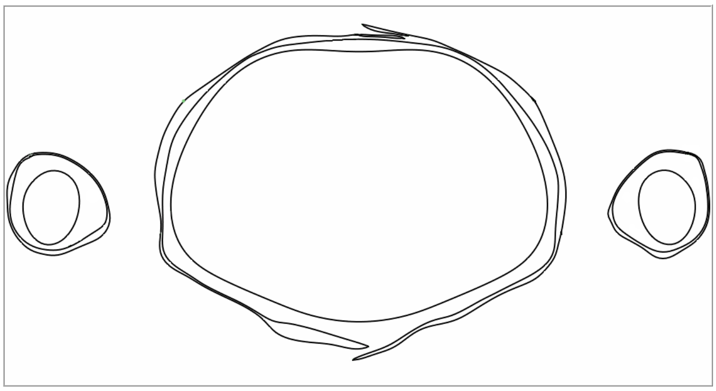

Figure 3: Cross Sections hip level Avatar and Jacket

3.5. Fit Tools

So far there is no clear protocol for a fit test of the 3D simulation programmes. However, they offer a comprehensive set of tools for checking the digital fit. These tools allow to analyse the structural changes of the textile through the material parameters and impact of the avatar. Yet, the findings show that the utilization requires comprehensive understanding of the digital process as described. Realistic fitting assessment of the jacket was only possible when performed with base layers.
Within the simulation programs there are different types of fit analysis, these relate to the structural change of the grid. Clo3D offers 3 different tools for analysis, the stress map, the strain map, the pressure point map and the fit map. These maps are calculated within the simulation and displayed in a colour gradient over a specific range. The Strain Map calculates the deformation of the textile by external influences and displays the mechanical influence of the pressure in kilo pascal. The stress map indicates the stretching of the textile. The pressure points show where the textile is in direct contact with avatars surface. The fit map calculates the 3 previous values and indicates where the clothing fits tightly or cannot be worn at all. In addition to the structural analysis, the fall of the material and thus the optical fit can be assessed.

3.6. Digital Fitting Tools

Figure 4: Stress Map

Figure 4 shows the stress map of the tested jacket. The cut parts in the shoulder and waist area are coloured bluish. This means that in this area the avatar and the clothing causes a pressure of 0 to ~15 kPa on the jacket. The display of the pressure on the shoulders is due to the weight of the jacket which lays on the shoulders. The realism of this simulation is supported by the subjective perception of the test person in the real fit test. In this the test person had the impression that the weight of the jacket is on the shoulder and that the jacket lies very close the hip area. On the sides of the jacket a pressure point is also shown, which indicates a tight fit.

Figure 5: Strain map

When checking the strain map (see Figure 5), the assumption of a too tight fit is again confirmed. The creases from the buttons to the side, which are already clearly shown in the optical fit, are here again underlined by a stretching in the blue to green area. In addition, on the sleeves a stretching of the textile in the blue-green area is visible.

3.7. Digital Sampling

The analysis of the digital sampling workflow revealed four important steps: Design, preparation, simulation, and rendering (see Figure 6). To generate reproducible results, processes in preparation and simulation were standardised and adapted.

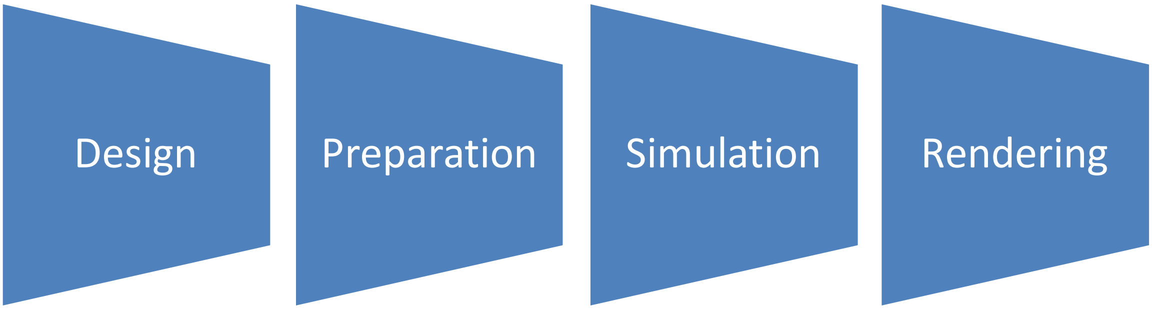

Figure 6: Workflow digital sampling

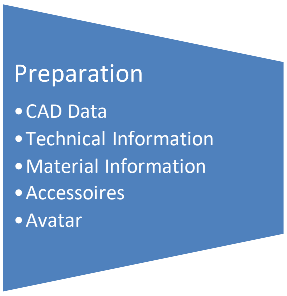

Figure 7: Close-up Preparation

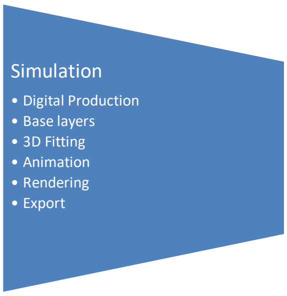

Figure 8: Close-up Simulation

The preparation includes many different processes which are necessary for a comprehensive garment simulation based on which a fit test is also possible. This standardisation must be recorded in a working protocol for each contributor. The preparation steps were carried out in different programs and were also completed there before the data was exported and imported into the simulation system. The preparation is in close contact with the design, so the pattern depends on the design and the material parameters must be adapted to the design choices. The cutting data must be prepared differently for the simulation than for production. Information from a cutting template can be transferred directly to the simulated pattern pieces. In the case of a size set check, a size table containing the grade rules for the pattern pieces must also be included. The material information consists of two groups. First, the material physical characteristics, which have been tested according to the system. On the other hand, the surface information, which consists of several layers of maps. These maps contain the pixel information with which the system calculates colour, reflection, and relief data of the textile surface. Accessories complete the textile surface; they must be prepared as geometry with textures in the right size. A very important point is the preparation of the avatar geometry. The circumference and length measurements must not only correspond to the target group of the company. It also includes the posture and the defined body type of the avatar. After all these data have been prepared and exported according to the guidelines, they can be imported into the simulation systems. At this point, the user then starts the digital production of the garment. For processing, the information from the tech pack is translated into the setting of the system's internal parameters. To keep the influence of the user as low as possible, definitions for repetitive work steps must be formulated. This not only reduces the degree of influence but also accelerates the working speed. For a 3D fitting, in addition to the points from the preparation, the fit class must also be considered. For an outerwear garment, it is also necessary to simulate the corresponding cloth base layers such as shirts, pullover, and pants. Otherwise it will lead to different and incorrect fitting results. Specifications must exist for the digital testing of the fit. These specifications can then be checked with the given tools using a guideline in the simulation. The fit test should not only be based on static renderings, the render settings have a high influence on the subjectivity of the result. Lighting settings can lead to wrinkles no longer being visible and camera settings can cause unrealistic distortion, which means that the optical fit can no longer be checked, and the result does not reflect reality. Within the simulation stage, changes resulting from design or styling decisions can be discussed. Renderings can also be generated within the simulation programs, but these are limited by the possibilities of light, camera, and colour management settings. Therefore, it is recommended to export the simulation and to render in programs that offer the possibility to make the appropriate settings. The stages named in Figure 8together form a fashion pipeline. For the preparation and the simulation not only technical knowledge of the simulation systems but also garment technical knowledge is required. This combination is also necessary for an evaluation of the results from the 3D fitting.

4. Conclusion

To achieve comprehensive and trustworthy results in the 3D simulation systems a few basics are required. In addition to the programs themselves, training time for complex systems are necessary. The analysis showed that for both the virtual fit testing and physical fit testing in-depth fit and pattern knowledge was essential to evaluate the results effectively. Traditional fit and pattern know-how plays a significant role, since the simulation systems are only as good as the users and the data used themselves.

The study revealed that up to now virtual simulation in CLO 3D can already portray the reality of fit to a certain extent. The most important factors are using the same target group/avatar virtually as the physical target group/people that are later intended to wear the garment. Testing and implementing the final fabric for their material properties and implementing these into the simulation software is key to visualize the drape and fall of the garment. Simulating with base layers, as it would be worn in real life was an important finding as this already makes the simulation more realistic and the fit is virtually closer to the physical reality. Making sure pattern know-how is applied from the beginning is essential, as ease already needs to be applied to the virtual pattern before any simulation is begun. If ease is not given within the pattern from the start, then there will not be enough ease within the physical garment either – even though the simulation might look “fine”. The biggest challenge is the interpretation of the simulation results. The avatar does not give feedback on whether the garment is too tight, shows pressure or if it has high tension. The 3D systems offer appropriate analysis tools for this purpose to evaluate the fit as mentioned earlier, although evaluating this data requires practice and a certain amount of abstract thinking.

Another challenge is to recognize when a wrinkle within the garment can be avoided and when it is acceptable. Wrinkle-free clothing is almost impossible in real life, but this is contrary to the aesthetic demands of the fashion world. The 3D systems allow the simulated garment to be edited until it is completely wrinkle-free. The user can iron, smooth and pin with virtual needles to “perfect” the garment. In terms of product evaluation in regards to silhouette, fit and customer expectations, this presents one of the biggest application errors. Also, it is necessary to choose a minimalistic optic for a better evaluation of wrinkles. Prints and colors often influence the judgment and wrinkles are less visible.

If the key factors outlined in this study are practiced and taken into consideration the virtual simulation programs demonstrates a good base to exclude certain fitting issues before the first physical prototype. It cannot fully replace a real physical fitting, since not all technical issues have been solved yet. Nevertheless, it is undisputed that 3D simulation systems allow for innovative fit strategies and help to make the product development smarter, more cost-efficient and more sustainable. The challenge is the connection between technological understanding of the simulation algorithms and traditional fit and pattern know-how. Only if both are successfully combined, the user can evaluate the simulations in a target-oriented way and only then the technology can fully unfold its significant advantages in the entire product development process.

Further investigation within this project will include evaluating other simulation programs, such as Vidya and V-Stitcher with the same avatar, material, and garment to compare the results. Evaluating garments across the whole size range, analyzing differences between female and male body shapes, and exploring avatars in motion are other fields that need to be explored. Implementing rigged avatars that can move will further help to analyze fit virtually in a more accurate way. It could show more clearly where ease is missing and weather certain movements such as lifting arms can be performed without restrictions. Soft tissue is another topic that requires further research within this study. For smaller sizes and garments such as a jacket it is not a major issue yet, but for garments closer to the body such as a bra or leggings soft tissue becomes a fundamental factor. For smaller sizes it might also not be as critical, but as the sizes grow and larger size ranges are evaluated, soft tissue also becomes a greater factor. Developing an evaluation system with grades as mentioned by Pilar, would be helpful to better communicate and scientifically analyze how well a garment fits.

This study is an important research effort for the clothing industry, as it demonstrates which key factors need to be taken into consideration for a realistic and accurate virtual fit testing with the help of 3D technologies, comparable to a physical and realistic garment evaluation.

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