Customizations of women bullet-proof jacket through 3D design process

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ABSTRACT

In today's scenario many personnels including police officers, security guards, field journalist etc. made it mandatory to wear ballistic protection garments while on duty. In order to give the required protection, most of the ballistic protecting garment (vests) were developed with higher number of fabic layers.The development of such garment using higher number of layers would also result higher weight and discomfort to the wearer while wearing in every condition throughout the day. However, the ballistic protection garment should be designed considering not only ballistic resistance toward projectile penetration but also reasonably light in weight and flexible to provide comforts. The current study brings a new techniques through 3D design process to develope the women bullet proof jackets on the women adaptive mannequin. The jacket can be worn along with the ballistic vest or can be removed to attain the different protection level at the different duty situations. The jacket can removed in order to increase the comfort and reduce the weight of the protection garment while the personnel is not in very dangerious duty areas. However, the designed jacket can also be wear along with the ballistic vest to give the required protection for the personnel at the very dangerous situations.

KEYWORDS

3D design process, adaptive mannequin, bullet proof jackets, customizations, parametrizations.

INTRODUCTION

Protection of the human body from different kinds of threats such as sharp object and combat projectile dates back to the history of mankind by wearing cloths made of different kinds of materials including animal skin (leather), wood, stones, copper, steel etc. Various textiles and laminates made of traditional fibres such as linen, cotton, silk and nylon have been also used not only for clothing but also as protecting materials against different threats including ballistic applications [1-3]. Nowadays, various police office authorities, private security personnel, disaster relief personnel, and other civilians in hostile situations (e.g. Journalists) wear various forms of clothing especially bullet-proof vest to protect themselves from deliberate threats against various types of hazards. The current flexible bullet-proof vest with front and back ballistic panel are made up of flexible material (textile) from a very strong fiber in order to absorb the impact energy of the bullet.

This helps the personnels to protect themselves from various fatal injuries during criminal conflicts, physical assaults, traffic accidents, battlefield confrontation and so on [4]. Besides, other than men, the number of women who are involved in the law enforcement, security personnel and other similar fields has been also significantly increasing across the world [5-6]. Considering such women involvement in the filed and thier unique body shapes, various researcher and body armour designer have been woking on the design and developments of women bullet proof vest considering not only the ballistic protection but also breathability, cost, fitness and comforts to the wearer [7]. Today, considering thier unique body shapes, there is various designing approach used in developing bullet proof vest for women personnel [8-9]. For example, cut-and-sew, fabric folding and stretch-molding are the common designing approaches. The cut-and-sew technique could develope the bust-shape using dart system to accommodate bust area [10] and fabric folding could also create domes in the bullet proof vest. However, such design also affects the comfort and personnel mobility due to much allowance for bullet proof vest deformation that lead to the panel thicker specially in the armpit region. Applying higher number of protective layers in the bullet proof panels may offer greater protection against projectiles, but it can also add undesirable weight and inflexibility of the vests [11-12]. The bullet proof vest with good ballistic resistance, lightweight and comfortable is extremely important for the women personnels working for long hours in various threat level. Based on this, many researchers has tried to develope various women bullet proof vest based on proper material selection, designing techniques and final finishing methods [13-16].

Even, further studies were carried out at large by researchers to enhance the overall performances of the women bullet proof vest not only in ballistic protection but also for reducing weight for better comfort. For example, tailor-made bullet-proof vest were developed on virtual body by optimizing the different protection zones for better comfort and protections [17]. Another researchers also proposed new design techniques through introducing different personal parameters. The technique applied on the real 3D measurement of the body to optimize the assembly process and projection zone which later leads for reduction of weight and waste quantity during the cutting operation. Moreover, various researcher has also worked on developments of a three dimensional seamless women bullet proof by combining unique designing technique along with specific production systems [18-21]. However, eventhough researchers have been engaged and used different techniques and materials for the developments of women bullet proof vest, it was found difficulty and still needs further research to achieve both good ballistic protection with a reasonable reduced weight. In order to reduce the weight of the bullet proof vest, it is mandatory to use either a very light weight material with good protection or minimise the panel layers. The minimization of layer in the vest would be possible, if the personel could wear different protective garments (vest and over coat) depending on the different threat conditions. For example, the minimum number of layers (20 layers for National Institute of Justic (NIJ) level-II that gives protection with maximum blunt trauma could be used to develop the bullet proof vest, whereas the additional layers (10 layers) for maximum protection with minimum trauma could be used in the jacket. The bullet proof vest could be used in the field, if it is considered the situation as minimum threat condition (including the personnels are inside the vehicle). Whereas if the situation in a very high risk, the jacket can be wear over the bullet proof vest to increase the number of layer for better protection level.

The aim of the current research is to introduced a new 3D design process to generate pattern for the developments of bullet resisting caots for women personnels. While developing, different antropometric circumferenceial lines on the 3D virtual adaptive bust mannequin were developed for reference. With thickness of the panel layer and cooresponding ease, various comfort lines were developed on the points of the circumferenceial lines. The circumferential line on this point helps to define the designs of the panel surfaces.

The protective layers were defined by the same technique as the bullet proof vest. Based on the surface of the jacket as a medium of creation, now it is possible to develop the different layers of protection. This new jacket panel pattern development system greatly helps to generate 2D pattern block for developing bullet proof jacket for better protection and comfort which can be wear along with the bullet proof vest depending on the level of threat situations. As the result it could not only give higher degrees of ballistic protection during risky conditions but also reduce the panel weight for the wearer at the low risk situations.

3D DESIGN PROCESSES FOR WOMEN'S BULLET PROOF JACKET

Digitalization and women body modeling

For the design process, an adaptive women body mannequin which was previously designed using Design Concept software with the relevant data has been used. The women mannequin was attained using a 3D scanner and the software scanWorx from the Human Solutions Company. After attaining the scanned body shape, its data was imported to software, called Rapidform. This software helps us to edit and correct the defects of the imported 3D meshed object. Finally, using the 3D Design Concept software, the 3D surface of the women body shape as shown in Figure 1 can be modeled. The operation of 3D scanning permits one to directly obtain the 3D body shape, on which the process used for analyses and modify the body shape.

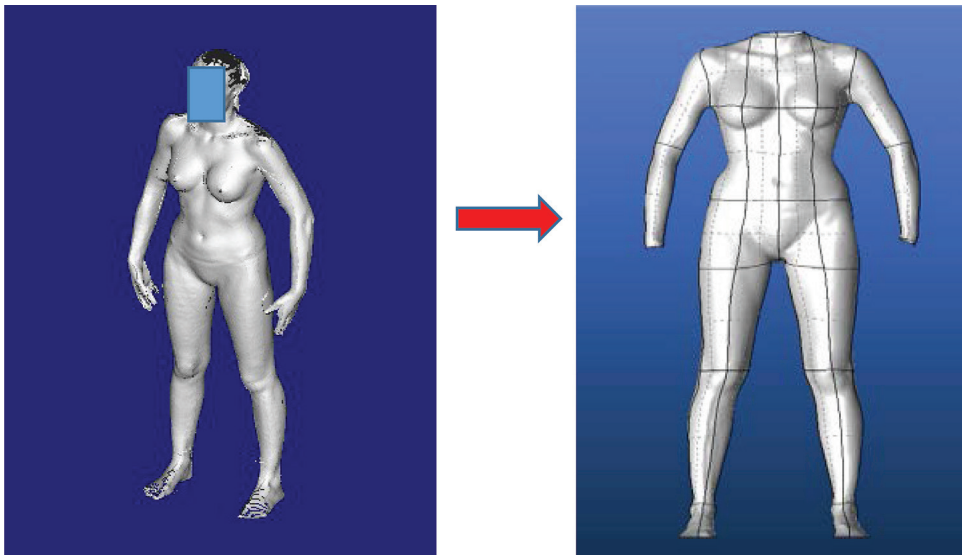

Figure 1. The sanned body model and customised 3D women body model

Developments of anthropometric and interpolation measurement on the manikin

In order to customize the partially bullet-resisting jacket, we have applied a designing technique which is similar a technique for normal bulletproof vest. As shown in Figure 2(a) different cross section curves on the body model (White color) based on the different basic and detailed morphological contours of the body curves were constructed on the 3D virtual body to develop the base of a bodice. Here, the structure was created on a 3D surface representing the basic bodice very close to the morphology of the front and back of the women body. Later, the braces (which are the distance between the 3D virtual manikin and the intended final product surface) were first positioned on the anthropometric lines of the 3D virtual manikin. This was done by using various set of featured points which was aligned on the anthropometric lines. Subse-

quent, another different line which could follow and passes through those various particular anthropometric points has been defined. This surface will lead and responsible to create the surface of the final products.

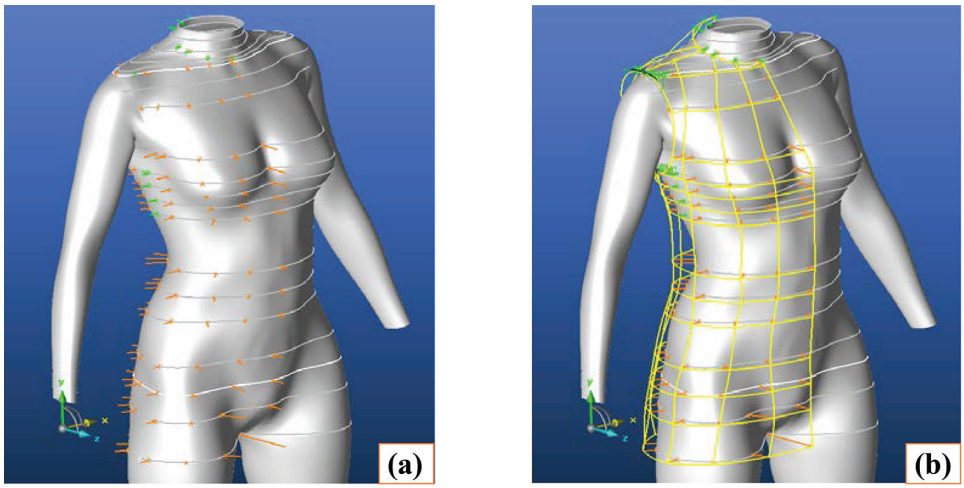

Figure 2. Development of anthropometric and interpolation curves on the develope 3D female body model

Later, as shown in Figure 2 (b), after determining the distance, the interpolation curve that is an anthropometric curve of the manikin were constructed at the end of each points of the waterline. Thus, it is now possible to create the new curve which is marked with yellow line on the curves of interpolation. This would help us to separate the front of the back and to increase the network of curves in the direction of the fall to improve the design of the future surface.

Patchwork surface creation and protective layer design

In the 3D design processes of the intended jackets, creating the patchwork on the network mesh gives a clear shape and garment surface contour. Figure 3 shows the creation of patch work type surface on the developed mesh surfaces. Those patchwork surfaces are a surface having different sections depending on the cut lines and help to manage the different shapes and sizes independently.

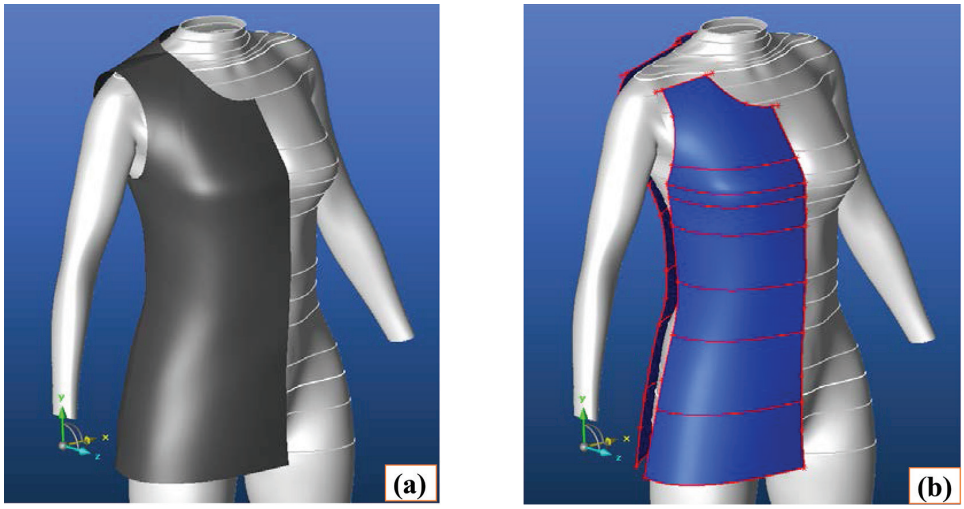

Figure 3. Surface creation (a) ''Patchwork'' type surface creation and, (b) Developing the different protective layer

Such development of a "patchwork" type surface has created a surface fitted to the body based on the previous network of curves (yellow color). Later on the created surface, it has been created the various cut lines of the intended jacket to extract the different useful surface of the jacket. This process also helps to create the 3D patterns on the 3D virtual mannequins. Moreover, as shown in Figure 3(b), **t**he different protective layers were defined by the same technique as of the ballistic vest design. However, during development of the jacket, the surface of the jacket was used as a medium of creation. However, while constructing the protective layers, it is not advised to completely cover the body with protective layers. This is due to the hardness and less flexibility of the material will hinder the expected comfort and flexibility to the wearer.

Application of dart for bust-shape creation

The major designing techniques used for ballistic protective garment are still based on cut-and-sew of the conventional fabrics with its drawbacks. Even though it could damage the continuity of fibers in the fabric which will reduces the level of protection, the cut-and-sew technique can form easily the dome shape to accommodate bust area [10]. In this paper, after developing the different protection layers on the surface, in order to give the wearer adequate protection, we have used a technique similar to the bulletproof vest (dart making system) for better shape and fitness. The cut-and-sew dart making system helps to attain the required shape on the bust areas as shown in Figure 4. While developing, the end of each protective layer was adjusted with a well-defined garment position and angle. This will give a better alignment of one layer against the next protective layers. While developing the protective layers, after the development of each creation of a layer, it offset from the previous by a distance of 5 mm.

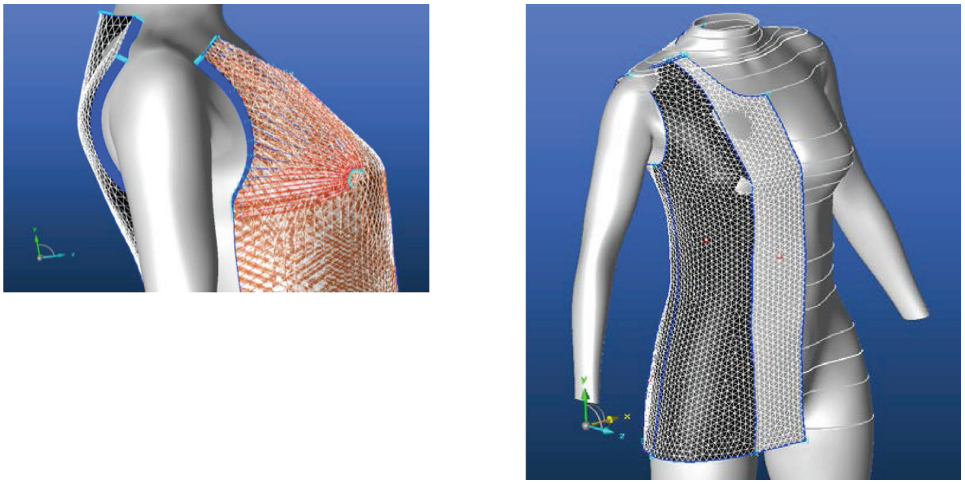

Figure 4. Bust-Shape creation on different protecting layer with dart

Flattening of bullet-proof jacket pattern

In general, generating bullet proof garment pattern design directly on the specific 3D virtual adaptive mannequin could give a very good result not only good ballistic protection but also better fitness and comfort. The developed mesh for the ballistic protecting jacket, its lining and layers of protection for both frontal and back panel block surface could be then under go to the flattening operation in order to generate the corresponding 2D basic block pattern. This pattern helps to fit the body form or a person with comfort ease. The generation of flattened 2D basic block pattern also strictly follows the principle of the classical 2D pattern design knowledge. The different successive flattened block patterns for the panel are shown in Figure 5.

Moreover, the patterns were also compared to the patterns of the jacket with those obtained by the traditional techniques of flat pattern design.

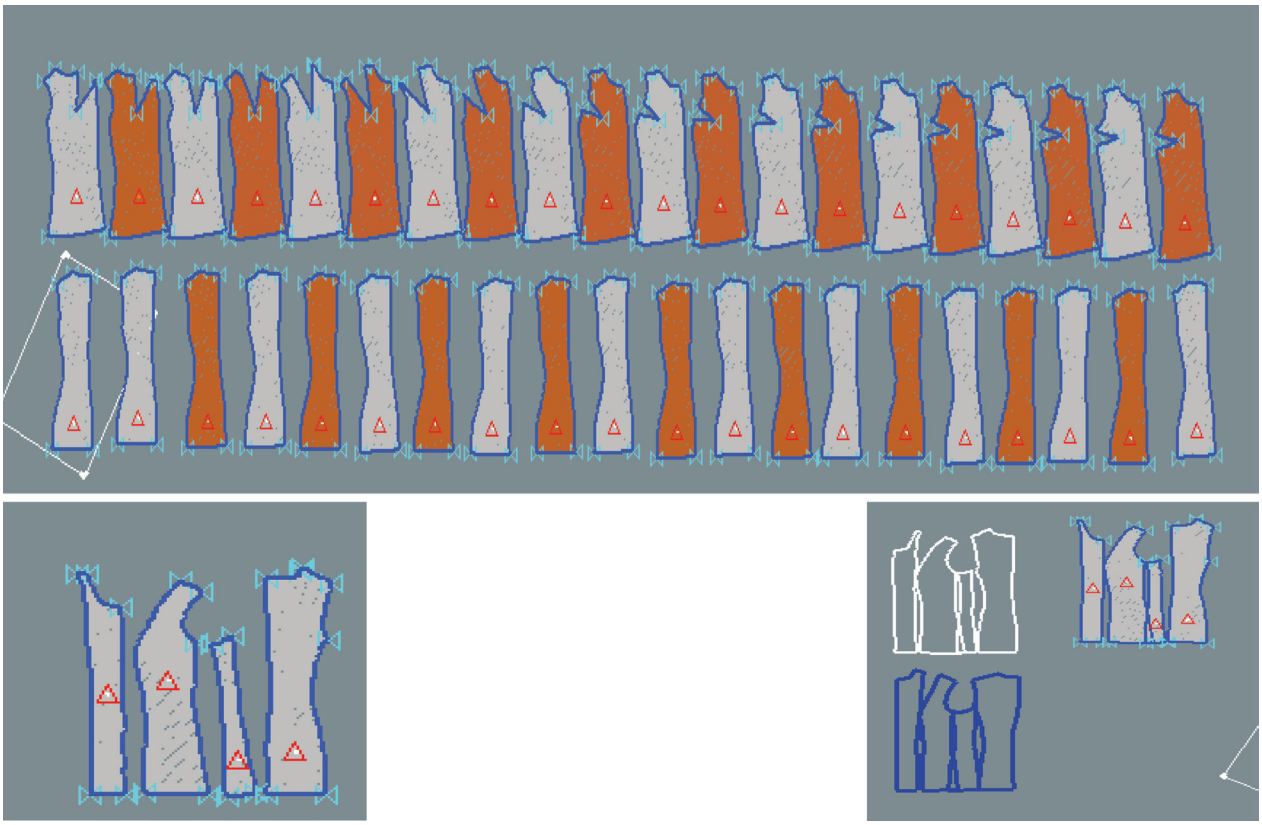

Figure 5. Flattening of the developed pattern

Finalizing the protective jacket

In order to observe whether the developed garment has been sewn correctly or not, the different protective layer within the garment were mounted layer by layer on the manikin. First, the different patterns were transferred in Modaris software as shown in Figure 6(a). The next step in Modaris is to assemble all the lines that need to be sewn, to define the garment's threading points as shown in Figure 6(b).

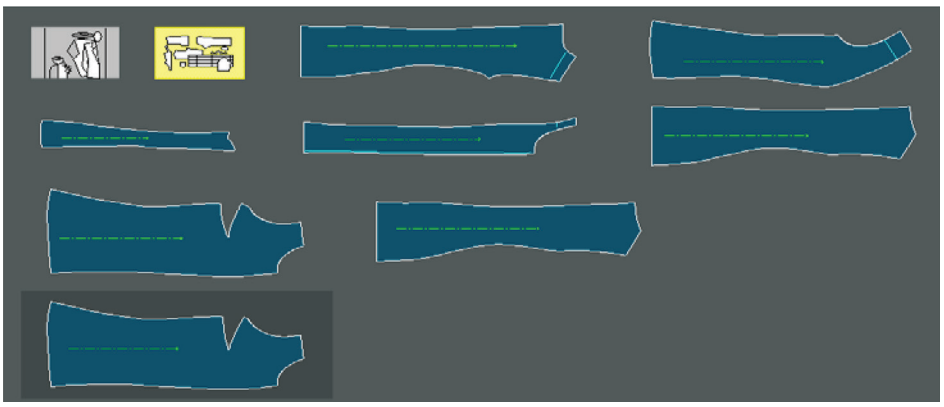

Figure 6. (a) Flattened pattern in Modaris

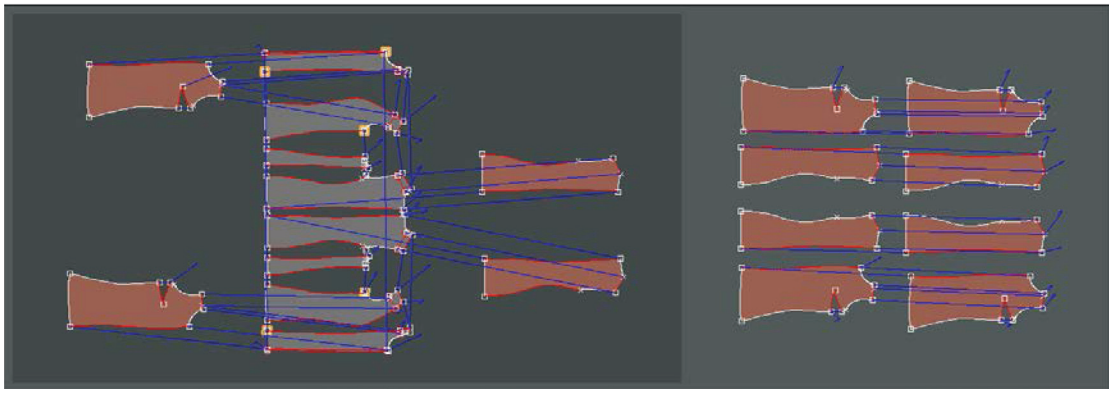

Figure 6. (b) Assembling of lines with threading points

The final protective jacket with different protective layer, lining and final fabric is shown in Figure 7. This help to correct the different parameters directly in Modaris mounting errors. While mounting, first the lining in the base were mounted for better comfort. Later, the different protective layers (second layer (first layer of protection), third layer (second layer of protection), and so on were added until it reaches the required number of layers for the given protections.

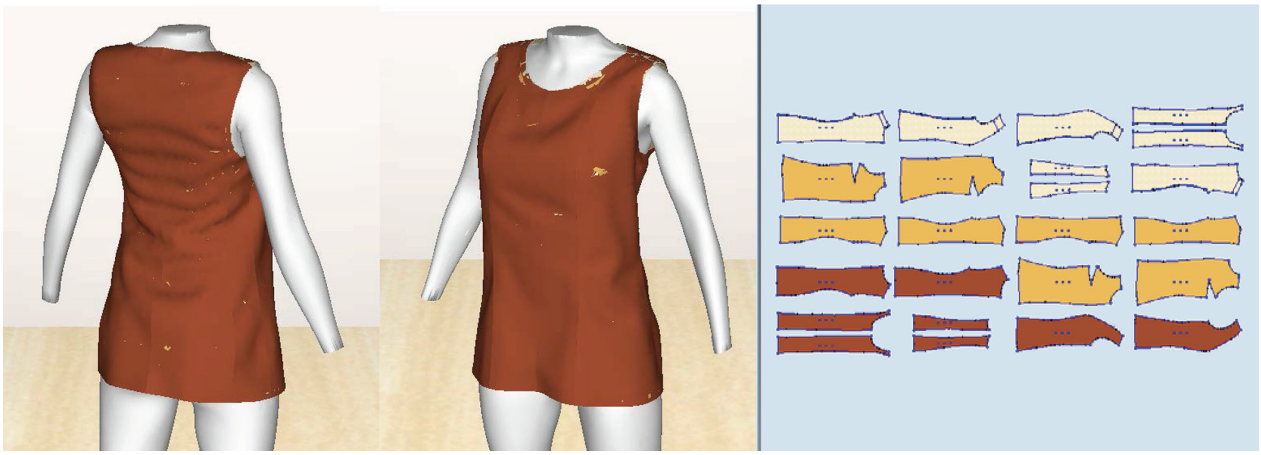

Figure 7. Finalizing the ballistic protective jacket

CONCLUSION

On this paper, a systematic 3D design process was used to develop the ballistic protective jacket on the conceived 3D virtual adaptive female mannequin. The different pattern for consecutive layers of multi-layer female jacket panels was generated. The different layers were performed based on the base layer position (lining), ballistic vest and the thickness of the layer (fabrics). The different patterns for each protection layer developed on the 3D virtual adaptive mannequin were flattened.

The developed ballistic protecting jacket helps to wear along with the ballistic vest or can be removed to attain the different protection level at the different duty situations. The jacket can be removed in order to increase the comfort and reduce the weight of the protection garment while the personnel is not in very dangerous duty areas. However, the designed jacket can also be wear along with the ballistic vest to give the required protection for the personnel at the very dangerous situations. However, beyond design and development, future works is very necessary to develop the jacket and experimental testing of the product for comfort, fitness and ballistic performances.

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