Pattern Engineering for Customized Women Seamless Ballistic Protection Vest on 3D Virtual Mannequin ⋆

Mulat Alubel Abtew [a,b,c,]*,   Pascal Bruniaux [a], Francois Boussu [a],
Carmen Loghin [b], Irina Cristian [b], Yan Chen [c], Lichaun Wang [c]

[a] *University of Lille, ENSAIT, GEMTEX-Laboratory, F-59100, Roubaix, France*

[b] *Technical University "Gheorghe Asachi" of Iasi, Faculty of Textiles - Leather Engineering & Industrial Management, 67, 700050 Iasi, Romania*

[c] *Soochow University, College of Textile and Clothing Engineering, Suzhou 215031, China*

Abstract

There has been a significant increase in the number of women involved in various security duties. However, they mostly wear men's ballistic vests with smaller sizes, which bring poor ballistic protection performance, less comfort, and negative psychological effects. In recent decades, considerable efforts have also been made to improve the overall performance of ballistic protective vest for women. However, a ballistic vest that properly adjusts the chest area for different morphologies to provide a good fit, comfort, and better ballistic protection is very important and in high demand. Our current research study introduces a new 2D-3D-2D pattern re-engineering design method and automatic pattern generation on the adaptive 3D virtual mannequin to develop the first and multi-layer pattern for a seamless women ballistic vest. The method mainly eliminates the inclusion of darts to achieve the required breast volume with better fit and most importantly satisfactory ballistic protection.

Keywords: 3D design process; Pattern Generation system; Women Ballistic Vest; Ballistic protection; Fit

1   Introduction

The ballistic vest is the most important piece of protective equipment for various individuals such as police officers, bodyguards and the civilian who are exposed to fragments of materials in the working place [1]. It usually consisted of a fabric carrier with a front and a back ballistic panel made of flexible material (textile) of a very strong fibre to absorb the impact energy. To date,

*Corresponding author.
Email address: mulat_a@yahoo.com (Mulat Alubel Abtew).

many serious and potentially fatal injuries in confrontations, physical attacks, traffic accidents, and battlefield confrontation have been prevented by the wearing of body armour [2]. Nowadays, the involvement of female officers in law enforcement and similar fields is also increasing significantly worldwide [3, 4]. However, in recent decades, they have been exposed to a hostile environment due to the use of body armour designed for men. Aside from the physiological differences, women wearing body armour tailored for men have experienced problems with fit, comfort, and ballistic protection. Although significant efforts have been made to improve the performance of body armour for women in terms of ballistic protection, breathability, cost, fit and comfort for the wearer in response to customer requirements and experiences, the majority is still primarily aimed at male wearers [5]. Therefore, the well-fitting ballistic vest for women is in high demand. Currently, there are various body vest designs that are specifically used for female users after considering the differences between male and female body shapes [6, 7]. The main design techniques are still based on cut-and-sew, folding fabric and stretch-forming the traditional fabrics with their disadvantage. The cut-and-sew technique can shape the dome shape to accommodate the bust area, but damages the continuity of fibers in the fabric which in turn reduces the level of protection [8]. Fabric folding is another method of creating domes in women's ballistic vest, but it also affects comfort and mobility of the personnel, as the deformation of the body armour is strongly considered, causing the panel to be thicker near the armpit than in other areas. Even though overlapping seams are much stronger, the small ballistic projectiles can still penetrate them directly and cut the loop of threads between the seams. The design methods for female body armour are made even more difficult by the curvaceous body shape of women [2]. This indicates that still very important to design a front panel for female ballistic vests that hat considers the chest area with better impact performance, comfort, and fit for the different women morphology without the need of cutting, stitching, stretch folding or folding is very imperative. The most common method to avoid such problems of women's ballistic vest is molding. Developing the required shape of women ballistic vest by molding process not only provides reasonable comfort but also good ballistic protection [9]. Moreover, it is known that the ballistic vest for women should be molded to the required human body morphology to ensure the effectiveness of the ballistic protection. In the molding process, the textile material possesses and considered different molding properties such as surface shear angle, material thickness variation, indentation values and the corresponding mechanical damages [10, 11–13]. When designing women body armour panel using the moulding method, it is possible to create a seamless front by mimicking the chest area without the need for cut and stitch or other finishing methods. This ultimately provides better comfort, fit, and better ballistic protection than other design methods. However, improvement is still needed in both the panel design and the appropriate ballistic material with better protection and formability. Even though the structural and geometric complexity causes many difficulties in numerical modeling [14], several research shows that 3D interlock woven fabrics are promising materials to replace 2D structures in ballistic protection because they have low shear stiffness and extraordinary formability [15–18].

In the current research, the new 2D-3D-2D pattern generation methods were introduced on a 3D virtual adaptive bust mannequin with average bra size (90B) to develop the first layers and then the multi-layer patterns of women ballistic vest. This new pattern development system for ballistic vest could help to generate 2D pattern block for better fit and comfort with the projection of body contour measurement directly onto the projection grid. the projection of the body contour measurement directly to the projection grid.