Pattern engineering and functional clothing

Noopur Anand
Department of Fashion Technology (Apparel Production), National Institute of Fashion Technology, Hauz Khas, New Delhi 110 016, India

Garments conventionally address the protective, social and aesthetic needs of individuals but they can also be engineered to carry out a range of specific functions. Besides incorporating the features to meet the specific demands of a particular function, the garment must meet the basic requirements of protection and comfort. Pattern engineering for functional clothing involves applying technical, scientific and mathematical knowledge of patterns to modify and develop patterns with the objective of developing a garment which meets the function specific requirements, is comfortable to wear and contributes to maximize the efficiency and performance of the wearer. This paper explores, through examples, use of pattern engineering for functional garments to achieve these stated objectives. It establishes pattern engineering as the first step of planning a purposeful, efficient and aesthetic functional garment. It shows how the techniques of pattern engineering can be used to find solutions to challenges posed by the anthropometry of the human body and how these techniques are used to generate the blueprint of a functional garment incorporating all functional and aesthetic components.

Keywords: Darts, Ease allowance, Functional garments, Girth, Pattern engineering

1 Introduction

Pattern engineering is the technique of working with a 2D medium (i.e. paper or fabric) to develop blocks (using either body or garment measurements) which will assist in making garments to drape a 3D body to achieve the desired fit with optimum utilization of resources. The key components influencing pattern engineering are as follows:

- Body shape vs garment shape
- Garment fit
- Fabric properties
- Garment assembling techniques
- End use.

Body Shape vs Garment Shape

The shaping in human body is primarily in two main areas – the side of the body and the depth of the body. The shape on the side of the body is addressed by shaping the side seam of pattern to bring the garment closer to the body on the side (Fig. 1a). The depth of the body in front is around bust and waist and in back is around shoulder and small of back. This shaping is more pronounced in case of women body and has to be addressed by folding in the surplus fabric to shape the body contours (Fig. 1b). This folded fabric is called darts.

Garment Fit

The desired fit of a garment is defined by the function for which it is intended. The required fit can be obtained by developing a suitable basic block generated from body dimensions. Basic block (for garments made from woven fabric) could be loose fitted, semi fitted or fitted (Table 1).

Loose fitting blocks are much bigger than the body girth measurements, the extra spacing between the wearer and the clothing being the ease. Bigger the ease, looser is the garment. Essentially, loose fitting garment block is one where the garment is more than 5” bigger than the body hip and chest girth measurements. It has a boxy shape, i.e. dimensions at chest, waist and hip are equal, and therefore falls away from the body (Fig. 2a). Such blocks are used in the production of shirts, windcheater and rain coat (Fig. 2b).

Semi fitted blocks are shaped closer to the body on the side. The blocks have chest and hip girth measurement 2- 4” bigger than the body measurement while waist girth is 6-8” bigger than the actual waist measurement (Fig. 3).

Fitted blocks are required when garment is to be made fitted around the body and fullness of the garment around the body is required to be reduced such as uniforms, swimsuits or action wear, etc. In such garments, the shape of the body at the front as
well as the sides needs to be addressed in the block. The blocks therefore are shaped in the circumference as well as the depth, as shown in Fig. 4. When using woven fabric in such applications, typically the blocks have chest, waist and hip girth measurement 2-4” bigger than the body measurement.

**Table 1—Ease allowance required for varying fits in upper bodice blocks**

<table>
<thead>
<tr>
<th>Body landmark</th>
<th>Loose block</th>
<th>Semi fitted block</th>
<th>Fitted block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td>+5” and above</td>
<td>+2-4”</td>
<td>+2”</td>
</tr>
<tr>
<td>Waist</td>
<td>Not required as garment does not have waist shaping</td>
<td>+6-8”</td>
<td>+2”</td>
</tr>
<tr>
<td>Hip</td>
<td>+5” above</td>
<td>+2-4”</td>
<td>+2-4”</td>
</tr>
</tbody>
</table>

**Fig. 1**—Body shaping on (a) side, and (b) front & back (depth) of the body

**Fabric Properties**

Fabric is a key element in fulfilling the desired function for which the garment is being designed. Each fabric type has its own unique properties and characteristics; inputs regarding these are required to develop the pattern in order to achieve the desired comfort, fit and functionality. Properties of the material selected determine the dimensions of the final block as the behavior and characteristics of the fabrics.

For example, while working with knitted fabrics, a key fabric characteristic is the “stretch” which can vary from 18% to 100% or more. Also, the direction of stretch is a critical element here, wherein the fabric may have one way (cross-wise), 2 way (both length and cross-wise) or 4 way stretch (all directions). Functional garments, where such fabrics are used are action wear, exercise wear, sportswear and swimwear.

Fabric which has 18-25% stretch on cross grain behaves more or less like the woven fabric hence the ease specified for woven fabrics (Table 1) is used with them. Fabric with stretch of more than 25% and less than 50% on cross grain has moderate stretch and the requirement of ease is half of that used for woven fabric. In case these fabrics are used to make body fitted garment the patterns are developed with actual body measurements. Such fabrics are used to make tee shirts for sportswear and so on.

Fabrics with more than 50% stretch may sag on the body if the stretch is not accounted for. The ease at block girth is significantly reduced depending on the properties of the desired end product and are smaller.
than the actual body dimensions (negative ease). Such fabrics are used to make tops, shirts, dresses, skirts, pull-on pants, shorts and easy jackets with enhanced comfort properties.

Fabric which has 50% or more stretch in 2 or 4 directions is suitable for making exercise swimwear and action wear (leotards, bodysuits and maillots). The measurements are further reduced and are much smaller (negative ease) than the actual body dimensions, chest and hip being approx. 15-20% smaller and waist being 7.5-10% smaller than the actual body measurement. Table 2 shows the reduction allowances recommended as per the fabric stretch percentage. The patterns thus developed have been superimposed, as shown in Fig. 5. Reduction is also done in the length direction for bifurcated garments i.e. the crotch point, the waist / hip level and bottom hem is raised, in garments which can be pulled down using stirrups.

Table 2—Approximate girth reductions allowances (in %) for knitted fabrics having different stretch percentages

<table>
<thead>
<tr>
<th>Body landmark</th>
<th>18-25%</th>
<th>26-50%</th>
<th>51-75%</th>
<th>76-100%</th>
<th>4 way stretch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest girth</td>
<td>Ease allowances similar to allowances</td>
<td>0</td>
<td>-10</td>
<td>-15</td>
<td>-20</td>
</tr>
<tr>
<td>Waist girth</td>
<td>used for woven fabric as indicated</td>
<td>0</td>
<td>-5</td>
<td>-7.5</td>
<td>-10</td>
</tr>
<tr>
<td>Hip girth</td>
<td>in Table 1</td>
<td>0</td>
<td>-10</td>
<td>-15</td>
<td>-20</td>
</tr>
</tbody>
</table>

End Use
Comfort, coverage and protection are the key requirements from any garment. For functional garments, inputs regarding the specific intended end use are required to develop the patterns. In fact, the entire concept of engineering of standard pattern designs revolves around achieving this specific end usage and governs the pattern engineering techniques employed.

2 Manipulation of Standard Blocks for Various Applications
Manipulation of standard blocks for various applications is the first step in generating the final design of a functional garment. We discuss below the use of pattern engineering for manipulations of patterns to address the functional needs of the
garment. Examples taken for this purpose are some of the common functional garments which we encounter and/or use in our daily lives.

2.1 Work Wear — Coverall

Coverall, overall or jump suits are the terms used to refer to a loose-fitting one-piece functional garment that covers or protects the everyday work clothes of the wearer. Coveralls are designed foremost for the protection of wearer from the paint splashes, grease, welding sparks, fire, water, etc. They also require safety features to be built in to make them flame retardant/resistant, water resistant, bacteria resistant, more conspicuous, etc. These safety features are generally achieved through selection of fabric, fabric finishing and incorporation of special safety features like retro reflective tapes.

Standard pattern blocks are manipulated to accommodate these additional features to generate the final pattern for such functional garment. Pattern of this one piece garment is made by combining the semi fitted upper and lower garment block (Fig. 6 a). These blocks are generously cut to fit over clothes or made with regular fit to be worn over under garments. Pattern related parameters to be kept in mind are discussed below.

2.1.1 Ease Allowance

Since they have to be worn over the normal clothing the jumpsuit blocks have large ease built in the horizontal as well as vertical direction to create roominess. In horizontal dimensions, the chest has ease allowance of 8-10” while waist is generally shaped by use of elastic, hip has 6-8” ease allowance, and thigh has 2-3” ease. Shoulder length is increased by 1-2” and shoulder slope is reduced by ¼- ½” to accommodate clothing worn inside. In the vertical direction, armhole depth is dropped by 1-2” to provide comfort while moving arm and crotch depth is dropped by ¼ - ¾” to provide comfort while bending and also to accommodate the crotch of the garment worn underneath (Fig. 6b).

2.1.2 Bi-swing Action Back

This feature is incorporated by providing additional folded fabric on the back panel (Fig. 7b) which makes wearer comfortable and provides ease of movement while bending, stooping or in any activity which may exert extra pressure across back. Figure 7a shows the pattern modifications in the back panel to achieve the desired feature.
2.1.3 Darted Knee

This feature is incorporated by addition of 4 darts or \( \frac{1}{2} - \frac{3}{4} \)" of intake around the knee area to bring more roominess in the knee region to provide comfort while bending crawling or stooping (Fig. 8b). The pattern modification is shown in Fig. 8b to achieve the desired feature. This feature is used sparingly as with the change in height of the person the level of knee changes hence will not fit the vast height ranges of personnel. It works fine for jump suits used in profession where the body structure of individuals is more or less same, like in defense forces.

2.1.4 Adjustable Leg Hem and Cuff

Controlling the opening of hem and cuff is a requirement both for ease and safety. Adjustable leg hem and cuffs openings are provided using take-up snaps. Generally, no pattern alteration is required for it except for addition of the fabric belt with a trim like buckle, velcro or elastic to control the opening.

2.1.5 Elasticized Back

Usually coveralls are designed and produced to accommodate large number of sizes and are not custom made for individuals. Also they have to accommodate garments worn underneath. For this purpose the waist is not generally shaped in these one piece garments. The surplus fabric adjustment is done using elastics on the waist, on the back panel or on the side seam.

2.2 Sports Wear

This is one area of functional wear which in recent years has undergone a renaissance of sorts. Advances in fabric technology and innovations in design and fit have resulted in creation of sportswear that is not only lighter and comfortable but allows the person to have more freedom of movement and assist in optimizing the sporting performance levels. The key requirement for sports wear is comfort and ease of movement. To achieve this, pattern adaptations are done to incorporate features that would provide desired functionality and make them appropriate for the intended sporting activity.

One example of such a feature is sleeve modification in sports wear. The sleeve in a sports wear is a very crucial area when it comes to comfort and ease of movement. While a comfortable sleeve can increase the sports performance, a restricting sleeve can kill the game.

2.2.1 Sleeve Adaptation

Sports persons need a greater range and freedom of motion in the sleeve area. This can often be achieved by adjusting the cap height or changing the style of sleeve. These modifications are described below.

Cap Height Adjustment

The cap height of a sleeve is the difference between the top of the sleeve and the underarm level (bicep level) (Fig. 9a). Cap height of the sleeve is inversely

Fig. 8—Darted knee (a) pattern with 4 darts around the knee area, and (b) finished garment

Fig. 9—(a) Sleeve, and (b-e) relationship between the cap height lift of the sleeve and the bicep
proportional to bicep girth and lift of the sleeve i.e. reduction in cap height will increase the space on the bicep and will also improve the lift of the sleeve, making it more comfortable for sports. Figures 9 b, c & d show a comparison between the sleeve of a kurta (Indian casual wear), shirt (formal wear) and a sports T shirt (sportswear), where the cap height is reduced in that order, thereby changing the lift or comfort of the sleeve. Figure 9e shows the pattern of sleeve of kurta, shirt and tee-shirt superimposed to show the difference of cap height, lift of sleeve and its bicep.

Styling of Sleeve

Styling of sleeve can also be used to facilitate sporting activity. Raglan sleeve shown in Fig. 10a is a preferred style for sportswear. This style line combines part of body of the T shirt (shaded) with the sleeve wherein sleeve and shoulder section is cut as one piece and attached to garment with an angular seam (Figs 10 b & c). This style line does not have a shoulder seam or a full or partial armhole seam, and hence seams do not cause restriction while playing. Additionally, it fits a wider range of body types also. In the following diagram, it is illustrated as to how the part of bodice is cut and attached to sleeve to eliminate the shoulder seam and partial or full armhole seam.

2.3 Bullet Proof Jacket

The quality and precision in design, fit, silhouette, material, and construction can be critical in saving life of an individual in this specialized functional garment. A lot of pattern manipulation is required to meet the desired specifications. Bullet proof jackets are required to have enough room between the shell and lining so that the typical features like hard armor panel, soft armor panel and trauma pads can be accommodated. Apart from it the total weight of the jacket is specified and no positive tolerance is acceptable in it. Similarly, no negative tolerance is permitted in the body area covered by the panels and is to be adhered to strictly. Some of the areas to be addressed by pattern making for bullet proof jackets are discussed below.

Front block has to be made wider at the chest area to give more coverage, and protect the vital body organs. Sides can be of various designs depending upon the degree of protection required (Fig. 11a). Sides with front and back overlapping are used to give maximum protection and are used in high-risk situations. The overlap is of 2-4” so in the chest girth measurement additional allowance of 4-8” is taken for overlap. In other designs, front and back ballistic panels are only touching on the side. This actually provides best compromise between maximizing protection and concealment as we are working with exact chest girth measurement. A third style provides
for a gap between the front and back panel. This provides extra ventilation and more movement comfort. The chest measurement is made 2-4" smaller than the chest girth in this design.

2.3.1 Length Center

The overall length of the bullet proof jacket required is such that there is no ‘Ride-up’ while sitting hence the length is extended from waistline by 1–2” at the center front which is taken from the collar bone notch to the belly button, so that the jacket does not hit belt while sitting or jab in throat while bending.

2.3.2 Panel Edges

Since in the area of the panels generally there is no negative tolerance permissible and similarly no positive tolerance is allowed in the weight of garment, it is a necessity to design a panel of such dimension so as to have maximum coverage with minimum weight. A design manipulation wherein the panel is made curved helps in this case as it takes off the weight as well as the dimension. Figure 11a shows the panel being curved on the corners of the side and on the crotch.

Fig. 12—(a) Accordion pocket in bullet proof jacket, and (b) pattern of pocket and flap

2.3.3 Pockets

The functionality of the bullet proof jacket can be increased by providing multiple pockets to carry grenades, magazines and radio, as shown in Fig. 12a. The patterns are cut such as to make accordion pockets wherein the pocket edges are folded to form pleats allowing space for large items. Pattern for the accordion pocket is shown in Fig. 12b. The flaps are provided in these pockets to hold the pleated folds in place with items securely.

2.4 Clothing for Elderly

The design of clothing for the elderly requires attention to the bodily changes resulting from ageing and incorporating functional adjustment which would make garments more comfortable, easily usable, enhance safety and adapt to their limitations in movement.

Pattern engineering requirements of elderly clothing in light of the bodily changes in elderly are discussed below.

Stooping posture of their body leads to garment hanging in front and riding high from the back (Fig. 13a). To accommodate this, the center back (CB) length in the pattern is increased by 2-4”, as shown in Fig. 13b. This will give a hem parallel to the ground in a stooped figure. Loose or box silhouette can be used to conceal irregularities of waist and hip. Comfort of movement is provided by incorporating yokes, gathers and pleats. Sleeves are also made with reduced cap height to increase comfort on bicep and improve lift as discussed in sportswear. Armoires are dropped for comfort of movement, front opening can be provided for ease of dressing and pockets for carrying keys and glasses and phone can leave the hands free for better balance. Oversize buttons or zippers with big pullers provide ease of gripping and operating.

Fig. 13—(a) Impact of stoop on garment hemline, (b) back panel of regular garment, and (c) growth on center back of the garment pattern to accommodate the stoop
3 Future Trends

The growth in the global functional garment market, be it work wear, sportswear, and medical wear, has been well-documented over the past decade and it is expected to grow further in coming years. One of the driving forces behind the demand for more functional garments is the mounting focus on health, safety and recognition of the fact that innovative functions incorporated in garments cannot only provide required protection and comfort but can actually assist in enhancing the performance and productivity.

Another observable trend in functional garments is convergence of function and fashion where the demand has been increasing for the garments which besides having the required functional qualities are aesthetic and provide the wearer a stylish and professional look. The demand for function and fashion has encouraged garment makers to introduce innovative design concepts in garments, fits and use fabrics and technologies that provide performance benefits and aesthetic qualities.

References
1 Armstrong Helen Joseph, Patternmaking for Fashion Design, 4th edn (Pearson Education & Dorling Kindersley, Delhi, India), 2009.
2 Mahjabeen Ahmad, Standardization of reduction allowance for stretch fabrics, Research Project (NIFT New Delhi) 2010.
6 Trehan Noopur, Clothing for the Elderly Consumer, Masters Dissertation, SNDT University, Mumbai, 1996.