# METHOD OF GENERATION ZONING AREAS IN PATTERN CONSTRUCTION NET OF SEAMLESS UNDERWEAR

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***Abstract:*** *It is well known that in order to develop tight-fit seamless garment of satisfactory fit it is necessary to use shaping in order to achieve 3D shapes that relate to the shape of the body. This requires a sophisticated approach to create suitable pattern design. In this paper a method of generation zoning areas for 3D shaping has been designed within a 2D pattern construction net of the seamless underwear. To non-contact measure and display a three-dimensional body form the topography technique of the shadow moiré has been applied. To evaluate obtained 2D pictures of digitised zones of moiré fringe pattern the processing system NIS-Elements has been used. The size and location of the editing zoning areas has been compared with the corresponding place positions of zoning areas on the tubular knitted fabric which covers the pelvic part of the female figurine EU size 38. The geometry of the stretch pattern profile has been evaluated through understanding the dynamic effect of the fabric behaviour. Experimental results verify the effectiveness of the moiré topography to determine geometry of a 3D human body surface to achieve information of zoning areas for 3D design of seamless stretch underwear. Measured size and location of the zoning areas have been used as a pattern parameter for generation a 2D construction net of a seamless girdle.*

***Keywords:*** *Seamless underwear, constructional net, non-contact body measurement, moiré, zoning area.*

## 1 INTRODUCTION

Currently there is a number of specialists knitted garment producers who are using type of seamless circular garments to create highly technical garments, using specific knit structures to map the body surface for comfort. These are mainly types of sportswear, therapy garments and others. In terms of fit, there is evidence to suggest that, although knitwear is stretchy and therefore there is an assumption it will fit a wide variety of body shapes and sizes; there is still need for fit improvements. Thus body mapping can be described as comfort mapping. The specific areas of the garment must map to specific areas of the body. It must be presumed that production technology development should include a sophisticated understanding not just of the functions of the body but also of body size, shape and proportion.

To create knitted garments that fit the body of 3D shape, it is important to have a suitable method of applying body measurement within product development processes. That can be one of non-contact contour mapping technics [1].

Research that is described in this paper has being focused on the development of pattern making method that is associated with seamless garments made by knit technology with the help of circular machinery.

## 2 EXPERIMENTAL

Experimental steps are concerned with the discovering the suitable way how to measure zoning areas of the female body surface geometry of the pelvic part and with the way how to determinate zoning areas within pattern construction net of seamless underwear.

### *2.1 Materials and methods*

To target experimental strategy and define a female somatotype, the figurine AlvaForm (Figure 1) made from soft memory foam which simulates a soft human tissue, has been chosen. This AlvaForm of the European size code 38, which is in the half scale form (WAIST = 36 cm, HIP = 49 cm), is accurately shaped and proportioned physical characteristics derived from relevant consumer data based on Europe female population analysis.

For capturing 3D form of body and to found out input pattern construction parameters and position of zoning areas in a tubular knit structure of seamless product, the effective non-contact topography technique of a shadow moiré has been applied. This is a well-known technique commonly used in analysis of spiral deformities in human body. For clothing application of "Moiré" technique were found in the area of pattern construction of clothing [1]. This is the contour mapping technique, which has been involved positioning a grating close to the surface of figurine and observed its shadow on the figurine through the grating [1, 4].

To measure the size and place position of zoning areas on obtained 2D pictures of digitised moiré fringe pattern the image processing system NIS-Elements AR 40.00.8 has been used.

**Figure 1** Figurine AlvaForm EU size code 38 (front, back and side view)

With regards of the research goal of this paper, to find out method for a design of a suitable seamless underwear shape including specific areas that must map specific areas of the body, a representative type of intimate apparel and an open bottom girdle has been selected. Thus it is necessary to create a suitable construction net. Its parameters should be determined as a dependent variable by computation using the regression equation and corresponding body measurement as an independently variable [5].

The quality of body contouring fit is inextricably linked with the stretch potential of fabric characteristics. Understanding the stretch behavior, visually and mechanically, is an essential part of predicting the pattern profile geometry and the optimum orientation of the pattern placement on the fabric to improve the fit-quality. This is achieved in part by maintaining the stretch extension of fabric within the lower modulus working range. The pattern orientation will affect the garment fit if the stretch fabric extension in the course and wale directions is different [1]. For this research a pattern profile is designed for (course) orientation on the fabric. Pattern grain line is situated in the vertical (wale) orientation.

The starting point of a research of a tight-fit garment pattern development is to use a law whereby the fabric tension, the radius of the part of the body being covered, determine garment pressure. Therefore a fabric circumference is of a smaller size than the body circumference. The suggested reduction of knitted fabric circumferences by 20-30% seams to by typical.

For this experiment the interlock knitted fabric (54% PA/46% EL, 319 g/m$^2$) of a tubular form is been used with the pattern dimensions reduction in weft direction by 26.5% [3].

## 3 RESULTS AND DISCUSSION

### *3.1 Non-contact body measuring method of the shadow moiré*

Extensive pre-tests concerning to find out appropriate method to give high quality records of body morphology and also reliable cross-sectional measurements were carried out. The technique of a shadow moiré has been applied, which enable to map a human body and create picture with a topography effect. The experimental maps of the scanned figurine are given in Figure 2. Those moiré maps were the foundations for creating zoning areas in pattern constructional net of seamless circular garment.

For the non-contact shape measurement of the figurine the developed moiré topographic system (Figure 3) was placed close to the grid, enabling a sharp image of the moiré fringes to the be obtained (Figure 2). For capturing the size of a pelvic part of the figurine, a vertical wooden frame 0.594 m (*L*) x 0.420 m (*W*), was designed to mount the plane of grid lines in an exact parallel manner.

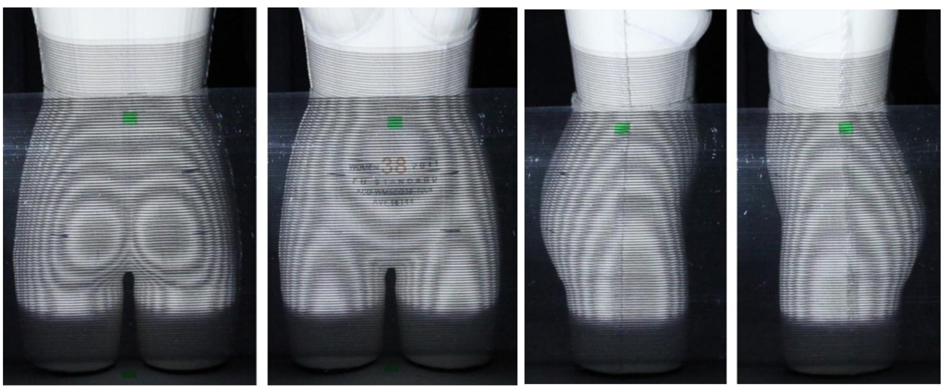

**Figure 2** Moiré image of AlvaForm (back, front, right and left side view) [3]

The plane of the grid lines (1 mm line thickness and pitch size 2 mm) was translated in its own plane in a vertical position. The distance between the figurine surface and the grid (Figure 3) at a given position $h$ = 0.08 m; the distance between the grid and light source $l$ = 1.8 m; d = 0.5 m represents the distance between the light source and camera.

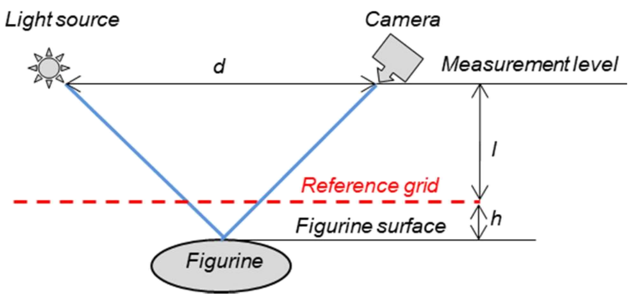


**Figure 3** Schematic setup of the moiré system

### *3.2 Image processing of moiré fringe patterns*

The contour map of the moiré fringes generates the required shape information across the pelvic part of the figurine body. A visual interpretation of the fringe pattern is a good means for assessing the shape conformity of three-dimensional seamless underwear (Figure 4).

For the objective measurement of a picture of the pelvic part of the figurine, a digital analysis of different sections of the back, front and side view was performed. The fringe pattern was then measured using tools of NIS-Elements system and a size of topography zones were determined. The shape and size characteristics of fringe zones were derived in the horizontal, vertical and bias direction. The profile of the zones was measured by evaluation of an intensity line profile distribution in Figure 4.

### *3.3 Evaluation of zoning areas position on the tubular knitted fabric*

To evaluate the results of capturing 3D form of body mentioned in paragraph above the size and location of the editing zoning areas has being compared with the corresponding place positions of zoning areas on the tubular knitted fabric which covers the pelvic part of the female figurine.

The static width dimension of the tubular has been set according the WAIST = 36 cm. For static length dimensions of the tubular: UPPER HIP DEPTH = 5 cm (from waist to upper hip level); HIP DEPTH = 10 cm (from waist to hip); BODY RISE = 15 cm (from waist to hem edge). The elements of the size 10x10 mm have been marked on the tubular knit (Figure 5). Then a stretch behaviour of the knit has been tested dressed on a dummy. The dynamic dimensions have been evaluated.

The geometry of the stretch pattern profile has been evaluated through understanding the dynamic form of these elements. Dynamic effect "Δ" of the element dimensions was evaluated in horizontal (course) position. A digital calliper was used. The Table 1 lists "Δ" value of dynamic effect of the elements of the centre back part of the figurine.

These presented experimental results, highlighted in Table 1, show the similarity of the individual zoning area shape with the comparison with the digitised moiré fringe pattern in Figure 4. The same differences we can see in the intensity line profile of moiré map Figure 2.

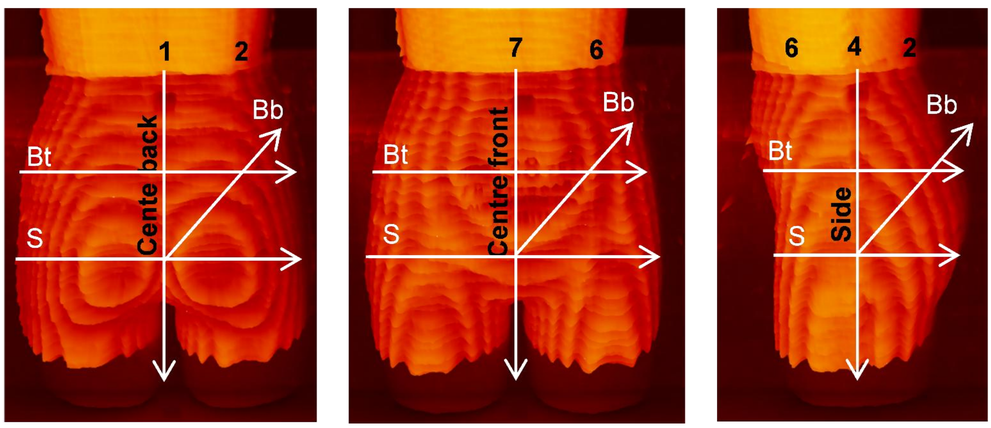


**Figure 4** Intensity line profil distribution (back, front and side view)

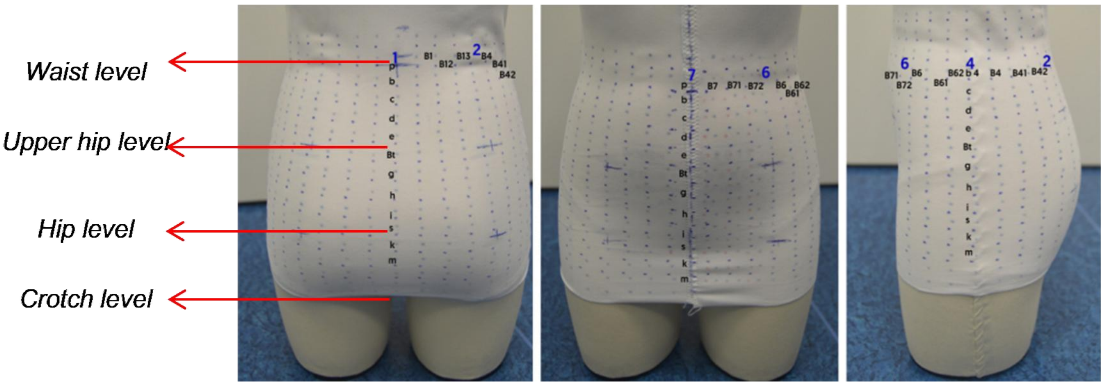


**Figure 5** Measured elements on tubular knitted fabric (back, front and side part) [3]

**Table 1** Dynamic effect of the measured elements

| Element | Dynamic effect Δ [mm] | | | | |
|---|---|---|---|---|---|
| | 1 | B1 | B12 | B13 | 2 |
| **P** (Waist level) | Δ1p = 1.00 | ΔB1p = 0.60 | ΔB12p = 0.68 | ΔB13p = 0.80 | Δ2p = 0.80 |
| b | Δ1b = 1.00 | ΔB1b = 1.00 | ΔB12b = 0.88 | ΔB13b = 0.82 | Δ2b = 0.89 |
| c | Δ1c = 1.78 | ΔB1c = 1.60 | ΔB12c = 1.26 | ΔB13c = 1.03 | Δ2c = 1.15 |
| d | Δ1d = 1.97 | ΔB1d = 2.05 | ΔB12d = 1.82 | ΔB13d = 1.72 | Δ2d = 1.98 |
| e | Δ1e = 2.52 | ΔB1e = 2.62 | ΔB12e = 2.18 | ΔB13e = 2.22 | Δ2e = 2.42 |
| **Bt** (Top hip level | Δ1Bt = 3.09 | ΔB1Bt = 3.16 | ΔB12Bt = 3.22 | ΔB13Bt = 3.62 | Δ2Bt = 4.24 |
| g | Δ1g = 3.16 | ΔB1g = 3.39 | ΔB12g = 3.28 | ΔB13g = 3.53 | Δ2g = 4.12 |
| h | Δ1h = 3.15 | ΔB1h = 3.45 | ΔB12h = 3.37 | ΔB13h = 3.53 | Δ2h = 4.47 |
| i | Δ1i = 3.86 | ΔB1i = 4.15 | ΔB12i = 3.38 | ΔB13i = 3.53 | Δ2i = 4.27 |
| **S** (Hip level) | Δ1s = 3.59 | ΔB1s = 3.89 | ΔB12s = 3.58 | ΔB13s = 4.44 | Δ2s = 3.98 |
| k | Δ1k = 3.59 | ΔB1k = 3.89 | ΔB12k = 3.58 | ΔB13k = 4.30 | Δ2k = 3.90 |
| l | Δ1l = 3.59 | ΔB1l = 3.89 | ΔB12l = 3.58 | ΔB13l = 4.30 | Δ2l = 3.90 |
| m | Δ1m = 3.59 | ΔB1m = 3.89 | ΔB12m = 3.58 | ΔB13m = 4.30 | ΔB1m = 3.89 |

### *3.4 Seamless girdle construction net development*

A close fitting girdle pattern block is constructed to be smaller than the body measurements and to stretch to the body shape. Some adjustments to the horizontal measurements may have made. This should be related to the stretch and relaxation of different fabrics. For this research is used 26.5% hip circumference reduction, which is static width dimension of the tubular knit width.

Experimental results are processed into the construction algorithm for a girdle pattern net design (Figure 6). Individual construction steps are listed in the Table 2.

The zoning areas in frame of the pattern constructional net are shown in the (Figure 6). The shape characteristics (in horizontal, vertical and bias direction) are match using the experimental results of image analyses of pelvic part of figurine in Figure 3.

**Table 2** Construction algorithm of seamless girdle pattern net

| Step | Definition | | Dimension (Formula) |
|---|---|---|---|
| | ***Horizontal lines drafting*** | | |
| 1. | Centre back line | 1 | |
| 2. | Waist line (**w**) | 1 ⊥ w ⇒ P1 | |
| 3. | Hip line (**h**) | 1 ⊥ h ⇒ S1 | P1S1= 0.125 HEIGHT |
| 4. | Upper hip line (**th**) | 1 ⊥ th ⇒ Bt1 | UPPER HIP DEPTH (0.5 P1S1) |
| 5. | Hem line (**cr**) | 1 ⊥ cr ⇒ R1 | P1R1= BODY RISE |
| | ***Vertical lines drafting*** | | |
| 6. | Construction net width | Tubular width | P1P7=(0.5 WAIST) P1P7=0.5 (73.5% HIP) |
| 7. | Centre front line | 7 ⊥ w, th, h, cr ⇒ P7, Bt7, S7, R7 | |
| 8. | Side line | 4 ⊥ w ⇒ P4, Bt4, S4, R4 | P1P4=P4 P7 = 0.5 P1P7 |
| 9. | Back longitudinal line | 2 ⊥ w ⇒ P2, Bt2, S2, R2 | 0.5 P1P4 |
| 10 | Front longitudinal line | 6 ⊥ w ⇒ P6, Bt6, S6, R6 | 0.5 P4P7 |

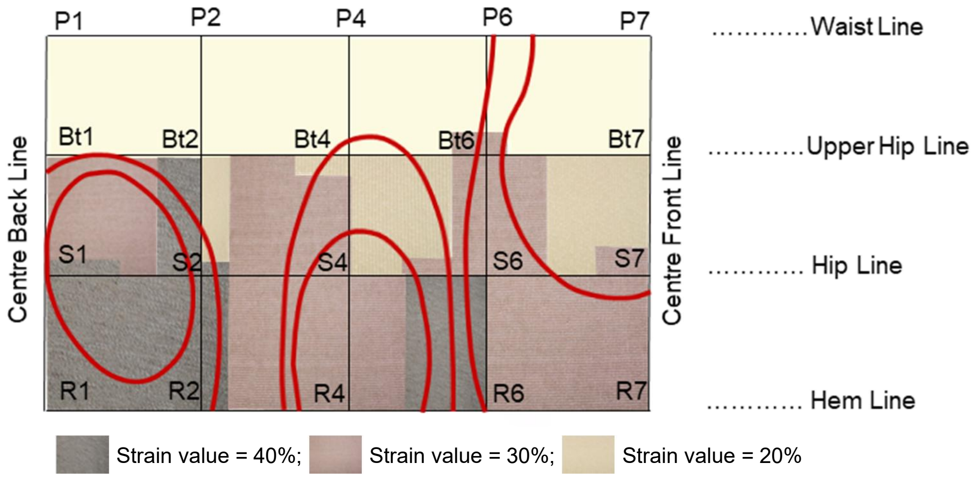


**Figure 6** Seamless girdle construction net with zoning areas

## 4 CONCLUSIONS

Machinery that has the ability to construct garments three dimensionally, such as seamless garment, implies the possibility of creating a product that can conform to the three dimensional shape of the body. Shaping the garment is limited by the number of needles available on which to knit. The zoning areas to map the 3D body shape must commence knitting on specific needles with an exact number of available needles within each zone and between them. There are difficulties associated with knitting tubular stretch garments and its pattern construction definition of a specific zoning area shape. Therefore this presented research is concerned with the development of a construction method for tight-fit seamless garment design that covers a pelvic part of human body.

Extensive experimental pre-tests concerning to find out appropriate method to give high quality records of body morphology, and also reliable cross-sectional measurements were carried out. For experiment of this paper the technique of a shadow moiré has been applied, which is able to map a human body and create picture with a topography effect. The moiré maps were the foundations for creating zoning areas in girdle pattern constructional net of seamless circular garment. Experimental results verify the effectiveness of the moiré topography to determine geometry of a 3D human body surface to achieve information of zoning area size and shape and their location within seamless construction net.

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