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Design Seamless Woven Garments with Precise Fit to Bodyline for Women's Wear

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ABSRACT

This paper is the third of a series of publications that deal with the development of seamless woven garments with desired shapes and sizes by producing woven tubular fabrics with differential shrinkage along the garment length. The first paper [1] focus was to produce the shape using filling yarns containing spandex at strategic places along the garment. The differential shrinkage between the regions with filling yarns containing spandex and those do not contain spandex allowed the development of garments with target shape and size. Six garments were produced using this concept with one warp (one on-loom fabric width). In the second paper [2], we demonstrated how to develop seamless garments with desired shape and size using the data of wide range of fabrics produced with different construction parameters and hence finished fabric shrinkage using one on-loom width. The seamless garments demonstrated in the first two papers exhibited intentional gathering and pleating due to high differential shrinkage between different parts of the garment. While the gathering and pleating provide intricacy to the garments, there is demand for garments without gathering. This paper addresses design and development of seamless woven garments with different shapes and sizes without darts, pleats or gathers to fit the bodyline using data obtained from 83 pre-produced tubular woven fabrics with different construction parameters that influence finished width shrinkage. The 83 tubular woven fabrics were intentionally structured to provide extremely wide range of shrinkage range (6.7%–48.7%). This allowed the creation of garments with required shape using different fabrics with gradual differential shrinkage along garment length. Six seamless garments with desired shape and sizes (Small, Medium, Large, and X Large) were designed using this technique.

Keywords: Seamless garment, Tubular woven fabric, Differential shrinkage, Apparel, Woven Fabric construction parameters

1. Introduction

Despite the advances in CAD systems, mass customization, automatic transport of garment pieces from process to process of cut and saw assembly line, the conversion of two-dimensional fabric to three-dimensional garment still requires too many steps and manual processes, which requires intensive labor and consequently high cost. Research in knitting led to the development of integral knitting technologies to produce seamless knitted garments with required shapes and sizes. The research in shaped seamless woven garment is limited and not yet commercialized. Due to the dimension stability, excellent drape, and the ability of making intricate woven designs, the demand for garments from woven fabrics exceeds the demand for knitted garments. This presents opportunities for woven fabric/garment developers to conduct work that led to produce shaped seamless woven garments without the need for cut and saw. The weaving technologies have advanced to the levels that will support the development in this area that will lead to the commercialization of seamless woven garments [3]. Examples of advances in weaving supporting the commercialization of seamless shaped woven garments include variable pick density, automatic weave/pattern change, and automatic filling selection that can be pre-programmed. However, before commercialization is possible research and development are needed. This paper addresses such needs.

The technology of seamless garments can minimize the production cost by eliminating production steps such as fabric laying, cutting, sewing processes and also the time consumed to produce a whole garment [4, 5]. Seamless woven fabrics were produced by weaving tubular double cloth and utilizing different construction parameters that influence fabric shrinkage. Most of these trials were used in medical applications [6, 7] while other trials dealt with development of seamless shaped garments using broad weaving machines [1, 2, 8-10]. While the previous work is important in terms of basic research, the work was limited to a few cases and did not establish methodology to broaden the application to pave the road for commercialization.

The main goal of this research was to design seamless shaped garments with different sizes using established relationships derived from broad woven fabrics with different construction parameters that influence their finished shrinkage, which decide the dimension at different parts of the garment along its length. To reach this goal, 83 fabrics with different construction parameters that are known to affect fabric finished shrinkage were produced [1, 2]. While these do not cover the entire demand of garment sizes since they were woven using one on-loom fabric width, the data generated from them can be expanded to determine the on-loom width to produce other range of garment sizes with desired shapes, which is demonstrated in this paper.

2. Design of Experiment

In all, 83 fabrics with a range of construction parameters that influence finished fabric shrinkage were produced by weaving tubular double cloth. This type of fabric has two layers, a top layer and a bottom layer. In this technique, the weft yarn loops circumferentially from the top layer to the bottom layer forming a seamless tube [11], which requires shuttle weaving machines, of which is the one that is used to produce the tubular fabrics in this research. The fabrics were washed and dried while in relaxed state (without tension application), and then were heat set to stabilize the dimensions.

Combinations of various construction parameters were used to produce the fabrics that includes weave structures (Plain 1/1, Basket 2/2, Twill 1/3, Twill 2/2 and Sateen 4), pick density (18, 20 and 22 picks/cm), weft yarn tension (low, medium and high) and weft yarn cotton count (20/1, 30/1, 40/1 and 16/1) with different weft yarn materials. Figure 1 shows the weave structures of the double cloth fabrics. The variables and their ranges were decided to obtain a broad range of finished fabrics shrinkages in order to produce seamless garments with inherent shapes and sizes. The 83 fabrics produced are shown in Tables 1.a and 1.b, which presents the variables along with their levels. One warp was used to produce all the 83 fabrics. The warp yarn cotton count was 25%/75% Cotton/Polyester of 40/2 cotton count.

Table 1.a. Fabrics specifications with different construction parameters using non elastic filling yarns

Weft Yarn Cotton Count and Fiber Content	Weft Setting	Weave Structures	Flat Fabric Width After Finishing (cm)	Fabric ID
40/2 25%–75 % Cotton/Polyester	20 Picks/cm Medium Tension	Plain 1/1	58.5	**1**
		Basket 2/2	57.5	**2**
		Twill 1/3	56.7	**3**
		Twill 2/2	56.5	**4**
		Sateen 4	56.4	**5**
40/2 100% Cotton	18 Picks/cm Medium Tension	Plain 1/1	62	**6**
		Basket 2/2	61	**7**
		Twill 1/3	59.3	**8**
		Twill 2/2	59.8	**9**
		Sateen 4	59	**10**
20/1 100% Cotton	18 Picks/cm Medium Tension	Plain 1/1	62.5	**11**
		Basket 2/2	61.5	**12**
		Twill 1/3	59.5	**13**
		Twill 2/2	60	**14**
		Sateen 4	59	**15**
	20 Picks/cm Medium Tension	Plain 1/1	62.5	**16**
		Basket 2/2	61	**17**
		Twill 1/3	59.8	**18**
		Twill 2/2	60	**19**
		Sateen 4	58	**20**
	22 Picks/cm Medium Tension	Plain 1/1	62	**21**
		Basket 2/2	60.5	**22**
		Twill 1/3	59.4	**23**
		Twill 2/2	59	**24**
		Sateen 4	58	**25**
30/1 100% Cotton	18 Picks/cm Medium Tension	Plain 1/1	61.2	**26**
		Basket 2/2	61.3	**27**
		Twill 1/3	59.5	**28**
		Twill 2/2	60	**29**
		Sateen 4	59	**30**
	20 Picks/cm Medium Tension	Plain 1/1	61	**31**
		Basket 2/2	60.5	**32**
		Twill 1/3	59	**33**
		Twill 2/2	59.3	**34**
		Sateen 4	59	**35**
	22 Picks/cm Medium Tension	Plain 1/1	60.6	**36**
		Basket 2/2	60.5	**37**
		Twill 1/3	58.7	**38**
		Twill 2/2	58.7	**39**
		Sateen 4	58.5	**40**
40/1 100% Cotton	18 Picks/cm	Plain 1/1	62	**41**
		Basket 2/2	59	**42**

	Medium Tension	Twill 1/3	59	**43**
		Twill 2/2	60.7	**44**
	20 Picks/cm Medium Tension	Plain 1/1	61.3	**45**
		Basket 2/2	60.5	**46**
		Twill 1/3	59	**47**
		Twill 2/2	59.5	**48**
		Sateen 4	59	**49**
	22 Picks/cm Medium Tension	Plain 1/1	60.5	**50**
		Basket 2/2	60.5	**51**
		Twill 1/3	59	**52**
		Twill 2/2	59.3	**53**
		Sateen 4	58	**54**
16/1 50%/50% Cotton/Polyester	18 Picks/cm Low Tension	Plain 1/1	62.2	**55**
	20 Picks/cm Medium Tension		61.6	**56**
	22 Picks/cm High Tension		61.5	**57**

Table 1.b. Fabrics specifications with different construction parameters using filling yarns containing spandex

Weft Yarn Cotton Count and Fiber Content	**Weft Setting**	**Weave Structures**	**Flat Fabric Width After Finishing (cm)**	**Fabric ID**
15/1 94.7%/5.3% Cotton/Spandex	18 Picks/cm High Tension	Plain 1/1	49.5	**58**
		Twill 1/3	35.7	**59**
		Sateen 4	35.5	**60**
	20 Picks/cm High Tension	Plain 1/1	51	**61**
		Twill 1/3	39	**62**
		Sateen 4	39	**63**
	20 Picks/cm Low Tension	Plain 1/1	52	**64**
		Twill 1/3	38	**65**
		Sateen 4	40.5	**66**
20/2 93.3%/6.7 % Cotton/Spandex	20 Picks/cm Medium Tension	Plain 1/1	51.3	**67**
		Basket 2/2	38	**68**
		Twill 1/3	37	**69**
		Twill 2/2	37.4	**70**
		Sateen 4	37	**71**
	22 Picks/cm High Tension	Plain 1/1	49.7	**72**
		Twill 1/3	37	**73**
		Sateen 4	38	**74**
	22 Picks/cm Medium Tension	Plain 1/1	50	**75**
		Twill 1/3	39.5	**76**
		Sateen 4	37.5	**77**
26/1	20 Picks/cm High Tension	Plain 1/1	49.2	**78**
		Twill 1/3	37.5	**79**

96.9%/3.1 % Cotton/Spandex		Sateen 4	34.4	**80**
	18 Picks/cm Medium Tension	Twill 1/3	36	**81**
	20 Picks/cm Medium Tension		37.5	**82**
	22 Picks/cm Medium Tension		38.5	**83**

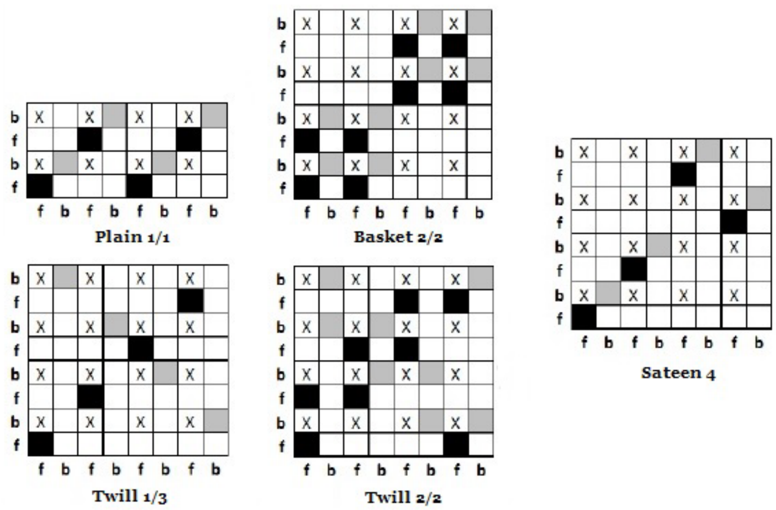


Figure 1. Double cloth weave designs

3. Fabric Formation

A shuttle weaving machine (TSUDAKOMA "LK") was used to produce the 83 double cloth tubular fabrics. The warp specifications were:

- Warp Yarn: 25%/75% Cotton/Polyester of 40/2 cotton count
- Total Warp Yarns: 4288
- Warp Density: 64 ends/cm
- Warp Width in Reed: 67 cm
- Number of Harnesses: 8
- Draw (Draft): straight
- Shedding Motion: mechanical dobby system

The tubular woven fabric is one of the unstitched double cloth techniques and has to be woven using shuttle weaving technology. Two distinct warp yarn sets, and two weft yarn sets are interlaced to form two separate fabrics termed face and back, making a two-ply fabric, upper layer and lower layer. The upper layer is formed by interlacing the face warp yarns with the face weft yarns, and the lower layer by interlacing the back warp yarns with the back weft yarns. The two layers are connected from both sides as a result of using a continuous weft yarn, which is fed from the quill carried by the shuttle, for both of the upper and lower layers of the fabric. It is worth mentioning here that shuttleless weaving could be also used to produce double cloth. In such case, the edges of the fabric will have fringed selvage, and the fabric must be turned inside out to hide the selvages. A garment produced from such fabric will look like it has seams on the side similar to sewing seams.

4. Finishing

All produced fabrics were submerged in a 90° C water bath containing a surfactant with enzymes for 30 minutes. During the 30 minutes the fabrics were agitated by manual stirring. Fabrics were turned inside out, and the process was repeated. Fabrics were then dried at 90° C for 30 minutes. Finally, all fabrics were heat set at 170° C for 30 minutes without applying tension.

5. Methodology of Expanding Garment Sizes

Fabrics using different structure parameters in this study are arranged in an ascending order in terms of the finished width. Figure 2 shows a ranking chart of the finished width of the 83 fabrics. The chart can be used to design a garment with desired shape and size using selected fabrics with known finished width (which decide the dimension at different parts of the garment along its length) and on-loom fabric width. While the 83 fabrics produced in this study provide opportunity to produce numerous garment sizes, they do not cover the entire demand of garment sizes. However, the data generated from this study can be used to determine the on-loom width to produce other range of garment sizes.

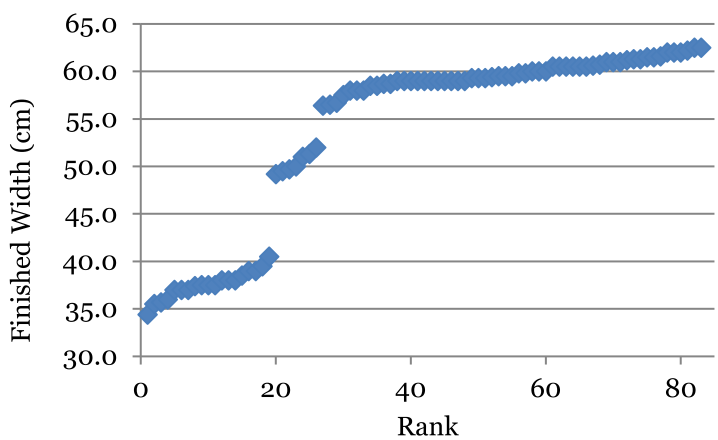


Figure 2. Fabrics ranking versus finished width (cm)

For example, the on-loom fabric width used to produce the 83 fabrics in this study is 67 cm. Fabric 11 (Table 1) has the largest finished width of 62.5 cm which is about 6.7% shrinkage. If a different finished fabric dimension is needed, the corresponding on-loom fabric width can be easily calculated, provided that the same construction parameters are used, from:

$$W_{olt} = \frac{W_{olr} \times W_{ft}}{W_{fr}}$$

Where;

W_{olt}: On-loom width of target fabric
W_{olr}: On-loom width of reference fabric
W_{ft}: Finished width of target fabric
W_{fr}: Finished width of reference fabric

Assume the target finished fabric width is 50 cm, and then the corresponding on-loom fabric width can be calculated from the above equation as:

$$W_{olt} = \frac{67*50}{62.5} = 53.6$$

To produce a fabric with a finished width of 50 cm, it is required to prepare a warp with the same specifications mentioned in section 4 above except the on-loom fabric width of 53.6 cm. This would provide 83 fabrics with different finished widths and hence allow the design and manufacture of garments with smaller sizes than the original 83 reference fabrics.

To demonstrate the methodology, six ladies' outer garments were designed by combining several fabrics of different finished widths for each garment to obtain a gradual change in width to realize desired shaping to bodyline of wearers. Garments were designed to match the bodyline without any additional sewing steps such as darts, gathers or pleats to fit the body size. The six designs were made to fit four different sizes (S, M, L and XL). The combinations of fabrics used for each design have different widths which are calculated using the above equation to deduce the widths of the target fabrics and the associated on-loom fabric width. The target fabrics widths were specified from the table of measurements of the standard women's body of W. Aldrich [12] for women of medium height, 160 – 172 cm. These measurements are compliant with the body measurement size chart given in the standard BS EN 13402-3, as shown in Table 2.

Garments designs contain pattern ease beyond the actual measurements to allow an adequate room for wearers. The measurements of each garment equal the measurement of a wearer's body plus the fitting ease [13]. All designs are made to closely fit the body, so there is a need to use closures to help wearing such garments. It was found that there are endless design possibilities with seamless shaping technology, with the variety of construction parameters that can be achieved within a single garment.

The six designs depend mainly on three basic measurements; bust, waist and hips, as shown in Figure 3. The distances between these measurements were divided into different parts according to the difference in sizes, each part represented by one fabric with definite width. To clarify the idea, for example, the distance between waistline and hips line for large size is 21.5 cm, and the difference between waist measurement and hips measurement for the same size (after adding 4 cm as pattern ease) is 24 cm. The 24 cm may be divided into 6 parts along the distance of 21.5 cm, each part can be chosen from the range of fabrics of different finished widths. The gradual change in size is obtained through the splitting of this difference in ascending order. The width sizes of the 6 fabrics along this distance should be as follows (from waist to hips); 92, 96, 100, 104, 108 and 112 cm. It was found that there are many design possibilities to obtain women's garment models by weaving seamless shaped fabrics.

Table 2. Women's Sizing according to the standard BS EN 13402-3

Women of medium height, 160 – 172 cm							
	S	**M**		**L**		**XL**	
Size code	**10**	**12**	**14**	**16**	**18**	**20**	**22**
Bust	84	88	92	96	100	104	110
Waist	68	72	76	80	84	88	94
Low Waist	78	82	86	90	94	98	104
Hips	92	96	100	104	108	112	117
Front Shoulder to Waist	40.6	41	41.4	42.3	43.2	44.1	45
Waist to Knee	58	58.5	59	59.5	60	60.5	61
Waist to Hip	20.3	20.6	20.9	21.2	21.5	21.8	22.1

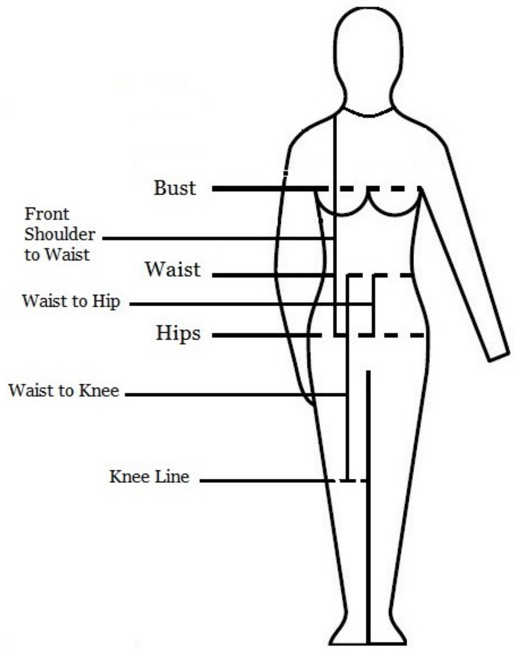


Figure 3. The standard body measurements chart

Tables 3-8 show the six garment designs. Each table shows the reference fabrics (actually woven) with on-loom width of 67 cm and the corresponding target on-loom width and associated target finished widths of the fabrics required to produce the garment. The chart of Rank-Finished Width for each of the designs is the reference fabric data with lines pointing at each reference fabric for a particular portion of the design. It should be pointed out that the target data of the design are shown in the tables.

Table 3 shows design 1 of a skirt sketch made up of a combination of different fabrics (ID 75, 64, 5, 320, 23, 41, 19, and 20) with different widths along the design to fit size X Large. Area A resembles the waist area of 98 cm (94 cm + 4 cm ease), while area F of 121 cm (117 cm + 4 cm ease) resembles the hips area. The skirt becomes narrower at the hem line. The distance between A and F is divided into 4 zones, the width difference between waist measurement and hips measurements is divided into these zones in ascending order. Area, I resembles the hem opening, the distance between area F and I is the difference between hips and hem opening measurements. Table 3 illustrates how the fabric width is distributed gradually along the skirt according to the target width after finishing. The widths were calculated for each area of the design using the above equation.

Table 4 illustrates design 2 of a dress sketch designed to fit a medium size. Areas A, E, and J are the measurement of bust, waist and hips (92+4 cm, 76+4 cm, and 100+4 cm, respectively). As it can be seen from the garment construction in Table 4, the remainder of the areas are selected from fabrics with widths to shape the garment in a gradual fashion to fit the bodyline.

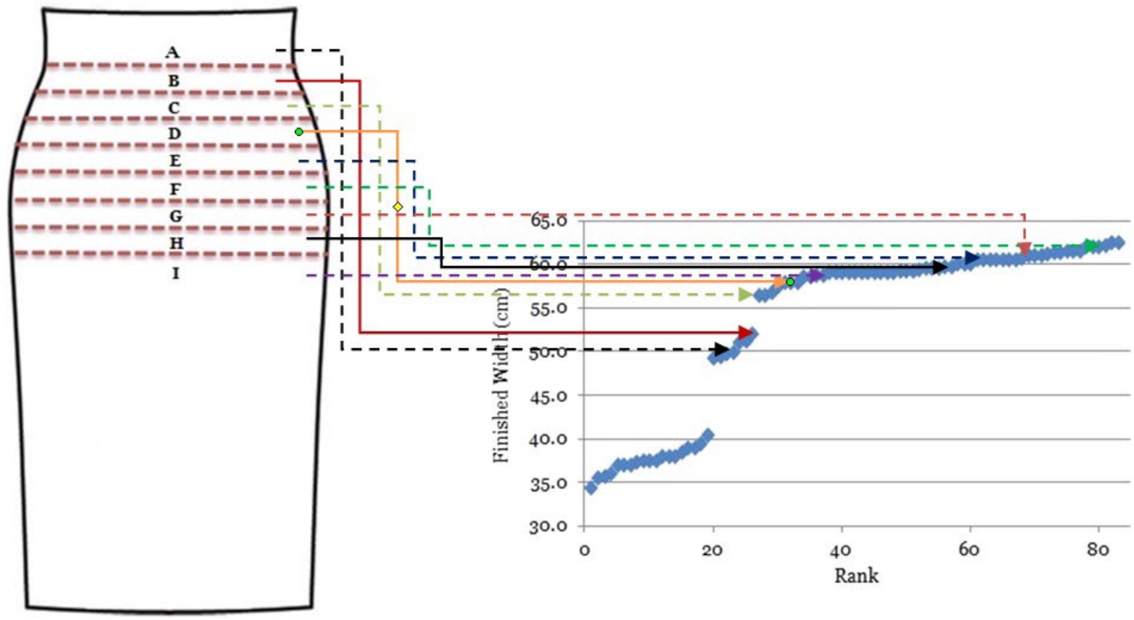
Table 5 shows design 3 of a low waist skirt design that requires two measurements (two fabrics with two different construction parameters) with dimensions shown in Table 5. This skirt was designed to fit small sizes. Zone A represents the low waistline (10 cm below the waistline), and zone G represents the hip line. The finished width of target fabric for zone A is from fabric containing spandex, with 62 cm that will expand during wear to fit the low waistline without the need for closures. The distance between zone A and G is divided into 5 zones. The difference between low waist measurement and hips measurement plus 4 cm as pattern ease is distributed along these zones to achieve a gradual change in size to fit the bodyline without any need to use darts.

Table 6 illustrates design 4 of a skirt design sketch to fit large size. Zone A represents the bust area, zone D represents the waist area and zone H represents the hips area. The difference between bust and waist measurements (plus 4 cm as a pattern ease) is divided into two zones and distributed gradually in a descending order. The distance between zone D and H resembles the difference between waist and hips measurements plus 4 cm as pattern ease, which is gradually distributed in an ascending order to shape the bodyline.

A knee-length dress (design 5) is shown in Table 7. Here, three fabrics with different construction parameters are utilized to construct the design. The dress was made to fit X large size. Zone A resembles the bust measurement (108=104+4 cm), zone G resembles waist measurement, zone L resembles hips measurement and zone N resembles the hem opening measurement. This dress has a fitted bodyline and a wide hem opening. The fabric for zone G is from weft yarn containing spandex and expands to fit the waistline of the target X Large size. The distance between A and G zones represents the difference between bust and waist measurements (plus 4 cm of pattern ease) which divided into 5 zones and arranged gradually in a descending order to fit the upper part of the body. The distance between G and L zones represents the difference between waist and hips measurements (plus 4 cm of pattern ease) divided into 4 zones and arranged gradually in an ascending order to fit the lower part of the body. To get the flares at the hem line of the dress as illustrated in the design sketch, the hem line was designed wider. Zone N, which resembles the hem line, was designed with width of 120 cm circumference.

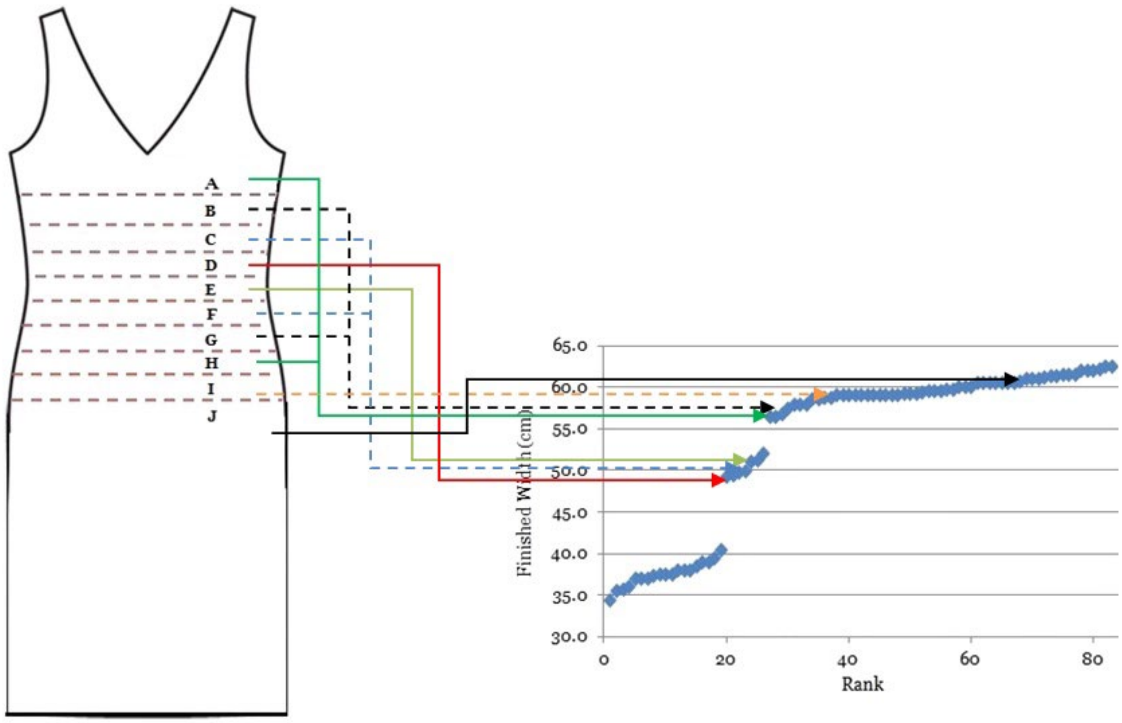
Table 8 shows design 6 that is made up of a combination of fabrics (ID: 67, 66, 75, 64, 4, 2 and 18) constructions. This design represents a long sleeveless dress made to fit medium size. Zone A represents the bust area, zone C represents the waist area and zone H represents the hip area. The distances between adjacent measurements were divided into different zones and the target fabrics widths were arranged gradually to fit the bodyline. This dress is straightly extending with the same width of the hip's measurement. Using fabrics containing spandex in both bust and waist areas to ensure fitting the bodyline by stretching/expanding while wearing the garment without any need to use darts.

Table 3. Design 1 construction parameters for X Large size



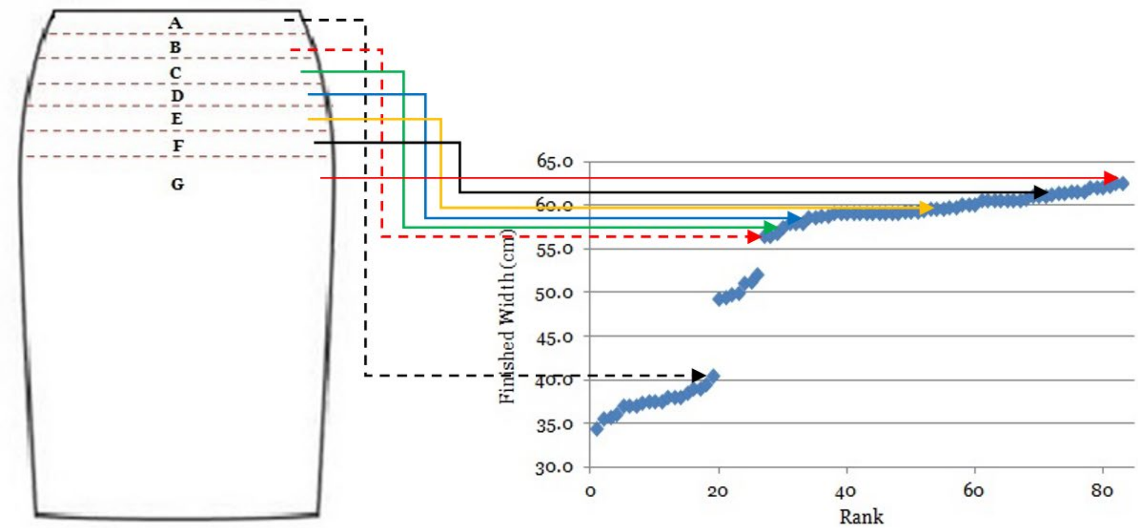
Zone	Reference Fabric			Target Fabric		Size code
	ID	On loom width (cm)	Finished width (cm)	On loom width (cm)	Finished width (cm)	
A	75	67	50.0	65.3	98 (49 x 2)	X Large (22)
B	64		52.0		102 (51 x 2)	
C	5		56.4		110 (55 x 2)	
D	20		58.0		113 (56.5 x 2)	
E	32		60.5		118 (59 x 2)	
F	41		62.0		121 (60.5 x 2)	
G	17		61.0		119 (59.5 x 2)	
H	19		60.0		117 (58.5 x 2)	
I	10		59.0		115 (57.5 x 2)	

Table 4. Design 2 construction parameters for medium size



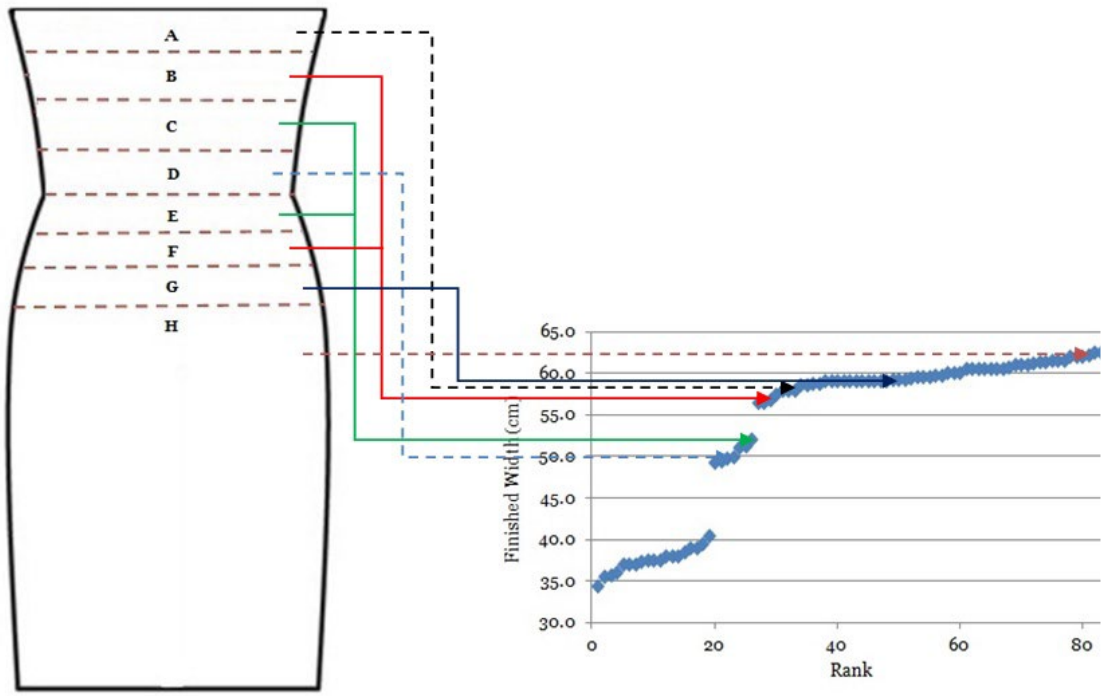
Zone	Reference Fabric			Target Fabric		Size code
	ID	On loom width (cm)	Finished width (cm)	On loom width (cm)	Finished width (cm)	
A	5	67	56.4	57	96 (48 x 2)	Medium (14)
B	64		52.0		89 (44.5 x 2)	
C	75		50.0		85 (42.5 x 2)	
D	78		49.2		84 (42 x 2)	
E	61		51.0		80 (40 x 2)	
F	75		50.0		85 (42.5 x 2)	
G	64		52.0		89 (44.5 x 2)	
H	5		56.4		96 (48 x 2)	
I	38		58.7		100 (50 x 2)	
J	17		61.0		104 (52 x 2)	

Table 5 Design 3 construction parameters for small size



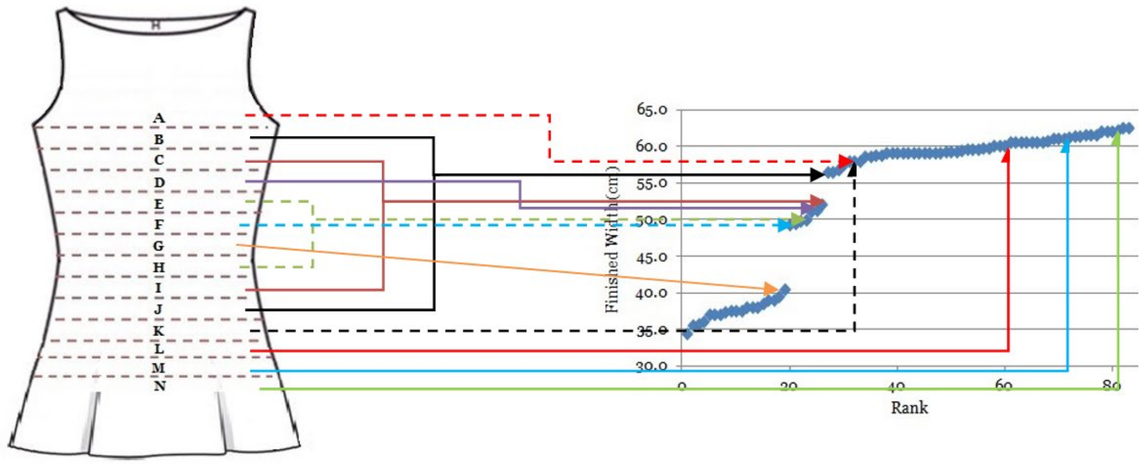
Zone	Reference Fabric			Target Fabric		Size code
	ID	On loom width (cm)	Finished width (cm)	On loom width (cm)	Finished width (cm)	
A	66	67	49.5	51.4	62 (31 x 2)	Small (10)
B	5		56.4		86 (43 x 2)	
C	3		56.7		87 (43.5 x 2)	
D	54		58.0		89 (44.5 x 2)	
E	18		59.8		92 (46 x 2)	
F	26		61.2		94 (47 x 2)	
G	16		62.5		96 (48 x 2)	

Table 6. Design 4 construction parameters for large size



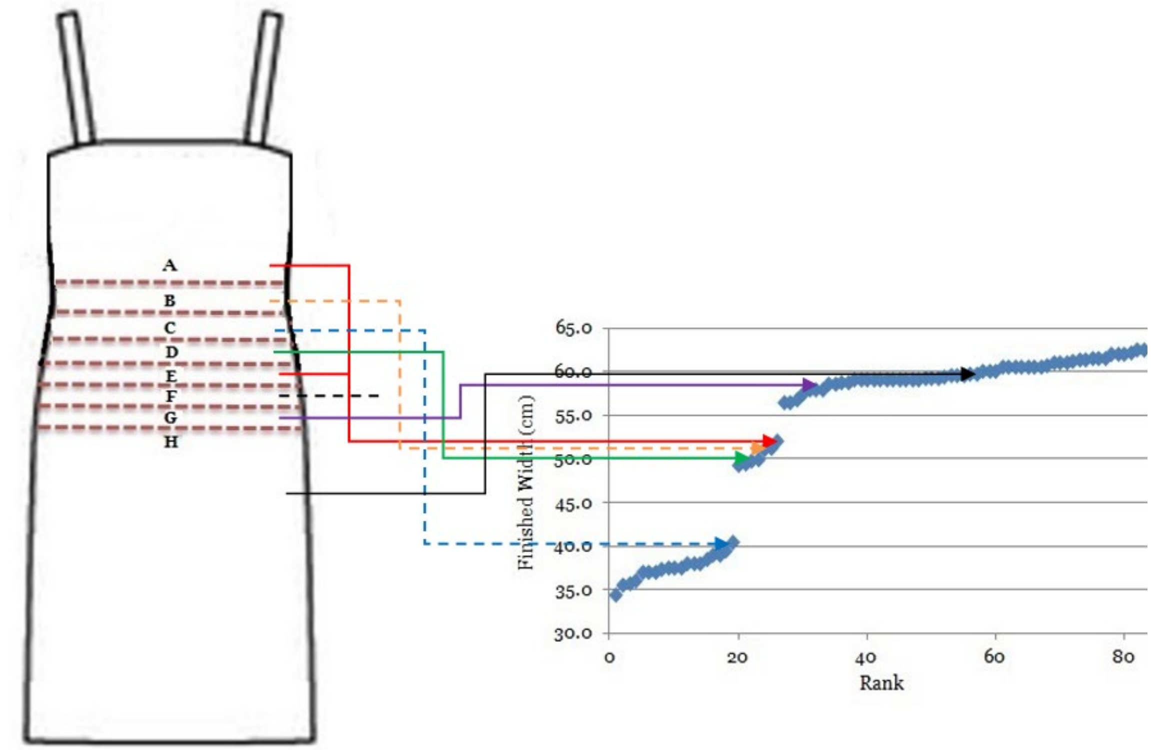
Zone	Reference Fabric			Target Fabric		Size code
	ID	On loom width (cm)	Finished width (cm)	On loom width (cm)	Finished width (cm)	
A	20	67	58.0	57.8	100 (50 x 2)	Large (16)
B	3		56.7		98 (49 x 2)	
C	64		52.0		90 (45 x 2)	
D	72		49.7		86 (43 x 2)	
E	64		52.0		90 (45 x 2)	
F	3		56.7		98 (49 x 2)	
G	52		59.0		102 (51 x 2)	
H	11		62.5		108 (54 x 2)	

Table 7. Design 5 construction parameters for X Large size



Zone	Reference Fabric			Target Fabric		Size code
	ID	On loom width (cm)	Finished width (cm)	On loom width (cm)	Finished width (cm)	
A	3		56.7		108 (54 x 2)	
B	5		56.4		109 (54.5 x 2)	
C	64		52.0		101 (50.5 x 2)	
D	67		51.3		99 (49.5 x 2)	
E	75		50.0		97 (48.5 x 2)	
F	72		49.7		96 (48 x 2)	
G	66	67	40.5	64.7	78 (39 x 2)	X Large (20)
H	75		50.0		97 (48.5 x 2)	
I	64		52.0		101 (50.5 x 2)	
J	5		56.4		109 (54.5 x 2)	
K	2		57.5		112 (56 x 2)	
L	29		60.0		116 (58 x 2)	
M	17		61.0		118 (59 x 2)	
N	21		62.0		120 (60 x 2)	

Table 8. Design 6 construction parameters for medium size



Zone	Reference Fabric			Target Fabric		Size code
	ID	On loom width (cm)	Finished width (cm)	On loom width (cm)	Finished width (cm)	
A	64	67	52	56	87 (43.5 x 2)	Medium (12)
B	67		51.3		86 (43 x 2)	
C	66		40.5		68 (34 x 2)	
D	75		50		84 (42 x 2)	
E	64		52		87 (43.5 x 2)	
F	4		56.5		94 (47 x 2)	
G	2		57.5		96 (48 x 2)	
H	18		59.8		100 (50 x 2)	

7. Conclusion

A broad range of tubular woven fabrics was produced with different construction parameters that influence finished fabric shrinkage. The fabrics (83 in total) were ranked in terms of their finished width and a relationship between rank and finished fabric width was established. The relationship along with an equation relating on-loom width of target fabric, on-loom width of reference fabric, finished width of target fabric, and finished width of reference fabric were used to illustrate how to design garments with desired shapes and sizes. While the 83 fabrics represent a broad range, more fabrics are possible to produce to cover more finished widths as can be seen from Figure 2, which shows a good number of missing finished widths.

This study illustrates the opportunity to produce numerous seamless shaped garments with different sizes. While they do not cover the entire demand of garment sizes, the data generated from them can be used to determine the on-loom width to produce other range of garment sizes using the methodology demonstrated here. Six designs for ladies' outer garments with different sizes (S, M, L and XL) were constructed to fit the bodyline. Shaping the bodyline can be achieved by combining different fabrics with different construction parameters into one garment along its length. The dimensions of the zones between the main measurements (taken according to standard BS EN 13402-3) were selected to provide gradual change to fit the bodyline.

Our work demonstrated methodology to expand reference finished width and on-loom width data that allow the construction of garments of different sizes without darts, pleats or gathers to fit the bodyline. The methodology contributes to advancing the development of weaving seamless garments with endless sizes and shapes and to paving the road to commercialization of the technology, which reduces waste and supports sustainability and circular economy.

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