Silhouette and handle design of cotton crepe fabrics for dresses

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Received 15 June 2018
Revised 20 February 2019
Accepted 20 March 2019

Abstract

Purpose – For over a century, traditional Japanese cotton crepe fabrics have been popular for men's underwear in the humid summer. Now, consumer demand is for crepe fabrics that are more attractive, reflecting a shift in use from underwear to women's dresses. The purpose of this paper is to clarify how the structures of the crepe and its constituent yarns affect the physical properties, handle and silhouette formability of crepe fabrics for dresses.
Design/methodology/approach – Three plain-weave gray fabrics were finished by four different processes to change their crepe structures. The mechanical and surface properties of the fabrics were measured using the Kawabata evaluation system for fabrics. The primary hand values and silhouette formability of the fabrics were calculated using conversion equations based on the physical properties. The handle of the crepe fabrics and the aesthetic appearance of flared collars made of them were assessed by female students using the semantic differential method.
Findings – Comparing the fabrics made from the same gray fabric, the piqué crepe fabrics showed larger *Hari* (anti-drape) and *Shari* (crispness) than the others. The subjective hand value of softness was closely related to fabric thickness. The assessors preferred the fine piqué crepe fabrics over the wide piqué fabrics regarding both the tactile feeling of the fabrics and the aesthetic appearance of the flared collars. The attractiveness of the flared collars was dominated by the shear stiffness of the fabrics.
Originality/value – The fine piqué crepe fabric made from fine yarns produced a more preferable handle. The fine piqué fabric made from thicker yarns produced flared collars with silhouettes that are more attractive. This indicates that the fine piqué structure is a positive feature that makes the fabric suitable for various types of dresses.

Keywords Physical properties, Silhouette, Crepe fabrics, Handle, Dresses, Constituent yarns

Paper type Research paper

1. Introduction

As a traditional Japanese textile, cotton crepe has been used for men's underwear worn in humid summer weather for over a century. Crepe fabrics are constructed by using hard twisted weft yarns that result in a wrinkled fabric surface. The crepe effect comes from the release of the shrinkage and twist energy stored in the twisted yarns. Theoretical studies of the crinkling mechanism of crepe fabrics have been conducted previously (Ishikura, 1988; Ishikura *et al.*,1992; Yamashita *et al.*,1997), and the general conclusion is that the shrinkage of the twisted yarn strongly affects fabric crinkling. Yang and Li (2007) presented a way to evaluate and control the crepe effect on fabrics, finding that the crepe level could be controlled by adjusting the fabric width.

Globalization of the clothing industry in recent years has increased consumer demand for crepe fabrics that are more attractive and new products for use in women's soft dresses. Using

The authors would like to express the authors' gratitude to Mr Shiro Takahashi of Takahashi Textiles Co., Ltd for providing the fabrics used in this work. This work was supported by JSPS KAKENHI Grant Nos 18K02187 and 15H01764.

cotton crepe in various types of garments is expected to help preserve traditional textile design techniques. One advantage of crepe is its high extensibility along the weft direction. Htike and co-workers (2015, 2016) investigated the effect of environmental humidity on the tensile properties of high-twist cotton yarns and crepe fabrics. The results showed that yarn twist is a key parameter controlling extensibility in highly humid environments, and that piqué crepe fabric is applicable as a new fabric for women's clothing in very high humidity.

In a previous study, the uniqueness of cotton crepe was determined in terms of its physical properties and handle (Yokura *et al.*, 2013). The mechanical properties and handle of various crepe fabrics were investigated, and it was found that fine crepe fabrics have the potential to be used for women's dresses and summer jackets in addition to men's underwear. The purpose of the present study is to clarify how the structures of the crepe and its constituent yarns affect the unique physical properties, handle and silhouette formability of crepe fabric for dresses.

2. Experimental details

2.1 Fabric specimens

We produced 12 cotton fabrics with different crepe structures and constituent yarn structures. Three plain-weave gray fabrics were finished by four different processes to change their appearances. Details of the yarn structure of the three gray fabrics are given in Table I(a), and the four finishing conditions of the fabrics are given in Table I(b). These fabrics were typical crepe fabrics in Takashima, Shiga Prefecture, Japan. The fine piqué crepe fabric I-1 has been traditionally used for men's underwear. The sample used for this study includes more fine crepe fabrics to extend a use in fashionable dresses. For comparison, a plain-weave fabric (*R0*) was also produced using the same warp yarn as that in the crepe fabrics. Table II lists the weave density, thickness (*T0*) and weight per unit area of the fabric specimens, each of which featured a plain weave. Figure 1 shows micrographs of the surfaces of fabrics that were made from the same gray fabric I and finished by four different processes, namely, embossed fine piqué crepe (I-1), embossed wide piqué crepe (I-2), embossed *chirimen* crepe (I-3) and natural crepe without embossing (I-4). The surface images of piqué samples I-1 and I-2 show uniform ribbed structures, and samples I-3 and I-4 appear randomly wrinkled.

2.2 Mechanical properties, hand values and silhouette formability

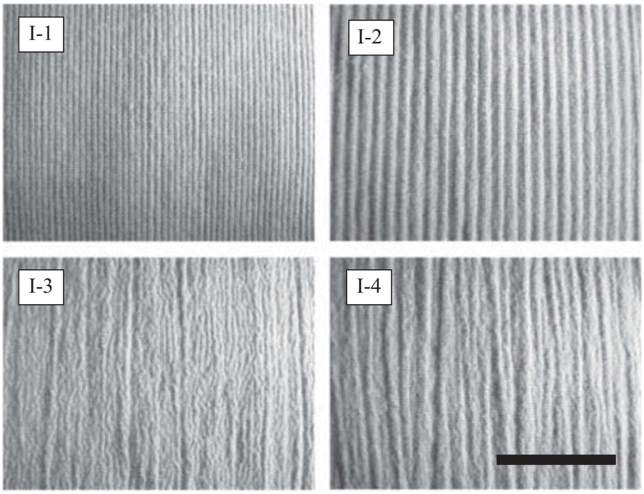
The mechanical and surface properties of the fabrics were measured using the Kawabata evaluation system for fabrics under conditions corresponding to women's thin dresses (Kawabata, 1980). The specific characteristic values and measurement conditions are given in Table AI. The primary hand values of women's thin dress fabrics were evaluated objectively using conversion equations based on the mechanical parameters of the fabrics (Kawabata and Niwa, 1989). The conversion equation used here is KN-202-LDY for

Table I.
Fabric designs, yarn structures and finishing conditions

		Warp yarn	Weft yarn
(a) Details of the gray fabrics and reference fabric R0			
R0	Plain	147.6 dtex, 1,000 t/m	147.6 dtex, 1,000 t/m
I	Gray	147.6 dtex, 1,000 t/m	147.6 dtex, 2,200 t/m
II	Gray	147.6 dtex, 1,000 t/m	295.3 dtex, 1,300 t/m
III	Gray	59.1 dtex, 1,600 t/m	98.4 dtex, 3,000 t/m
(b) Conditions of finishing			
1	Crepe with embossing, 6.7 piqué per cm (fine piqué)		
2	Crepe with embossing, 3.9 piqué per cm (wide piqué)		
3	Crepe with embossing, 0 piqué per cm (*Chirimen*)		
4	Treated via normal finishing without embossing		

Table II. Details of the crepe fabrics

No.	Weave density/cm Warp	Weft	Thickness T0, mm	Weight W, g/m^2	Symbols
R0	38.4	27.9	0.480	99.1	✖
I-1	39.0	22.0	0.809	101.3	○
I-2	39.0	22.0	0.861	97.5	□
I-3	39.5	22.0	0.827	98.0	△
I-4	37.0	21.5	0.846	102.5	◇
II-1	36.0	19.5	0.983	133.3	●
II-2	40.0	19.5	1.133	153.3	■
II-3	35.5	18.5	1.052	131.5	▲
II-4	35.0	19.5	1.112	112.8	◆
III-1	55.8	28.0	0.713	87.2	●
III-2	57.6	30.0	0.873	88.0	■
III-3	61.5	30.5	0.773	100.0	▲
III-4	59.5	29.0	0.813	90.8	◆



Notes: (I-1) embossed fine piqué crepe; (I-2) embossed wide piqué crepe; (I-3) embossed *chirimen* crepe; and (I-4) natural crepe without embossing. Bar: 20 mm

Figure 1. Micrographs of surfaces of fabrics made from same gray fabric I

obtaining *Koshi* (stiffness), *Hari* (anti-drape stiffness), *Shari* (crispness), *Fukurami* (fullness/softness), *Kishimi* (scroop) and *Shinayakasa* (suppleness).

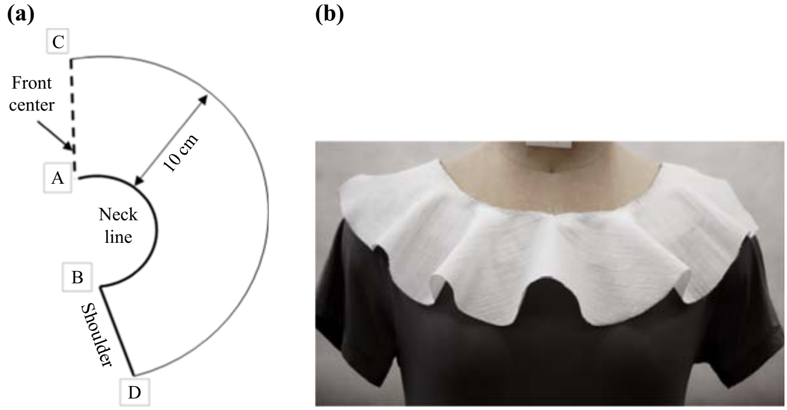
A method has been established for classifying fabric silhouette designs using the fabric weight per unit area and the tensile, bending and shears properties (Niwa *et al.*, 1997). According to this method, the garments worn by Western women are classified into three main silhouette types: the tailored type, which forms a beautiful shape covering the female body; the drape type, which emphasizes a beautiful draped silhouette; and the anti-drape (*Hari*) type. We investigated the silhouette formability of our crepe fabrics using the silhouette classification equation of Ref. (Inoue and Niwa, 2002) combined with fabric mechanical data.

2.3 Subjective evaluation of tactile feel

The tactile feel of each crepe fabric was assessed by 21 female students (18–24 years old) (Yokura and Takahashi, 2015). In the present research, we emphasize how the crepe fabrics feel tactilely to young women with the aim of expanding the use of crepe fabrics for dresses. The assessors were told that the end use of these fabrics would be for a thin dress, and they evaluated the fabrics by touching them by hand. We did not specify a procedure for the evaluation; the assessors were asked to judge the tactile feel based only on the sensations from contact with the materials. The test fabrics were hidden from view behind a curtain to prevent the visual appearance of the fabrics from influencing the evaluation. The evaluation categories were "soft/hard," "smooth/rough" and "prefer/not prefer." Evaluations were performed in random order using a scale from −2 to +2 according to the semantic differential method. We used the mean score of the subjective assessments as the tactile feel of the products.

2.4 Flared collar preparation and aesthetic evaluation

From the 12 crepe fabrics listed in Table II, 9 were used in this experiment. We chose a flared collar as the decorative design of the dress. The pattern used to make the flared collar is shown in Figure 2(a). The neck line (AB) was 16-cm long, the hem had a circumference of 46 cm and the collar was 10-cm wide. We cut two types of collar from each fabric, taking the front centerline of the collar in either the warp or weft direction of the fabric. As a result, 18 collar samples were offered for subjective evaluation. We seamed the facing and collar together along the neckline. As shown in Figure 2(b), we placed each collar on a mannequin that wore a gray T-shirt and fixed it with dress pins in three places, namely, one on the neck-point and one on each shoulder-point. The aesthetic appearance of each flared collar was assessed by 34 female students (19–23 years old). The assessors were asked to judge only the attractiveness of the flare based on visual appearance; the evaluation categories were "beautiful/ugly." Evaluations were performed in random order using a scale from −2 to +2 according to the semantic differential method. We examined the correlation between the individual and mean scores of the subjective assessments, excluding the evaluations by three assessors whose scores were not significantly correlated with the mean score at the 0.1 level; their assessments tended to differ somewhat from those of the majority of the assessors. We used the mean score of the subjective assessments of the remaining 31 assessors as the aesthetic appearance of each product.



Notes: (a) Pattern for making flared collar; (b) example of a collar on display

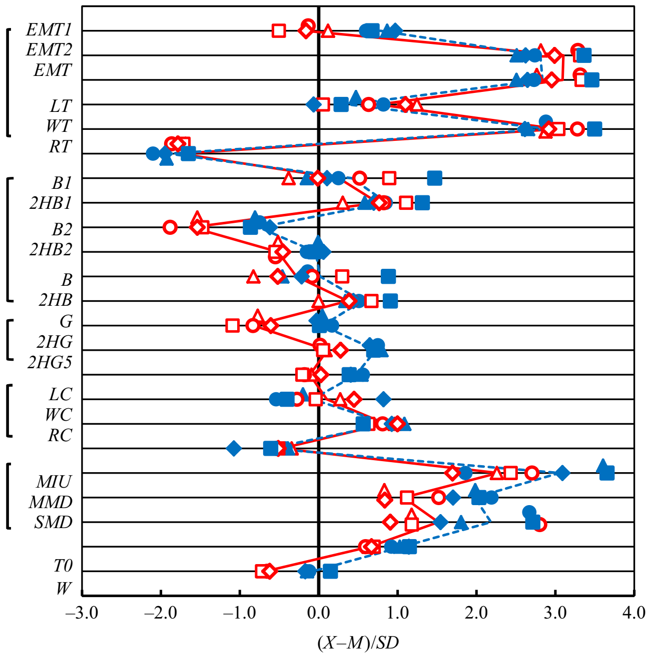
Figure 2.
Pattern used to make the flared collar and example of a collar on display

3. Results and discussion

3.1 Mechanical and surface properties of cotton crepe fabrics for dresses

Figure 3 shows the mechanical and surface properties of four crepe fabrics made from gray fabric I and four made from gray fabric II. We used the data chart of fabrics used for women's garments (Inoue and Niwa, 2002) when inspecting the crepe fabrics. The horizontal axis was normalized by the mean value and standard deviation of each corresponding characteristic value of the fabrics ($n = 280$) used for Western-style women's garments (Inoue and Niwa, 2002). The mean values of each parameter for the four fabrics I crepe fabrics and the four fabrics II crepe fabrics are denoted by solid and dashed lines, respectively. The distinctive features of the crepe fabrics are their large values of tensile strain at maximum load (*EM2*) in the weft direction, tensile energy (*WT*) and large values for the surface properties, namely, coefficient of friction (*MIU*), mean deviation of *MIU* (*MMD*) and geometrical roughness (*SMD*). This tendency is the same as that reported previously for crepe fabrics (Yokura *et al.*, 2013). The other physical properties were within the range of −2 to +2, at the same levels as those for other dress fabrics.

The wide piqué crepe fabrics (I-2 and II-2) showed larger values for *EM2* and *WT*. Piqué fabrics are more extensible because their wave parts flatten upon stretching. Regarding the bending properties, the bending rigidity (*B1*) and hysteresis of bending moment (*2HB1*) in the warp direction of wide piqué fabrics were larger than those of non-piqué fabrics, which we attribute to surface crinkling in the warp direction in the case of piqué crepe fabrics. Clothing made from such fabrics creates an air space between the fabric and the skin of its wearer, thereby facilitating the transfer of heat and moisture and giving a comfortable feel



Notes: $n = 280$. The scale is normalized by the mean value (*M*) and standard deviation (SD) of the dress fabrics. See Table II for an explanation of the symbols. Solid lines indicate mean values of each parameter for the four crepe fabrics made from gray fabric I. Dashed lines indicate mean values of each parameter for the four crepe fabrics made from gray fabric II

Figure 3. Mechanical and surface properties of four crepe fabrics made from gray fabric I and four made from gray fabric II

when used for summer clothes. The effect of surface crinkling on the heat transfer in the presence of water will be discussed in another paper.

The fabrics made from gray fabric II had larger values of shear stiffness (*G*) and hysteresis of shear force (*2HG, 2HG5*) compared with those made from gray fabric I. The bending rigidity (*B2*) and hysteresis of bending moment (*2HB2*) in the weft direction of the fabric II crepe fabrics were higher than those of the fabric I crepe fabrics. The thickness of the weft yarns should influence the fabric stiffness.

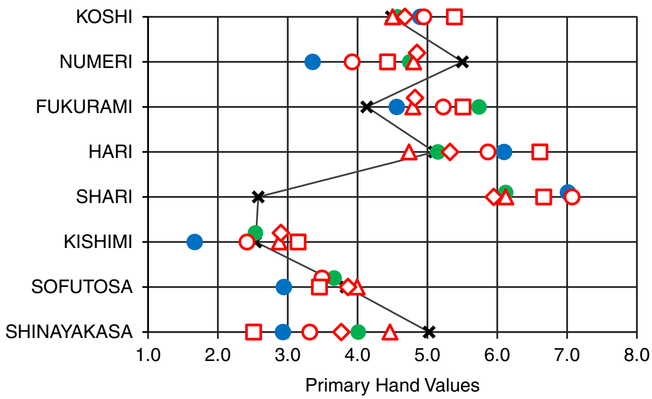
3.2 Primary hand values of cotton crepe fabrics for dresses

The primary hand values of the cotton crepe fabrics as calculated from their mechanical and surface properties are shown in Figure 4. The grading of the feeling intensity of each primary hand value is expressed numerically on a scale of 1: weakest to 10: strongest (Kawabata and Niwa, 1989). Crepe fabrics show larger values for *Shari* (crispness) and smaller values for *Shinayakasa* (suppleness) compared with those the plain-weave fabric *R0*.

Fabrics I-1 to I-4 were made from the same gray fabric I, and the piqué fabrics I-1 and I-2 showed larger values of *Fukurami* (fullness), *Hari* (anti-drape) and *Shari* (crispness) compared with the other crepe fabrics (I-3 and I-4). This tendency was due to surface crinkling in the warp direction in the case of the piqué crepe fabrics. Fabrics I-1, II-1 and III-1 have the same fine piqué structure, with III-1 showing larger values of *Fukurami* and *Shinayakasa* and a smaller value of *Shari*. In a previous study, the female assessors did not exhibit a strong preference for *Shari*, even though *Shari* is a unique feeling that provides a cool sensation in summer humidity (Yokura and Takahashi, 2015). Based on the present findings, we reason that piqué crepe fabric III-1 made from fine yarns could produce a more preferable handle for dresses.

3.3 Tactile feel and mechanical properties of fabrics

Table III lists the coefficients of correlation between the tactile feel of the crepe fabrics and their mechanical and surface parameters. The highest correlation was that between tactile feel and fabric thickness *T0* at a 1 percent significance level. Regarding the crepe fabrics, softness, smoothness and preference were closely related to *T0*, with the relatively small value for *T0* being associated with the higher scores for softness, smoothness and preference. In a previous study, it was also found that softness, smoothness and preference were closely related to fabric thickness with regard to cotton crepe fabrics (Yokura *et al.*, 2013). That was despite the fact that the previous study included non-crinkling fabrics, whereas the present study is of



Notes: See Table II for an explanation of the symbols. Dashed lines indicate values for plain weave fabric *R0*

Figure 4. Primary hand values for four piqué crepe fabrics made from gray fabric I and fine piqué crepe fabrics II-1 and III-1

	Softness	Smoothness	Preference
Tensile			
EMT	0.549	0.205	0.249
LT	−0.040	0.403	0.369
WT	0.564	0.331	0.372
RT	0.434	0.334	0.369
Bending			
B1	−0.491	−0.463	−0.500
2HB1	−0.674*	−0.546	−0.605*
B2	−0.802**	−0.584*	−0.584*
2HB2	−0.815**	−0.563	−0.564
Shear			
G1	−0.680*	−0.517	−0.505
2HG1	−0.752**	−0.548	−0.549
2HG5-1	−0.698*	−0.480	−0.481
G2	−0.619*	−0.308	−0.306
2HG2	−0.735**	−0.428	−0.441
2HG5-2	−0.697*	−0.411	−0.413
Surface			
MIU	−0.394	−0.484	−0.561
MMD	−0.640*	−0.509	−0.508
SMD	−0.108	0.050	0.070
Compression			
LC	−0.323	−0.413	−0.306
WC	−0.261	−0.101	−0.040
RC	0.477	0.340	0.339
Thickness			
T0	−0.895**	−0.871**	−0.823**
Weight			
W	−0.783**	−0.635*	−0.596*

Notes: Suffix 1: warp direction, suffix 2: weft direction. *Significant at 5 percent level: $r > 0.576$ ($n = 12$); **significant at 1 percent level: $r > 0.708$

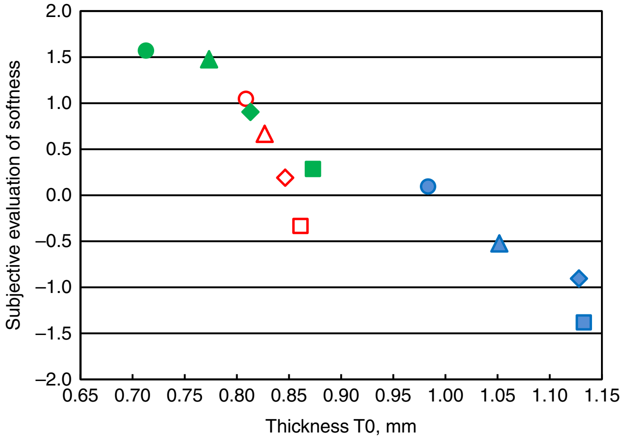
Table III. Coefficients of correlation between tactile feel of the crepe fabrics and their mechanical and surface parameters

fabrics that all had crinkling on their surfaces. Therefore, the *T0* of crepe fabrics can be used as a key parameter in fabric design.

Figure 5 shows the relationship between the subjective evaluation of softness and *T0*. Those crepe fabrics with smaller values of *T0* were assessed as being softer. The value of *T0* is one of the measurable characteristics for estimating the height of crepe. We expected those crepe fabrics with smaller values of *T0* (small crepe) to be regarded as softer and smoother. Among the three different groups of gray fabric, the fine piqué crepe fabrics were judged to be softest, not the wide piqué crepe fabrics.

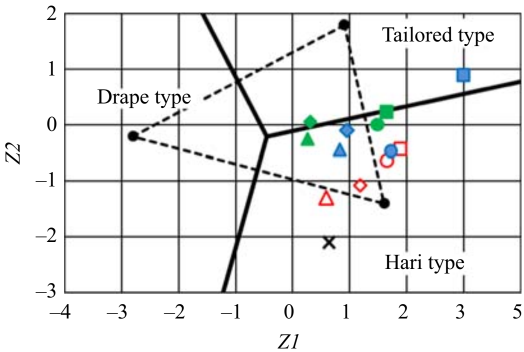
3.4 Silhouette formability of crepe fabrics and aesthetic evaluation of flared collars

We investigated the silhouette formability of the crepe fabrics by applying the classification equation of Ref. (Inoue and Niwa, 2002), which separates silhouettes into three types (tailored, anti-drape (*Hari*) and drape) onto planes *Z1* and *Z2*, according to the first canonical variable *Z1* and second canonical variable *Z2*. Figure 6 shows the silhouette types of the test fabrics. The crepe fabrics were plotted in the anti-drape (*Hari*) silhouette regions as considered for Western-style garments. Several fabrics lie on the



Note: See Table II for an explanation of the symbols

Figure 5.
Relationship between subjective values for softness and fabric thickness *T0*

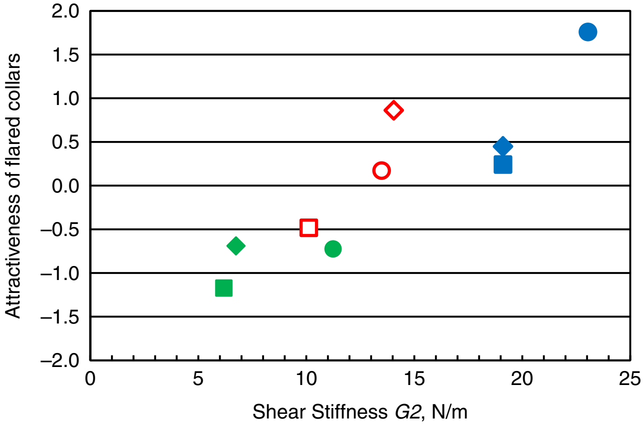


Notes: ●: Center of each silhouette (Inoue and Niwa, 2002). See Table II for an explanation of the symbols

Figure 6.
Silhouette types of cotton crepe fabrics and reference fabric

boundary between the anti-drape and tailored types, indicating that crepe fabrics can be used for summer jackets or dresses whose decoration involves the use of flare. From this result, we chose the flared collar as a suitable design for the silhouette properties of the crepe fabrics for aesthetic evaluation.

We investigated the correlations between the subjective evaluation of the attractiveness of each flared collar and the mechanical properties of the crepe fabric from which it was made. We found high correlation between the attractiveness of the flare and the shear properties of the fabric. This result is similar to those in previous studies that evaluated the silhouettes of dresses (Niwa *et al.*, 1997; Inoue and Niwa, 2002). Figure 7 shows the relationship between the shear stiffness (*G2*) in the weft direction of the fabrics and the subjective evaluation of the attractiveness of those flared collars whose front centerline was taken in the weft direction of the fabric. We expected those crepe fabrics with larger values of *G2* to provide a better aesthetic appearance. The flared collar made from fine piqué crepe fabric II-1 was judged to be the most attractive, whereas those made from wide piqué crepe fabrics were evaluated as being not attractive.



Note: See Table II for an explanation of the symbols

Figure 7. Relationship between shear stiffness (*G2*) in weft direction of fabrics and subjective values of attractiveness of flared collars

4. Conclusions

We investigated how the structures of crepe and its constituent yarns affected the physical properties, handle and silhouette formability of crepe fabrics to establish a basis for a system for designing crepe fabrics for dresses. The cotton crepe fabrics showed larger values for their surface properties and tensile strain at maximum load in their weft direction compared with other dress fabrics ($n = 280$). In terms of primary hand values, high *Shari* (crispness) and low *Shinayakasa* (suppleness) were identified as distinctive features of the present crepe fabrics. Comparing fabrics made from the same gray fabric, the piqué crepe fabrics showed larger *Hari* (anti-drape) and *Shari* (crispness) compared with non-piqué crepe fabrics. The subjective hand values of softness, smoothness and preference with regard to cotton crepe fabrics were closely related to fabric thickness *T0*, with smaller values of *T0* being associated with higher scores for softness, smoothness and preference. The crepe fabrics gave anti-drape (*Hari*) silhouettes as considered for Western-style garments. The attractiveness of flared collars made from the crepe fabrics was dominated by the shear properties of the fabrics. Female assessors preferred the fine piqué fabrics over the wide piqué fabrics in both the tactile feeling of the fabrics and the aesthetic appearance of the flared collars. The fine piqué fabric made from fine yarns produced preferable handle, whereas the fine piqué fabric made from thicker yarns produced a more beautiful silhouette of the flared collars. This indicates that the fine piqué structure is a positive feature that makes such fabric suitable for various types of dress. From these characteristics of fabric, we considered that fine piqué fabrics made from fine yarns is suitable for blouse because of low thickness and soft hand, whereas the fine piqué fabric made from thicker yarns is suitable for summer jackets and/or one-piece dresses with flared silhouette. For the future consideration, we would like to made these garments from the fine piqué fabrics, and confirm the suitability for design of each garment.

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Appendix

Properties	Symbol	Characteristic value	Unit	Measuring conditions
Tensile	*EM*	Strain at maximum load	%	Strip biaxial deformation
	LT	Linearity	None	Maximum load: 49 N/m
	WT	Tensile energy	N/m	Speed: 0.1 mm/s
	RT	Resilience	%	
Bending	*B*	Bending rigidity	μNm	Pure bending
	2HB	Hysteresis of bending moment	mN	Maximum curvature K, $\pm 250\,m^{-1}$
Shearing	*G*	Shear stiffness	N/m	Shear deformation under constant tension of 9.8 N/m
	2HG	Hysteresis of shear force at 8.7 mrad	N/m	
	2HG5	Hysteresis of shear force at 87 mrad	N/m	
Compression	*LC*	Linearity	None	Maximum pressure: 0.98 kPa
	WC	Compression energy	N/m	Rate of compression: 20 μm/s
	RC	Resilience	%	
Surface	*MIU*	Coefficient of friction	None	Ten steel-piano-wire with 0.5 mm diameter and 5 mm length
	MMD	Mean deviation of *MIU*	None	Contact force: 0.49 N
	SMD	Geometrical roughness	μm	A steel-piano-wire with 0.5 mm diameter and 5 mm length Contact force: 0.1 N
Thickness	*T0*	Thickness at 49 Pa pressure	mm	
Weight	*W*	Weight per unit area	g/m^2	

Table AI. Characteristic values of basic mechanical properties and measuring conditions

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