Chapter 11

Hand Evaluation and Formability of Japanese Traditional 'Chirimen' Fabrics

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Additional information is available at the end of the chapter

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1. Introduction

Clothes, which are used in direct contact with the human body, are mostly made of fabrics of planar fiber construction, that is, they are manufactured for the most part from textiles. Needless to say, the quality of clothes directly affects both the human mind and body. For this reason, it is essential to have a system which allows us to accurately and thoroughly evaluate the qualities and use-value of textiles. Since Prof. Sueo Kawabata of Kyoto University developed the *KES* (Kawabata Evaluation System) in 1972 (Kawabata, 1972), research into fabric handle and quality based on physical properties has made remarkable progress, and objective evaluation of fabrics using the *KES* system is now common around the world. Evaluation formulas for fabric formability, tailoring appearance, and hand evaluation of the tailored-type fabrics represented by those used in tailored men's suits have been created, and allow us to objectively evaluate the fundamental performance capabilities of fabrics, unaffected by changing times and fashions (Kawabata, 1980). Furthermore, fabric formability, tailoring appearance, hand evaluation, and quality of tailored-type fabrics can now be influenced at every stage, even the very earliest: at the fiber-to-yarn stage, the yarn-to-fabric stage, and then at all the subsequent stages, up to the finishing of the material. This is invaluable for the fabric design process (Kawabata et al., 1992).

Each region of Japan has unique textile weaves and dyeing methods for traditional fabrics. Japanese traditional 'Chirimen' fabrics are used for making the traditional Japanese garments generically referred to as 'kimono', which have a fixed structure and are worn in very particular ways. These 'Chirimen' fabrics have also been used as dress fabrics in recent years, and polyester has come to be used in addition to the traditional silk in these fabrics or making kimonos for people of all ages, since it is easy to wash.

This chapter describes the mechanical properties of different types of 'Chirimen' fabric, including polyester 'Chirimen' fabric, by using an objective evaluation system for fabric. The differences in formation and performance among the various types are also examined here (Inoue & Niwa, 2010a). In our description of the mechanical properties, we look at the warp and weft direction of tensile properties and bending properties, because fabrics wrap around a cylindrical body beautifully in the direction of the weft direction and assume a form when worn that hangs down in the direction of the warp. Evaluation formulas derived to describe the specific handle (comprising *KOSHI* [stiffness] and *TEKASA* [hand quantity]) of 'Chirimen' fabric, and the mechanical properties which contribute to the handles are also explained and discussed. In addition, this chapter shows how to determine optimum silhouette design under the standard measurement conditions for ladies' thin dress fabrics (discussed in Inoue & Niwa, 2010b) rather than the high-sensitivity measurement conditions used hitherto (Niwa et al., 1998), and the criteria for the silhouettes using 'Chirimen' fabric are shown (Inoue & Niwa, 2011).

By examining 'Chirimen' fabric in the ways indicated above, the authors hope to clarify the importance of fabric mechanical properties contributing to fabric formability, hand evaluation, and silhouettes.

2. Japanese traditional 'Chirimen' fabrics

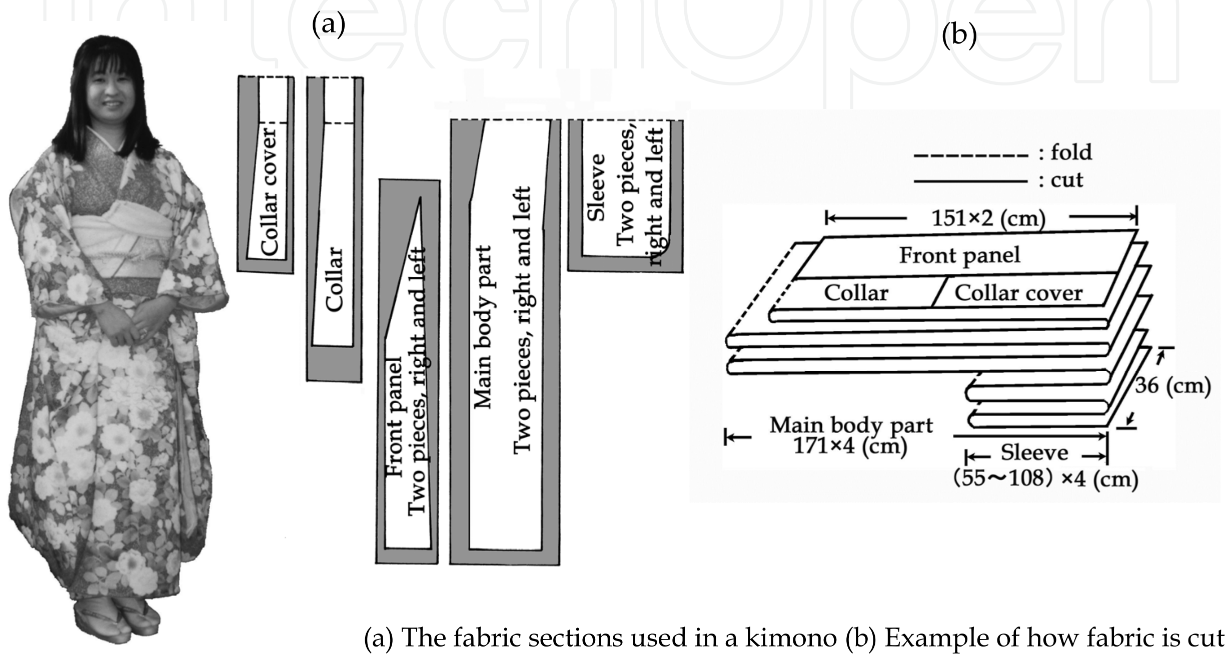
Each region of Japan has unique textile weaves and dyeing methods (Tomiyama & Ohno, 1967) for traditional fabrics. The textile weave and the dyeing method are two sides of the same coin, in the sense that either the weaving or the dyeing can be done first. Consequently, there are both fiber- or yarn-dyed fabrics and piece-dyed fabrics. Traditional fabrics called 'Chirimen' are produced in Tango, Nagahama, Hokuriku, and Gifu, as well as other districts, and are typical of woven piece-dyed fabrics produced in great amounts throughout Japan. 'Chirimen' is the generic name for silk fabric in which right-laid and left-laid hard-twist yarn is alternately woven to make weft yarn. There are crimps on the surface, and these crimps create a unique hanging down feeling and tinctorial effect. 'Chirimen' are considered very high-grade silk fabrics although artificial fiber has been used in them in recent years, and they are used to make formal 'kimono' (the famous traditional Japanese garment).

2.1. Construction of the traditional garment 'kimono' and how it is worn

The Japanese traditional garment called 'kimono' evolved over a long period into a garment well-suited to the climactic conditions peculiar to Japan. Stylistically, it is a formal garment similar to the Western formal wear and gowns worn on cermonial occasions, a result of its being constructed from one continuous piece of cloth (Yamamoto, 1960). The cloth is 36～38cm in width; using approximately 12m of cloth in total, the sleeves, main body parts (front and back), front panels, collar and collar cover are cut out and sewn together in a straight line. When it is put on, it is secured around the body with a waist cord, which is then covered with a decorative sash called an 'obi'. Fig. 1 shows the construction of a women's kimono and a photo of how it is worn.

2.2. Japanese traditional fabrics and varieties of 'Chirimen' fabrics

'Chirimen' fabrics were collected from the largest producing area, the Tango District near Kyoto, in 1981 (Komatsu & Niwa, 1981), and silk Chirimen and 33 polyester Chirimen samples were added to the collection of samples in recent years, resulting in a total of 304 samples. (The details are shown in Table 1.) Chirimen are classified by difference in yarn,



(a) The fabric sections used in a kimono (b) Example of how fabric is cut making kimono

Figure 1. Photo of women's kimono, showing its construction and how it is worn

Fiber	Kind of Chirimen		The number of Chirimen fabrics
Silk	Hitokoshi･Kodai Chirimen	Hitokoshi Chirimen	78
		Kodai Chirimen	26
	Kawari Muji Chirimen		14
	Mon Chirimen	Muji (Mon) Isho Chirimen	76
		Rinzu Chirimen	63
		Fuutsuu Chirimen	6
		Others	8
Polyester			33
		Total	304

Table 1. Chirimen fabrics

fabric construction, and the size of the rugged crimps on the surface (Nakae, 1993). Among the classifications of Chirimen fabrics examined are: 1) Hitokoshi Chirimen (crimp is minute, and filament yarn that is not twisted is used for the warp yarn; this is the typical Chirimen, with right-laid and left-laid hard twist yarn alternately woven to make weft yarn); 2)Kodai Chirimen (filament yarn that is not twisted is used for the warp yarn; thicker hard-twist yarn than that used in Hitokoshi Chirimen is alternately woven right-laid and left-laid to make weft yarn, namely "two jump" yarn, right/right-laid and left/ left-laid hard-twist yarn; there are larger crimps than in Hitokoshi Chirimen; also called "Futakoshi Chirimen", "Futakoshi" meaning "two jumps"); 3) Kawari Muji Chirimen (crimp is more minute than that of Hitokoshi Chirimen; hard twist yarn called "Chirimen Yoko" ["Yoko" meaning "weft"] is not used, rather, fancy twist yarn is used [i.e., yarn twisted differently from the usual way: perhaps one yarn made from non twisted yarn and right-laid yarn, another yarn made from non twisted yarn and right-laid yarn are twisted together to make one yarn], consequently, the degree of shrinkage is small; produced in greater amounts than Hitokoshi Chirimen in recent years); 4) Mon Chirimen (Chirimen which has warp yarn in plain weave fabric at the surface to highlight the woven pattern; comes in different varieties such as Mon Isho Chirimen [Muji Isho Chirimen] and Mon Rinzu Chirimen); 5) Fuutsuu Chirimen (woven pattern in the cloth is double-weave, using warp and weft yarn; the pattern is woven in high relief). In this chapter, each kind of Chirimen introduced here is examined.

3. Fabric handle and objective evaluation system

3.1. Measurement of fabric mechanical properties

Fabric mechanical properties were measured using the *KES-FB* system (Kawabata et al., 1996~1997) under the standard conditions (Kawabata, 1980) shown in Table 2.

The tensile properties, bending properties, shearing properties, surface properties, compression properties and the weight of the fabrics were measured.

3.2. The subjective hand-evaluation method

Sensory tests (Inoue et al., 2010) were performed for the subjective evaluation of the hand value of Chirimen. A standard sample was assumed to represent the standard feel of Chirimen; comparing Chirimen samples with the standard sample, we ranked the Chirimen samples by how strong they felt to the touch, using a scale of 0 to 10, with the standard sample being 5. This subjective hand-evaluation provided an indication of *KOSHI* (stiffness) and *TEKASA* (hand quantity), both of which influence the quality of Chirimen. (*TEKASA* is defined as a sense of the great bulk and rich feeling of cloth with substantial "give" to the touch, a feeling of thickness and warmth as well as elasticity under pressure [Kawabata, 1980].) Judges were four experienced technical engineers who were well acquainted with the silk 'Chirimen' fabrics of the special production site in the environs of the Kyoto Prefectural Institute of Northern Industry.

3.3. The mechanical parameters and three basic components of tailorability

The mechanical parameters and three basic components of tailorability were calculated to make a *TAV* (Total Appearance Value) prediction (Kawabata & Niwa, 1989). The mechanical parameters are as follows:

(Formability)
Weft-directional extensibility

$$\log_{10} EL2 = \log_{10} (EM2/LT2) \tag{1}$$

Effective bending stiffness in weft-bending mode

$$\log_{10} BS2 = \log_{10} [M2(1) + HB2],\ M2(1) = B2 \cdot K,\ K=1 \tag{2}$$

Effective shear stiffness

$$\log_{10} SS = \log_{10} [Fs(1) + HG5],\ Fs(1) = G \cdot \phi,\ \phi = 1^{\circ} \tag{3}$$

(Elastic Potential)

Bending elastic potential per unit area at K=2.5cm^{-1}

$$\log_{10} BP = \log_{10} [B(2.5 - HB/B)^2/2] \tag{4}$$

Shear elastic potential per unit area at ϕ=8°

$$\log_{10} SP = \log_{10} [G'(8 - HG/G')^2/2],\ G' = G + (2HG - 2HG5)/5 \tag{5}$$

(Drape)

Bending stiffness relating to drape

$$\sqrt[3]{BS/W} \tag{6}$$

Shear stiffness relating to drape

$$\sqrt[3]{SS/W} \tag{7}$$

Where, K : Bending curvature (cm^{-1}), ϕ: Shear angle (degree), M : Elastic bending moment (gf · cm · cm^{-1}), Fs : Elastic shear force (gf · cm^{-1}).

3.4. Determination of optimum silhouette design

Ladies' garments come in a wide variety of designs, and make use of fabrics with greatly varying mechanical properties, making a considerable range of silhouettes possible (Inoue & Niwa, 2003, 2009). Ladies' garment fabrics are divided into three categories, based on the silhouette types which they can yield: 1. Tailored Type, which results in the formation of a beautiful shape covering the female body; 2. Drape Type, which emphasizes a beautiful drape silhouette; and 3. *Hari* Type, or anti-drape silhouette which spreads out horizontally away from the surface of the human body.

The discriminant equations for ladies' garment fabrics related to silhouette design which divides the fabrics into three optimum silhouette types have been derived from the mechanical properties of fabrics under both high sensitivity conditions (Niwa et al., 1998), and standard conditions (Inoue & Niwa, 2010b). The tensile properties of these samples are measured under standard conditions up to a maximum load of 500gf/cm. In this chapter, three optimum silhouettet types are derived using the first canonical variate Z_1 and the second Z_2 obtained under standard conditions, as follows:

Symbols	Characteristic value	Unit	Measuring conditions Standard (Kawabata, 1980)
EM	Tensile strain at max. load	%	Strip biaxial deformation.
LT	Linearity	-	Upper limit tensile force (max. load) : 500 gf/cm
WT	Tensile energy	gf·cm/cm^2	
RT	Resilience	%	
B	Bending rigidity	gf·cm^2/cm	Pure bending.
2HB	Hysteresis	gf·cm/cm	Max. curvature, $K = \pm 2.5$cm^{-1}
MIU	Coefficient of friction	-	Contactor for friction measurement : Ten parallel steel-piano -wires with 0.5mm dia. and 6mm length simulating finger
MMD	Mean deviation of *MIU*	-	skin geometry. Contact force; 50gf.
SMD	Geometrical roughness	micron	Contactor for geometrical roughness : A steel piano wire, with 0.5mm dia. and 5mm length. Contact force ; 10gf.
G	Shear stiffness	gf/cm·degree	Shear deformation under constant tension of 10gf/cm.
2HG	Hysteresis at ϕ =0.5°	gf/cm	Max. shear angle, ϕ =±8°
2HG5	Hysteresis at ϕ =5°	gf/cm	
LC	Linearity	-	Upper limit pressure : 50 gf/cm^2
WC	Compressional energy	gf·cm/cm^2	
RC	Resilience	%	
T	Thickness at 0.5gf/cm^2	mm	Thickness at 0.5gf/cm^2 pressure.
W	Weight per unit area	mg/cm^2	Weight of specimen per unit area.

Table 2. Characteristic values of basic mechanical properties and measuring conditions for *KESF* measurements.

$$Z_1 = \sum_{i=1}^{8} C_{1i} U_i \tag{8}$$

$$Z_2 = \sum_{i=1}^{8} C_{2i} U_i \tag{9}$$

Where, $U_i = (x_i - m_i)/\sigma_i$: normalized mechanical data, and x_i : mechanical data from a sample. The coefficients C_{1i}, C_{2i}, the mean m_i and standard deviation σ_i are listed in Table 3.

4. Characteristics and performance of 'Chirimen' fabrics

4.1. Characteristics of mechanical properties

In order to clarify the mechanical properties of Chirimen fabrics, a data chart was created using the mean value and the standard deviation for 271 silk Chirimen fabrics (Fig. 2). We added warp and weft direction to tensile properties and bending properties in Fig. 2 because kimono fabrics wrap around a cylindrical body beautifully in the direction of the weft and assume a form when worn that hangs down in the direction of the warp. The mean value and the standard deviation for men's suiting, Women's Suiting, dress-shirt fabrics, and polyester Chirimen were used to represent the features of Chirimen. From the chart, it is clear that men's suiting and dress shirts fabrics have narrower ranges of mechanical properties than women's suiting.

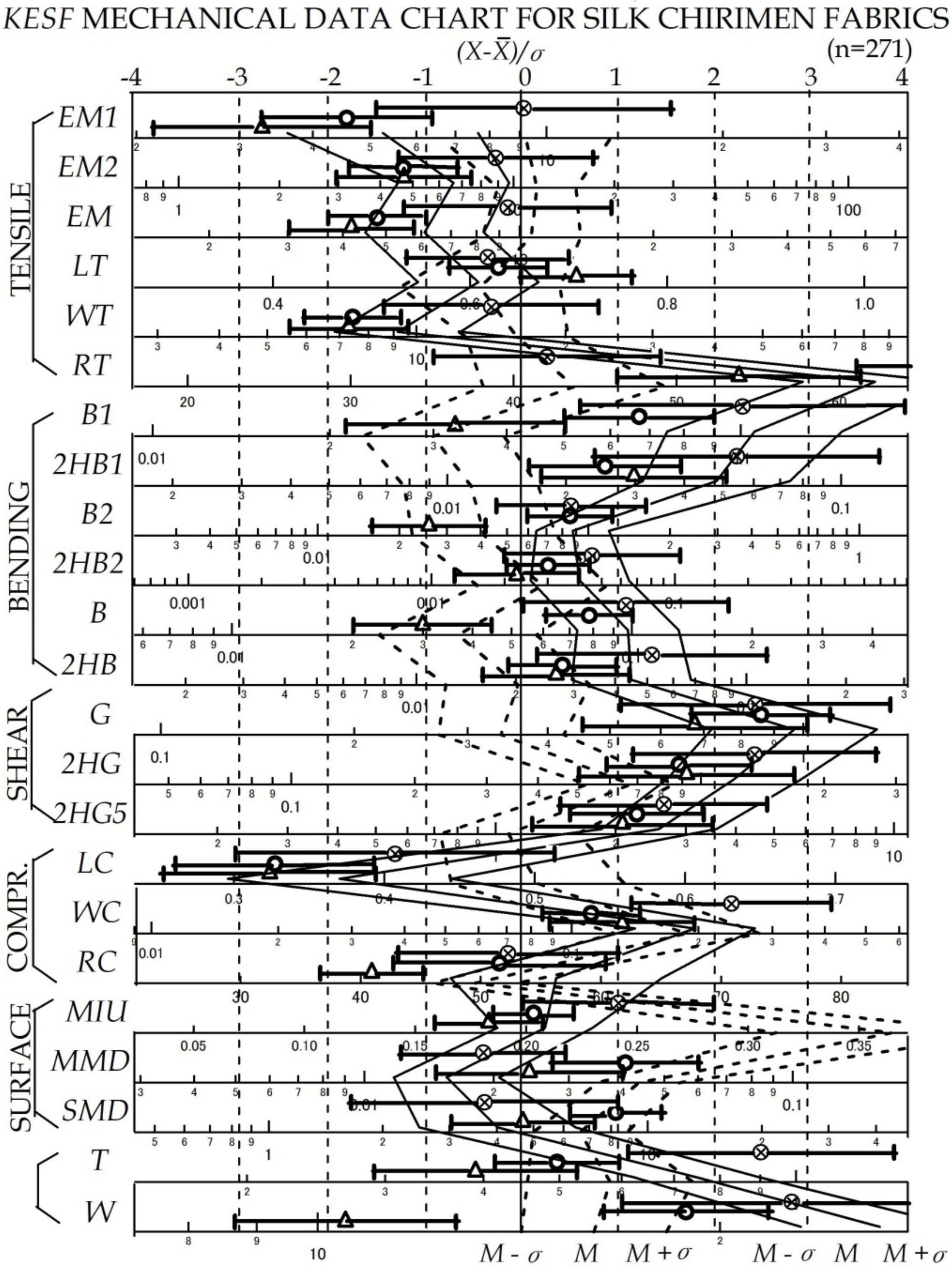
i	Parameter	Description	Unit	m_i	σ_i	C_{1i}	C_{2i}
1	*LT*	Linearity of tensile curve	none	0.6094	0.1614	-0.0477	0.0892
2	log*EM*	Elongation at Max. load	%	0.9179	0.2545	0.0786	-0.3391
3	log*B*	Bending rigidity	gf・cm²/cm	-1.1222	0.4658	0.6852	-0.0333
4	log2*HB*	Hysteresis at K=1cm⁻¹	gf・cm/cm	-1.4469	0.5826	0.1658	-0.4825
5	log*G*	Shear stiffness	gf/cm・deg	-0.3607	0.2204	0.4434	0.1804
6	log2*HG*	Hysteresis at ϕ=0.5°	gf/cm	-0.3748	0.4967	-0.1794	2.4200
7	log2*HG5*	Hysteresis at ϕ=5°	gf/cm	-0.0645	0.4443	0.0053	-3.0857
8	log*W*	Fabric weight	mg/cm²	1.1782	0.2406	0.1649	1.2555

Table 3. Values of C_{1i}, C_{2i}, m_i and σ_i to calculate Z_1, Z_2

The distinctive features of silk Chirimen are its low values of bending properties, shearing properties, and thickness & weight, but the values for the weft direction of tensile properties *EM2*, *LT* and the bending properties *B2* and *2HB2* have the same ranges for men's and women's suit-fabric characters, and the ranges are wide.

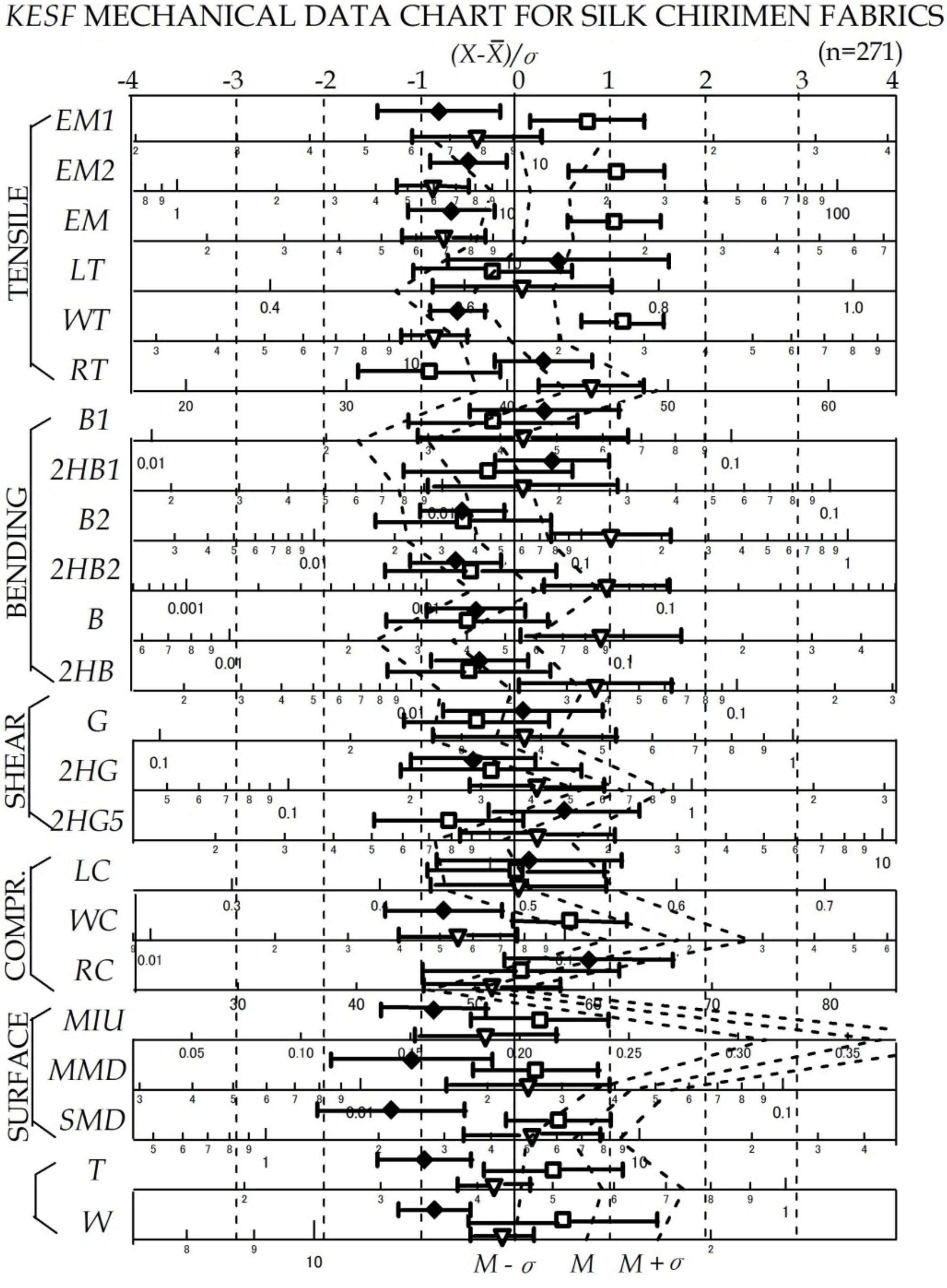
The key characteristics of the polyester Chirimen indicated by the dashed line in Fig. 2 are: 1. the values for bending rigidity and the hysteresis of warp direction of polyester Chirimen are low and it bends softly, 2. the values of hysteresis at shear angle ϕ=0.5°of polyester Chirimen are higher than those for silk Chirimen. Further, 3. the values of the surface properties of polyester Chirimen are higher than those for silk Chirimen, men's suiting, women's suiting, and dress shirt fabrics. In addition, 4. the thickness and the weight of the fabric is higher than that of silk Chirimen: When we wear it, we feel the weight. From this list, it should be clear that there are differences as well as similarities between polyester Chirimen and silk Chirimen. It is understood that the feature of polyester Chirimen distinguishing it from silk Chirimen is its ability to create a silhouette as clothing when used in clothing.

The mean value and the standard deviation of each Chirimen group are plotted in Fig. 3 and Fig. 4. The characteristic ranges of mechanical properties are shown for each group. The values of tensile properties *EM1*, *EM2*, *WT* of Hitokoshi Chirimen and Kodai Chirimen are high, as are those of the surface properties and the thickness and weight ; this is most likely due to the fact that there are crepes in the surface. Tensile resilience *RT* is low, the reason for these Chirimen shrinking easily. The values of the surface properties of Rinzu Chirimen are the lowest in the Chirimen groups, and its surfaces are the smoothest. On the other hand, Fuutsuu Chirimen is made from double-weave cloth, so the thickness values of the fabrics are high, and with the woven patterns brought into high relief, the coefficient of friction



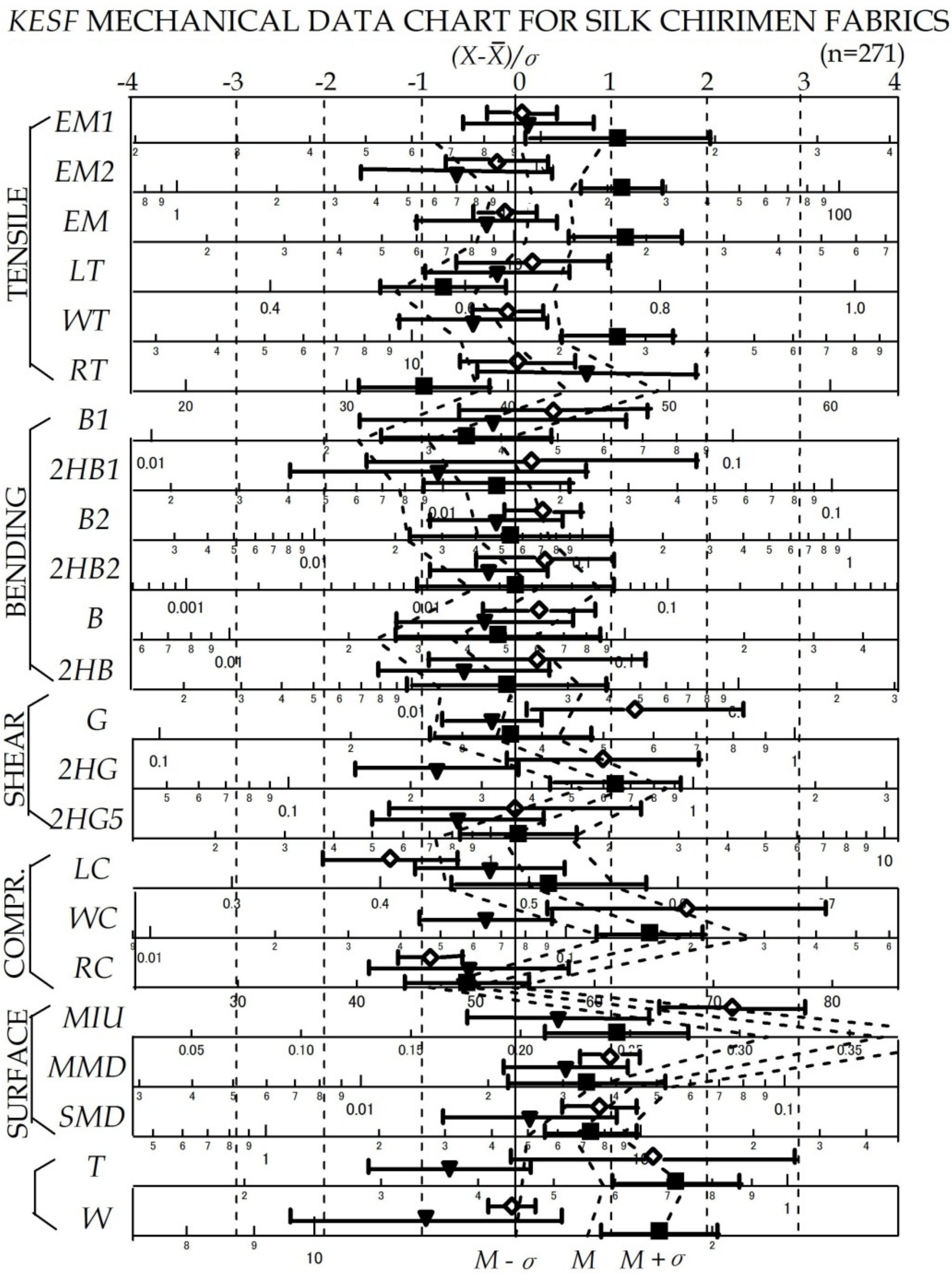
Suffix *1*: warp direction, suffix *2*: weft direction,
├─Δ─┤ **:** dress shirt (n=116), ├─⊗─┤ : women's suiting (n=220), ├─○─┤ **:** men's summer suiting (n=156), ├────┤ : mean value and ± standard deviation.
Men's winter suiting (n=214) is indicated by the solid line.
Polyester Chirimen (n=33) is indicated by the broken line.

Figure 2. The Mechanical properties of fabrics used in clothing in the west and polyester Chirimen fabrics



Suffix *1*: warp direction, suffix *2*: weft direction, ├─□─┤: Hitokoshi Chirimen (n=78), ├─∇─┤: Muji Isho Chirimen (n=76), ├─◆─┤: Rinzu Chirimen (n=63), ├───┤: mean value and ± standard deviation.
Polyester Chirimen (n=33) is indicated by the broken line.

Figure 3. The mechanical properties of Chirimen fabrics



Suffix *1*: warp direction, suffix *2*: weft direction, ├▼┤ : Kawari Muji Chirimen (n=14), ├■┤ : Kodai Chirimen (n=26), ├◇┤ : Fuutsuu Chirimen (n=6), ├──┤ : mean value and ± standard deviation.
Polyester Chirimen (n=33) is indicated by the broken line.

Figure 4. The mechanical properties of Chirimen fabrics

MIU is also high. Regarding Kawari Muji Chirimen, its thickness and weight values are low and it has the distinctive feature of lower-value tensile properties than those of Hitokoshi Chirimen and Kodai Chirimen. The values for the bending properties of weft direction of all Chirimen groups are at the same level, and they have a range corresponding to those of men's suit fabrics, women's suit fabrics and dress shirt fabrics; the values of tensile properties are at the same level as those for women's suit fabrics. This can be said to be a distinctive characteristic of Chirimen fabrics.

4.2. Hand value (*HV*) and formability

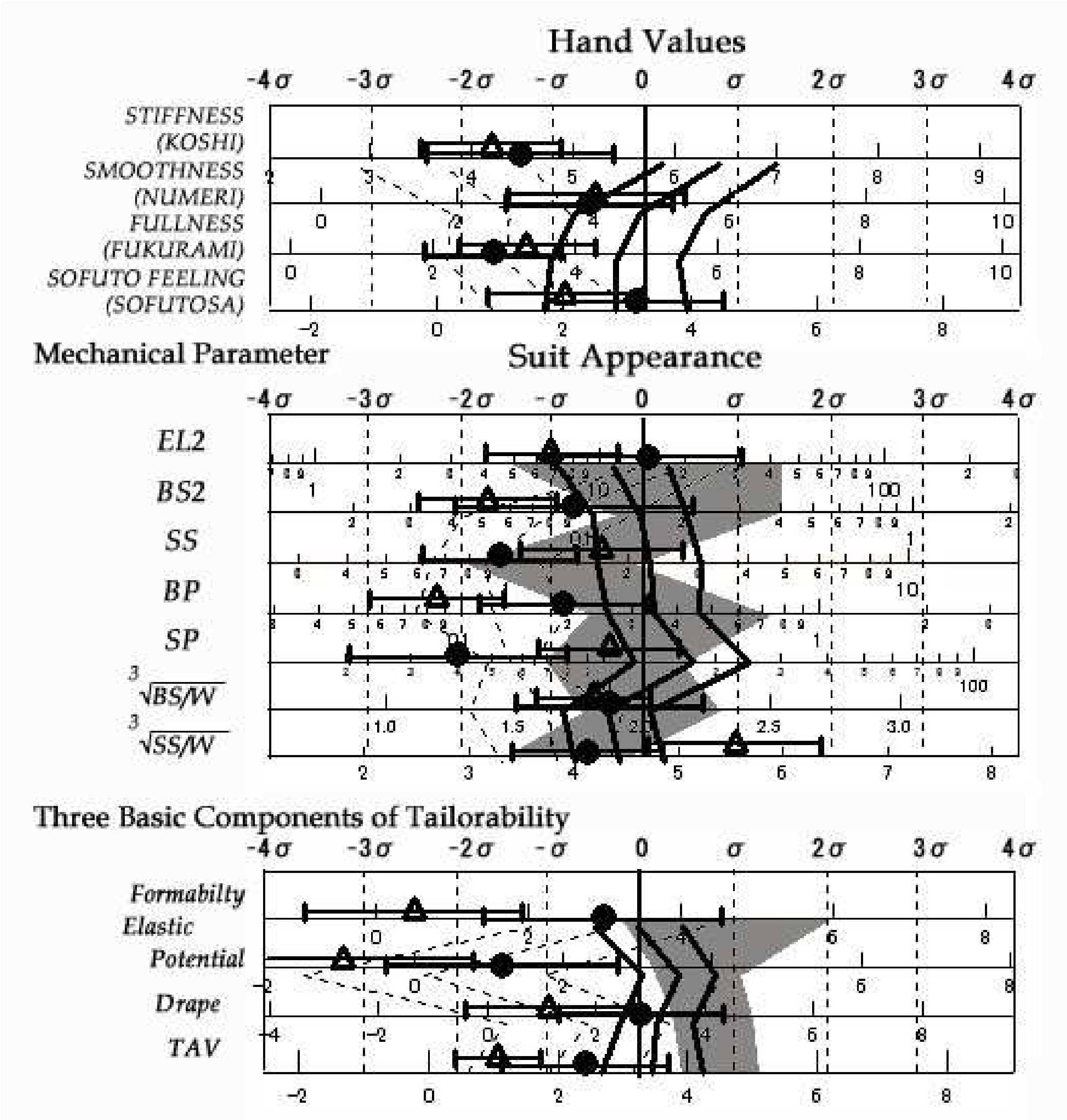
The criteria chart for ideal men's autumn/winter suiting (Kawabata et al., 2002) was normalized again using the mean value and the standard deviation for women's suit fabrics; the mean value and standard deviation for hand value and the mechanical parameters of suit appearance for all Chirimen groups were calculated using the *KN*201 equation (Kawabata, 1980) and are shown in Fig. 5. The values for *KOSHI*, *NUMERI* (smoothness) and *FUKURAMI* (fullness and softness) of silk Chirimen are at the same level as those of dress shirt fabrics, but the value for *SOFUTOSA* (soft feeling) is high, at the same level as the values for men's suit fabrics and women's suit fabrics. A distinctive characteristic here of Chirimen is that the values for mechanical parameters for suit appearance are within the range of those for ideal men's suiting, excluding *SP* (equation (5)). The values for the basic components of tailorability are located almost in the middle of the range for men's suit fabrics and dress shirt fabrics.

The mean value and the standard deviation for each Chirimen group are plotted in Fig. 6 and Fig. 7. Values for *KOSHI* and *SOFUTOSA* in each group are different, but the values for the mechanical parameters in each group are located within the range of those for ideal men's suiting (excluding *SP* and *BS*2). Values for the basic components of tailorability are slightly different from group to group: the drapability values for Muji Isho Chirimen are high, so it is possible that this type can create a beautiful silhouette; the formability and elastic potential values for Muji Isho Chirimen are higher than for other Chirimen groups, which accounts for the fact that Muji Isho Chirimen is used to make Tomesode (married women's formal kimono decorated with five crests and a pattern around the skirt, the highest-grade kimono and the most formal ceremonial dress) and Houmongi (kimono for formal visiting, quasi-ceremonial dress decorated with a full-body pattern).

4.3. Analysis of mechanical properties affecting hand evaluation

How the mechanical properties of Chirimen affect the criteria for subjective evaluation of hand evaluation was examined. First, 139 samples of Chirimen were chosen without disparity among groups from a total of 271 samples of silk Chirimen. 47 Hitokoshi Chirimen, 7 Kodai Chirimen, 7 Kawari Muji Chirimen, 40 Muji Isho Chirimen, and 38 Rinzu Chirimen were chosen.

The stepwise-block regression method was applied, using 19 characteristic values of six blocks of the mechanical properties—tensile, bending, surface, shearing, compression, and thickness & weight—and the mean value of each hand evaluation value was used as the subjective value (*KOSHI*, *TEKASA*). The regression equation is shown below.

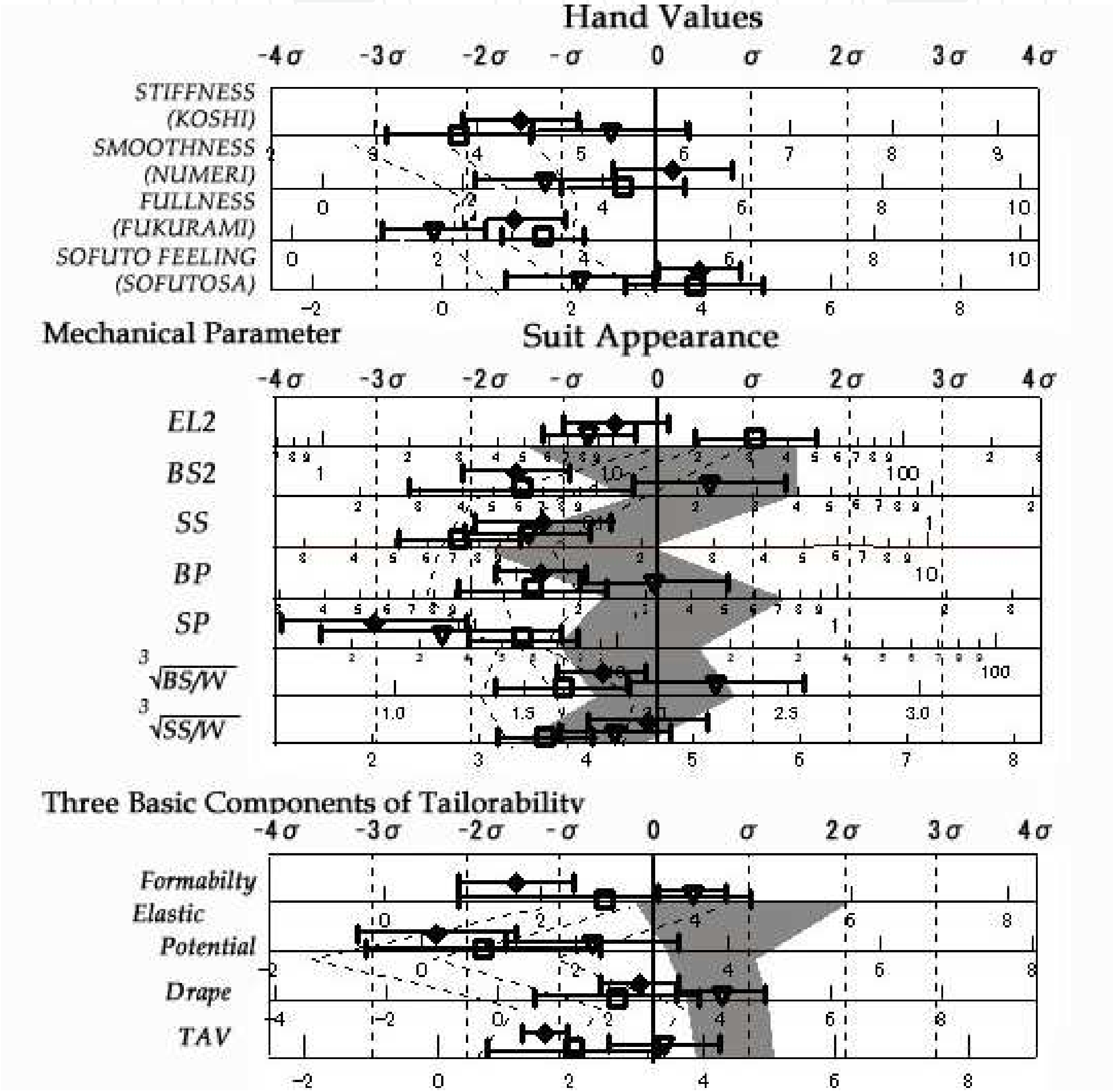


Suffix *1*: warp direction, suffix *2*: weft direction, ├─Δ─┤: dress shirt (n=116), ├─●─┤: silk Chirimen (n=271), ├───┤: mean value and ± standard deviation, men's winter suiting (n=214) is indicated by the solid line.
Polyester Chirimen (n=33) is indicated by the broken line.
Perfect property zone of men's suiting is indicated by the shaded zone.

Figure 5. Hand value and the mechanical parameters of Chirimen

$$HV = C_0 + \sum_{i=1}^{19} \left(C_{i1} \frac{X_i - M_{i1}}{\sigma_{i1}} + C_{i2} \frac{X_{i2} - M_{i2}}{\sigma_{i2}} \right) \quad (10)$$

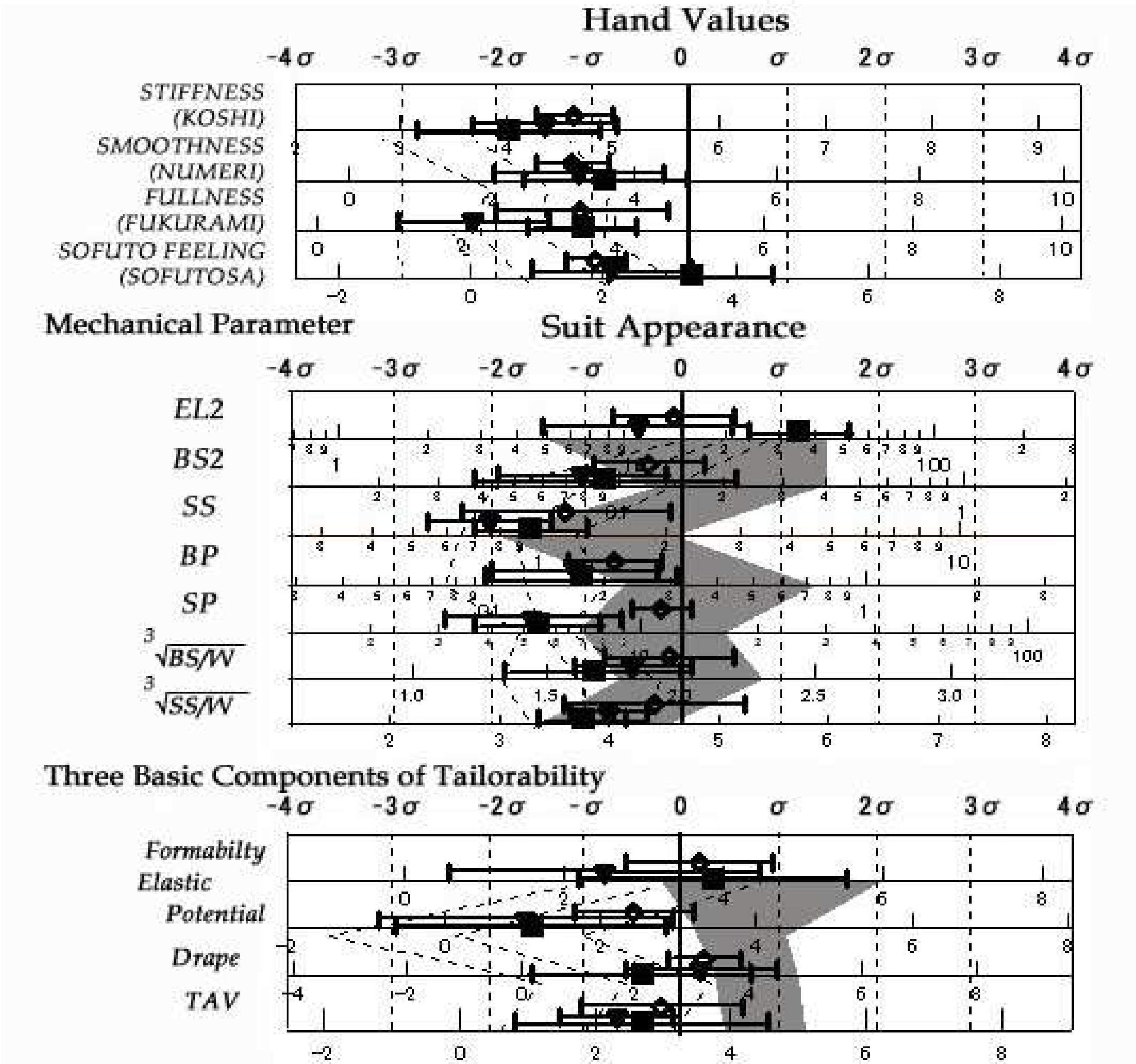
Where C_0, C_{i1}, C_{i2} = constant coefficients of the ith variable terms; X_i = mechanical property of the ith variable term M_{i1} ; σ_{i1} = the population mean and standard deviation M_{i2} ; σ_{i2} = the square mean and standard deviation (listed in Table 4). From this analysis, the order of the contribution to HV can be clarified, and we can discover the relationship between the criteria of subjective evaluation and the mechanical properties.



Suffix *1*: warp direction, suffix *2*: weft direction, ├□┤ : Hitokoshi Chirimen (n=78), ├▽┤ : Muji Isho Chirimen (n=76), ├◆┤ : Rinzu Chirimen (n=63), ├──┤ : mean value and ± standard deviation.
Polyester Chirimen (n=33) is indicated by the broken line.
Perfect property zone of men's suiting is indicated by the shaded zone.

Figure 6. Hand value and the mechanical parameters of Chirimen

The contributions of each characteristic block to hand value were examined; the contributions to *KOSHI* are shown in Fig. 8 and the contributions to *TEKASA* are shown in Fig. 9. The results were as follows: 1) the contributions of bending properties to *KOSHI* are significant, the multiple correlation coefficient being 0.742; 2) the bending properties of weft direction contribute more to *KOSHI* than those of warp direction, judging from the figures indicating contributions; 3) thickness & weight contribute to *KOSHI*, the close positive relationship between weight and *KOSHI* being particularly clear; 4) thickness & weight contribute significantly to *TEKASA*, while the other mechanical properties hardly contribute at all: *TEKASA* will be high when the thickness & weight values are high; 5) the subjective evaluation of *KOSHI* and *TEKASA* are especially affected by the thickness & weight of fabrics.



Suffix *1*: warp direction, suffix 2: weft direction, ├▼┤ : Kawari Muji Chirimen (n=14), ├■┤ : Kodai Chirimen (n=26), ├◇┤ : Fuutsuu Chirimen (n=6), ├──┤ : mean value and ± standard deviation.
Polyester Chirimen (n=33) is indicated by the broken line.
Perfect property zone of men's suiting is indicated by the shaded zone.

Figure 7. Hand value and the mechanical parameters of Chirimen

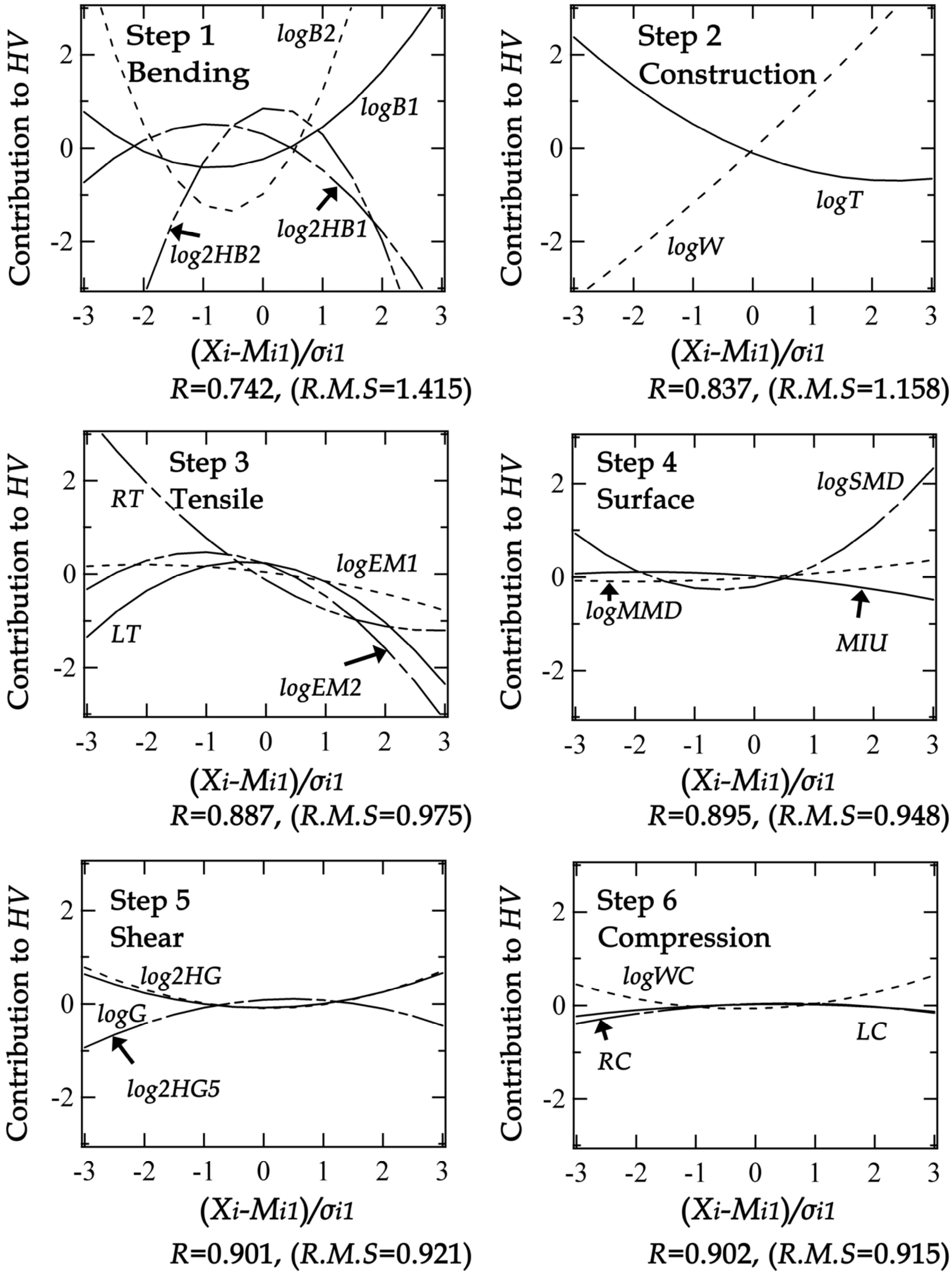
Table 4. Parameters for translating mechanical values into hand values for Chirimen fabrics

(a) C_{1i}, C_{2i} table

KOSHI			*TEKASA*		
Importance order *Xi*	C_0: 3.7821 C_{i1}	C_{i2}	Importance order *Xi*	C_0: 3.7755 C_{i1}	C_{i2}
1. Bending			1. Construction		
logB1	6.6610	6.4144	*logT*	1.2341	0.3498
logB2	7.7449	6.3543	*logW*	-7.0396	8.3058
log2HB1	-7.0768	-6.7456	2. Tensile		
log2HB2	-6.7346	-6.7956	*LT*	0.2771	-0.1679
2. Construction			*logEM1*	6.1277	-5.9271
logT	0.3426	0.8121	*logEM2*	-4.0092	3.6738
logW	-0.2476	1.4344	*RT*	0.0651	-0.4849
3. Tensile			3. Bending		
LT	3.8422	-3.9285	*logB1*	3.2375	3.1516
logEM1	0.7865	-0.9586	*logB2*	3.2438	2.3411
logEM2	2.4756	-3.0446	*log2HB1*	-5.8773	-5.8259
RT	-2.6962	1.8785	*log2HB2*	-5.1234	-4.0671
4. Surface			4. Surface		
MIU	0.1663	-0.2863	*MIU*	1.4497	-1.5179
logMMD	0.3402	0.2634	*logMMD*	1.1149	1.1132
logSMD	-0.6171	0.7915	*logSMD*	-0.1162	0.2109
5. Shear			5. Shear		
logG	0.7408	0.7425	*logG*	-0.3474	-0.2097
log2HG	0.4447	0.6033	*log2HG*	-0.3245	-0.2806
log2HG5	0.1643	-0.1160	*log2HG5*	0.0785	0.1211
6. Compression			6. Compression		
LC	0.4654	-0.4600	*LC*	0.3061	-0.3627
logWC	0.9128	0.8409	*logWC*	1.7455	1.7135
RC	0.5144	-0.5053	*RC*	0.0034	0.0438

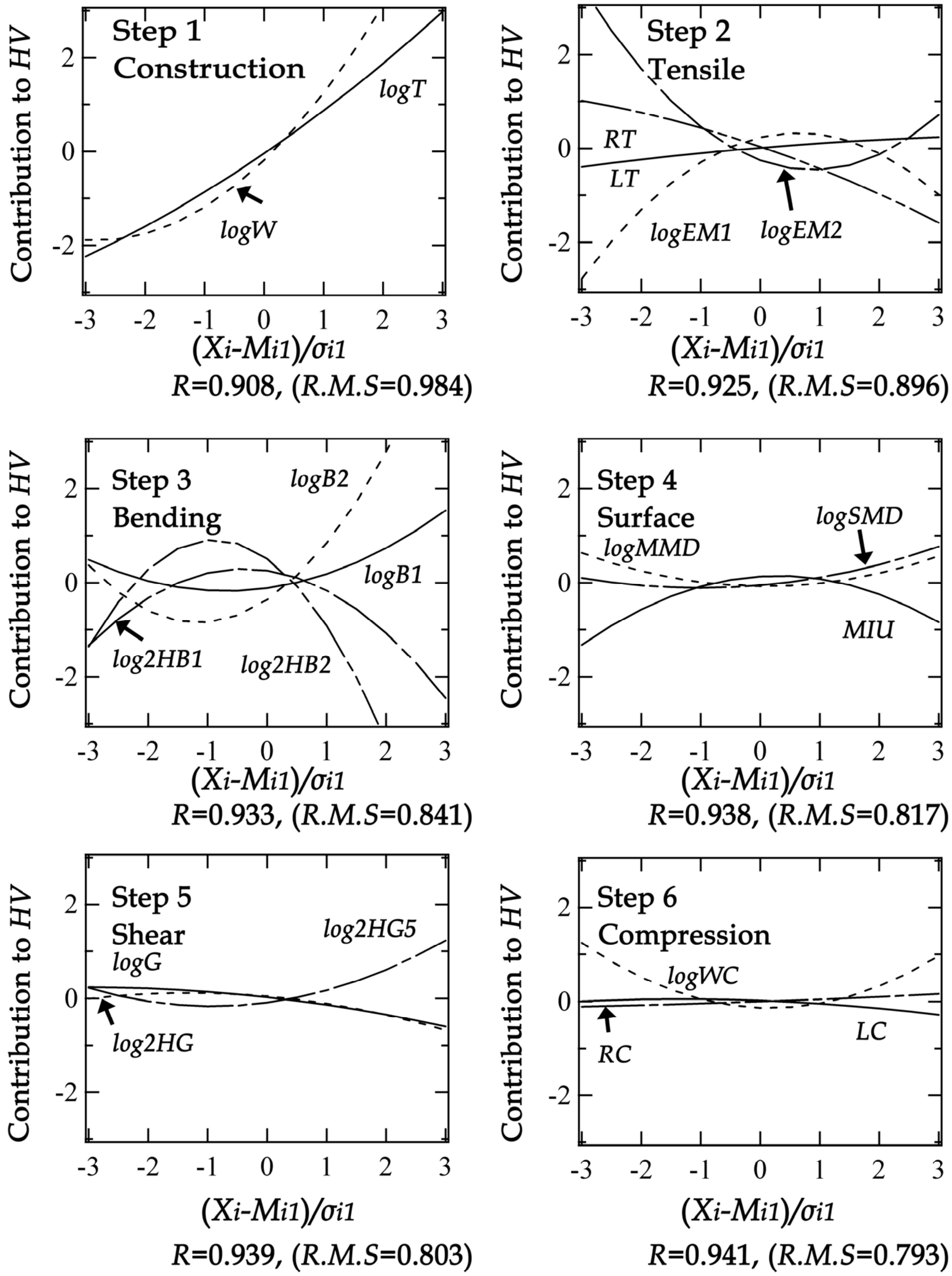
(b) M_{i1} M_{i2}, σ_{i1} and σ_{i2} table

Mechanical properties *Xi*	Chirimen fabrics (n=139) M_{i1}	M_{i2}	σ_{i1}	σ_{i2}
Tensile				
LT	0.7103	0.5112	0.0819	0.1140
logEM1	1.9060	3.6570	0.1536	0.5955
logEM2	1.9920	4.0520	0.2920	1.2029
RT	40.500	1672.0	5.7041	449.39
Bending				
logB1	-1.2750	1.6360	0.1042	0.2735
logB2	-1.1510	1.4460	0.3483	0.7825
log2HB1	-1.7040	2.9230	0.1433	0.4997
log2HB2	-1.5250	2.4630	0.3714	1.0944
Shear				
logG	-0.4257	0.1900	0.0935	0.0803
log2HG	-0.4486	0.2343	0.1819	0.2156
log2HG5	0.1141	0.0665	0.2313	0.0714
Compression				
LC	0.4772	0.2300	0.0480	0.0470
logWC	-1.2010	1.4760	0.1851	0.4252
RC	57.550	3380.0	8.2580	1008.4
Surface				
MIU	0.1765	0.0324	0.0349	0.0137
logMMD	-1.7330	3.0570	0.2299	0.7874
logSMD	0.5596	0.3851	0.2683	0.2791
Construction				
logT	-0.3769	0.1512	0.0959	0.0692
logW	1.1510	1.3280	0.0607	0.1404



(Number of samples =139, number of subjects =4, suffix *1* in the figure of tensile and bending properties: warp direction, suffix *2* in the figure of tensile and bending properties: weft direction.)

Figure 8. The contribution of each mechanical property to the hand value *KOSHI* of Chirimen



(Number of samples =139, number of subjects =4,
suffix *1* in the figure of tensile and bending properties: warp direction,
suffix *2* in the figure of tensile and bending properties: weft direction.)

Figure 9. The contribution of each mechanical property to the hand value *TEKASA* of Chirimen

5. Silhouette design of 'Chirimen' fabrics

5.1. Silhouette distribution of fabrics used in clothing in the west

The determination of silhouette design under standard conditions was also made for men's suiting (Kawabata, 1980); the results are shown in Fig. 10. The materials for men's suits were manufactured in Japan, and their sample values from 1980 were used for this analysis. Winter suits are either wool or blends, while those for summer use are also mainly wool or blends, with some linen or cotton. The center of gravity of the men's winter suiting is in almost the same area as that of ladies' suiting, but it is located away from the drape area, and is inclined in the direction of that for the *Hari* type.

Men's summer suiting is similar to the ladies' spring and summer suiting analyzed thus far (Inoue & Niwa, 2009), both being inclined in the direction of the *Hari* type. The difference between men's and ladies' suiting for spring and summer is that many ladies' silhouettes are located near the Drape type area (Inoue & Niwa, 2009), while men's silhouettes are away from the Drape type area. It was established that the silhouettes of men's suiting are distributed in the Tailored type area, in which silhouettes conform to the human's body shape, and in the direction of the *Hari* type area, in which silhouettes do not conform to the human's body shape.

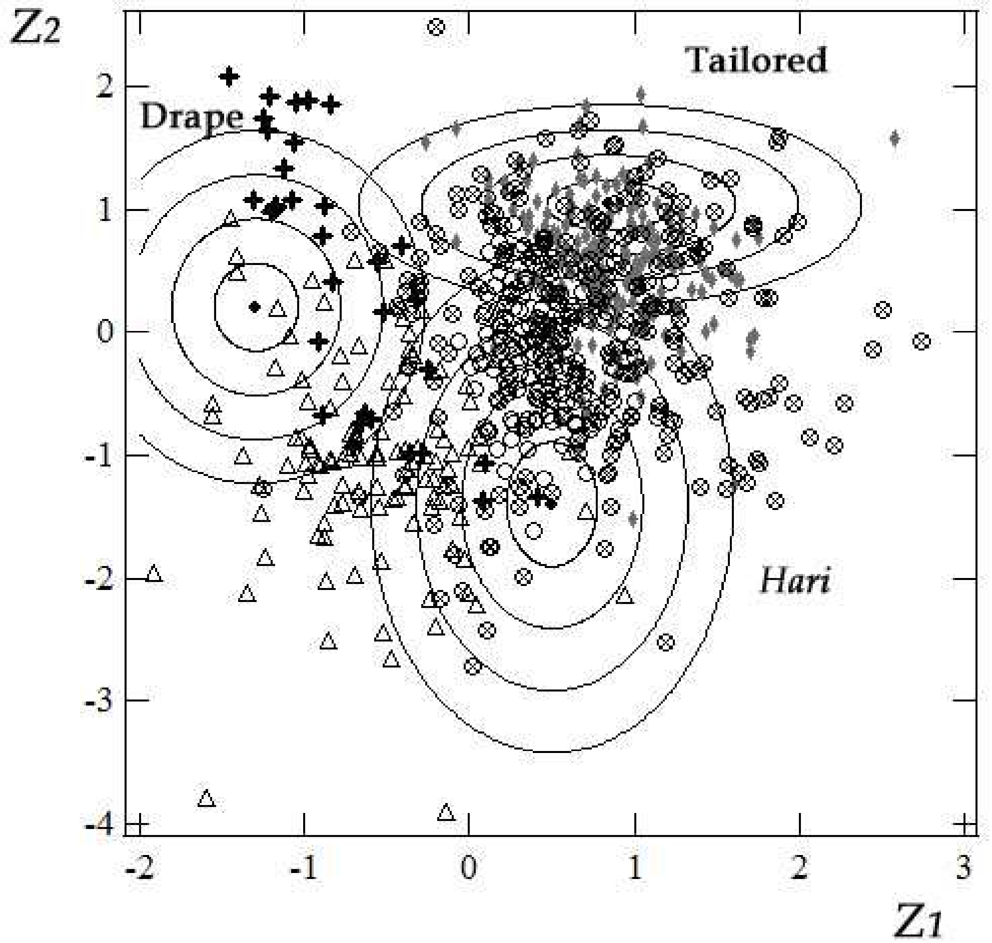
Fig. 10 also shows the distribution of the silhouettes of ladies' medium thick suiting (Kawabata, 1980) and dress shirt fabrics (Matsudaira et al., 1984). These fabrics were manufactured in Japan; the sample values used for this analysis are from the 1980s. The materials were either wool or blends in ladies' medium thick suiting, and cotton, silk, polyester, wool or blends in dress shirt fabrics. Ladies' suiting is totally different from men's suiting, having a wide distribution, and being in the area where the beauty of each silhouette can be demonstrated. The silhouette range of dress shirt fabrics is between the Drape type area and the *Hari* type area, and there is a wide distribution.

As a result of clarifying the silhouette area of each fabric for each purpose via the above analysis, it was established that the range of clothing that humans are comfortable with is narrow.

5.2. Silhouette distribution of 'Chirimen' fabrics

The 271 silk Chirimen fabrics and 33 polyester Chirimen fabrics were divided into three optimum silhouette design groups on the basis of their mechanical properties. Fig. 10 shows the Z_1-Z_2 values plotted for each silhouette type of polyester Chirimen fabrics; those for silk Chirimen fabrics are shown in Fig. 11. Each symbol plotted represents a separate type of Chirimen fabric.

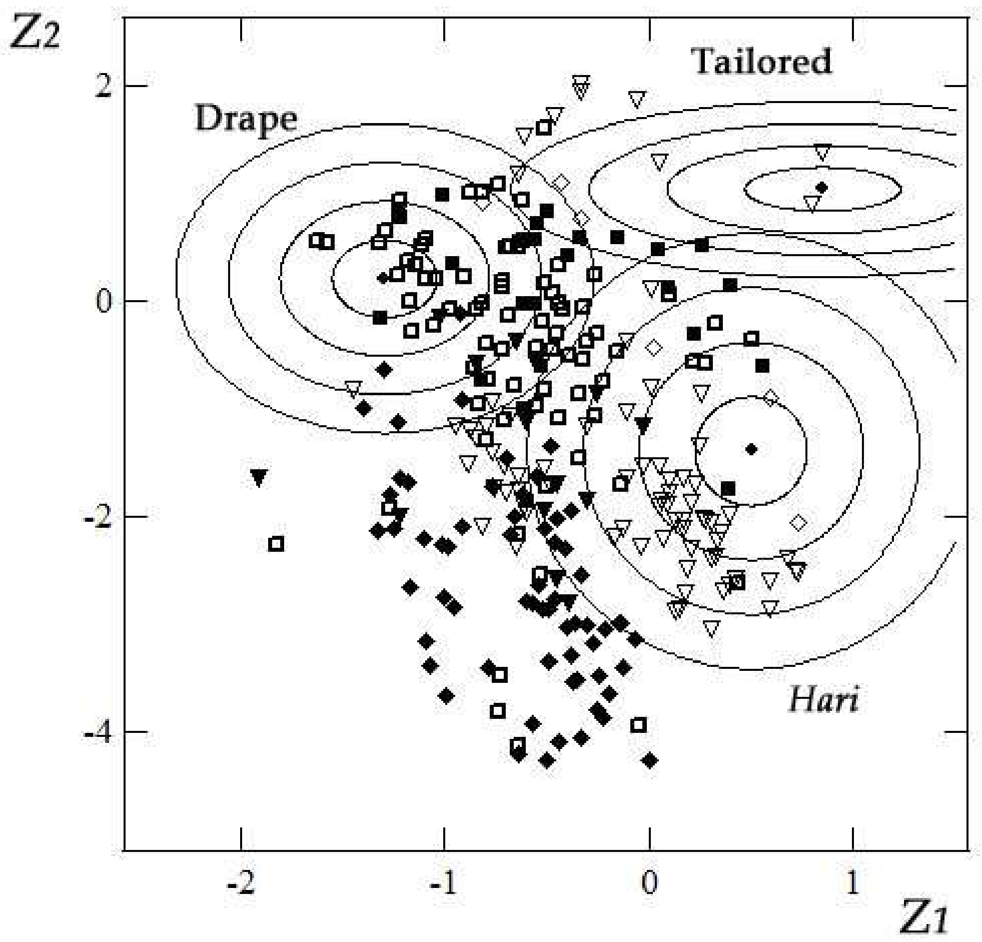
Chirimen fabrics are widely distributed in the range from Drape type to *Hari* type. Hitokoshi Chirimen fabrics are located towards the Drape type area, while Kodai Chirimen fabrics are inclined towards the Tailored type a little more than Hitokoshi Chirimen fabrics. Muji Isho Chirimen fabrics, meanwhile, are widely distributed in the range from *Hari* type to Drape type, although some are distributed in the range from Tailored type to Drape type. Rinzu Chirimen fabrics are also widely distributed in the range from *Hari* type to Drape type, but they tend to be further away from the center of gravity than the Muji Isho Chirimen fabrics. Chirimen fabrics are more widely distributed in the range from *Hari* type to Drape type than western fabrics used in clothing; their individual distribution areas have their own characteristic silhouettes depending on fabric type.



Men's winter suiting: ♦ (n=214), men's summer suiting : ○ (n=156),
Women's suiting : ⊗ (n=220), dress shirt: Δ(n=116), polyester Chirimen: + (n=33)

Figure 10. Determination of optimum silhouette design for fabrics used in clothing in the west and for polyester Chirimen fabrics, based on measurements made under standard conditions

The 33 polyester Chirimen fabrics used have silhouette areas largely overlapping with those of Hitokoshi Chirimen fabrics, but, unlike silk Chirimen fabrics, some of the polyester ones have silhouette distributions farther away from the center of gravity of the Drape type, and others have distributions which are located at the center of gravity of the *Hari* type. From this it is clear that, when used for making the traditional Japanese kimono, polyester Chirimen fabrics may not perform at the level of quality achievable with silk Chirimen ones, since it will yield different silhouettes, and cannot create the same unique atmosphere as the silk Chirimen fabrics can. On the positive side, however, the fact that polyester Chirimen fabrics will yield different silhouettes also means that it is possible with polyester Chirimen to express silhouettes which cannot be created with silk Chirimen.



Hitokoshi Chirimen: □ (n=78), Muji Isho Chirimen: ∇(n=76)
Rinzu Chirimen: ◆ (n=63), Kawari Muji Chirimen: ▼ (n=14)
Kodai Chirimen: ■ (n=26), Fuutsuu Chirimen: ◇(n=6)

Figure 11. Determination of optimum silhouette design for silk Chirimen fabrics based on measurements made under standard conditions

6. Conclusions

Japanese traditional 'Chirimen' fabrics are used for making kimonos, which have a fixed structure and are worn in very particular ways. These fabrics have also been used as dress fabrics in recent years. When the characteristics of the mechanical properties of various types of Chirimen were investigated to clarify differences in their hand value and appearance in clothing, the principal results were as follows.

1. Values for the weft direction of bending properties of all Chirimen groups, men and women's suit fabrics, and dress shirt fabrics were at the same level.

2. A significant feature of the mechanical parameters of each Chirimen group (excluding *SP* and *BS2* which are compound values of bending properties and shearing properties) was that they were in the range for ideal men's suiting.
3. Regarding hand value, '*KOSHI*' (stiffness) of Chirimen was found to be closely related to the bending properties, thickness and weight of the fabric, and '*TEKASA*' (hand quantity) of Chirimen was found to be closely related to the thickness and weight of the fabric.
4. When silhouettes were determined, the Chirimen fabrics were found to be widely distributed in the range from Drape type to Hari type, with their individual distribution areas having their own characteristic silhouettes depending on fabric type.
5. Differences in the silhouette designs of Chirimen fabrics and fabrics used in clothing in the West became clear.
6. The range of silhouette distribution for each kind of Chirimen fabric was clarified; this revealed that the silhouettes possible with Chirimen fabrics varied according to the type of Chirimen used.

It is hoped that the knowledge of the basic performance of Japanese traditional 'Chirimen' fabrics will help those in the industry recognize the importance of the mechanical properties of fabric, and further promote the designing of polyester 'Chirimen' fabrics.

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