Kansei Evaluation of Tactile Response to New Leather Textile Made
Using the NISHIJIN-ORI Technique

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Abstract

Nishijin-ori is a traditional yarn-dyed fabric of the Nishijin district in Kyoto, Japan. Since 1975, the number of Nishijin-ori companies, looms, employees, and total shipments has been shrinking. To generate new demand, a dramatic shift towards delivering value-added fabric products is required. The Nishijin district is renowned for its traditional technique called hikibaku, whereby Japanese washi paper is cut to a thickness of about 0.2 to 0.3 mm, and woven with the yarn in a weft direction. We applied this hikibaku technique to develop a fabric that incorporates cut leather instead of washi paper. The purpose of this study is to clarify the texture and physical properties of the new leather-silk woven hikibaku-leather fabric and demonstrate its advantages to pure cowhide. A questionnaire on tactile sensations was conducted on 26 men and women to determine the perceived texture of the fabric. Physical properties relating to the tactile sensation were then measured and compared with the questionnaire results. In order to obtain a guideline for the direction of future textile development that matches the assumed user's sensibilities, we first verified the correlation between the factor scores extracted from the Kansei (subjective response) evaluation, and the physical properties of the textiles. Next, we discerned the physical properties that should be focused on for each of the extracted factors and clarified the newly developed textile material in the extracted factor space.

Key Words: Textile, KES (Kawabata Evaluation System), Semantic differential method, Factor analysis

1. Introduction

Nishijin-ori is a traditional dyed textile of Nishijin district Kyoto. However, since 1975, the number of production companies, looms, employees, and the total shipment amount has been shrinking. The causes of the slump are long-term weakness after the economic bubble burst, rising raw silk prices due to the depreciation of the Japanese yen since 2013, aging of employees, and a lack of weavers [1]. Before the Meiji period (1868–1912), the obi (kimono belt), kimono, and kinran (golden brocade) divisions accounted for 90% of the products produced by the Nishijin-ori industry. Therefore, it can be said that each weaving shop specialized in a specific product [2]. For these reasons, it is extremely difficult for the textile machinery industry to change as a whole, and it is thought that the industry will continue to decline unless demand increases. Nishijin-ori employs a traditional technique called hikibaku [3]. This is a technique in which Japanese washi paper is cut to a fineness of about 0.2 to 0.3 mm and the thread-shaped Japanese paper is woven with yarn in a weft direction (Fig. 1 (a)). The cut Japanese washi paper may be colored and the texture is reflected in the fabric (Fig. 1 (b)).

We intended to create a new value-added fabric by applying the hikibaku technique and weaving cut leather instead of Japanese washi paper, to produce a high-end leather fabric. In this study, we used the Kansei engineering (referred to as ‘kansei’) evaluations and physical property tests to first see if the fabric created by weaving leather into silk fabric using the hikibaku technique (referred to as “hikibaku-leather”) offers new added-value, and to determine if it can replace existing leather products.

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the physical properties of the fabric. The fourth section discusses the relationship between physical properties and tactile sense evaluation, and the fifth section details our conclusion.

2. Experimental methods

2.1 The method of weaving leather into silk fabric using Hikibaku technique

The hikibaku technique was employed to weave leather into a fabric composed of silk yarn; cut leather was used in place of the washi paper (Fig. 1 (c)) and incorporated into the silk yarn structure using an automated hikibaku device which was attached to a jacquard loom. The jacquard loom used was a 90 cm wide loom from a company based in the Tango region of Kyoto prefecture. Fig. 2 shows the automated hikibaku device attached to the jacquard loom.

As the leather is several times thicker than the washi paper used for hikibaku (about 0.1 mm), there was an issue with wrinkles and distortions appearing in the weave. However, if the leather was thinned too much, the added softness caused twists that did not occur with Japanese washi paper. To mitigate these issues, we thinned the leather to a thickness of 0.4 mm.

In normal hikibaku, when washi paper is interlaced in a weft direction, it is smoothly woven with the yarn. Yet, as the back of the leather is finely brushed, causing friction, it could not be pulled in the same manner as the paper. Therefore, we attached a thin Japanese washi paper to the back of the leather before cutting it into thin pieces.

In the case of a normal drawing foil using washi paper, the paper is cut between 0.152 mm and 1.01 mm thick depending on the desired style and pattern. The thicker it is, the stronger the impression of Japanese paper is. As the impression formed by the material used is considered the novelty of the hikibaku technique we wanted the texture of the leather itself to be strongly reflected in the fabric. Therefore, we aimed for the thickest size possible without causing problems during the weaving process. As a result, a thickness of 1.317 mm, which is not normally used with washi paper was achieved.

| No. | Evaluation Term Pairs |
|-----|-----------------------|
| 1   | Bad                   | Good                      |
| 2   | Simple                | Complex                   |
| 3   | Unattractive          | Attractive                |
| 4   | Bland                 | Charming                  |
| 5   | Hard                  | Soft                      |
| 6   | Thin                  | Thick                     |
| 7   | Tacky                 | Luxurious                 |
| 8   | Masculine             | Feminine                  |
| 9   | Rough                 | Smooth                    |
| 10  | Ordinary              | Unique                    |
| 11  | Cold                  | Warm                      |
| 12  | Weak                  | Strong                    |
| 13  | Artificial            | Natural                   |
| 14  | Light                 | Heavy                     |
| 15  | Stiff                 | Elastic                   |
| 16  | Non-resilient         | Resilient                 |
2.2 Kansei evaluation experiments (Subjective response)

2.2.1 Selection of evaluation term pairs for semantic differential method

We used evaluation terms for clothing, belts, and leather products taken from reference material [4-7] to evaluate our leather-silk woven fabrics (hikibaku-leather) and pure cowhide. Next, we asked the developer of the sample to select the evaluation words to be used in the experiment and made 16 pairs for tactile sensation (Table 1).

2.2.2 Samples for evaluations

Here, the following three kinds of fabrics were prepared as samples and compared. Sample A was pure cowhide used for the foil, Sample B was our new hikibaku-leather fabric without jacquard pattern, and Sample C was our new hikibaku-leather fabric with a twill weave and jacquard pattern. Samples A, B, and C were cut into 30 cm squares and used for the evaluation experiments (Fig. 3 (a) - (c)). Table 2 shows the manufacturing conditions for each sample.

![Sample Images](a) Sample A (pure cowhide before cutting). (b) Sample B: Hikibaku-leather (Silk fabric woven with cowhide leather; no jacquard pattern). (c) Sample C: Hikibaku-leather (Silk fabric woven with cowhide leather; jacquard pattern).

![Table 2 Sample production conditions.](Table 2 Sample production conditions.)

| Dough composition          | Sample A                      | Sample B                                      | Sample C                                      |
|----------------------------|-------------------------------|-----------------------------------------------|-----------------------------------------------|
| Dough composition          | Natural pure cowhide          | Without Jacquard Pattern                      | With Jacquard Pattern (Sayagata)              |
|                            | White pigment finish          |                                               |                                               |
|                            | For volleyball shoes          |                                               |                                               |
|                            | Shaving process (0.6mm)       |                                               |                                               |
|                            | Half-cutting (about 250ds)    |                                               |                                               |
|                            | ※ ds = dm²                    |                                               |                                               |
| Hikibaku material          | Not applicable                | Natural pure cowhide                          | Same as Sample B                              |
|                            |                               | White pigment finish                          |                                               |
|                            |                               | For volleyball shoes                          |                                               |
|                            |                               | Shaving process (0.6mm)                        |                                               |
|                            |                               | Cutting (w1:1.01mm)                           |                                               |
|                            |                               | Silk                                          |                                               |
| Warp                       | Not applicable                | White dying                                   | Same as Sample B                              |
|                            |                               | 252 Deniers                                   |                                               |
|                            |                               | Silk                                          |                                               |
| Ground weft                | Not applicable                | White dying                                   | Same as Sample B                              |
|                            |                               | 84 Deniers                                    |                                               |
|                            |                               | Silver thread                                 | Same as Sample B                              |
|                            |                               | 100 Deniers                                   | Same as Sample B                              |
| Figure weft                | Not applicable                | (Asahi Kasei Bemberg with Japanese paper and    | ※ For jacquard pattern                         |
|                            |                               | polyester film deposited on aluminum)         |                                               |
|                            |                               | ※ For fabric backing                          |                                               |
Figs. 4 (a) and (b) show the weave of Sample B and C, respectively. In Sample B, three warps are straddled by washi paper-backed leather and one warp straddles washi paper-backed leather repeatedly using the hikibaku technique. Two figure wefts and two ground wefts are also intertwined with the warp threads between the washi paper-backed leather, as shown in Fig. 4 (a). In the jacquard pattern part of Sample C shown in Fig. 4 (b), three warps straddle the washi paper-backed leather to expose more figure warps, creating the jacquard pattern and appearance. Thereafter, the structure is almost the same as in Sample B. Consequently, the weave densities of Sample B and C (excluding the leather) are equal: weft density of 16.67 threads per cm, warp density of 14.19 threads per cm. When calculating with the washi paper-backed leather, which has a density of 6.5 threads per cm to the warp direction, the total weft density amounts to 20.69 threads per cm.

2.2.3 Kansei evaluation methods

(1) Experimental environment

Tactile sense evaluation experiments were conducted on the above mentioned three samples using the evaluation terms in Table 1. To assume a general living environment, the evaluation was performed under a white fluorescent lamp, and a table (approximately 66 cm high) covered with gray fabric was used as a test bench.

(2) Tactile sense evaluation

The experiment was conducted on 26 male and female subjects (18 females and 8 males) aged 22 to 77 years. The subjects were divided into two groups: a younger group and an older group. In the younger group, there were eight male and one female (Ages: $M = 24.3, SD = 1.7$), and in the older group, there were 17 females (ages: $M = 64.3, SD = 9.4$). As the fabrics are intended for use as cushions and other interiors, the three samples were placed over white square cushions of approximately 26 cm x 26 cm on the test bench (Fig. 5 (a)). The inside of the cushion was filled with polyester cotton with the thickest section measuring about 50 mm thick. The two corners of the fabric were fixed with thread so that the sample and the cushion did not shift. In the tactile sense evaluation, each sample was covered with a white box to reduce the influence of the visual senses. A white cloth curtain was installed on the front of the box, and the subject inserted his/her hand through the curtain for evaluation as shown in Fig. 5 (b). The samples were placed on the cushion with the warp yarn facing in the vertical direction and the weft yarn in the horizontal direction when viewed by the subjects. The subjects were instructed to touch the fabric at their leisure. Subjects were allowed to touch only the surface of the fabric.
evaluation order was set randomly to ensure that there was no order effect. The subjects evaluated the tactile sensation of each sample and immediately wrote their result for each sample on the evaluation sheet provided. A semantic differential method of 7-step evaluation based on the reference [8-10] was used. The subjects chose one answer from each of the 16 pairs of evaluation words for tactile sensation for each of the three samples using a mark sheet. The subjects were given a sufficient explanation before the evaluation.

(4) Data analysis

The adjective on the left side of the evaluation word pair for each sample was set as the negative scoring side, and the right side was set as the positive scoring side and rated from -3 to +3. Then, a factor analysis with maximum likelihood method and varimax rotation was performed on the obtained evaluation scores using SPSS. Then, a multiple test was performed on the average value of the factor scores for each sample, and a significant difference between the results was confirmed for each sample. The factor analysis results of the younger group and the older group was then compared using the 2-way ANOVA.

2.3 Measurement of physical properties related to tactile sense

The physical properties of compression (Thickness, WC, LC, and RC), mean deviation of surface roughness (SMD), average friction coefficient (MIU), and its variation (MMD) related to the tactile sensation of Samples A, B and C were measured using: a KES-G5 handy compression tester for WC, LC, and RC; a KES-SE-STP surface tester for SMD; and a KES-SE friction tester for MIU and MMD. The measurement was performed in the laboratory of the Kyoto Institute of Technology. The physical properties were measured under the default condition settings for KES evaluations. Table 3 shows the measurement conditions for each property. The measurement was performed 3 times, with the cloth placed in different locations, and the average value was obtained.

### Table 3 Physical property measurement conditions.

| Test Type                  | Conditions                                                                 |
|----------------------------|-----------------------------------------------------------------------------|
| Compression test           | Maximum load: 50 gf/cm²  
Speed: 0.02 mm/sec 
Shape of compression attachment: Round 
Compressed area: 2 cm² |
| Surface friction test      | Speed: 1 mm/sec  
Shape of friction attachment: 10 mm×10 mm  
(10mm wide wire side by side, shape resembling a fingerprint)  
Initial load: 50 gf 
Effective length: 4 cm |
| Surface roughness test     | Speed: 1 mm/sec  
Shape of attachment: 1 wire, 5mm wide  
Initial load: 10 gf 
Effective length: 2 cm |

3. Experimental results

3.1 Kansei evaluation results

Kansei evaluations were conducted on January 16, 2020 for all the older group and one of the subjects from the younger group. The remaining evaluations for the younger group were conducted successively between 16 and 31 January, 2020 in order of the subjects’ readiness. The laboratory was air-conditioned at a setting of 22 °C. No humidifier was used. The average of temperature, minimum temperature, and maximum temperature in January 2020, when the experiment was conducted, were 7.5 °C, 4.3 °C, and 11.2 °C, respectively. The average humidity was 70 %.

The results of the Kansei evaluation experiment using the semantic differential (SD) method in section 2.2 are shown in the following Fig. 6 for tactile sensation. The average score of the questionnaire results of 26 subjects was color-coded for each

![Fig. 6 Average of tactile evaluation scores.](image-url)
sample in each evaluation.

3.2 Factor analysis results

Table 4 shows the results of factor analysis on the evaluation scores obtained in 2.2.3 (2). From the results in Table 4, it was found that the tactile sensation of three samples can be explained by the six factors. We chose these factors because their eigenvalues were higher than one. We named each of the obtained factors as shown in Table 5. The cumulative sum of the percentage of the loading factors after varimax rotation was 56.7 % for the 6 factors. Table 6 and Fig. 7 show the average values of the factor scores obtained for each sample. Also, the factor scores of Samples A, B, and C were subjected to a multiple test using a one-way analysis of variance for each factor. At the significance level of less than 5 %, a significant difference was seen between the factor scores of A vs. B and A vs. C in Factor 1.

Next, we compared the factor analysis results between the younger group and the older group using the 2-way ANOVA. Significant differences were confirmed in the main effects between samples and the interaction between samples and age groups for Factor 1. Therefore, we examined the simple main effect in each sample and age group for this factor. The values of B and C were significantly higher than those of Sample A for all age groups (p < 0.01). In Sample A, the value in the elderly group was significantly large (p < 0.01), while in Samples B and C, the value in the young group was significantly low (p < 0.01). For Factors 2 and 4, a significant difference was found in the main effect of the age groups (p < 0.05). A post-hoc test revealed that the elderly group had a

| Factor NO. | Factor Name   |
|------------|---------------|
| 1          | Originality   |
| 2          | Strong Impression |
| 3          | Attractiveness |
| 4          | Solid Form    |
| 5          | Stability     |
| 6          | Femininity    |

Table 4 Factor matrix after rotation.

|                | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 |
|----------------|----------|----------|----------|----------|----------|----------|
| Simple - Complex | 0.785    | 0.049    | 0.148    | 0.104    | -0.019   | -0.019   |
| Rough - Smooth   | -0.76    | 0.11     | -0.008   | 0.108    | 0.287    | 0.193    |
| Ordinary - Unique| 0.44     | 0.242    | -0.116   | 0.074    | 0.073    | 0.046    |
| Light - Heavy    | 0.055    | 0.771    | 0.013    | 0.112    | 0.088    | -0.082   |
| Thin - Thick     | 0.066    | 0.656    | -0.003   | -0.013   | 0.049    | 0.001    |
| Weak - Strong    | 0.044    | 0.447    | 0.26     | -0.182   | -0.096   | 0.069    |
| Hand - Charming  | 0.2      | -0.018   | 0.931    | 0.114    | 0.148    | 0.065    |
| Unattractive - Attractive | -0.274 | 0.256 | 0.475 | 0.089 | 0.443 | 0.164 |
| Tacky - Luxurious | -0.124 | 0.419 | 0.463 | 0.046 | 0.171 | 0.117 |
| Stiff - Elastic  | 0.051    | 0.059    | 0.036    | 0.932    | 0.065    | 0.345    |
| Artificial - Natural | 0.039 | -0.059 | 0.036 | 0.576 | 0.035 | -0.137 |
| Bad - Good        | -0.363   | 0.031    | 0.01     | 0.119    | 0.615    | -0.03     |
| Hard - Soft       | -0.124   | -0.158   | 0.138    | 0.148    | 0.531    | 0.39      |
| Cold - Warm       | 0.259    | 0.098    | 0.11     | -0.096   | 0.512    | 0.098     |
| Non-resilient - Resilient | -0.046 | 0.099 | 0.143 | 0.333 | 0.364 | -0.043 |
| Masculine - Feminine | -0.065 | 0.022 | 0.123 | -0.014 | 0.117 | 0.982 |

Factor Extraction Method: Maximum likelihood
Rotation Method: Varimax Rotation with Kaiser Normalization

Table 5 Name of each extracted factor.

| Factor NO. | Factor Name |
|------------|-------------|
| 1          | Originality |
| 2          | Strong Impression |
| 3          | Attractiveness |
| 4          | Solid Form |
| 5          | Stability |
| 6          | Femininity |

Table 6 Average of factor scores of each sample.

| Sample      | Factor 1 | Factor 2 | Factor 3 | Factor 4 | Factor 5 | Factor 6 |
|-------------|----------|----------|----------|----------|----------|----------|
| Sample A    | -0.914   | 0.00412  | -0.163   | -0.256   | 0.192    | 0.180    |
| Sample B    | 0.437    | -0.139   | -0.0898  | -0.129   | -0.0280  | 0.112    |
| Sample C    | 0.478    | 0.135    | 0.253    | 0.384    | -0.164   | -0.292   |

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significantly higher evaluation than the young group, regardless of the sample (p < 0.05). For Factors 3, 5 and 6, no significant deference was found in the main effect of samples and age groups, and interaction between them. In summary, in Factor 1 (Originality) there was a significant difference in the factor scores between the younger and the older groups, but the evaluation tendency was similar between the two. For Factor 2 (“Strong Impression”) and Factor 4 (“Solid Form”), there was no observable main effects in the evaluation between the samples. However, the older group evaluated all samples higher than the younger group.

3.3 Measurement results of physical properties related to tactile sensation

The physical properties were measured on December 4, 2019. The test room was air-conditioned at a setting of 22 °C. No humidifier was used. The average of temperature, minimum temperature, and maximum temperature in December 2019, when the experiment was conducted, were 8.3 °C, 4.7 °C, and 12.3 °C, respectively. The average humidity was 67%.

As shown in Figs. 4 (a) and (b), while Sample C features thin patterns created by exposing a silver thread over a few warp threads, the fabric is composed mostly of the leather-silk woven part also used in Sample B. Therefore, the difference in tactile sensation between Samples B and C was considered to result from the jacquard pattern part. The physical properties were measured according to this hypothesis. In addition, as it was difficult to get a sufficient length of the sample material with the jacquard pattern part to the weft and warp direction, we measured only in the direction that the jacquard pattern appears (see Fig.3 (c)).

(1) Measurement results of thickness, WC, LC, and RC

The results of Thickness, WC, LC, and RC performed on each
sample are shown in Figs. 8 (a) – (d). In consideration of the pattern of jacquard, Sample C was measured separately for the leather part and the pattern part. In addition, multiple tests were conducted between samples. The characteristics with significant differences are indicated with an asterisk (*).

(2) Measurement results of SMD, MIU, and MMD

Figs. 9 (a) – (c) show the results of SMD, MIU, and MMD for each of the samples. Sample A was the pre-cut pure cowhide. As it was assumed that the surface properties were independent of the direction, only one direction was measured. In Sample B, however, both the warp and weft directions were measured due to the defined variances in the surface characteristics between the two. When comparing Sample C and Sample B, the difference in surface properties appeared only in the jacquard pattern parts of Sample C, so the jacquard pattern parts was selectively measured. Multiple tests were also conducted between samples. The characteristics with significant differences are indicated with an asterisk. There was no significant difference in MIU.

4. Discussion

4.1 Kansei evaluation

Only Factor 1 named “Originality” showed a significant difference in the factor scores among the three samples. Furthermore, there was no significant difference between B and C in terms of tactile sensation. From this point, it can be said that the jacquard pattern made of silver thread has a minimal influence on tactile sensation. The difference in the texture of the fabric between A and B was that A had a uniform surface, while B had a rough surface where thin cuts of cowhide leather were woven with silk thread. These differences are thought to be reflected in the evaluation words: “Complex”, “Rough”, and “Unique” which were strongly related to Factor 1. Furthermore, as there was no significant difference between the samples for Factors 2 to 6 (Fig.6), it can be said that there was no change of tactile sensation for “Strong Impression”, “Attractiveness”, “Solid form”, and so on. Therefore, hikibaku-leather fabric created utilizing the hikibaku technique can replace pure cowhide by adding a sense of “Originality” to interior products such as a cushion, and sofas. It may also be used as a product that comes into contact with the body, such as car seats. We also investigated the differences in the Kansei evaluation results between the age groups and found that the younger and the older groups has the same evaluation tendencies in Factor 1. However, in Factors 2 and 4, the older group gave a higher evaluation than the younger groups for all samples.

4.2 Physical properties related to tactile sensation

Significant differences in physical properties were confirmed between Samples A and B, and B and C in all items of the compression test. A significant difference was confirmed between B and C (jacquard pattern part) for WC and RC. In the surface properties, significant differences were found in SMD between all samples except between B (warp) and C (jacquard pattern part). And, in MMD between Samples A and B (weft), and between C (jacquard pattern part) and B (warp).

Although the number of samples was limited, the following trends were observed when evaluating the relationship between the results of the factor analysis and the results from measuring the
physical properties as shown in next section.

4.3 Relationship between Kansei evaluation results and physical properties

Table 7 shows the findings on the correlation coefficients between the mean values of factor scores for each factor and the mean values of the measured compression properties of each sample. Table 8 shows the findings on the correlation coefficients between the mean value of factor scores for each factor and the mean value of the measured surface properties of each sample. As shown in Table 7, correlations were found with all factors for Thickness, WC, and LC. Positive correlations were found for Factors 1 to 4 and negative correlations for Factors 5 and 6. The association of soft and thin materials with “Femininity” and “Stability” aligns with our expected outcome and supposed common thinking. As for RC, the positive and negative correlations were reversed between “Originality” and “Strong impression”. It is presumed that the high resilience of the material provoked a strong sense of originality together with tensile springy qualities.

For the measured surface properties, the correlation coefficient was relatively higher when the value of Sample B (weft) was used than when the value of Sample B (warp) was used as shown in Table 8. The reason for this is described below. The surface properties in the weft direction of Sample B were almost identical to those of Sample A. Consequently, the regression line connected at two points surrounding the measurement values of Sample A and Sample B (warp) and the measurement value of Sample C (jacquard pattern part). Therefore, we believe it appropriate to discuss the correlation between Kansei (subjective response) evaluation and surface properties in Sample B (warp). “Originality” was found to have a strong positive correlation (>0.7) with all surface properties, while the other factors had a strong correlation with only one property. The trends of rest factors can be summarized as follows.

- The lower the MMU was, the higher the “Strong Impression”.
- The higher the MMU was, the higher the “Attractiveness” and “Solid Form.”
- The lower the SMD was, the higher the “Stability.”
- The lower the MIU was, the higher the “Femininity.”

These results are expected to serve as a guideline for what physical properties should be focused on in material development in the future, depending on the concept and aims of the developer.

On the other hand, when characterizing the new textiles made from weaving cowhide leather into silks using the hikibaku technique we focused on Factor 1 (“Originality”), which was significantly different between samples, and the relationship between the physical properties and the subjective impressions of the textiles.

Table 7  Correlation between factor scores and compression properties.

| Factor | Thickness | WC | LC | RC |
|--------|-----------|----|----|----|
| Factor 1 (“Originality”) | 0.88 | 0.80 | 0.93 | 0.73 |
| Factor 2 (“Strong Impression”) | 0.47 | 0.59 | 0.37 | -0.69 |
| Factor 3 (“Attractiveness”) | 0.93 | 0.98 | 0.89 | -0.04 |
| Factor 4 (“Solid Form”) | 0.94 | 0.98 | 0.90 | -0.02 |
| Factor 5 (“Stability”) | -0.99 | -0.96 | -1.00 | -0.44 |
| Factor 6 (“Femininity”) | -0.92 | -0.97 | -0.87 | 0.07 |

Table 8  Correlation between factor scores and surface properties.

| Factor 1 (“Originality”) | In the Case of Sample B (Weft) | In the Case of Sample B (Warp) |
|--------------------------|-------------------------------|-------------------------------|
| SMD | MIU | MMU | SMD | MIU | MMU |
| Factor 2 (“Strong Impression”) | 0.99 | 0.56 | 1.0 | 0.89 | 0.95 | 0.70 |
| Factor 3 (“Attractiveness”) | 0.01 | 0.83 | 0.07 | -0.46 | 0.31 | -0.71 |
| Factor 4 (“Solid Form”) | 0.66 | 0.99 | 0.71 | 0.23 | 0.85 | -0.08 |
| Factor 5 (“Stability”) | 0.68 | 0.99 | 0.72 | 0.25 | 0.87 | -0.06 |
| Factor 6 (“Femininity”) | -0.94 | -0.82 | -0.96 | -0.67 | -1.00 | -0.40 |
| Factor 1 (“Originality”) | -0.64 | -1.0 | -0.69 | -0.20 | -0.84 | 0.11 |
Table 9 shows the results of Factor 1 and compression test side by side. Numerical values indicate the rank based on the significant difference of the average value of each. Since the leather parts of Samples B and C have the same woven structure, their physical properties are classified in the same rank. Although there is a difference in rank of the physical properties between B and C in regard to the jacquard pattern part, as there is no difference in ranks between B and C in the Kansei evaluation, it is considered that the jacquard pattern part had no effect. Table 10 shows the results of Factor 1 and the surface properties side by side. The surface properties of weft and warp directions without the jacquard pattern part of Sample C are the same as those of B, and therefore were not measured. It is considered that the difference between SMD greatly affects the difference of Kansei evaluation. In particular, it seems that the deviation in the warp direction has a great influence. Regarding MMU, it is considered that the variation in the warp direction also caused the difference between samples in the Kansei evaluation.

While no significant differences were found, Sample C comparatively had higher mean factor scores of "Attractiveness" and "Solid Form" and low means scores for "Stability", "Femininity". This offers opportunity for further review into whether these characteristics are appropriate for the intended user group of this new textile material.

5. Conclusions and future work

In this study, we developed new textile by weaving thinly cut cowhide leather into silk fabric and investigated its market potential by evaluating tactile sensation using the Kansei engineering evaluation method and measuring the physical properties. First, each sample was evaluated by the factors extracted from the Kansei evaluation and the mean of the factor scores for these materials were compared. The only significant difference was found in Factor 1 ("Originality"). The physical properties of each sample were then measured and the correlations between the means of the factor scores and the physical properties were then analyzed to reveal the physical properties that were strongly associated with each factor. This result is expected to offer a valuable indication of the physical properties that should be focused on when developing new materials for targeted users. Furthermore, the results showed that the hikibaku leather textile elicited a high sense of "Originality" compared to pure cowhide; indicating a high potential to replace the pure cowhide products. Our results when measuring of the physical properties, strongly indicate that the "Originality," compared to pure cowhide, was achieved from all the compression properties, SMD and MMU; especially in the warp direction of the samples.

In the future, we will conduct a both a visual sensation evaluation and a physical property measurement experiment related to visual sensation, and investigate the relationship between the two. Since jacquard patterns include many elements such as colors, shapes, and fabric texture, it is necessary to prepare and compare various samples of jacquard patterns. In this study, we conducted a simple comparison between pure cowhide and our jacquard hikibaku-leather fabric. Therefore, we need to prepare more varieties of samples for comparison.

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