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# DEVICE TO MEASURE THREE-DIMENSIONAL COMPRESSION PROPERTY FOR SURFACE *KANSEI* OF PILE MATERIALS

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## ABSTRACT

Objective evaluation of woven/kitted fabrics with normal thickness has been completed for their KANSEI, applying handle values calculated from mechanical properties since 1970. KES (Kawabata Evaluation System) testing instruments for fabrics were developed at the same time [1]. For the research on KANSEI of rather thick materials like pile fabrics, carpets, natural and fake furs, handle touch is very important and becomes a first step for the evaluation. Although it is so important that the KANSEI by the first touch/vision becomes the first impression and forms the basis of the objective evaluation, the development of measurement of the frictional and compression behavior has been left. In this paper, porous materials of various kinds including piles and furs are investigated for the compression properties in relation to the coefficient of kinetic friction [2,3]. For the measurement of the compression property, the special testing machine with full equipment of 3D-compression stresses is used. On the other hand the sensory test is carried out for surface feeling of the same samples in the mechanical property measurement test by 32 subjects. Results involved in human touch sense are discussed the interrelationship with surface and compression mechanical properties.

***Keywords:*** *objective evaluation, pile materials, sensory test, 3D compression property, special testing machine*

## 1. INTRODUCTION

In our previous study, the surface friction of various thick fibrous materials has been reported for the success of measurement with a special sensor like human finger- tips [1]. The results showed the close relation with the sensory test criteria by touch and vision. In the study, compression property was noted that it should be involved. The compression property of those materials may greatly affect their surface properties and the performance of their end products.

In this study, a special testing device has been developed for the sake of measuring three-dimensional compression property of thick materials (Fig.1). When thick materials are compressed in the thickness direction, the stress works parallel to the surface (Fig. 2). The novel device to detect stresses of two directions along the surface was added to the body of the KES-G5 multiple compression instruments. This instrument provides three-dimensional stresses of the specimen quickly and easily. The friction coefficient of thick fibrous materials could be predicted taking account of the circumference compression behavior.

## 2. EXPERIMENTAL

### 2.1. 3D-compression stress measuring

Fig.1 shows the structure of the special testing instrument for the compression stress-strain. For the measurement of the compression property of normal thickness weave/knitted fabrics, it is enough to measure the stress-strain (compression power-thickness along Z-axis. In the case of the measurement of thick materials like piles, as shown in Fig. 2, their surfaces are various and sometimes it is observed unevenness of thickness (hair length) and/or lie of hairs (fibers).  To detect the stresses parallel to the surface during compressing, parts were added to the pressure catching machine. The parts consist of board springs. Fig. 3 shows setting up two sets of board springs.

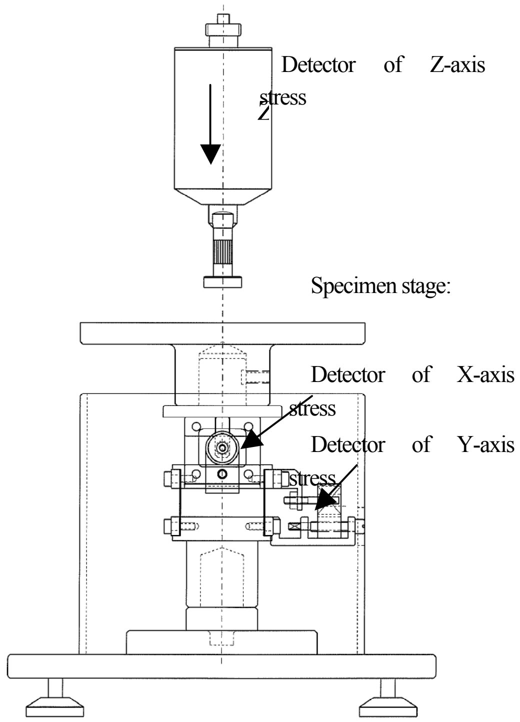


Fig.1 Schematic of apparatus for 3D- Compression stresses measuring.

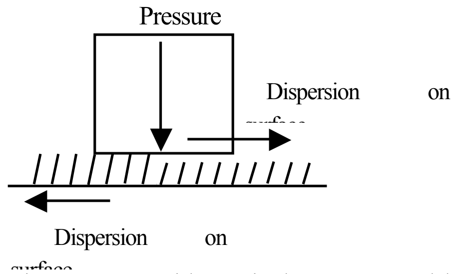


Fig. 2 Stress with vertical pressure and lateral pressures. The machine detects accurate 3D stresses in cases of uneven surface and strong lie of hair /fibers.

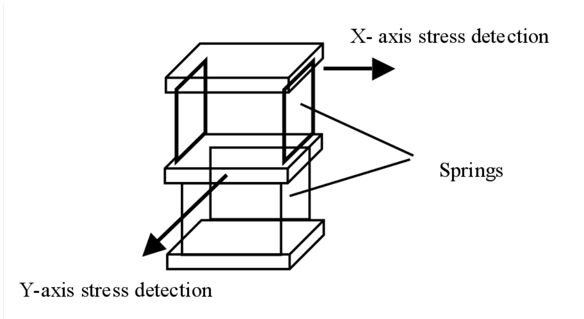


Fig. 3 Mechanism of stress detection using board springs.

Boards springs and detectors of differential motion transfer were equipped as double layered. The spring is special to deform only one direction that means never deform vertical and Y-axis direction for the X-axis deformation of the pair of springs detecting X-axis stress. And the deformation of each layer senses the stress along X and Y, respectively. The deformation is converted to the direct current voltage and then stress is given as the voltage.

### 2.2 Samples

Table 1 the specimens used in this study.

| Name Name | Fiber content % | Thickness $10^{-3}$m | Weight kg/m$^2$ |
|---|---|---|---|
| Corduroy | Cotton 100% | 0.991 | 0.172 |
| Velvet | Rayon 100% | 1.31 | 0.195 |
| Velveteen | Cotton 100% | 1.31 | 0.23 |
| Cashmere | Cashmere 100% | 2.02 | 0.329 |
| Mink fur | Natural fur | 9.72 | 0.668 |
| Rum fur | Natural fur | 7.56 | 0.641 |
| Possum fur | Natural fur | 12.2 | 0.933 |
| Fake fur (short) | Acrylic 100% | 5.44 | 0.356 |
| Fake fur (long) | Acrylic 100% | 6.49 | 0.555 |
| Silicone | Rubber 100% | 3.00 | 3.938 |
| Sponge | Polyurethane foam | 14.5 | 0.214 |
| Loop Carpet P | | 8.65 | 1.47 |
| Cut Pile Carpet Nc | Wool & Jute | 12.7 | 1.79 |
| Cut Pile Carpet Nt | Wool & Jute | 12.1 | 1.92 |
| Cut Pile Carpet Y | Wool & Jute | 12.5 | 2.52 |
| Wool wad A | Merino 25micron | - | - |
| Wool wad B | Corriedale 35micron | - | - |
| Supplalle: Synthetic | leather | 0.802 | 0.249 |

(Top; Poly-urethane incl. Protein powder, Base: Rayon 80%, Nylon 20%)

Samples were eighteen kinds of porous materials as shown in Table 1. The coefficients of kinetic friction, that we call *MIU* in this paper, have been measured using the special attachment [1]. Cut Pile Carpets named by Nc and Nt are conventional and non-slip treated, respectively.

### 2.3 Sensory test

Sensory test was conducted for 32 subjects using the questionnaire sheets with 12 bipolar attributes, SD grids of 5 ranks. Subjects inspect each sample by touch and sight, and judge the rank of feeling. twelve bipolar attributes applied were as follow: smooth-harsh, glossy-not glossy, elastic-not elastic, warm-cold, thick-thin, dense-sparse, bulky-papery, light-heavy, sticky- crisp, hard- soft, rich-not rich, like- dislike. Scores subjects responded were summed up and investigated for the correlations of MIU statistically.

### 2.4 Measurement

Compression properties were measured for 16 samples at deformation speed 0.05cm/s, maximum compression strain at 4.9kPa in the room conditioned at 20±2□、65±5%R.H..

### 2.5 Three-dimensional compression property

To quantify the X and Y-stresses, the value is defin

$$SCQ = \sqrt{X^2 + Y^2} \qquad (1)$$

where X is the X-stress and Y is the Y-stress, then *SCQ* means the amount of whole stress working on the surface of materials.

## 3. RESULTS

Fig. 4 is the plot of 3D compression for the fake fur sample with short hair. The upper line shows the compression (Z-axis)-thickness curve. Lower two curves are X-axis and Y-axis stresses. In this case, it was observed that short acrylic fibers added on surface behave symmetrically, X-axis stress works on the surface lie during sample compressing and Y-axis shows the minus stress which means the pushing work at surroundings deformation area. Such situation of materials compressed process was clearly detected for most of materials with piles quantitavely. The compression energy for 3D is shown in Fig. 5. Corduroy is a cut-weft pile fabric in which the cut fibers form the surface. The binding points of pile wefts are arranged so that after the pile has been cut, cords or ribs are formed in the direction of warp as shown in the picture in Fig. 5. In the space between cords, less stress can be observed and to the contrary much stress was recorded in cords where fibers planted densely. To catch the characteristics of 3D-compression stress behavior, the *SCQ* values were calculated using X- and Y- stresses measured.

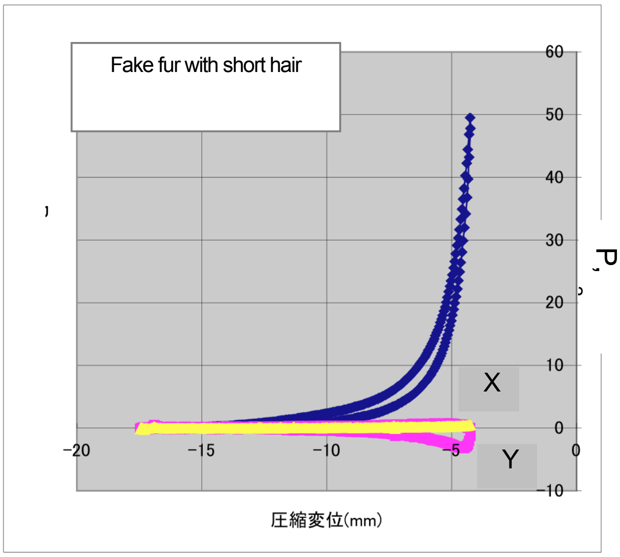


Fig. 4 Plot of datum of the logger measuring three coordinate axes stresses for fake fur sample.

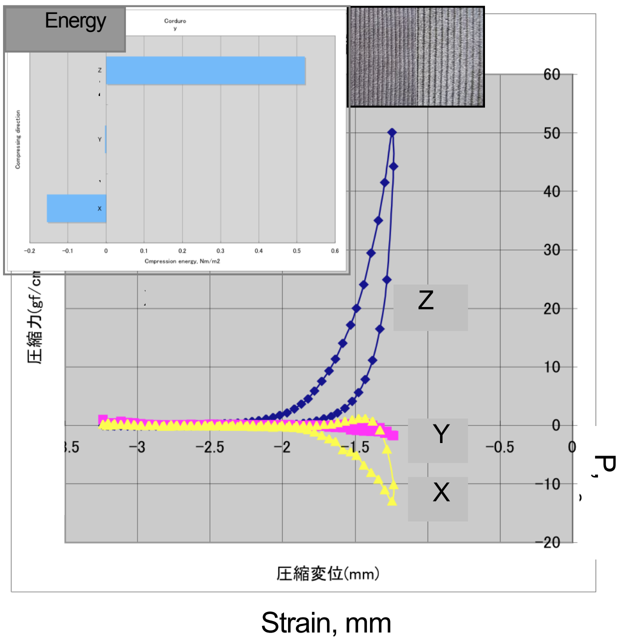


Fig. 5 3D-stresses, compression energy, a surface photo for Corduroy.

In the upper left corner of Fig. 5, the small graph on compression energies that are calculated using measured 3D-stresses and a Z-axis strain are shown. Comparing the 3D-works, we can see that at the same time of compressing the corduroy fabric, the energy is gathered at 20-30% level of Z-axis compressing work. Human being handle and touch feeling seems to be very sensitive. We judge the surface characteristics of fibrous materials and feel energies when we touch/see materials.

We examined the sensory test for the judgment significance of 18 kinds samples. The feelings of subjects on materials' "Smooth-harsh" "Hard- soft"" Sticky- Crisp" and "Dense-sparse " of surfaces show the significance among samples and on the correlation of sensory score and *MIU* of materials.

Fig. 6 shows the relationship between "smooth-harsh" score of materials and the mean value of coefficients of kinetic friction, *MIU*. The vertical axis shows that score one means "very smooth", two for "slightly smooth, three for neutral, four for "slightly harsh" and five for "very harsh", respectively.

Subjects have the tendency to judge harsher with an increase in *MIU* of materials. Dependency difference was observed among three groups. The judgment was done delicately. Coarse wool carpets and wad are estimated as to be harsh (score around four) and velvet, merino wool wad and possum fur realized as to be very smooth or slightly smooth, that is score one or two.

Sponge has the highest *MIU* among samples in this study and recognizing "harsh". As the distribution of both these values was rather wide, we investigate the relation of the compression properties. Compression resilience *RC* and *LC* show the slightly strong correlation of the surface friction coefficient *MIU*. *LC* is called the linearity of compression property and is the ratio of compression energy of samples to the compression energy of complete elastic materials at the same level of maximum stress (490kPa) and strain for each sample. Fig. 7 shows the relation between *LC* and *MIU*. With an increase of *LC*, *MIU* increases. *LC*, The correlation coefficient to determine, $r^2$, was 0.465 that results the slightly strong interrelation. To clarify the effect of compression deformation to the surface friction, *SCQ* is used.

in Fig.8, results of *MIU* and the parameter *SCQ* are plotted. The relation between *MIU* and *SCQ* shows the characteristics of sample group. Since *SCQ* quantifying the X and Y-stresses of samples, various samples in study could be categorized into three groups. The right-hand side circle includes the materials with short hairs-piles such as velvet, corduroy, velveteen etc.. Natural furs and fake furs with long piles belong to the middle circle. The left-hand side circle group that showed relative lower *SCQ* has synthetic leather, sponge, wool wads and cashmere. The solid line, broken line and dotted line showed the correlation for each of groups. In all groups, with an increase of *SCQ*, *MIU* increases. The right side (short piles group) showed a larger range of *SCQ* than other groups. And the middle group (furs group) posses a smaller range of *MIU* than that of short pile group. It reflects natural furs role that is to protect animals with furs from a danger.

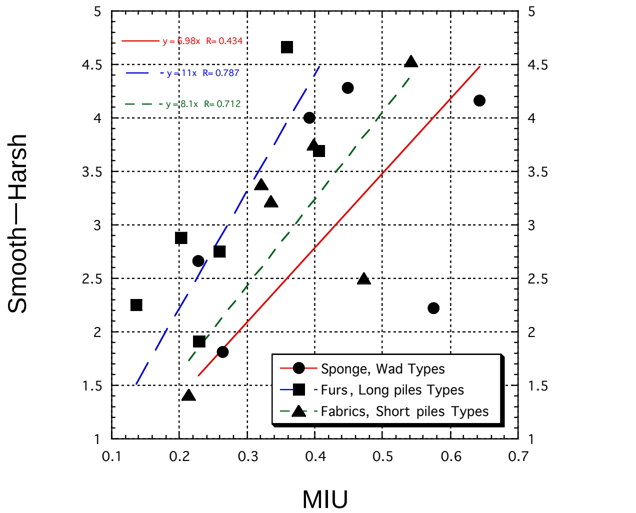


Fig. 6 Plot of mean value of sensory scores 32 people judged versus *MIU* of samples.

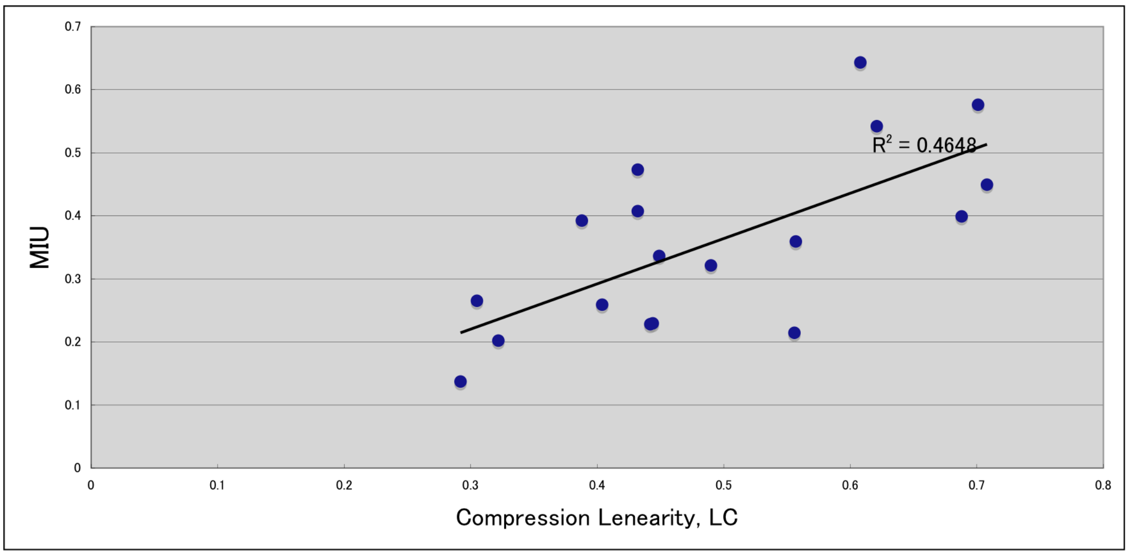


Fig. 7 Plot of *MIU* versus compression linearity *LC*. Solid line is the correlation of them calculated.

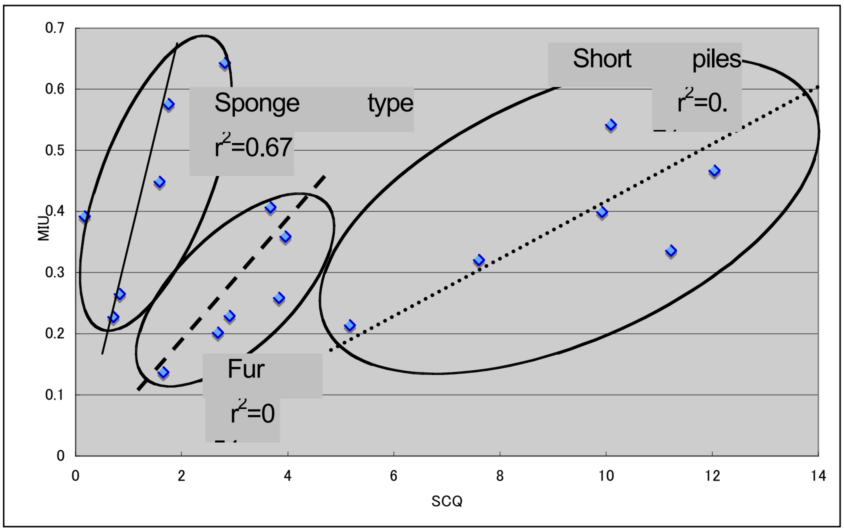


Fig. 8 Relation between the parameter *SCQ* and *MIU*.

## 4. CONCLUSIONS

Human touch sense on various porous materials was investigated in the sensory test. In order to study what subjects feel by touch from samples, both the surface frictional and compression properties of materials should be caught accurately. The tester to detect the frictional property of wide range porous materials has been already developed in our previous study [2]. The interrelation between *MIU* and touch sense such as sticky-crisps and smooth-harsh showed the close correlation. When people touch the object and stroke by fingers, compression energy works simultaneously. In this study, we have developed novel apparatus to detect 3D-compression stresses-strain property. We succeeded to measure 3D-compression stresses of samples and quantify surface stresses as *SCQ* value. *SCQ* showed the surface characteristics of materials well. Reflecting the surface forms of various material groups, the relationship between the coefficients of kinetic friction, *MIU and SCQ* has the strong correlation. We found that the probability to control MIU applying *SCQ* value. In future, collecting datum further, *KANSEI* from sensory test on the surface of various materials including thick materials with special features shall be predicted by applying MIU and 3D compression property.

### ACKNOWLEDGEMENT

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