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Objective and Subjective Handle Evaluation for Disposable Diaper's Top Sheets and Reusable Diaper's Fabrics

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Abstract

In order to examine objective evaluation equations for disposable diaper's top sheets, representative top sheets are evaluated by those equations and by subjective method comparing with reusable diaper's fabrics. Following conclusions were obtained. Objective evaluation equation for primary hand (DPCM-1) is useful for calculation of primary hands "NAMERAKASA" and "KOSHI", however, it is not effective to "SOFUTOSA" and "FUKURAMI". Two objective evaluation equations for total hand value (THV) (DPCM-2, 3) are both available for top sheets. THV decreased in the order of spunbond, air-through, meltblow, and spunlace for both objective and subjective values. Used fabric for reusable diapers examined here (plain weave) has higher "NAMERAKASA", "SOFUTOSA", "FUKURAMI" and THV, however, lower "KOSHI" than the original fabric.

Key Words: Fabric handle, Top sheet, Diaper, Subjective evaluation, Objective evaluation

1. Introduction

Objective evaluation equations for fabric handle using basic mechanical parameters of the fabrics have been developed by Kawabata and Niwa [1, 2], and several equations for different end-uses have been used widely now [3]. Similar objective equations for Futon (bedclothes) fabrics are also reported by Matsudaira et al. [4–6], and those for non-woven fabrics are developed recently [7]. Further, investigation about the top sheets of disposable diapers is carried out objectively by Yokura et al. [8, 9]. Original primary hands for the top sheets have also been defined by Matsudaira et al. [10] such as "NAMERAKASA", "SOFUTOSA", "KOSHI" and "FUKURAMI" based on opinions of consumers. Objective evaluation equation for total hand value is also derived from those primary hands [11, 12].

However, the applicability of those objective evaluation equations has not been examined fully yet. The applicability of those equations is studied for new top sheet samples made by representative manufacturing methods for non-woven fabrics in this paper, and it is also examined for reusable diaper's fabrics. Subjective evaluation was carried out for non-woven top sheet samples and reusable woven fabrics at the same series of test.

2. Experimental method

2. 1 Primary hands of disposable diaper's top sheet

Primary hands of disposable diaper's top sheets defined for their original primary hands are shown in Table 1 [10]. "NAMERAKASA" is the peculiar primary hand for the top sheet of disposable diapers. These primary hands covered 87% of the total quality expression concerning fabric handle of the top sheet by consumers.

2. 2 Samples

Samples used in this paper are shown in Table 2. Top sheets are representative four types of samples used widely now (2003–04) in Japan for disposable diapers. Each sample is an average one of the type of spunbond, air-through, meltblow (reinforced with spunbond) and spunlace in the point of its structure such as weight and thickness. Fabrics for reusable diapers are plain weaves before use (original

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Table 1 Terms and definitions of original primary hands of disposable diaper's top sheet [10].

No.	Term	Definition	Remark	Frequency
1	NAMERAKASA (Smoothness)	A mixed feeling come from smooth and dry feeling having slippery touch without hitching to fingers.		28 %
2	SOFUTOSA (Soft feeling)	A soft feeling, mixed feeling of bulky, flexible and smooth feeling.	Same definition as HESC*	26 %
3	KOSHI (Stiffness)	A feeling related to bending stiffness. Springy property promotes this feeling.	Same definition as HESC	21 %
4	FUKURAMI (Fullness & softness)	A feeling come from bulky, rich and well formed feeling. Springy in compression with warm feeling.	Same definition as HESC	12 %

HESC*: Hand Evaluation and Standardization Committee in the Textile Machinery Society of Japan [1].

Table 2 Details of top sheets and fabric samples used for experiments.

Symbol	Kind	Material	Fineness (tex)	Weight (g/m^2)	Thickness* (mm)
A	Air-Through	PE/PET	0.22	23.01	1.24
B	Spunbond	PP	0.20	17.87	0.82
C	SMS(Spunbond-Melt-blow-Spunbond)	PP	0.12	14.91	0.66
D	Spunlace	Rayon:PE T=8:2	Rayon:0.17, PET:0.16	22.55	0.82
E	Plain Weave, Original	Cotton	28.2	120.5	0.94
F	Plain Weave, Used	Cotton	29.6	97.0	1.04

*Thickness is measured at the pressure 49 Pa.

sample) and after repeated use of 400 cycles (2 years used sample). The fabric was the most popular reusable one in the age of 1950～1970 in Japan and could be compared easily with disposable diaper's top sheets.

Basic mechanical parameters of those samples were measured by KES-system in the conditions of 20°C and 65% relative humidity. Measurements were carried out for 3 pieces of each sample and the average value was used for further analysis.

2. 3 Calculation of the primary hands and total hand value

Primary hands were calculated from the basic mechanical parameters measured by KES-System using the objective evaluation equation (DPCM-1 [10]) for the original primary hands developed by one of the authors recently. Total hand values (THV) were calculated by DPCM-2 [11] and DPCM-3 [12].

2. 4 Subjective evaluation of the primary hand and total hand value of the top sheet

In order to evaluate the primary hands and total hand value (=THV) of the samples, paired comparison method [13] was carried out as follows.

Subjects were asked to handle two samples. The evaluation handle terms were original primary hands for top sheet such as "NAMERAKASA", "SOFUTOSA", "KOSHI", "FUKURAMI" and total hand value. The task was for each subject to give a score of 1 to the sample she judged had the higher "NAMERAKASA", the higher "SOFUTOSA", etc. The evaluators were fourteen female students from 20 to 22 years age of Kanazawa University. As stated above, the samples were presented to them in pairs. Each sample was paired with the other 5 samples. So in all, each evaluator observed 15 sample pairs. The pairs were presented in random order. All the evaluators judged these pairs in the same session with their eyes open. When all the subjective evaluations were completed, a raw score was determined for each primary hand by summing all the "1s" given to fabric by each evaluator. The maximum possible raw score was 70 (each fabric was in 5 pairs and scored by 14 evaluators). The lowest possible raw score was 0 indicating that a fabric was never judged to be the better. The average raw score was then 35 indicating that half of time it was selected as the better. These raw scores were converted to a 10-point scale scores for primary hand and 5-point scale scores for total hand value, because it is easy to understand and suitable for the comparison with objective values. A score of ten on the 10-point scale then indicated that all evaluators judged the same fabric to be the better for a primary hand each time it was presented. A score of five on the 10-point scale was then the average score. A score of zero on the 10-point scale indicated that a fabric was never selected as the better for the primary hand.

To assure the results, the coefficient of agreement in paired comparison is calculated and examined. The

coefficient means the degree of agreement between the subjects whether or not they are right in absolute sense. If the results are assured, the data are compared with objective data.

Subjective evaluations were carried out in the conditions of 20°C and 65% relative humidity. These conditions agreed with those of physical measurements of samples.

3. Results

3. 1 Subjective evaluation

Results of paired comparison were checked their agreement and it was shown that all the results (four primary hands and total hand value) between judges agreed very well by the coefficient of agreement using Chi-square distribution. Therefore, it is worth to use these subjective values for comparison with objective data.

3. 2 Objective evaluation of primary hands

Results of a primary hand "NAMERAKASA" obtained by DPCM-1 [10] equation are shown in Fig. 1 comparing with subjective values. In the case of top sheets, although the absolute values are different, objective values decreased in the order of spunbond (B), air-through (A), meltblow (C) and spunlace (D) and this tendency agreed well with that of subjective values. Objective values of reusable weaves (E and F) showed extremely smaller values than subjective values. This means DPCM-1 equation is not useful for woven fabrics.

Reusable weaves examined here showed quite a large value of surface roughness (mean deviation of thickness); SMD (13μm for new sample E and 12μm for used sample F) compared to that of top sheets (3-5μm). It is easy to know that large SMD brings smaller values of "NAMERAKASA" from the coefficient of DPCM-1 equation. Yokura [14] also reported that diaper's reusable

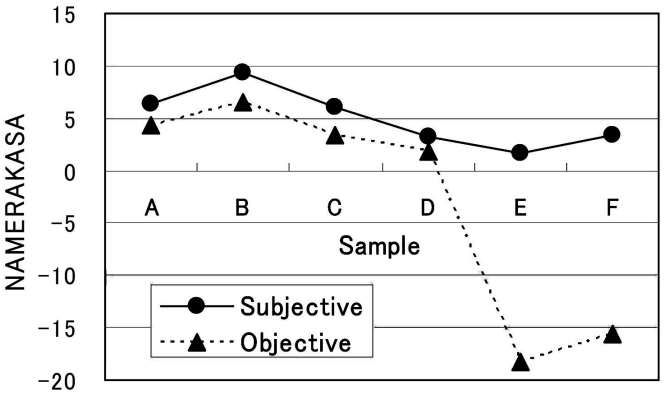

Fig. 1 Results of a primary hand "NAMERAKASA".

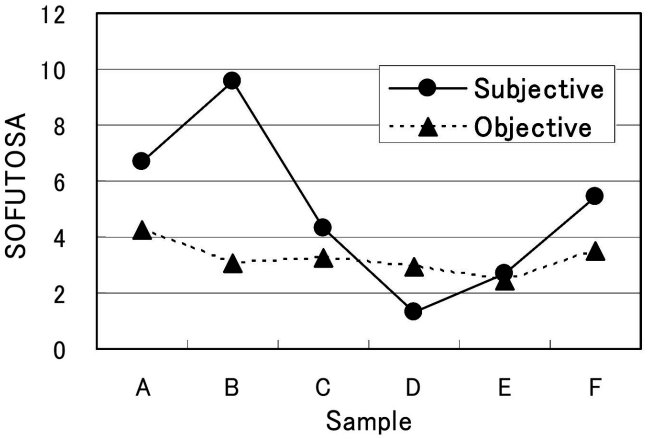

Fig. 2 Results of a primary hand "SOFUTOSA".

cloths had a large value of SMD compared to top sheets. It is interesting that used fabric for reusable diaper has a larger "NAMERAKASA" for both subjective and objective values.

Results of "SOFUTOSA" are shown in Fig. 2. It is clear that objective values did not agree with subjective values. Although the range of objective values is quite small (from 2 to 4), that of subjective values is quite large (from 1 to 10). The spunbond top sheet is evaluated to have very high "SOFUTOSA" by subjective evaluation. It is interesting that used fabric for reusable diaper shows higher "SOFUTOSA" for both objective and subjective values.

Results of "KOSHI" are shown in Fig. 3. Although the absolute vales are different, the order of the objective value decreased in the order of spunlace (D), air-through (A), meltblow (C) and spunbond (B) in the case of top sheets and this tendency agreed well with that of subjective values. New fabric for reusable diaper showed higher value of "KOSHI" for both objective and subjective values.

Bending stiffness; B, of used fabric for reusable diaper examined here was 2.7μN·m^2/m and that of new fabric was 5.1μN·m^2/m. Therefore, it is easy to know that large B brings larger value of "KOSHI" from the coefficient of

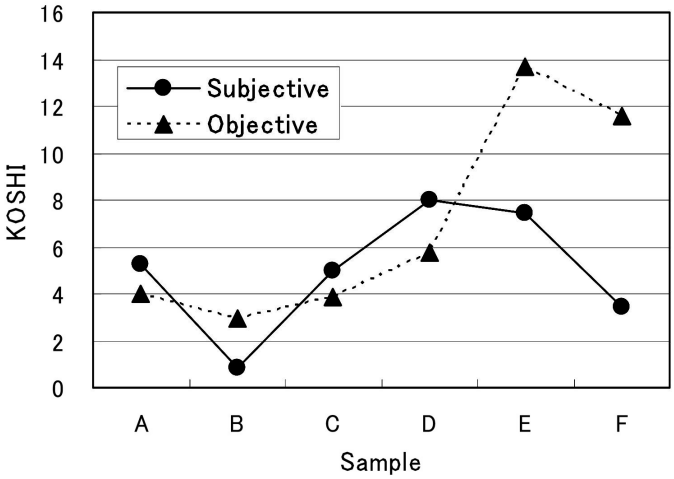

Fig. 3 Results of a primary hand "KOSHI".

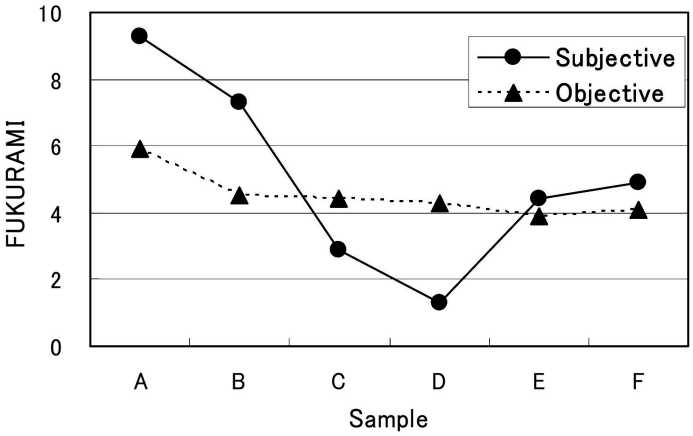

Fig. 4 Results of a primary hand "FUKURAMI".

DPCM-1 equation.

Results of "FUKURAMI" are shown in Fig. 4. It is clear that objective values did not agree with subjective values. However, it is considered that tendency of order is similar. That is, objective value of "FUKURAMI" decreased in the order of air-through (A), spunbond (B), meltblow (C) and spunlace (D) for top sheets. This tendency agrees fairly well with that of subjective values (r=0.80: significance level; 20%). It is interesting that used fabric for reusable diaper shows a little higher "FUKURAMI" for both objective and subjective values.

3. 3 Objective evaluation of total hand value (THV)

THV is calculated by DPCM-2 [11] and DPCM-3 [12] equations from primary hands obtained objectively by DPCM-1 equation. THV for reusable weaves were extremely low (original fabric; −101, −77, reused fabric; −79, −60 by DPCM-2 and 3, respectively) compared with those of top sheets and subjective values of reusable weaves (original fabric; 1.7, reused fabric; 2.8). This means that DPCM-2 and DPCM-3 equations are not valid for woven fabrics.

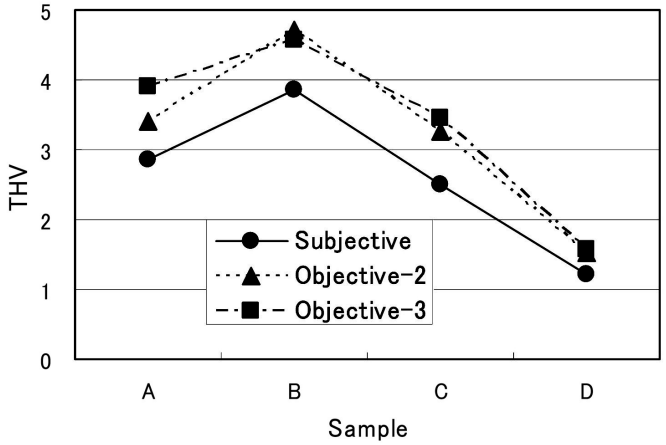

Fig. 5 Results of THV for four representative top sheets.

Results of top sheets are shown in Fig. 5. Subjective values agreed fairly well with objective values for both equations. In the case of air-through, meltblow and spunlace top sheets, the results of DPCM-2 are closer to subjective values. However, the result of DPCM-3 is closer to subjective value in the case of spunbond top sheet. Anyway the difference is little and it is concluded that DPCM-2 equation is better.

4. Discussion

In the case of air-through top sheet, "FUKURAMI" by subjective evaluation was the highest and this result was explained by bulky feature of the fabric. On the other hand, spunbond top sheet showed the highest "NAMERAKASA" and the lowest "KOSHI" for both objective and subjective evaluations. THV of the spunbond top sheet showed the highest for both objective and subjective evaluations. Spunbond top sheet is produced by direct spinning of polypropylene and has the feature of high strength and stability for various uses. Therefore it is concluded that spunbond non-woven fabric is the best for top sheet.

Fine fibers are used in meltblow top sheet, however, the feature was not displayed to primary hand and THV. As the meltblow sheet is sandwiched between two spunbond layers as shown in Table 2, the feature of meltblow was disappeared. Spunlace top sheet showed the highest "NAMERAKASA", "SOFUTOSA", "KOSHI" and the lowest "FUKURAMI" and THV for both objective and subjective evaluations. It is supposed that spunlace is not adequate for top sheet from this experiment.

It is clear that DPCM-1 equation is not useful to reusable diaper's woven fabrics. Another equation such as KN-201MDY [3] equation developed by Kawabata and Niwa was used for the fabrics and investigated their applicability. This equation was developed to evaluate fabric handle of women's outerwear fabrics with medium thickness. As the thickness and weight of fabrics for reusable diapers are within the range of women's outerwear, the equation is applied here.

Primary hands "SOFUTOSA", "KOSHI" and "FUKURAMI" obtained by KN-201MDY are show in Table 3 comparing with the results obtained by DPCM-1. In the case of "SOFUTOSA" and "FUKURAMI", objective values did not agree with subjective values for both original and used fabrics. Therefore, KN-201MDY equation is not useful for diaper's reusable fabrics. It is concluded that another new equations are necessary for objective evaluation of reusable diaper's woven fabrics.

It is said that DPCM-2 equation is useful to the condition

Table 3 Results of primary hands for reusable fabrics.

Fabric	Primary hand	Subjective value	by DPCM-1	by KN-201MDY
Original fabric	SOFUTOSA	2.71	2.41	1.01
	KOSHI	7.43	13.67	4.20
	FUKURAMI	4.40	3.90	0.60
Used fabric	SOFUTOSA	5.43	3.51	2.44
	KOSHI	3.43	11.56	2.89
	FUKURAMI	4.90	4.10	1.10

when the value of primary hand "SOFUTOSA" > 3.0 [12], and the results obtained here satisfied this limitation. If "SOFUTOSA" < 3.0, the result of DPCM-3 becomes closer to subjective values.

5. Conclusions

Disposable diaper's top sheets and reusable diaper's fabrics were evaluated their fabric handle by objective and subjective evaluations. Following conclusions were obtained.

(1) Objective evaluation equation for primary hand (DPCM-1) is useful for calculation of primary hands "NAMERAKASA" and "KOSHI". However, this equation is not effective to "SOFUTOSA" and "FUKURAMI". Spunbond type is best for top sheet of disposable diapers. It is difficult to apply to woven fabrics used for reusable diapers.

(2) Two objective evaluation equations for total hand value (DPCM-2, 3) are both available for top sheets, however, DPCM-2 is better. THV decreased in the order of spunbond, air-through, meltblow, and spunlace for both objective and subjective values.

(3) Used fabric for reusable diaper examine here has higher "NAMERAKASA", "SOFUTOSA", "FUKURAMI" and THV, however, lower "KOSHI" than the original fabric.

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