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Handle Assessment of Tissue Paper

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Abstract

Handle has a primary influence with nearly everything surrounding us as it gives the essential information to interact with our neighbourhood. The need to know how this affects our decisions is fundamental and leads to the study and understanding of this human sense. Tissues paper is one of the most common elements of interaction in the day-to-day human life; it can be produced in various ways leading to different textures which can transmit various sensations. The FRICTORQ® is a laboratory equipment developed at the University of Minho to measure the friction coefficient in fabrics, to enable a quantitative assessment of touch/handle, in order to predict the comfort behaviour of 2D structures when used or touched by humans. In the present study the existence of a correlation between a subjective assessment and the objective measurement of different parameters analysed in paper tissues has been investigated. With the FRICTORQ instrument a great accuracy in the analysis was obtained when compared with the KES-FB4. An inverse relationship between parameters Rough-Smooth and Thin-Thick with Friction coefficient was found, meaning that the increase of the value of the friction coefficient expresses a decrease in the sensation.

Key Words: Handle, FRICTORQ, KES, Tissue paper, Objective and subjective analysis

1. Introduction

Comfort is present in all actions in our life. Authors such as Fourt and Hollies [1] concluded that the thermal comfort involves thermal and non-thermal components that are related to the circumstances in which clothes are used, for example, at work or at critical or non-critical conditions. For a long time it has been recognized that it is difficult to describe comfort from a positive point of view but discomfort is easily defined by terms such as: hot, cold, rough and causes skin irritation. Therefore, a definition [2, 3, 4] of comfort that is generally accepted is that it transmits freedom from pain and discomfort, in other words, it is in a neutral state.

Physiological responses of the human body to a certain combination of clothing and the ambient conditions are predictable when it reaches an equilibrium state with the textile. There are measurable factors that help to predict textile comfort both in physiological and environmental levels, such as heat resistance, moisture recovery, weather conditions and the level of physical activity, etc. As these assessments can be made in two ways, they will be addressed separately, by a subjective and an objective analysis.

1.1 Subjective evaluation

Sensory analysis is a subjective evaluation [5] which is reflected in an action of all the experiences assimilated over a lifetime. This directly measures the person's opinion through surveys in order to analyze preferences. Urdapilleta [6] in the Treaty of Sensory Evaluation defines two concepts to take into account when preparing an evaluation; Feeling: "the state resulting from the entry into receptors activity after sensory stimulation of one sense." Perception: "the cognitive process of recognition, identification, organization and interpretation of sensory information."

In 1968 Kawabata [7] placed two hypotheses for the concept of handle; (1) One person thinks the touch sensation by proving the mechanical properties of tissues, and (2) The criterion of judgment is based on the possibility of having or not the fabric suitable to be

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used as clothing. To define handle Kawabata [7] selected several expressions that relate the transmitted sensations with the mechanical properties; these expressions describe a set of primary sensations which provides a good touch and they are: Smoothness (Numeri): mixed feeling of softness, flexibility and soft; Stiffness (Koshi): Feeling connected to the rigidity when subjected to curvature. The elasticity promotes this feeling. Tissues, such as compact meshes and fabrics with high resilience and elasticity represent that feeling; Fullness and Softness (Fukurami): Feeling of volume. The resilience after compression and thickness connected to a hot "touch" is closely linked to this feeling; Crispness (Shari): Feeling that comes from a grim and rough surface, obtained by the use of many hard twisted wires. Displays a sense of cold; Anti-drape stiffness (Hari): refers to the stiffness that opposes the fall, whether or not the elasticity of the tissue. To evaluate the subjectivity of fabric hand and then compare with objective data surveys were carried out. It became necessary to use psychometric scales in which the set of descriptors attributes or qualifying adjectives is to convey the everyday experience.

The method adopted in this study uses an observer's panel to measure subjectively the different samples. An exhaustive list of possible adjectives to be used in the description of the ring was formulated. The groups of adjectives used in the study of handle evaluation were proposed by North Carolina State University (NCSU) [8] and are shown in Table 1. Typically the panel consists of 30 to 40 observers, with men, women or both sexes depending on the purpose of the analysis [8]. NCSU submits to these studies healthy individuals, non-smokers, aged between 18 and 35 years, being first considered those who already have some experience. The observers come in a temperature controlled environment where they wait 30 minutes to stabilize. All test samples were placed in a conditioned atmosphere for the required humidity and temperature before each test. The questionnaire consisted of two parts: the first refers to the social characterization of the inquired being composed of four issues: gender, age, experience in sensory analysis and profession. These questions allow an exchange of data between the social characterization and professional activity, with the sensory analysis. The second part refers to the sensory analysis of samples, consisting of thirty-six sets of questions and each question consists of 9 pairs of adjectives. At the beginning of the survey the inquired were asked whether they were familiar with the terms used; after their positive answer they would move to the next phase. If they were unaware of the terms used the respondents were eliminated. Before starting the process the respondents were asked to wash their hands to remove as many impurities as possible to improve test performance.

Table 1 Parameters proposed for the assessment of fabric hand.

Parameters	
Hard / Soft	Damp / Dry
Stiff / Flexible	Thick / Thin
Rough / Smooth	Warm / Cool
Heavy / Light	Loose / Dense
Nonstretchy / Very Stretchy	

1.2 Objective analysis

Expressions like "good touch" or "bad touch", which are generally used to analyze the quality of fabric, have different meanings when talking to an expert. For the expert "good touch" represents a fabric with high softness and a moderate stiffness, smoothness, and voluminosity, because, for him/her, the interaction of this entire core values of "handle" transmits a clear total value of handle. Kawabata [7] proposed the use of the total value of handle (Total Hand Value - THV) as an indicator of "touch". The good "touch" THV value is the sum of the primary qualities evaluations of fabrics and they are taking into account the comfort, appearance and function of the garment.

The devices that are used to determine the properties are: the KES-FB (Kawabata Evaluation System) [7], the SiroFAST System [9] and the FRICTORQ [10]. Excluding the SiroFAST System since it is only used in woollen fabrics, the other textile equipments evaluate various types of textile materials [11-13] and also nontextile materials [10, 14, 15]. The KES-FB [7, 11] includes a set of measurements that compose the analysis of fabric hand, consisting of six parameters of properties, which are: tensile, bending, surface, thickness, weight and compression. Surface properties, thickness and weight are not mechanical properties but physical, although they are indirectly related to the mechanical properties. The KES-FB consists of four blocks, each block measuring a certain set of properties present in the total final handle by the values previously determined.

1.3 FRICTORQ

Developed in the University of Minho, FRICTORQ [10] aims at measuring the coefficient of friction of fabrics and other planar soft surfaces such as papers and nonwovens, to be used in their characterization. It comprises three blocks, namely: (1) the torque sensor with the respective data acquisition system; (2) the direct current motor and the mechanical transmission, and (3) the control of the entire system with a software application. The principle of operation [14] of the first model, designed for fabric-to-fabric tests, is based on the dry disk clutch principle, where an annular flat body is rotary drawn in contact on a flat surface under the action of a specified normal force, which results in a uniformly distributed contact pressure. Figure 1 is a general view of the FRICTORQ I instrument.

The coefficient of friction, μ, is determined through the relative displacement of two surfaces, one above the other, in a relative

Fig. 1 FRICTORQ I system.

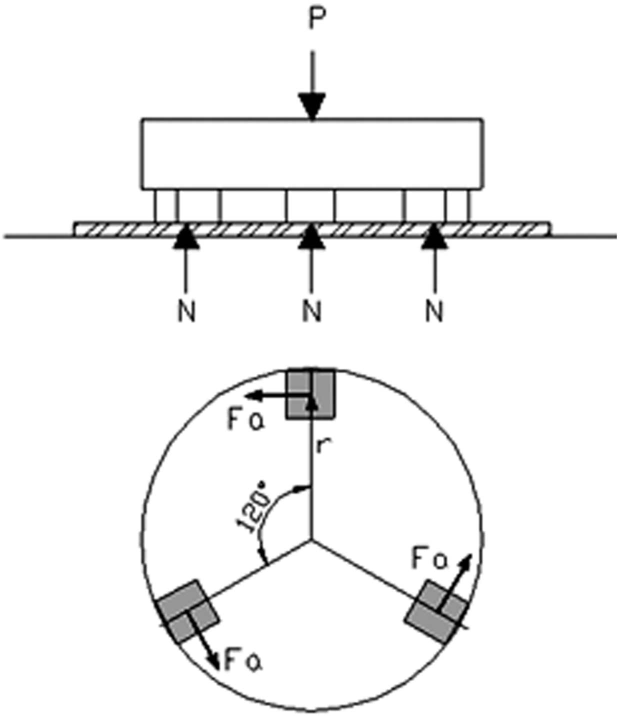

Fig. 2 Geometry of FRICTORQ II model.

sliding rotational very low constant speed [10, 14]. The main goals, as well as the design and development of this testing equipment is referred elsewhere [10, 14], resuming the testing results obtained with knits and other non-woven fabrics are also depicted, and new frontiers regarding its innovation and other testing procedures are presently being researched. On a second phase, FRICTORQ II was developed. The upper body has now 3 small square areas of contact at 120° as seen in figure 2. Providing a relative displacement of approximately 90°, it is assured that a new portion of fabric is always moved under the contact sensors. For this model, torque is given by:

$$T = 3\ Fa\ r \quad (1)$$

Being, by definition, $Fa = \mu N$ and from Fig.2, $N = P/3$, where P is the vertical load, the coefficient of friction is expressed by equation 2,

$$\mu = \frac{T}{P \times r} \quad (2)$$

The own weight P of this upper body is standardized in order that a constant pressure of 3.5 kPa is exerted at the contact areas. This device has demonstrated readiness for evaluation of the coefficient of friction for various textile and non-textile materials [10, 14]. Figure 2 represents a graphic display of an experiment showing the most relevant parameters. The shape of the graph is stable and nearly horizontal for the duration of the test. For dynamic friction data collected between 5 and 20 seconds of the test is used.

2. Methodology

Friction tests were carried out using the instrument FRICTORQ with contact probe NB3.5 (for Needle Body at 3.5 kPa of contact pressure) in a set of 11 paper samples of tissue paper (cellulosic fibers) produced by the Portuguese RENOVA company. Table 2 summarizes company references of all tested materials. For each of the materials, samples with 11.3 cm diameter (100 cm^2) were cut, and 13 samples were tested in the outer face (O) and in the inner face (I). The obtained results were analyzed using SPSS18® statistical package. KES tests were performed according to the procedure given in the manual provided by the manufacturer. Specimens were cut square with 20 cm side, and tested in KES-FB4. The samples were fixed to the module through a system integrated in it, and the tests were carried out on all samples and repeated five times. The sample handling required latex gloves to

Table 2 Tissue papers.

N°	Materials	N° of Sheets	Fragrant	Tickness (mm)	Weight (g/m^2)	Colour
1	L1_3F_Black	3	No	0.19	0.52	Black
2	L2_3F_Orange	3	No	0.2	0.51	Orange
3	L3_3F_Green	3	No	0.22	0.47	Green
4	L4_3F_Red	3	No	0.24	0.51	Red
5	L5_4F_Citrus	4	Yes	0.35	0.6	Orange
6	L6_4F_Mint	4	Yes	0.31	0.6	
7	L7_2F_Plenitude	2	No	0.23	0.3	
8	L8_2F_Renova	2	No	0.21	0.28	White
9	L9_3F_Active	3	No	0.32	0.44	
10	L10_3F_Magic	3	No	0.35	0.43	
11	L11_2F_Sensitive	2	No	0.25	0.49	

prevent contamination; the values were then transferred to an SPSS18® spreadsheet for analysis. All objective tests were carried out under a standard atmosphere (of 20 ± 2℃ and 65 ± 5% RH), and all fabrics were conditioned for a time period over 48 hours.

In order to achieve Qualitative parameters it was necessary to select the tool to be used for the collection of the qualitative data. This choice was a research already used by Martins [6] in the study on the "Contribution to the objective measurement and subjective handle mesh fabric." This survey contains a questionnaire of closed questions divided into two parts: in the first part appears the general characterization of the sample and the second consists of an attitude scale to describe the material under study.

3. Results and discussion

The results are graphically displayed in figures 3 and 4. In order to display five statistics at once within each categorical value a *boxplot* graphical output was used. The statistics are the minimum value, first quartile, median value, third quartile, and maximum value. Each vertical column of graphics represents all the values for a category. The values marked with either circles or stars are the ones beyond the extents of the first and third quartiles. The ones marked by stars are the *outliers*.

The samples reaching the highest coefficient of friction with FRICTORQ are L8_2F_Renova (L8_O) on the Outer-face and L7_2F_Plenitude (L7_I) in the Inner-face. When accessed by KES-MIU, the friction coefficient of sample L1_3F_Black (L1_O; L1_I) reaches the maximum on both faces. For the standard deviation, it is greater for sample L1_3F_Black to the Outer-face (L1_O) and to L7_2F_Plenitude Inner-face (L7_I) when referring to values obtained by FRICTORQ. But when examining the values obtained by KES-MIU, L3_3F_Green samples (L3_O) are those that reach the maximum values to the Outer-face and L2_3F_Orange in the Inner-face (L2_I).

The lower values of coefficient of friction by FRICTORQ are obtained for sample L11_2F_Sensitive (L11_O; L11_I) on both faces, which also happens in KES-MIU for the sample L4_3F_Red (L4_O; L4_I). The two instruments revealed a lower amplitude of values for the same samples, L11_2F_Sensitive in the Outer-face

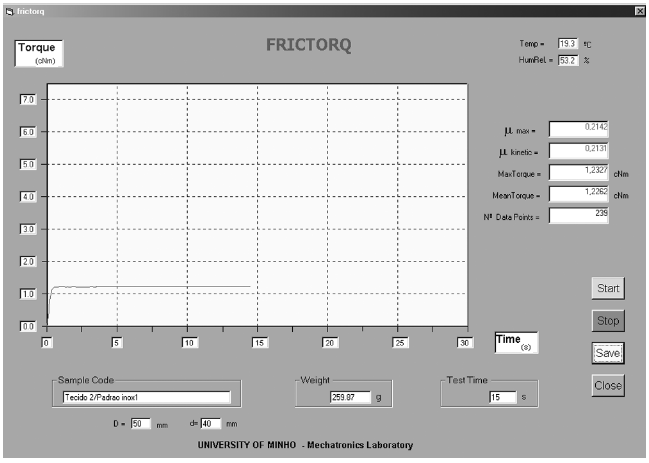

Fig. 3 Front panel of the FRICTORQ software, showing an example of a typical friction test.

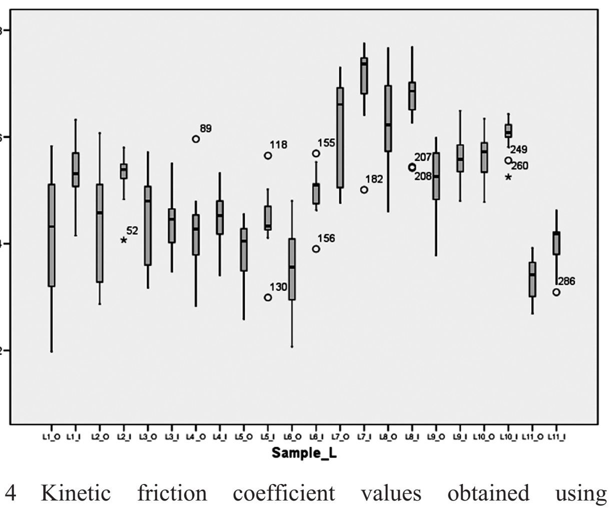

Fig. 4 Kinetic friction coefficient values obtained using FRICTORQ, μ_{kin}.

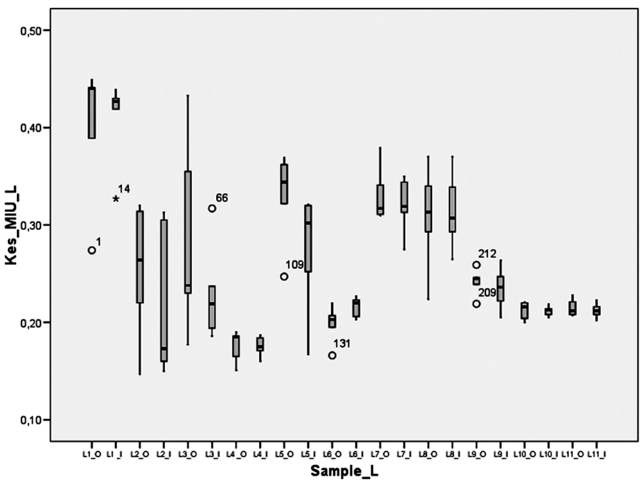

Fig. 5 Kinetic coefficient of friction values obtained using KES-MIU, μ_{kin}.

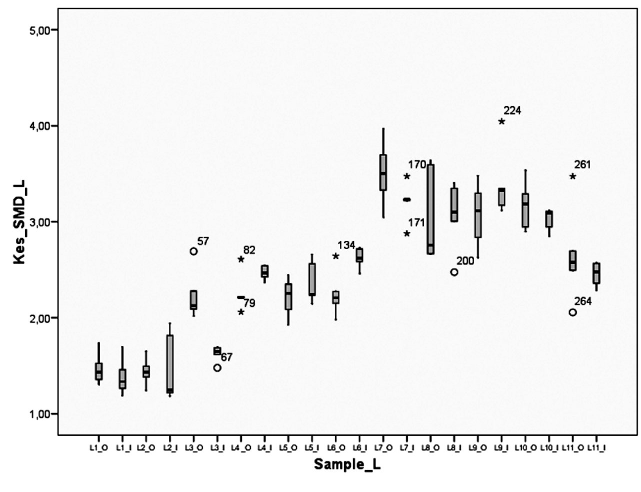

Fig. 6 Values of roughness values obtained using KES-SMD, μ_{m}.

(L11_O) and L10_3F_Magic in the Inner-face (L10_I). Figure 5 shows the average roughness of the samples. The higher value is for L7_2F_Plenitude to the Outer-face (L7_O) and L9_3F_Active to the Inner-face (L9_I), the last sample also has the highest dispersion values. The sample having the largest dispersion to the Outer-face is L11_2F_Sensitive (L11_O). The lowest average and standard deviation to the Outer-face is obtained by sample L2_3F_Orange (L2_O), and to the Inner-face the lowest average belongs to sample L1_3F_Black (L1_I) and the smallest deviation to sample L4_3F_Red (L4_I). Figure 6 shows the parameters of the analysis carried out, respecting the scale stipulated in the development of the survey. The scale has values from 1 to 7 which correspond to the range of sensations of the different parameters. The first value corresponds to the maximum initial adjective sensation of each of the sets of parameters; the latter corresponds to the respective opposite. At the interior of the graph there are two lines, at 3.5 and 4.5, defining the zone of “no opinion”, i.e., the area where the responders had more difficulty in deciding a sensation. As seen in figure 6 parameters Very Stretchy-Nonstretchy, Warm-Cool and Dense-Loose do not have any statistical significance in all samples. Parameters Rough-Smooth, Thick-Thin, Heavy-Light, Flexible-Stiff, Soft-Hard and Dry-Damp tend toward the more extreme values in the semantic differential antonyms.

In order to obtain the statistical system differences a Scheffe analysis was carry out. It is a method for adjusting significance levels in a linear regression analysis to account for multiple comparisons. For example, when mean values of variables that have been analyzed using an ANOVA are presented in a table, they are assigned to a different column based on a Scheffé contrast. Values that are not significantly different based on the post-hoc Scheffé contrast will be assigned in the same column and values that are significantly different will have different column [16].

The behaviour of paper tissues regarding the coefficient of friction mean value leads to the formation of the 10 groups by FRICTORQ, Table 3, with sample L11_2F_Sensitive_O to produce the different performance at lower values and sample L7_2F_Plenitude_I at higher values. The number of groups is reduced to three in the analysis by KES-MIU, table 4, and many samples have different performance at lower values, namely: L4_3F_Red_

Table 3 Scheffe analysis of FRICTROQ.

Sample_L	N	Subset for alpha = .05									
Mkin_L		1	2	3	4	5	6	7	8	9	10
L11_2F_Sensitive_O	13	0,1331									
L6_4F_Mint_O	13	0,1344	0,1344								
L5_4F_Citrus_O	13	0,1384	0,1384	0,1384							
L11_2F_Sensitive_I	13	0,1399	0,1399	0,1399	0,1399						
L1_3F_Black_O	13	0,1413	0,1413	0,1413	0,1413	0,1413					
L4_3F_Red_O	13	0,1417	0,1417	0,1417	0,1417	0,1417					
L3_3F_Green _I	13	0,1436	0,1436	0,1436	0,1436	0,1436					
L2_3F_Orange_O	13	0,1441	0,1441	0,1441	0,1441	0,1441	0,1441				
L5_4F_Citrus_I	13	0,1443	0,1443	0,1443	0,1443	0,1443	0,1443				
L3_3F_Green _O	13	0,1446	0,1446	0,1446	0,1446	0,1446	0,1446				
L4_3F_Red_I	13	0,1449	0,1449	0,1449	0,1449	0,1449	0,1449	0,1449			
L6_4F_Mint_I	13		0,1498	0,1498	0,1498	0,1498	0,1498	0,1498	0,1498		
L9_3F_Active_O	13			0,1519	0,1519	0,1519	0,1519	0,1519	0,1519	0,1519	
L2_3F_Orange_I	13			0,1529	0,1529	0,1529	0,1529	0,1529	0,1529	0,1529	
L1_3F_Black_I	13			0,1535	0,1535	0,1535	0,1535	0,1535	0,1535	0,1535	
L10_3F_Magic_O	13				0,156	0,156	0,156	0,156	0,156	0,156	0,156
L9_3F_Active_I	13					0,1562	0,1562	0,1562	0,1562	0,1562	0,1562
L10_3F_Magic_I	13						0,1604	0,1604	0,1604	0,1604	0,1604
L7_2F_Plenitude_O	13							0,161	0,161	0,161	0,161
L8_2F_Renova_O	13								0,1624	0,1624	0,1624
L8_2F_Renova_I	13									0,1671	0,1671
L7_2F_Plenitude_I	13										0,1705
Sig.		0,653	0,107	0,126	0,054	0,143	0,051	0,06	0,503	0,114	0,196

Table 4 Scheffe analysis of KES-MIU.

Sample_L	N	Subset for alpha = .05		
Kes_MIU_L		1	2	3
L4_3F_Red_O	5	0,1754		
L4_3F_Red_I	5	0,1754		
L6_4F_Mint_O	5	0,1982		
L10_3F_Magic_I	5	0,2118		
L10_3F_Magic_O	5	0,2122		
L11_2F_Sensitive_I	5	0,2122		
L11_2F_Sensitive_O	5	0,2152		
L6_4F_Mint_I	5	0,2158		
L2_3F_Orange_I	5	0,2202		
L3_3F_Green_I	5	0,2306	0,2306	
L9_3F_Active_I	5	0,2348	0,2348	0,2348
L9_3F_Active_O	5	0,2416	0,2416	0,2416
L2_3F_Orange_O	5	0,253	0,253	0,253
L5_4F_Citrus_I	5	0,2724	0,2724	0,2724
L3_3F_Green_O	5	0,2866	0,2866	0,2866
L8_2F_Renova_O	5	0,308	0,308	0,308
L8_2F_Renova_I	5	0,3148	0,3148	0,3148
L7_2F_Plenitude_I	5	0,3202	0,3202	0,3202
L5_4F_Citrus_O	5	0,3288	0,3288	0,3288
L7_2F_Plenitude_O	5	0,3316	0,3316	0,3316
L1_3F_Black_O	5		0,3986	0,3986
L1_3F_Black_I	5			0,4084
Sig.		0,179	0,085	0,057

Table 5 Scheffe analysis of KES-SMD.

Sample_L	N	Subset for alpha = .05					
Kes_SMD_L		1	2	3	4	5	6
L1_3F_Black_I	5	1,389					
L2_3F_Orange_O	5	1,441	1,441				
L1_3F_Black_O	5	14,712	14,712				
L2_3F_Orange_I	5	14,812	14,812				
L3_3F_Green_I	5	16,258	16,258	16,258			
L5_4F_Citrus_O	5	22,126	22,126	22,126	22,126		
L3_3F_Green_O	5	22,402	22,402	22,402	22,402		
L6_4F_Mint_O	5	22,508	22,508	22,508	22,508		
L4_3F_Red_O	5	2,261	2,261	2,261	2,261		
L5_4F_Citrus_I	5	2,37	2,37	2,37	2,37	2,37	
L11_2F_Sensitive_I	5		24,514	24,514	24,514	24,514	
L4_3F_Red_I	5		24,688	24,688	24,688	24,688	24,688
L6_4F_Mint_I	5			26,224	26,224	26,224	26,224
L11_2F_Sensitive_O	5			26,592	26,592	26,592	26,592
L10_3F_Magic_I	5				30,216	30,216	30,216
L8_2F_Renova_O	5				30,636	30,636	30,636
L8_2F_Renova_I	5				30,662	30,662	30,662
L9_3F_Active_O	5				30,718	30,718	30,718
L10_3F_Magic_O	5				31,708	31,708	31,708
L7_2F_Plenitude_I	5				32,084	32,084	32,084
L9_3F_Active_I	5					34,012	34,012
L7_2F_Plenitude_O	5						35,092
Sig.		0,105	0,061	0,057	0,089	0,058	0,052

Table 6 Correlation between the analyzed objective and subjective parameters.

L	Rough/ Smooth	Dry/ Damp	Soft/ Hard	Flexible/ Stiff	Heavy/ Light
μ_{kin}	**				*
KES MIU					
KES SMD					
L	Dense/ Loose	Very stretchy / Nonstretchy	Warm/ Cool	Thick/ Thin	
μ_{kin}				**	
KES MIU					
KES SMD					

** Significant correlation = 0.01 * Significant correlation = 0.05

O, L4_3F_Red_I, L6_4F_Mint_O, L10_3F_Magic_I, L10_3F_Magic_O, L11_2F_Sensitive_I, L11_2F_Sensitive_O, L6_4F_Mint_I and L2_3F_Orange_I. For higher values, only sample L1_3F_Black_I presents distinct behaviour. Regarding roughness, Table 5, the number of groups formed is six, and sample L1_3F_Black_I a different behaviour in the sample below and the higher values L7_2F_Plenitude_O. Table 6 shows all the parameters, both objective and subjective, as well as the statistically significant correlations. It is observed the existence of a statistically significant correlation ($p = 0.01$) between parameters Rough-Smooth and Thick-Thin with FRICTORQ and a statistically significant correlation ($p = 0.05$) between FRICTORQ and Heavy-Light parameter.

4. Conclusions

In order to evaluate the accuracy of the experimental results an ANOVA test was performed. The behaviour obtained for the samples demonstrates, in general, that FRICTORQ instrument can obtain a greater accuracy in the analysis, as the number of groups formed is higher than by KES-FB4. Comparing Tables 3 and 4 for the FRICTORQ instrument values and for the KES-FB4 values, Table 3 highlights in column 1 the lowest values obtained and column 10 the highest values for FRICTORQ values, and column

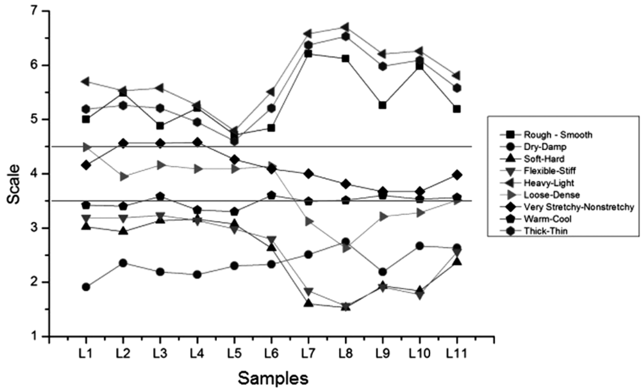

Fig. 7 Average values of the subjective analysis of tissue papers.

1 in Table 4 presents the same lowest values for KES-FB4 as well the column 3 for the highest values. Samples that have the lower and higher values are in the same groups when the analysis is performed by FRICTORQ (column 1 and column 10) or KES-FB4 (column 1 and column 3).

Parameters Very Stretchy-Nonstretchy, Warm-Cold and Dense-Loose present values, defined by the semantic differential scale, closer to four (not know area). It can be concluded that these parameters do not contribute to defining their characteristics. Sample L8_2F_Renova was simpler to define, because values tend to one of the parameters; the more difficult was L5_4F_Citrus, because values tend to the "not know" area.

In order to compute the degree of similarity or difference between the variables, a correlation between subjective and objective parameters in Tissue Papers had a significant one of 0.05 and two of 0.01. In the correlation with significance of 0.01, the first one was between FRICTORQ and Rough-Smooth with a value of -0.154 and the second between FRICTORQ and Thin-Thick with a value of -0.155. Although the obtained correlation values are very small it was noticed that there is an inverse relationship between these parameters, i.e., the increasing of the value means a decrease in the sensation in the respective analysis.

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