Influence of Physical Parameters on Fabric Hand

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Abstract

In this paper we introduce one part of the early stage research in HAPTEX (HAPtic sensing of virtual TEXtiles, http://haptex.miralab.unige.ch) –project. This study analyses both the factors that effect on fabric hand and subjective and objective assessments of it. In experimental study most common method, KES-F system, has been used to evaluate objectively fabric hand and drape of extensive collection of fabrics.

1. Introduction

Identification of materials is not only knowledge of the technical specification, but also sensory evaluation. By touching you get such information you cannot get with other senses, e.g. perception of the surface of the product, its temperature, hardness and roughness. Textiles differ from other technical structures in that it must have sufficient strength and at the same time it has to be flexible, elastic and easy to pleat and shape. Very important criterion when you evaluate textiles in traditional use is that the fabric and the garment are comfortable in aesthetic and in physiological sense.

The comfort sensation of a fabric has multi-dimensional attributes and is impossible to quantify through a single physical property. In order to find a method for the comfort evaluation of textiles, the concept of "fabric hand" is commonly used to assess fabrics. Term "fabric handle" or simply "handle" or "hand" is also used. Fabric hand refers to the total sensations experienced when a fabric is touched or manipulated in the fingers [1]. It is a complex parameter and is related to the fabric properties such as flexibility, compressibility, elasticity, resilience, density, surface contour (roughness, smoothness), surface friction and thermal character. Hand is often the fundamental aspect that determines the success or failure of a textile product.

The role of drape in a garment is an important aspect of aesthetics. Drape can be defined as a property which characterises the shape of a fabric when it is hanging down of its own weight. Drape properties are needed when modelling the cloth in virtual environment.

The aim of our study is to produce a database with extensive physical data on parameters that influence hand and drape of different types of fabrics. The objective measurements are performed with the KES-F system, which is the most common method for objective evaluation of fabric hand and drape. Additional information of deformations in the fabric with small forces is also needed and suitable test method has been investigated.

2. Factors effecting on the fabric hand

In textiles raw material, yarn structure, planar structure and finishing treatments affect the fabric hand. Properties of yarns and fabric made from them are influenced by the degree of twist in the yarn. In woven and knitted fabrics the woven / knitted fabric type and the yarn /stitch densities affect to the fabric hand. By knitting it is not possible to produce so tight fabrics than by weaving. The density of knitted fabric depends on the gauge (needle density) of the knitting machine. Nonwoven fabrics differ from knitted or woven fabrics, because they are not based on yarns. They are based on webs of individual fibres, which can be bonded to each other by several means. The texture ranges from soft to harsh [1]. Finishing is an extremely complex subject because of the large number of changes that occur in fabric properties during a finishing sequence. The effects of many finishing operations are interactive. By using various finishing treatments different kind of end products can be produced from the same unfinished woven or knitted fabric.

3. Subjective and objective assessments of fabric hand

Fabric hand is a generic term for descriptive characteristics of textiles obtained through tactile comparison. Fabric hand attributes can be obtained through subjective assessment or objective measurements. [2]
Subjective assessment is the traditional method of describing fabric handle based on the experience and variable sensitivity of human beings [2]. Textiles are touched, squeezed, rubbed or otherwise handled to obtain information about physical parameters. In the clothing industry, professional trained handle experts sort out the fabric qualities.
Objective assessment has a different primary goal: it is to predict fabric hand by testing relationships between sensory reactions and instrumental data. The most commonly used method is the Kawabata Evaluation System for fabrics (KES-F). Based on the results from KES-F measurement regression equations have been deduced for calculation of Primary hand values and Total hand value, which can be compared to the subjective assessment results [8].
However, although objective assessments are precise from a mechanical point of view, these methods have not been commonly used in the textile and clothing industry. Even today, many companies still use subjective evaluation to assess fabric properties. The main reason for this situation is the repetitive and lengthy process of measurement and the lack of knowledge for a good interpretation of the test results.

4. Factors effecting on subjective assessment

In the subjective assessment process of textiles, fabric hand is understood as result of a psychological reaction through the sense of touch. There are variations in how individuals actually feel textiles because people do not have the same sensory perception of identical occurrences. Affecting aspects can be regrouped in sociological factors and the physiological factors.
Research works that focused on the sociological aspects used traditional statistical methodologies applied to experiments on representative samples. Gender, age, education and cultural backgrounds were tested and studied as potential influencing factors. Female individuals in general respond more delicately and sensitively than male individuals and therefore have a finer assessment of a specific parameter [3] [4].
Beyond the sociological or psychological considerations, physiological factors of evaluators also have a direct impact on the subjective assessment. Different skin hydrations of individuals affect notably the feel of a textile [5]. A higher moisture level on the skin makes it more sensitive to the sense of touch.
In order to ensure the reliability of subjective assessments it is critical to choose the right expressions for the description of a fabric handle parameter. People may use the same word meaning different hand values. For this reason it is preferable to use a paired comparison technique, the so-called bipolar pairs of sensory attributes, such as “thin/thick” or “soft/harsh” [6] [7]. For the same reason, fabric hand attributes are measured on specific scales thus avoiding the intrinsic weakness of descriptive terminology.

5. Testing methods and test fabrics

5.1 Kawabata Evaluation System of Textiles

The KES-F system (Kawabata’s hand evaluation system for fabrics) was developed in Japan by the Hand Evaluation and Standardization Committee (HESC, established in 1972) organized by Professor Kawabata [8]. In this fabric objective measurement method scientific principles are applied to the instrumental measurement and interpretation of fabric low stress mechanical and surface properties such as fabric extension, shear, bending, compression, surface friction and roughness. The fabric handle is calculated from measurements of these properties. Empirical equations for calculating Primary Hand values and Total Hand Values were put forward by Kawabata and Niwa [9].

The characteristic values (Table 1) are calculated from recorded curves obtained by each tester both warp and weft direction. Tensile properties (force-strain curve) and shear properties (force-angle curve) are measured by same machine. Bending properties (torque-angle curve) are measured bending first reverse sides against each other and after that the face sides against each other. Pressure-thickness curves are obtained by compression tester. The measurements of surface friction (friction coefficient variation curve) and surface roughness (thickness variation curve) are made with the same apparatus using different detectors.

Characteristic values in KES-F system		
Tensile	LT	Linearity of load-extension curve
	WT	Tensile energy
	RT	Tensile resilience
Shearing	G	Shear rigidity
	2HG	Hysteresis of shear force at 0.5º shear angle
	2HG5	Hysteresis of shear force at 5º shear angle
Bending	B	Bending rigidity
	2HB	Hysteresis of bending moment
Compression	LC	Linearity of pressure-thickness curve
	WC	Compressional energy
	RC	Compressional resilience
Surface	MIU	Coefficient of friction
	MMD	Mean deviation of MIU, frictional roughness
	SMD	Geometrical roughness
Weight	W	Weight per unit area
Thickness	T	Thickness at 0.5 gf/cm^2

Table 1 : Characteristic values in KES-F system [8]

5.2 Tests with tensile tester

In reality, the fabric of a garment undergoes small extensions and relaxations. To better study this behaviour, some trials have also been performed with a tensile tester, Testometric M500. Samples are elongated at slow deformation rate to get the results closer to the static case. In that way it is possible to get a good view of the behaviour of the fabric for small forces and deformations. For the real time simulations of fabrics within the haptex project the hysteresis behaviour of fabrics is not directly taken into account. However to know the hysteresis behaviour of a fabric it is important to device an average curve between elongation and relaxation. The actual strain-stress point evolves somewhere inside the hysteresis loop.

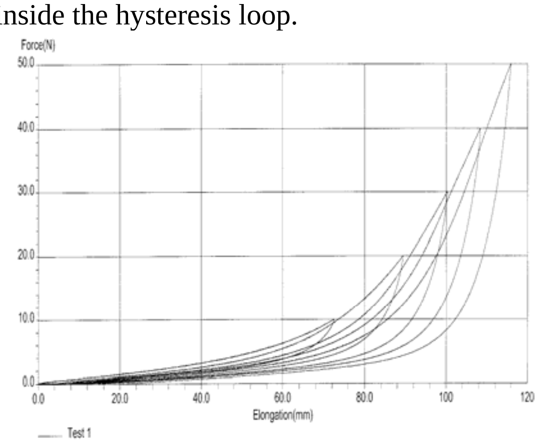

Figure 1 : Step tensile curve of sample 20 in machine direction.

The final conclusion was that the appropriate way of measuring is step tensile (five loops) of progressive amplitude and 120 s wait between each loop. The constant rate of jaw is 10 mm/min and the maximum forces of each loops are 200, 400, 600, 800 and 1000 N/m (Figure 1). This measuring method allows better analyzing the actual strain-stress behaviour of the fabric, taking into account not only 1 but 5 hysteresis loops.

5.3 Fabric selection process

A collection of samples was chosen for evaluating the HAPTEX system. The aim of the fabric selection process was to represent a range of very different fabrics in terms of fibres, structure and dimensions. The total number of samples was limited to 32 in a first selection process. For selecting the different kind of fabrics to be contained in the fabric properties database, three criteria were identified (Figure 2).

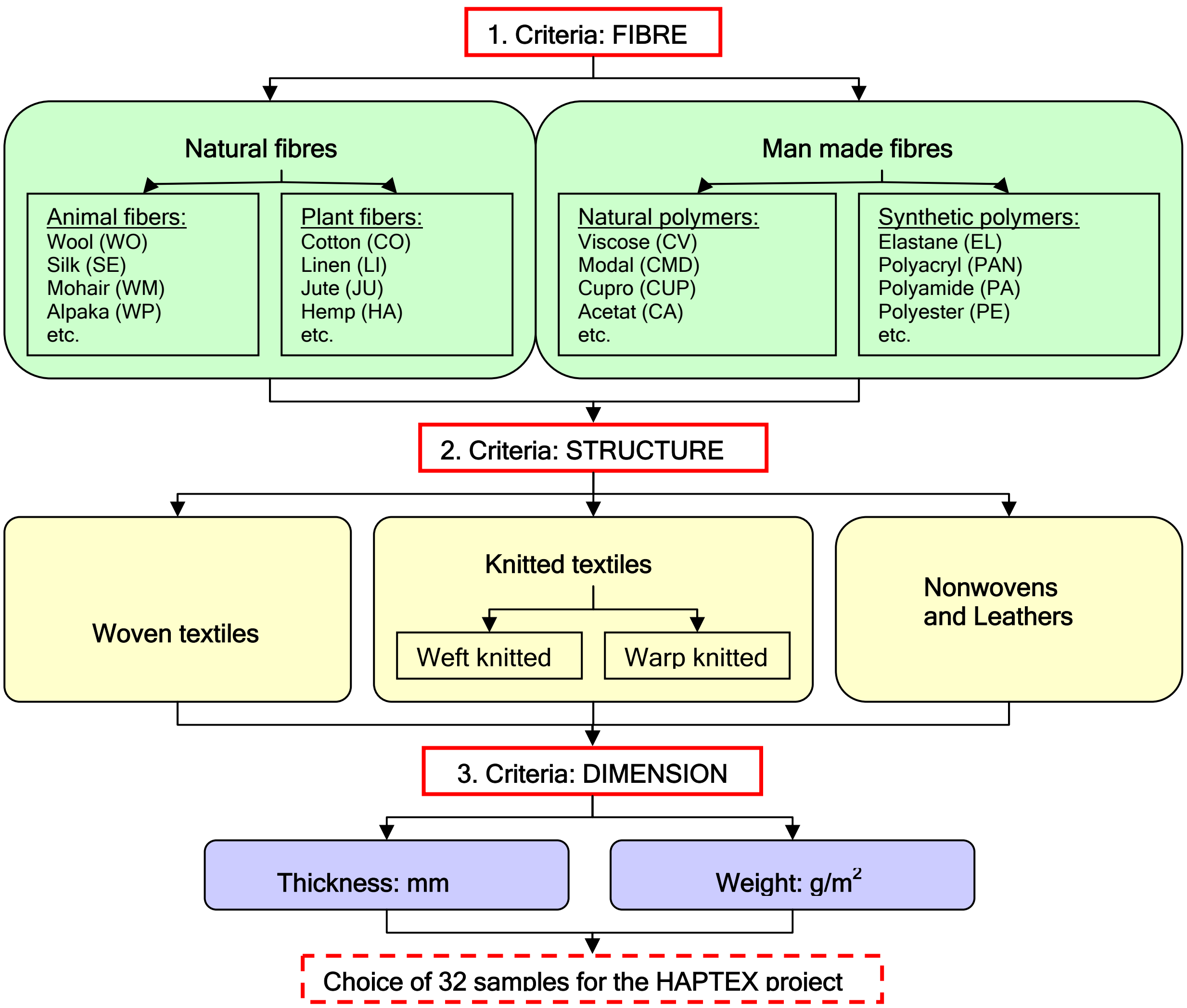

Figure 2 : Fabric selection process.

1. Criterion: Fibre

The fibre has been chosen as the first criterion for the fabric selection process. Different fibre properties (natural/man made, staple/filament) influence on the fabric parameters. In today's clothing collections in stores, synthetic and blended fabric qualities play an important role.

Garments out of synthetic or blended fibres are less expensive and easier to care. This aspect is represented in the fabric selection. Samples 1-10 (Table 2) are made of natural fibres, samples 11-21 of blended fibres and samples 22-31 of synthetic fibres.

2. Criterion: Structure

In the fabric selection process a variety of different fabric structure has been chosen: 23 woven fabrics, 7 knitted fabrics, one nonwoven and leather. The fabric structure has a high influence on the fabric properties, i.e. knitted textiles are mostly more elastic than woven fabrics. In the selection process fabrics with the same fibre composition different structures have been chosen to analyze the influence of the structure to the hand parameter.

3. Criterion: Dimension

The third criterion of selection was based on the physical aspect and dimension of the fabrics, like thickness, yarn density and weight. Fabrics, composed of the same fibre and the same structure, can still be different among thickness and weight, caused by yarn number, yarn and loop densities or finishing treatments. To ensure a realistic virtual simulation of textiles for the Haptex project, it is important to study the characteristics of a broad range of fabrics. Therefore, each fabric group is represented in the selection. The described criteria for the selection process of the fabrics represent as most variety as possible in terms of physical parameters and expected haptic characteristics.

Sample	Description	Fibre content	Structure	Weight g/m2	Thickness mm
1.	Denim	100% CO	twill	380	1,60
2.	Shirt cotton	100% CO	combined twill	120	0,61
3.	Cord	100% CO	velveteen	330	1,76
4.	Linen	100% LI	plain weave	250	1,09
5.	Gabardine	100% WO	twill	175	0,55
6.	Crepe	100% WO	plain weave	145	0,93
7.	Silk	100% SE	plain weave	15	0,10
8.	Natural silk (bourette)	100% SE	plain weave	150	0,80
9.	Wild silk (dupion)	100% SE	plain weave	80	0,44
10.	Jute	100% JU	plain weave	300	1,44
11.	Flannel	80% WO 20% PES	twill	290	1,53
12.	Denim	62% PES 35% CO 3% EL	twill	275	1,13
13.	Plaid	35% PES 35% AF 30% WO	twill	270	1,14
14.	Tweed	66% AF 14% WO 10% PES 10% CMD	combined twill	270	3,90
15.	Velvet	92% CO 8% CMD	velvet	300	1,88
16.	Lurex knit	70% PES 30 % PA	held stitch knit	215	2,94
17.	Crepe-jersey	85% PES 15% EL	rib knit	135	0,73
18.	Woven motorcyclist wear fabric, coated	72% PA 28 % PU	plain weave	90	0,39
19.	Woven easy care fabric	65% PES 35 % CO	twill	180	0,57
20.	Warp knitted velour fabric	90% PA 10% EL	warp knit velour	235	1,56
21.	Weft knitted plain fabric	98% CLY 2% EL	single jersey	172	1,21
22.	Taffeta	100% CA	plain weave	125	0,33
23.	Crepe	100% PES	plain weave	85	0,25
24.	Satin	100% PES	satin	125	0,30
25.	Felt	100% PES	nonwoven	155	1,25
26.	Organza	100% PES	plain weave	25	0,16
27.	Fleece	100% PES	weft knit	250	3,99
28.	Woven upholstery	100% PES	woven Jacquard	600	2,38
29.	Woven outdoor leisure wear fabric	100% PES	plain weave	90	0,20
30.	Tulle	100% PA	warp knitted tulle	10	0,30
31.	Warp knitted tricot-satin	100% PA	warp knitted tricot-satin	100	0,40
32.	leather	100% Leather	----------------	815	1,68

Table 2 : Specification of selected samples.

5.4 Digitized output

In its standard version the KES-F equipment provides analog output signals that have to be digitized in order to be stored in an electronic database. The principle of digitizing the output of Kawabata measurements is that similar curves as in analog form can be recorded using the measured values. The output parameters are the same as in analog form in the x- and y-axis. The sampling rates in various measurements can be fixed differently and according to requirements. E.g. in bending the sample rate is 20 Hz and in surface profiles and friction 1 kHz. The program calculates the characteristic values in KES-F system (Table 1) printing them on the report page.

6. Results

6.1 KES-F results

In figures 3 – 7 five parameters of KES-F measurements are illustrated in diagrams to clarify the comparison of different fabrics. It can be seen that tensile resilience (Figure 3) is the highest on tight woven fabrics (samples 5, 7, 18, 22, 23, 26, 29) and the lowest on knitted fabrics (samples 16, 21) and nonwoven (sample 25).
Woven fabric for motorcyclist wear and leather (samples 18, 32) have the highest shear rigidity (Figure 4). Knitted fabrics (samples 16, 17, 20, 21) and also some woven fabrics, e.g. combined twill, crepe structure and loose woven fabric (samples 2, 6, 14) have quite low resistance to shear.
Bending rigidity (Figure 5) is often different in machine/warp and cross/weft direction of the fabric. It can be due to the unbalanced fabric, i.e. warp and weft densities differ a lot or the yarn in the other system is much thicker. It is quite usual in woven fabrics that the warp density is higher than the weft density. Bending rigidity in denim fabric (sample 1) is clearly different in warp and weft directions. Also in leather (sample 32) the stiffness differ a lot in long and cross direction. The difference between the bending rigidity values e.g. in samples 22 and 23 is quite significant if you touch and bend these fabrics by fingers, although the difference in the diagrams seems so small.
Samples that are compressed a lot (soft and voluminous fabrics) are returned back poorly and those with low compression (samples 7, 18, 29, 30) returned well (Figure 6).
The woven or knitted structure or the unbalance of the fabric is influenced significantly to differences of the surface roughness in machine and cross direction (Figure 7). It is only natural that twill line in sample 1, corduroy structure (sample 3), wales in knitted structure (sample 16), unbalanced taffeta structure (sample 22) and tulle in warp knit (sample 30) affects significantly to the surface roughness. Roughness of the smooth fabrics, plain weave silk (sample7) and satin structure (sample 24), is quite low, but slightly different in warp and weft directions.

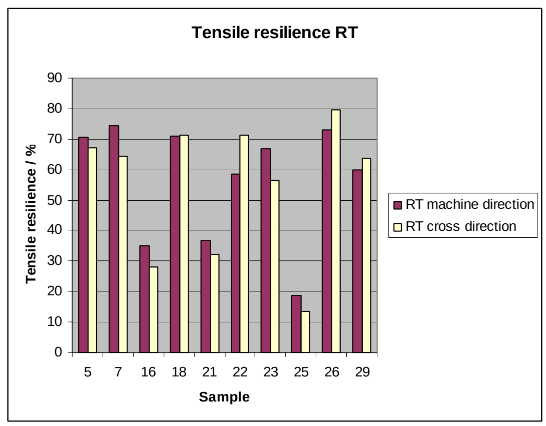

Figure 3 : Tensile resilience of selected samples measured with KES-FB1 device.

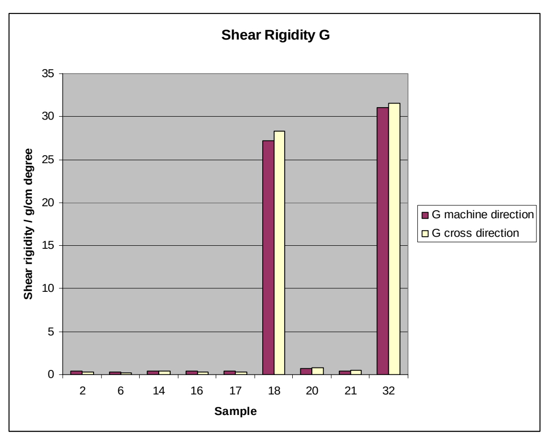

Figure 4 : Shear rigidity of selected samples measured with KES-FB1 device.

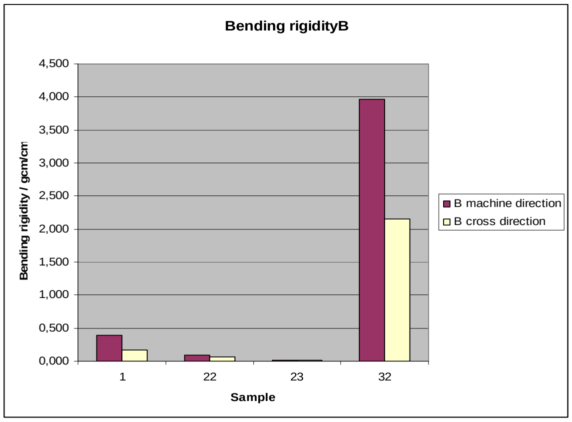

Figure 5 : Bending rigidity of selected samples measured with KES-FB2 device.

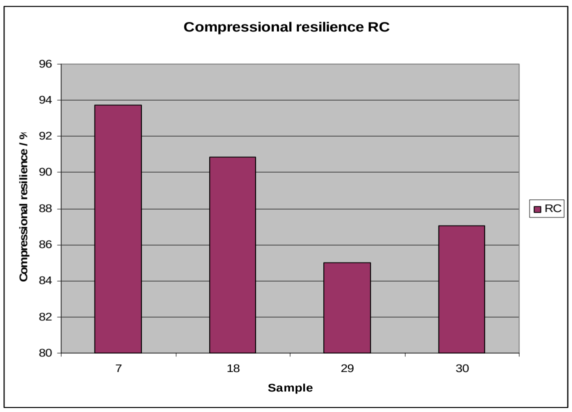

Figure 6 : Compressional resilience of selected samples measured with KES-FB3 device.

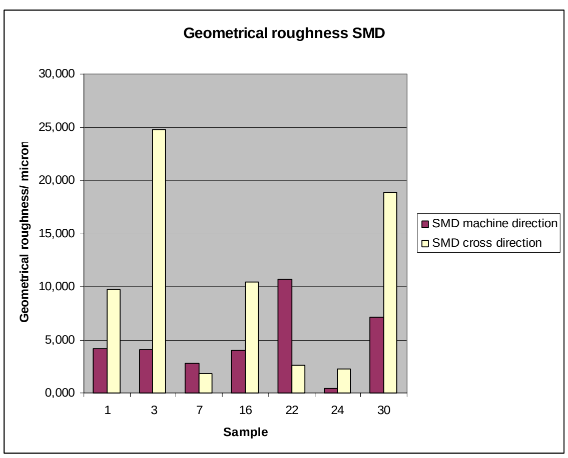

Figure 7 : Geometrical roughness of selected samples measured with KES-FB4 device.

6.2. Transfer of the physical properties to the simulation engine

The final demonstrator of Haptex should allow the user to choose a textile from the fabric database and sense a haptic feedback of virtual textiles according to their visual and haptic representation of mechanical properties. For a realistic virtual simulation of clothing, the simulation engine needs to be fed with parameters for the interpretation of the real world behaviour of fabrics. The easiest way to detect the right input parameters is to measure the properties of real fabrics and to apply them to the virtual simulation engine. Most of the parameters can be measured with standard measurement devices, such as the Kawabata Evaluation System. However, for certain parameters there are still no suitable measuring devices and they have to be approximated through other experiments.

Elasticity and plasticity parameters and the coefficient of friction are evaluated parameters from KES-F measurements. Standard experimental procedures do not yet exist for the measuring of deformation-speed dependant forces, such as viscosity.

Mechanical parameters are divided into internal and external forces. Internal forces, such as elasticity, viscosity and plasticity, occur from surface deformations. External forces caused by environment interactions, consist in gravity, air viscosity, contact reaction, such as friction or other miscellaneous interactions.

The surface deformations are divided into in-plane deformations (the 2D deformations along with the cloth surface plane in warp, weft and shear) and bending deformation (the 3D surface curvature for weft and warp). Both, in-plane and out-of-plane deformations, consist of elasticity, viscosity and plasticity parameters (Figure 8) [10].

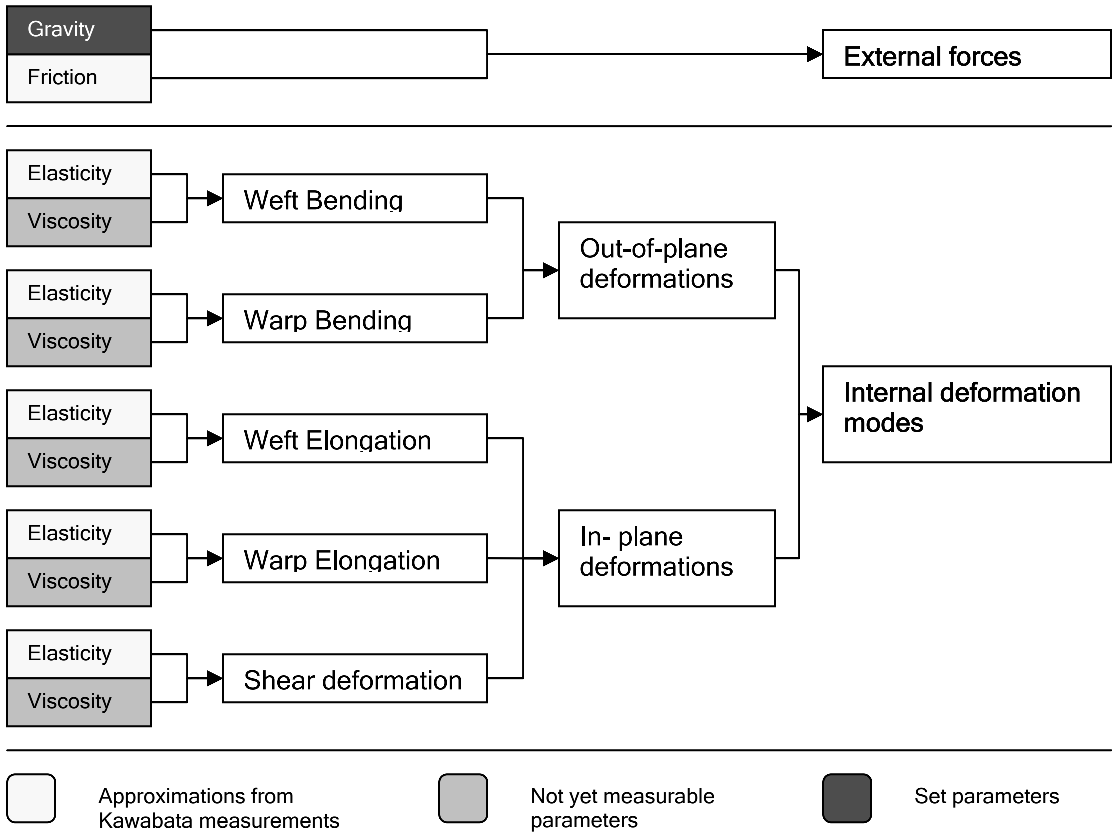

Figure 8 : Mechanical properties in the simulation engine.

7. Discussion

Virtual simulation of clothing needs parameters of the real world behaviour of fabrics. In this first laboratory test series database with physical data has been produced. The parameters have been measured with the standard version of KES-F equipment. However, there are still certain parameters which have to be approximated through other experiments. Therefore further study is necessary to refine physical parameters through more systematic analysis. The more exactly virtual simulation behavior is approximated to the behavior of real materials, the more processes of the garment manufacturing chain can be executed virtually.

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