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HAPTEX

HAPtic sensing of virtual TEXtiles

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Deliverable D3.2

Second set of fabric measurements

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The HAPTEX Project Consortium groups the following Organizations:

ORGANIZATION	SHORTNAME	ROLE	STATE
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University of Hanover	UHAN	Partner	Germany
Tampere University of Technology	SWL	Partner	Finland

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1. Introduction

This document is a progress report and it presents the test results of the second set of fabrics that have been measured using Kawabata Evaluation System for fabrics (KES-F) and tensile tester. Also some non-standard measurements of surface properties have been made using different sensor material in friction measurement and different shape sensor head in roughness measurements. The results are analysed further per sample and the hand properties of the fabrics are compared to each other.

The result data and the sample details have been gathered in excel format in a separate database file.

The first set of measurements was presented in HAPTEX Deliverable D3.1 First set of measurements.

2. Selection of test materials for the 2nd set

There is a vast variety of different kinds of fabrics available on the market today for textiles and clothing materials. The range of their hand properties is as versatile as the fabric selection and they are a complex combination of different physical aspects. Therefore it is important to have as broad selection as possible representing different kinds of raw materials, fibre types, fabrics constructions and dimensions.

The aim of selecting the test materials for the second set was to increase the sample selection. Especially samples having elastic fibres/elasthane in their construction and on the other hand men`s woven suit fabrics were chosen. The number of samples was restricted to ten to be able to analyze them more deeply.

The second set consists of six thin and four relatively thick samples. The samples have very different constructions, different raw materials, yarns and different densities. Two of them contain elastane fibre (samples 36 and 38). The surface properties vary from smooth to piles and holes. Samples 35, 36, 38 and 39 represent thicker fabrics. Their surface is ranging from smooth to hairy and pile loops. One of them is weft knitted terry fabric (sample 39) while the other three are woven ones. The second set of fabrics are grouped by the origin of the raw material and they are presented in tables 2.1, 2.2 and 2.3 .

Table 2.1. Fabrics of natural fibre.

	Description	Fibre content	Structure	Weight g/m^2	Thickness mm
34.	Men’s woven suit fabric	100WO	herringbone (broken twill)	232	0,83

Table 2.2. Blended fabrics.

	Description	Fibre content	Structure	Weight g/m^2	Thickness mm
33.	Men's woven suit fabric	60WO 38PES 3EL	plain weave	195	0,57
35.	Men's woven overcoat fabric	80WO 20PA	modified plain weave	324	2,64
36	Men's woven overcoat fabric	59CO 25PAN 11WO 5 PES	twill	460	3,23
38.	Weft knitted jersey fabric	48CO 48CMD 4EL	single jersey	208	1,09
39.	Weft knitted terry fabric	55CV 45PES	weft knit terry	288	1,69

Table 2.3. Fabrics of man-made fibres.

	Description	Fibre content	Structure	Weight g/m^2	Thickness mm
37.	Woven outdoor leisurewear fabric	100PES	plain weave	98	0,26
40.	Warp knitted jersey-based fabric	100PES	warp knit jersey-based	154	0,51
41.	Warp knitted mesh fabric	100PES	warp knit mesh	128	0,51
42.	Brushed warp knitted fabric	100PES	brushed warp knit	215	0,98

The fabric weight describes how heavy or light the material is. The mass per square meter and the thickness were determined. Depending on the yarn count and the yarn densities normally or more often the heavier material means the thicker material. Sample 36 (Men's woven overcoat fabric, blended staple yarn fabric) is the heaviest and sample 37 (Woven outdoor leisurewear fabric, synthetic filament fiber yarns) is the lightest fabric. In table 2.4 there is gathered examples of weights of different types of fabrics.

Table 2.4. Examples of fabric weights.

Fabric description	Weight range g/m^2
Chiffon	~30
Shirt fabric	100 - 150
Cotton denim	~400
Heavy coated fabric	~800
Hospital sheet fabric	160-200

3. Test results and discussion

3.1 KES-F results of standard measurements

All measurements were made in standard testing conditions of RH (65±5)% and T (20±2)°C. Two parallel measurements were made normally for each sample and the result was the mean of these parallel measurements. The determinations were performed in warp and weft direction for woven samples and in machine and cross direction for knitted samples on the right side and on the back side.

3.1.1 Bending

Bending was determined according to the standard settings. The settings are selected according to the material thickness. The very thick materials like sample 36 may have difficulties when bended in Kawabata equipment – the bending movement may not reach the end point. This happened with sample 36; however it did not seem to effect the result (an example of measuring graph 1 in Annex 1).

The measuring data of bending rigidity B (gf*cm^2/cm) and hysteresis 2HB (gf*cm/cm) are presented in table 3.1 and in figure 3.1.1 below in warp and weft direction (woven samples) or machine and cross direction (knitted samples).

Table 3.1 The measuring data of bending rigidity B (gf*cm^2/cm) and hysteresis 2HB (gf*cm/cm).

Sample	B warp	B weft	2HB warp	2HB weft
33	0,054	0,054	0,0176	0,0193
34	0,143	0,096	0,071	0,040
35	0,268	0,129	0,228	0,118
36	0,843	0,622	0,632	0,423
37	0,026	0,105	0,022	0,063
38	0,028	0,025	0,030	0,033
39	0,015	0,014	0,015	0,014
40	0,022	0,049	0,017	0,036
41	0,020	0,027	0,012	0,019
42	0,017	0,061	0,015	0,041

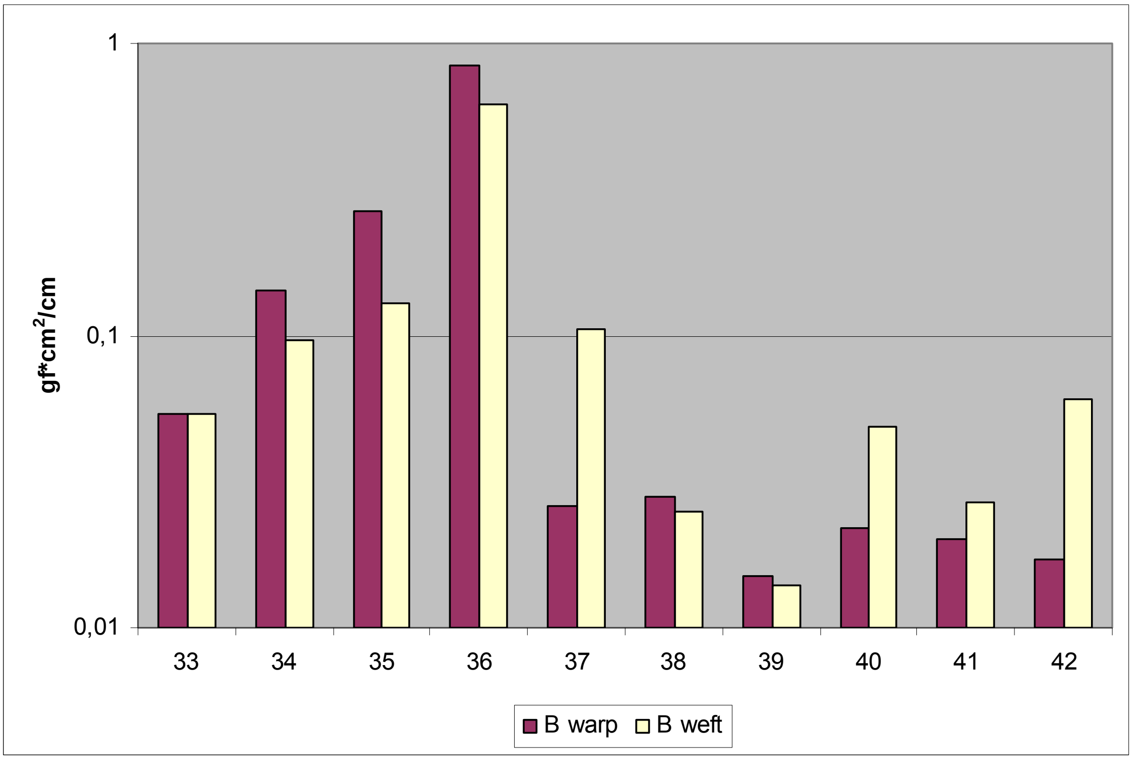

Figure 3.1.1 The bending rigidity B of samples 33 – 42 (gf*cm^2/cm). Note the logarithmic scale.

The low value of bending rigidity means that the fabric bends easily, high value means that the fabric resists its bending. In warp direction the values are ranging from 0,015 to 0,889 gf*cm^2/cm and in the weft direction from 0,014 to 0,643 gf*cm^2/cm. The lowest value has sample 39 (weft knitted terry fabric and the highest value sample 36 (men's woven overcoat fabric (twill)) in both warp and weft direction.

The differences between the warp and weft direction per sample were assessed as well. Samples 36, 35, 37, 34 and 42 have the greatest differences and the smallest differences with samples 33, 39, 38 and 41.

The low value of hysteresis means that the return curve goes near the bending curve and high value that the return curve differs remarkably from the bending curve. The hysteresis values range from 0,012 to 0,632 gf*cm/cm in warp/machine direction and from 0,014 to 0,423 gf*cm/cm in weft/cross direction. Sample 36 has the highest values.

The samples have then been analysed further.

Sample 33 The bending rigidity (B) of the men's woven suit fabric (plain) is rather low for these samples. It is same in warp and weft direction. The structure is the same on both sides and the yarn densities are nearly the same as well. The construction is in balance. The mass per square meter is 195 g/m^2. The hysteresis values are rather low and they are nearly the same in warp and weft direction, the weft direction being a little higher.

Sample 34 The men's woven suit fabric (herringbone) has rather low bending rigidity (B) of these samples. The value is higher in warp than in weft direction. The herringbone structure is the same on both sides and the yarn densities are nearly the same in both directions the warp density being slightly higher. The yarn densities are rather low and the yarns are quite coarse. The mass per square meter is medium heavy 232 g/m^2. The hysteresis values are rather low and the value is higher in warp direction.

Sample 35 This men's woven overcoat fabric has rather high bending rigidity (B) for these samples. The value is two times higher in warp direction than in weft direction. The structure looks the same on both sides and the yarn densities are nearly the same as well the warp density being slightly higher. The mass per square meter is heavy 324 g/m^2. The fabric has an applied plain weave structure so that one weft yarn is always crossing over three warp yarns meaning that the warp yarns are grouped in to threes. The surface has been brushed and then calendered. The yarns are rather rough wool/polyamide blended staple fiber yarns. The hysteresis values are rather high as well and the value is higher in warp direction as was the bending rigidity value.

Sample 36 The men's woven overcoat fabric (twill) has the highest bending rigidity (B) for these samples. The value of bending rigidity is higher in warp direction than in weft direction. The fabric has a twill weave structure on both sides. The diagonal lines are distinguished clearly. The construction is rather thick and the mass per square meter is heavy 460 g/m^2. Weft yarn density is a little bit higher than the warp yarn density. The diagonal lines and long, soft weft yarn leaps cause the higher bending values in weft direction. The construction is soft and pliable. The yarns are rather rough - cotton in warp yarns and polyacrylnitrile/wool/polyester blended weft yarns. The hysteresis values are rather high as well and the value is higher in warp direction as was the bending rigidity value.

Sample 37 The woven outdoor leisurewear fabric has rather low bending rigidity (B) in warp direction and four times higher in weft direction. The dense and plain weave structure as well the polyester filament yarn causes smooth surface. The warp yarn density is 1,4 times higher than weft yarn density. The mass per square meter is light 98 g/m^2. The hysteresis values are rather low as well and the value is higher in weft direction as was the bending rigidity value.

Sample 38 This weft knitted jersey fabric has very low bending rigidity (B) for these samples. It is slightly higher in machine direction. The weft knitted structure is rather dense but pliable. The stitch wales may cause that the bending rigidity is slightly higher in machine direction. The mass per square meter is medium heavy 208 g/m^2. The hysteresis values are very low.

Sample 39 The weft knitted terry fabric has the lowest bending rigidity (B) within these samples. It is nearly the same in both directions. The construction is very pliable and soft and the stitch density is rather low. The mass per square meter is medium heavy 288 g/m^2. The hysteresis values are also very low.

Sample 40 This warp knitted jersey-based fabric has very low bending rigidity (B) of these samples. It is a little higher in cross direction than in machine direction. On back side the stitch rows may cause higher bending rigidity in cross direction. The stitch density is a little higher in machine direction than in cross direction. The density is rather coarse. The mass per square meter is light 154 g/m^2. The hysteresis values are also very low and it is higher in cross direction.

Sample 41 The warp knitted mesh fabric has very low bending rigidity (B) for these samples. It is a little higher in cross direction than in machine direction. On back side the stitch rows may cause the higher bending rigidity in cross direction. The stitch density is higher in machine direction and it is rather high about 24 loops/cm. The mass per square meter is light 128 g/m^2. The hysteresis values are also very low and it is a little higher in cross direction.

Sample 42 The brushed warp knitted fabric has very low bending rigidity (B) of these samples. It is higher in cross direction than in machine direction. On face side the cut pile may cause the higher bending rigidity in cross direction. The stitch density is higher in machine direction and it is rather high about 32 stitches/cm. The mass per square meter is medium heavy 215 g/m^2. The hysteresis values are also very low and it is a little higher in cross direction.

3.1.2 Compression

Compression was measured according to standard settings which are affected by the fabric thickness and density. The compression measurement data of linearity LC, compressional energy WC ($gf*cm/cm^2$), resilience RC (%) and thicknesses T0 and Tm (mm) are presented in table 3.2. The results of resilience RC are also presented in figure 3.1.2.

Table 3.2 The compression measuring data of linearity LC, compressional energy WC ($gf*cm/cm^2$), resilience RC (%) and thicknesses T0 and Tm (mm).

Sample	LC	WC	RC	T0	Tm	(T0-Tm)/T0*100
33	0,418	0,097	57,61	0,57	0,47	17,54
34	0,402	0,209	58,85	0,83	0,62	25,30
35	0,419	1,212	51,09	2,64	1,49	43,56
36	0,540	1,307	44,34	3,23	2,26	30,03
37	0,294	0,059	73,79	0,26	0,18	30,77
38	0,357	0,422	37,56	1,09	0,62	43,12
39	0,474	0,640	45,36	1,69	1,15	31,95
40	0,543	0,098	53,08	0,51	0,44	13,73
41	0,453	0,114	44,30	0,51	0,40	21,57
42	0,560	0,359	48,32	0,98	0,69	29,59

The compressibility has been calculated as a proportional difference (%) between T0 (thickness at 0.5 gf/cm^2) and Tm (thickness at 50 gf/cm^2) and it is presented in table 3.2 and in figure 3.1.3. It is not normally used but it describes how much the material is compressed with the maximum force 50 gf/cm^2.

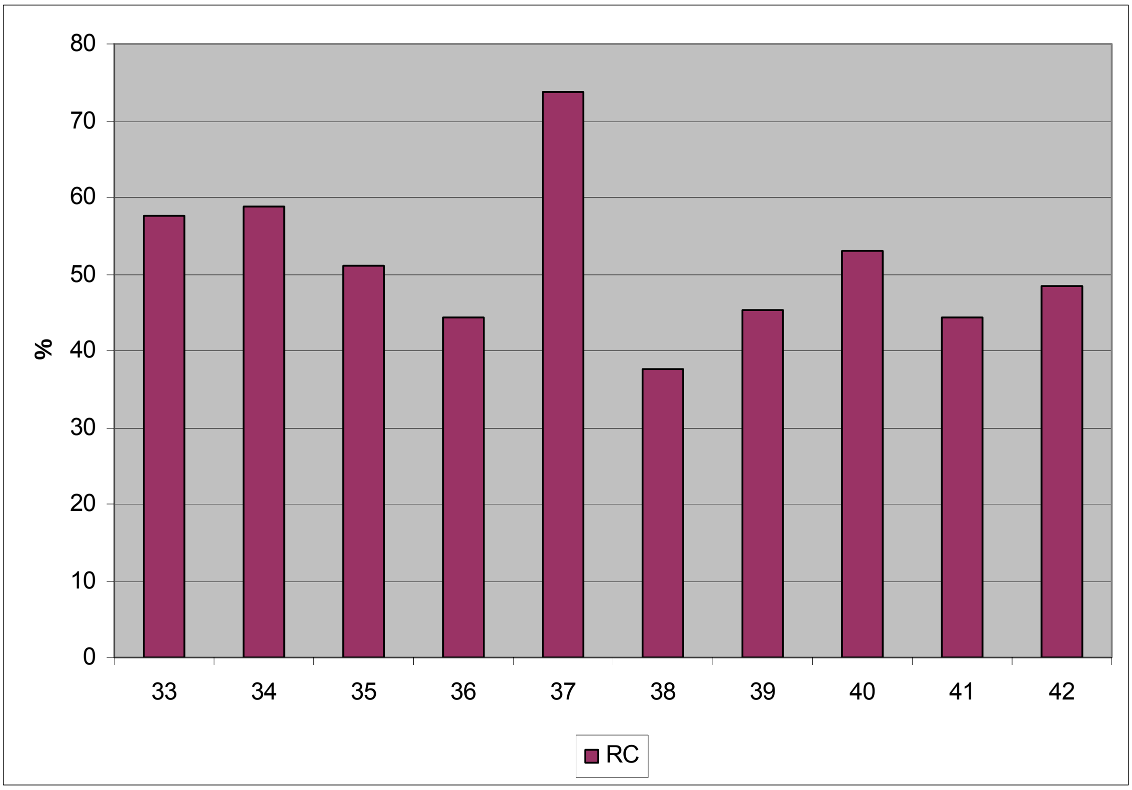

Figure 3.1.2 The results of resilience RC (%).

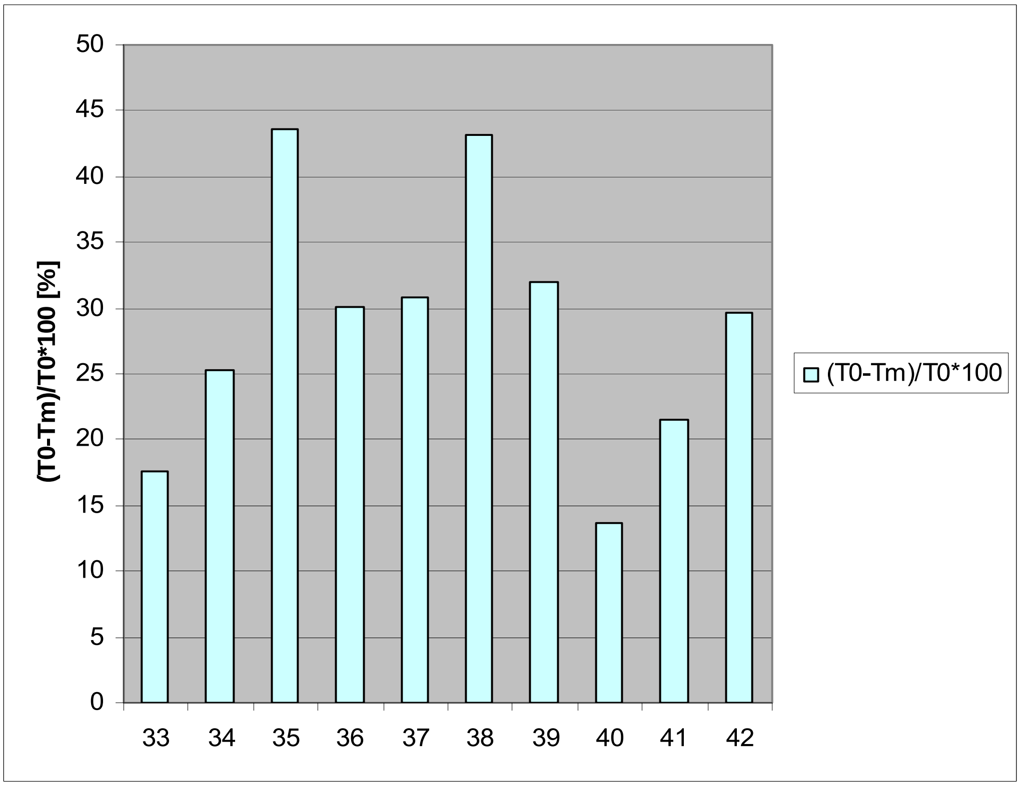

Figure 3.1.3 The results of the compressibility calculated as a proportional difference between T0 (thickness at 0.5 gf/cm^2) and Tm (thickness at 50 gf/cm^2).

The low value of linearity LC (-) means that the compression curve deviates substantially from straight line and the high value means that the form of the curve is close to the straight line. The values are ranging from 0,294 to 0,560 and sample 37 (woven outdoor leisurewear fabric) has the lowest value. Sample 42 (brushed warp knitted fabric) has the highest value.

When compressional energy WC (gf*cm/cm^2) has low value it means that the compression needs little energy supply, high value stands for that compression needs high energy supply. The values are ranging from 0,059 to 1,307 gf*cm/cm^2. The lowest value is registered for sample 37 (woven outdoor leisurewear fabric) and the highest value for sample 36 (men's woven overcoat fabric (twill)). The values are not analogues with LC values but they seem to correspond to the fabric thickness.

The low value of RC resilience (%) signifies that the return curve of compression follows near the compression curve. The high value signifies that the return curve deviates substantially from the compression curve. It is ranging from 37,56 to 73,79 % and sample 38 (weft knitted jersey fabric) has the lowest value. The highest value is registered for sample 37 (woven outdoor leisurewear fabric). The fabrics which are woven, thin and dense seem to have the highest values.

T0 thickness at 0.5 gf/cm^2 (mm) values range from 0,26 to 3,23 mm. Sample 37 (woven outdoor leisurewear fabric) has the lowest value and sample 36 (men's woven overcoat fabric (twill)) has the highest value. T0 value has been used to designate the thickness of the sample (e.g. in tables 2.1, 2.2 and 2.3)

Tm thickness at 50 gf/cm^2 (mm) values range from 0,18 to 2,26 mm. The lowest value is recorded for sample 37 (woven outdoor leisurewear fabric) and the highest one for sample 36 (men's woven overcoat fabric (twill)). Tm values seem to follow the same order as T0 values. According to HAPTEX deliverable D3.1 samples that are compressed a lot (soft and voluminous) return poorly and those with low compression return well.

Linearity LC (-) is not used very much because it is a complex parameter. It has not been analysed further in this context.

The further analyses of the samples show their different characters.

Sample 33 The men's woven suit fabric (plain): the compressional energy WC is very low for these samples. The thickness is quite low. The yarns are relatively thin and the plain structure is thin as well. Material compresses very little.
Resilience RC is rather high among these samples.

Sample 34 The men's woven suit fabric (herringbone) has rather low compressional energy WC for these samples. The thickness is quite low. The yarns are rather thick and the herringbone structure is rather rough. The yarn densities in both directions are rather low. The surface has been calendered which has decreased the thickness to some extent. The effect of pressing on the thickness of fabric has been studied with wool and wool blended fabrics and it seems to decrease the thickness remarkably compared to heat setting and scouring treatments [Tomasino, 2005]. Resilience RC is rather high among these samples. Material compresses rather little.

Sample 35 The men's woven overcoat fabric has very high compressional energy WC for these samples. The thickness is very high. The mass per square meter is heavy 324 g/m^2 and the woolblended yarns are thick and rough and hairy. The fabric has an applied plain weave structure so that one weft yarn is always crossing over three warp yarns meaning that the warp yarns are grouped in to threes. The yarns are partly lying over each other which increases the thickness and the volume/bulkiness. The surface has been brushed and then calendered. Resilience RC is rather high for these samples. This material has the highest compressibility of these samples.

Sample 36 This men's woven overcoat fabric (twill) has the highest compressional energy WC and highest thickness within these samples. The twill structure has long weft yarn leaps and rather high yarn densities compared to the yarn thicknesses in warp and weft directions. The mass per square meter is heavy 460 g/m^2. The diagonal lines are distinguished clearly. The double layer construction is rather thick and both sides have the same structure. Weft yarn density is a little bit higher than the warp yarn density. The construction is soft and volume/bulky. The yarns are rather rough - cotton in warp yarns and polyacrylnitrile/wool/polyester blended weft yarns. Resilience RC is rather low for these samples. The material has rather high compressibility.

Sample 37 The woven outdoor leisurewear fabric has the lowest compressional energy WC and the lowest thickness. The dense and plain weave structure and the thin polyester filament yarns cause the thin structure. The mass per square meter is light 98 g/m^2. Resilience RC is very high of these samples and it has rather high compressibility.

Sample 38 The weft knitted jersey fabric has rather low compressional energy WC and rather low thickness. The weft knitted structure is rather dense but the stitches give softness and volume to the structure. The mass per square meter is medium heavy 208 g/m^2. It has the lowest resilience RC of these samples but it has the second highest compressibility.

Sample 39 The weft knitted terry fabric has medium high compressional energy WC and rather high thickness. The construction is very voluminous/bulky and soft due to the stitch density. The mass per square meter is medium heavy 288 g/m^2. Resilience RC is rather low of these samples. Material has rather high compressibility.

Sample 40 The warp knitted jersey-based fabric has low compressional energy WC and low thickness for these samples. The warp knitted structure is thin due to the thin filament yarns. The stitch densities are rather low. The mass per square meter is light 154 g/m^2. Resilience RC is rather high among these samples. Material has the lowest compressibility of these samples.

Sample 41 The warp knitted mesh fabric has low compressional energy WC and low thickness for these samples. The warp knitted mesh structure is thin due to the thin filament yarns. The stitch densities are rather low especially in cross direction. The mass per square meter is light 128 g/m^2. Resilience RC is rather low and the material has low compressibility of these samples.

Sample 42 The brushed warp knitted fabric has rather low compressional energy WC and rather low thickness. On face side the cut pile cause softness and bulkiness. The base knit consists of rather thin filament yarns. The stitch density is higher in machine direction and it is rather high about 32 stitches/cm. The mass per square meter is medium heavy 215 g/m^2. Resilience RC is rather high of these samples and the material compresses rather little.

3.1.3 Friction

Friction is defined by Kawabata as follows: friction coefficient is the relationship of frictional force and normal force (normal force by which the sensor is pressed on the fabric sample). Friction was determined according to the standard settings. The weight attached to the sensor is selected according to the material. The friction was measured between the metal “finger” sensor and the fabric in warp and weft direction (or machine and cross direction for knitted samples) on face (right) side and on reverse (back) side. The results of frictional coefficient (MIU) and mean deviation of MIU (MMD) are gathered in table 3.3 and in figure 3.1.4 the frictional coefficient values are presented.

Non standard measurements were made for friction by using a leather covered button shaped finger to see the effects of material which is close to human finger. These results are presented later in chapter 3.3.

Table 3.3 The friction results (MIU and MMD).

Sample	MIU warp	MIU weft	MMD warp	MMD weft
33	0,148	0,167	0,026	0,022
33back	0,147	0,174	0,025	0,022
34	0,143	0,144	0,011	0,013
34back	0,146	0,147	0,014	0,015
35	0,240	0,238	0,016	0,014
35back	0,246	0,250	0,016	0,016
36	0,299	0,320	0,026	0,029
36back	0,345	0,301	0,043	0,034
37	0,148	0,161	0,038	0,017
37back	0,162	0,166	0,031	0,011
38	0,220	0,229	0,013	0,012
38back	0,231	0,209	0,016	0,012
39	0,376	0,321	0,025	0,026
39back	0,256	0,305	0,016	0,027
40	0,153	0,219	0,013	0,029
40back	0,204	0,172	0,045	0,021
41	0,139	0,217	0,015	0,025
41back	0,226	0,162	0,043	0,020
42	0,265	0,256	0,009	0,016
42back	0,181	0,216	0,010	0,025

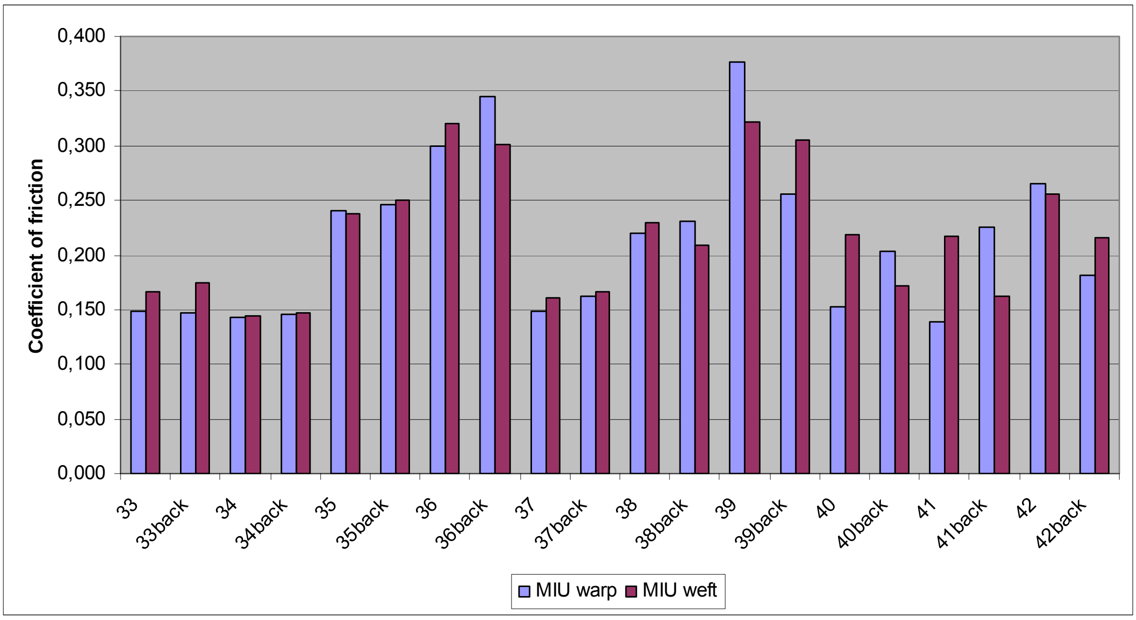

Figure 3.1.4 The results of frictional coefficient (MIU).

For MIU friction coefficient (-) the low value indicates low friction and the high value high friction. In warp or machine direction the values range from 0,139 to

0,376. The lowest value was recorded for sample 41 right side (warp knit with holes) and the highest value for sample 39 right side (weft knitted terry fabric). The smallest difference between the right and back side is recorded for samples 33, 34 and 35. The greatest difference between the right and back side correspondingly for samples 39, 41, 42 and 36. In cross direction the values are ranging from 0,144 to 0,321. The lowest value is marked for sample 34 right side and the highest value for sample 39 right side (weft knitted terry fabric). Samples 34, 37 and 33 have the smallest difference between the right and back side and samples 41, 40 and 42 have the greatest difference between the right and back side.

The following differences of friction coefficient between the warp/machine and weft/cross direction per sample were received:

● greatest differences with samples 41, 40, 41b, 39 , 39b

● smallest differences with samples 34, 34b, 35, 35b, 37b, 38, 42

The following questions arose during analysing the results: do the holes interfere the measurement (sample 41), or the fabric structure, long weft yarn runs, soft surface (sample 36) or long yarn loops (sample 39). Therefore e.g. samples 36 and 39 were decided to investigate further with non standard measurements (chapter 3.3 KES-F results of non-standard measurements).

For MMD mean deviation of MIU (-) the low value implies that the friction coefficient is even and high value that it is uneven. In warp/machine direction the values are ranging from 0,009 to 0,045. The lowest value was recorded for sample 42 right side (brushed warp knitted) and the highest value for sample 40 back side (warp knitted jersey-based). The smallest difference between the right and back side was found for samples 35, 33, 42, 38 and 34 and the greatest difference correspondingly for samples 40, 41 and 36.

In weft/cross direction the values are ranging from 0,011 to 0,034. Sample 37 back side (woven outdoor leisure wear) has the lowest value and the highest value was found for sample 36 back side (men`s woven overcoat fabric, twill). The smallest difference between the right and back side was found for samples 33, 38, 39, 34 and 35 and the greatest difference correspondingly for samples 42, 40, 37 and 36. Following differences between the warp/machine and weft/cross direction per sample were recorded:

● greatest differences with samples 40b, 41b, 37, 37b, 40, 42b

● smallest differences with samples 35b, 39, 38, 34b, 34, 35

Further analysis of samples were made.

Sample 33 The men's woven suit fabric (plain) has rather low friction coefficient (MIU) of these samples. The value is a little bit higher in weft direction than in warp direction. The friction coefficient is nearly the same on face and back sides of the fabric in warp direction and a little bit higher in the back side in weft direction. The fabric has a plain weave structure and the yarn densities are nearly the same in warp and weft direction meaning the fabric construction is in balance. The yarns are wool/polyester/elastane blended having elastane in the core and staple wool and polyester in the shell. Elastane containing yarns seem to be in every second yarn. Staple yarn causes that there is some "hair" on the fabric surface. MMD value is lower in weft direction than in warp direction but there is no difference between the face and back sides in either direction. MMD value is rather low.

Sample 34 The men's woven suit fabric (herringbone) has low friction coefficient (MIU) of these samples. The value is quite the same in warp and weft direction. The friction (mean) is nearly the same on face and back sides of the fabric in both directions.

The fabric has a herringbone structure and the yarn densities are nearly the same in warp and weft direction meaning the fabric construction is in balance. The woollen yarns have single ply in weft direction and single and 2-plied yarns in warp direction. Staple yarn causes that there is some "hair" on the fabric surface but the fabric has been flattened or smoothened by calendering. MMD value is slightly lower in warp direction than in weft direction but there is only slight difference between the face and back sides in either direction. MMD value is very low.

Sample 35 The men's woven overcoat fabric has rather high friction coefficient (MIU) for these samples. The value is quite the same in warp and weft direction. The friction is a little bit higher on back side than on face side of the fabric in both directions.

The fabric has basically a plain weave structure with the exception of having one weft yarn travelling over three warp yarns. The yarn densities are nearly the same in warp and weft direction. The yarns are wool/polyamide blended yarns, single ply. Staple yarn causes that there is some "hair" on the fabric surface and in the addition to that the fabric surface has been carded or brushed and then it has been flattened or smoothened by calendering. MMD value is quite the same in all directions, except in weft direction on face side it is lowest. MMD value is very low.

Sample 36 The men's woven overcoat fabric (twill) has high friction coefficient (MIU) of these samples. The value is lowest in warp direction on face side and highest in warp direction on back side. The friction is higher in weft direction on face side than in warp direction and on the back side it is higher in warp direction than in weft direction.

The fabric has twill weave structure and long weft yarn leaps on both sides. The weft yarn density is a little bit higher than warp yarns. Warp yarns are thinner than weft yarns. The yarns are cotton in warp yarns and polyacrylnitrile/wool/polyester blended weft yarns and single ply. Staple yarn causes that there is some "hair" on the fabric surface. MMD value is lower on face side than on back side being highest in warp direction on back side. MMD value is rather high.

Sample 37 The woven outdoor leisurewear fabric has low friction coefficient (MIU) for these samples. The value is lowest in warp direction on face side and a little bit higher in other directions. The friction is higher in weft direction on both sides.

The fabric has a rather dense plain weave structure. The warp yarn density is higher than the weft yarn density. The yarns are 100 % polyester multifilament yarns which together with the plain weave structure make the smooth surface. MMD value is higher in warp direction and it is rather high..

Sample 38 The weft knitted jersey fabric has rather low friction coefficient (MIU) of these samples. The value is a little lower in machine direction than in cross direction on face side and vice versa on back side.

This is due to the weft knitted construction having face stitches in vertical rows on the face side and rather dense structure. The yarns are 48/48 % cotton modal blended combed yarn and elastane filament. The elastane yarn is inlaid in the structure along the stitch or stitch feet. Staple yarn causes that there is some "hair" on the fabric surface. MMD values are among the lowest ones for these samples. It is a little bit higher on back side in machine direction meaning that the friction coefficient is a little bit more uneven in that direction than in other directions on either side.

Sample 39 This weft knitted terry fabric has the highest friction coefficient (MIU) values on face side and they are among the highest on back side as well for these samples. It is higher in machine direction on the face than in cross direction. This is probably due to the pile loops which are facing a little bit downwards. On back side it is higher in cross direction than in machine direction.

Due to the weft knitted construction the fabric is more elastic in cross direction than in machine direction and it has also face stitches in vertical rows on the back side which may cause more friction. On face side the direction of the pile loops may cause more friction. The coefficient friction value is a little higher when the metal “finger” sensor travels backwards towards “the wrong way” of the loops (figure 3.1.5). The value is a little higher in cross direction as well when the sensor is travelling backwards (figure 3.1.6). The sensor may change the position of the loops when first travelling forward.

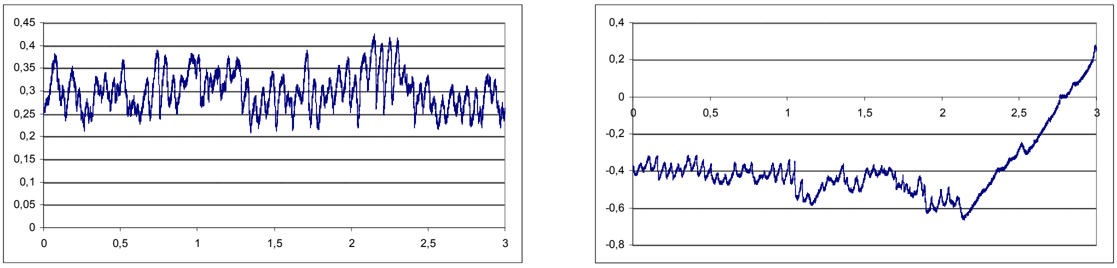

Figure 3.1.5 The graph of friction measurement of sample 39 right side in machine direction.

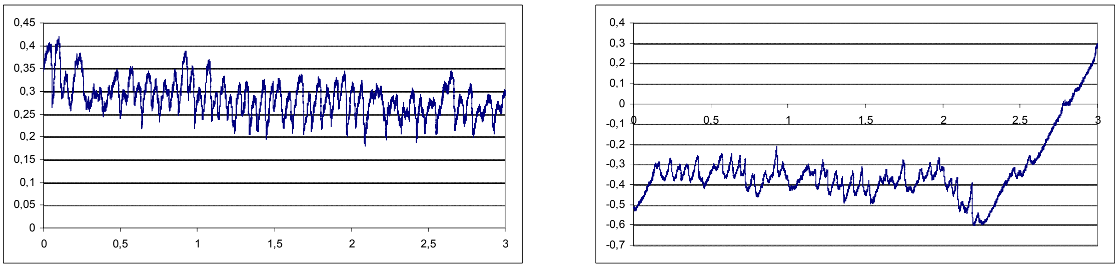

Figure 3.1.6 The graph of friction measurement of sample 39 right side in cross direction.

The yarns of sample 39 are 55/45 % viscose polyester blended combed yarn or polyester yarn in the base knit and viscose yarn in the stitches. The loop yarn has a very high twist factor making the yarn feel hard and making the loops crimpy. Staple yarn causes that there is some "hair" on the fabric surface. MMD value is rather high in cross directions on both sides and in machine direction on the right side for these samples. It is a little bit lower on back side in machine direction meaning that the friction coefficient is a little bit more even in that direction than in other directions on either side.

Sample 40 The warp knitted jersey-based fabric has rather low friction coefficient (MIU) values on face side in machine direction and on back side in cross direction. It is higher in cross direction on the face and in machine direction on the back side. This is due to the long stitch legs across the friction is measured. The yarns are 100 % polyester filament yarn which makes the yarn and the surface slippy. However, the construction on the face side is pearly and rough. On the back side the surface is smoother in cross direction. MMD value in machine direction is the highest one within these samples. It is rather high in cross direction on the face side. In those directions where the friction coefficient was rather low the friction coefficient was rather even as well.

Sample 41 This warp knitted mesh fabric in machine direction on the face side has the lowest friction coefficient (MIU) value among these samples. It is rather low on back side as well in the cross direction. It is higher in cross direction on the face and in machine direction on the back side. This is due to the stitch rows on the face side and the long stitch legs on the back side. The yarns are 100 % polyester filament yarn which makes the yarn and the surface slippy in machine direction on face side and in cross direction on back side. MMD values are lowest in the directions where the friction coefficients are lowest.

Sample 42 The brushed warp knitted fabric has rather high friction coefficient (MIU) values in other directions except in machine direction on back side. This is due to the cut pile loops on the face side and stitch rows on the back side. The yarns are 100 % polyester filament yarn which makes the surface slippy in machine direction on back side. MMD values are lowest in other directions except in cross direction on the back side.

3.1.4 Roughness

Roughness was determined using the same Kawabata equipment as for friction except that the measuring sensor is different. The roughness was measured according to standard settings. Very thick and voluminous and uneven and soft/pliable/easily stretchable materials may have difficulties in roughness measurements. They cause difficulties in finding the appropriate sensitivity area for the measuring scale. If the sensitivity area is enlarged the measuring head seem to press more on the sample which may cause unnecessary stretching and accumulation of the material so that the measuring head may “jump” over the fabric ridge. This may cause very high peak values which are not real and not typical for the material. Another problem is that when using too small sensitivity scale the values within the scale are recorded but the values beyond that are not taken into account. This is not real for the material either.

Therefore also some non standard measurements were made for some samples using different base for the test piece and different sensor head and different sensitivity areas (chapter 3.3).

The geometrical roughness SMD (µm) values are collected in table 3.4 and in figure 3.1.7. The roughness has been determined in warp and weft direction on the right and the back side of the fabric.

Table 3.4 The geometrical roughness (µm) results.

Sample	SMD warp	SMD weft
33	7,92	6,69
33back	8,03	6,78
34	5,12	6,52
34back	5,92	6,13
35	6,31	5,91
35back	5,83	5,45
36	14,51	12,13
36back	17,17	14,15
37	3,23	1,26
37back	3,27	1,15
38	6,05	2,82
38back	5,66	6,31
39	10,57	11,47
39back	6,18	10,80
40	5,72	8,98
40back	18,61	3,56
41	4,54	9,21
41back	10,84	5,21
42	3,08	7,44
42back	3,10	12,44

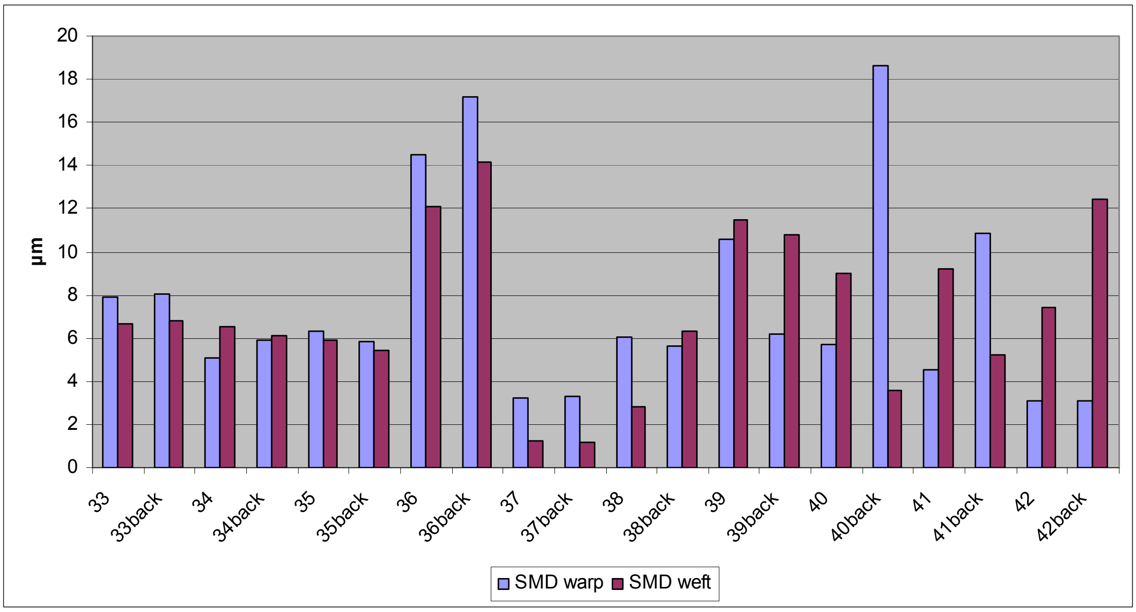

Figure 3.1.7 The results of geometrical roughness SMD in microns.

For SMD geometrical roughness (µm) the low value indicates smooth/even surface and the high value uneven surface. In warp/machine direction the values are ranging from 3,08 to 18,61 µm. The lowest value is recorded for sample 42 right side (brushed warp knitted) and the highest value correspondingly for sample 40 back side (warp knitted jersey-based fabric). Samples 42, 37 and 33 have the smallest difference between the right and back side. The greatest difference between the right and back side is noted for samples 40, 41 and 39.

In weft/cross direction the values are ranging from 1,15 to 14,15 µm. Sample 37 back side (woven outdoor leisurewear) has the lowest value and sample 36 back side (men`s woven overcoat, twill) has the highest value. The smallest difference between the right and back side is calculated for samples 33, 37 and 34 and the greatest difference between the right and back side for samples 40, 42 and 41.

The greatest differencies between the warp/machine and weft/cross direction per sample were with samples 40b, 42b, 41b, 41, 39b and 42. The smallest differencies were with samples 34b, 35b, 35, 38b and 39.

The same questions arose as during friction measurement: do the holes interfere the measurement (sample 41), or the fabric structure, long yarn runs, soft surface (sample 36) and long yarn loops (sample 39)? However, the 5 mm wide sensor does not probably note e.g. the holes of sample 41 (warp knitted mesh fabric). The situation is probably different when using the narrow head sensor (chapter 3.3).

The samples have been analysed further in following.

Sample 33 The men's woven suit fabric (plain) has rather low geometrical roughness (SMD) for these samples. The value is a little bit higher in warp direction than in weft direction. The roughness is the same on both sides of the fabric.

The plain weave structure is the same on both sides and the yarn densities are nearly the same in both directions. Every second yarn is S-twisted and every second yarn Z-twisted which gives a special surface appearance. The yarns are wool/polyester/elastane blended having elastane in the core and staple wool and polyester in the shell. Staple yarn causes that there is some "hair" on the fabric surface.

Sample 34 The men's woven suit fabric (herringbone) has rather low geometrical roughness (SMD) for these samples. The value is a little bit higher in weft direction than in warp direction. The roughness is lowest in warp direction on face side. The structure is the same on both sides and the yarn densities are nearly the same in both directions. The yarn densities are rather low and the woollen worsted yarns are rather coarse. Staple fiber yarn causes that there is some "hair" on the fabric surface. The surface has been calendered.

Sample 35 The men's woven overcoat fabric has rather low geometrical roughness (SMD) for these samples. The value is a little bit higher in warp direction than in weft direction. The roughness is a little bit higher on the face side of the fabric. The structure looks the same on both sides and the yarn densities are nearly the same as well.

The fabric has an applied plain weave structure so that one weft yarn is always crossing over three warp yarns. The surface has been brushed and then calendered. The yarns are wool/polyamide blended yarns. Staple fiber yarns and the brushing cause that there is some "hair" on the fabric surface.

Sample 36 The men's woven overcoat fabric (twill) has a very high geometrical roughness (SMD) for these samples. The value is higher in warp direction than in weft direction. The roughness is a little bit higher on the back side of the fabric.

The fabric has a twill weave structure on both sides and the construction is rather thick. The diagonal lines are distinguished clearly. Weft yarn density is a little bit higher than the warp yarn density. The diagonal lines and long, soft weft yarn leaps cause the high roughness values. The construction is soft and it is stretching a little in warp and weft direction. There are cotton in warp yarns and polyacrylnitrile/wool/polyester blended weft yarns. Staple yarn cause that there is some "hair" on the fabric surface.

Sample 37 The woven outdoor leisurewear fabric has the lowest geometrical roughness (SMD) in weft direction on both sides for these samples. The value is higher in warp direction than in weft direction. There is no difference between the face and back side roughness. The plain weave structure is the same on both sides and the yarn density is higher in warp direction than in weft direction and the densities are rather high. The dense and plain weave structure causes smooth surface as well the polyester filament yarn.

Sample 38 The weft knitted jersey fabric has low geometrical roughness (SMD) among these samples. The value is higher in machine direction than in cross direction on face side. On back side the roughness is higher in cross direction. The weft knitted structure is rather dense which makes the surface quite smooth. However the knitted fabric may stretch during the measurement. The combed cotton modal blended yarn is rather smooth, staple fiber yarns cause some hairiness on the surface.

Sample 39 The weft knitted terry fabric has high geometrical roughness (SMD) among these samples. The value is highest in machine and cross direction on face side and in cross direction on back side. On back side the roughness is lower in machine direction. The fabric is more elastic in weft direction and also the pile loops cause more roughness on face side. Due to the weft knitted construction having face stitches in vertical rows on the back side the roughness is higher in cross direction. The yarns are 55/45 % viscose polyester blended combed yarn or polyester yarn in the base knit and viscose yarn in the loops. The loop yarn has very high twist factor making the yarn feel hard and making the loops crimpy. Staple fiber yarn causes that there is some "hair" on the fabric surface.

Sample 40 The warp knitted jersey-based fabric in machine direction on back side has the highest geometrical roughness (SMD) of these samples. The value is higher in cross direction than in machine direction on face side. On face side in cross direction the wavy stitch wales cause the higher roughness than in machine direction. On back side the stitch rows cause higher roughness in machine direction. The polyester filament yarn gives smooth and slippy surface.

Sample 41 The warp knitted mesh fabric has high geometrical roughness (SMD) in cross direction on face side and in machine direction on back side. On face side in cross direction the stitch wales causes the higher roughness than in machine direction. On back side the stitch rows cause higher roughness in machine direction. The polyester filament yarn gives smooth and slippy surface.

Sample 42 The brushed warp knitted fabric has rather low geometrical roughness (SMD) in machine direction both on face and back side. In cross direction on both sides the roughness is high. This is mainly due to the cut pile on face side or stitch wales on the back side. The polyester filament yarn gives smooth and slippy surface on the back side.

3.1.5 Shear

Shear values were determined according to the standard measurements. The shearing stiffness G (gf/cm*degree) and the hysteresis values at shearing angles of 0.5 degrees 2HG (gf/cm) and of 5 degrees 2HG5 (gf/cm) were determined. All the results are presented in warp/machine direction and in weft/cross direction in table 3.5. In figure 3.1.8 the shear stiffness values are shown and in figure 3.1.9 the hysteresis values at 5 degrees are shown.

Table 3.5 The shearing results.

Sample	G warp	G weft	2HG warp	2HG weft	2HG5 warp	2HG5 weft
33	0,718	0,764	0,23	0,287	1,411	1,405
34	0,65	0,499	0,701	0,552	1,595	1,223
35	0,613	0,667	0,835	1,427	1,374	1,917
36	0,536	0,514	0,580	0,838	0,821	1,052
37	2,357	2,285	3,515	2,583	8,732	8,659
38	0,838	0,968	1,362	1,555	1,818	1,627
39	0,488	0,459	1,169	0,784	1,271	0,999
40	2,057	1,593	5,906	3,692	7,341	5,607
41	2,567	2,538	4,047	3,785	6,174	5,311
42	2,410	2,121	5,975	3,184	7,864	5,265

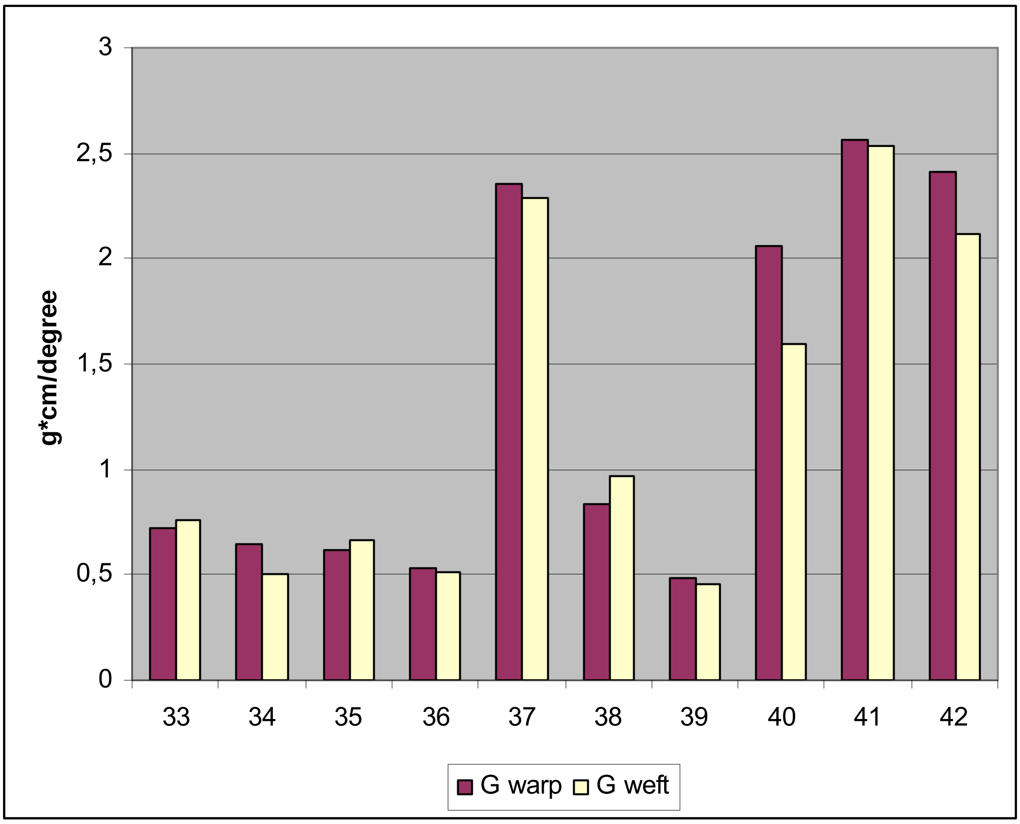

Figure 3.1.8 The shear stiffness values.

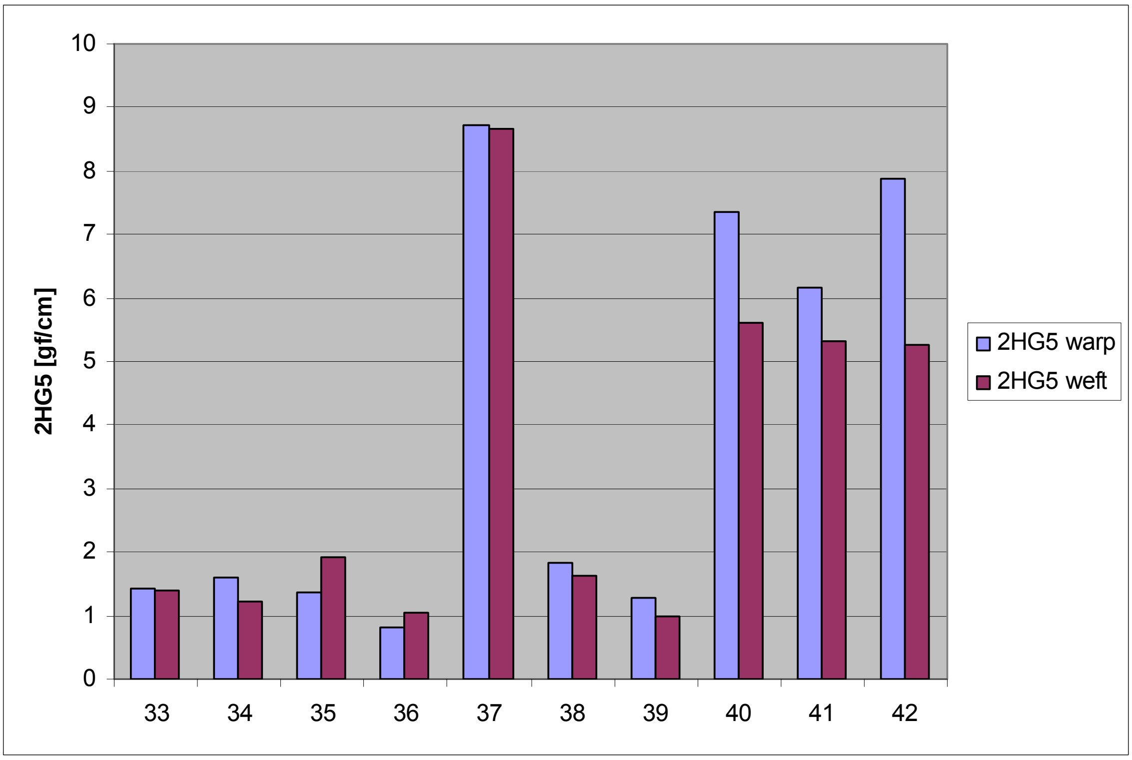

Figure 3.1.9 The hysteresis values at 5 degrees.

For G shear stiffness (gf/cm*°) the low value means that the sample is easy to shear and the high value means that it resists the shearing. In warp/machine direction the values are ranging from 0,488 to 2,567 gf/cm*°. The lowest value is recorded for sample 39 (weft knitted terry fabric) and the highest for sample 41 (warp knitted mesh fabric). In weft/cross direction the values are ranging from 0,459 to 2,538 gf/cm*°. The lowest value is found for sample 39 (weft knitted terry fabric) and the highest correspondingly for sample 41 (warp knitted mesh fabric). Differences between the warp/machine and weft/cross direction per sample were noted as follows:

- greatest differencies with samples 40, 42, 34 and 38
- smallest differencies with samples 36, 39, 41 and 33

For 2HG5 hysteresis at 5° (gf/cm) the low value means that the return curve goes nearby the shear curve. In warp/machine direction the values range from 0,821 to 8,732 gf/cm. Sample 36 (men's woven overcoat fabric (twill)) has the lowest value and sample 37 (woven outdoor leisurewear fabric) has the highest value. In weft/cross direction the values are ranging from 0,999 to 8,659 gf/cm. Sample 39 (weft knitted terry fabric) has the lowest value and sample 37 (woven outdoor leisurewear fabric) has the highest value. Differences between the warp/machine and weft/cross direction per sample were as follows:

- greatest differences with samples 42, 40 and 41
- smallest differences with samples 33, 36, 38 and 39

Further analysis of results per sample are presented below.

Sample 33 The men's woven suit fabric (plain) the shear stiffness G is rather low within these samples meaning that it shears rather easily. In weft direction the stiffness is slightly higher than in warp direction. The fabric and the yarns are thin and the construction is in balance. The hysteresis at 0.5 degrees is the lowest both in warp and weft direction of these samples. The hysteresis at 5 degrees is very low too in warp and weft direction.

Sample 34 The men's woven suit fabric (herringbone) has low shearing stiffness G for these samples. The stiffness is a little higher in warp direction than in weft direction. The structure is rather rough and the yarn densities in both directions are rather low. The hysteresis at 0.5 degrees is rather low both in warp and weft direction. The hysteresis at 5 degrees is rather low too in warp and weft direction. It is a little higher in warp direction at both angles.

Sample 35 The men's woven overcoat fabric has low shearing stiffness G among these samples. The stiffness is a little higher in weft direction than in warp direction. The warp yarn density is a little higher than the weft yarn density meaning that the construction gives in easier in weft direction, the weft yarns have more space to slide while the warp yarns are grouped in to threes. The construction is rather rough, the woolblended yarns are thick and rough. The hysteresis at 0.5 degrees and at 5 degrees are rather low both in warp and weft direction within these samples. It is a little higher in weft direction at both angles.

Sample 36 The men's woven overcoat fabric (twill) has very low shearing stiffness G for these samples. The stiffness is slightly higher in warp direction than in weft direction. The twill structure has long weft yarn leaps and rather high yarn densities compared to the yarn thicknesses in warp and weft directions. The weft yarn density is a little higher than warp yarn density. Due to the double layer twill construction and rather thick yarns the construction is soft and pliable. The higher stiffness in warp direction is mainly due to the long weft yarn leaps and higher weft yarn density. The hysteresis at 0.5 degrees and at 5 degrees are low both in warp and weft direction. It is a little higher in weft direction at both angles.

Sample 37 The woven outdoor leisurewear fabric has high shearing stiffness G for these samples. The stiffness is slightly higher in warp direction than in weft direction. The dense and plain weave structure and the thin polyester filament yarns cause the high stiffness. The hysteresis at 0.5 degrees is high as well being higher in warp than in weft direction. At 5 degrees it has the highest hysteresis values both in warp and weft direction within these samples.

Sample 38 The weft knitted jersey fabric has rather low shearing stiffness G for these samples. The stiffness is slightly higher in cross direction. The weft knitted structure is rather dense but the stitches give slightly space and volume to the structure. The hysteresis at 0.5 degrees and at 5 degrees are rather low both in machine and cross direction within these samples. At 0.5 degrees it is higher in cross direction and at 5 degrees it is higher in machine direction.

Sample 39 The weft knitted terry fabric has the lowest shearing stiffness G of these samples. The stiffness is slightly higher in machine direction. The construction is very volume and soft due to the loop density. The hysteresis at 0.5 degrees and at 5 degrees are rather low both in machine and cross direction within these samples. In both cases it is higher in machine direction.

Sample 40 The warp knitted jersey-based fabric has rather high shearing stiffness G for these samples. The stiffness is clearly higher in machine direction than in cross direction. The warp knitted structure is thin due to the thin filament yarns. The stitch densities are rather low. The structure is rather hard and unpliable. The row density is higher than the wale density. The hysteresis at 0.5 degrees and at 5 degrees are high both in machine and cross direction. In both cases it is higher in machine direction.

Sample 41 The warp knitted mesh fabric has the highest shearing stiffness G of these samples. The stiffness is slightly higher in machine direction than in cross direction. The warp knitted mesh structure is thin due to the thin filament yarns. The stitch densities are rather low especially in cross direction. The structure is rather hard and unpliable. The row density is higher than the wale density. The hysteresis at 0.5 degrees and at 5 degrees are high both in machine and cross direction. In both cases it is higher in machine direction.

Sample 42 The brushed warp knitted fabric has high shearing stiffness G among these samples. The stiffness is clearly higher in machine direction than in cross direction. On face side the cut pile cause softness and bulkiness. The base knit consists of rather thin filament yarns. The stitch density is higher in machine direction and it is rather high about 32 loops/cm. The hysteresis at 0.5 degrees and at 5 degrees are rather high in both directions. In both cases it is higher in machine direction.

3.2 Step tensile results using tensile tester

Step tensile test was determined using a tensile tester Testometric M500 (tensile tester is presented in HAPTEX deliverable D3.1). The rectangular shape sample fixed in jaws was stretched in five steps to forces 10, 20, 30, 40 and 50 N and it was immediately returned to the starting position after reaching the desired force value. Before next tension the test piece was kept for 120 seconds in a relaxed state. The elongation values (mm) in warp/machine and weft/cross directions were recorded at each step and a step-tensile graph was drawn (figure 3.2.1).The results are presented in figures 3.2.2 and 3.2.3. The following test parameters were used:

- 10 mm/min test speed
- 100 mm gauge length
- 50 mm wide test piece
- no pretension

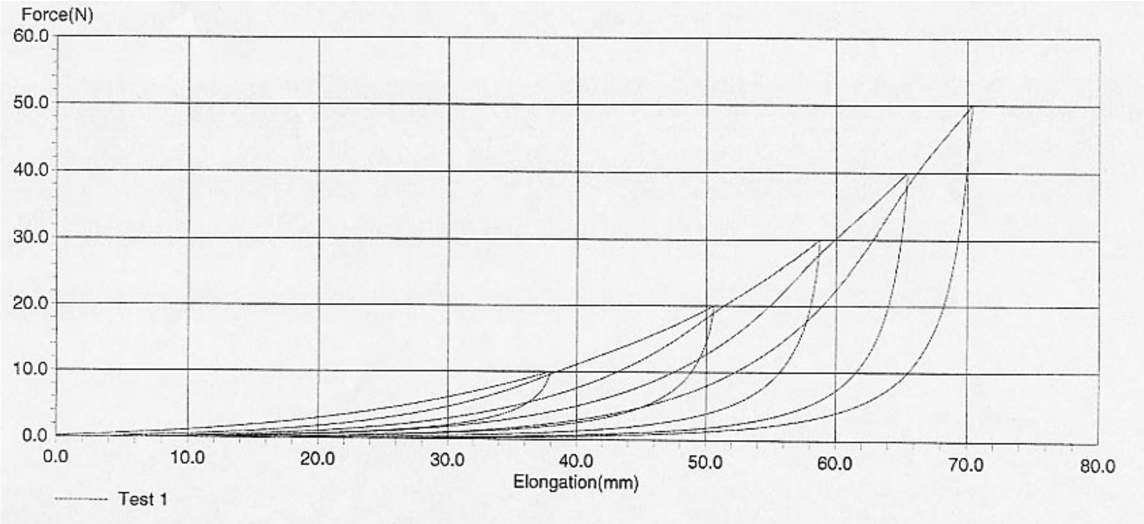

Figure 3.2.1 Elongation curves of step tensile tests e.g. for sample 38 (weft knitted jersey fabric) in machine direction, 1st parallel measurement.

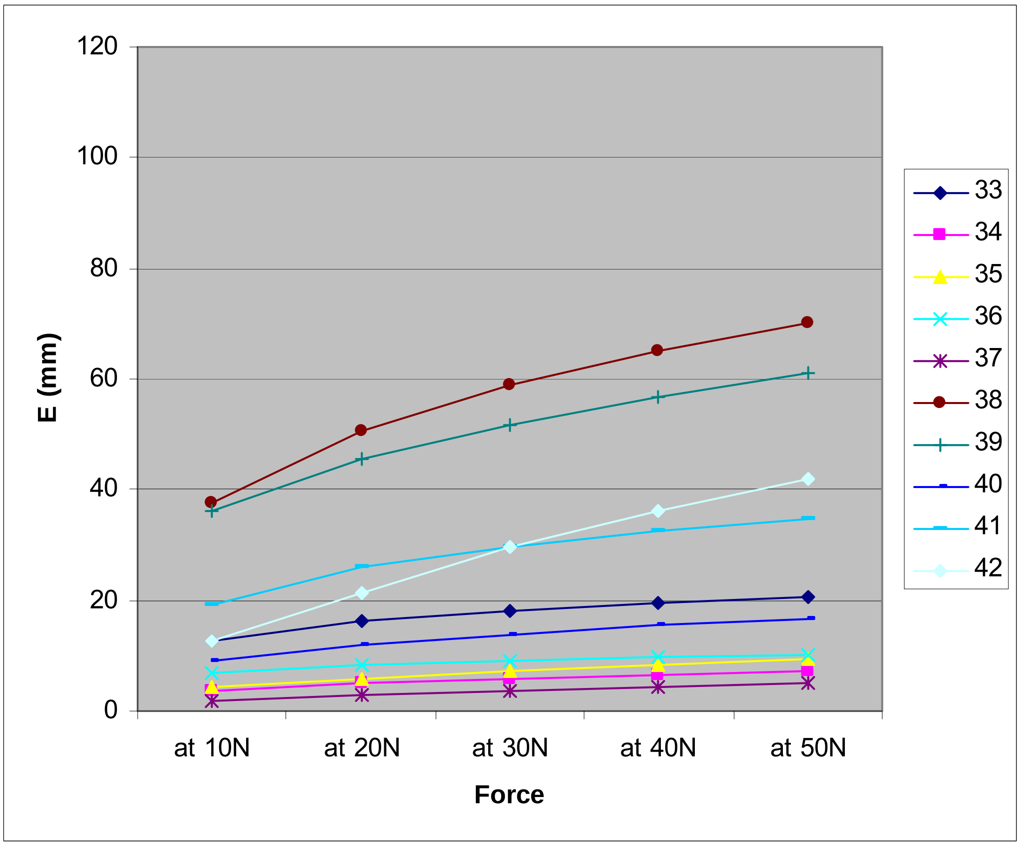

Figure 3.2.2 Elongation values of step tensile tests to different forces in warp/machine direction.

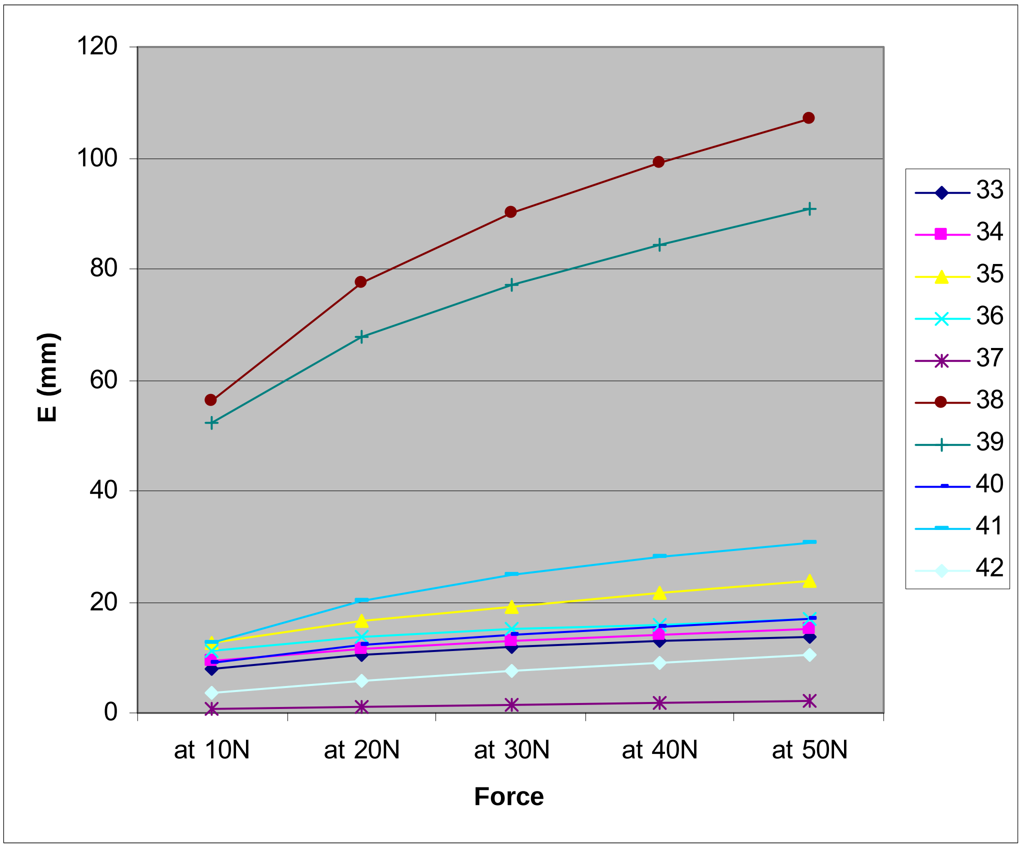

Figure 3.2.3 Elongation values of step tensile tests to different forces in weft/cross direction.

Elongation describes the ability of the material to stretch under tension without breaking. It is expressed either in mm or in % as a proportion of elongation and the original length. It is affected by fibre and yarn type and fabric construction. Typically woven fabrics stretch very little compared to knitted fabrics unless they have elastic components imparted in their structure. Weft knitted fabrics normally elongate more in cross than in machine direction. Warp knitted fabrics stretch more in machine direction.

Among these samples the weft knitted fabrics had the highest elongation values (sample 38 ranging from 37.6 to 70.0 mm in machine direction and from 56.3 to 107.1 mm in cross direction). The lowest values had plain weave sample 37. The elongation was higher in warp direction (ranging from 1.8 to 5.2 mm) than in weft direction (ranging from 0.7 to 2.2 mm). Steep increase in elongation means high elasticity.

Sample 33 The men's woven suit fabric (plain) has rather low elongation in warp (ranging from 12.8 to 20.7 mm) and weft (ranging from 7.8 to 13.8 mm) direction among these samples. But it has the highest elongation in warp direction among the woven fabric samples. This is mainly due to the elastane it contains in every other yarn in warp and weft direction. In weft direction the elongation is a little lower. The elongation increases at every force step. The construction is in balance. The yarn densities are nearly the same in both directions. Every other yarn is S- and Z-twisted.

Sample 34 The men's woven suit fabric (herringbone) has rather low elongation values both in warp and weft direction when compared to all samples. In warp direction it has very low values ranging from 3.7 to 7.1 mm. In weft direction the values are a little higher ranging from 9.3 to 15.0 mm. The weft yarns seem to have more twist than the warp yarns. Wool fibre itself is an elastic natural fiber due to its natural crimp and chemical construction.

Sample 35 The men's woven overcoat fabric has rather low elongation in warp and weft directions for these samples. In warp direction the elongation ranges from 4.4 to 9.4 and weft direction from 12.6 to 23.9 mm. In weft direction it has the highest elongation of woven samples. This may be due to the construction, the weft yarns always crossing over three warp yarn. The warp yarns form bundles which stretch less than single weft yarns.

Sample 36 The men's woven overcoat fabric (twill) has rather low elongation among the samples in warp and weft direction. The elongation is higher in weft direction (range from 11.1 to 16.8 m) than in warp direction (range from 6.8 to 10.2 mm). The weft yarn density is higher than the warp yarn density. The weft yarns form long yarn leaps on the surface. The double twill construction gives volume to the fabric.

Sample 37 The woven outdoor leisurewear fabric has the lowest elongation among the samples. The elongation is higher in warp direction (ranging from 1.8 to 5.2 mm) than in weft direction (ranging from 0.7 to 2.2 mm). The plain weave structure is very dense and the untwisted flat filament warp and weft yarns stretch very little.

Sample 38 The weft knitted jersey fabric has the highest elongation values ranging from 37.6 to 70.0 mm in machine direction and from 56.3 to 107.1 mm in cross direction. It stretched a lot more in cross direction. The construction is rather dense and the yarn is rather thin but the better elongation is received having elastane in the construction.

Sample 39 The weft knitted terry fabric has a very high elongation values in machine and cross direction. The values ranged from 36.3 to 60.9 mm in machine direction and from 52.2 to 90.9 mm in cross direction. Due to the construction of the stitch they stretch more in their width than in their length direction.

Sample 40 The warp knitted jersey-based fabric has rather low elongation for these samples. The elongation values are nearly the same in machine and cross direction. The values range from 9.0 to 16.7 mm in length direction and from 9.0 to 16.9 mm in transverse direction. The construction consists of flat untwisted filament yarns.

Sample 41 The warp knitted mesh fabric has rather high elongation values of the samples. The values range from 19.0 to 34.7 mm in machine direction and from 12.5 to 30.8 mm in cross direction. They are a little higher in length direction. The mesh construction gives in more in length direction than in cross direction. The flat untwisted filament yarns do not stretch easily since they have no twist.

Sample 42 The brushed warp knitted fabric has rather high elongation values in machine direction ranging from 12.5 to 41.9 mm. In cross direction the values are very low ranging from 3.6 to 10.3 mm. The warp knit construction together with flat untwisted filament yarns impart the low elongation properties.

3.3 KES-F results of non-standard measurements

3.3.1 Friction between leather and fabric

In standard measurements a five millimeter wide metal “finger” sensor is used which has a waved surface similar to human fingertip. To imitate more the skin material on fingertips the friction (MIU) was determined using a special button shaped sensor which was covered with leather material (figure 3.3.1). Two different kind of materials were selected for the measurements: one thin plain weave fabric and one thick double layer twill fabric. The determinations were made in warp and weft directions.

The results are presented in figures 3.3.2 and in Table 3.6.

Figure 3.3.1 A special button shaped sensor covered with leather material used in non standard measurements on the left side and a metal “finger” sensor used in standard measurements on the right side. The metal “finger” sensor is in measuring position, the measuring surface facing up.

Table 3.6 The friction results of non standard measurements. Samples 36, 36 back , 37 and 37 back represent the standard measurements.

Sample	MIU warp	MIU weft
36	0,299	0,320
36back	0,345	0,301
36Rleather	0,298	0,305
36Bleather	0,277	0,275
37	0,148	0,161
37back	0,162	0,166
37Rleather	0,274	0,306
37Bleather	0,311	0,330

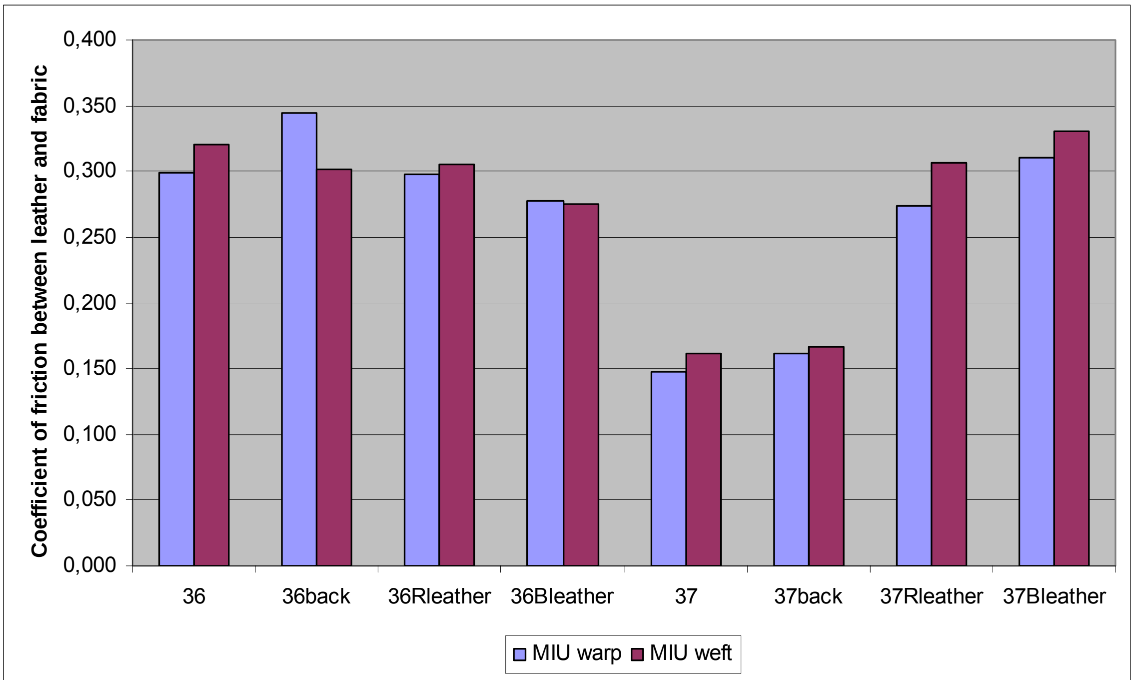

Figure 3.3.2 The non standard friction results.

Sample 36 The men's woven overcoat fabric (twill) has a little higher values in standard measurement than in non standard measurement. In warp direction on the right side of the fabric the values are nearly the same. On the back side the standard measurement value is clearly higher than the values received with the non standard method. In weft direction the highest value is received with the standard method on both sides. The leather covered sensor gives lower values than the metal sensor. The differences between warp and weft directions are much lower with the leather sensor.

The leather covered button shaped sensor gives lower results than the metal finger sensor. Leather material when stretched over the button is rather smooth and slippy. This probably cause that it slides over the sample during the measurement.

Sample 37 The woven outdoor leisurewear fabric has low friction coefficient (MIU) in standard measurement and the values are clearly lower when compared to the non standard measurements. The highest differences between warp and weft directions were registered for samples measured with the leather sensor.

Sample 36 has a very rough surface structure compared to sample 37. The yarns are thicker and the weave form clear diagonal lines, ridges over the fabric. Sample 37 has very smooth surface due to the dense plain weave and thin untwisted multifilament yarns. Sample 36 has less contact points with leather sensor but sample 37 has them a lot more. This may explain the lower friction values with sample 36 and higher values with sample 37 when compared to the standard measurement with the metal “finger” sensor.

3.3.2 Roughness measured on plane surface with different measuring sensitivities

In standard roughness measurement following remarks were made for some samples:

- the standard sensitivity area is exceeded when measuring some samples (figure 3.3.3)
- when sensor travels on the surface some samples tend to stretch during the measuring and accumulate a fabric ridge in front of the sensor which may cause peak values when the sensor jumps over the ridge (figure 3.3.4)
- the standard measuring head 5 mm wide does not reach all the deeps and voids of the surface

For non standard measurements following settings were applied:

- Change of sensitivity area was tried for samples where the standard area was exceeded.
- The stretching issue was tried to solve using a planar surface under the test piece for samples which stretch easily. The sample was fixed on it.
- Instead of the standard measuring head a narrow head sensor was used (figure 3.3.5).

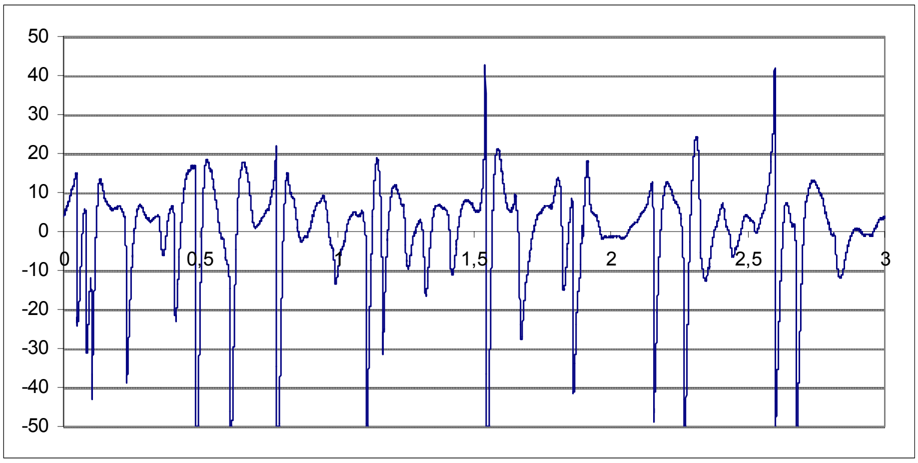

Figure 3.3.3 An example of exceeding the sensitivity area, sample 36 back side in warp direction, sensitivity area 5x5.

Figure 3.3.4 Fabric stretching and accumulation and yarn twisting during roughness measurement e.g. as a consequence of changing the sensitivity area.

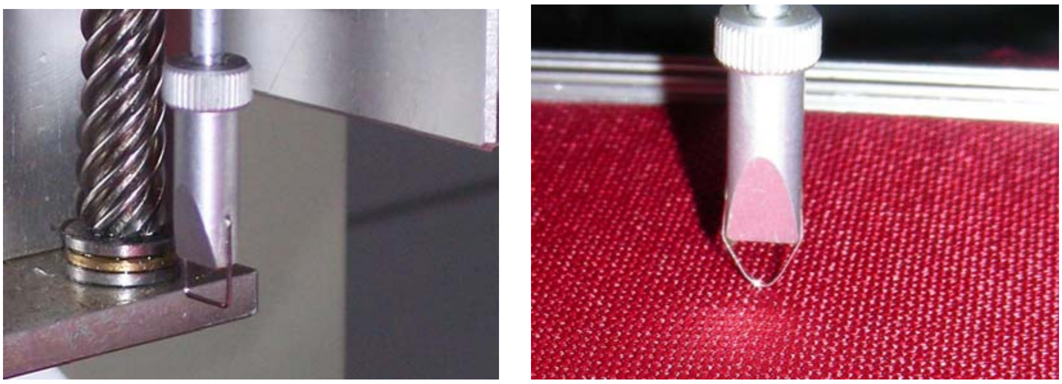

Figure 3.3.5 A standard measuring head and a narrow measuring head for roughness determination.

The roughness (µm) was measured using non standard settings for following four different kind of samples: 36, 37, 39 and 40. The results will be analysed and presented later.

3.3.3 Roughness measured with narrow head sensor

The roughness (µm) was measured using non standard settings for following four different kind of samples: 36, 37, 39 and 40. Measurements were made using the standard drum sample holder (HAPTEX deliverable D3.1) instead of planar surface with narrow head sensor and using different kind of sensitivity areas (note chapter 3.3.2). The results will be analysed and presented later.

Literature

Meinander, H (editor), Luible, C., Mäkinen, M. (contributor/author). 2006. First Set of fabric measurements, D3.1. Deliverable of HAPTEX project funded by EU.

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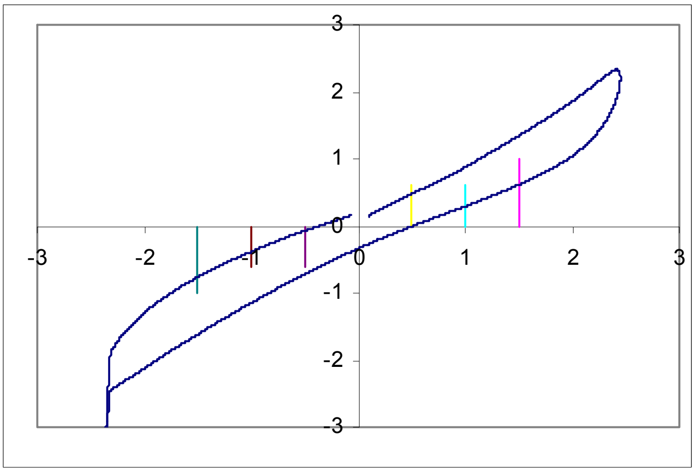
Meinander, H. 1991. Objective determination of textile hand properties with the Kawabata-system (in Swedish). VTT Research Reports 751. 34 p + app. 18 p. ISBN 951-38-3999-0.

Tomasino, C. Effect of mechanical finishing on fabric hand. In Behery, H. M (ed.). Effect of mechanical and physical properties on fabric hand. The Textile Institute, 2005. pp 342-371.

Annex 1



Graph 1. An example of bending graph of the thickest sample 36 in wale direction.

Annex 2

Table A2.1 Step tensile results.

Step tensile+wait (120 sec.), Steps 10N-20N-30N-40N-50N, No pretension										10 mm/min			25 kg	100mm/50mm	
E(mm) @10N				E(mm) @20N			E(mm) @30N			E(mm) @40N			E(mm) @50N		
Sample	**warp1**	**warp2**	**mean**	**warp1**	**warp2**	**mean**	**warp1**	**warp2**	**mean**	**warp1**	**warp2**	**mean**	**warp1**	**warp2**	**mean**
33	13,065	12,467	12,766	16,585	15,887	16,236	18,56	17,825	18,1925	19,992	19,233	19,6125	21,095	20,322	20,7085
34	3,646	3,684	3,665	4,866	4,975	4,9205	5,705	5,87	5,7875	6,416	6,627	6,5215	7,017	7,261	7,139
35	4,191	4,619	4,405	5,745	6,177	5,961	6,999	7,443	7,221	8,17	8,59	8,38	9,184	9,62	9,402
36	6,775	6,899	6,837	8,217	8,395	8,306	9,067	9,274	9,1705	9,674	9,912	9,793	10,101	10,38	10,2405
37	1,814	1,687	1,7505	2,773	2,677	2,725	3,598	3,566	3,582	4,386	4,428	4,407	5,164	5,213	5,1885
38	37,9	37,249	37,5745	50,556	50,297	50,4265	58,76	58,79	58,775	65,411	64,803	65,107	70,338	69,643	69,9905
39	37,812	34,7	36,256	47,514	43,725	45,6195	53,63	49,559	51,5945	58,828	54,403	56,6155	63,188	58,66	60,924
40	8,787	9,283	9,035	12,111	11,893	12,002	14,209	13,554	13,8815	15,99	14,81	15,4	17,662	15,72	16,691
41	18,853	19,197	19,025	25,784	26,334	26,059	29,487	30,04	29,7635	32,141	32,89	32,5155	34,413	35,038	34,7255
42	12,64	12,45	12,545	21,544	21,392	21,468	29,634	29,473	29,5535	36,297	35,94	36,1185	42,198	41,562	41,88

Sample	**Step tensile+wait (120 sec.), Steps 10N-20N-30N-40N-50N, No pretension**														
33	E(mm) @10N			E(mm) @20N			E(mm) @30N			E(mm) @40N			E(mm) @50N		
	weft1	**weft2**	**mean**	**weft1**	**weft2**	**mean**	**weft1**	**weft2**	**mean**	**weft1**	**weft2**	**mean**	**weft1**	**weft2**	**mean**
34	7,575	8,075	7,825	10,087	10,656	10,3715	11,543	12,156	11,8495	12,614	13,218	12,916	13,471	14,106	13,7885
35	9,117	9,55	9,3335	11,369	11,875	11,622	12,75	13,277	13,0135	13,806	14,339	14,0725	14,783	15,232	15,0075
36	12,236	12,977	12,6065	16,043	16,836	16,4395	18,906	19,407	19,1565	21,494	21,738	21,616	23,843	23,925	23,884
37	10,601	11,524	11,0625	13,043	14,102	13,5725	14,395	15,596	14,9955	15,34	16,706	16,023	16,115	17,459	16,787
38	0,782	0,708	0,745	1,252	1,172	1,212	1,637	1,538	1,5875	1,966	1,846	1,906	2,273	2,132	2,2025
39	56,063	56,449	56,256	77,468	77,203	77,3355	90,077	89,961	90,019	98,868	99,587	99,2275	106,57	107,58	107,075
40	51,745	52,705	52,225	67,058	68,361	67,7095	76,402	77,806	77,104	83,686	85,21	84,448	90,162	91,72	90,941
41	9,717	8,28	8,9985	12,546	11,784	12,165	14,261	13,957	14,109	15,486	15,736	15,611	16,422	17,424	16,923
42	12,677	12,376	12,5265	20,312	20,012	20,162	24,893	24,587	24,74	28,202	27,988	28,095	30,889	30,686	30,7875
	3,567	3,639	3,603	5,627	5,834	5,7305	7,317	7,591	7,454	8,799	9,166	8,9825	10,105	10,533	10,319