WOOL SEERSUCKER FABRIC DEVELOPMENT

A Bachelor Thesis on the Development of a Wool Seersucker Fabric using Differential Shrinkage

Bernd Glorie

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Preface

The Bachelor thesis you are currently reading was fully produced and written by myself, a graduation student of the Fashion & Textile Technology course at Saxion University of Applied Sciences in Enschede, the Netherlands. This thesis is considered a free graduation project. This means that the graduation project was done from the students own initiative and interest where it would otherwise be in the interest of a company. The research and writing for this thesis has been done in the 20-week graduation semester with an extension of 10 weeks.

During my time at Saxion, I gained personal interest in (fashion) fabric development and textile chemistry. This was a result of the foundation of knowledge that was laid by the course and the understanding of the various aspects of the textile industry that came with it. By combining the foundation of knowledge with information from various research articles that I read, I came up with an idea for a new process to create seersucker fabrics. With this thesis, I took the opportunity to research if this process would work. My idea resulted in the research question: 'How can a seersucker fabric be created, by weaving with a single loom beam and using the differential shrinkage of plasma-treated and regular wool yarns to create a puckering effect on the fabric?'.

This research proved to be a real challenge, facing a lot of setbacks and difficulties along the way. Fortunately, with the excellent support of my external graduation coach Prof. Dr. Crisan Popescu and internal graduation coach Usha Bhaskara, I managed to answer my questions. Therefore, I would like to thank them first. I would also wish to thank all the interviewees because they have helped me a tremendous amount to make this project a success. A special thank you goes out to the following people that supported me with the practical aspects of thesis: Richard Groeneveld, for helping me in the textile lab, Stefan Franke of the Woolmark Company for bringing me in contact with Crisan Popescu and enabling me to get yarns for free and Michel Mastio of Suedwolle, for supplying the yarns.

To all the teachers I have had the pleasure of getting to know during my study career: I would like to thank you for the great classes, inspiration and excitement with which you all shared your knowledge. Lastly, I would like to say that I greatly appreciate all the support from my friends and family and the fact that they pushed me to explain technical matter in a simple way.

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Bernd Glorie

Synopsis

Seersucker fabrics are fabrics characterized by a puckering surface, often with puckering in warp direction in stripes. The most common way of producing a seersucker fabric is by weaving with warp yarns divided over two loom beams and with one loom beam operating at a lower tension than the other. In this case, the difference in tension results in a puckering in the fabric. This process is called slack-tension weaving. Previous research proved other methods for the creation of seersucker fabrics woven using one loom beam. These methods use the differential shrinkage principle and chemical finishing to create a puckering surface. The most recent researches focused on development of seersucker effects by using regular yarns and core spun yarns with elastic cores to achieve puckering by differential shrinkage.

Wool is a natural fiber. One of its characteristics is its felting ability. Felting happens when wool fibers move together and become entangled. The fibers get entangled due to the surface of the fiber being scaled. When yarns and fabrics felt, they shrink. Therefore, a lot of research towards imparting shrink resistance to wool has been done. Recent researches focused on using plasma-treatment to impart shrink resistance. Yarns treated with low-temperature air-plasma are currently commercially available.

For this thesis, research towards the creation of a seersucker fabric by weaving using one loom beam and using the differential shrinkage of plasma-treated and regular wool yarns to create a puckering effect on the fabric has been done. The subject stems from an idea that arose after the researcher read about imparting shrink resistance to wool using plasma-treatment.

To answer the main question, interviews with experts were held, conventional materials have been researched, a fabric was woven and treated with washing and dyeing processes and tests have been performed.

From the research, a possible way of creating a seersucker fabric, by weaving using one loom beam and using the differential shrinkage of plasma-treated and regular wool yarns to create a puckering effect on the fabric, becomes clear. A plain woven fabric with plasma-treated and regular wool stripes was treated with a washing process and a subsequent acid dyeing process to achieve the result. The washing was done at 40°C for 60 minutes using AATCC 1993 Standard Reference Detergent WOB and for the acid dyeing process, the Dystar standard dyeing process for Isolan dyes was used with Isolan Blue GLW dyestuff. Subsequent testing of the fabric showed the possibility for Woolmark Certification.

1 Introduction – Reason for Research

While studying, the author has gained for two main passions regarding textiles: fabric development and dyeing and finishing processes – both intended for aesthetic use in clothing. When reading into different topics, ideas are born. The possibility of doing a free assignment as graduation assignment was the perfect opportunity to work on one of these ideas. When reading about the most important effect of plasma treatment on wool yarns, namely its shrinkage resistant properties, the idea for an innovation was born.

Wool is widely known for a lot of aspects like its natural water repellency, good insulation properties and being 100% biodegradable (Woolmark Company, 2019). Another property of wool is its ability to felt. Felting is caused by the surface of the wool fiber, which consists of scales. The felting occurs when wool fibers are agitated or put under pressure in water, for example during centrifuging or squeezing by hand. During these processes, the fibers to move together and become entangled because the scales lock into each other. When this happens the fabric will shrink and become denser (Kuffner & Popescu, 2012).

There has been a lot of research towards imparting shrink resistance to wool. Using plasma treatment to make wool shrink resistant is one of the methods (Gandhi, 2012). However, there are many more. The option to impart shrink resistance on wool fibers was the inspiration to innovate the seersucker fabric.

Seersucker is a medium weight plain woven fabric, characterized by puckering stripes. The fabric is regularly used for summer shirts and suits (Gandhi, 2012). Figure 1 shows an example of a seersucker fabric.

Figure 1: Seersucker Fabric (Barrington Fabrics, 2019)

The seersucker fabric has stripes that run along the whole fabric, mostly along the warp. The fabric is usually made by using a so-called slack-tension weaving process. This weaving method utilizes rows of warp yarns alternating between two warp beams. The warp beams contain an equal number of warp yarns. One warp beam is put under high tension while the other operates at normal tension. This causes the rows of warp yarns to be either slack or under tension. The difference in tension is what creates the puckering effect when the fabric is relaxed after weaving. Due to the requirement for two warp beams, a special weaving machine is needed to create this kind of fabric (Maqsood, Nawab, Javaid, Shaker, & Umair, 2014).

Research has been done to find ways to produce seersucker fabrics on regular weaving machines. For wool specific, one research found that the seersucker effect can be obtained after weaving by heat treatment of the wool fabric under pressure, after an impregnation step using an alkali solution (Sims & Speakman, 1959). Maqsood, Nawab, Javaid, Shaker, & Umair (2014) proved that seersucker fabric can be made on a regular weaving machine by using stretch recovery of core spun yarns to recreate the difference in tension obtained by slack-tension weaving. This method uses the so-called differential shrinkage of the more stretchy and more rigid yarns. The Woolmark Company used a similar method to create their 'Merino Retract' fabric. Their fabric uses wool yarns in the warp and wool/lycra core spun yarns in the warp. This results in a fabric with a similar appearance to seersucker. Figure 2 shows the Merino Retract fabric.

Figure 2: Merino Retract Fabric (Woolmark Company, 2019)

The innovation that will be researched in this thesis is a concept for the development of a seersucker fabric using one warp beam by alternating plasma treated and regular plasma treated yarns.

As mentioned before, the plasma treated yarns have the advantage over regular wool yarns that they have been made shrink resistant. Therefore, a differential shrinkage effect can be obtained by arranging plasma-treated and regular wool warp yarns on a warp beam and thereafter weaving them. The shrinkage will be imparted by a washing and acid dyeing process.

The aim of this research is to find the requirements for the creation of a wool seersucker fabric using a single warp beam by differential shrinkage effect. This research will be confined to the use of plasma treated wool yarns as shrink resistant wool fiber.

To be able to perform this research, an untreated fabric using plasma-treated and regular wool yarns has to be obtained. Due to the unconventionality of such fabric, the choice was made to weave one at Saxion University of Applied Sciences. Their textile lab has a CCI Evergreen sampling loom that will be used to weave the fabric.

The relevance of the research is proved because it complements the developments regarding wool seersucker fabrics by approaching the subject differently. The fact that this research obtains the differential shrinkage effect by using plasma-treated and regular wool yarns makes it substantially different from other researches. Another difference is that using this method the seersucker effect will be achieved in warp direction as opposed to the weft, that was used for other researches using the differential shrinkage method. Additionally, this research adds to the understanding of the behavior of plasma-treated and regular wool yarns when exposed to washing and acid dyeing processes.

1.1 Literature Research

1.1.1 Seersucker fabric development

Seersucker is a fabric with a puckering surface, often with a striped pattern. The stripes run along the whole fabric, mostly in warp direction. Traditionally, seersucker fabrics are used in shirts and shorts for summer as well as informal suits (Gandhi, 2012). There are three ways to obtain a puckered effect:

1. Slack-tension weaving

   This weaving method utilizes rows of warp yarns alternating between two warp beams. The warp beams contain an equal number of warp yarns. Therefore, the fabric density is uniform throughout the fabric. One warp beam is put under high tension while the other operates at normal tension. The difference in tension is what creates the puckering effect when the fabric is relaxed after weaving. Due to the requirement for two warp beams, a special weaving machine is needed to create this kind of fabric (Maqsood, Nawab, Javaid, Shaker, & Umair, 2014).

2. Differential Shrinkage

   Differential shrinkage is a way of creating a puckering effect on a fabric by using two types of yarns with different shrinkage percentages. The shrinkage recreates the tension used in the slack-tension weaving method. Shrinkage can be achieved in two ways. One being by using two yarns with different shrinkage percentages that are shrunk through wet treatment (Gandhi, 2012). The other works by using regular and core-spun yarns, with the core-spun yarn having a stretch-core which results in a more stretchy yarn. The fabric is woven with regular warp yarns and alternating regular and core spun yarns in the weft. The core-spun yarn will contract after weaving and therefore shrink while the regular yarn will not, creating the differential shrinkage effect (Maqsood, Nawab, Javaid, Shaker, & Umair, 2014). A similar process was developed for knitting. This was achieved by using the difference in contraction of regular and core-spun yarns in two sets of courses (Ashraf, et al., 2015).

3. Chemical Finishing

   Different chemical finishes have been able to achieve a puckering effect on fabrics. For cotton, printing stripes caustic soda has been proven to effectively create a puckering effect by shrinking the printed areas (Bissell, 1980). For wool, the puckering effect can be obtained by treatment of wool fabric using a heated pressured calendar, after an impregnation step using an alkali solution (Sims & Speakman, 1959).

The seersucker fabric is traditionally used for its aesthetic and comfort properties in clothing. However, Matusiak, Wilk, & Zieliński investigated the therapeutic properties seersucker fabrics. The research focused on development and testing of different seersucker fabrics to prevent cellulite formation. The main advantage that seersucker fabrics have over other fabrics, is the convex – concave structure of the puckering. This creates a mechanical micro-massaging effect and stimulation of the blood circulation, which helps prevent the formation of cellulite.

1.1.2 Wool

Wool is a natural fiber, coming from sheep and other animals. From all mammalian hairs, wool from sheep is the most common in its usage in textiles. Sheep produce about 0.6 kg clean wool per year. The wool fiber has properties that exceed man-made fibers. These properties include natural breathability, the ability to absorb and release water and natural flame retardancy. Another property is the ability for the fibers to felt due to the scaled surface of the wool fiber. Felting happens when wool fibers are agitated or put under pressure in water (Kuffner & Popescu, 2012). **Error! Reference source not found.** shows the surface of a wool fiber.

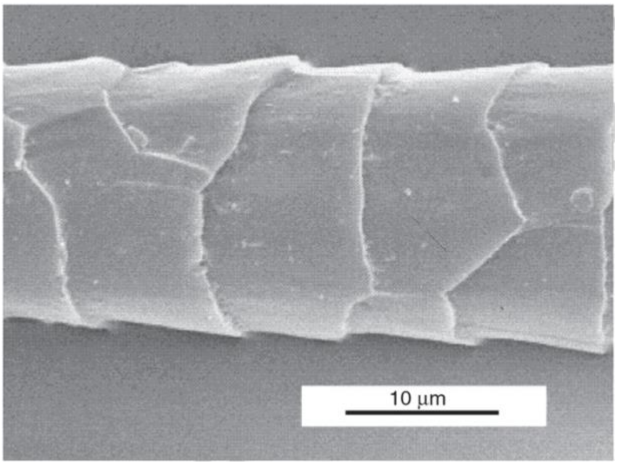

Figure 3: Surface of a Wool Fiber (Kuffner & Popescu, 2012)

Wool is used in many sectors including fashion, aviation, flooring and the medical sector due to its properties. Additionally, wool also has ecological benefits because it is natural, renewable, sustainable and biodegradable. It also has a low carbon impact and is relatively energy efficient.

After shearing the wool contains dirt, grease vegetable matter and other impurities. Therefore, before the fibers can be spun into yarns there are some processing steps the wool goes through, the most important steps are discussed below (Cottle & Wood, 2012):

1. Scouring

   In the scouring step the wool fibers are put through a series baths with detergent to get rid of the contamination, cleaning the fibers.

2. Carbonizing

   The carbonizing step removes any left-over vegetable matter and other impurities in the fibers that still is present between the fibers. This is done by using an acid bath with subsequent drying which makes the vegetable matter brittle. By a subsequent crushing step, the brittle vegetable matter is made into dust, which is then washed out.

3. Mechanical Processing

   The aim of the mechanical process is to disentangle and mix the fibers, forming a uniform strand of the fibers and reducing the thickness of the strand to prepare for spinning.

1.1.3 The Woolmark Company

The Woolmark Company is a non-profit organization which falls under the Australian Wool Innovation (AWI). The AWI started in the 1930's under the name International Wool Secretariat (IWS) that was started by multiple wool producing countries to promote wool on an international scale (Australian Wool Innovation Limited, 2020). Another activity of the IWS was performing researches towards wool and develop testing standards (Breitenberg, 1993). As part of IWS, the Woolmark started in 1964 as a label to guarantee fiber content and the quality of the wool. After restructuring in 1993, IWS became part of the AWI and the Woolmark Company was established in 1997 (The Woolmark Company, 2020). Today, the Woolmark Company is still responsible for the licensing of the Woolmark label with the aim to guarantee quality. Before obtaining the license and therewith the ability to use the Woolmark logo, all wool products have to go through a series of tests to determine if they meet the standard (The Woolmark Company, 2020). Additionally, these standards have also been used in scientific researches such as Zaisheng & Yiping (2007) their research towards the effect on the anti-felt properties of athmospheric preasure plasma treated wool.

1.1.4 Imparting shrink resistance to wool

There has been a lot of research towards imparting shrink (felting) resistance to wool. Hassan & Carr, reviewed the sustainable methods of imparting shrink resistance to wool fabrics, giving an overview of over 100 different methods of doing this.

By far the most common and cheapest treatment is the so-called Chlorine-Hercosett process. This is a process using a chlorination step followed by a coating of polyamide-epichlorohydrin resin. Chlorination makes the fibers hydrophilic and etches off the edge of the scales on the wool fibers while the Hercosett resin makes the fiber surface smoother. Due to the presence of an Adsorbable Organic Halide (AOX) effluent this process is environmentally hazardous (Hassan & Carr, 2019).

A more sustainable alternative is plasma treatment. This method shows excellent shrinkage resistance and durability while also being more sustainable compared to conventional methods (Hassan & Carr, 2019). Plasma is the ionized state of a gas. For plasma treatment of wool, different gasses can be used like air, oxygen or argon. To ionize a gas, an electrode with a charge of about 10,000 volts is used to create a spark. When this spark jumps to the counter electrode through the gas, the plasma is created.

For NATURETEXX, a commercially available yarn from Suedwolle. A continuous process, using air plasma under atmospheric pressure is used. Wool yarn is fed through the plasma between electrodes, treating the fabric. The plasma breaks down fatty acid lipids and produces hydroxyl and carboxyl groups on the surface of the fiber. Removing and adding the molecular groups decreases the hydrophobicity. Additionally, the process etches away the edges of the scales of the fiber, decreasing its tendency to felt. The result of this process is that clothing made of this fiber can be permanently machine washed at 40°C without felting. Additionally, due to only using air and electricity in the plasma treatment process, there are no environmental hazards (Thouvay, 2018) (Hassan & Carr, 2019).

Research towards the effect of low-temperature plasma treatment on the tailorability and thermal properties of wool fabrics has been done. The ability of the air plasma treatment to modify the surface of wool was proven. Figure 4 shows the surface modification caused by plasma treatment for different durations.

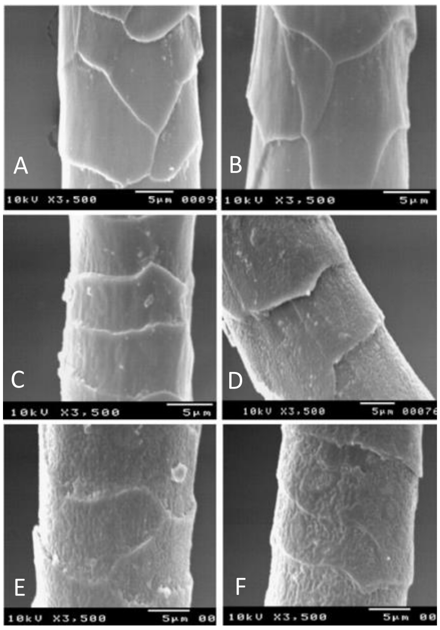

Figure 4: SEM picture of (a) untreated wool fibres, (b) 2 min, (c) 5 min, (d) 10 min, (e) 20 min and (f) 30 min.

The etching effect of the plasma treatment starts to show from 5 minutes of treatment and becomes more pronounced when the duration is extended. Results from the research showed the decreased extensibility of the fibre, which is directly proportional with the time of plasma treatment. Additionally, increased thermal resistance and conductivity was also proven (Goud & Udakhe, 2011).

1.1.5 Dyeing of Plasma Treated Wool

Research towards the effects of plasma treatment on the dyeability of wool has been done. The effects of different plasma-treatment types and different dye types have been researched. Helium/argon, acetone/argon and oxygen plasma-treated wool all have been proved to show increased dyeing rate and saturation dye exhaustion with acid dyes. The research using oxygen plasma to treat the wool yarns also proved increased dyeing rate and saturation dye exhaustion of oxygen low-temperature plasma-treated wool when dyed with Color Index (CI) Basic Violet (Wakida, et al., 1993) (Wakida, et al., 1996).

1.2 Research Questions

Main Question:

How can a seersucker fabric be created, by weaving with a single loom beam and using the differential shrinkage of plasma-treated and regular wool yarns to create a puckering effect on the fabric?

Sub-Questions:

1. What defines seersucker fabrics?
2. What are the requirements regarding the yarns for creating a wool seersucker sample fabric?
3. What are the requirements regarding the weave for creating a wool seersucker sample fabric?
4. How does the surface of the wool sample fabric visually change after washing?
5. How does the surface of the washed wool sample fabric visually change after acid dyeing?
6. How does the appearance of the treated sample fabric compare with the definition of a seersucker fabric?
7. Can the treated sample fabric be Woolmark and Cool Wool Certified?

1.3 Description of Structure

This thesis is divided in four sections. The first section preceded this description and explained the reason for research and gave an overview of the different developments surrounding the topic. In the next section, all the different methodologies that were used for this research will be explained. Please note that the methods are split into two subcategories: Methods Pre-Weaving and Methods Post-Weaving. While the weaving process is part of this research, it cannot be considered a method[1]. Therefore, the chapter is split in two, showing the difference between the methods used before the weaving process and the methods used after the weaving process. The thesis continues by showing the results obtained by using the methods as described before drawing conclusions based on the results. The thesis is rounded out by the recommendations and explaining the limitations of the research.

[1] The weaving specifications can be found in Appendix 16.

2 Methodologies

2.1 Methodologies Pre-Weaving

2.1.1 Interviews

To help determine the specifics of the yarns to be used as well as the weaving and finishing process, interviews with industry experts were held. Interviews provide qualitative data that gives insight into the possibilities and limitations. The subjects that have been covered by the different experts are: (wool-) yarns, (seersucker-) weaving and (wool-) treatment.

The industry experts were chosen based on their work and/or research experience to ensure good knowledge of the topics. The total population consists of all industry experts and researchers worldwide that have knowledge in any of the aforementioned fields. However, researchers that contributed to researches mentioned in the literature review as well as already known experts were contacted.

Five experts have been interviewed to take into account for the possibility of different views on the topics. Four interviews were done orally, on location as well as via telephone. One interview was done digitally through email contact. The base set of interview questions can be found in Appendix 1. To gain better insight in the answers of the interviewees, the interviews have been open and axial coded.

2.1.2 Conventional Material Examination

To get a better understanding of seersucker fabrics, different seersucker three different fabrics have been examined. The different aspects that have been reported are: weave, warp and weft yarns per cm, fiber contents, weight and thickness. The weave as well as the amount of warp and weft yarns per cm were determined by visual assessment using a loupe. The thickness was measured using a Schmidt DD-50 thickness Gauge and the weight was measured on Mettler AE200 analytical balance. The fiber contents have been requested from the companies supplying the fabric, A. Boeken Stoffen & Fournituren and Textielstad. The information gathered has been used in the process of determining the specifics for the woven fabric.

2.1.3 Method for Yarn Selection

The base for the selection of the yarns is the theory which this research is based on. This theory is that a seersucker fabric can be created by using the felting and non-felting properties of regular wool and plasma-treated wool respectively. Therefore, one type of plasma treated wool yarn and one type of non-plasma treated wool yarn must be selected. To comply with the Woolmark Cool Wool Certification Standard, yarns should be made in the worsted production system and have an average fiber diameter of 22.5 micron or lower.

Other parameters of yarns that are to be determined are:

- Yarn Count
- Twist
- Ply

To determine these parameters, the answers on the interview questions have been used.

2.1.4 Yarn Testing

The selected yarns were researched to have preliminary data on their characteristics. The yarn count (in Tex) has been determined by taking the average weight (in g) of 3 samples of 1m yarn from each different type and multiplying this number by 1000. The weighing was done using a Mettler AE200 analytical balance. A tensile strength test according ISO 2062:1993 was performed to measure elongation and breaking strength. The ISO Standard can be found in Appendix 8. A microscopic image has been taken of both the regular wool and plasma-treated wool fiber to show the effects of plasma-treatment on the surface of the wool fiber.

2.1.5 Warp and Weft Yarns Calculation

In a weave, the amount of warp and weft yarns per measuring unit is called the cover factor. The cover factor can be used to ascribe different properties to fabrics. It is also used during the weaving process to determine how 'open' a weave is and to make sure that there are no overlapping yarns in the weave. To calculate the cover factor, the amount of warp and weft yarns in a fabric are used, together with other yarn properties. Due to the fact that the amount of warp and weft yarns are used to calculate a cover factor, setting a certain cover factor and calculating backwards will result in an amount of warp and weft yarns to be used for the set cover factor. The cover factor calculation shown in the book Woven Textile Structure – Theory and Applications[2] in chapter 2.3.2 was used backwards to calculate the amount of warp and weft yarns that were used for the fabric.

[2] (Woven Textile Structure - Theory and Applications, 2010)

2.2 Methodologies Post-Weaving

2.2.1 Washing and Dyeing Methods

Aftertreatments have been selected based on the chemicals and dyestuffs available at Saxion University of Applied Sciences. From the woven fabric, samples of 12 by 8 cm (warp by weft direction) were taken. The samples were overlocked to prevent fraying. Two types of after treatment are used, washing and acid dying.

The aim of the washing was to see if a seersucker effect can be created by differential shrinkage of the plasma-treated and regular wool yarns during this process. For the washing treatment, two different anionic detergents have been selected to be able to compare possible differences in effects on the shrinkage of the yarns. The two detergents that have been selected are:

- AATCC 1993 Standard Reference Detergent WOB
- Sodium Dodecyl Sulphate

The composition of the AATCC 1993 Standard Reference Detergent WOB can be found in Appendix 11. The washing processes has been executed at both 40 and 60°C for 60 minutes. The washing was done in a Mathis Labomat machine using washing beakers, running at 40 rpm. A liquor ratio of 1:20 was used. The exact washing recipes can be found in Appendix 12.

The aim of the acid dyeing was to see if a differential shrinkage seersucker effect can be created during this process. Additionally, the aim was to try to get a contrasting stripe in fabric where the plasma-treated yarns would achieve better color depth than the regular wool yarns. For this, the theory presented in 1.1.5 Dyeing of Plasma Treated Wool was used. The acid dyeing was done according the procedure shown in Figure 5.

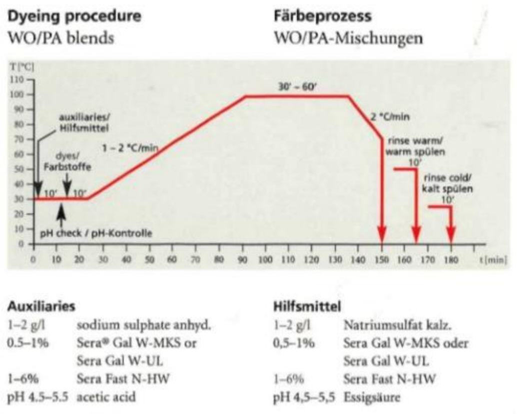

Figure 5: Supralan Dyeing Process

The dyeing was done using a Mathis Labomat machine using dyeing beakers and running at 40 rpm. From the available dyestuffs, Isolan Blue GLW has been used for the dyeing process due to its good contrast between the medium and dark shade. Samples have been dyed for 60, 45 and 30 minutes. The exact dyeing recipes can be found in Appendix 13.

A total of 12 samples have been treated. An overview of the treatments per sample can be found in Table 1.

Table 1: Sample Treatment

Sample #	Washing Process	Dyeing Time
Sample A	ECE-1 Detergent at 40°C	Undyed
Sample B	ECE-1 Detergent at 60°C	Undyed
Sample C	Sodium Dodecyl Sulphate at 40°C	Undyed
Sample D	Sodium Dodecyl Sulphate at 60°C	Undyed
Sample E	ECE-1 Detergent at 40°C	60 min
Sample F	ECE-1 Detergent at 60°C	60 min
Sample G	Sodium Dodecyl Sulphate at 40°C	60 min
Sample H	Sodium Dodecyl Sulphate at 60°C	60 min
Sample I (1)	ECE-1 Detergent at 40°C	45 min
Sample I (2)	ECE-1 Detergent at 40°C	45 min
Sample J (1)	ECE-1 Detergent at 40°C	30 min
Sample J (2)	ECE-1 Detergent at 40°C	30 min

Note: Samples A-D were visually assessed on the formation of puckering, surface modification and color. Due to the limited visual difference, four more samples, I(1,2) and J (1,2) were washed at 40°C to minimize energy usage.*

2.2.2 Sample and Fabric Assessment

All samples have been visually assessed on the formation of puckering, surface modification and color to get an idea of the possible effect of the different processes have on the fabric. Based on the results,, a piece of the woven fabric of 80 by 50 cm (warp by weft) was washed and dyed according the process used for sample I (1,2). This treated fabric, together with the fabric before treatment was also visually assessed on the formation of puckering, surface modification and color. Additionally, the shrinkage percentage in warp and weft was calculated for each sample by measuring the samples pre- and post-processing.

2.2.3 Fabric Testing

To find out if the fabric can be Woolmark Certified, the fabric will be tested according Woolmark Test Method – TWC-TM04 Breaking Strength of Fabrics[3] and Test Method – TWC-TM112 Abrasion Resistance of Fabrics[4] (Martindale Machine Method). As stated in the Woolmark Certification Standard for Flat Woven Apparel Fabrics[5], the minimum values for these tests are 147N and 15000 rubs respectively. To comply with the Woolmark Cool Wool Certification Standard[6] the fabric should have a maximum weight of 190 g/m^2. Therefore, the weight of the fabric after washing and dyeing will be measured.

Additional aesthetic requirements for the fabric have been determined based on the conventional material examination and interviews. The fabric should be aesthetically comparable with Figure 6. This implies having a having a puckered surface with the following qualities:

1. The puckering should be defined
2. The puckering should be along the weft; in stripes
3. The non-puckering stripes should remain relatively flat

Additionally, the fabric should have a striped, colored appearance. To determine how the fabric compares, visual assessment will be performed.

[3] The Test Method TWC TM-04 can be found in full in Appendix 6
[4] The Test Method TWC TM112 can be found in full in Appendix 7
[5] The Woolmark Certification Standard for Flat Woven Apparel Fabrics can be found in Appendix 4
[6] The Woolmark Certification Standard for CoolWool Fabrics can be found in Appendix 5

3 Findings

3.1 Interviews

The aim of the interviews was to identify preliminary specifications for the sample fabric. Five experts in the different fields of (wool-) yarns, (seersucker-) weaving and (wool-) treatment have been interviewed. One expert was predominantly knowledgeable with the topic of wool yarns and wool treatment, three experts were predominantly knowledgeable with weaving and one expert was predominantly knowledgeable with seersucker weaving. Additional questions were asked during the interview based on the expertise of the interviewee and to get a better understanding of the different subjects. The interviews can be found in full in Appendix 3.

All experts answered with information that was used for the coding process. Open and axial coding was done to be able to compare the information of the different experts on the same subjects. The results of the coding have been used for setting the aesthetic requirements for the fabric, selection of the weave, weaving density and the parameters to be determined for the selection of yarns. The coding can be found in Appendix 2.

The aesthetic requirements for the fabric that were determined based on the coding are:

1. Puckering should be defined
2. Puckering should be along the weft; in stripes
3. Non-puckering stripes should remain relatively flat

The weave that was selected based on the interviews is the plain weave. For the weave density it was taken into account that the weave should be more open, 10% was advised and used. The determined parameters for the yarns are:

- Yarn Count (single): 52 Nm
- Twist: Normal for plasma-treated wool, lower for regular wool to enable shrinkage
- Ply: 2

3.2 Conventional Material Examination

From the examination of different seersucker fabrics, it can be said that the conventional seersucker fabric is very difficult to define. Seersucker fabrics come in various weights, fiber contents and colors. Additionally, the processes used to create the effect also vary. The only aspect that unites seersucker fabrics is their puckering surface. The examined seersucker fabrics can be found below.

Figure 6: Navy Stripe Seersucker Fabric

Weave:	Plain
Warp/Weft Yarns per cm:	44 x 28
Fiber Contents:	1% elastane, 51% cotton, 48% polyester
Weight:	153 g/m^2
Thickness:	0.73 mm
Method for obtaining seersucker effect:	Weaving Using Two Loom Beams

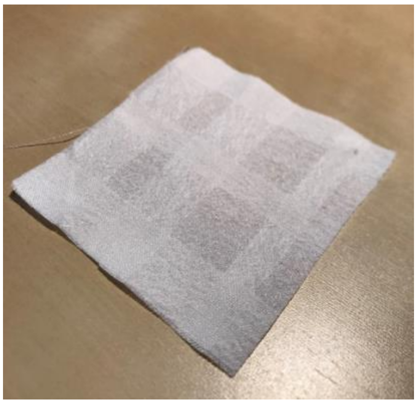

Figure 7: White Squared Seersucker Fabric

Weave:	Plain
Warp/Weft Yarns per cm:	32 x 32
Fiber Contents:	5% elastane, 70% cotton, 25% polyester
Weight:	160 g/m^2
Thickness:	0.48 mm
Method for obtaining seersucker effect:	Differential Shrinkage


Figure 8: Multi Colored Seersucker Fabric

Weave:	Plain
Warp/Weft Yarns per cm:	28 x 32
Fiber Contents:	99% Cotton, 1% Metallic yarn
Weight:	70 g/m^2
Thickness:	0.72 mm
Method for obtaining seersucker effect:	Weaving Using Two Loom Beams

Based on the fabric shown in Figure 6, the amount of yarns used for the striped pattern for the woven fabric was determined. The navy stripe seersucker fabric has 11 warp yarns for the white stripe and 9 for the blue stripe. For this fabric, the choice was made to go with an equal ratio of 10 by 10 plasma-treated and regular wool yarns respectively.

3.3 Yarn Selection

The yarns used for the woven fabric were requested at Suedwolle, a wool yarn manufacturer. Two yarns with the following pre-determined specifications have been requested:

- Production System: Worsted
- Average fiber diameter: 22,5 micron or lower
- Yarn Count (single): 52 Nm
- Twist: Normal for plasma-treated wool, lower for regular wool to enable shrinkage
- Ply: 2
- Treatment: 1 Plasma-treated, 1 Regular Wool

Due to limited availability, the following two yarns have been received: Moldau and Bellflower. The Moldau yarn is a regular wool yarn and the Bellflower is an air plasma-treated yarn. Their properties can be found in Table 2.

Table 2: Yarn Properties

Property	Moldau	Bellflower
Treatment	None	Plasma
Fiber Content	100% Wool	100% Wool
Fiber Micron	21.5	19.5
Production System	Worsted Ring Spun	Worsted Ring Spun
Yarn Count in Nm	48/2	48/2
Twist Single Yarn	560 z-twist	575 z-twist
Twist Plied Yarn	590 s-twist	300 s-twist
Color	Ecru	Ecru

It can be noted from Table 2 that the actual properties deviate from the requested properties. The yarn count is lower than the requested 52Nm and the twist levels are not lower for the regular wool yarn but higher.

3.4 Yarn Testing

To have preliminary data on the characteristics of the Moldau and Bellflower yarns, microscopic images have been made and tests have been executed. Figure 9 and Figure 10 show the microscopic images of a fiber from the Moldau and Bellflower yarn respectively. The fiber from the Moldau yarn shows a more defined scaled structure compared to the fiber from the Bellflower yarn. Therefore, it can be assumed that the fiber has had a plasma treatment.

The structure of the fibers shown in Figure 4: SEM picture of (a) untreated wool fibres, (b) 2 min, (c) 5 min, (d) 10 min, (e) 20 min and (f) 30 min., also show a difference in scaled structure depending on the time of plasma treatment. However, due to the possible differences in processing and the difference in magnification of the microscopic image, the images cannot be compared.

Figure 9: Microscopic Image of Moldau Fiber, 40x magnification

Figure 10: Microscopic Image of Bellflower Fiber, 40x magnification

To find out the actual yarn count in Tex and Nm of the Moldau and Bellflower yarns, 3 samples of 1m of each yarn were weighed for the calculations. Table 3 shows the results.

Table 3: Yarn Measurement Results

Sample No.	Weight in g/m	Tex	Nm (2 ply)
Bellflower #1	0.0382	38.2	52.4
Bellflower #2	0.0389	38.9	51.4
Bellflower #3	0.0385	38.5	51.9
Average:	**0.038533**	**38.5**	**51.9**
Moldau #1	0.0395	39.5	50.6
Moldau #2	0.0409	40.9	48.9
Moldau #3	0.0411	41.1	48.7
Average:	**0.0405**	**40.5**	**49.4**

It can be seen from the table above that the Moldau fiber is a heavier fiber. All of the values of the Moldau fiber are higher compared to those of the Bellflower yarn. The difference is 2 Tex on average with the Moldau yarn averaging 40.5 Tex and the Bellflower averaging 38.5 Tex. Another thing to note is that the Nm of the Bellflower yarn is 4Nm higher than described by Suedwolle, shown in Table 2. The actual Nm comes close to the requested 52Nm.

The tensile strength of the Moldau and Bellflower yarns have been tested according ISO 2062:1993. A full overview of results can be found in Appendix 9. The average breaking force, elongation and tenacity can be found in Table 4.

Table 4: Yarn Tensile Strength Results

Parameter	Moldau	Bellflower
Average breaking force (cN)	352.549	288.316
Average elongation (%)	15.560	4.034
Average tenacity (cN/tex)	8.705	7.489

Table 4 shows a difference in average breaking force between the Moldau and Bellflower yarn with the Moldau yarn having an about 70 cN higher breaking force. This means that the Moldau yarn is stronger than the Bellflower yarn. Another difference that can be noted from the table is the difference in elongation. The Moldau yarn has a higher elongation of over 11%. From this result it can be said that the Bellflower yarn is much more rigid.

3.5 Warp and Weft Yarns Calculation

To calculate the warp and weft yarns for the fabric, the cover factor calculation was used in reverse. According Bertam Wevers (personal communication, January 16, 2020), textile lecturer at Saxion University of Applied Sciences, up to 50% cover can be considered an open weave, 50%-70% can be considered a normal weave and above 70% can be considered a tightly woven fabric.

To leave room for shrinkage but to with the aim to end up with a tightly woven fabric after treatment, a cover factor of 70% has been chosen. With the cover factor the amount of warp and weft yarns per cm can be calculated. Either the same or different amount of warp and weft yarns can be used. In this case, to facilitate shrinkage in warp direction, a higher number of warp yarns was used. The calculations shown in Appendix 10, give a result of 20 warp and 15 weft yarns per cm for a cover of 70%.

3.6 Sample and Fabric Assessment

The different samples and the sample fabric were assessed during different stages to get an idea of the changes happening before, during and after the various processes. Additionally, the shrinkage percentage in warp and weft was calculated for each sample by measuring the samples pre- and post-processing. The results can be found in Table 5.

Table 5: Shrinkage Percentage of Samples

Sample #	Washing Process	Dyeing Time	Shrinkage Percentage Warp	Shrinkage Percentage Weft
Sample A	ECE-1 Detergent at 40°C	Undyed	3.3%	1.25%
Sample B	ECE-1 Detergent at 60°C	Undyed	5%	1.25%
Sample C	Sodium Dodecyl Sulphate at 40°C	Undyed	3.3%	2.5%
Sample D	Sodium Dodecyl Sulphate at 60°C	Undyed	5%	0%
Sample E	ECE-1 Detergent at 40°C	60 min	6.7%	2.5%
Sample F	ECE-1 Detergent at 60°C	60 min	8.3%	1.25%
Sample G	Sodium Dodecyl Sulphate at 40°C	60 min	6.7%	1.25%
Sample H	Sodium Dodecyl Sulphate at 60°C	60 min	7.5%	1.25%
Sample I (1)	ECE-1 Detergent at 40°C	45 min	11.7%	10%
Sample I (2)	ECE-1 Detergent at 40°C	45 min	11.7%	10%
Sample J (1)	ECE-1 Detergent at 40°C	30 min	13.3%	11.25%
Sample J (2)	ECE-1 Detergent at 40°C	30 min	15.8%	11.25%

It can be noted from Table 5 that the washing temperature directly influences the shrinkage in warp direction both with and without dyeing. The difference is 1.7% for the washed samples and an average of 1.2% for the washed and dyed samples. Additionally, an increase in shrinkage can be linked to a decrease in dyeing time for the dyed samples. Lowering the dyeing time from 60 to 30 minutes results in an average increase of shrinkage of 7.3% and 10% in warp and weft respectively.

The samples and sample fabric have been visually assessed after weaving, the washing processes and the dyeing processes. The full assessment can be found in Appendix 14. An excerpt of the visual assessment can be found in below.

- Fabric before treatment

  Shown in Figure 11 a., the fabric before treatment has the natural wool color and the surface is showing slight puckering in warp direction on the regular wool stripes. A slight color difference between the plasma-treated and regular wool yarns can also be observed with one yarn being darker in color than the other.

- Sample A

  Shown in Figure 11 b., the sample that was washed at 40°C with the ECE-1 Dye Transfer Test Detergent shows a rougher surface compared to the fabric before treatment and slight puckering in warp direction on the plasma-treated stripes. No visual color difference appeared after washing.

- Fabric after dyeing for 45 minutes

  After washing the fabric at 40°C with the ECE-1 Dye Transfer Test Detergent and subsequent dyeing for 45 minutes, the fabric shown in Figure 11 c. shows striped surface with puckering in warp direction on the regular wool stripe. The non-puckering stripe remains relatively flat. A difference in color can be observed between the plasma-treated and regular wool stripes with the plasma-treated wool stripe showing a darker blue color.

a. b. c.

Figure 11: a. fabric before treatment, b. Sample A, c. fabric after dyeing

3.7 Fabric Testing

An overview of the specification of the intended fabric, fabric after weaving and the fabric after treatment can be found in Table 6.

Table 6: Fabric Specification Overview

Specification	Intended Fabric	Sample Fabric After Weaving	Sample Fabric After Treatment
Warp/Weft Threads per cm	20/15	22/16.5	24/18
Cover Factor	70%	76%	80%
Fabric Weight	≤190 g/m^2	148 g/m^2	200 g/m^2
Fabric Thickness	/	0.69mm	0.96mm
Fabric Width	50cm	49cm	42.7cm

As to be seen from Table 6, the number of warp and weft threads per cm for the actual fabric after weaving is not the same as for the intended fabric. The difference is 2 and 1.5 for warp and weft respectively. The cover factor differs 6% and the fabric width 1cm. The fabric weight is as intended, staying below 190 g/m^2 at 148 g/m^2.

A difference between the actual fabric after weaving and after treatment can also be identified. After treatment, the number of warp and weft threads per cm increases by 2 and 1,5 for warp and weft respectively. The cover factor increases by 4%, the fabric weight goes up to 200 g/m^2 from 148 g/m^2, the thickness goes up to 0.96mm from 0.69mm and the fabric width decreases from 49cm to 42.7cm.

The fabric was tested according Woolmark Test Method – TWC-TM04 Breaking Strength of Fabrics and Test Method – TWC-TM112 Abrasion Resistance of Fabrics (Martindale Machine Method).An excerpt of the results of Test Method – TWC-TM04 can be found in Table 7: Results Breaking Strength of Fabric, the full list of test results can be found in Appendix 15.

Table 7: Results Breaking Strength of Fabric

Parameter	**Warp**	**Weft**
Average breaking force (N)	350.52	252.39
Average elongation (%)	27.952	18.241

It can be seen from Table 7 that there is a difference in average breaking force between warp and weft of 98.13N. There is also a difference in average elongation between warp and weft of 9.711%.

The result of Test Method – TWC-TM112 is an average >16000 rubs with none of the three samples showing any yarn breakage. Pictures of the fabric after 6000 rubs, 11000 rubs and 16000 rubs can be found in Appendix 17.

4 Conclusion

The purpose of this research was to find a way to make a seersucker fabric that was woven using one loom beam and used the differential shrinkage of plasma-treated and regular wool fibers to create puckering and a striped pattern in warp direction. The interviewed experts advised to use a plain weave using fine yarns and making it 10% more open to allow for the shrinkage to happen.

The differential shrinkage after washing happened in line with the expectations. Due to the decreased felting ability of the plasma-treated yarns, the regular wool yarns were expected to felt and therefore shrink more. This principle was also expected to work when dyeing, which would result in puckering plasma-treated yarns. However, this was not the case.

The results of the washing tests showed an inversion of puckering going from the regular wool stripe to the plasma-treated stripe, proving an increased shrinkage of the regular wool yarns compared to the plasma-treated yarns during the washing process. After dyeing for 60 minutes the fabric did not show any puckering, proving an equal shrinkage of the yarns. However, after dyeing for 45 and 30 minutes, puckering did show, with the regular wool yarns puckering as opposed to the plasma-treated yarns. Results also showed increased puckering when dyeing at 30 minutes as opposed to 45 minutes. This proves a reversed differential shrinkage when dyeing, with the difference in shrinkage increasing when lowering the dyeing time.

Based on Table 5, the shrinkage differential when dyeing at shorter times can be explained. When the plasma-treated yarns are dyed, a considerable amount of shrinkage occurs, also the shrinkage happens substantially faster compared to the regular wool yarns. However, when plasma-treated wool yarns are exposed to the dyeing bath for an extended period of time, the fibers relax and elongate again due to the tension from the regular wool yarns.

Another advantage of the successful creation of a seersucker effect when dyeing at a shorter amount of time is that the contrast between the two stripes increases. Contrast means that there is a difference in color and because this fabric is dyed in one dyebath using the same dyestuff for the whole of the fabric, having a contrast means that one part of the fabric is interacting with the dyebath different than the other. In this case, the difference in dye uptake between the plasma-treated wool yarns and regular wool yarns is causing the contrast. Due to the regular wool yarn being the lesser colored of the two, it can be said that the dye uptake and exhaustion rates are better for the plasma-treated wool compared to the regular wool yarns.

Additionally, the contrast also makes the fabric more in line with the aesthetic requirements for the fabric. Other aesthetic requirements for the sample fabric have also been met, the puckering is defined, in weft direction and the non-puckering stripe remains relatively flat. The quality criteria have been exceeded and it can be assumed that the fabric can be Woolmark Certified. All-but-one criterion for the Coolwool Certification have been met. The due to the shrinkage percentage and cover factor being higher than intended. The final sample fabric came out 10g/m^2 too heavy.

4.1 Recommendations

A wool seersucker fabric can be made according the process described in this research. However, the possibilities for industrial production have to be looked into. Before industrial production is done using this process it is advised to look into the effects that sizing and desizing processes and dyeing in rope form have on the result.

Additionally, based on the theory discussed in this research, an additional method for the creation of a seersucker fabric by weaving with a single loom beam and using the differential shrinkage of plasma-treated and regular wool yarns to create a puckering effect on the fabric can be identified. This method is based on the differential shrinkage between the plasma-treated yarns and regular wool yarns. With the ability for the plasma-treated yarns to be washed at 40°C with minimal shrinkage, the additional shrinkage of the regular wool yarns when washing should result a puckering surface on the fabric. For this process it is advised to use low-temperature reactive dyed yarns or to dye the fabric using a low-temperature reactive dyeing process.

Another interesting topic for further research could be the shrinkage and relaxation of plasma-treated wool over time when dyed using acid dyes. Due to the Woolmark Test Standard for Machine Washable Wool being used to determine the shrinkage and felting of plasma-treated wool, researches have only tested shrinkage and felting properties at 40°C washing cycles. Therefore, no information on the effects of increased temperature are available. Further research could look into the effects of temperature, pH and other factors that might influence the shrinkage and felting.

4.2 Limitations of the Research

This specific way of making a seersucker fabric has not been tried before. This impacted the interviews because it can be assumed that no expert has extensive knowledge on the topic. During the interview this resulted in predominantly receiving general answers to the questions asked. In addition to the base set of questions, topics that the interviewee addressed were further discussed. This was done to gain additional information on the discussed subject and specific information regarding the field of specialization of the respondents. Due to a lot of subjects only being addressed by a single respondent, a lot of information could not be coded. Therefore, the coding does not give a good overview of all the information gathered from the interviews.

The yarn selection procedure was limited by the availability of yarns at Suedwolle. The intention was to receive two identical yarns in terms of average fiber diameter and Nm. However, both the Nm and average fiber diameter levels differed.

The woven fabric was not supposed to pucker. However, this can occur when working two different kinds of yarns, especially when their stretch levels differ. Due to the tension put on the warp beam when weaving, it is very possible that the stripes of the more stretchy yarn elongates during the weaving process before contracting again after, resulting in the other stripe to pucker. This possibly also had an influence on the amount of puckering after washing because the regular yarns first had to shrink to match with the plasma-treated wool yarns and then have additional shrinkage to create the differential shrinkage effect. Additionally, due to weaving the fabric on a sample loom a maximum amount of fabric of about $1m^2$ could be made. Therefore, being limited to this small amount of fabric made the amount of tests that could be done limited as well.

The shrinkage percentages are calculated based on the shrinkage of the samples. The size of the samples before treatment were 5 x 12cm. Normally, one would execute an official dimensional stability test to find out the shrinkage of a fabric. However, due to the limited amount of fabric, making all of the samples this size would be impossible. Additionally, the samples had to be overlocked to prevent the edges from fraying. This could also have an influence on the shrink ability of the sample. Therefore, it can be concluded that the results are not trustworthy. However, the results do support a possible explanation as to why the puckering did not appear in the sample dyed for 60 minutes but did appear in the samples dyed for 30 and 45 minutes.

The fabric turned out to be 200 g/m^2 instead of the intended 190 g/m^2. With the fabric before treatment being 148 g/m^2 it was to be expected that the fabric after treatment would still be under 190 g/m^2. However, due to the increase in fabric density, the fabric turned out 10 g/m^2 too heavy.

It can be said for all testing done that the laboratory at Saxion University of Applied Sciences is not climate controlled. Therefore, all tests performed cannot be assumed as accurate and are merely used to give an indication of the overall quality.

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Appendices

Appendix 1: Interview Questions

Variable	Indicator	Interview Question
	Definition	What defines a seersucker fabric?
Weaving Pattern	Suitability	What weave would be most suitable for a seersucker fabric?
	Possibilities	What would be advantages/disadvantages of different weaves?
Fabric Properties	Density	What kind of fabric density would you advise to use?
Yarn Properties	Yarn Count	What kind of yarn count would you advise?

Appendix 2: Open and Axial Coding

Open Coding

Examples	**Category**
The seersucker fabric is defined by a waving surface. A fabric which shows a puckering effect. Warp-wise generally. You have an uneven surface. A vertically striped fabric in which one yarn puckers more than the other. The seersucker fabrics are characterizing by alternate puckered and flat strips, usually in warp direction.	Definition
plain or crepe weave or something with a high floatation because this gives the fabric the ability to shrink more in the finishing process. In general it is a plain weave. I usually applied the plain and rep weave. A plain weave is the standard. in a plain weave the 3d effect shows nicely. the easiest thing to do in the beginning is a plain weave.	Fabric: Most suitable weaving pattern
If you make a twill or gabardine, the waviness will be lost due to the image of the weave. twill will give a twill line in the fabric and often that is not what people want in a seersucker fabric. the only thing you could do is a basket weave because it adds more drape. For proper process of weaving the weaves of longer yarns floats are more convenient.	Weaving Pattern: Variations
The opener the weave, the more room for shrinkage there is. Make the fabric 5-10% looser, leave room for development of the effect. you should use a little bit less picks than ends. You should use 10% less minimum.	Weave Density
If you go for finer yarns, this makes for a thinner, lighter fabric, nicer and softer drape so it has advantages. Seersucker is meant for ladies wear or shirting, fine yarns suit its application well. I would advise using a 52 x 2 (ply), 52 x 2 is very common for wool weaving. A finer yarn … always results in a higher quality.	Yarn Count

Axial Coding

Category
Definition Surface: waving, puckering, uneven Stripes: alternating puckered and non-puckered, warp direction
Fabric: Most suitable weaving pattern Plain weave: standard, easy, showing 3d effect nicely
Weaving Pattern: Variations Twill: bad, image of weave not suitable Basket weave: possible, more drape Weaves with longer floats: more convenient, more space for shrinkage
Weaving Density More open weave: giving room for shrinkage, 10%
Yarn Count Finer yarns: higher quality, suited for seersucker fabrics, 52 x 2 common yarn

Appendix 3: Interviews

Interview Prof. Dr. Crisan Popescu, 20-09-2019

How would you define a seersucker fabric?

The seersucker fabric is defined by a waving surface.

What kind of yarn count would you advise?

A fine yarn for a fine fabric, as seersucker is meant for ladies wear or shirting, these fine yarns suit its application well. I would advise using a 52 x 2 (ply). Single ply is expensive as you need a high quality yarn to create the same strength. Also, because it is only twisted in one direction, it has a tendency to unwind. 52 x 2 is very common for wool weaving. To ensure the regular wool yarn has the ability to shrink well, a less twisted yarn is advised. For example a knitting yarn as these yarns have less twist compared to a weaving yarn. The treated yarn should be a regular weaving yarn as this should not shrink. In terms of fibre count 19,5 micron is most common for apparel. Like, mens suits and shirting.

What weave would be most suitable for a seersucker fabric?

Plain weave is the standard. Also, it is advised to use a 10-15% looser weave to give space for the shrinkage to happen.

What would be advantages/disadvantages of different weaves?

If you make a twill or gabardine, the waviness will be lost due to the image of the weave. Therefore, when using a plain weave the 3d effect shows nicely.

You mentioned that the felting of the wool already takes place when put in water at 40 degrees, what is the minimum temperature?

The minimum temperature is room temperature, ph is more important
If you put the yarn an in acid solution, for example an acid dye bath, the inner yarn itself will develop more felting and shrinkage while when put in an alkaline bath like a washing process, the surface of the yarn will get more bulky.

What is the shrinkage percentage of regular wool yarns?

5-8% for non-treated, 0,5-1% treated. However, testing is always necessary.

What kind of fabric density would you advise to use?

Make the weave 5-10% looser, leave room for development of the effect.

What should I take into account regarding the dyeing process?

> Winch dyeing would allow to develop the effect but the wrinkles that become present have to be avoided, so anti creasing agent has to be added.
> Take a type of medium shade to get a good difference in stripes, make sure the contrast present.

Interview Bertram Wevers, 02-10-2019

How would you define a seersucker fabric?

A fabric which shows a puckering effect. Warp-wise generally.

When making a seersucker fabric what kind of weave would you expect?

In general it is a plain weave. Based on my experience in the business it was plain weave. Why? Because it is the cheapest weave because you have the most coverage and normally it is for summer fashion so there was a need for a lot of cover for cheap prices and therefore, plain was the most common.

What would be advantages/disadvantages of different weaves?

Twill is not interesting because a twill will give a twill line in the fabric and often that is not what people want in a seersucker fabric – optical wise –. So the only thing you could do is a basket weave, 2x2. Why? Because it adds more drape.

What kind of fabric density would you advise to use?

What we have usually done is 76 warp x 68 weft using an Nm 30 yarn. Why? Because it gives you good drape, it's soft, light and pretty cheap because Nm 30 is a very common yarn in the far east. This is based on my information because I was buying in the far east.

My guiding professor, Mr Popescu advised to use a Nm 54 wool yarn, why do you think he would advise such a fine yarn?

That is pretty thin. Because of the wool structure of the fibre. Because I was talking about cotton. Wool has more bulkiness, the fiber itself is longer. Therefore, you can make finer yarns pretty easy. I think it has to do with softness and drape.

What kind of yarn count would you advise?

If you go for finer yarns with a higher density, what you get is the main difference being a little bit thinner yarn. This makes for a thinner, lighter fabric, nicer and softer drape so it has advantages. The finer the yarn, the finer the fabric.
You will need a lot of density to get coverage, so in the weaving process it might be more expensive. There is not right or wrong, it just depends on the price level people are looking for.

Do you have any advice in terms of weave density?

When you go to your Nm 52's then you would actually go to somewhere … well this is calculatable by the way … so … just to put a number, which is difficult because normally you calculate this. But I think you would have to go to about warp 130, based on very quick calculations to get the same coverage.

Also regarding the yarns, the idea was to use a treated weaving yarn and a non-treated knitting yarn in the warp to give the latter more room to shrink. What do you think about this?

I think you will get a tension problem if you use the knitting yarn in the warp. If you're going to weave, you're going to put tension on the warp. If you're going to do this with a very open structured yarn, the chance of yarn breakage during production is huge. Because the yarn is weak.

Interview Annemieke Koster, 22-10-2019

Hoe zou jij een seersucker omschrijven?

Ik zou het als een verticaal toegepaste streep zien met vaak twee kleuren waarbij een garen wat meer bobbelt dan het andere garen omschrijven

Wat voor garen zou je adviseren?

*Sidenote: Ik heb per ongeluk eigenlijk een seersucker ontwikkeld door garens van verschillende diktes te combineren in een streepje en vervolgens vrij warm te wassen waarbij de ene garen meer krimpt dan de ander en je dus dat gekrinkelde effect krijgt. Dat is hoe ik hem zelf zou maken, daarbij ook nog eens horizontaal geweven ipv verticaal omdat je dan meer kleurvariaties kunt maken op de zelfde ketting maar dat is echt heel erg ‘out of the ordinary’ natuurlijk.

Als ik deze vraag puur als producent moet beantwoorden is het altijd een afweging van kosten en baten. Wat je kostprijs of verkoopprijs mag zijn voor zo’n product. En dan geld dat een zo’n fijn mogelijk garen en een zo fijn mogelijk geweven doek altijd een hogere kwaliteit oplevert. Dan zou ik een zo dun mogelijk vezel met een zo fijn mogelijk garen en weefsel gebruiken om een zo hoog mogelijke kwaliteit te krijgen.

Wat zou de beste weefvorm zijn voor een wollen seersucker stof?

Ik zou zeggen plain weave of een crepebinding, of iets met een hoge flotering zodat het meer kan krimpen in je finish proces. Want hoe hoger de flotering, hoe meer het nog kan krimpen in het finish proces.

Wat voor dichtheid zou jij aanraden?

Hoe opener hoe meer ruimte voor krimp. Dat is het spel tussen flotering en dichtheid, wat je goed moet spelen om het gewenste effect te krijgen.

Hoe zou je de mogelijkheid kunnen creëren om dit te testen?

Wat ik meestal doe is dat ik een variabele tegelijk verander. Dat is natuurlijk een soort ‘basic testing principle’ maar dat vergeet je nog wel eens al je enthousiast bezig bent. Als je dichtheid test, dan moet je alle andere variabelen hetzelfde houden en alleen de dichtheid aanpassen. Daarna zou je de weeftechnieken kunnen aanpassen, dan een combinatie van binding en dichtheid en dan dat tegen elkaar afzetten. Dat je bijvoorbeeld een platbinding met een crepebinding met de zelfde dichtheid met elkaar gaat vergelijken en dan meerdere dichtheden test. Dat zou een beetje het process zijn hoe ik hem zou aanvliegen zelf.

Heb je nog suggesties of opmerkingen?

Wat ik heel erg merk bij dit soort testen is dat er zo veel variabelen zijn, dat het heel moeilijk word om alles te testen. De kleur van het garen, als je vezel of garen-geverfde garens hebt, kan het hierbij ook nog aardig van resultaat veranderen. Dus die zou ik ook zeker niet vergeten te vergelijken met elkaar.

Interview Detlef Pogge, 14-01-2020

Have you been brought up to speed on the idea? What it is about exactly?

> Yes, I think the idea is quite nice actually!

What defines a seersucker fabric? What are the characteristics?

> A seersucker fabric is always .. it looks .. How should I explain to you? You have an uneven surface. So that means to get it you need a yarn which is stable and a yarn which is in a way a little bit elastic. So you get an uneven surface.

What weave would be most suitable for a seersucker fabric?

> (I am just reading your mail Which kind of yarns do you have at the moment? - Plasma treated and regular wool Nm 48 x2 yarns -)
>
> In my opinion the easiest thing to do in the beginning is a plain weave. And then you can do three variations in warp and weft; plasma treated warp/weft, reg. wool warp/weft and 1 by 1. Then you have all the possibilities that you could do and you see the difference. If you have enough material and it is workable for you try the three versions, then you have the maximum output.

If you use 1 by 1, instead of rows of 10 or so, do you still see the nice bubbly puckers?

> Yes you will still see them, don't worry about it. When you use 5 or 10 ends you just have a bigger package that is unstable and give the puckering. So the possibilities you have are endless.
>
> (But the issue is, you also need to finish it. Do you have the possibility to do that? – Yes, I have all the equipment I need at school -)

Should I take into account the shrinkage in warp direction?

> Yes, then you should use a little bit less picks than ends. You should use 10% less minimum. But you can also test this. If you are making 3 meter, maybe make 1 meter with 20 and 1 meter with 22 or so.

What kind of tests would be good to perform on the fabric to get an idea of the quality?

> I cannot give you a good advice on which tests to do. There are so many and we do not have a standard selection of tests we perform.

Interview Małgorzata Matusiak, 21-01-2020

How would you define a seersucker fabric?

> The seersucker fabrics are characterizing by alternate puckered and flat strips, usually in warp direction.

Are there any yarn parameters that are particularly important when weaving a seersucker fabric?

> The seersucker fabrics can be manufactured by different ways, usually:
>
> - woven,
> - thermal,
> - chemical.
>
> Dependably on the way of manufacturing the importance of particular parameters of yarn is also different. For instance, in thermal method of seersucker fabrics manufacturing, the thermal properties are crucial.
>
> I deal with the seersucker fabrics in which the seersucker effect is created on loon (woven method). In this case the structure of fabrics is very tight, especially in puckered area. Die to this, a hairiness of the warp creating the puckered strips is very important for correct process of weaving. In my opinion, the evenness of yarn, tenacity and evenness of tenacity are also very important, especially in the case of the warp yarns.

What is the influence of using different yarn count yarns?

> Using yarns of different linear density also enables creating the seersucker effect. It can be applied in weaving method. The coarse yarn should be applied as yarn creating the puckered effect.

What weave is most suitable for creating a seersucker fabric and why?

> I do not know. In my investigations I usually applied the plain and rep weave. I do not check others. However, it is impossible to answer such question. The range of the weaves is unlimited. It is commonly known that weave influences the properties and performance of the woven fabrics. However, weave should be taken into consideration together with linear densities of yarns: warp and weft and also functions of fabrics.
>
> For proper process of weaving the weaves of longer yarns floats are more convenient. However, it is not sense to select of weave according to easier work of loom operator.
>
> Designing follows functions.

What would be advantages/disadvantages of different weaves?

> Maybe more attractive appearance? Generally, see above.

How would different weaves alter the aesthetic properties of the fabric?

Each weave gives particular appearance of the fabrics. It is obvious that weaves alter the aesthetic properties. However, we cannot tell how. Aesthetic is rather subjective filling.

What cover factor is suitable for a seersucker fabric when using contracting/shrinking yarns to create the puckering?

I do not know. I do not deal with seersucker fabrics made using the yarn shrinkage effect. Additionally, I do not know how cover factor can be calculated for the puckered area of the fabrics. The method suitable for standard flat woven fabrics cannot by applied for seersucker fabrics.

What is a good deviation in puckering and non puckering yarns?

In the weaving method different tension of puckering and not puckering yarn is applied. The difference should be adjusted on the loom via indirect trials. Dependably on the thickness of yarns, number of ends per cm, kind of fibers, kind of yarn (OE, ring spun, others) and weave the tension should be adjusted. We can rather speak about the deviation in shrinkage (working up). It is ca. 50 %.

What is the effect of altering the amount of puckering/non puckering yarns?

It is impossible to answer. It depends on a kind of change: number of ends, thickness of yarn or shrinkage of the puckering yard.

What parameters should a seersucker fabric be tested on - considering it is to be used for summer wear -?

First of all comfort-related properties: water -vapor resistance, air permeability, thermal resistance, liquid moisture transport. Also thickness and mass per square meter. However, both are higher for the seersucker fabrics than for standard fabrics.

Appendix 4: Woolmark Specification SF-2

THE WOOLMARK COMPANY

WOOLMARK SPECIFICATION

FLAT WOVEN, PILE WOVEN AND PRESSED FELT APPAREL FABRICS

SPECIFICATION SF-2

Effective 1 January 2016

WOOLMARK SPECIFICATION

SPECIFICATION SF-2*: 2016*

FLAT WOVEN, PILE WOVEN
AND PRESSED FELT APPAREL FABRICS

FABRICS

Woolmark, Woolmark Blend or **Wool Blend labelling** may be applied to woven fabric:

Woolmark Blend and **Wool Blend labelling must not** be applied to:
- pile garment shells
- pressed felt fabrics.

The use of a Woolmark approved fabric ***does not*** confer the right to use the mark on later end products.

SPECIFICATIONS

- Woolmark Blend labelling **must not** be used on pressed felt (ie fabric produced directly from fibres and not by felting woven or knitted fabric) or pile garment shells.
- Specifications for Woolmark Blend and Wool Blend fabrics are the same as those for Woolmark, except where indicated.
- The term 'Blend' used in this specification includes both Woolmark Blend and Wool Blend.
- If the fabric care claim (words or symbols) is for both 'Dry clean' and 'Hand wash', the fabric shall meet both claim requirements.

All fabrics

Property	Test method	Flat woven or pressed felt fabrics			Woven pile fabrics
		Fabric type			
		1 Suits trousers	2 Coats, jackets, costumes, skirts, dresses, kimonos, dressing gowns, accessories	3 Shirts, blouses, nightwear	4 Garment shell
Wool fibre content (%: minimum)	155	Woolmark 100% Pure New Wool Woolmark Blend 50% new wool Wool Blend 30% new wool			NA
Non-wool fibre content (%: maximum)	155	Woolmark Blend 50% Specification F-5 Wool Blend 70% Specification F-7			NA
Surface pile weight (g/m2: minimum)	15				220
Tensile strength (N: minimum)	4	196 (>150g/m²) 177 (<150g/m²)	98	147	NA
Colourfastness to light: Blue reference (grade: minimum)	5	Darker than 1/12 standard depth 4 Lighter than, or equal to, 1/12 standard depth 3 *Bright and pastel colours* Darker than 1/12 standard depth 3 Lighter than, or equal to, 1/12 standard depth 2–3			
Colourfastness to rubbing: dry Stain (grade: minimum)	165	3–4			

- This table must be read in conjunction with the notes that follow.

NOTES

1. **Woolmark TM155: Wool content**
   The wool content of Woolmark labelled fabrics is fully described in by specifications F-1 to F-4.
   The wool content of Woolmark Blend labelled fabrics is fully described in Specification F-5.
   The wool content of Wool Blend labelled fabrics is fully described in Specification F-7.
   All pile fabrics must have a pure wool pile but the backing material may be manufactured of an alternative material.

2. **Woolmark TM15: Surface pile weight**
   This property is only measured on pile fabrics

3. **Woolmark TM04: Tensile strength**
   Both the warp and weft directions must meet the specification.
   Tensile strength measurements are not required for fabric manufactured to accessories.

4. **Woolmark TWC-TM5: Colourfastness to light**

- Undyed and bleached white fabric must not be evaluated.
- For fabrics sold in Australia and South Africa, colourfastness to light, blue reference grade 5 is required for shades darker than 1/3 standard depth and grade 4 for shades between 1/3 and 1/12 standard depth.
- **Naturally coloured wool**
  Such wools may exhibit poor colour fastness to light, however, the fabric may carry the Woolmark or Woolmark Blend providing the following text (or similar) is used on the ticket: ‘It is an inherent feature of some naturally coloured wools that the colour may fade’.

- **Bright and pastel colours**
  Only the specific shades given on The Woolmark Company shade reference card; bright and pastel colours and intermediate shades at maximum brightness are included. No other shades will be classed as bright or pastel shades without prior approval by the Woolmark Management Group.

5. Woolmark TM165: Colourfastness to rubbing

This test is not required on fabrics lighter in shade that 1/12 standard depth.

Fabrics with a 'Dry clean only' care claim

Property	Test method	Flat woven or pressed felt fabrics			Woven pile fabrics
		Fabric type			
		1 Suits trousers	2 Coats, jackets, costumes, skirts, dresses, kimonos, dressing gowns, accessories	3 Shirts, blouses, nightwear	4 Garment shell
Dimensional change (%)	ISO	–3% < DC < 3% in warp and weft			
number of cycles	3175	3 Normal			
Colourfastness to water	6				
change of colour (minimum)		3–4			
stain wool (grade: minimum)		3			
stain cotton (grade: minimum)		3			NA
For blend fabrics only					
Stain other fibre (minimum)		3			

- This table must be read in conjunction with the notes that follow.

NOTES

1. **ISO 3175: Dimensional stability to dry cleaning**
   In the event that equipment for ISO 3175 *Normal* cycle testing is not available, three commercial dry clean cycles are a suitable alternative.
   For all dimensional stability testing, 'shrinkage' is denoted by a negative (–) value and an 'extension' by a positive (+) value.
   –3% < DC < 3% indicates that the shrinkage must be less than –3% and the extension must be less than +3%.

2. **Woolmark TWC-TM6: Colourfastness to water**
   Undyed and bleached white fabrics must not be evaluated.
   'Stain other fibre' is defined as the most severely stained fibre in the adjacent fabric.

Fabrics with a ‘Hand wash’ or ‘Hand wash or dry clean’ care claim

Property	Test method	Flat woven or pressed felt fabrics			Woven pile fabrics
		Fabric type			
		1 Suits, trousers	2 Coats, jackets, costumes, skirts, dresses, kimonos, dressing gowns, accessories	3 Shirts, blouses, nightwear	4 Garment shell
Dimensional change – relaxation (%)	31				
width		–3<DC	–3<DC	–3<DC	–3<DC
length		–3<DC	–3<DC	–3<DC	–3<DC
No and type of wash cycles		1 x 7A	1 x 7A	1 x 7A	1 x 7A
Dimensional change – felting (%)	31				
width		–	–	–	–
length		–	–	–	–
differential cuff edge felting		–1<DC<+1	–1<DC<+1	–1<DC<+1	–1<DC<+1
No and type of wash cycles		1 x 7A	1 x 7A	1 x 5A	1 x 7A
Dimensional change – total (%)	31				
width		–3<DC	–3<DC	–3<DC	–3<DC
length		–3<DC	–3<DC	–3<DC	–3<DC
Colourfastness to hand washing	250				
change of colour (grade: minimum)		3–4			
stain wool (grade: minimum)		4			
stain other fibre (grade: minimum)		3–4 (blend fabrics only)			NA
Colourfastness to wet alkaline contact	174	Multi–coloured fabrics only			
change of colour (grade: minimum)		3–4			
stain wool (grade: minimum)		4			
stain other fibre (grade: minimum)		3–4 (blend fabrics only)			NA

- This table must be read in conjunction with the notes that follow.

NOTES

1. **Woolmark TM31: Dimensional stability**
   -3 < DC indicates that the shrinkage of the fabric in washing must not exceed 3%. -1 < DC < +1 extension must not exceed 1% and shrinkage must not exceed 1%.

2. **Woolmark TWC TM-250: Colourfastness to hand washing**
   Undyed and bleached white fabrics are not to be evaluated.
   ‘Stain other fibre’ is defined as the most severely stained fibre in the adjacent fabric.

3. **Woolmark TM174: Colourfastness to wet alkaline contact**
   Applied to multi-coloured fabric only.

Fabrics with a ‘Machine wash’ care claim

Property	Test method	Flat woven or pressed felt fabrics			Woven pile fabrics
		Fabric type			
		1 Suits, trousers	2 Coats, jackets, costumes, skirts, dresses, kimonos, dressing gowns, accessories	3 Shirts, blouses, nightwear	4 Garment shell
Dimensional change – relaxation (%)	31				
width		–3<DC	–3<DC	–3<DC	–3<DC
length		–3<DC	–3<DC	–3<DC	–3<DC
No. and type of wash cycles		1×7A	1×7A	1×7A	1×7A
Dimensional change – felting (%)	31				
width			–	–	–
length		–	–	–	–
differential cuff edge felting		–1<DC<+1	–1<DC<+1	–1<DC<+1	–1<DC<+1
No. and type of wash cycles		3×5A	3×5A	5×5A	3×5A
Dimensional change – total (%)	31				
width		–3<DC	–3<DC	–3<DC	–3<DC
length		–3<DC	–3<DC	–3<DC	–3<DC
Colourfastness to machine wash	193				
change of colour (grade: minimum)		3–4			
stain wool and nylon (grade: minimum)		4			
stain other fibre (grade: minimum)		3–4			
Colourfastness to wet alkaline contact	174	Multi-coloured fabrics only			
change of colour (grade: minimum)		3–4			
stain wool and nylon (grade: minimum)		4			
stain other fibre (grade: minimum)		3–4			

- This table must be read in conjunction with the notes that follow.

NOTES

1. **Woolmark TM31: Dimensional stability**
–3 < DC indicates that the shrinkage of the fabric in washing must not exceed 3%.
–1 < DC < +1 indicates extension must not exceed 1% and shrinkage must not exceed 1%. For fabrics designed for accessories (hats, shawls, scarves, gloves or ties) only 1×7A plus 1×5A wash cycles are required.

2. **Woolmark TM193: Fastness to machine washing** The test method is divided into two parts:
Part A standard detergent without perborate
Part B standard detergent with perborate.
Both test methods are to be carried out and both sets of results must be reported.
If fabrics fail Part B but pass Part A, additional labelling requirements must be observed to prevent problems that could arise during the washing of garments should a bleach containing detergent be used. In this case, all labels and tickets attached to garments must carry an advisory statement: ‘Wash using a Woolmark approved detergent’ (or similar). Full details of these additional requirements are available from The Woolmark Company.
Undyed and bleached white fabrics must not be evaluated.

3. **Woolmark TM174: Colourfastness to wet alkaline contact** Specification applies to multi-coloured fabrics only.

Fabrics with a 'Machine wash and tumble dry' care claim

Property	Test method	Flat woven or pressed felt fabrics			Woven pile fabrics
		Fabric type			
		1	2	3	4
		Suits, trousers	Coats, jackets, costumes, skirts, dresses, kimonos, dressing gowns, accessories	Shirts, blouses, nightwear	Garment shell
Dimensional change – relaxation (%)	31				
width		–3<DC	–3<DC	–3<DC	–3<DC
length		–3<DC	–3<DC	–3<DC	–3<DC
No. and type of wash /dry cycles		1×[7A+TD]	1×[7A+TD]	1×[7A+TD]	1×[7A+TD]
Dimensional change– felting (%)	31				
width		–	–	–	–
length		–	–	–	–
differential cuff edge		–1<DC<+1	–1<DC<+1	–1<DC<+1	–1<DC<+1
No. and type of wash/dry cycles		5×[5A+TD]	5×[5A+TD]	5×[5A+TD]	5×[5A+TD]
Dimensional change – total (%)	31				
width		–3<DC	–3<DC	–3<DC	–3<DC
length		–3<DC	–3<DC	–3<DC	–3<DC
Colourfastness to machine washing	193				
Change of colour (grade: minimum)		3–4			
Stain wool and nylon (grade: minimum)		4			
Stain other fibre (grade: minimum)		3–4			
Colour fastness to wet alkaline contact	174	Multi-coloured fabrics only			
Change of colour (grade: minimum)		3–4			
Stain wool and nylon (grade: minimum)		4			
Stain other fibre (grade: minimum)		3–4			

- This table must be read in conjunction with the notes that follow.

NOTES

1. **Woolmark TWC-TM193: Colourfastness to machine washing**
   Undyed and bleached white fabric must not be evaluated
   The test method is divided into two parts:
   Part A: standard detergent without perborate
   Part B: standard detergent with perborate.
   Both test methods are to be carried out and both sets of results must be reported.
   If fabrics fail Part B but pass Part A, additional labelling requirements must be observed to prevent problems that could arise during the washing of garments should a bleach containing detergent be used. In this case, all labels and tickets attached to garments must carry an advisory statement: 'Wash using a Woolmark approved detergent' (or similar). Full details of these additional requirements are available from The Woolmark Company.
   Undyed and bleached white fabrics must not be evaluated

2. **Woolmark TWC-TM31: After wash and dry appearance**
   Assessment to be carried out following ironing.
   In addition to the fabric-related appearance retention criteria, the fabric must not exhibit problems related to garment trim which are likely to lead to consumer complaint (eg no colour bleeding from waist band trim, zip must function, button must not be loose, belt loops must not become detached or distorted).

3. **Woolmark TWC- TM174: Colourfastness to wet alkaline contact** Undyed and bleached white fabric must not be evaluated.
   'Stain other fibre' is defined as the most severely stained fibre in the adjacent fabric.

TEST AND REPORT CRITERIA

All samples must be tested using the test methods in the following table, however there is no pass or fail criteria for the properties tested. The licensee must test all samples to the appropriate method and report the result to the customer.

The failure of the fabric to meet the guideline performance level must be highlighted to the licensee by the Key Account Manager. When requested, The Woolmark Company can provide advice or assistance to the licensee to improve the performance of the fabric under normal commercial arrangements for consultancies. The decision to accept or reject a particular fabric should be subject to agreement between the fabric manufacturer and the customer. The Woolmark Company **shall not** act to arbitrate between the two parties on such issues.

Woolmark TM13 Mass per unit area
This measurement **must** be made on all fabrics

Woolmark TWC-TM112: Abrasion
Testing **must** be carried out and the results reported.
The abrasion resistance of fabrics is related to many factors (e.g. fibre fineness, yarn count, yarn type, weave, etc) and it is difficult to correlate the abrasion conditions of a fabric during wear with test results because of the many facets of abrasion. An individual test can provide only a comparison with previous experience with a particular fabric rather than an exact prediction of the wear life of a fabric. However, fabrics must be tested according to Woolmark TWC-TM112 and it is advised that the guideline performance given in the following table be achieved.

Property	Test method	Flat woven or pressed felt fabrics			Woven pile fabrics
		Guideline Performance level			
		1 Suits, trousers	2 Coats, jackets, costumes, skirts, dresses, kimonos, dressing gowns, accessories	3 Shirts, blouses, nightwear	4 Garment shells
Abrasion ('000 rubs: minimum)	112	20	10	15	10
Seam slippage (mm opening: maximum)	117	6	10	6	10
Pilling: indication of propensity	196	3–4			

- This table must be read in conjunction with the notes that follow.
- Not applicable to accessories.

1. **Woolmark TWC-TM117: Seam slippage**
   Testing **must** be carried out and the results reported.
   It is recognised that seam slippage can be reduced by special seaming techniques but fabrics **must** be tested according to Woolmark TWC-TM117 and it is advised that the guideline performance given in the preceding table be achieved.

2. **Woolmark TWC-TM196: Indication of** pilling propensity
   Testing **must** be carried out and the results reported.
   Due to the many factors affecting pilling there is no universally accepted test method that accurately predicts the likely propensity of a fabric to pill during use. However, fabrics **must** be tested according to Woolmark TWC-TM196.

   COMMENTS:
   Pilling in wear is a highly variable process. The same fabric worn by different people under similar circumstances may pill quite differently. Further differences exist between consumers in their perception of what is unacceptable. The Woolmark Company pilling test is a simple method that indicates the propensity to pilling for most fabrics, although it may not always give a true comparative indication of differences between fabrics because pilling is assessed after a fixed time interval. Pilling is a dynamic property and

the rate of pilling can often change according to time and wear. Some of the most important factors influencing pilling propensity are:

- *fibre diameter* — *fibre length*
- *twist level* — *fabric construction*.

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GD1270

Appendix 5: Woolmark Specification SC-1

THE WOOLMARK COMPANY

WOOLMARK SPECIFICATION

COOL WOOL FABRICS

SPECIFICATION SC-1

Effective 1 January 2016

WOOLMARK SPECIFICATION

SPECIFICATION SC-1: 2016

COOL WOOL FABRICS

PRODUCTS

Cool Wool may be applied to **Woolmark** and **Woolmark Blend labelled** fabrics that meet the criteria in this specification.

Wool Blend labelling cannot be used on Cool Wool products

The use of a Woolmark approved fabric does not confer the right to use the Mark on later end products unless the later product also meets the appropriate Product Specification.

Cool Wool criteria for all products

Products must meet all requirements in Specifications SF-1 or SF-2 as appropriate.

Property	Test method	Requirements
Cool Wool yarn production system	–	Worsted
Mean wool fibre diameter (µm: maximum)	22 or 23 or 24 Blends TM24 only	22.5
Cool Wool product surface		Clear, clean
Fabric weight (g/m²: maximum)	13	190

- This table must be read in conjunction with the notes that follow.

NOTES

1. **Woolmark Blend:**
   Specifications for Woolmark Blend products are the same as those for Woolmark, except where indicated.

2. **Blends with other fibres:**
   Only blends of wool with natural fibres (cellulosic or animal fibres, including silk) are permitted for use with the Cool Wool label in conjunction with the Woolmark Blend label. All requests to use Cool Wool on fabrics that meet the above requirements but contain synthetic or man-made fibres (with the exception of elastane-type filaments) must be referred to the Woolmark Management Group for consideration. However, such fabrics are unlikely to be approved unless the blend with synthetic fibre is judged to be innovative. The inclusion of elastane-type filaments to impart stretch characteristics to the fabric is permitted. The Woolmark logo cannot be used on elastane-containing fabrics, except in those countries covered by Specification F-4.

3. **Mean wool fibre diameter:**
   All measurement methods have a tolerance and this tolerance is included in the criterion of an absolute maximum mean fibre diameter for the wool fibres of 22.5µm. In the case of Woolmark Blend products, Woolmark TM24 (projection microscope) **must be used**. TM22 (Laserscan) or TM23 (OFDA) **must not be used** to evaluate Woolmark Blend products because neither apparatus distinguishes between wool and non-wool fibres.

4. **Fabric Surface:**
   The surface of the fabric is smooth and relatively free from protruding fibres.

5. **Fabric Weight:**
   A fabric weight of 190g/m2 is equivalent to ~285g/linear metre based on a fabric width of 1.5m. This limit represents the required maximum of 187g/m² (~280g/linear metre) with a 3g/m² allowance for testing error.

6. **Sampling:**
   For woven fabric, a composite specimen, including all warp and weft yarns, must be evaluated, including all yarns in at least a full pattern repeat. For knitted fabric, a composite specimen, including all yarn types, must be evaluated in the proportion in which they appear in the fabric.

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Appendix 6: Woolmark Test Method TWC-TM04

Woolmark Test Method

Test Method – TWC-TM04

BREAKING STRENGTH OF FABRICS

Version 2009

BREAKING STRENGTH OF FABRICS

1. SCOPE

This method is intended to be used for determining the tensile strength of prepared strips of woven fabric using a Constant Rate of Extension (CRE) tensile testing machine. The method is applicable to all flat or pile woven fabrics.

2. PRINCIPLE

A strip of fabric is extended at a constant rate between two jaws until it breaks. A reading of the maximum breaking strength is taken either directly from the machine or from a load/extension curve produced by the machine.

3. DEFINITIONS

Breaking Strength: The maximum force observed during a test in which the specimen is stretched until it breaks.

4. APPARATUS

4.1 Tensile Testing Machine

The Tensile Testing Machine should be a Constant Rate of Extension (CRE) type, ie the rate of separation of the jaws must be independent of the extensibility of the fabric.

The machine must be capable of a constant rate of extension of 200 mm/min, and must give a reading of the maximum load applied to the specimen either directly or in the form of a load/extension diagram.

The jaws or clamps of the machine must be at least 20 mm wider than the specimen width, ie not less than 70 mm wide.

Where a constant rate of extension machine is not available either of the following methods may be used but if so this must be noted on the report.

a) A Constant Rate of Traverse machine on which after the first 5 seconds of the test the rate of traverse of the pulling jaw is 200 mm/min.

b) A Constant Rate of Load machine adjusted to apply the required force to break within 20 ± 5 seconds or 30 ± 5 seconds.

Note: In case of dispute the constant rate of extension method shall be used.

5. STANDARD ATMOSPHERE

The standard atmosphere for conditioning and testing is:-

Relative Humidity: 65 ± 3% Temperature: 20 ± 2°

The standardised atmosphere for testing must accord with the descriptions in IWTO-52. Specimens shall be conditioned from the dry side (specimens having a regain less than 10% but not oven dry) as described in IWTO-52. Each testing laboratory shall determine the time required to pre-condition specimens prior to conditioning in the standard atmosphere.

6. TEST SPECIMENS

Specimens 300 x 75 mm shall be cut with the longer lengths parallel to warp or weft. The longitudinal edges of the specimen should be frayed down to 50 mm so that no threads are lost during testing.

A fringe of 5 mm width is usually adequate but may need to be wider in open fabrics and can be less in dense fabrics.

When fabrics cannot be frayed the specimen may be cut to width 50 mm exactly.

The specimens should be as representative of the sample as possible. No two specimens shall contain the same longitudinal threads. Warp specimens must be taken at least 50 mm in from the selvedge end.

At least three warp specimens and three weft specimens should be tested.

Specimens should be left flat, singly, for a minimum of 24 hours in the standard atmosphere for conditioning, prior to testing.

7. TEST PROCEDURE

7.1 Adjust the jaws of the machine to a separation of 200 ± 1 mm. The edges of the jaws must be parallel to each other and perpendicular to the direction of movement of the jaws. Calibrate the tensile machine according to the manufacturer's instructions.

7.2 Mount the specimen centrally in the width of the jaws.

7.3 Tighten the upper jaw first. Tension the specimen to approximately 1% of the expected breaking strength, then tighten the bottom jaw. Ensure that the specimen is held securely in both jaws.

7.4 Extend the specimen to the break point at a rate of 200 mm/min.

7.5 Record the maximum load in Newtons (or kilograms) applied in stretching the specimen to break.

7.6 If the range of measured values exceeds the critical value below, repeat the trial 2 more times and average the 5 values of tensile strength.

Property	Critical range
Tensile Strength	10% of mean

Range = difference between the highest and the lowest test value

8. CALCULATION OF RESULTS

Calculate the arithmetic mean of the results for warp and weft separately to the nearest Newton.

NOTE: If any specimen breaks within a distance of 5 mm from either jaw, and/or has a tensile strength significantly lower than the other specimens, that result should not be included in the calculation mean. Wherever possible a further specimen should be tested.

9. REPORTING OF RESULTS

Note: All specimens shall be identified by a traceable and unique number that shall be recorded on the report.

- Report that the test was carried out according to Woolmark TWC-TM4.
- Report the identification of the sample
- Report the test date.
- Report the mean breaking strength of warp and weft separately to the nearest Newton.
- Report any deviation from the procedure described (eg, no conditioning before measurement).

10. REFERENCES

This test is based on ISO 5081

11. RELATED TEST METHOD

Woolmark Test Method	Title (abbreviated)
4	Breaking Strength of Fabric
112	Abrasion Resistance of Fabrics ('Martindale' Machine Method)
117	Seam Slippage (Woven Fabrics)
172	Tear Strength of Woven Fabric
179	"Stretch" and "Growth" Properties of Textile Fabrics
196	Pilling of Wool Fabrics (Martindale Machine Method)
258	Oil and Water repellency
288	Tailored Garment Inspection Criteria

12. APPENDICES

None

Appendix 7: Woolmark Test Method TWC-TM112

Woolmark Test Method

Test Method – TWC-TM112

ABRASION RESISTANCE OF FABRICS
(MARTINDALE MACHINE METHOD)

Version 2009

ABRASION RESISTANCE OF FABRICS
(MARTINDALE MACHINE METHOD)

1. SCOPE

This method is intended to determine the resistance to abrasion of flat woven and warp knitted fabrics; it is also be applicable to certain non-woven fabrics and fabrics having a pile of less than 2mm.

2. PRINCIPLE

Circular specimens of a fabric are abraded under a known pressure against a standard abradant fabric. Abrasion resistance is expressed as the number of rubs required to cause a breakdown in the test specimens or to lead to an unacceptable visual change

3. DEFINITIONS

Abradant fabric: The standard fabric which forms the surface against which the test fabric is rubbed.

End point: The change in the sample agreed to be the point at which it fails in abrasion.

4. APPARATUS

4.1 **Martindale Abrasion Machine**; an electrically driven machine capable of rubbing the test specimens under a known load against a reference abradant fabric. The rubbing motion is in the form of a Lissajous figure. The machine must be fitted with a pre-setting stop switch. The total load to be applied to each specimen must be 595±7g (9kPa) for apparel fabrics and 795±7g (12kPa) for upholstery fabrics.

4.2 **Reference Abradant fabric; SM25** a 100% wool plain weave, crossbred, worsted fabric, of the following construction:-

	Warp	**Weft**
Yarn linear density	R 63 ± 4 tex/2	R 74 ± 4 tex/2
Threads per 10 centimetres	175 ± 10	135 ± 8
Singles twist, t.p.m.	540 ± 20 Z	500 ±20Z
Twofold twist, t.p.m.	450 ± 20 S	350 ±20S
Mean fibre diameter,µm	27.5 ± 2.0	29.0 ± 2.0
Minimum mass, gm-2	215 ± 10	
DCM Extract %	0.8 ± 0.3	

NOTE 1: The yarn and fibre are measured before fabric manufacture, therefore their properties may change in fabric form.

4.3 **Woven felt, SM26** of mass 750 ± 50 gm-2 and is approximately 2.5 ± 0.5 mm thick.

4.4 **Polyurethane polyether foam, SM28** approximately 3 ± 1 mm thick and having a density of 30 ± 1 kgm-3 and hardness 190 ± 20N, cut to the same size as the specimens. This specimen backing should be renewed with every test.

4.5 **Fabric punch or press cutters**, diameter 38 mm and 140 mm

4.6 **Stereo microscope** with a magnification of approximately x10

4.7 **Grey scales**

5. STANDARD ATMOSPHERE

The standard atmosphere for conditioning and testing is:-

Relative Humidity: 65 ± 3% Temperature: 20 ± 2°

The standardized atmosphere for testing shall meet the conditions described in IWTO-52. Specimens shall be conditioned from the dry side (specimens having a regain less than 10% but not oven dry) as described in IWTO-52. Each testing laboratory shall determine the time required to pre-condition specimens prior to conditioning in the standard atmosphere.

6. TEST SPECIMENS

Using the fabric punch or press cutter, take 4 circular specimens of 38 mm diameter at random from the whole of the available fabric sample. If a patterned fabric is being tested ensure that the test specimens are representative of the whole pattern, avoid fabric faults such as knots and excessively thick or thin places etc and do not include fabric containing stains and other obvious contamination

7. TEST PROCEDURE

7.1 Ensure that the Martindale machine is set up correctly, (Appendix 1), and that temperature and humidity are within the appropriate limits.

7.2 Specimens should be left flat, singly (pile surface uppermost) for a minimum of 24 hours in the standard atmosphere for conditioning prior to the test.

7.3 Remove the top plate.

7.4 Mounting of the abradant.

Place a piece of the standard abradant fabric over the standard felt on each of the abrading tables, making sure that there are no wrinkles, knots, thick or thin places in the fabric. Place the weight on the abradant and fit the clamping ring securely over felt and abradant. Replace the abradant at the start of each test or after 50000 rubs if the test is continued beyond this number.

7.5 Mounting of the specimen

Place the specimen holder nut in the mounting device on the machine frame. Place a circle of the test specimen face downwards in the holder, followed by the foam insert, the specimen holder insert and finally the specimen holder body. Screw down the specimen holder body to secure the test specimen in the holder

NOTE: No foam insert is required for fabrics >500gm-2 or those already having a backing.

7.6 Place the specimen holders on the abradant tables, replace the top plate and push the spindles through the bearings into the holders and add the appropriate weights to give a total loading on each specimen of 595 ± 7g (9kPa) for apparel fabrics and 795 ± 7g (12kPa) for upholstery fabrics.

7.7 Set the counter to zero and the pre-set counter to give a suitable number of rubs eg 5000, then start the machine. After the selected number of rubs has been reached examine the specimens and assess the intervals required for subsequent stops. The intervals between examination should be decreased as end point is approached. Any pills that form on the test specimens should be cut off with sharp scissors.

7.8 Record the rubs to end point for each of the replicates. Information on end-point determination is given in Appendix 3.

7.9 If the range of measured values (defined as the difference between the highest and lowest test result) exceeds the critical value below, repeat the trial and average all the values of rubs to end point.

Property	Critical range value
Rubs to end point	5000

8. CALCULATION OF RESULTS

Calculate the arithmetic mean of the results from individual specimens to the nearest 100 rubs.

9. REPORTING OF RESULTS

Note: All specimens shall be identified by a traceable and unique number that shall be recorded on the report.

- Report that the test was carried out according to Woolmark TWC-TM112.
- Report the identification of the sample
- Report the test date.
- Report the total loading on the specimens.
- Report the mean result (for the end point applicable) and the range of results.
- When applicable give the details of first end point (ie change of shade or appearance).
- Report any deviation from the procedure described

10. REFERENCES

The method is based on EN IS0 12947-2.

11. RELATED TEST METHOD

none

- **APPENDICES**

Appendix 1: SUPPLIERS FOR MATERIALS AND REAGENTS

The standard materials required are:

SM25 Standard abradant fabric

James H Heal & Company Limited
Richmond Works 4
HALIFAX
HX3 6EP
United Kingdom

Tel : + 44 (0) 1422 366355
Fax : + 44 (0) 1422 352440

SM26 Standard felt
SM28 Polyurethane polyether foam
The Martindale Abrasion Tester:

James H Heal & Company Limited
Richmond Works 4
HALIFAX
HX3 6EP
United Kingdom

Tel : + 44 (0) 1422 366355
Fax : + 44 (0) 1422 352440

SDL International Limited
P O Box 162
Crown Royal
Shawcross Street
STOCKPORT
SK1 3JW
United Kingdom
Tel: +44 (0) 161 480 8485
Fax: +44 (0) 161 480 8580

Appendix 2:

- **SETTING UP AND MAINTAINING THE MACHINE**

1.1 Ensure that the faces of the inserts of the specimen holders are parallel to the surfaces of the abrading tables. This should have been checked by the machine maker but it should be re-checked periodically.

1.2 To check that the top plate and abrading tables are parallel, insert a dial gauge through the spindle bearing and move the top plate by turning the drive shaft by hand. The needle movement of the dial gauge should be within ± 0.05 mm over the whole surface of an abrading table

1.3 Assemble each empty specimen holder and place each one in position on the appropriate abradant table and insert the spindles. Use a feeler gauge to check for any gap between the face of the specimen holder insert and the table. On a new machine there should not be a gap greater than 0.025 mm. Rock the spindle from side to side and re-check with the feeler gauge.

1.4 For those machines operating with ball bearings, clean out the cups carrying the ball bearings and apply two or three drops of low viscosity lubricating oil approximately every 2 weeks. Also lubricate the three driving pins.

1.5 Periodically clean all the spindles and bearings and apply a thin layer of silicone grease to the spindles.

- **CALIBRATION**

2.1 To ensure that the machine is correctly set, set it in motion using a specimen of plain, dark pigment printed cotton fabric. Proceed for 7000 cycles and then examine the specimen for colour change. If this is uneven, the machine is not correctly set.

2.2 Two internal reference fabrics relevant to the work of the laboratory should be used at regular and frequent intervals for monitoring the machines, using the full test to breakdown. If uneven wear is indicated either between machines or between testing positions, refer again to sections 1.1 and 1.2

2.3 To check the Lissajous figure, attach a piece of self adhesive paper over the abrading table. Then place a pen through the spindle holder so it touches the abrading table (pen should fit spindle holder tightly). Switch on the machine so a Lissajous figure is drawn on the paper. Compare drawn Lissajous with figure 1a. If the diagram is not the same contact the manufacturer of the machine.

- **ACCURACY OF THE TEST**

The SM25 Abradant Fabric specified in 3.2 has been tested extensively in one laboratory and by means of an inter-laboratory trial, using the following three fabrics:-

Fabric 1 - 100%Wool Challis
Fabric 2 - 100%Wool Worsted Knitted
Fabric 3 - 100%Wool Woollen Spun Woven

The results obtained from these trials gave the information shown in Tables 1 and 2, indicating the accuracy of the test for wool fabrics.

Table 1 - Coefficients of Variation

Fabric	Expected End Point	CV%	
		Within One Laboratory	Between Laboratory
1	25000	6.2	22.0
2	10000	3.8	14.7
3	25000	3.8	18.5

Table 2 - Standard Error

Fabric	Expected End Point	Within One Laboratory	Between Laboratory
1	25000	± 1660	± 5400
2	10000	± 670	± 1290
3	25000	± 810	± 4000

5. **PRECAUTIONS**

4.1 Reject any abradant fabric containing knots, very thick or very thin yarns.

4.2 Change the abradant fabric for every new specimen and at 50000 cycles if breakdown has not been reached.

4.3 Make sure that the abradant is held in place firmly and that there are no tucks or ridges present.

4.4 Examine the test specimens before mounting them; they should be circular and not elliptical. If they are elliptical it is possible that the specimens will be tested under the wrong conditions, or they may be pulled out of the holders during testing.

4.5 Do not allow any oil or grease to come into contact with the specimens or abradant.

4.6 Every time a specimen holder is taken from the machine to check the specimen or endpoint, make sure that it is properly tightened before it is replaced on the machine.

4.7 Make sure that the correct end point has been reached.

4.8 The felt need not be renewed until damaged, soiled on both sides, or until 25 tests have been completed.

Appendix 3:

DETERMINATION OF END POINT

Woven Fabric: end point is reached when two or more threads have completely broken down, or on a knitted fabric when a hole appears, ie one thread is broken. End point can also occur because of a change in shade or appearance that is sufficient to cause a customer to complain. Where physical breakdown of a specimen is being examined, the specimen in the holder should be inspected using a low power stereo microscope, ie x5 or x10 magnification. The whole area of the specimen should be checked and special care must be taken, especially in the case of tightly sett fabrics made from fine yarns, in which case a magnification higher than x10 might have to be used.

Cut Pile Fabric: end point is reached when the base fabric shows and the pile has worn away on all or any part of the test specimen.

Loop Pile Fabric: end point is reached on a loop pile fabric when a loop has completely broken.

Changes in shade can arise from a variety of causes, eg, loss of raised finish from a fabric or of boucle loops or effects from fancy yarns. Where various types of fibres are dyed differently in an intimate blend, differential loss of yarn or fibre can cause pronounced changes in shade or appearance. In this case end point is assessed against the grey scale used in colour fastness assessing. End point is reached when the shade change is assessed as grey scale rating 3.

Appendix 8: EN ISO 2062:2009

Nederlandse norm

NEN-EN-ISO 2062

(en)

Textiles - Yarns from packages - Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester (ISO 2062:2009,IDT)

Vervangt NEN-EN-ISO 2062:1995;
NEN-EN-ISO 2062:2008 Ontw.

ICS 59.080.20

december 2009

NEN-EN-ISO 2062

Als Nederlandse norm is aanvaard:
EN ISO 2062:2009,IDT
ISO 2062:2009,IDT

Normcommissie 330061 "Textiel en kleding"

Postbus 5059, 2600 GB Delft
Telefoon (015) 2 690 390, Fax (015) 2 690 190

NEN-EN-ISO 2062

Nederlands voorwoord

Voor de in deze norm vermelde normatieve verwijzingen bestaan in Nederland de volgende equivalenten:

vermelde norm	Nederlandse norm	titel
ISO 139	NEN-EN-ISO 139	Textiel - Standaardatmosferen voor het conditioneren en de beproeving
ISO 2060	NEN-EN-ISO 2060	Textiel - Garens uit verpakkingen - Bepaling van de lineïeke dichtheid (massa per eenheid van lengte) met de strengmethode

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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN ISO 2062

December 2009

ICS 59.080.20 Supersedes EN ISO 2062:1995

English Version

Textiles - Yarns from packages - Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester (ISO 2062:2009)

Textiles - Fils sur enroulements - Détermination de la force de rupture et de l'allongement à la rupture des fils individuels à l'aide d'un appareil d'essai à vitesse constante d'allongement (ISO 2062:2009)

Textilien - Garne von Aufmachungseinheiten - Bestimmung der Höchstzugkraft und Höchstzugkraftdehnung von Garnabschnitten unter Verwendung eines Prüfgeräts mit konstanter Verformungsgeschwindigkeit (CRE) (ISO 2062:2009)

This European Standard was approved by CEN on 21 November 2009.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN Management Centre or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the CEN Management Centre has the same status as the official versions.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

Ref. No. EN ISO 2062:2009: E

Contents Page

Foreword

This document (EN ISO 2062:2009) has been prepared by Technical Committee ISO/TC 38 "Textiles" in collaboration with Technical Committee CEN/TC 248 “Textiles and textile products” the secretariat of which is held by BSI.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2010, and conflicting national standards shall be withdrawn at the latest by June 2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN ISO 2062:1995.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

Endorsement notice

The text of ISO 2062:2009 has been approved by CEN as a EN ISO 2062:2009 without any modification.

INTERNATIONAL STANDARD

ISO 2062

Third edition
2009-12-01

Textiles — Yarns from packages — Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester

Textiles — Fils sur enroulements — Détermination de la force de rupture et de l'allongement à la rupture des fils individuels à l'aide d'un appareil d'essai à vitesse constante d'allongement

Reference number
ISO 2062:2009(E)

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 2062 was prepared by Technical Committee ISO/TC 38, *Textiles*, Subcommittee SC 23, *Fibres and yarns*.

This third edition cancels and replaces the second edition (ISO 2062:1993), which has been technically revised.

Introduction

In the 1950s and 1960s when this International Standard was first prepared, three types of tensile testers were in wide use: constant rate of specimen extension (CRE), constant rate of travel (CRT) and constant rate of loading (CRL). It was therefore advisable to state the rate of operation in a way which would be common to all three types of tester. In addition, the best possible agreement was sought between the test results of the three types of tester. Consequently, the principle of constant time to break was adopted, and 20 s to break was chosen for this International Standard and also for a number of national standards.

In the early 1990s, CRE testers were recognized as the best type. As CRT and CRL testers were still in use internationally, the procedure for using them was included in an informative annex. There is no assurance that the results from the three types of tester will agree. This International Standard considers CRE testers only, so the time-to-break principle was no longer needed and a simpler statement of rate of extension was used. The rate of extension of 100 % per minute has been adopted as standard, but higher rates were permitted by agreement for automatic testers.

CRT and CRL testers are now considered to be obsolete. The methods of using them are deprecated and their inclusion in informative Annex A does not have an influence on the status of this International Standard.

Textiles — Yarns from packages — Determination of single-end breaking force and elongation at break using constant rate of extension (CRE) tester

1 Scope

1.1 This International Standard specifies methods for the determination of the breaking force and elongation at break of textile yarns taken from packages.

Four methods are given:

—A: manual; specimens are taken directly from conditioned packages;

—B: automatic; specimens are taken directly from conditioned packages;

—C: manual; relaxed test skeins are used after conditioning; —D: manual; specimens are used after wetting.

1.2 Method C is used in cases of dispute regarding elongation at break of the yarn.

NOTE Methods A, B and C are expected to give the same results for yarn strength, but Method C might give somewhat truer (and higher) values of elongation than A or B. Method D is likely to give results differing, for both breaking force and elongation at break, from those obtained by methods A, B or C.

1.3 This International Standard specifies methods using constant rate of specimen extension (CRE) tensile testers. Testing on the now obsolete constant rate of travel (CRT) and constant rate of loading (CRL) instruments is covered, for information, in Annex A, in recognition of the fact that these instruments are still in use and can be used by agreement.

1.4 This International Standard applies to all types of yarns, except glass, elastomeric, aramid, high molecular polyethylene (HMPE), ultra high molecular polyethylene (UHMPE), ceramic and carbon yarns and polyolefin tape.

NOTE A method for the testing of glass yarns is given in ISO 3341.

1.5 This International Standard is applicable to yarns from packages but can be applied to yarns extracted from fabrics, subject to agreement between the interested parties.

1.6 This International Standard is intended for the single-end (single-strand) testing of yarns.

NOTE The skein method of testing is given in ISO 6939.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 139, *Textiles — Standard atmospheres for conditioning and testing*

ISO 2060, *Textiles — Yarn from packages — Determination of linear density (mass per unit length) by the skein method*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 breaking force maximum force applied to a specimen in a tensile test carried to rupture

NOTE For yarns, the breaking force or load is preferably expressed in centinewtons.

3.2 elongation at break increase in length of a specimen corresponding to the breaking force

NOTE For yarns, elongation at break is expressed as a percentage of the initial length.

3.3 breaking tenacity ratio of a yarn's breaking force to its linear density

NOTE For yarns, breaking tenacity is expressed in centinewtons per tex.

3.4 constant rate of specimen extension (CRE) tester testing machine in which one end of the specimen is held in a virtually stationary clamp and the other end is gripped in a clamp that is driven at a constant speed

NOTE A suitable system is provided for detecting and recording the force applied and the elongation.

3.5 clamp

that part of a tensile testing machine used to grip the specimen by means of suitable jaws

3.6 jaws
those elements of a clamp which grip the specimen

3.7 gauge length nominal length distance between the clamping points of the tester

NOTE With bollard or capstan clamps, it is the distance between their gripping points, measured along the path of the yarn.

3.8 initial length

length of a test specimen (between the clamping points) under specified pretension at the beginning of the test

3.9

package length of yarn in a form suitable for use, handling, storing, etc.

NOTE Packages can be supported (e.g. cones, bobbins) or unsupported (e.g. skeins, balls).

4 Principle

A specimen of yarn is extended until rupture by a suitable mechanical device, and the breaking force and elongation at break are recorded. A constant rate of extension of 100 % per minute (based on the gauge length) is used, but higher or lower rates are permitted by agreement. Two gauge lengths are permitted: usually 500 mm (with a rate of extension of 500 mm/min), and exceptionally 250 mm (with a rate of extension of 250 mm/min).

5 Apparatus and reagents

5.1 Constant rate of specimen extension (CRE) tester, which complies with the following requirements.

The tester shall be capable of being set at gauge lengths of 500 mm ± 2 mm or 250 mm ± 1 mm, or preferably both.

The constant rate of extension of the moving clamp shall be 500 mm/min ± 10 mm/min or 250 mm/min ± 5 mm/min, to an accuracy of ± 2 %, with lower or, for automatic testers, higher rates being permitted by agreement.

The maximum error of the indicated force shall not exceed 2 % of the true force.

The tester may be of the manual or automatic type.

The clamps for gripping the specimens shall prevent slipping or cutting of the specimens and breaks at the jaws. Flat-faced unlined jaws shall be the normal type but, if these cannot prevent slippage, then other types of clamps may be used on agreement, such as lined jaws, bollard clamps or other types of snubbing devices. As the type of clamp may influence the reading of the elongation, all interested parties shall use the same type.

The tester shall be equipped with an autographic force/elongation recording device of sufficiently fast response, or with a system directly recording the breaking force and elongation at break.

The tester shall be capable of setting a pretension either by means of a set of pretensioning weights or by using the force-measuring device.

5.2 Reel, for preparing test skeins from the laboratory sample (for methods C and D).

5.3 Swift or **similar device**, for holding the test skein under zero tension and permitting easy transfer of the yarn to the tensile tester (for Method C).

5.4 Receptacles, for immersing the sample or the specimens in water (for Method D).

5.5 Tap water, at room temperature (for Method D).

5.6 Non-ionic surfactant, 0,1 % (volumetric) aqueous solution (for Method D).

6 Sampling

6.1 Samples shall be taken in accordance with

the directions given in the material specification when available, or

the procedures described in 6.2 to 6.7.

A bulk sample shall be taken of one or more cases, as representative of the lot to be tested as shown in Table 1.

Table 1 — Sampling frequency

Number of cases	Number of cases selected at random
3 or less	1
4 to 10	2
11 to 30	3
31 to 75	4
76 or more	5

If only mean values are required, then 10 packages shall be taken from the bulk sample, distributed as evenly as possible among the cases and among the levels in each case.

Except for the provisions of 6.5, the minimum number of specimens to be tested shall be 50 for single-spun yarns and 20 for other yarns. The specimens shall be distributed as evenly as possible among the 10 packages.

If the variability of the test is known and only mean values are required, then the number of specimens shall be calculated as 0,17 CV^2, where CV is the coefficient of variation of the individual breaks (expressed as a percentage) obtained from experience on similar material.

NOTE This number of specimens will give a precision (1,96 times the standard error of the mean) of ± 4 % at a probability level of 90 %.

Strength testing is a “one-tail” test; that is “yarn shall not be weaker than...” but “may be stronger than...”. When specifying 90 % probability, one tail of the distribution is 5 %, or exactly the same as the two tails together or the more common 95 % probability appropriate for a “two-tail” test.

If the coefficient of variation is to be determined in addition to the mean, then 20 packages shall be taken from the bulk sample and at least 200 specimens shall be tested for single-spun yarns and at least 100 specimens for all other types of yarn.

If specimens are to be extracted from fabrics [not suitable for automatic testers (Method B)], then the fabric sample shall be large enough to furnish a sufficient number and length of specimens. The test specimens shall be taken so that the twist in the yarn is not changed during sampling. In woven fabrics, warp specimens shall be taken from different ends and weft specimens shall be taken at random from several sections of the sample to be as representative of the yarn as possible. In knitted fabrics, specimens shall represent as many different yarns as possible.

7 Preconditioning and conditioning

7.1 The atmospheres for preconditioning, conditioning and testing shall be as specified in ISO 139.

7.2 For methods A to C, the sample packages or test skeins shall be preconditioned for a minimum of 4 h.

NOTE Preconditioning can often be dispensed with if the samples are conditioned directly “from the dry side”.

7.3 After preconditioning, the sample shall be brought to moisture equilibrium under the conditioning atmosphere. For skeins, overnight conditioning is usually sufficient, but for tightly wound packages a minimum of 48 h is necessary.

7.4 Preconditioning and conditioning are not required for wet tests (Method D).

8 Procedure

8.1 General

8.1.1 If more than one condition of testing is permitted, usually by agreement, then all parties interested in the test results shall perform the test under the same conditions (i.e. gauge length, rate of extension, type of clamp, temperature, pretension).

8.1.2 Two gauge lengths are permitted: the usual length of 500 mm, and a length of 250 mm which can be used only if

the extension of the instrument is insufficient to accommodate a 500 mm specimen, or

by agreement between the interested parties.

8.1.3 If a calculation of breaking tenacity is required, determine the linear density of the yarn in accordance with ISO 2060.

8.1.4 Use a rate of extension of 500 mm/min or 250 mm/min at the gauge length of 500 mm or 250 mm. In addition, for automatic testers only (Method B), higher rates are permitted by agreement; 2 000 mm/min and 5 000 mm/min are recommended. Lower extension rates may be used on agreement; e.g. 50 %/min or 20 %/min.

8.1.5 Unwind the yarn from the package as is done in normal use.

8.1.6 Before clamping the specimen, check that the jaws are correctly aligned and parallel, so that the force applied produces no angular deviation.

8.1.7 Insert the specimen in the clamps with a pretension of 0,5 cN/tex ± 0,1 cN/tex for conditioned specimens, or 0,25 cN/tex ± 0,05 cN/tex for wet specimens. If the specimen is inserted under unknown tension, the tester must be able to determine its initial length (under specified pretension).

For untwisted technical and industrial multifilament yarns, to ensure that all filaments have the same tension at the beginning of the test and to prevent slippage of individual filaments in the clamps during the test, a twist should be applied prior to the test. A twist of 60 ± 1 turns/m for yarns below 2 200 dtex and a twist of 30 ± 1 turns/m for yarns above 2 200 dtex are recommended. Other twist amounts may be allowed on agreement of the interested parties.

8.1.8 For textured yarns, use a pretension which will remove the crimp but not stretch the yarn. The following pretensions are recommended (unless otherwise agreed), calculated on the nominal linear density of the yarn:

—2,0 cN/tex ± 0,2 cN/tex, for polyester and polyamide yarns;

—1,0 cN/tex ± 0,1 cN/tex, for acetate, triacetate and viscose yarns;

—0,5 cN/tex ± 0,05 cN/tex, for bi-shrinkage and jet-bulked yarns, except for carpet yarns heavier than 50 tex.

8.1.9 Finally, secure the specimen in the clamps.

8.1.10 Perform the test under the standard atmosphere for testing, as specified in 7.1.

8.1.11 During the test, check that the specimen does not slip between the jaws by more than 2 mm. If it does so repeatedly, change the clamps or jaw lining. Discard the results of the tests where slippage occurs. Also discard results involving jaw breaks where breaks occur 5 mm from the jaws or closer, but record the number of specimens for which the results were discarded.

8.1.12 Record the breaking force and elongation at break (done automatically in Method B). For fancy yarns, record values for the first component that breaks. The values recorded for fancy yarns may be lower than those defined in 3.1 and 3.2.

8.1.13 With bollard or capstan clamps, measurement of the elongation is not accurate and is discouraged.

8.2 Method A — Manual

Take specimens directly from the conditioned packages. Follow the procedures given in 8.1.1 to 8.1.13. Insert the test specimens manually into the clamps to perform the tensile test.

8.3 Method B — Automatic

Take specimens directly from the conditioned packages. Follow the procedures given in 8.1.1 to 8.1.6 and 8.1.9 to 8.1.13. Set the instrument to take specimens from the 10 or 20 packages of the sample (see 6.3 and

6.6). The test will be performed automatically.

8.4 Method C — Manual for conditioned specimens

8.4.1 Using the reel (5.2), take one test skein from each package of the sample. The test skeins shall be of sufficient length to give the required number and length of test specimens.

8.4.2 Using the swift (5.3), allow the test skeins to relax under minimal tension in the preconditioning and conditioning atmospheres (see 7.1).

8.4.3 Follow the procedures given in 8.1.1 to 8.1.13. When taking a specimen from the test skein for insertion between the clamps, make sure that its length is at least 100 mm greater than the selected gauge length; an excess of 500 mm is recommended. Be careful not to change the twist.

NOTE With suitable modifications (see 6.7), this method can also be used for yarns from fabrics.

8.5 Method D — Manual for wet specimens

8.5.1 Take test skeins as described in 8.4.1.

8.5.2 Before removing the test skein from the reel, wrap two or three turns of a strong thread (e.g. sewing thread) tightly around the skein at two places about 2 cm apart and securely tie the ends of the thread. Cut the skein midway between the two places. Fill a receptacle (5.4) with tap water (5.5). Then lay the cut skein flat on the surface of the water and leave it until it sinks below the surface under its own weight.

8.5.3 If the skein will not sink in the water, then hold the yarn under the surface, e.g. by means of weights attached to the ends, until the yarn is thoroughly saturated (e.g. for 30 min). When the yarns are normally resistant to wetting, use a non-ionic wetting agent (5.6). Rinse out the wetting agent thoroughly with water before testing the yarn.

8.5.4 Remove the specimens individually from the water and test them within 60 s thereafter, following the procedures given in 8.1.1 to 8.1.13.

9 Test report

9.1 General information

The test report shall include the following information:

a reference to this International Standard (ISO 2062);

lot number or other identification of the sample;

type of package (cone, bobbin, etc.), its condition (dyed, bleached, etc.), and the manner in which the yarn was withdrawn from the package (over-end or from the side);

conditioning atmosphere and testing atmosphere used;

sampling scheme used, the number of specimens tested, and if applicable, the number of specimens discarded (see 8.1.11);

make and model of tester used;

test method used (A to D);

gauge length, rate of extension and pretension used;

NOTE If untwisted technical or industrial multifilament yarns are tested, report the twist amount and direction (“S” or “Z”) used.

type of clamp and jaws used;

date of the testing.

9.2 Test results

The following test results shall be given:

mean breaking force, in centinewtons (to two significant figures);

mean elongation at break, as a percentage (to two significant figures);

coefficient of variation of the breaking force, if required (to the nearest 0,1 %);

coefficient of variation of percent elongation at break, if required (to the nearest 0,1 %);

linear density of the yarn, if determined, in tex (to two significant figures);

breaking tenacity, if required, in centinewtons per tex (to the nearest 0,1 %).

Annex A

(informative)

Alternative methods using constant rate of travel (CRT) and constant rate of loading (CRL) testers
A.1 Scope
This annex describes seven methods: these methods are given for information only and can be used by agreement between the interested parties. They do not have an influence on the status of this International Standard.

—E: CRT testers, manual: specimens are taken directly from conditioned packages;

—F: CRT testers, manual: relaxed test skeins are used after conditioning;

—G: CRT testers, manual: relaxed test skeins are used after wetting;

—H: CRL testers, manual: specimens are taken directly from conditioned packages;

—J: CRL testers, automatic: specimens are taken directly from conditioned packages;

—K: CRL testers, manual: relaxed test skeins are used after conditioning; —L: CRL testers, manual: relaxed test skeins are used after wetting.
A.2 Procedure
A.2.1 General
Follow 8.1.2, 8.1.3, 8.1.5, 8.1.6, if possible 8.1.7, and also 8.1.8 to 8.1.13 and Clause 9.
A.2.2 Method E: CRT testers, manual
A.2.2.1 Use the pendulum tester which complies with the following requirement. After the first 2 s of the test, the average rate of travel for the pulling clamp in any 2 s interval shall not differ by more than 5 % from the average rate of travel over the whole period of the test.

Adjust the instrument so that the average time-to-break shall be 20 s ± 3 s. Also adjust the tester so that the recorded breaking force lies between 15 % and 85 % of the instrument's scale. **A.2.2.2** Follow the procedure given in Method A (8.2), omitting 8.1.4.
A.2.3 Method F: CRT testers, manual
Follow the procedure given in A.2.2.1 and then follow the procedure given in Method C (8.4), omitting 8.1.4. **A.2.4 Method G: CRT testers, manual**
Follow the procedure given in A.2.2.1 and then follow the procedure given in Method D (8.5), omitting 8.1.4.
A.2.5 Method H: CRL testers, manual
A.2.5.1 Use an inclined-plane tester complying with the following requirement. After the first 4 s of the test, the average rate of increase of force in any 2 s interval shall not differ by more than 25 % from the average rate of increase of force over the whole period of the test.

Adjust the instrument so that the average time-to-break shall be 20 s ± 3 s. Also adjust the tester so that the recorded breaking force lies between 15 % and 85 % of the instrument's scale. **A.2.5.2** Follow the procedure given in Method A (8.2), omitting 8.1.4.
A.2.6 Method J: CRL testers, automatic
Follow the procedure given in A.2.5.1 and then follow the procedure given in Method B (8.3), omitting 8.1.4. **A.2.7 Method K: CRL testers, manual**
Follow the procedure given in A.2.5.1 and then follow the procedure given in Method C (8.4), omitting 8.1.4.
A.2.8 Method L: CRL testers, manual
Follow the procedure given in A.2.5.1 and then follow the procedure given in Method D (8.5), omitting 8.1.4.

Bibliography

ISO 3341, *Textile glass — Yarns — Determination of breaking force and breaking elongation*
ISO 6939, *Textiles — Yarns from packages — Method of test for breaking strength of yarn by the skein method*

ICS 59.080.20

Price based on 10 pages

Appendix 9: Yarn Tensile Strength Test Results

Test of Yarn Traction with MesdanLab Strength Tester

According to the standard ISO 2062-EN ISO 2062 Traction On Yarns - Second Edition 1993-10-01/ Ref.Num. ISO 2062:1993(E)

Customer Code	MOLDAU	Test Code	MOLDAU Date	12-2-2020 Time	15:36:19

Sample Description				Sample Number	20
Parcel		Lot		Count	40,5 [tex]
Material					
Examiner					
Sample Length	500 [mm]	Load cell ID/FS [kg]	1 / 2	X 1	
Clamp Speed	500 [mm/min]	Pretension	20 [cN]		
Test Machine					

Observations Method:A /

Statistical Results of the Test

	Force [cN]		Elongation [%]		Tenacity [cN/tex]		Average Time of Breakage 9,5 [s]
Maximum	411,879	(19)	23,927	(19)	10,170	(19)	
Minimum	304,006	(10)	10,037	(10)	7,506	(10)	
Average	352,549		15,560		8,705		
Range	30,598	[%]	89,263	[%]	30,598	[%]	
CV	8,196	[%]	22,908	[%]	8,196	[%]	
Deviation	28,895		3,565		0,713		
IC95%	12,663		1,562		0,313		
IC99%	16,643		2,053		0,411		

Results of Single Samples

Sample #	Max Force [cN]	Max Elongation [%]	Time [s]	Tenacity [cN/tex]
1	324	10,59	6,4	7,991
2	353	15,42	9,4	8,717
3	343	19,85	12,0	8,475

4	363	17,80	10,8	8,959
5	392	14,33	8,7	9,686
6	353	18,22	11,2	8,717
7	373	17,20	10,5	9,201
8	382	18,62	11,4	9,443
9	333	15,23	9,3	8,233
10	304	10,04	6,1	7,506
11	333	14,25	8,7	8,233
12	343	17,82	10,9	8,475
13	373	16,27	9,9	9,201
14	373	11,78	7,2	9,201
15	324	13,65	8,4	7,991
16	324	13,03	8,0	7,991
17	324	13,57	8,3	7,991
18	333	10,60	6,4	8,233
19	412	23,93	14,6	10,170
20	392	19,01	11,6	9,686

Test of Yarn Traction with MesdanLab Strength Tester

According to the standard ISO 2062-EN ISO 2062 Traction On Yarns - Second Edition 1993-10-01/ Ref.Num. ISO 2062:1993(E)

Customer CodeBELLFLOWER	**Test Code**	**BELLFLOWER Date**		**12-2-2020 Time**	**16:22 :06**

Sample Description				**Sample Number**	**20**
Parcel		**Lot**		**Count**	**38,5 [tex]**
Material					
Examiner					
Sample Length	**500 [mm]**	**Load cell ID/FS [kg]**	**1 / 2**	**X 1**	
Clamp Speed	**500 [mm/min]**	**Pretension**	**19 [cN]**		
Test Machine					

Observations Method:A /

Statistical Results of the Test

	Force [cN]		Elongation [%]		Tenacity [cN/tex]		Average Time of Breakage 2,4 [s]
Maximum	323,619	(9)	4,457	(8)	8,406	(9)	
Minimum	254,973	(6)	3,261	(13)	6,623	(6)	
Average	288,316		4,034		7,489		
Range	23,810	[%]	29,659	[%]	23,810	[%]	
CV	6,658	[%]	8,168	[%]	6,658	[%]	
Deviation	19,196		0,329		0,499		
IC95%	8,413		0,144		0,219		
IC99%	11,056		0,190		0,287		

Results of Single Samples

Sample #	Max Force [cN]	Max Elongation [%]	Time [s]	Tenacity [cN/tex]
1	265	4,01	2,4	6,877
2	275	3,93	2,4	7,132
3	265	4,18	2,5	6,877
4	284	3,81	2,3	7,387
5	294	4,22	2,6	7,642
6	255	3,80	2,3	6,623
7	304	4,22	2,6	7,896

8	314	4,46	2,7	8,151
9	324	4,34	2,6	8,406
10	275	3,81	2,3	7,132
11	304	4,35	2,6	7,896
12	284	3,81	2,3	7,387
13	284	3,26	2,0	7,387
14	284	4,05	2,4	7,387
15	314	4,17	2,5	8,151
16	265	3,63	2,2	6,877
17	294	4,30	2,6	7,642
18	304	4,34	2,6	7,896
19	304	4,45	2,7	7,896
20	275	3,52	2,1	7,132

Appendix 10: Cover Factor Calculations

$Cf\ \% = (K^1 + K^2 – (K^1 * K^2\ \ 28.02) : K^{Max} * 100$
K = Cover Factor $(K^1 + K^2 – (K^1 * K^2 / 28.02)$ (K^1= Warp, K^2= Weft)
$K = E\sqrt{(T)} * 10\text{-}1$
E = Threads per cm
T = Yarn Tex
$K^{Max} = 28.02\sqrt{(\phi\rho f)}$
ϕ = Packing Factor (Staple Fiber Yarn = 0.6)
ρf = Fiber Density (Wool = 1.314)

K^{Total} = 100% for K^{Max}

$(28.02\sqrt{(\phi\rho f)})$ = 100%
$28.02\sqrt{(0.6 \times 1.314)}$ = 100%
$28.02\sqrt{(0.7884)}$ = 100%
28.02*0.888 = 100%
24.879 = 100%

K^{Total} 70% = d/p = 0.7

K^{Total} 70% = (K1 + K2 – (K1*K2/28.02)) / 24.879 * 100

K^{Total} 70% = $((E^{Warp}\sqrt{(T)} * 10\text{-}1) + (E^{Weft}\sqrt{(T)} * 10\text{-}1) – (((E^{Warp}\sqrt{(T)} * 10\text{-}1) * (E^{Weft}\sqrt{(T)} * 10\text{-}1)) / 28.02)) / 24.879 * 100$

For E^{Warp} = 20 and E^{Weft} = 15, K^{Total} = 69.98142667%

Appendix 11: Composition AATC 1993 Standard Reference Detergent WOB

Table 11-1: *Composition AATC 1993 Standard Reference Detergent WOB*

Composition	Mass fraction %
Linear alkylbenzene sulfonate sodium salt[a]	18
Sodium aluminosilicate solids	25
Sodium carbonate	18
Sodium silicate solids[b]	0,50
Sodium sulfate	22,13
Polyethylene glycol[c]	2,76
Sodium polyacrylate	3,50
Silicone, suds suppressor	0,04
Moisture	10
Miscellaneous (unreacted in surfactant stocks)	0,07
Total	**100**

[a] C11.8LAS, introduced as Stepan's Calsoft L-50-12.

[b] SiO_2/Na_2O = 1,6.

[c] 2 % introduced via base granulates and 0,76 % introduced via a suds suppressor admixture.

Note: Adapted from NEN-EN-ISO 105-C06:2010

Appendix 12: Washing Process Recipes

Sample A,E
40 degrees
Start: 21 degrees , 6 degrees/min, end at 40.
40 rpm
1:20 Liquor ratio
Total Weight of 2 samples and 12 threads: 3.528 gr
70 ml Soft Water
1,5 gr/l ECE-1 Dye Transfer Test Detergent (0.105 gr)
Sodium Carbonate for pH 8 (none used)
pH of water: 8.3
pH: 9.6

Rinsed two times under running cold tap water for 0.5 min and squeezed by hand

Sample B,F
40 degrees
Start: 21 degrees, 6 degrees/min, end at 40.
40 rpm
1:20 Liquor ratio
Total Weight of 2 samples and 12 threads: 3.567 gr
70 ml Soft Water
1,5 gr/l Sodium dodecyl sulphate (0.105 gr)
pH of water: 8.3
pH: 8.2

Rinsed two times under running cold tap water for 0.5 min and squeezed by hand

Sample C,G
Start: 21 , 6 degrees/min, end at 40.
40 rpm
1:20 Liquor ratio
Total Weight of 2 samples and 12 threads: 3.631 gr
70 ml Soft Water
1,5 gr/l ECE-1 Dye Transfer Test Detergent (0.105 gr)
Sodium Carbonate for pH 8 (none used)
pH of water: 8.3
pH: 9.6

Rinsed two times under running cold tap water for 0.5 min and squeezed by hand

Sample D,H
60 degrees
Start: 21 , 6 degrees/min, end at 40.
40 rpm
1:20 Liquor ratio
Total Weight of 2 samples and 12 threads: 3.566 gr
70 ml Soft Water:
1,5 gr/l Sodium dodecyl sulphate (0.105 gr)
pH of water: 8.3
pH: 8.2

Rinsed two times under running cold tap water for 0.5 min and squeezed by hand

Appendix 13: Dyeing Process Recipes

Samples A-D
Total weight of 4 samples: 6.612
Liquor ratio: 1:50
330.6 ml
0.495 gr (1,5 g/l) sodium sulphate
0.099 gr (1.5%) Sera Gal W-UL
pH 4.98 (4,5-5,5) Acetic Acid
0.192 gr (2.9%) Supralan Blue GLW

Samples I (1,2)
45 minute dyeing process (2 samples)
Total weight of 2 samples: 3.3 gr
Liquor ratio: 1:50
165 ml
0.248 gr (1,5 g/l) sodium sulphate
0.05 gr (1.5%) Sera Gal W-UL
pH 4.85 (4,5-5,5) Acetic Acid
0.1 gr (2.9%) Supralan Blue GLW

Samples J (1,2)
30 minute dyeing process (2 samples)
Total weight of 2 samples: 3.3 gr
Liquor ratio: 1:50
165 ml
0.248 gr (1,5 g/l) sodium sulphate
0.05 gr (1.5%) Sera Gal W-UL
pH 4.84 (4,5-5,5) Acetic Acid
0.1 gr (2.9%) Supralan Blue GLW

45 minute dyeing process (80cm of fabric)
Total weight: 63.195 gr
Liquor ratio: 1:50
3160 ml
4.74 gr (1,5 g/l) sodium sulphate
0.95 gr (1.5%) Sera Gal W-UL
pH 5 (4,5-5,5) Acetic Acid
1.83 gr (2.9%) Supralan Blue GLW

Appendix 14: Visual Assessment Sample Assessment

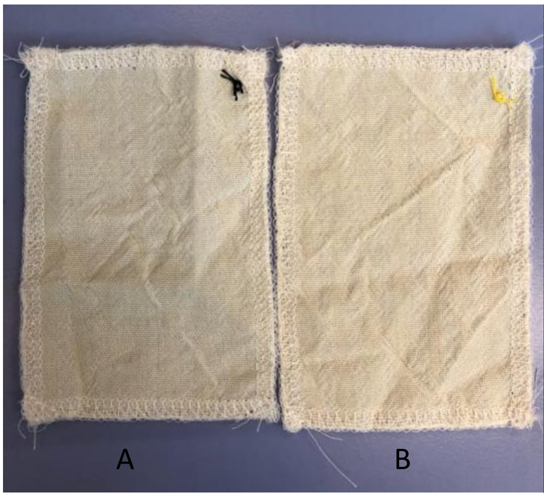

Figure 13-1: *Washed Samples A and B*

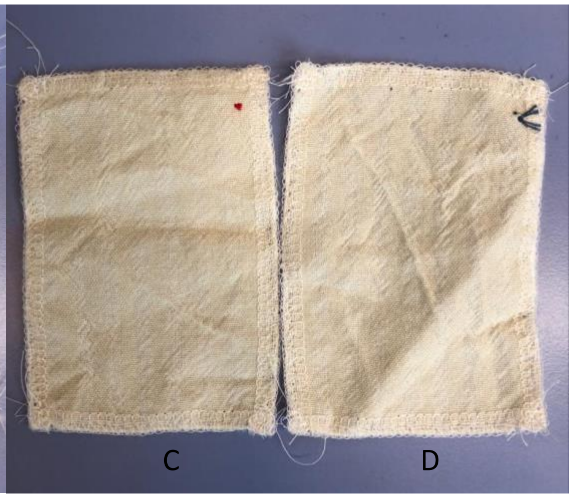

Figure 13-2: *Washed Sample C and D*

- Sample A

  This sample, washed at 40°C with the ECE-1 Dye Transfer Test Detergent shows a rougher surface compared to the fabric before treatment shown in CROSS REFERENCE. Slight puckering in warp direction on the plasma-treated stripes can also be seen. No visual color difference appeared after washing.

- Sample B

  This sample, washed at 40°C with sodium dodecyl sulphate shows a rougher surface compared to the fabric before treatment shown in CROSS REFERENCE. Slight puckering in warp direction on the plasma-treated stripes can also be seen. No visual color difference appeared after washing.

- Sample C

  This sample, washed at 60°C with the ECE-1 Dye Transfer Test Detergent shows a rougher surface compared to the fabric before treatment shown in CROSS REFERENCE. Slight puckering in warp direction on the plasma-treated stripes can also be seen. No visual color difference appeared after washing.

- Sample D

  This sample, washed at 60°C with sodium dodecyl sulphate shows a rougher surface compared to the fabric before treatment shown in CROSS REFERENCE. Slight puckering in warp direction on the plasma-treated stripes can also be seen. No visual color difference appeared after washing.

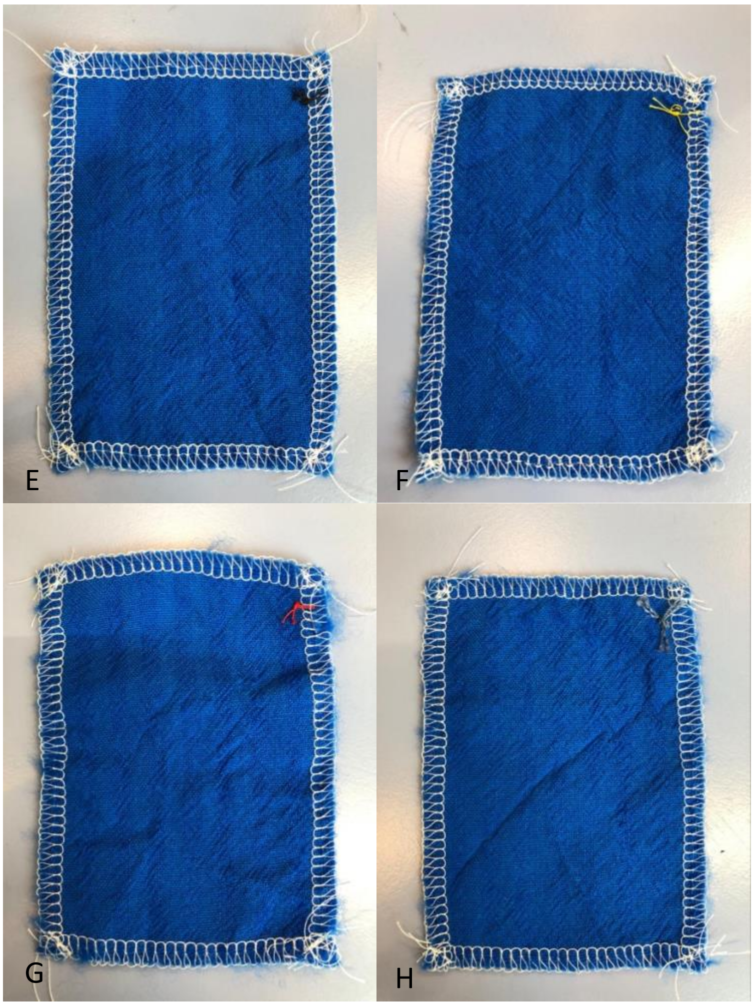

Figure 13-3: *Washed and Dyed Samples E, F, G, H*

- Sample E

  This sample, washed at 40°C with the ECE-1 Dye Transfer Test Detergent and dyed for 60 minutes shows a blue color with a slight difference in color depth between the plasma-treated and regular wool stripes. The plasma-treated wool shows a deeper color. Slight puckering is visible.

- Sample F

  This sample, washed at 40°C with sodium dodecyl sulphate and dyed for 60 minutes shows a blue color with a slight difference in color depth between the plasma-treated and regular wool stripes. The plasma-treated wool shows a deeper color. Slight puckering is visible.

- Sample G

  This sample, washed at 60°C with the ECE-1 Dye Transfer Test Detergent and dyed for 60 minutes shows a blue color with a slight difference in color depth between the plasma-treated and regular wool stripes. The plasma-treated wool shows a deeper color. Slight puckering is visible.

- Sample H

  This sample, washed at 60°C with sodium dodecyl sulphate and dyed for 60 minutes shows a blue color with a slight difference in color depth between the plasma-treated and regular wool stripes. The plasma-treated wool shows a deeper color. Slight puckering is visible.

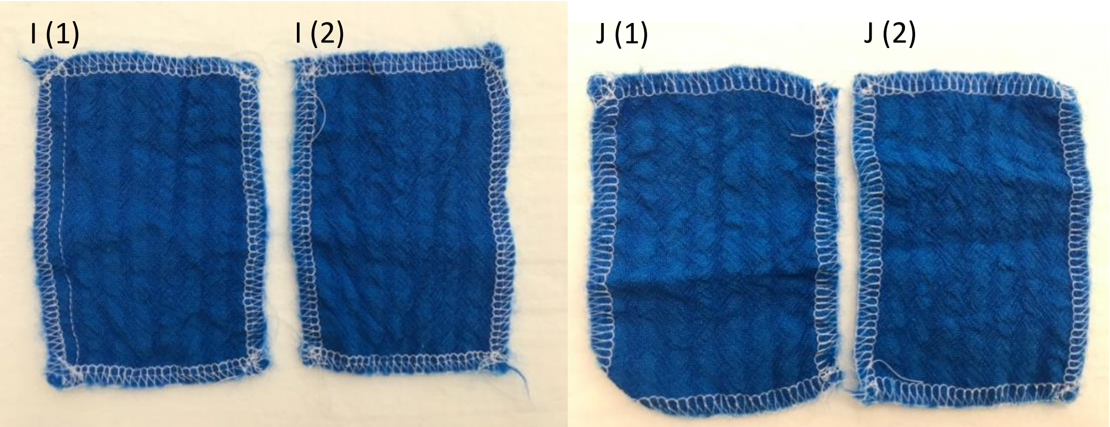

Figure 13-4: *Washed and Dyed Samples I (1), I (2), J (1), J (2)*

- Sample I (1,2)

  These samples, washed at 40°C with the ECE-1 Dye Transfer Test Detergent and dyed for 45 minutes show a blue color with a clearly visible difference in color depth creating a contrast between the plasma-treated and regular wool stripes. The plasma-treated wool stripes show a deeper color. Puckering is present in warp direction on the regular wool stripes. The non-puckering stripe remains relatively flat.

- Sample J (1,2)

  These samples, washed at 40°C with the ECE-1 Dye Transfer Test Detergent and dyed for 30 minutes show a blue color with a clearly visible difference in color depth resulting in a good contrast between the plasma-treated and regular wool stripes. The plasma-treated wool stripes show a deeper color. Heavy puckering is present in warp and weft direction on both the plasma-treated and regular wool stripes. The regular wool stripes are showing more puckering than the plasma-treated wool stripes.

Appendix 15: Breaking Strength of Fabric Test Results

Test of Fabric Traction with MesdanLab Strength Tester

According to the standard ISO 13934/1-EN ISO13934/1 Fabric traction Strip Meth. -First Edition 1999-02-15/ Ref.Num. ISO 13934-1:1999(E)

Customer Code **423574** Test Code **FABRICTENSILE** Date **28-2-2020** Time **16:02:21**

Sample Description		Sample Number	**6**
Parcel		Lot	
Material			
Examiner			
Sample Length	**200** [mm]	Load cell ID/FS [kg]	**6 / 1000 X 1**
Clamp Speed	**100** [mm/min]	Pretension	**2** [N]
Test Machine			

Observations *Method:Dry sample /*

Statistical Results of the Test

	Weft		**Warp**	
	Average Time of Breakage 23,4 [s]		Average Time of Breakage 36,0 [s]	
	Force [N]	Elongation [%]	Force [N]	Elongation [%]
Maximum	273,02 (3)	19,925 (3)	362,16 (4)	29,972 (6)
Minimum	219,77 (1)	16,837 (1)	335,98 (5)	26,549 (5)
Average	252.39	18.241	350.52	27.952
Range	21,098 [%]	16,925 [%]	7,470 [%]	12,247 [%]
CV	11,324 [%]	8,566 [%]	3,803 [%]	6.414 [%]
Deviation	28.58	1,563	13,33	1,793
IC95%	32,34	1,768	15,09	2,029
IC99%	42,50	2,324	19,83	2,666

Results of Single Samples

Sample #		MaxForce [N]	MaxElongation [%]	Time [s]
1	Weft	219,77	16,84	21,7
2	Weft	264,39	17,96	23,0
3	Weft	273,02	19,92	25,4
4	Warp	362,16	27,34	35,5
5	Warp	335,98	26,55	34,2
6	Warp	353,43	29,97	38,3

Appendix 16: Weaving Specifications

The weaving was done on a CCI Evergreen jacquard sampling loom. 6 harnesses were used, 4 for the actual fabric and two for the selvedge. The plain weave was done on 4 harnesses to ensure proper weight distribution. The weave was made by lifting cams 1,3 and 5 and subsequently lifting cams 2,4 and 5. The warp tension was 10kg and the weaving speed was 15 picks per minute.

The maximum fabric width possible on the CCI Evergreen weaving machine is 500mm or 50cm. The determined warp density is 20 per cm. Therefore, 1000 warp yarns should be used. However, due to the limited number of reeds available, the choice was made to use a 560mm wide reed with 543 dents. Due to the fabric width limitation of 500mm, only 493 dents were used. To facilitate an amount of yarns as close to 1000 as possible, each dent was given two yarns, resulting in a total of 986 yarns on 500mm width. Therefore the actual warp density is 19.36 per cm.

Due to the possibility for the weaving machine to do any number of weft yarns per cm, the amount of weft yarns per cm was set to 15. The weft yarn that was used is the Moldau yarn.

Appendix 17: Pictures of Abrasion Resistance Test Samples

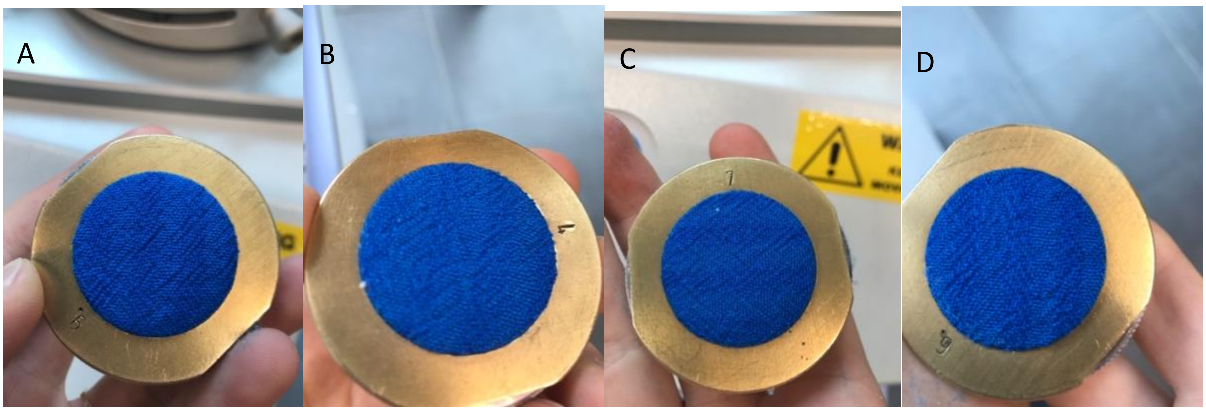

Figure 18-1: Samples A-D after 6000 rubs

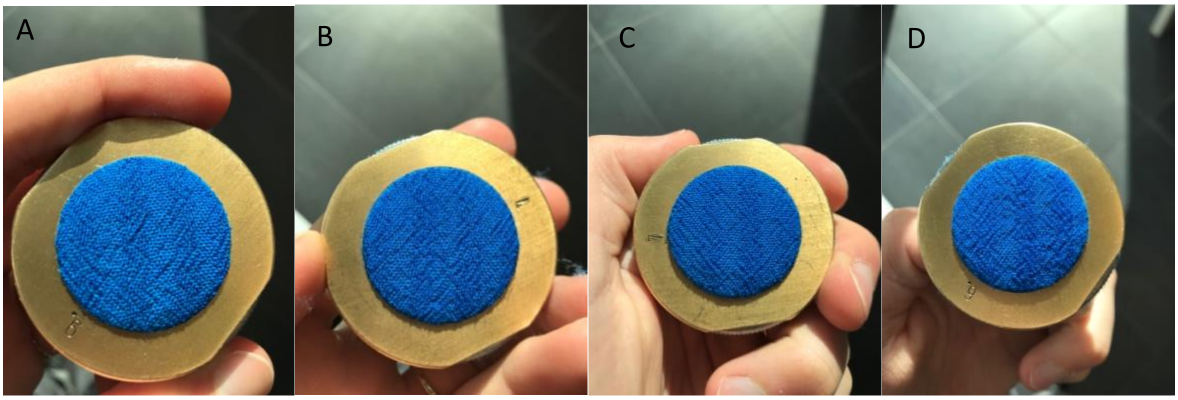

Figure 18-2: Samples A-D after 11000 rubs

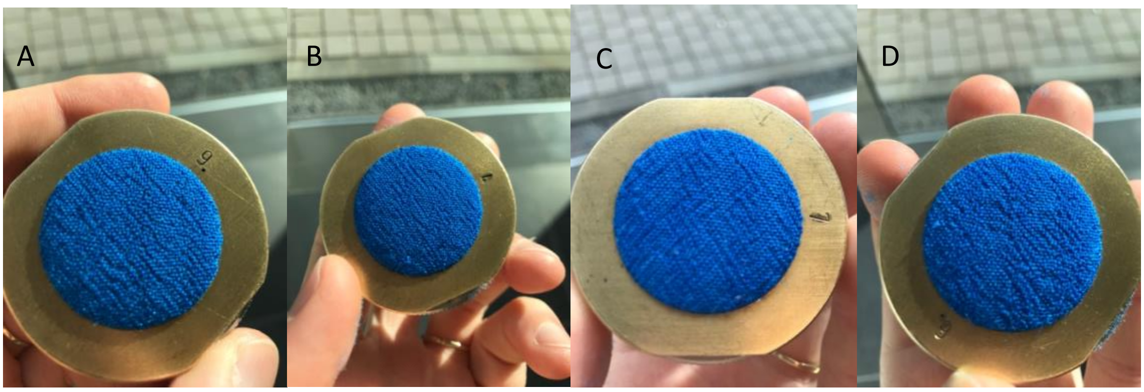

Figure 18-3: Samples A-D after 160000 rubs