A STUDY OF AIR PERMEABILITY INFLUENCES ON PATTERN CUTTING

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Abstract: *This paper is presenting part of the research for "Redefining Men's Shirt Pattern by means of Thermal Insulation, Water Vapor Permeability, Air Permeability and Body Movement". In this part, the research studies the effects of air permeability on four important parameters for clothing comfort and pattern cutting. The four parameters are the grain lines, aging fabric, wash and dry cycle of fabric and moisture content of the fabric. Results will be analyzed and be collected as one of the factors to create an ideal pattern for a men's shirt.*

Keywords: *air permeability, pattern cutting, grain lines, aging fabric, moisture.*

1 INTRODUCTION

Men's shirt is one of the important garment production in the industry. In 2018, the top men's shirt production country, the United State had produced 1034.51 million of pieces of shirts for men and boys, over US$ 23205.6 million in revenue [1]. This popular item which has been developed over a hundred of years ago [2, 3] by directly draping fabric onto the customer's body to obtain the clothing pattern [4, 5]. Later on, pattern drafting technique was developed and became the standard of pattern cutting [6, 7]. Until nowadays, even the shirt patterns have been changed for so many times according to the fashion trends; however, the basic pattern pieces and shapes are remaining very similar. Collar, collar stand, bodice front, bodice back, yoke, sleeve and cuff pieces are the basic elements to make up a shirt [8]. With the rapid and innovative invention in textile and fabric [9], developers and manufacturers need more than just a regular pattern shapes to satisfy and compatible with their high-end products. A new set of pattern that is not just offering the wearing comfort but is also concerning the breathability rate, movement comfort, thermal insulation and perspiration rate of the clothing that the traditional pattern may not offer.

In fact, a lot of articles had been published that were related to pattern improvement, breathability and wearing comfort. For examples, Hes researched on moisture absorptivity rate, water vapor permeability rate and the composition of woven shirt fabric and its influences on body cooling effect [10-12]; some articles tried to predict the air permeability rate related to woven fabric's mechanical properties [13, 14]. Musilova, Jang and Xu et al. were using computer software and men's body measurements to predict and to perfect men's shirt pattern and wearing ease [15-17]. However; all these researches are still based on the traditional pattern shapes and forms, not a new invention for the future needs and purposes.

This paper is part of a series of research to redefining men's shirt pattern through four major parameters which are thermal insulation, water vapor permeability, air permeability and mobility. The goal of this paper is to find out how air permeability related to men's shirt pattern. Air permeability or breathability was tested through grainlines, aged sample, wash/dry cycle and moisture content of the sample. Results were analyzed and would be combined with the other three parameters' results in order to create a better pattern shapes for men's shirt for the future usages.

2 EXPERIMENTAL PART

2.1 Materials

Three popular woven materials were chosen for the experiment which were:

1) 100% cotton, 139 g/m^2, thickness 0.43 mm, warp 26/cm, weft 24/cm;
2) 50% cotton/50% polyester blended, 153 g/m^2, thickness 0.44 mm, warp 26/cm, weft 24/cm;
3) 98% cotton/2% elastan blended, 110 g/m^2, thickness 0.27 mm, warp 42/cm, weft 34/cm.

Samples of 25x25 cm were cut from the materials for the grainline test, wash/dry cycle test, and moisture content test. Samples for the aged sample test were cut bigger; 31x31 cm for storage and easier to be found. All samples were basket weave and had been pre-washed, pre-shrunk and ironed flat to clean out the finishing before experiments.

2.2 Methods

Three materials were prepared for the experiment. Each material went through four groups of tests. They were:

Group 1 - grainlines test, this test served two purposes: a) to show the air permeability influences on the straight grain, cross grain and bias; b) to act as a reference/standard for other tests.

Group 2 - aged sample test, to find out any different from the grainlines test after materials were put in an open environment for a period of 6 months.

Group 3 - wash/dry cycle test, to find out any different from grainlines test after materials were gone through 3 times of washing, hang drying and iron flat cycle.

Group 4 - moisture content test, to stimulate samples when soaked with sweat and to find out the air permeability influences.

Samples from each material were tested three times by these four groups to get the mean value.

Fabric Breathability Test Machine was used for group 1, 2 and 3 tests. According to the standard of CSN EN ISO 9237, the air pressure was maintained at 100 Pa, testing head ring diameter was 50.5 mm and the tested surface area was 20 cm^2. For group 4, FX 3300 Air Permeability Tester III was used and the air pressure was set to 100 Pa for apparel materials. Results were analyzed in the conclusion.

3 RESULTS AND DISCUSSION

3.1 Group 1 - grainlines test

Samples were marked with direction arrow on the straight grain (weft) in back, cross grain (warp) in blue and bias (diagonal) in red (Figure 1). Test spots were randomly chosen and marked in a circle with 50.5 mm in diameter. Each spot went through 3 tests: straight grain, cross grain and bias. Only successfully test spots were numbered 1, 2 and 3. Some test spots were given unstable reading due to uneven weaving pattern (Appendix 1).

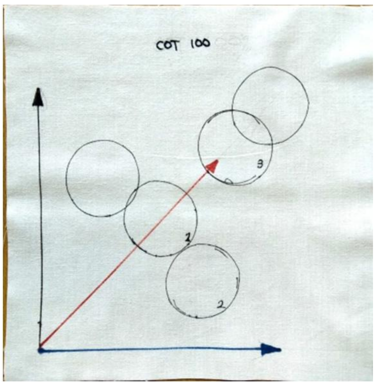

Figure 1 Sample of 100% cotton marked with grainline directions and the three successful circle tests

3.1.1 Grainline test result

Results in unit liter per minute (L/min) were converted into standard unit (mm/s) by the following formula:

$$R = qv/A*167 \quad (1)$$

where *qv* is the result in L/min from the Fabric Breathability Test Machine; *A* is the tested surface area 20 cm^2, 167 is a constant and the resulting unit is in standard mm/s.

Results are shown in Table 1 and Figure 2.

Table 1 Results of three materials from grainlines tests

Unit in mm/s	100% cotton	50% cotton 50% polyester	98% cotton 2% elastan
Straight grain*	256	245	346
Cross grain*	259	246	346
Bias*	257	244	346
Mean	257	245	346
SD	1.23	1.21	0.02

*arithmetic mean

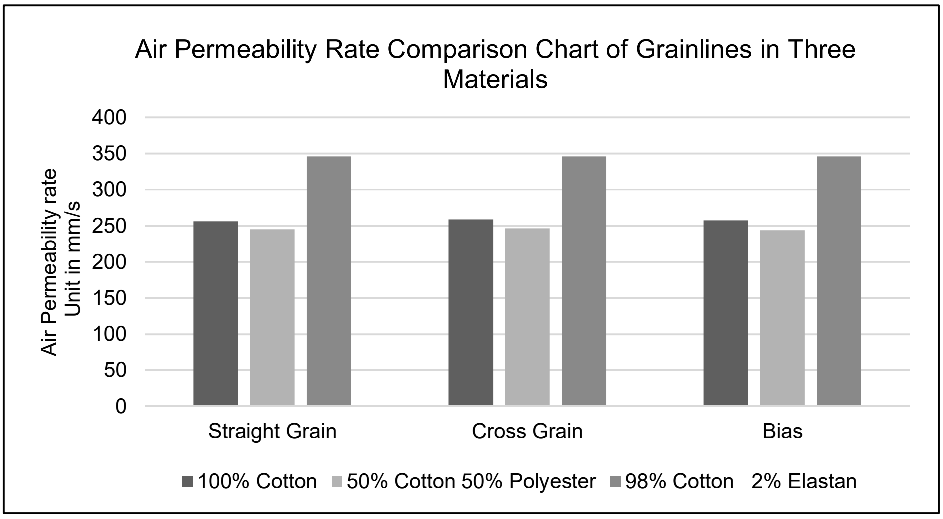

Figure 2 Comparison chart between three materials for the air permeability rate of grainlines

The results from Table 1 show that the air permeability rate from three samples of each material is highly similar through straight, cross and bias grainlines. Especially cotton/elastan blended, the results are identical. When comparing results between materials, cotton/elastan blended also has the highest air permeability rate; and the second is 100% cotton.

3.2 Group 2 - aged sample test

Three 31x31 cm samples were cut from each material, then put aside in the open area in the laboratory with no restrictions on any condition for 6 months, from 09/2017 to 02/2018. Weather, wind speed, humidity, heat and other unexpected conditions were changing every moment. After that, two spots were chosen randomly from each sample of the same material. Total six results were recorded from one material (Table 2, Figure 3).

Table 2 Air permeability rate results from aged sample test

Unit in mm/s	100% cotton	50% cotton 50% polyester	98% cotton 2% elastan
Mean	326	272	433
SD	59.81	16.03	89.15

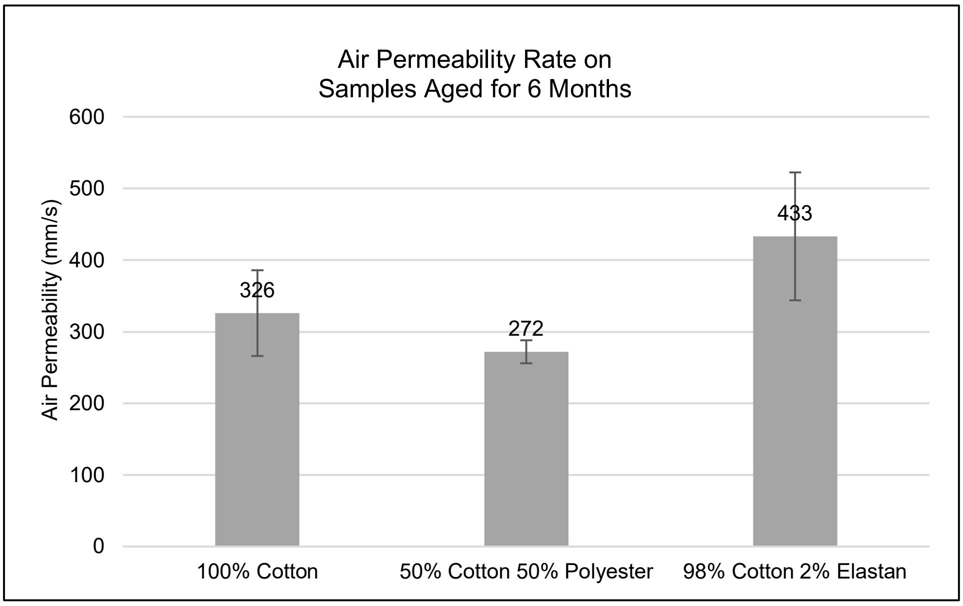

Figure 3 Aged sample test results

3.2.1 Aged sample test result

When comparing the mean values of the aged sample test results (Table 2) to the grainlines test results (Table 1); the air permeability rate increases in all three materials. This may cause by the expansion of the pores (spaces between wefts and warps) in the fabric due to being exposed in the open environment; temperature and humidity constantly changing all the time. Under natural heat expands, cold contracts conditions, it may affect the samples' mechanical structure. When looking at the enlarged pictures by Navitar micro camera Zoom 12X (Appendix 1, Figures a-i) and comparing the center reference sample column to the aged sample column on the right, pores are slightly bigger and less blocked pores than the reference column and the wash/dry cycle sample column.

3.3 Group 3 - wash/dry cycle test

Three 25x25 cm samples were cut from each material. Nine samples were in total. Each sample was tested twice and the mean value was recorded. Before tests, all samples went through 3 times of washing and drying cycle. Each cycle included one wash, one dry and one ironed flat. Washing condition was 40±°C in gentle cycle with mild detergent and tumble dry. Drying condition was hanging to dry naturally then ironed flat. Results are in Table 3 and Figure 4.

Table 3 Air permeability rate results from wash/dry cycle test

Unit in mm/s	100% cotton	50% cotton 50% polyester	98% cotton 2% elastan
Mean	275	249	464
SD	15.23	5.74	24.31

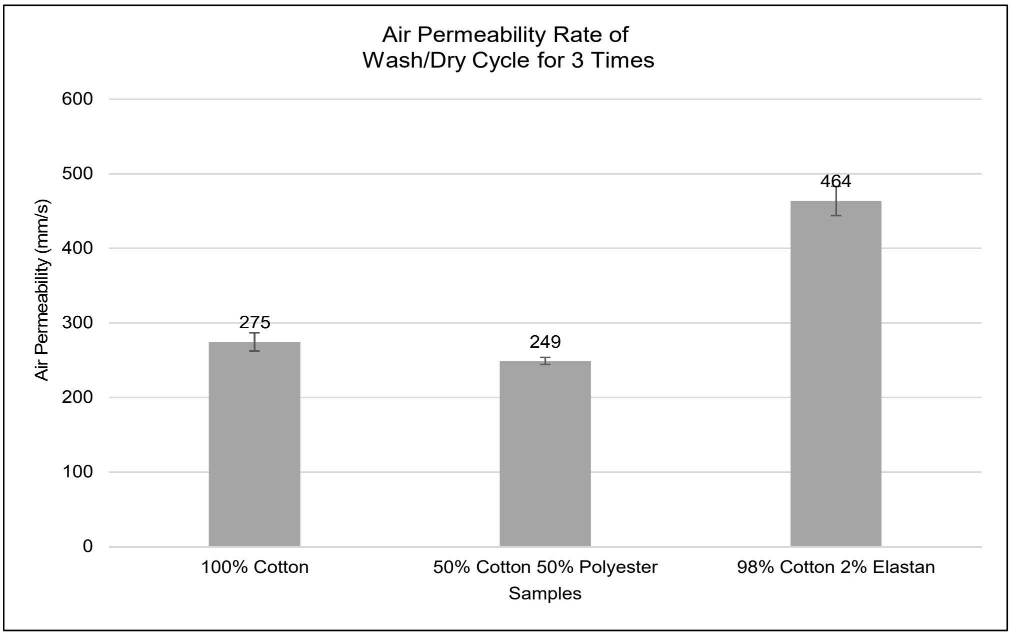

Figure 4 Wash/dry cycle test results

3.3.1 Wash/dry cycle test result

Comparing the results to grainlines test results in Table 1, a slight increase in all three materials. When comparing the results from the grainlines test (Table 1), aged sample test (Table 2) and wash/dry cycle test, (Table 3) altogether, it shows that the air permeability rate continues to rise up through wash/dry process and time (Table 4, Figure 5).

Table 4 Comparing results from grainlines, wash/dry cycle and aged samples of three materials

Unit in mm/s	100% cotton	50% cotton 50% polyester	98% cotton 2% elastan
Grainlines	257	245	346
Wash/Dry	275	249	464
Aged	326	272	433

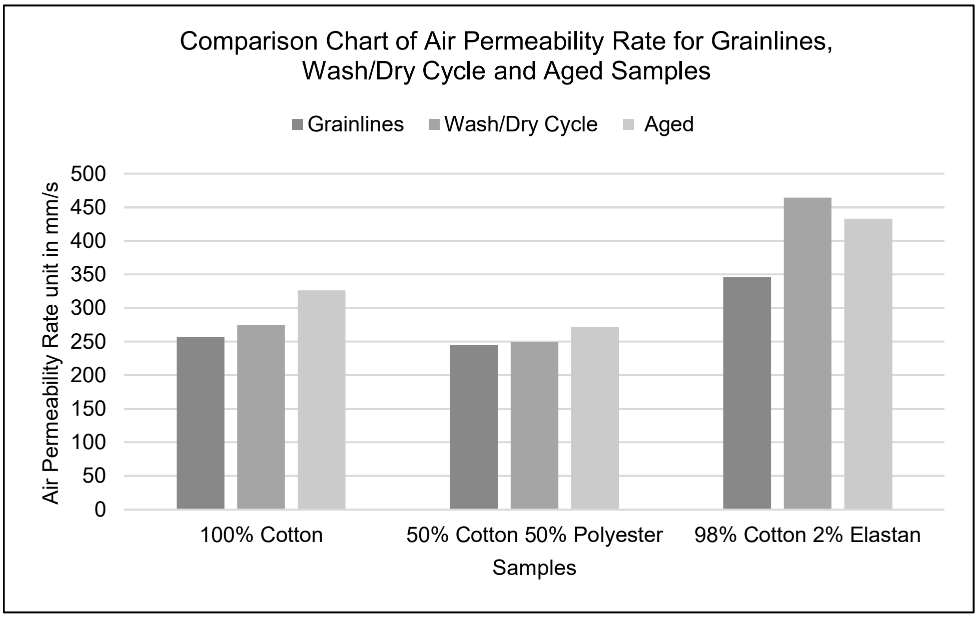

Figure 5 Comparison chart of air permeability rate of grainlines, aged, wash/dry cycle samples from three materials

3.4 Group 4 - moisture content test

FX 3300 Air Permeability Tester III was used for this group. The test area was a circle with a 20 cm^2 testing surface, EN ISO 9237 standard for apparel fabrics test was applied and the air pressure was set to 100 Pa. One 25x25 cm sample was cut from each material. Three samples are in total. Each sample was tested according to the following procedures:

1. The dry mass of each sample was weighted.
2. Each sample was soaked in water (stimulation of sweat), then towel dried. Noted that it was difficult to maintain the same moisture content.
3. Wet mass of each sample was weighted.
4. Calculated the moisture content by the following equation:

$$\text{Moisture content [\%]} = \text{Wet mass - Dry mass/Dry mass*100} \tag{2}$$

5. Each wet sample was tested by following the order of directions in a pattern, a total of four patterns of directions from 1 to 4 (Figure 6). Each pattern contains nine testing directions. These four patterns were used to minimize error because the testing device continued to blowing air to the wet sample that would dry up the moisture content fast.
6. All three wet samples were tested by the same pattern of directions each time. After that, all three samples would go through from step 2 to step 5 until all four patterns of directions were done.

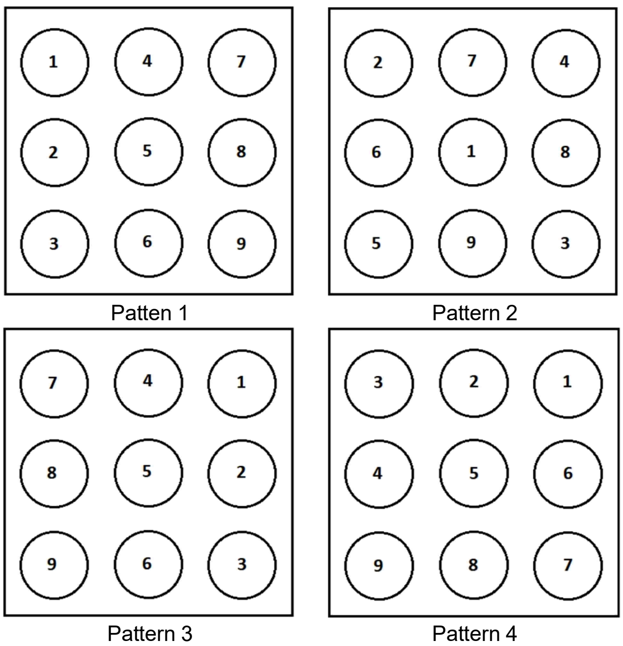

Figure 6 Four patterns of the order of directions were used to minimize error caused by the testing machine blowing out air drying the wet samples fast

3.4.1 *Moisture content test result*

From the results (Figure 7a-c) of three materials went through four patterns of directions, a similar trend has been noticed in all samples tests. The trend is when the moisture content is high, the air permeability is low and vice versa. This forms an inverted proportional relationship between air permeability and moisture content. Only in results from pattern 2 which took three to four seconds longer to finish the process than other patterns 1, 3 and 4; plus the directions on pattern 2 did not run in a continuous manner which affected the irregular drying time of the spots and caused error.

4 CONCLUSIONS

Air Permeability on grainlines (group 1)

Air permeability does not have any influence on straight grainline, cross grain nor bias grainline. Hence, it will not affect the clothing patterns that are being positioned on fabric for cutting. However, the grainlines still have a certain effect on wearing comfort; for example, bias cut clothing has more drapability than the cut on straight grainline or cross grainline even for woven fabrics because of better shearing and bending strength [18].

Air permeability on aged and wash/dry cycle (group 2 and 3)

When fabrics are exposed to the environment, being used, washed and dried for some time, air permeability tends to rise up. This influence may be caused by the wear off or damaged of the materials that the pores of the materials enlarged and become more porous. When comparing the columns of the wash/dry and aged to the column of grainlines in Figure 8a-i, it is clearly shown that pores in the wash/dry and aged samples that are more open and clearer; less blocked by the fibers itself.

Air permeability on moisture content (group 4)

Air permeability is inversely proportional to the moisture content of the fabric. When the moisture content is high, air permeability will be low. When the moisture content is low, the air permeability will become high. It is because when the moisture content is high, pores of the woven fabric are blocked by water, allowing less air to go through the fabric and vice versa.

Pattern cutting is influenced by grainlines for its drapability effect which will affect the air flow between the skin and the clothing. Aging clothing and wash/dry process will increase the air permeability rate; however, high moisture content or sweat will decrease air permeability. Overall, air permeability will not directly influence pattern cutting.

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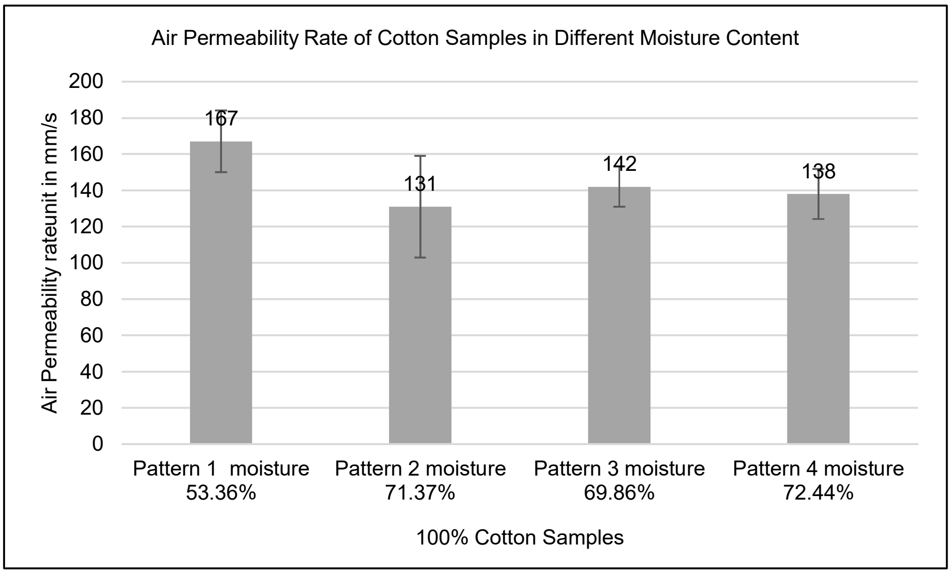
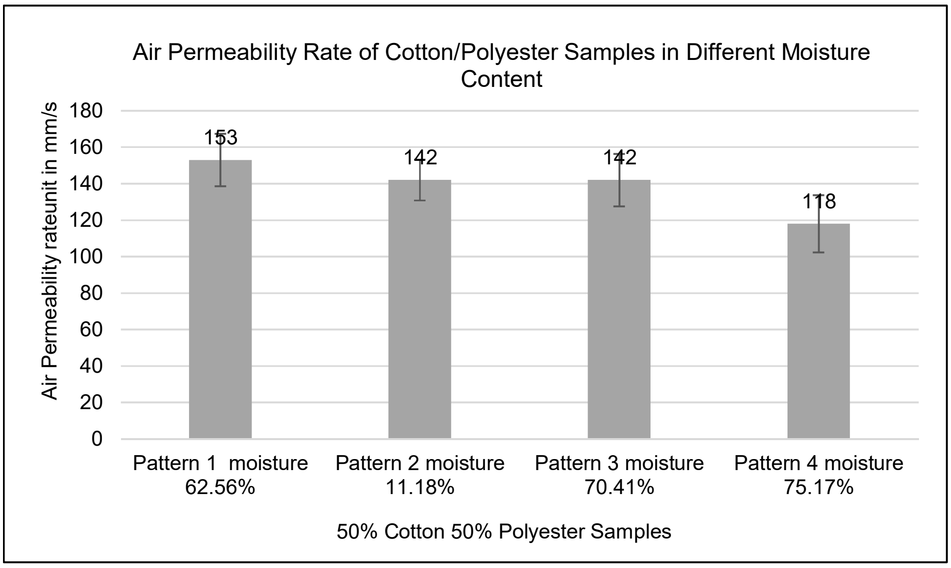
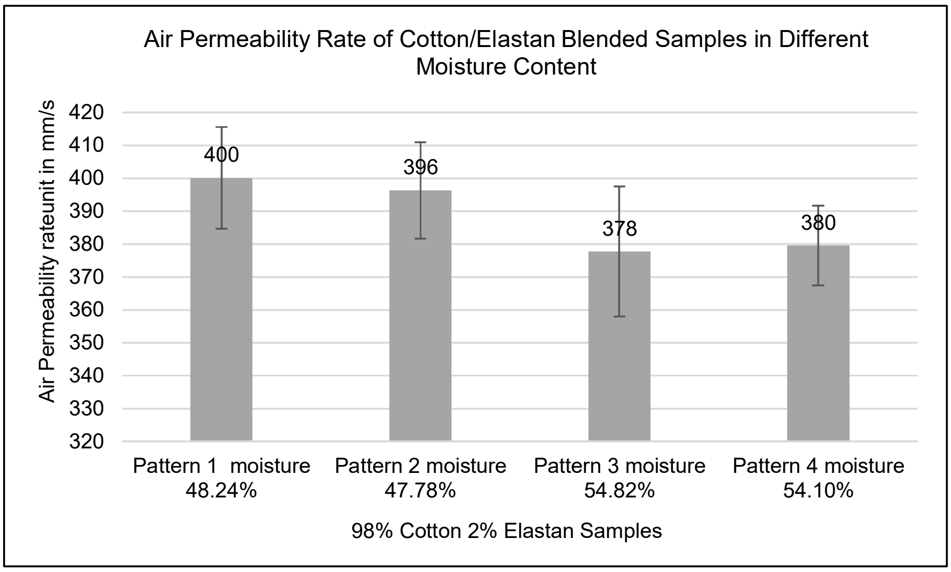


a) Results from 100% cotton samples with different moisture content



b) Results from 50% cotton 50% polyester samples with different moisture content



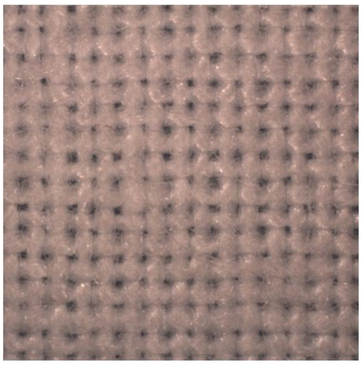
c) Results from 98% cotton 2% of elastan samples with different moisture content

Figure 7 Air permeability rate results from three materials with different moisture content

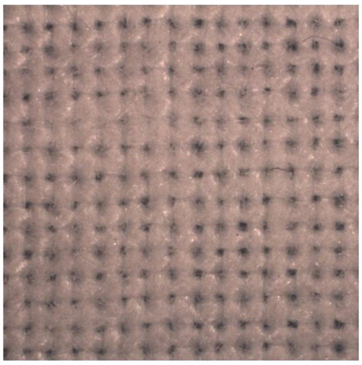
5 REFERENCES

1. "Shirts (men & boys)", Europe, Statista Market Forecast, Accessed: 27-Mar-2019, https://www.statista.com/outlook/90020500/102/shirts--men-boys-/europe
2. "Timeline of clothing and textiles technology", Wikipedia, Accessed: 16-Mar-2019, https://en.wikipedia.org/wiki/Timeline_of_clothing_and_textiles_technology
3. Cunnington C.W., Cunnington P.: The history of Underclothes, Dover Publications, 1992, 227 p., ISBN **10:** 0486271242, ISBN 13**:** 978-0486271248
4. Sterlacci F.: What is Draping? An Overview and History, University of Fashion Blog, Accessed: 25-Jul-2013, https://www.universityoffashion.com/blog/what-is-draping-an-overview-and-history/
5. "History of clothing and textiles", Wikipedia, Accessed: 17-Mar-2019, https://en.wikipedia.org/wiki/History_of_clothing_and_textiles
6. Collins H.: "Clothing pattern", 22-May-1951
7. Aldrich W.: Metric Pattern Cutting for Menswear, John Wiley & Sons, 2011, ISBN10: 1405182938, ISBN 13: 9781405182935
8. "Pinterest (Canada)", Pinterest, Accessed: 28-Mar-2019, https://www.pinterest.ca/pin/53198839320875696/
9. "Tale 2 - A History of Smart Fabric", LOOMIA, Accessed: 27-Apr-2016, https://medium.com/@LoomiaCo/tale-2-a-history-of-e-textiles-and-conductive-fabrics-dbe9c4a0cb03
10. Hes L.: An indirect method for fast evaluation of surface moisture absorptivity of shirt and underwear fabrics, Vlakna a textil (Fibres and Textiles) 7(2), 2000, pp. 178-185
11. Hes L.: Analysis and experimental determination of effective water vapor permeability of wet woven fabrics, Journal of Textile and Apparel, Technology and Management 8(4), 2014, pp. 1-8
12. Hes L.: Optimisation of shirt fabrics' composition from the point of view of their appearance and thermal comfort, International Journal of Clothing Science and Technology 11(2/3), 1999, pp. 105-119, https://doi.org/10.1108/09556229910276250
13. Zupin Z., Hladnik A., Dimitrovski K.: Prediction of one-layer woven fabrics air permeability using porosity parameters, Textile Research Journal 82(2), 2012, pp. 117-128, https://doi.org/10.1177/0040517511424529
14. Fatahi I., Yazdi A.A.: Assessment of the relationship between air permeability of woven fabrics and its mechanical properties, Fibres and Textiles in Eastern Europe 18(6) , 2010, pp. 68-71
15. Musilova B., Nemcokova R.: Study of Czech male body proportions and evaluation of men's shirt pattern making methods., Tekstil ve Konfeksiyon 24(4), 2014, pp. 399-404
16. Jang S.-E.: A study on sizing system and preferable ease in a men`s dress shirt for virtual mass customization system, Journal of the Korean Society of Clothing and Textiles 32(1), 2008, pp. 99-109, https://doi.org/10.5850/JKSCT.2008.32.2.294
17. Xu J., Zhang W., Xiao P.: A study on impact factors of the distance eases between body and garment, in 9th International Conference on Computer-Aided Industrial Design and Conceptual Design, Kunming, China, 22-25 Nov. 2008, pp. 201–205, DOI**:** 10.1109/CAIDCD.2008.4730551
18. Omeroglu S., Karaca E., Becerir B.: Comparison of bending, drapability and crease recovery behaviors of woven fabrics produced from polyester fibers having different cross-sectional shapes, Textile Research Journal 80(12), 2010, pp. 1180-1190, https://doi.org/10.1177/0040517509355351

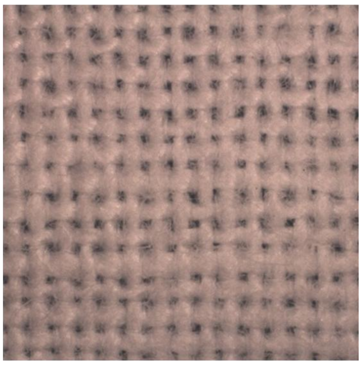
Appendix 1



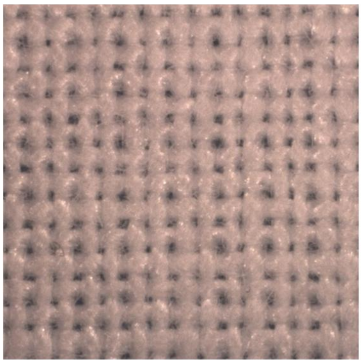
a) 100% cotton wash/dry 3 cycle



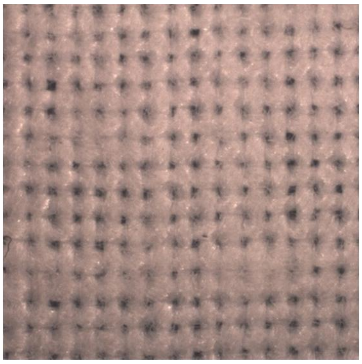
b) 100% cotton



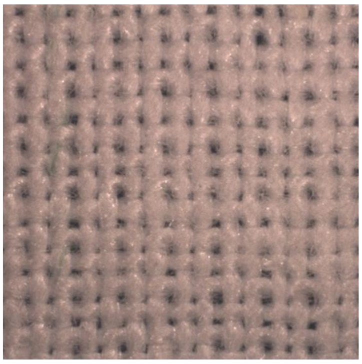
c) 100% cotton aged for 6 months



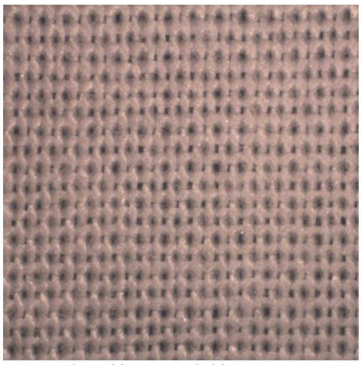
d) 50% cotton/50% polyester
wash/dry 3 cycle



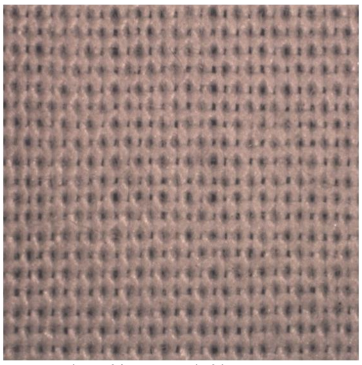
e) 50% cotton/50% polyester



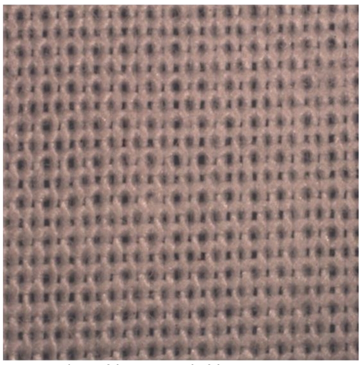
f) 50% cotton/50% polyester
aged for 6 months



g) 98% cotton/2% elastan
wash/dry 3 cycle



h) 98% cotton/2% elastan



i) 98% cotton/2% elastan
aged for 6 months

Figure 8 Left column are the samples which have been washed and dried for 3 cycles, middle column are the regulars for reference and the right column are samples that have been aged for 6 months. When compare the empty spaces (pores) between weft and warp threads, noticed that pores are getting bigger and wider in aged samples than the regulars. especially in cotton/elastan blend shows more spacing than the regular sample. The regular cotton sample has a lot of blocked spaces by its own fiber when it compares to the aged cotton samples. Photographs are taken by Navitar Micro Camera, zoom 12x