

Modelling the Behavior of Commercial and Test Textiles against Laundering Process by Statistical Assessment of Their Performance

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I. INTRODUCTION

Abstract—Various exterior factors have perpetual effects on textile materials during wear, use and laundering in everyday life. In accordance with their frequency of use, textile materials are required to be laundered at certain intervals. The medium in which the laundering process takes place have inevitable detrimental physical and chemical effects on textile materials caused by the unique parameters of the process inherently existing. Connatural structures of various textile materials result in many different physical, chemical and mechanical characteristics. Because of their specific structures, these materials have different behaviors against several exterior factors. By modeling the behavior of commercial and test textiles as group-wise against laundering process, it is possible to disclose the relation in between these two groups of materials, which will lead to better understanding of their behaviors in terms of similarities and differences against the washing parameters of the laundering. Thus, the goal of the current research is to examine the behavior of two groups of textile materials as commercial textiles and as test textiles towards the main washing machine parameters during laundering process such as temperature, load quantity, mechanical action and level of water amount by concentrating on shrinkage, pilling, sewing defects, collar abrasion, the other defects other than sewing, whitening and overall properties of textiles. In this study, cotton fabrics were preferred as commercial textiles due to the fact that garments made of cotton are the most demanded products in the market by the textile consumers in daily life. Full factorial experimental set-up was used to design the experimental procedure. All profiles always including all of the commercial and the test textiles were laundered for 20 cycles by commercial home laundering machine to investigate the effects of the chosen parameters. For the laundering process, a modified version of “IEC 60456 Test Method” was utilized. The amount of detergent was altered as 0.5% gram per liter depending on varying load quantity levels. Datacolor 650®, EMPA Photographic Standards for Pilling Test and visual examination were utilized to test and characterize the textiles. Furthermore, in the current study the relation in between commercial and test textiles in terms of their performance was deeply investigated by the help of statistical analysis performed by MINITAB® package program modeling their behavior against the parameters of the laundering process. In the experimental work, the behaviors of both groups of textiles towards washing machine parameters were visually and quantitatively assessed in dry state.

Keywords—Behavior against washing machine parameters, performance evaluation of textiles, statistical analysis, commercial and test textiles.

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CURRENTLY, novel textiles and textile materials are being increasingly manufactured due the recent developments in technology and science and they have become essential parts of our lives. Because of wide range variation in the structures of these new textile products, as their consumption increased, many different factors to be coped with have been encountered by the manufacturers and the consumers. As it is with all the materials, textile materials can also be affected by environmental conditions and external stresses caused by these conditions [1], [2]. Therefore, there are various studies in the literature regarding the effects of these exterior factors on textiles. In these studies, most particularly, the washing process having many different simultaneous mechanical and chemical effects on structures, characteristics, durability and lifespan of textiles has been examined [3]-[5].

The impacts of household washing machines on the characteristics of hydro-entangled cotton nonwoven fabrics such as weight, thickness, tearing strength, tensile strength, elongation, absorbency, and dimensional changes, having different structural properties were studied in the research conducted by Sawhney et al. In this study, mainly, it was intended to expose the reasons of tensile strength loss of textiles that are subjected to laundering process with multiple laundering cycles. The greige cotton fabric which can withstand for up to 15 washing and drying cycles in laundering process was found to be a reference product in terms of its endurance and mechanical properties for the production of nonwoven fabrics [3]. The impacts of temperature on the surface and dimensional characteristics of cotton and polyester knitted fabrics in laundering process were investigated in the study of Quaynor et al. For a comparison with silk, they utilized silk filament yarns, combed, ring-spun, and mercerized cotton yarns, and polyester yarns for the production of knitted fabrics. In the study, each of the samples was laundered 10 times with a specifically designed algorithm possessing three profiles with different temperatures as 20, 35 and 50 °C. During laundering, as the water temperature increased, surface friction of cotton fabric was found to decrease in time with growing shrinkage. On the other hand, cover factors of the fabrics displayed a negative correlation with them [4].

In this study, the relationship between the commercial and test textiles was studied in detail as a statistical analysis. By using MINITAB® package program, their behavior against

laundering process was investigated and the correlation, if exists, was tried to be explored.

II. EXPERIMENTAL

A. Materials

In the current study, two different groups of textile materials, standard test textiles and commercial textiles, were utilized.

Standard Test Textiles

Standard test textiles were supplied by Swisstest Material Company from Switzerland. The standard textiles, possessing different textile characteristics, that were preferred to be used in this study have the codes as 106, 252 and 304.

Swisstest 106 fabric contains mineral oil and carbon black soil and it was used to display color changes, since this type of fabric is really sensitive to the amount of detergent and the level of mechanical agitation. It is capable of distinguishing different levels of mechanical agitation after one laundering cycle, which reveals the effects of mechanical agitation in laundering process.

Swisstest 252 is a kind of knitted fabric containing 94% cotton and 6% elastane in its content and having four different colored regions. This fabric is capable of revealing the level of pilling formation. Therefore, in the current study assessment of pilling during laundering and drying processes was performed by using Swisstest 252 Pilling fabric. After 20 washing cycles, color measurement was conducted by the help of spectrophotometer to show the level of pilling formation.

Swisstest 304 is a kind of polyamide woven fabric that can easily show the effects of mechanical agitation in laundering process. It has rectangles on the surface, that help the number of yarns to be counted easily. Each red rectangle has 25 yarns while each blue rectangle has 5 yarns. After one washing cycle, the number of yarns in each of the rectangles were counted to determine how many yarns exist in the fabric structure. Therefore, in the study measurement of mechanical action was performed with the Swisstest 304 Fraying Fabric.

Standard test textiles are given in Fig. 1.

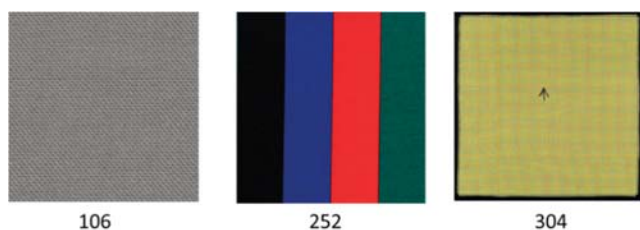


Fig. 1 Standard test textiles

Commercial Textiles

Commercial textiles were chosen from different product groups to represent textiles from different product groups and types. For this purpose, ladies' and men's T-shirts, woven men's shirt, woven jeans and knitted socks made of synthetic fibers were obtained. Commercial textiles are given in Fig. 2.



Fig. 2 Commercial textiles

Jean with dark blue color that was dyed with dark indigo dyestuff was utilized to examine the deformation on its structure. The surface of the yarns in the blue jean was dyed, therefore as the surface of the yarns was abraded, fibers that were not dyed could be observed as white on the fabric surface. The knitted fabrics, T-shirts, were all made of 100% cotton fiber.

One kind of a shirt with black color and two different kinds of t-shirts with variety of colors such as black and red were selected to evaluate their color changes. These colors were chosen since they are the most preferred colors by the customers, and alterations in color can be easily observed with these colors, namely black and red. Shirt had silicon finish in its structure to provide easy-to-iron property.

A pair of socks having a very similar structure and quality as Falke socks were produced with 98% cotton and 2% elastane.

Standard white hand towels were utilized instead of polyester ballast fabric.

B. Machines and Equipment

Commercial home washing machine that is a front-loaded type with a loading capacity of 11 kg, maximum speed of 1400 rpm and multi-sensors for loading weight, water amount, rinsing and rotational speed etc. was utilized in the current study to take the advantage of its variety of programmable properties for different types of textiles and washing durations.

The spectrophotometer Datacolor 650® was used to detect rate of the color change for each fabric with its quantitative assessment standard.

C. Methods and Processes

To determine the relationship between commercial and standard test textiles, temperature, mechanical agitation and load quantity were chosen as variable parameters. Other parameters in the washing algorithm were considered as constant. Details of the washing algorithm can be seen in Table I.

TABLE I
 DETAILS OF THE WASHING ALGORITHM

Washing Steps	Duration (min)	Rpm
Cold Wash	15	52
Heating	40	52
Warming	5	30
Spinning after Main Wash	7	600
Rinsing	5	52
Middle Spinning	4	1000
Softening	4	52
Last Spinning	14	1200
Total	94	

To examine the effect of temperature, the effect of mechanical agitation and the effect of load quantity, three different temperature levels as 20 °C, 40 °C and 60 °C, two different mechanical action percentage as 45% and 85% and three different load quantities as 2, 5 and 8 kg were chosen as the parameters. These parameters can be seen in Table II. Full factorial experimental set-up was used for the comparison of standard test textiles and commercial textiles while designing the experimental process with its washing profiles.

TABLE II
 PROFILES WITH THEIR TESTING PARAMETERS

Temperature (°C)	Mechanical Agitation (%)	Load Quantity (kg)
20	45	2
20	45	5
20	45	8
20	85	2
20	85	5
20	85	8
40	45	2
40	45	5
40	45	8
40	85	2
40	85	5
40	85	8
60	45	2
60	45	5
60	45	8
60	85	2
60	85	5
60	85	8

In the washing profiles, the amount of detergent was adjusted according to the capacity. Therefore, the amount of detergent was changed as 0.5% gram per liter depending on varying load quantity levels. Only IECA base detergent was used, however, bleaching agent and TAED were not used. The water amount in the main wash was adjusted according to the load quantity. The test materials are required to be present in the loading content according to the capacity. After the content was adjusted, IEC60456 standard hand towel was added to the content in order to fill the remaining empty capacity.

For each of the profiles, commercial home laundering machine was utilized. The tests were performed with the washing machine's cotton program by choosing the relevant temperature in accordance with Table II. Standard test textiles 106 and 304 were tested by being changed in each of the first 5 washing cycles, since the results from these two textiles can be obtained after 1 washing cycle. The commercial textiles and the standard test textile 252 were washed in 20 consecutive washing cycles without being taken out. Therefore, each washing profile always consisting of men's shirt, trousers, men's and women's T-shirts, a pair of socks, Swisstest 304 Fraying fabric, Swisstest 252 Pilling fabric and Swisstest 106 Mineral oil/Carbon Black Soil fabric were washed for 20 cycles.

The ballast fabrics as standard hand towels were being tested from the first cycle to the end of the 20th cycle and they were rinsed after the end of the 20th cycle.

For washing process, a modified version of "IEC 60456 Test Method - Clothes Washing Machines for Household Use – Methods for Measuring the Performance" was utilized.

After the tests concluded, the standard test textiles and the commercial textiles were flat dried, whereas the ballast fabrics were tumble dried.

D. Testing and Characterization

For the determination of the relation between the commercial textiles and the standard test textiles, the effects of the variable parameters in laundering process on both of the textile groups were analyzed by subjective and objective assessment criteria, which would enable better comprehension of the behavior similarities and differences of the textiles existed in these two groups by leading to a relation in between the customer perception of commercial textiles and standard test results of standard test textiles. Therefore, the effects of the variable test parameters were analyzed through the changes existed in the standard test textiles and commercial textiles after the washing process.

After 20 washing cycles, eighteen different profiles that were formed for assessing the color changes, pilling, shrinkage, collar abrasion, sewing defects, other defects other than sewing, whitening and overall properties of textiles were evaluated by using both visual point scoring assessment system as a qualitative method for color changes, pilling, shrinkage, collar abrasion, sewing defects, other defects other than sewing and whitening and overall properties of textiles, and spectrophotometer Datacolor 650® as quantitative method for color changes.

"The other defects other than sewing" as an evaluation criteria was defined as the defects such as holes, tears, worn and torn areas on textiles, loss of buttons and accessories and problems with zippers. "Whitening and overall properties of textiles" as an evaluation criterion was defined as the preference of the customers whether they wear the textiles or not, and evaluated according to the whitening and color loss of textiles caused by surface abrasion and fiber loss due to wear during mechanical action in laundering process.

Spectrophotometer Datacolor 650® was used to explore almost all alterations in color of the commercial textiles.

Degree of pilling was determined by the EMPA Photographic Standards for Pilling Test (3 x 4 knitted) and EMPA Photographic Standards for Pilling Test (3 x 4 woven) with 1 to 5 point system according to the existence of more or less pilling.

Shrinkage, collar abrasion, sewing defects, whitening and overall properties, and other defects other than sewing were evaluated visually according to the standards customized specifically for this study. According to the visual assessments, eighteen different profiles were evaluated by six qualified evaluators that gave points from 1 to 5, after these profiles being performed under both mechanical and chemical

action during laundering process were completed. Average points were considered for the comparison of the profiles.

After the experimental process, the evaluation of the Swisstest standard test textiles were performed with different methods according to the behavior of these materials. Swisstest 106 fabric was evaluated before and after the washing process by Spectrophotometer Datacolor 650®. Swisstest 252 fabric has black, blue, red and green regions on its surface and these regions were evaluated before and after the washing process by Spectrophotometer Datacolor 650®. Each of the colors were evaluated separately and average values were compared. The evaluation for Swisstest 304 fabric was performed according to the number of yarns that were lost after washing process. Therefore, the number of yarns existing in the structure of the Swisstest 304 fabric before and after the washing process were compared.

III. RESULTS AND DISCUSSION

In the current study, the behavior of commercial and standard test textiles against laundering parameters such as temperature, load quantity and mechanical action was aimed to be determined. Hence, basically the correlation between these two groups of textiles were analyzed by benefitting from the MINITAB® statistical analysis package program in order to reveal the relationship between commercial textiles and test textiles in terms of their behaviour against laundering parameters.

A. Swisstest 304 Standard Test Fabric

When Swisstest standard test textiles were analyzed in terms of yarn loss values, main and binary interactions of mechanical action and load quantity were found to be significant. R-sq(adj) was found as 99.14%. Main effects plot and interaction plots for Swisstest 304 can be seen in Figs. 3 and 4, respectively.

B. Swisstest 252 Standard Test Fabric

Temperature, mechanical action and load quantity were found to be influential on Swisstest 252 standard test fabric reflection values. R-sq(adj) was found as 95.07%. Main effects plot for Swisstest 252 can be seen in Fig. 5.

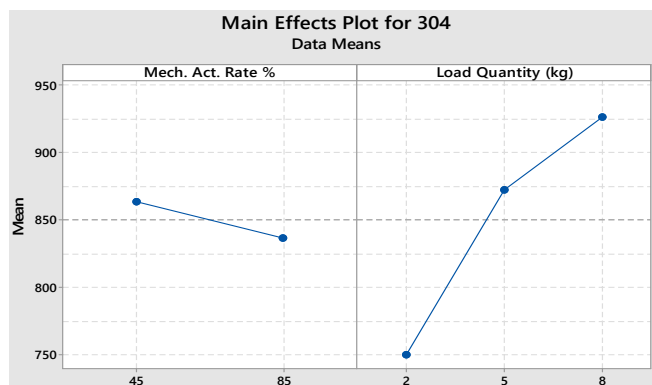


Fig. 3 Main effects plot for Swisstest 304

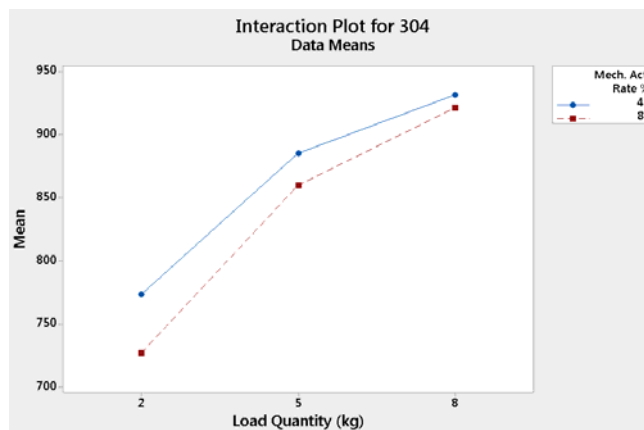


Fig. 4 Interaction plot for Swisstest 304

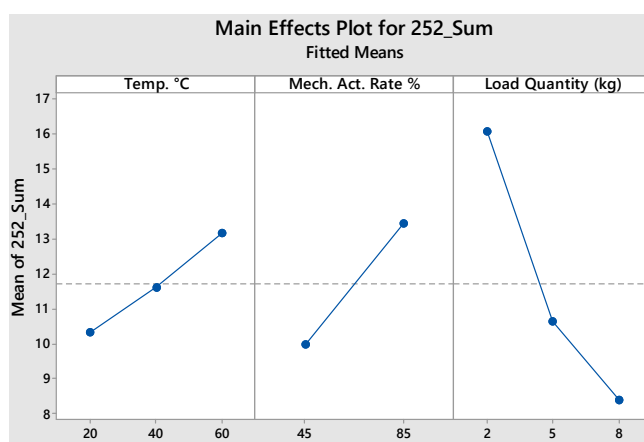


Fig. 5 Main effects plot for Swisstest 252

C. Swisstest 106 Standard Test Fabric

The only parameter that is influential on Swisstest 106 standard test fabric was found as load quantity. R-sq(adj) was found as 85.56%. Main effects plot for Swisstest 106 can be seen in Fig. 6.

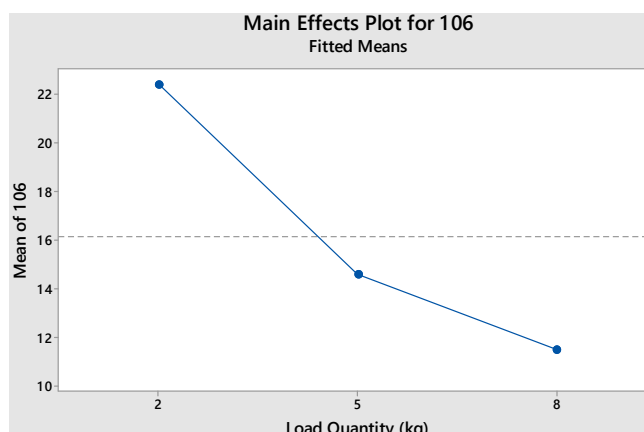


Fig. 6 Main effects plot for Swisstest 106

D. Commercial Textiles

Evaluations were performed with average values for commercial textiles. None of the parameters was found to

have any effect on men's T-shirt and shirt. R-sq(adj) for men's T-shirt was found as 11.73% whereas R-sq(adj) shirt was 5.07%. Although temperature was found influential as the parameter according to the visual assessment for ladies' T-shirt, R-sq(adj) was really low with a value of 30.05%. Main effects plot for ladies' T-shirt can be seen in Fig. 7.

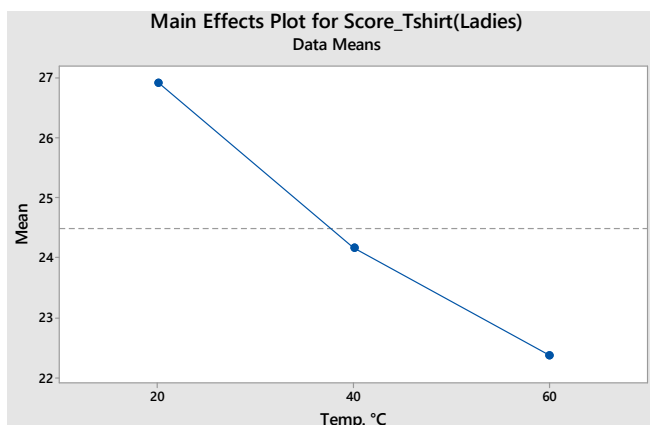


Fig. 7 Main effects plot for ladies' T-shirt

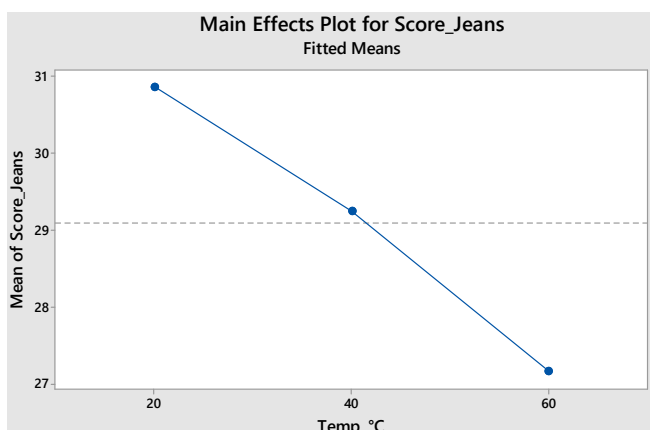


Fig. 8 Main effects plot for jeans

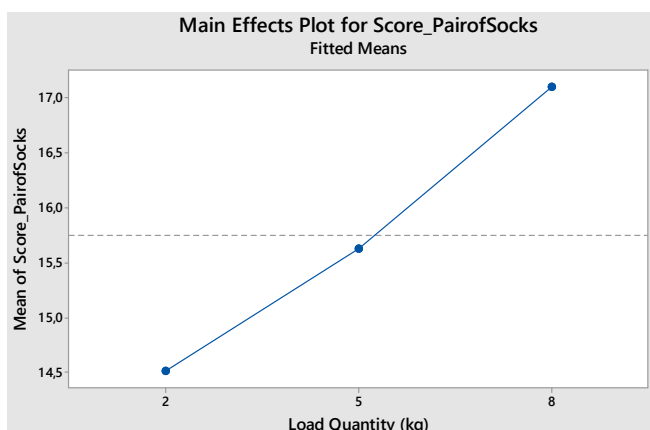


Fig. 9 Main effects pair of socks

Although temperature as the parameter was found influential according to the visual assessment for jean, R-

sq(adj) was really low with a value of 24.17%. Main effects plot for jeans can be seen in Fig. 8.

Although load quantity as the parameter was found influential according to the visual assessment for socks, R-sq(adj) was really low with a value of 32.79%. Main effects plot for pair of socks can be seen in Fig. 9.

E. Correlation in between Standard Test Textiles and Commercial Textiles

In order to find the correlation in between the standard test textiles and commercial textiles, the results were analyzed and correlation values can be seen in Fig. 10.

According to the figure standard test textiles were found to have high correlation in between each other, whereas socks from commercial textiles group were found to have high correlation with standard test textiles.

Correlation: 304; 252_Sum; 106; Score_Tshirt; Score_Tshirt; Score_MensSh; Score_Jeans; ...

252_Sum	304 -0,889 0,000	252_Sum	106	Score_Tshirt(Lad
106	-0,953 0,000	0,913 0,000		
Score_Tshirt(Lad	0,226 0,367	-0,392 0,107	-0,286 0,250	
Score_Tshirt(Men	-0,006 0,982	-0,255 0,307	0,029 0,909	0,638 0,004
Score_MensShirt	0,274 0,271	-0,256 0,306	-0,315 0,202	0,658 0,003
Score_Jeans	-0,273 0,274	0,075 0,766	0,187 0,458	0,774 0,000
Score_PairofSock	0,656 0,003	-0,635 0,005	-0,680 0,002	0,528 0,024
		Score_Tshirt(Men	Score_MensShirt	Score_Jeans
Score_MensShirt	0,330 0,181			
Score_Jeans	0,463 0,053	0,386 0,114		
Score_PairofSock	0,099 0,695	0,610 0,007	0,144 0,568	

Cell Contents: Pearson correlation
P-Value

Fig. 10 Correlation in between the textiles

IV. CONCLUSION

Laundering is one of the most crucial factor affecting the quality of the textiles. It is uncertain that standard test textiles, that are developed for the determination of the effect of different washing parameters on textiles, represent commercial textiles adequately. While washing algorithms are developed, standard test textiles that show the change quickly and prominently in the testing process are used.

In the study, an experimental set-up was created in order to investigate the changes occurring on the commercial and standard test textiles due to washing parameters and the behavior in between the commercial and standard test textiles. The materials used in the study are Swisstat standard test textiles with the codes 106, 252 and 304 having different properties and commercial textiles that represent different product groups and textiles types such as men's and ladies' T-shirts, woven men's shirt, woven jean and knitted synthetic socks. Therefore, the purpose of this study is to determine the change occurring in the standard test textiles and commercial textiles due to different washing parameters and to reveal the

correlation in between the standard test textiles and commercial textiles.

After the experimental process, the Swisstat standard test textiles with the codes 106 and 252 were evaluated with spectrophotometer, while the Swisstat standard test textile 304 was evaluated according to the number of loss yarn from the structure. However, the commercial textiles were evaluated visually with visual point scoring assessment system.

According to the findings of this study regarding the standard test textiles, when the standard test textile 304 was evaluated according to the number of loss yarns from the structure, the main and binary interactions of mechanical action and load quantity were found to be significant. Temperature, mechanical action and load quantity were all found to be effective on the standard test textile 252, whereas the only parameter found effective on the standard test textile 106 was load quantity.

When the results of the commercial textiles are considered, the effective parameters on ladies' t-shirt was temperature, on jeans temperature, on socks load quantity. On the other hand, none of the parameters were found to be effective on men's t-shirt and shirt.

When the correlation in between the standard test textiles and commercial textiles is investigated, standard test textiles were found to have high correlation in between each other. On the other hand, socks from the commercial textiles group were found to have correlation with the standard test textiles.

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