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RESEARCH ARTICLE

The hydro treating effect on the elastic properties of previously fixed cotton-lycra blended fabric

Antypas Imad Rezakalla*, Tatiana Petrovna Savostina

Don State Technical University. Gagarin square 1, Rostov-on-Don 344000, Russian Federation

***Corresponding author:** Antypas Imad Rezakalla imad.antypas@mail.ru

ABSTRACT

The article materials are devoted to the hydro treating effects research, such as scouring and dyeing, on the elastic properties of the previously single jersey for a certain period of time and at the different temperatures by comparing the force necessary to lengthen the fabric by 80% of the original length and width after the process of fixing, scouring and dyeing in light, gray and dark. Thermal fixation affects the fabric physical properties, increasing the force required for a certain elongation of the fabric in the longitudinal and transverse directions, especially in the transverse direction (weft) due to the large influence of flexibility, since it is directly affected by this process when the fixation temperature increases. In addition, other processes following the hydro treating, for example, dyeing, reduce efforts, and dyeing in gray and dark colors is more effective, since it contains washing phase after dyeing at the high temperatures to remove any traces of non-fixed dye on the fabric.

Keywords: cotton / lycra; single jersey; hydro treating

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1. Introduction

Currently, single jersey with an admixture of cotton / lycra, which is considered one of the single jersey fabrics types, is becoming more and more popular on the international market due to the elasticity and stretch ability high properties, compared with other types of fabric, containing lycra in its composition [1-3].

Lycra yarn can be used wound on independent coils on a knitting machine directly so that the lycra thread is intertwined with cotton thread at the required percentage of lycra (**Figure 1**) or the threads can contain a lycra thread in their structure (as an internal thread) called in this case (core yarn) (**Figure 2**):

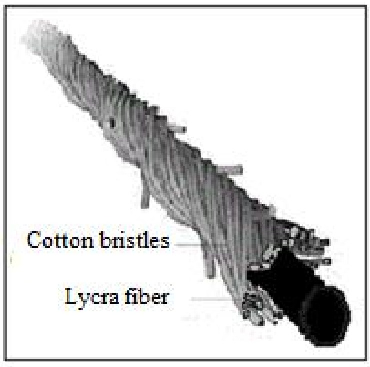

Figure 1. Core yarn structure.

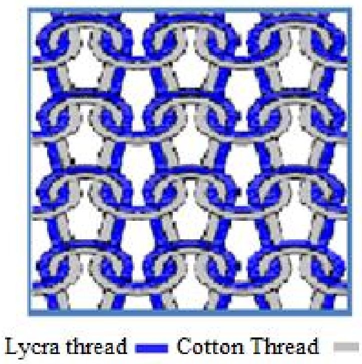

Figure 2. Direct lycra thread use.

Single jersey fabrics, containing lycra, have high elasticity and elasticity properties mainly due to the lycra thread, which is defined in accordance with the ISO 2076 standard as fibers consisting of polyurethane chains of at least 85% of its weight, the molecules residence structure in which is represented as alternately interchanging flexible and rigid chains.

Flexible chains are aliphatic chains of polyester or copolyester, making up approximately 60-90% of the polymer. The remaining portion of the fiber, which constitutes approximately 10-40% of the polymer, consists of randomly intertwined chains relative to each other. The low crystallization degree is resulted in a random rearranging of these chains and the appearance of an association with twisted bonds can be possible. As for rigid chains, they are crystallized aromatic isocyanates, the binding type of which is responsible for the appearance of the necessary space that ensures their flexibility [4].

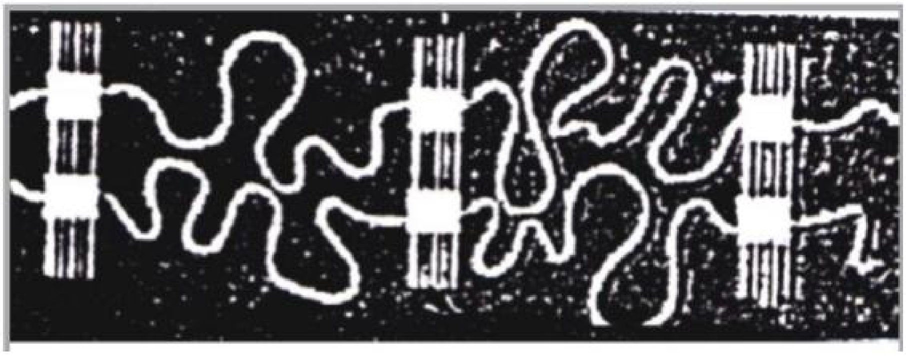

Figure 3. Micro-structure of lycquarium (lycra fibers) [5] .

Thermal damage to lycra fibers occurs significantly when they are heated to temperatures exceeding 170 ℃ . This damage manifests primarily as a yellow discoloration, which serves as an indicator of degradation and is often associated with chemical changes within the fiber structure. Additionally, thermal exposure leads to a loss of strength and elasticity, rendering the fibers weaker and less capable of stretching or returning to their original shape—an essential characteristic for applications that rely on the elastic properties of lycra.

Under microscopic examination, thermally damaged lycra fibers exhibit notable structural alterations; they appear deformed, indicating that their original shape has been compromised. Furthermore, these fibers may show signs of aggregation, where individual fibers clump together instead of remaining separate. This aggregation can result in the fibers becoming stuck to one another or to other surfaces, complicating their performance and usability. The interaction between these damaged fibers and neighboring coatings or fibers suggests that heat affects not only the fibers themselves but also their relationships with other materials. Consequently, this can lead to challenges in processing and using lycra in various textile applications, as the altered state of the fibers impairs their intended functionality.

The degree temperature of lycra fibers softening varies within 170-230 ℃, depending on the lycra type, and melting and decomposition begin in the temperature range 230-290 ℃, which contributes to the removal of water from the chain rigid sections bonds (secondary equivalence bonds as a result of hydrogen bonds), therefore hydrothermal treating causes more damage than those, which are performed dry at the same temperature. In addition, the application of a supplementary load to the lycra fibers can further increase the damage (thermomechanical damage) to its structure [6-9].

It is possible to compare undamaged samples with others damaged as a result of heating by studying the stress / strain behavior, in which damaged samples will have lower strength and elongation than undamaged ones [10].

The fixation temperature effect on the elastic properties of single jersey with cotton / lycra obtained on a knitting machine by combining threads № 40s and 40 denier lycra threads tested at temperatures (200, 210 and 220) °C during the fixed time (36 sec) was studied in works [11].

The study showed a decrease in the elasticity of the fabric with an increase in the fixation temperature, and with the addition of 20% and 30% of the load to the fabric, the elastic elasticity results showed that it decreased slightly with an increase in temperature when fixing the warp, while the weft elasticity decreased significantly, the best value of elasticity turned out to be at the lowest temperature of 200 °C, which is optimal for the fixing.

The work [12] studied the fixation temperature effect of single jersey with cotton / lycra, intertwined on a knitting machine of cotton thread № 34Ne and 20 denier lycra thread at two temperatures of 185 and 195 °Cat a speed of 10 m/min and a width of 165 cm. The study showed the stability of length and width after the laying process as well as a reduction in the percentage of scouring and the bleaching degree.

In work [13] the physical, color and dimensional properties of single jersey were studied after a number of different water treatments of two samples groups made of 100% organic cotton single jersey with thread number 40 / 2, exposed to two series of primary treatments before dyeing. One of the two groups was exposed to the mercerization and scouring processes, and the second one was limited only to performing the scouring process, after which the whole process was completed by dyeing both groups.

The study showed an increase in the elastic fabric properties after preparatory operations, as for the shrunken fabric, the coloring process did not significantly affect these properties, as for the mercerized fabric, its elasticity increased more and clearer.

In work [14] the author studied the washing temperature regime effect on the change in length, stiffness and elongation during cutting for different numbers of lycra threads, as well as different percentages of elongation during thermal fixation of threads, and the tests were carried out at three values of the washing temperature: 25, 40 and 60 ℃. The experiments have shown that with an increase in temperature there was a slight decrease in the hardness and elongation of the threads during cutting.

The research is aimed at studying the effect of hydro treating certain types, such as scouring and dyeing, on the elastic properties of a previously single jersey during a fixed period of time and at different temperatures by comparing the force needed to lengthen the fabric by 80% of the original length and width after the process of its fixation, scouring and dyeing in three color scales: light, grey and dark.

2. Materials and Methods

2.1. Elastic Properties Measurement

Standard Methodology: The elastic properties of the fabrics were measured according to the British Standard BS 4952-1992, which provides guidelines for assessing the elasticity of knitted fabrics. This standard outlines the procedure for determining how much force is required to elongate the fabric by a specified amount, thereby quantifying its elastic behavior.

2.2 Testing Equipment

The testing was conducted using a Testometric model M350-10 CT tensile testing machine. This machine can handle a maximum tensile strength of 10,000 kg, making it suitable for testing various types of fabrics, including those with significant elasticity **Figure 4**.

The machine was equipped with specially designed flat sponges that securely held the fabric samples during testing, ensuring consistent and accurate measurements.

A specific software program provided by the manufacturer allowed for controlled testing conditions and precise data collection, which is essential for replicability and reliability of results.

Figure 4. A Testometric device.

2.3. Fabric Specifications

The fabric tested was a single jersey made from cotton thread No. 30/1 Ne combined with Lycra thread No. 200 denier, with the Lycra content constituting 9% of the total fabric composition. This blend is typical for applications requiring both comfort and stretch.

2.4. Experimental Conditions

Stretching experiments were performed over a fixed duration of 40 seconds, allowing for a controlled assessment of the fabric's response to elongation.

Tests were conducted at four different temperatures (180, 190, 200, and 210 °C) to evaluate how thermal treatment affects the elastic properties of the fabric. These temperatures are relevant for processes like heat setting or thermofixing, which can alter the structure and performance of the fabric.

2.5. Scouring Procedure

After the stretching experiments, a scouring process was performed using a Rota dyer dyeing machine. Scouring is a crucial step in textile processing that removes impurities, oils, and other substances from the fabric, enhancing its cleanliness and preparing it for subsequent treatments.

The scouring was conducted in a water bath, which is a common method for ensuring even treatment across the fabric samples.

2.6. Material Concentrations

The concentration values of the materials used in the scouring process were documented in **Table 1** which would include details on the types and amounts of surfactants, alkalis, or other chemicals used to facilitate the cleaning process.

Table 1. Materials used for scouring.

Material	Concentration
Oil Purifier	2 g/l
H_2O_2	4 g/l
NaOH	2 g/l

The scouring process was conducted according to the scheme shown in **Figure 5**.

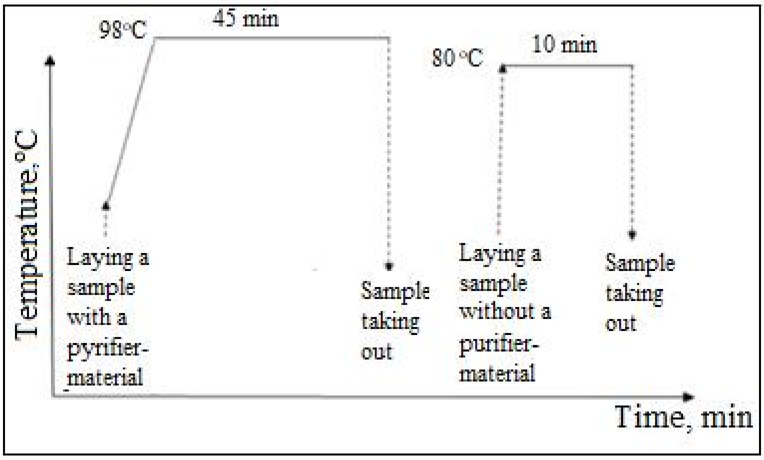

Figure 5. Scouring process scheme.

Further, the heating effect to which the fabric was exposed during dyeing without using any materials within this process was studied, since the concentrations of materials are directly related to the concentration of the dyes used and vary depending on their manufacturers in addition to the other factors (**Figure 6, 7 and 8**):

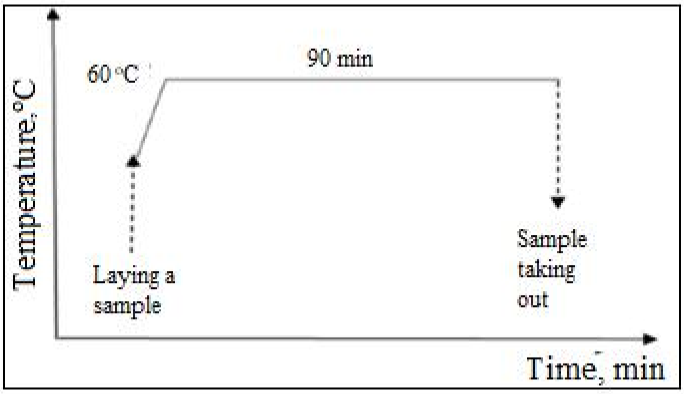

Figure 6. Light color dyeing scheme.

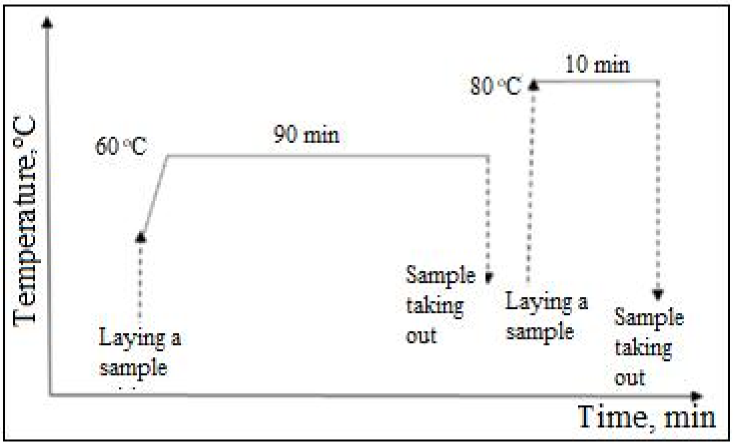

Figure 7. Grey color dyeing scheme.

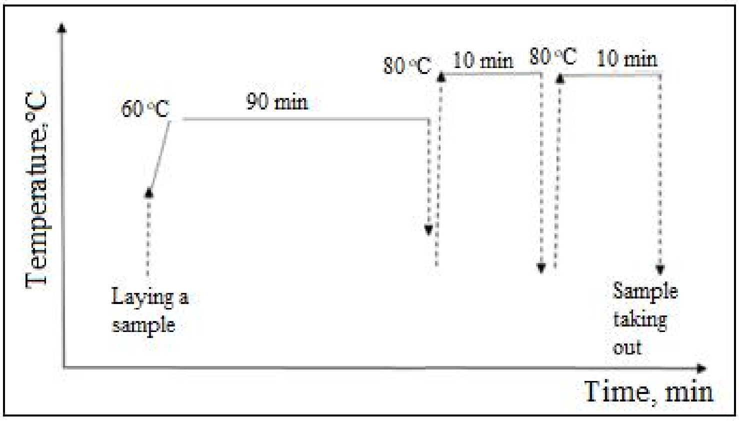

Figure 8. Dark color dyeing scheme.

3. Results and Discussion

3.1. The force research necessary for a certain lengthening of the fabric after fixation

The samples were made from the studied fabric, and experiments were conducted to measure the forces FHL and FHW, which are expressed in Newton's. These forces cause the sample to elongate by 80% of its initial length and width after the fixation process, as well as their subsequent combination with hydro treatment. The research results are summarized in **Table 2**.

Table 2. The force required to elongate the samples by 80% after fixation.

Temperature	**180 °C**		**190 °C**		**200 °C**		**210 °C**	
№ sample	**FHL**	**FHW**	**FHL**	**FHW**	**FHL**	**FHW**	**FHL**	**FHW**
1	49	43	77	58	80	74	80	78
2	52	55	67	71	78	75	85	74
3	62	58	73	68	63	68	73	65
4	53	51	66	81	79	75	83	68
5	62	52	63	56	75	65	74	77
Average	56	52	70	67	75	72	79	73

The results given in **Figure 9** show an increase in the effort required for a certain elongation of the fabric with an increase in the fixation temperature, which directly affects the decrease in its strength.

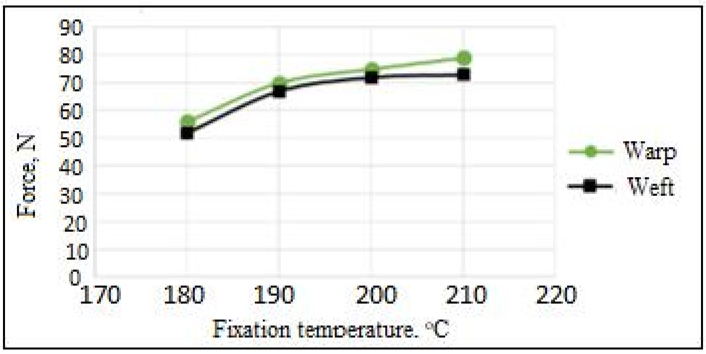

Figure 9. The force required to elongate the samples by 80% after fixation.

3.2. The force study necessary for a certain elongation of the fabric after scouring

The forces FBL and FBW, in Newton's, that cause the sample to elongate by 80% of its length and width after the scouring process are shown in **Table 3**.

Table 3. The force required to obtain 80% elongation of samples after scouring.

Temperature	180 °C		190 °C		200 °C		210 °C	
№ sample	**FBL**	**FBW**	**FBL**	**FBW**	**FBL**	**FBW**	**FBL**	**FBW**
1	43	49	63	48	77	59	82	67
2	56	35	54	43	85	69	69	57
3	52	39	66	45	66	77	76	65
4	48	41	64	53	79	58	85	62
5	51	46	68	56	73	62	88	69
Average	50	42	63	49	76	65	80	64

The results shown in **Figure 10** show an increase in the force required for a certain elongation of the fabric, with an increase in the fixation temperature of the fabric with a decrease in this force after scouring compared to the previous phase.

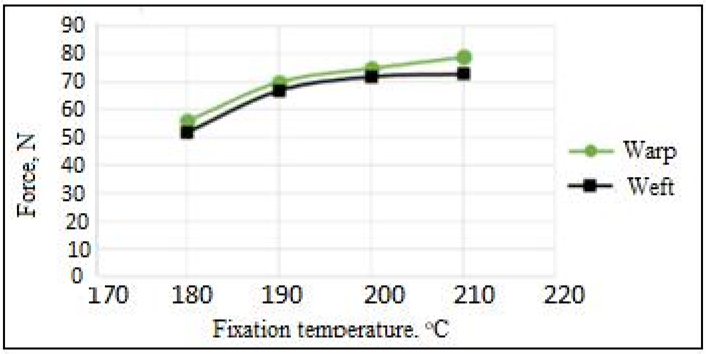

Figure 10. The force necessary to elongate the samples by 80% after scouring.

3.3. The force study necessary for a certain elongation of the fabric after light dyeing

The forces FLL and FLW, in Newton's, that cause the sample to elongate by 80% of its length and width light dyeing are shown in **Table 4**.

Table 4. The force necessary to elongate the samples by 80% after light dyeing.

Temperature	180 °C		190 °C		200 °C		210 °C	
№ sample	**FLL**	**FLW**	**FLL**	**FLW**	**FLL**	**FLW**	**FLL**	**FLW**
1	41	30	52	37	71	47	77	52
2	30	33	47	49	83	54	74	59
3	35	31	49	45	79	56	79	50
4	47	29	50	43	74	49	89	61
5	37	27	57	41	73	59	86	63
Average	38	30	51	43	76	53	81	57

The results given in **Figure 11** show a decrease in the effort necessary for a certain elongation of the fabric during light dyeing compared to a more complete phase, characterized by an increase in flexibility as a processing result.

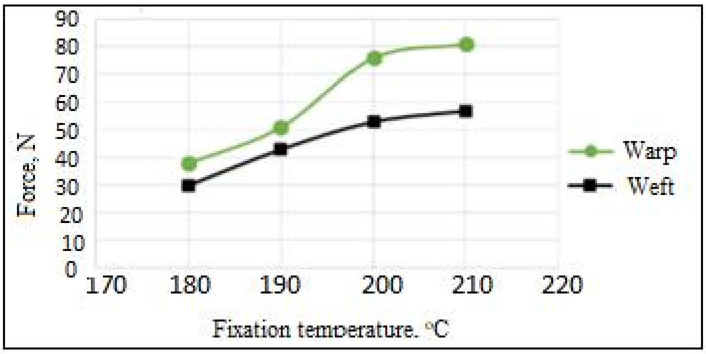

Figure 11. The force necessary to elongate the samples by 80% after light dyeing.

3.4. The force study necessary for a certain elongation of the fabric after gray dyeing

The forces FML and FMW, in Newton's, that cause the sample to elongate by 80% of its length and width after gray dyeing are shown in **Table 5**.

Table 5. The effort required to obtain 80% elongation in the samples after staining in gray.

Temperature	180°C		190°C		200 °C		210 °C	
№ sample	FML	FMW	FML	FMW	FML	FMW	FML	FMW
1	24	26	50	40	62	56	67	55
2	23	24	59	37	73	47	71	52
3	27	22	46	40	71	45	79	57
4	32	20	41	42	74	49	85	50
5	29	28	54	36	65	58	83	61
Average	27	24	50	39	69	51	77	55

The results given in **Figure 12** show a constant decrease in the effort required for a certain fabric lengthening when dyed gray is compared to light coloring, which is reflected in the increased fabric flexibility as a result of its processing.

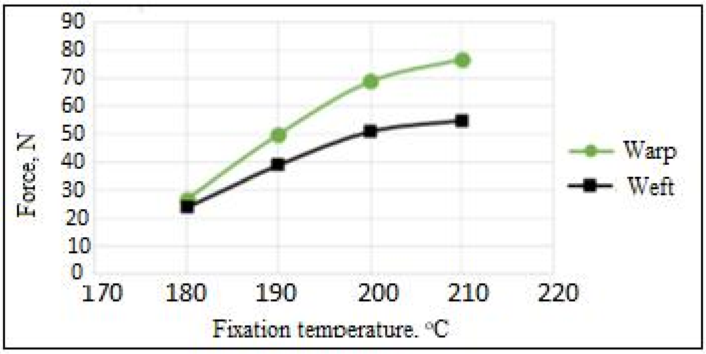

Figure 12. The force necessary to elongate the samples by 80% after dyeing the environment.

3.5. The study of the force necessary for a certain fabric elongation after a dark color dyeing

The forces FDL and FDW, measured in Newton's, that cause the sample to elongate by 80% of its length and width after dark dyeing are shown in **Table 6**.

Table 6. The force necessary to lengthen the samples by 80% of their initial length after dyeing them in a dark color.

Temperature	**180** ℃		**190** ℃		**200** ℃		**210** ℃	
№ sample	FDL	FDW	FDL	FDW	FDL	FDW	FDL	FDW
1	33	26	51	31	66	43	84	50
2	29	28	49	39	63	46	72	55
3	22	23	41	36	61	53	78	49
4	26	19	47	33	71	40	91	63
5	35	29	52	36	74	50	75	58
Average	29	25	48	35	67	46	80	55

The results given in **Figure 13** show a slight decrease in the effort required for a certain fabric elongation when dyed in dark color compared to their coloring in gray.

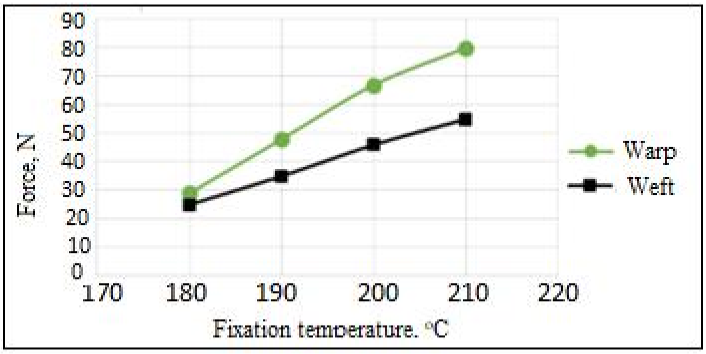

Figure 13. The force necessary to elongate the samples by 80% of their initial length after dark dyeing.

The comparison of the force values required to elongate the sample by 80% in the longitudinal direction (the warp) at different stages, as a result of the effects of hydro procedures, can be carried out according to the diagram shown in **Figure 14.** Where: 1 – after fixation, 2 – after scouring, 3 – after light dyeing, 4 – after dyeing in gray color, 5 – after dyeing in dark color

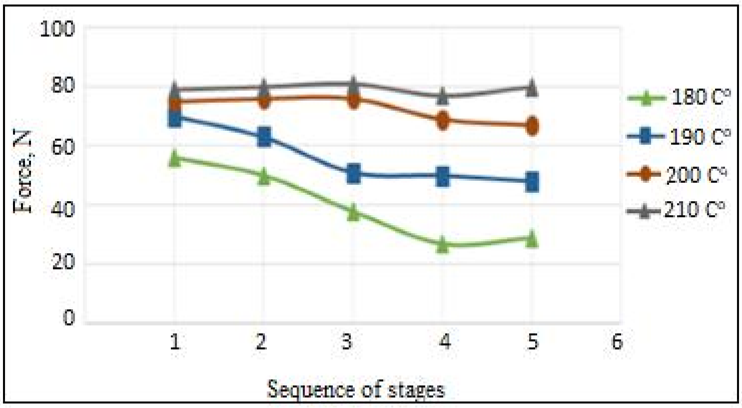

Figure 14. The hydro treating effect on the strength necessary to lengthen the sample by 80% of its initial length.

Similarly, the force values necessary to cause the sample elongation by 80% in the weft direction at different phases are shown in **Figure 15** as a result of the hydro procedures effects:

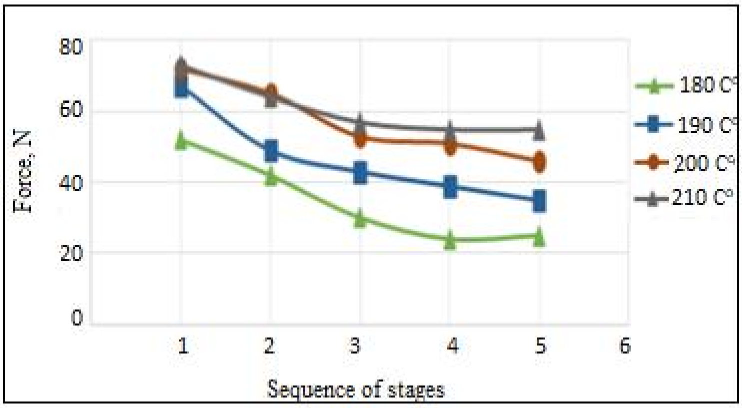

Figure 15. The hydro treating effect on the strength necessary to elongate the sample by 80% in width from its initial value.

Figures 15 and 16 demonstrate that hydro treating reduces the force required to achieve the same elongation in both directions, while maintaining a similar relationship between temperature and force. The greatest reduction in force occurs after the initial fixation treatment, which involves a scouring process. Additionally, all dyeing processes result in a decrease in force, with the most significant reductions observed during the dyeing processes in gray and dark colors, noting that there are no significant differences between these two processes.

4. Conclusion

The thermal fixation process significantly impacts the physical properties of the fabric, particularly by increasing the force required for a given elongation. This results in a reduction of the fabric's elastic properties in both the longitudinal (warp) and transverse (weft) directions. It's important to note that the flexibility of the fabric is more profoundly influenced in the transverse direction, where the weft is directly affected by the thermal fixation process due to the elevated temperatures involved. As a result, the fabric exhibits increased rigidity and reduced elasticity after undergoing this fixation treatment.

In contrast, the scouring process has a different effect on the fabric's physical properties. During scouring, the fabric is subjected to high temperatures, which lead to a decrease in the force necessary for achieving a certain elongation. This indicates an increase in the fabric's elasticity post-scouring. The weft, which contains lycra threads, is particularly susceptible to the effects of scouring. The high temperatures during this process can alter the internal structure of the lycra, leading to enhanced flexibility and a more pronounced reduction in the force needed for elongation compared to the warp.

Following scouring, the application of hydro treatments—regardless of whether they involve light, gray, or dark dyeing—further reduces the forces required for elongation, thereby enhancing the fabric's flexibility. Notably, dyeing processes in gray and dark colors demonstrate greater effectiveness in this regard. This is attributed to the additional washing steps involved after dyeing at high temperatures, which serve to remove any residual non-fixed dye from the fabric. These washing steps not only contribute to the fabric's aesthetic qualities but also play a crucial role in improving its physical properties by further enhancing elasticity and flexibility.

The interplay of thermal fixation, scouring, and subsequent hydro treatments illustrates a complex relationship between processing techniques and the resulting physical characteristics of the fabric, highlighting the importance of careful management of these processes to achieve desired performance attributes.

Conflict of interest

The authors declare no conflict of interest.

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