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Influence of the Backrest Roller Position on the Properties of Denim Fabrics

Abstract

Denim is one of the most traditional and fashionable fabrics. The quality of denim fabrics based on their usage is important. The physical and mechanical properties of denim fabrics have considerable influence on their application and comfort . In this study, the effect of the backrest roller position and finishing process on the physical and mechanical properties of denim fabrics was investigated. For this purpose, grey and finished fabrics at five different positions of the backrest roller on a weaving loom were separately produced. Statistical analysis of the results shows that in grey fabric, the position of the backrest roller has significant influence on the breaking strength in the warp direction, breaking elongation, warp yarn density, abrasion resistance, tear resistance, air and water permeability, fabric surface colour, and fabric thickness; and it has no significant influence on the breaking strength in the weft direction, weft yarn density, abrasion resistance, and fabric weight. Moreover, no meaningful effect of the back rest roller position on the properties of the finished fabric was observed.

Key words: *denim fabrics, backrest roller position, fabric properties, warp tension.*

Introduction

Denim fabrics have developed into a part of the garment fashion since the 19th century. Most consumers around the world prefer cotton apparel; in particular, they enjoy wearing denim. The success of denim is due to its ability to change with every social and cultural evolution [1].

Moreover the weaving process is one of the most important parts of the textile industry. The accurate function of weaving loom components has considerable influence on the quality and quantity of fabrics produced. Among loom components, the backrest roller is a crucial part which adjusts the tension of warp yarns; therefore it could affect fabric properties [2, 3]. The backrest roller motion is also important in improving the efficiency of the weaving process, especially when the loom speed is increased [4]. Adanur and Jing [5, 6] studied the effects of tension on the properties of denim fabrics made on an air-jet weaving loom. The variations in warp yarn tension during the weaving process become smaller by the backrest roller's swinging motion. At a high speed of the weaving machine, it could be possible to obtain a suitable relationship between movements of the backrest roller and warp yarn tension [7].

Sheikhzadeh et al. [8] investigated the relationship between the ratio of the force applied on the warp yarn by the backrest roller to the warp yarn tension, and the vertical and horizontal position of the backrest roller with variations in warp beam radius during the weaving process.

Weinsdorfer et al. [9] studied the distribution of warp tension over the warp width connected with the changes in shed geometry (backrest positions). They found that by changing the shed geometry, the warp tension also varies. By lifting the backrest, the elongation of warp yarn in the lower shed increases, as a result the warp tension in the lower shed also increases. On the other hand, the warp tension in the upper shed decreases. Turhan et al. [10] presented experimental, computational intelligence based, and statistical investigations of warp tensions in different back-rest oscillations. To have different backrest oscillations, springs with different stiffness were used. For each spring, fabrics with various weft densities were woven, and the warp tensions were measured and saved during the weaving process. The empirical data were analysed by using linear multiple and quadratic multiple regression, and an artificial neural network model. Osthus et al. [11] reported that the warp end tensions are influenced by changing the height of the backrest roller. They evaluated the fabric appearance using an image processing system. The results for different backrest heights show that in the higher position of the backrest, the colour of the fabric become darker; and the fabric density is greater with an increasing backrest height.

Turhan and Eren [12] inspected the effect of weaving machine settings on the weavability limits of air-jet machines. They found that changing the shed adjustment from the zero level of the backrest to higher values increased the maximum weavable weft density slightly; however, increasing the shed asymmetry further (backrest height) has no significant influence on the weavability limit.

Haghighat et al. [13] studied the effect of the backrest roller position on the physical and mechanical properties of worsted fabrics. The results showed that the position of the backrest roller has a significant effect on the breaking strength in the warp direction, weight per area unit, and thickness of fabric.

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In order to verify the influence of the backrest movement in the warp tension fluctuation and beat-up strip width in the weaving process, an analytical examination was developed by Azzam and Büsgen [14]. The results showed that by improving the backrest movements, the warp cycle tension could be more even. In addition to fabric structure, parameters of the weaving process, such as the warp tension, the reciprocal position of the backrest and cloth support have an influence on the shrinkage of grey fabric [15]. The technological and constructional parameters as a position of the back rest geometry of the shed may influence the fabric structure [16].

One of the practicable procedures to obtain a closer pick-spacing (i.e. tighter packing of picks), especially in high warp cover factors, is increasing the height of the backrest. It is known from experience that it is possible to obtain closer pick spacing if the backrest is raised above its normal position (warp yarns between the cloth fell and backrest are horizontal), provided that the headls cross well before beat-up. In a higher position of the backrest, the yarns in the upper shed are shorter and the tension on them is less than in the normal position. Therefore the upper shed is slack and the lower one tight. In effect, the last pick inserted is forced downwards [17], and it is possible to weave fabrics with higher weft densities.

In order to produce denim garments (particularly trousers), usually heavy and extra heavy fabrics are used. In such fabrics, coarse cotton yarns are utilized, and the warp and weft densities, related to yarn counts, are partially high. Thus the gaps between yarns are very small. As a result, to obtain the yarn densities required without encountering the bumping condition and to reduce the breakage of warp yarns and forces applied in the weaving process, it is essential to precisely adjust the machine setting, the backrest position etc. However, increasing the backrest height is very common in cotton weaving and helps to achieve close pick-spacing when the warp cover factor is high enough to ensure good cover despite changes.

According to the articles surveyed, it can be concluded that just a few works are concentrated on the backrest roller. Therefore a study of the effect of the backrest roller position on the physical and mechanical properties of the denim fabric warrants further research and it can be well established that the influence of the backrest roller's position is important in determining the final product's properties. Accordingly the aim of this study was to investigate the influence of the backrest roller position on the physical and mechanical properties of grey and finished denim fabrics on a high speed weaving machine.

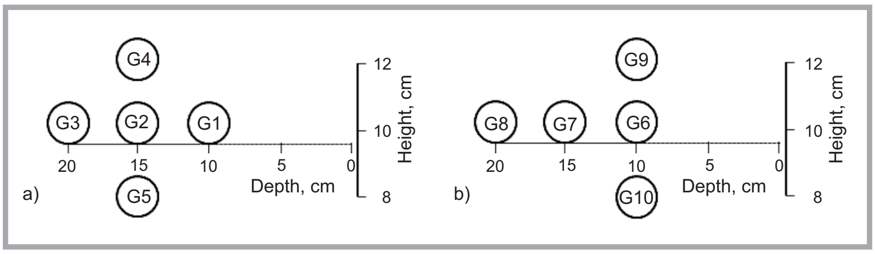

Figure 1. *Position of backrest roller; a) grey fabric, b) finished fabric.*

Table 1. *Characteristics of grey and finished woven fabrics.*

Status of fabrics	Yarn count, tex		Yarn density, 1/cm	
	warp	weft	warp	weft
Grey	74	59	26	19
Finished	74	74	30	21

Table 2. *Standards and testing instrument applied for examination of fabric properties.*

Fabric Properties	Standard No.	Testing Instrument
Breaking and elongation strength	ASTM D5034	Instron tensile tester 5566
Weight per unit area	ASTM D3776	Cutting Die
Thickness	ASTM D1777	Shirley thickness tester (SDL 94)
Air permeability	ASTM D737-04	Shirley air permeability tester (SDL)
Abrasion resistance	ASTM D4966	Martindale 2000
Tear resistance	ASTM D2261	Elmendorf tear tester
Water permeability	BS 2833	Water permeability tester (Shirley)

Martials and methods

In this work, to evaluate the influence of the backrest roller's position on the properties of grey and finished woven denim fabrics, ten fabric samples with a twill weave structure (T 3/1) were produced. For producing the denim fabrics, the warp cotton yarns were dyed on a warp indigo dyeing machine (*RAMLLUMIN* dyeing machine), then denim fabrics (G1, G2, …, and G10) were woven on a *PICANOL OMNIPLUS 800* air-jet loom with different positions of the backrest roller (***Figure 1***) at a speed of 700 r.p.m. Finally five of them (G6, G7, ..., and G10) were finished using a *H.T.P UNITEX* finishing machine. Characteristics of the fabrics are listed in ***Table 1***. The zero point (0) in ***Figure 1*** is the nearest horizontal position of the backrest to the sley.

It is notable that after changing the position of the backrest, the tension of warp yarns readjusts to 3.5 kN, which was kept constant in all experiments. Also during the production of the fabric samples, the breakage of warp yarns was not observed. Therefore from this setting it could be supposed that the trend of warp breakage for different positions of the backrest is quite similar.

In order to determine the effect of the backrest roller's position on the properties of denim fabrics, including the breaking strength, abrasion and tear resistance, air and water permeability, yarn density, and so on, experiments were carried out according to ASTM and BS Standards. ***Table 2*** shows the instruments and standard No. which were used for measuring the fabric properties.

In denim garments, the lightness and darkness of fabric colour is important. To investigate the effect of the backrest roller's position on the fabric appearance (surface colour), a spectrophotometer was used. The index L^* was obtained from the spectrophotometer. When the minimum value of L^* is zero, it represents black colour, and when the maximum value is 100, it shows a perfect reflection diffuser (white colour) [18]. In order to precisely evaluate the influ-

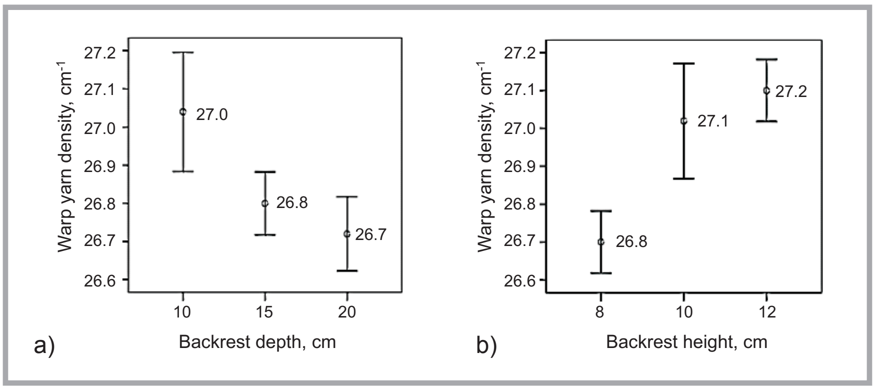

***Figure 2.** Influence of backrest roller's depth (a) and height (b) on the warp yarn density of grey fabric.*

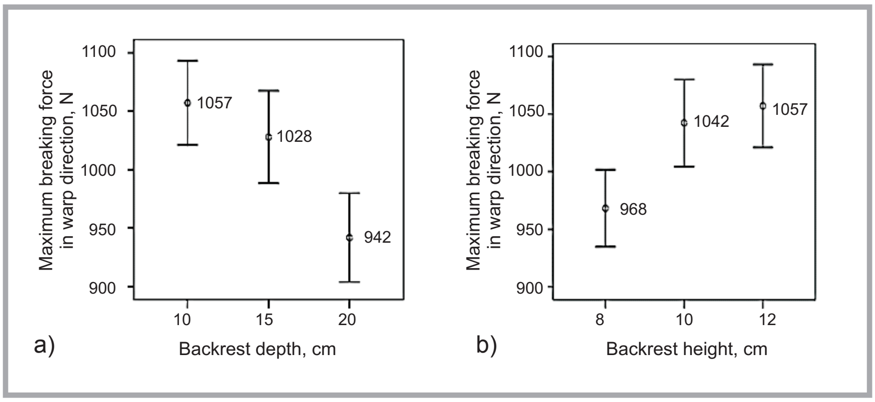

***Figure 3.** Influence of backrest roller's depth (a) and height (b) on the breaking strength of grey fabric in warp direction.*

***Table 3.** ANOVA analysis results based on experimental data; *If Sig. ≥ 0.05, the backrest position has no significant influence on the given parameter, and when Sig. < 0.05, the parameter is influenced by the backrest position.*

Parameter	Sig. (P-Value) *			
	Vertical position		Horizontal position	
	Finished fabric	Grey fabric	Finished fabric	Grey fabric
Warp yarn density	0.546	0.016	0.810	0.024
Weft yarn density	0.335	0.756	0.139	0.262
Breaking strength in warp direction	0.061	0.029	0.403	0.002
Breaking strength in weft direction	0.068	0.257	0.706	0.488
Breaking elongation in warp direction	1.000	0.000	0.396	0.000
Breaking elongation in weft direction	0.353	0.000	0.183	0.001
Weight per unit area	0.128	0.435	0.665	0.121
Thickness of fabric	0.188	0.001	0.060	0.014
Air permeability	0.866	0.037	0.196	0.044
Water permeability	0.124	0.032	0.277	0.000
Abrasion resistance	0.051	0.884	0.431	0.182
Tear resistance in warp direction	0.352	0.047	0.440	0.010
Tear resistance in weft direction	0.395	0.602	0.919	0.936

***Table 4.** Influence of backrest roller position on the warp and weft yarn densities,*

Backrest position		Grey fabric	Finished fabric	
		weft density, cm-1	warp density, cm-1	weft density, cm-1
8	Height, cm	20.0	31.9	23.1
10		19.9	31.7	23.2
12		20.0	31.8	23.0
10	Depth, cm	19.9	31.8	23.0
15		19.9	31.7	23.2
20		20.2	31.8	23.0

ence of the backrest roller's position on the fabric properties, the effect of vertical (height) and horizontal (depth) positions was investigated separately. The experiments were performed under standard conditions (65 ± 2% RH and 20 ± 2 °C) [19]. The results obtained from statistical analyses by One-Way ANOVA (Analysis of Variance) at a 95% level of confidence arepresented in ***Table 3***. The confidence interval for the mean at 95% level isalso shown in ***Figures 2 - 9***.

Results and discussion

Effect of the backrest roller's position on the warp and weft yarn density

Statistical analysis of the results shows that both the horizontal and vertical backrest positions have a significant influence on the warp yarn density of grey fabric. According to the results, with an increase in the depth of the backrest from 10 to 20 centimeters, the warp density decreases (***Figure 2.a***). When the distance between the backrest roller and sley increases (depth increases), the length of yarns in the upper and lower sheds (between the backrest and beat-up point) enlarges, and the tension in the longer yarns is lower than that in the shorter yarns. Therefore the warp yarns become looser, causing a reduction in the warp yarn density.

With raising the backrest height from 8 to 12 centimeters, the warp density increases (***Figure 2.b***). In the higher position of the backrest, the shed becomes asymmetric, the tension on warp yarns in lower sheds increases and in the upper shed decreases [9]. The yarns stretch in the lower shed and the distance between warp yarns decreases. Thus a higher density of warp yarns results. Also the results show that the horizontal and vertical positions have no effect on the weft yarn density of grey fabric nor on the warp and weft yarn densities of the finished fabric, the reason for which being that in the finishing process there is overfeed of fabrics, causing the fabrics to have similar quality. The results are shown in ***Table 4***.

Effect of the backrest roller's position on the breaking strength

The backrest position has a significant influence on the breaking strength of grey fabric in the warp direction. Increasing the backrest depth causes a reduction in the maximum breaking force in the warp direction (***Figure 3.a***). The decrease in the breaking force may possibly be due to a decrease in warp yarn density. Increasing the backrest height causes a rise in breaking force in the warp direction (***Figure 3.b***). When the backrest is raised, the warp yarn density increases, therefore the fabric strength will increase. On the other hand, the breaking strength in the warp direction augments with an increase in the amount of warp yarn density.

The backrest position has no significant effect on the breaking strength of grey fabric in the weft direction nor on finished fabric in both the warp and weft directions (***Table 5***).

Effect of the backrest roller's position on the elongation at break

The elongation at break of grey fabrics was affected by the backrest roller's position in both the warp and weft directions. With more depth, the more elongation in the warp direction and less elongation in the weft direction resulted.

As mentioned previously, with an increase in the backrest depth, the tension on the warp yarns in the upper and lower sheds decreases, thus the warp yarns can lie more loosely in the fabric structure. Hence the warp yarns can extend more and the fabric elongation in the warp direction increases. Furthermore in the weft direction the crimp of weft yarns in the fabric structure decreases when the depth of the backrest increases, thus the fabric elongation in the weft direction decreases.

In the vertical position, an inverse trend is observed, thus fabric elongation in the warp direction decreases and elongation in the weft direction increases as the backrest roller rises. When the backrest goes up, the yarns in the lower shed, because of increasing the tension, become straighter. As a result, the crimp of weft yarns augments. Hence the elongation of fabrics decreases in the warp direction and increases in weft. The results are shown in ***Figures 4*** and ***5***.

The backrest roller's position has no significant effect on the elongation of the finished fabric in both the warp and weft directions (***Table 5***).

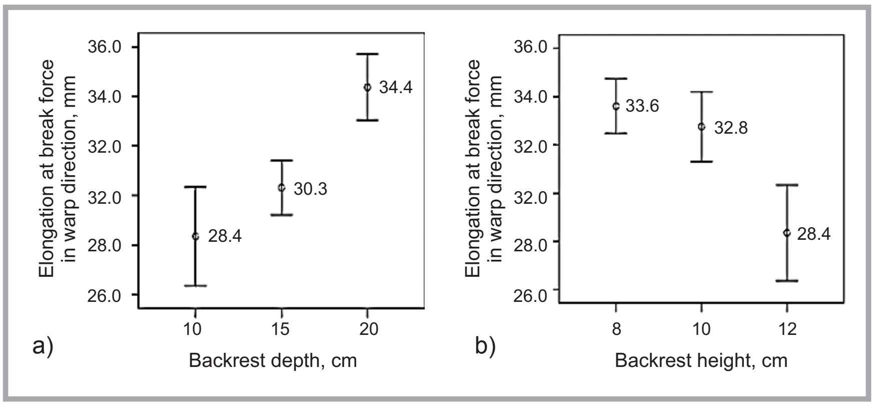

Figure 4. *Influence of backrest roller's depth (a) and height (b) on the elongation at break of grey fabric in warp direction.*

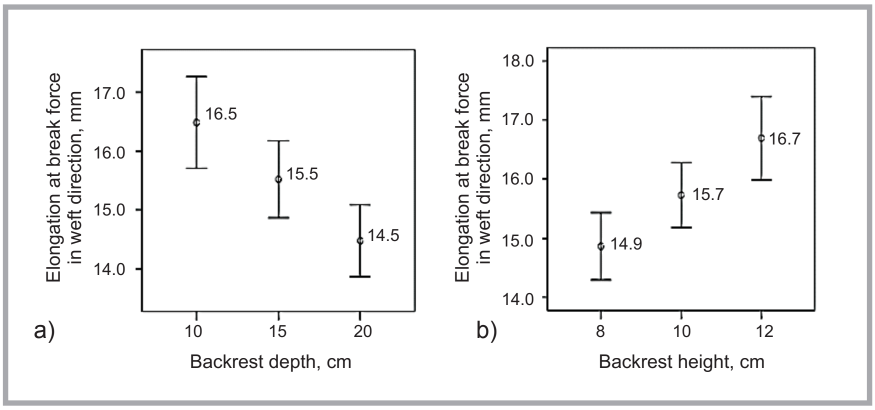

Figure 5. *Influence of backrest roller's depth (a) and height (b) on the elongation at break of grey fabric in weft direction.*

Table 5. *Influence of backrest roller's position on the breaking strength and elongation at break of finished fabric.*

Backrest position		Maximum breaking force, N		Elongation at break, mm	
		warp direction	weft direction	warp direction	weft direction
8	Height, cm	985	971	60.4	22.6
10		1139	979	60.4	23.3
12		1139	934	60.4	22.8
10	Depth, cm	1097	970	60.6	23.1
15		1139	979	60.4	23.3
20		1122	963	62.1	22.6

Table 6. *Influence of backrest roller's position on the weight and thickness of fabric.*

Backrest position		Weight per unit area, g		Thickness, mm
		Grey fabric	Finished fabric	Finished fabric
8	Height, cm	292	414	0.789
10		294	411	0.797
12		295	410	0.800
10	Depth, cm	294	411	0.760
15		294	411	0.784
20		299	409	0.793

Effect of the backrest roller's position on the weight per unit area

The position of the backrest roller has no meaningful effect on the weight of grey and finished fabrics. In view of the differences in warp yarn densities, which are generated by changing the position of the backrest roller, the weight of the fabrics is expected to be significantly changed; however, the statistical analysis refutes this presumption. ***Table 6*** shows the results.

Effect of the backrest roller's position on the thickness of the fabric

The thickness of grey fabric was significantly influenced by the backrest roller's position in both the horizontal and vertical directions. With an increase in the backrest

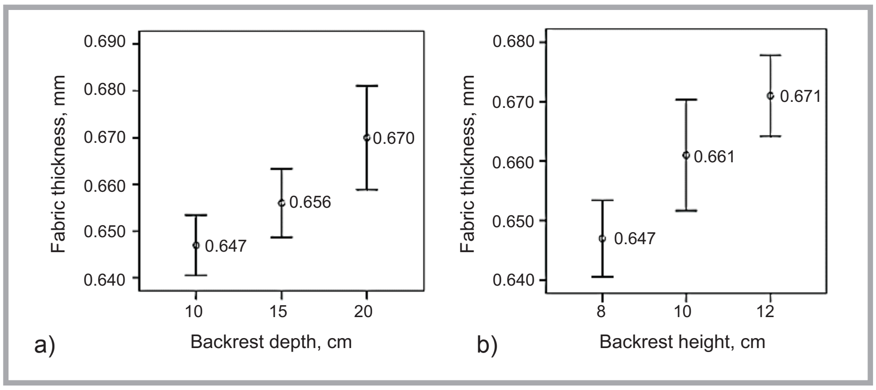

__Figure 6.__ Influence of backrest roller's depth (a) and height (b) on the thickness of grey fabric.

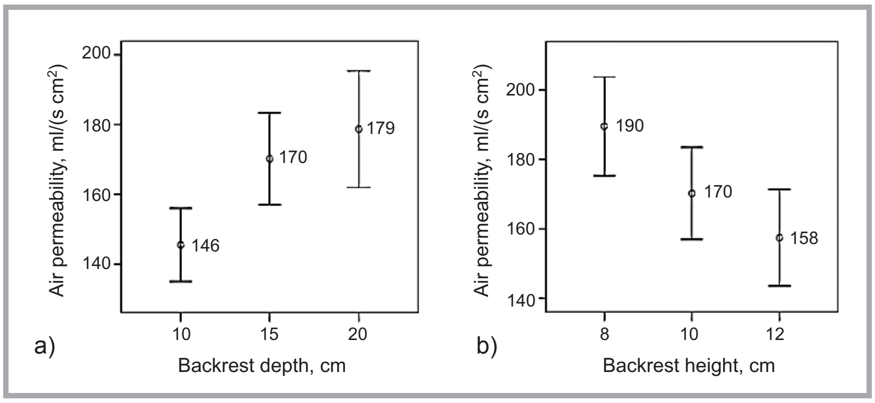

__Figure 7.__ Influence of backrest roller's depth (a) and height (b) on the air permeability of grey fabric.

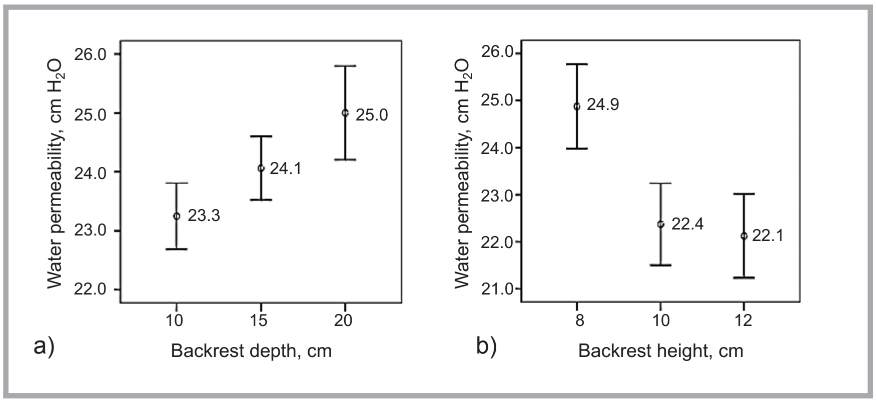

__Figure 8.__ Influence of backrest roller's depth (a) and height (b) on the water permeability of grey fabric.

roller's depth, the fabric thickness also increases. As mentioned before, in this situation the warp yarns lie more loosely in the fabrics structure. On the other hand, the height of warp yarn crimp augments, thus the fabric thickness increases.

At a higher height of the backrest roller, the crimp of weft yarns increases; hence an increase in the thickness of the grey fabric can be observed. The results are shown in ***Figure 6***.

The backrest position has no significant effect on the thickness of the finished fabric (***Table 6***).

Effect of the backrest roller's position on air permeability

The backrest roller's position in the horizontal and vertical directions has a significant effect on the air permeability of grey fabric. In the deeper position of the backrest roller, the air permeability increases. In this position, the warp yarns in the fabric structure are loose and unstrained. Moreover the warp density decreases and free spaces (voids) between yarns in the surface of the fabric enlarge; consequently a large amount of air can pass through the fabric. Accordingly it could be concluded that the air permeability augments in the deeper position. However, in the higher position of the backrest roller, air permeability decreases. With an increase in the height, the warp density increases, causing free spaces between warp yarns to decrease; thus the flow of air that passes through the fabric will decrease. The results are plotted in ***Figure 7***. In the finished fabric, air permeability is not affected by the position of the backrest roller. ***Table 7*** shows the air permeability results.

Effect of the backrest roller's position on water permeability

The horizontal and vertical positions of the backrest roller have a significant effect on the water permeability of grey fabric, but there is not any meaningful influence on the finished fabric. As ***Figure 8.a*** shows, with an increase in the depth of the backrest roller, the water permeability increases. The reason for this trend is the same as for the air permeability trend - in the deeper position the warp yarns are looser and the size of holes between yarns in the fabric

__Table 7.__ Influence of backrest roller's position on the air and water permeability of finished fabric.

Backrest position		Air permeability, ml/sec.cm^2	Water permeability, cm H_2o
8	Height, cm	19.2	42.3
10		20.0	39.6
12		19.2	40.9
10	Depth, cm	20.7	41.7
15		20.0	39.6
20		20.1	39.7

__Table 8.__ Influence of backrest roller's position on the abrasion resistance of fabric.

Backrest position		Weight reduction, %	
		Grey fabric	Finished fabric
8	Height, cm	3.26	1.57
10		3.51	2.39
12		3.00	1.31
10	Depth, cm	3.51	2.51
15		2.68	2.39
20		2.82	1.99

structure is larger, therefore the water can easily pass through the fabric structure. When the height of the backrest is raised, fabric resistance to water penetration increases. Because of the higher position of the backrest, warp yarns get close together, the warp density increases, and the spaces between yarns decrease, causing the water permeability to decrease (***Figure 8.b***). The results of the finished fabric are presented in ***Table 7***.

Effect of the backrest roller's position on abrasion resistance

The fabric resistance to abrasion was expressed in terms of the percentage weight loss of the fabrics after the abrasion process. The results show that the backrest roller's position has no significant influence on the abrasion resistance of grey and finished fabrics in both the vertical and horizontal directions. The abrasion resistance of fabrics is influenced by the fibre type, yarn construction and fabric structure [6]. In this study, the yarns which were used for producing the denim fabrics have the same characteristics; therefore the trend observed for abrasion resistance in grey and finished fabrics could be reasonable. The results are displayed in ***Table 8***.

Effect of the backrest roller's position on tear resistance

The position of the backrest has no effect on the tear resistance of the finished fabric in both the weft and warp directions (***Table 9***). Hence the backrest position has no effect on the breaking strength in the weft and warp directions nor on the densities of warp and weft yarns in the finished fabric. Consequently it could be deduced that these results are reasonable.

In grey fabric, the tear resistance is significantly influenced in the warp direction, but in the weft direction no significant effect is seen.

With an increase in the height of the backrest, the tear resistance in the warp direction increases. It can be explained that an increase in the warp density due to raising the backrest roller's height causes variations in the resistance to fabric tear. Thus the force required to tear the fabrics in the warp direction increases. In the horizontal position the trend is contrary - the tear resistance in the warp direction decreases with an increasing backrest depth. The decrease in warp density because of the increasing depth causes a lessening of the tear force. The results are given in ***Figure 9***.

Table 9. *Influence of backrest roller's position on the tear resistance of fabric.*

Backrest position		Grey fabric	Finished fabric	
		Tear force in weft direction, N	Tear force in warp direction, N	Tear force in weft direction, N
8	Height, cm	43.6	45.5	37.6
10		44.3	43.5	38.9
12		43.2	44.8	39.7
10	Depth, cm	44.3	42.1	39.1
15		44.5	43.5	38.9
20		44.1	43.2	38.4

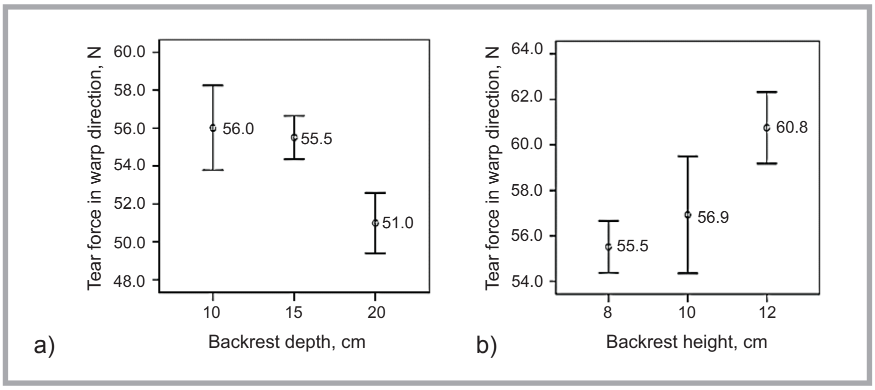

Figure 9. *Influence of backrest roller's depth (a) and height (b) on the tear resistance of grey fabric.*

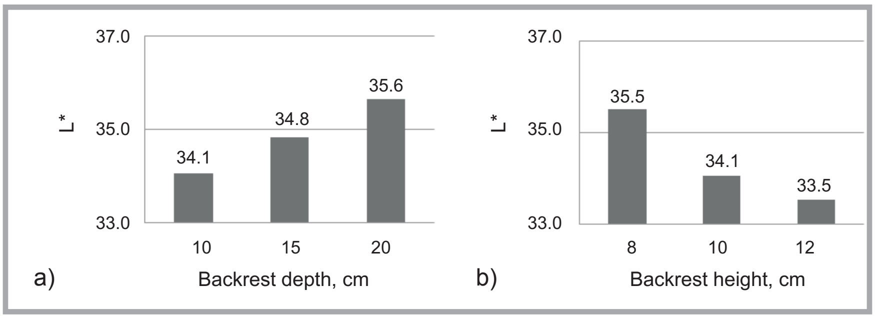

Figure 10. *Influence of backrest roller's depth (a) and height (b) on the surface colour of grey fabric.*

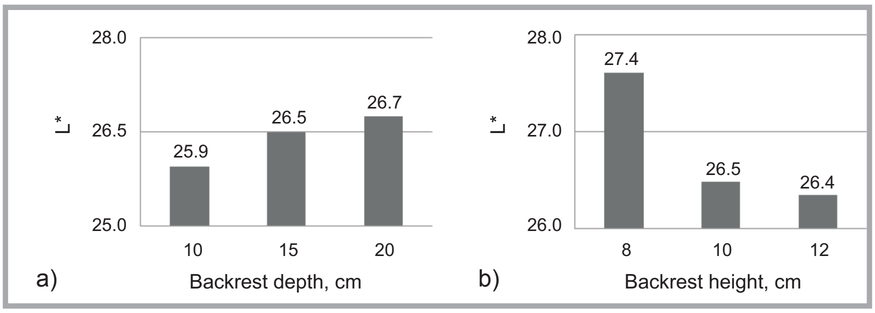

Figure 11. *Influence of backrest roller's depth (a) and height (b) on the surface colour of finished fabric.*

Effect of the backrest roller's position on fabric appearance (fabric surface colour)

When the backrest depth increases, the value of L* increases too, which means that the colour of the fabric becomes brighter (***Figure 10.a***). It is known that in a deeper position of the backrest the warp yarns are looser. Thus weft yarns can appear on the surface of fabrics, and because of the white colour of weft yarns, the fabric colour seems brighter.

In a higher position of the backrest, the value of L* decreases, which indicates the fabric colour is darker. It was mentioned that the warp density increases when the backrest is raised, thus the indigo colour of warp yarns causes the colour of fabrics to appear darker (***Figure 10.b***).

The results for the finished fabric are the same as for grey fabric. ***Figure 11*** (see page 65) show that for the finished fabric the value of L* is lower than that for grey fabric, which could be explained by the fact that the ratio of warp density to weft density in the finished fabric is greater than in grey fabric; therefore the colour of the finished fabric seems darker. Also the difference between maximum and minimum values of L* in the finished fabric is lower compared to grey fabric; the finishing process being the reason for this fact because in the process of finishing the fabrics become homogeneous, which causes differences between the properties of various fabrics to disappear.

Summary

In this paper, the effect of the backrest roller's position on the properties of grey and finished denim fabrics was studied. The results of the experiments are summarised below:

1) The results show that the depth and height of the backrest roller have a significant effect on the warp yarn density of grey fabric. With an increase in the backrest depth, the warp density decreases, and with a rise in the backrest height the warp density increases. Also the horizontal and vertical positions of the backrest roller have no effect on the weft yarn density of grey fabric.
2) Increasing the backrest depth causes a decrease in the maximum breaking force in the warp direction. In the higher position of the backrest, an increase in the maximum breaking force in the warp direction is observed. The backrest position has no significant influence on the breaking strength of grey fabric in the weft direction.
3) In grey fabric, with an increase in the depth of the backrest roller, elongation in the warp direction increases, and that in the weft direction decreases. As the backrest roller is raised, elongation in the warp direction decreases and in the weft direction increases.
4) The position of the backrest roller has no meaningful effect on the weight per unit area of grey fabric.
5) Increasing the backrest depth causes grey fabric's thickness to increase. At a higher height of the backrest roller, an increase in the thickness of grey fabric can be seen.
6) In the deeper position of the backrest roller, the air permeability of grey fabric increases. However, at a higher position of the backrest, air permeability decreases.
7) The depth and height of the backrest roller have a significant effect on the water permeability of grey fabric. The water permeability decreases when the depth decreases. When the height of the backrest is raised, the water permeability decreases.
8) The results show that there is no significant influence on the abrasion resistance of grey fabric due to the backrest roller's vertical and horizontal positions.
9) In grey fabric, with an increase in the height of the backrest, tear resistance in the warp direction increases. Tear resistance in the warp direction decreases with an increasing backrest depth.
10) The physical and mechanical properties of the finished fabric due to the finishing process become partially similar, because during the finishing operation about 12 percent overfeed of fabric is applied. This treatment causes homogeneity in the fabric properties. Therefore the horizontal and vertical position of the backrest roller have no significant influence on the physical and mechanical properties of the finished fabric, including the warp and weft yarn density, breaking strength and elongation at break in the warp and weft directions, weight per unit area, fabric thickness, air permeability, water permeability, abrasion resistance, and tear resistance.

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