Regarding the effect of finishing processes on some properties of stretch denim fabrics

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Regarding the effect of finishing processes on some properties of stretch denim fabrics

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Abstract. The present study aimed to evaluate the effect of industrial finishing and washing processes on some properties of stretch denim fabrics. The investigations have been carried out using stretch denim fabrics with a composition of 98% CO/2% EL and 3/1 Z twill weave. Starting from a greige denim fabric, through the application of various finishing treatments, six variants of finished denim fabrics were obtained. Subsequently, the finished fabrics have been subjected to washing processes commonly used for washing denim garments, in order to attain the appearance and properties as close as possible to those required by the garment products to be made of these materials. The effect of finishing treatments and washing processes on the denim fabrics was assessed by measuring certain structural and physical-mechanical properties. Have been selected and determined by usual laboratory testing methods - as objective assessment - those fabric properties that can be also subjectively assessed by the customers: fabric weight and thickness, fabric extensibility and flexural rigidity, coefficient of friction. The obtained results showed significant changes of fabrics properties both after industrial finishing treatments and after washing processes. These confirm the possibility of obtaining a diverse range of denim fabrics featuring various properties, starting from a single type of greige fabric, by using various finishing treatments and washing processes.

1. Introduction
Traditionally, denim is a strong and durable cotton fabric, produced with 2/1 or 3/1 twill weave constructions, in which the warp yarns are dyed with blue pigment obtained from indigo dye and the weft yarns are white. It is used for making jeans, jackets, shirts, skirts and many other garments for men and women of any age, as well as for children. Denim fabrics are widely used in the clothing industry because they bring together several features highly appreciated by the consumers. The denim garments are comfortable, durable, versatile, affordable, and always fashionable, being an appropriate choice for all age groups [1, 2, 4].

Since the people prefer comfortable and fashionable clothing, denim brands have become more interested in improving both the comfort and functional properties of their products, giving customers the opportunity to feel better while wearing these products. Consequently, a major area of innovation and development is devoted to diversifying the range of denim fabrics, by using varied types of fibres, yarns and finishing treatments [3,4]. Among these approaches, one important trend is represented by the manufacture of stretch denim fabrics. These fabrics, in which the weft system incorporates elastic core-spun yarns, show a high elasticity compared to other types of denim and ensure valuable comfort properties of the garment such as formability, fitting to the human body and shape retention after wearing [5, 6, 7].

The supply chain for denim products includes, among other stages, the necessary steps required for production of denim fabrics, garments manufacturing and finishing of denim garments. Generally,
after weaving, the denim fabric is subjected to mechanical and chemical treatments designed to ensure dimensional stability, soft surface and to prevent contraction in subsequent finishing and washing processes. Furthermore, by applying various fabric finishing processes, denim manufacturers have the opportunity to diversify their production and get a varied range of denim fabrics. Additionally, the finished denim fabrics may be subjected to diverse type of washings in order to obtain those aesthetic features expected by the customers for the garment products [8, 9]. This is a marketing strategy that results in a number of competitive benefits such as quicker response to market and fashion demands, higher flexibility in production, more design options available already in fabric stage, large variety of possible wash-down effects and increased added value. For these reasons, the denim companies make substantial investments in machines and equipment as well as in the development of processes and techniques allowing them to achieve a flexible production and to quickly meet the continuous changing in fashion trends.

2. Materials and methods

After manufacturing, the denim garments are often subjected to washing processes to obtain a wide variety of aesthetic and tactile effects. Therefore, for denim manufacturers, not only the characteristics of the finished fabrics provided to the garment factories are important, but also the way the washing processes can amend these. Considering this aspect, the present study aims to evaluate the effect of industrial finishing and washing processes on some properties of stretch denim fabrics.

The research has been carried out using stretch denim fabrics with a composition of 98% CO/2% EL and 3/1 Z twill weave, produced on PICANOL OMNI PLUS 800- air jet weaving machines. Structural characteristics of greige denim fabric are displayed in table 1.

| Table 1. Structural characteristics of greige denim fabric. |
|-------------------------------------------------------------|
| Fabric code | V0 |
| Composition | 98% CO/ 2% EL |
| Weave | Twill 3/1 |
| Yarn density | warp | 265 |
| (yarns/10 cm) | weft | 200 |
| Weight (g/m2) | 328 |
| Yarn linear | warp | 57 |
| density (tex) | weft | 63 |

Starting from one type of greige fabric, through the application of four types of finishing treatments (F1-F4), six variants of finished denim fabrics was obtained. The finished fabrics were subsequently washed by three different washing processes (W1-W3), commonly used for washing denim garments. The finishing processes applied to greige fabric as well as the washing processes used for finished fabrics are briefly described in table 2.

To assess the effect of finishing treatments and washing processes on denim fabrics, have been selected and measured by the usual laboratory testing methods - as objective assessment - those fabric properties that can be subjectively assessed by the customers: fabric weight and thickness, fabric extensibility and flexural rigidity, fabric coefficient of friction. These properties are important because contribute to creating a certain sensory feeling to customers when they manipulate the fabric and may have a considerable influence on their decision regarding the buying a specific garment item [10].

Physical-mechanical properties of the resulted denim fabrics variants were evaluated using specific testing equipment and methodologies, according to the applicable standards, as follows:

- Fabric weight, $M$ (g/m²) was measured using a Digital Electronic Balance-MESDAN, following the SR EN 12127:2003 standard.
- Fabric thickness, $g_p$ (mm) was measured with a Digital Thickness Tester Lab-MESDAN, according to the SR EN ISO 5084:2001 standard.
• Fabric extensibility in warp direction, $E$ (%) was determined with the Fryma Extensometer-SDL ATLAS, according to the BS EN 14704-1:2005 standard.
• Fabric flexural rigidity in warp direction, $R$ (mg·cm) was measured using the Fabric Stiffness Tester MTFEEM FF20-METRIMPEX, following the ASTM D1388:1996 standard.
• Dynamic coefficient of friction, $\mu_D$ was determined using the Shirley Fabric Friction Tester-SDL ATLAS, according to ISO 8295:1995 standard.

Before testing, all denim fabric samples were conditioned for 24 h at 65% relative humidity and 20°C, according to the SR EN ISO 139:2005 standard.

Table 2. Description of finishing and washing processes

| Industrial finishing process | Expected effect on the fabric surface appearance | Washing process | Fabric code |
|-----------------------------|------------------------------------------------|----------------|------------|
| $F1$: Brushing → Singeing → Caustification → Sanforizing → Acrylic coating* → Softening → Drying → Sanforizing | - Lustrous surface, leather effect | $W1$: Light rinse - protects the coating and gives the fabric an extra shine effect. | V1 |
|                             | - Mat surface effect                           |                | V2         |
|                             | - Semi-lustrous surface effect                 |                | V3         |
| $F2$: Brushing → Singeing → Caustification → Drying → Sanforizing → Resin treatment → Softening → Drying → Sanforizing | - Anti-crease and soft surface effect          | $W2$: Replica of the stonewashing process - used to achieve the worn and faded look of the fabric | V4 |
| $F3$: Brushing → Singeing → Caustification → Drying → Sanforizing | - Soft surface effect                          |                | V5         |
| $F4$: Brushing → Singeing → Overdyeing → Softening → Drying → Sanforizing → Heat setting | - Various shades and soft surface effect        | $W3$: Rinse for over dyed articles - used to remove the sizing agents and unfixed dyes | V6 |

*Acrylic coating allows obtaining different fabric surface effects by changing the composition of coating component

3. Results and discussion

Table 3 summarizes the values of physical-mechanical properties for both finished and washed denim fabrics, obtained as an average of five tests. The results show differences, sometimes considerable, between the properties of various finished denim fabrics. Changes of these properties were also observed after performing the washing process.

Table 3. Physical-mechanical properties of finished and washed denim fabrics.

| Fabric code | Fabric weight $M$ (g/m²) | Fabric thickness $g_p$ (mm) | Fabric extensibility $E$ (%) | Flexural rigidity $R$ (mg·cm) | Dynamic coefficient of friction $\mu_D$ |
|-------------|--------------------------|-----------------------------|-------------------------------|-------------------------------|----------------------------------------|
|             | Finished | Washed | Finished | Washed | Finished | Washed | Finished | Washed | Finished | Washed | Finished | Washed | Finished | Washed |
| V1          | 405     | 412    | 0.67     | 0.79   | 2.5      | 3.6    | 815.4   | 525.1  | 0.5546   | 0.6791 |
| V2          | 361     | 376    | 0.69     | 0.82   | 3.4      | 3.7    | 493.4   | 433.7  | 0.7129   | 0.8102 |
| V3          | 351     | 376    | 0.68     | 0.84   | 3.3      | 4.3    | 512.4   | 426.9  | 0.6809   | 0.7605 |
| V4          | 341     | 358    | 0.72     | 0.88   | 4.2      | 4.3    | 385.4   | 349.9  | 0.7540   | 0.8497 |
| V5          | 343     | 360    | 0.70     | 0.89   | 5.5      | 6.0    | 316.8   | 301.2  | 0.7534   | 0.8388 |
| V6          | 332     | 373    | 0.72     | 0.91   | 6.0      | 6.5    | 279.1   | 413.4  | 0.7530   | 0.8385 |
3.1. Fabric weight
As a result of the finishing processes, all variants of finished denim fabrics exhibit an increase in weight compared to the greige fabric (figure 1). This effect can be explained by the normal changes of fabric structural parameters, such as increasing the yarn density due to the fabric shrinkage, but also by the addition of finishing products such as coating components, resins, softeners. The highest increase of fabric weight was observed for the fabrics V1 (23.4%), V2 (10%) and V3 (7%), which were finished by acrylic coating, while for the others fabric variants the percentage increase was under 5%.

Following the washing process, the fabric weight increases again, but to a lesser extent (<7%), except for V6 variant that show a growth of weight by 12%.

3.2. Fabric thickness
Finished denim fabrics do not show significant differences in thickness (0.67 mm - 0.72 mm), the smallest values being obtained for acrylic coated fabrics V1 - V3.

After washing processes, the thickness increases at all fabric variants, but the trend is more significant for V4-V6 (figure 2). These fabric variants have undergone other finishing processes than the acrylic coatings - treatment with resin, overdyeing - and have been washed in a more aggressive manner to obtain the desired surface effect.

Based on these results it can be concluded that the acrylic coating has contributed to reducing the tendency of the fabric to shrink (by fixing the yarns in the fabric structure) thereby diminishing the effect of increasing the thickness.

3.3. Fabric extensibility
Fabric extensibility measures the increase in fabric dimensions when it is subjected to an applied load and is a significant mechanical parameter that influences the proper fit of the garment and the wearing comfort. From this point of view, the results revealed a different behaviour of the examined denim fabrics (figure 3). In this case of finished denim fabrics, the variants V1 - V4 exhibit lower values of extensibility (2.5% - 4.2%), while for the V5 and V6 variants this parameter has higher values (5.5% - 6%). Again, the particularities of the finishing processes can explain this behaviour. For V1-V4 variants, acrylic coatings and resin treatment limit the mobility of the yarns and hence reduce the fabric's ability to increase its size when subjected to loading, while for the other two finishes this effect does not occur.

Following the washing process, the extensibility of all fabric variants examined has increased, but in a different manner. The trend is more pronounced for variants V1 and V3 with 44% and respectively 30% increase, while for the other variants the increase in extensibility is under 10%.
3.4. Fabric flexural rigidity

Bending properties of the fabrics are determined by an assembly of factors such as yarn bending behaviour, fabric weave, finishing treatments and have a major influence on fabric's hand value and draping behaviour.

In terms of flexural rigidity, the analysed fabrics showed a quite different behaviour, but in agreement to the trends amending extensibility (figure 4). Acrylic coating imparts stiffness to finished denim fabric and this effect is confirmed by the high flexural rigidity values obtained especially for fabric variants V1 but also for V2 and V3. The other variants of denim fabrics are less rigid, but they are also different from each other. After washing processes, the rigidity of fabrics decreased, with percentages varying between 35% (V1) and 5% (V5); only for fabric variant (V6) it was seen that the washed fabric is stiffer than the finished fabric.

![Figure 3. Effect of the applied treatments on the fabric extensibility.](image)

![Figure 4. Effect of the applied treatments on the fabric rigidity.](image)

3.5. Coefficient of friction

Coefficient of friction is a parameter that can be used to evaluate the fabric’s surface appearance in terms of smoothness or roughness, the smaller values showing a smoother surface.

The obtained results confirm that both the finishing and washing treatments have influenced the surface properties of denim fabrics (figure 5). Analysing the coefficient of friction's values, one can say that the variants of acrylic coated denim fabrics (V1-V3) have a smoother surface compared to the other variants. The same situation is maintained after the washing process, but in this case the coefficient of friction has higher values and the differences between fabric variants become smaller, except the variant V1 which remain in first place, with the smoothest surface.

![Figure 5. Effect of the applied treatments on the fabric coefficient of friction.](image)
4. Conclusions
This study aimed to evaluate the effect of industrial finishing and washing processes on the properties of denim stretch fabrics by assessing some physical-mechanical properties important from the point of view of the sensory perception that customers have when handling the material.

The results showed substantial changes in the fabric properties both after the industrial finishing treatments and after the washing processes, confirming the possibility of obtaining a range of denim fabrics with different properties, starting from a single type of greige fabric. For denim factories, this is an intelligent strategy that allows them to be more flexible and respond quickly to the changing demands of the market and customers.

Complementing the classic strategy for testing finished denim fabrics with testing of washed denim fabrics give a clearer picture of the possibilities for further diversification, providing designers and garment manufacturers with more information about how the final products will look like.

It is important, however, to find out whether these differences can be perceived by customers who do not have a specialized training in textiles. In our future studies, we will try to establish the relationship between the fabric profile obtained by objective evaluation and the perception of the customers, obtained by subjective evaluation.

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