# THE IMPACT OF THE RAW MATERIAL COMPOSITION OF MEN'S RIB-KNITTED SOCKS ON THEIR COMPRESSION PROPERTIES

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**Abstract:** *The study examines the impact of the raw material composition of men's rib-knitted socks on their compression properties and, indirectly, on their comfort during use. The research involves six different fibers that constitute the dominant yarn in the sock composition, making up 77%. The remaining yarns consist of polyamide and wrapped rubber threads, accounting for a total of 23%. Measurements determined that the sock with the highest softness is made from a cotton/polyester yarn blend, while socks made from other yarns lag significantly behind. Additionally, socks knitted from cotton or blends with polyester provide the highest values for linearity and compression energy. For the elastic recovery of socks after compression, the sample made from modal fibers proved to be the best. The thickness of the knit under different pressures is the greatest in socks made from bamboo yarn, for both pressure levels. Socks with a cotton/polyester yarn exhibit weaker elastic recovery, while socks with modal yarn show better elastic recovery. Through six combinations of raw material compositions and the evaluation of multiple compression properties, rib-knitted sock models can be selected for appropriate purposes, whether in a medical context, for home use, or for active wear outside the home.*

**Keywords:** raw material composition, men's socks, rib knit, compression.

# UTICAJ SIROVINSKOG SASTAVA MUŠKIH ČARAPA U REBRASTOM PREPLETAJU NA NJENA KOMPRESIJSKA SVOJSTVA

**Apstrakt:** *Istraživanje razmatra uticaj sirovinskog sastava čarapa u rebrastom prepletaju na svojstva kompresije a posredno i na svojstva komfora tokom korišćenja. U istraživanju učestvuje šest različitih vlakana koja izgrađuju dominantnu pređu u sastavu čarapa, 77%. Ostale pređe su od poliamida i obmotane gumene niti, ukupno 23%. Merenja su utvrdila da je čarapa sa najvećom mekoćom izrađena iz mešavine pamuk/poliestar pređe, dok čarape od ostalih pređa znatno zaostaju. Takođe, čarape ispletene od pamuka ili u mešavini sa poliestrom daju najviše brojne vrednosti za linearnost i energiju kompresije. Za elastičan oporavak čarapa posle kompresije, najboljim se pokazao uzorak čarapa od modalnih vlakana. Debljina pletenine pri različitom pritisku najveća je kod čarapa od bambus pređe, za oba nivoa pritiska. Čarapa sa pamuk/poliestar pređom ima sla-*

*biji, dok čarapa sa modalnom pređom, ima bolji elastični oporavak. Kroz šest kombinacija sirovinskog sastava i provere više kompresijskih svojstava, mogu se odabrati modeli čarapa u rebrastom prepletaju za odgovarajuću namenu u medicinskom smislu, kućnoj varijanti ili tokom aktivnog nošenja izvan kuće.*

**Ključne riječi:** sirovinski sastav, čarape, rebrasti prepletaj, kompresija.

## 1. INTRODUCTION

Rib knit fabric is a type of knitted textile characterized by its distinct vertical ribs or raised lines formed by alternating knit and purl stitches. This unique structure gives the fabric excellent stretch and recovery, making it highly elastic and form-fitting. Rib knit fabric is soft, durable, and typically medium to heavy in weight, with a textured appearance and a somewhat stiff drape. Socks made from rib knit fabric, which is a type of stretchy, textured knit material featuring vertical ribs. These socks are known for their elasticity, comfort, and snug fit [1, 2].

Compression properties of knitted fabrics refer to their ability to apply pressure to the body's surface, which is utilized in various applications such as medical textiles (compression stockings), sportswear, and protective equipment. These properties depend on the knit structure, material, and manufacturing process [3, 4].

Factors influencing the compression properties of knitted fabrics include the knit structure, material, stress level, manufacturing process, and more [5, 6].

Compression socks are specialized hosiery designed to apply gentle, graduated pressure to the legs and ankles, which helps improve blood flow and circulation. They are tightest around the ankle and gradually loosen toward the calf or thigh, promoting the upward flow of blood back to the heart and preventing blood from pooling in the lower extremities [7].

Compression properties of socks refer to their ability to apply controlled pressure to the legs, improving blood circulation and reducing swelling. This type of sock is designed to provide gradient pressure—the highest pressure is typically applied at the ankles and gradually decreases toward the upper part of the leg [8].

The benefits of compression socks include improved circulation, i.e., prevention of blood pooling in the lower legs; reduction of swelling, which is particularly useful for individuals who stand or sit for extended periods; alleviation of symptoms associated with varicose veins, leg pain, and chronic venous insufficiency; and a reduced risk of thrombosis, which is important for travel and postoperative recovery [9, 10].

This research aims to fundamentally present the impact of the raw material composition of men’s rib-knitted socks on their compression properties and, indirectly, on their comfort properties. Through six combinations of raw material compositions and the evaluation of multiple compression properties, the most suitable raw material composition of rib-knitted socks is selected for specific purposes, whether in a medical context, for everyday home use, or during active wear outside the home.

## 2. MATERIALS AND METHODS

The study utilized men's socks with the same knit structure (rib R3:1 knit structure), made from yarns of different fibers: the first yarn is the dominant yarn made from bamboo, modal, viscose, cotton, cotton-compact, or a cotton/polyester blend; the second yarn is polyamide; and the third is a wrapped rubber thread. All sock samples were knitted in a rib-knitted structure, sized 11 (42-43). The nominal linear density of the dominant yarns is 30 tex in all cases, the filament yarn from PA 6.6 has a nominal linear density of 4.4/13×2 tex, while the third type of yarn, the wrapped rubber thread, has a nominal linear density of 100 tex.

The evaluation of key characteristics of the socks was conducted according to relevant standards and methods:

- Thickness, according to the EN ISO 5084 standard.
- Surface mass, according to the EN 12127 standard.
- Porosity was calculated based on the literature [11].
- The compressibility properties of knitted fabrics under low loads were tested on the KES-FB system (Kato Technical Co. Ltd., Japan). The testing conditions for the compressive characteristics of the knitted fabrics involved lateral compression of a 2 $cm^2$ surface tube at a speed of 50 $s{\cdot}mm^{-1}$ within a compression range of 0.5 $cN{\cdot}cm^{-2}$ to 50 $cN{\cdot}cm^{-2}$.

Table 1 presents the results of the reometrical parameters of men’s rib-knitted socks. The thickness of the socks varies depending on the type of dominant yarn, as the other yarns in the sock composition are identical. Since the socks are made from yarns with similar linear densities and twist counts, significant differences in knitted fabric thickness arise due to differences in the raw material composition. Socks made with cotton and cotton-compact as dominant yarns have slightly greater thickness.

The surface mass of the knit fabric for socks varies depending on the dominant yarn in the composition. Socks knitted with BB dominant yarn have the highest values for surface mass. This is an important technological parameter and largely depends on its horizontal and vertical density. Additionally, surface mass integrates all key parameters of the knit structure and is an important economic factor, as it significantly influences the cost of the knit fabric [12].

The porosity of the knit fabric indicates the volumetric proportion of voids in the fabric. Generally, socks with CO and COc fibers in the dominant yarn have the highest percentage of porosity. Porosity also depends on the thickness of the knit; as the thickness of the material increases, its volume also increases, which is generally accompanied by a greater amount of incorporated air. This air, trapped between the fibers in the yarn and between the yarns in the knit, slows down the process of heat transfer [13].

The highest numerical value for thickness, regardless of raw material composition, corresponds to the highest numerical values for porosity. Individually, based on the composition of the dominant yarn, it was observed that socks made from viscose and bamboo dominant yarns have slightly lower porosity values, which is associated with the fact that these yarns typically have lower bending stiffness. This allows the knit loops to be easily compressed, thereby reducing the thickness of the knit.

## 3. RESULTS AND DISCUSSION

According to the results in Table 2 for socks in rib R3:1 knit structure and size 11 (42-43), the sock with the highest softness is made from a CO/PES dominant yarn blend, while socks made from other yarns significantly lag behind. Additionally, socks knitted from natural fibers or blends with polyester show the highest numerical values for linearity and compression energy. For elastic recovery after compression, the best performance is observed in socks made from modal dominant yarn. The thickness of the knit under different pressures (49 or 4,900 $N \cdot m^{-2}$) varies depen-

**Table 1:** Geometrical parameters of men's socks in rib knit structure

| Sample Labels | Raw material composition of socks | Thickness (mm) | Surface mass ($g \cdot m^{-2}$) | Porosity (%) |
|---|---|---|---|---|
| BB | Bamboo, 77%<br>PA 6.6, 22%<br>Wrapped elastic thread, 1% | 1.700 | 315.5 | 87.8 |
| MD | Modal, 77%<br>PA 6.6, 22%<br>Wrapped elastic thread, 1% | 1.734 | 314.7 | 88.1 |
| CV | Viscose, 77%<br>PA 6.6, 22%<br>Wrapped elastic thread, 1% | 1.655 | 313.2 | 87.5 |
| CO | Cotton, 77%<br>PA 6.6, 22%<br>Wrapped elastic thread, 1% | 1.933 | 314.9 | 89.5 |
| COc | Cotton-compact, 77%<br>PA 6.6, 22%<br>Wrapped elastic thread, 1% | 1.867 | 310.4 | 89.3 |
| CO/PES | Cotton/Polyester, 77%<br>PA 6.6, 22%<br>Wrapped elastic thread, 1% | 1.783 | 307.1 | 88.4 |

ding on the raw material composition, with the highest thickness observed in socks made from bamboo dominant yarn at both pressure levels. As expected, at higher pressure (4,900 $N \cdot m^{-2}$), the sock thickness is reduced.

In the case of an ideally elastic textile material, the thickness would decrease linearly with applied load, and the parameter characterizing the linearity of the compression curve (LC) would have a value of 1. According to Table 2, the LC value for the sock model labeled COc is close to 1 (0.93), meaning that as compression increases, the thickness of the sock decreases almost proportionally.

Compression curves constructed based on recorded changes in knit thickness during loading and unloading, shown in Figures 1–4, allow for a more precise analysis of the phenomenon of lateral compression. The compression curves illustrate a nonlinear relationship between changes in knit thickness and increasing compression load, except at the beginning of the compression cycle, where, under lower load values, the knit thickness changes linearly with the load, corresponding to elastic deformation. With further increases in compression load, the compressibility of the knit decreases, which can be explained by its structure. In this phase, where the relationship between knit thickness and compression load ceases to be linear, fiber friction and slippage occur, accompanied by a reduction in the amount of air. The third phase of compression, in which small changes in knit thickness occur with increasing compression load, involves the lateral compression of the fibers themselves [8, 14].

As can be seen from the pressure/thickness diagrams (Figs. 1–4), the nonlinear region is longer than the first and second linear regions. The hysteresis exhibited by knits of different raw material compositions confirms the presence of permanent deformation during sock compression. Since the ability of a material to elastically recover is inversely proportional to the area of the hysteresis loop, a smaller hysteresis area indicates better elastic recovery of the socks.

"Harder" socks exhibit a steeper rising compression, indicating lower values for compression linearity. This is typical for "harder" knits, as the LC value is highly sensitive to thickness under low pressure. It should be noted that the segments of each region varied significantly depending on the type of fiber in the yarn. For all sock samples, the first and second linear regions were smaller, while the nonlinear region was considerably larger. The nonlinear region primarily arises due to internal and inter-fiber friction; as the nonlinear region increases, the compression of the socks becomes softer and more compressible.

When comparing sock models of the same knit structure but different raw material compositions (Figs. 1–4), similarities in the appearance of the compression and decompression curves can be observed. The difference is that, for example, in socks made from CO/PES dominant yarn, the thickness during compression ranges from 2.35 mm, while decompres-

**Table 2:** Measurement results of various compression parameters (KES-FB system) of men's socks

| Sample Labels | C (%) | LC | WC ($J \cdot m^{-2}$) | RC (%) | TO ($\times 10^{-3}$m) | TM ($\times 10^{-3}$m) |
|---|---|---|---|---|---|---|
| BB | 25.18 | 0.79 | 1.37 | 35.12 | 2.82 | 2.11 |
| MD | 35.71 | 0.67 | 1.23 | 41.88 | 2.10 | 1.35 |
| CV | 34.67 | 0.69 | 1.17 | 33.22 | 1.99 | 1.30 |
| CO | 38.69 | 0.88 | 1.90 | 38.59 | 2.30 | 1.41 |
| COc | 37.90 | 0.93 | 1.90 | 29.71 | 2.19 | 1.36 |
| CO/PES | 42.37 | 0.85 | 2.06 | 31.43 | 2.36 | 1.36 |
| Legend | C – Relative compressibility<br>LC – Linearity of compression<br>WC – Compression energy<br>RC – Compression resistance (compression elasticity)<br>TO – Knitted fabric thickness at a pressure of 49 $N \cdot m^{-2}$<br>TM – Knitted fabric thickness at a pressure of 4,900 $N \cdot m^{-2}$ | | | | | |

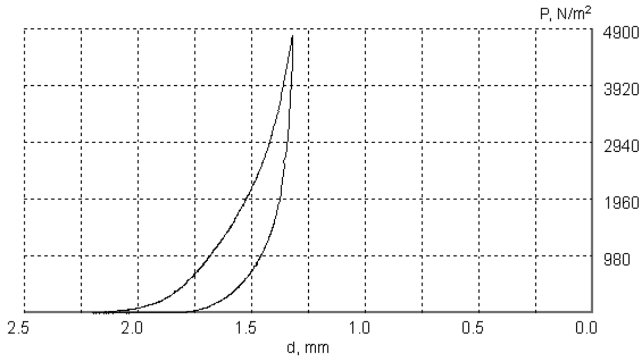


**Figure 1:** Pressure/thickness diagram for bamboo men's socks

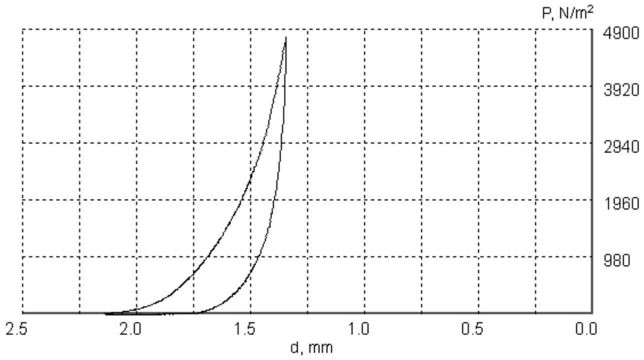


**Figure 2:** Pressure/thickness diagram for modal men's socks

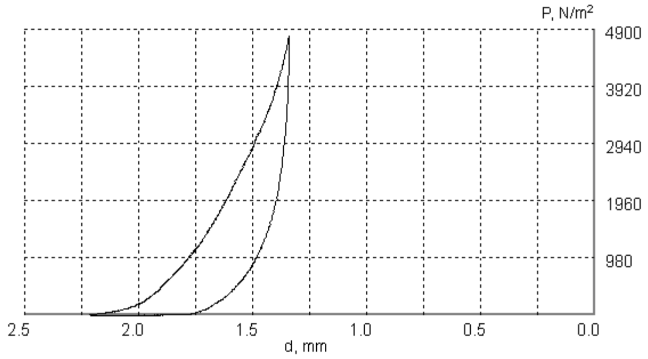


**Figure 3:** Pressure/thickness diagram for cotton-compact men's socks

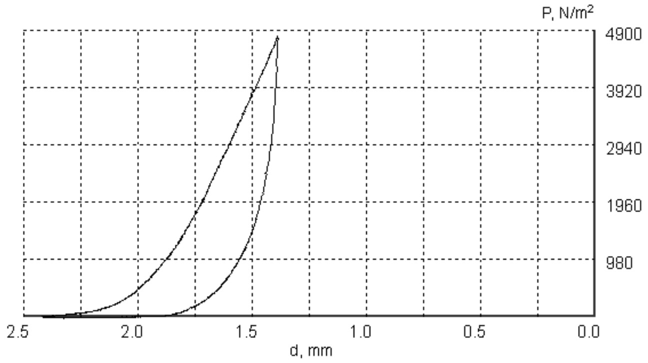


**Figure 4:** Pressure/thickness diagram for CO/PES men's socks

sion ends at 1.85 mm. In socks made from modal, the thickness range during compression/decompression spans from 2.1 mm to 1.74 mm. A greater difference between the start and end of the hysteresis loop primarily results in a larger loop area. Since the elastic recovery ability of the knit is inversely proportional to the area of the hysteresis loop, socks with CO/PES yarn will exhibit weaker recovery, whereas socks with MD yarn will show better elastic recovery.

## 4. CONCLUSION

The paper analyzes the impact of the raw material composition of men's rib-knitted socks on their compression properties, allowing for their use in various situations.

If a sock with the highest softness is desired, the one made from a CO/PES dominant yarn blend should be chosen, as it is ideal for home wear.

For elastic recovery of socks after physical activity, a model made from modal dominant yarn is preferred.

The knit thickness changes least under different pressures in socks made from bamboo dominant yarn, which is helpful for certain foot medical issues.

Through six combinations of raw material compositions and the examination of several compression properties, the most favorable combination of raw material composition for men's rib-knitted socks is selected for the appropriate purpose: recreation, medical use, home wear, or outdoor use.

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