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BENDING BEHAVIOR OF RAYON AND WOOL TYPE POLYESTER FIBERS THERMAL TREATED

BORDEIANU Demetra Lăcrămioara[1], HRISTIAN Liliana[2], LUPU Iuliana Gabriela[3], VILCU Adrian[4]

[1, 2, 3, 4] *"Gh.Asachi" Technical University of Iasi, Romania, Faculty of Textile, Leather and Industrial Management, Prof. Dr. Doc. Dimitrie Mangeron Str., No. 29, 700050, Iasi*

Corresponding author: Bordeianu Lăcrămioara Demetra, e-mail: dlb@tex.tuiasi.ro

Abstract: *Given the fact that bending rigidity influences to a great extent the product handle and considering that the market demands products with a soft, pleasant handle, one must pay a special attention to these characteristics and especially to the treatments that modify the bending rigidity.*
It was found that any mechanical or thermal treatment brings modifications of the bending rigidity, in terms of the fibers nature and treatment conditions.
In most of the methods meant to determine the bending rigidity one must measure the amount of deflection of the fibers end in constant cross-section either under the action of the weight.
The textile products are subjected to flexion, to repeated and frequent bending due to knotting and kinking during both the processing and exploitation. All these result in the appearance of stresses of various natures depending on the fibers type. The strains and fiber destruction as the result of these stresses depend on a series of factors related to the fibers composition and intermolecular and intra-molecular structure, their yarn count, elastic modulus, fiber flexibility, finishing procedures or products texture, etc.
Following the performed measurements, we calculated the bending rigidity for the witness samples and for thermally cured fibers; then we divided them in classes and we graphically represented their distribution in terms of the bending rigidity.

Key words: *bending rigidity, flexion, wrapped fiber, deflection*

1. INTRODUCTION

Among the methods used to determine the bending rigidity, we can specify:
Cambridge Method: the device measures either the force necessary to produce a constant deflection, or the deflection corresponding to a force of a conventional size [1], [2].

$$R_i = \frac{F \cdot l^3}{48 \cdot f} \quad \textbf{(1)}$$

where f - maximum deflection;
F- force that produced the bending;
l - fiber length, mm
***Peirce Method*:** the determinations can be performed either on a fiber or a bundle of fibers shaped as a loop.The loop elongation is measured in percentages or in absolute value.The bigger the loop elongation, the smaller the bending rigidity [3], [4], [5].

$$R_i = \frac{F \cdot L^2}{z} \quad \textbf{(2)}$$

where: z = d/L;
d- loop deformation;
F- tensile strength, cN;
L-bending length, mm

***Suthrie Method*:** the deflection is measured for a fiber or a bundle of fibers embedded at one end, while a conventional force is acting at the other end:

$$f = \frac{F \cdot l^3}{3 \cdot E \cdot I} \quad \textbf{(3)}$$

where: f maximum deflection (arrow);
F- tensile strength;
l - fiber length, mm;
I- inerta moment;
E- Young's modulus.
Bending rigidity can by calculated using the following relation:

$$R_i = \frac{F \cdot l^3}{3 \cdot f} \cdot E \cdot I \quad \textbf{(4)}$$

Method proposed by Prof. I. Vlad has as a principle winding the fibers round a plate of known perimeter, with a standard stress (0.5 cN/tex), thus producing turns whose radius of curvature will be the higher, the bigger the fiber flexion.

Taking as reference the perimeter of the winding cross-section, given by the formula:

$$P = 2(a + b) \quad \textbf{(5)}$$

$$P = l \cdot r \quad \textbf{(6)}$$

a - plate thickness
b - plate width,
the bending rigidity is calculated with the formula:

$$R_i = \frac{P}{l_s} \cdot 100 \ (\%) \quad \textbf{(7)}$$

l_s – mean length of the turn wound on the plate

$$l_s = \frac{N_s}{l_f} \quad \textbf{(8)}$$

l_f – initial fiber length
N_s – number of wound turns.

The bending rigidity is determined as follows:
- determine the initial fiber length (l_1);
- wrap a round number of turns (n) on a plate;
- determine the difference of unwrapped length;
- calculate the length of the wrapped fiber corresponding to the number of turns n;

$$l_{ns} = l_1 - l_2 \quad \textbf{(9)}$$

- calculate the length of a turn:

$$l_s = \frac{l_{ns}}{n} \quad \textbf{(10)}$$

- calculate the bending rigidity with the formula:

$$R_i = \frac{l_r}{l_s} \cdot 100 \quad (\%) \quad \textbf{(11)}$$

In the case R_i = 100%, the fibers have the smallest rigidity, i.e. this is the ideal case.

2. EXPERIMENTAL PART

In order to analyze the fibers bending rigidity we performed studies on a rayon fiber and a synthetic fiber: wool type polyester.

Following the performed measurements, we calculated the bending rigidity for the witness samples and for thermally cured fibers; then we divided them in classes and we graphically represented their distribution in terms of the bending rigidity.

From Table 1 can be notice for the polyester fibers that very close values of bending rigidity were obtained.

The polyester fiber suffered small stiffening. This can be explained by the fact that the polyethylene terephtalate absorbs a very small amount of water and resists very well to thermal cure up to 150°C.

Structural modifications can appear due to the mobility of molecular segments in non-crystalline zones.

With the increase of the treatment temperature and duration, the packing density increases, this being ascribed to a corresponding increase of crystallinity.

Since, according to the measurements, the results obtained for rayon fibers were contrary to those for polyester fibers, namely after the thermal cure the fiber does not get stiffer but softer, we ascribed this to the non-uniformity of fiber diameter.

Table 1: *Bending Rigidity and Coefficient of Variation Values*

No.	Fiber denomination	Bending rigidity (R_i) (%)	Coefficient of variation (CV) (%)
1.	Polyester 4 den/76 mm, untreated	87.39	2.02
2.	Polyester 4 den/76 mm, treated (dyed)	87.19	1.59
3.	Rayon type L 15 den/100 mm untreated	90.86	1.22
4.	Rayon type L 15 den/100 mm, heat treated for 10 minutes	90.74	1.17
5.	Rayon type L 15 den/100 mm, heat treated for 20 minutes	90.71	1.10
6.	Rayon type L 15 den/100 mm, heat treated for 30 minutes	90.64	1.10
7.	Rayon type L 15 den/100 mm, heat treated for 40 minutes	90.62	1.22

We performed a new series of measurements, determining at first the diameter of each fiber and then the corresponding rigidity. We noticed that the diameter does not influence too much the rigidity and indeed, after the thermal cure, the wool-type rayon fiber has a softer handle.

The coefficient of variation (CV) refers to a statistical measure of the distribution of data points in a data series around the mean. It represents the ratio of the standard deviation to the mean. The coefficient of variation is a helpful statistic in comparing the degree of variation from one data series to the other, although the means are considerably different from each other [6].

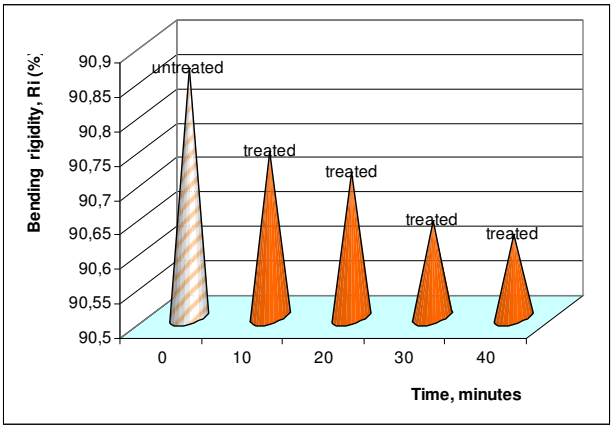

Fig.1: *Distribution in terms of the bending rigidity*

This is due to the fact that viscose has a very non-uniform structure with a core/coating structure having a different degree of orientation and crystallization.

3. CONCLUSIONS

Viscose presents an important diminution of resistance in wet condition, due to swelling and sliding of molecular chains as the result of intermolecular chains breaking.

The hydroxyl groups of cellulose, which became free during water absorption, are not completely able to re-form the initial bonds. One should add to this a certain rigidity of the large cellulose macromolecules which, due to their inertia, obstruct the return of fiber structural elements to their initial position; this results in a looser structure, less rigid to bending.

By analyzing the polyester fibers, one can notice that the variation range is much narrower, and the variation coefficient is much smaller. After the thermal cure, polyester does not change its bending rigidity; being a fiber very resistant to high temperatures, it is not very affected by the treatment to which it is subjected during dyeing.

The rayon fiber does not satisfy the statements made in the case of polyester, such that, following the thermal cure, as the cure duration increases its bending rigidity decreases. This can be explained by the fact that during the thermal cure in wet medium the cohesion forces between molecules decrease and the fibers have a looser structure and, as new cohesion forces can not appear, their softness increases.

A characteristic of the rayon is that there are two maxima in its distribution curves, probably due to the variation of the fiber diameter. The variation range is quite wide, but the coefficient of variation has still quite small values.

It results that during fibers and products manufacturing, as well as during the exploitation of textile products, one should pay a very great attention to both the temperature and duration of exposure to these temperatures. If it is not possible to carry out the process at high temperatures, it should be correlated with durations as short as possible, in order to avoid fiber destruction that can down-grade the corresponding products.

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