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Influence of some parameters on the warping of the sawn wood of *Pinus caribaea Morelet, var. Caribaea*

Influencia de algunos parámetros en el alabeo de la madera aserrada de *Pinus caribaea Morelet, var. Caribaea*

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ABSTRACT

The aim of this paper is to describe the influence of the fibre inclination and the width of the growth rings on the deformations (warping), in the radial direction of the sawn wood (post drying) of *Pinus caribaea Morelet, var. caribaea.* One hundred sawn wood pieces were taken from three positions in the log, at different distances from the pith in the radial direction, coded as A (12 cm), B (24 cm) and C (36 cm). To measure the width of the growing rings, a callipers was used, taking a referential position in the horizontal direction. The inclination of the fibre was measured using a pointed piece and a tape measure and the length of the sides was determined: the opposite cathetus and the hypotenuse of the triangle formed and applying the expression the studied angle was determined. As a result, it was obtained that the inclination of the fibre, the width of the growth rings and warping decrease towards the bark. The correlation coefficient between warping and fibre inclination is 0.372 and between warping and ring width is r = 0.859.

Keywords: warping; rings; sawn wood; fibre; inclination.

RESUMEN

El trabajo que se presenta tiene como objetivo describir la influencia de la inclinación de la fibra y el ancho de los anillos de crecimiento en las deformaciones (alabeo) en la dirección radial de la madera aserrada (postsecado) de *Pinus caribaea Morelet*, *var. Caribaea.* Se tomaron 100 piezas aserradas de tres posiciones en la troza, a diferentes distancias de la médula en la dirección radial, codificadas como A (12 cm), B (24 cm) y C (36 cm). Para medir el ancho de los anillos de crecimiento se utilizó un pie de rey, tomándose una posición referencial en la dirección horizontal. Se hicieron mediciones de la inclinación de la fibra, haciendo uso de una pieza puntiaguda y una cinta métrica y se determinó la longitud de los lados: cateto opuesto e hipotenusa del triángulo formado y aplicando la expresión se determinó el ángulo objeto de estudio. Como resultado se obtuvo que la inclinación de la fibra, el ancho de los anillos de crecimiento y alabeo disminuyen hacia la corteza. El coeficiente de correlación entre alabeo e inclinación de la fibra es de 0,372 y entre alabeo y ancho de los anillos es de r = 0,859.

Palabras clave: alabeo; anillos; aserrada; fibra; inclinación.

INTRODUCTION

The need for industrialization, the increase in the standard of living of the population and the development of agriculture that has been taking place in recent times in Cuba, requires every day a greater demand for wood; however, in the sawmill industry there is a problem: the sawn wood of *Pinus caribaea Morelet,* var. *Caribaea,* does not meet the demands of the construction sector, given the deformations it presents after drying.

Because of the need to increase the market for wood, it is a priority to find a way to minimize twisting. Twisting or deformation is one of the main causes affecting wood quality. The lack of straightness in wood is one of the main reasons that limit the satisfaction of wood products in the world. Johansson *et al.,* (1994).

A study of deformations can lead to the identification of relevant properties, as well as the most important parameters that have a direct influence on the quality of the product, and therefore help in the proper selection of the material before sawing and drying in order to optimise the use of each log received in the sawmill. Álvarez, (2007).

During the drying process of sawn timber, a humidity gradient appears, which is unavoidable given the existence of the wood thickness, as well as a drying tension which, due to the difference in shrinkage, conditions twists and other deformations.

Authors such as Calderón (2016) refer to the simultaneous warping of the faces of a squared piece in the longitudinal and transversal directions, which results in a twisting of the wood in the manner of a corkscrew; generally, the twisting manifests itself in wood with intercrossed grain.

The tensions of growth harm to a great extent some uses of wood, because they promote the presence of cracks and crevices in the heads of rolls and sawn pieces, as well as causing the manifestation of warps in sawn pieces Calderón, (2016). This author recognizes that the spiral grain is presented with greater intensity in the wood close to the pith, decreasing in the growth rings formed far from it.

Calleros, (2015) considers that wood fibre grows parallel to the axis of the tree, but sometimes it acquires other senses and, as a consequence of this, in some operations such as when drying, the tendency to bend increases and the resistance of the wood decreases in the direction of the axis of the tree. Other authors such as Sosa and others (2016) conclude in their study that the load that the wood bears depends on the direction in which it is applied with respect to the direction of the fibre.

Forsberg (2001) states that the two parameters most commonly associated with twisting are: distance from the marrow (which is an indirect expression of the curvature of the annual ring) and the angle of inclination of the fiber.

Perstorper *et al.,* (2001) and Johansson *et al.,* (2001) have shown experimentally that the twist is given by major factors such as the annual ring curvature and the spiral grain angle.

One way to deal with the problem of wood deformations is to understand the mechanisms that regulate wood deformations; consequently, the aim of this paper is to describe the influence of the fibre inclination and the width of the growth rings on the deformations (warping) in the radial direction of the sawn wood (post-drying) of *Pinus caribaea Morelet, var. Caribaea.*

MATERIALS AND METHODS

The sawn pieces were obtained from plantations belonging to the Unidad Silvícola "San Simón de las Cuchillas", San Juan and Martínez. The sawmill "Álvaro Barba" and the sawmill located on the road to San Juan y Martínez, all belonging to the Agroforestry Enterprise of Pinar del Río, are taken as reference.

The measurements, referring to the physical properties were made in the laboratories of the Tropical Scientific Research Institute and the Civil Engineering Laboratory in Lisbon, Portugal, using specimens from logs obtained in the Agroforestry Enterprise of Pinar del Río.

Considering the procedure established by Durán (1999) and ASTM D245 (2006), the study of the fibre inclination was carried out, which allowed defining its influence on the warping of the sawn wood of *Pinus caribaea Morelet, var. Caribaea*. 100 sawn pieces were taken from three positions in the log, at different distances from the pith in the radial direction, coded as A (12cm), B (24 cm) and C (36cm) (Figure 1).

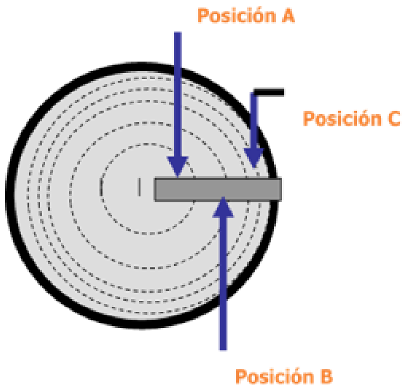

Fig. 1. Posiciones en dirección radial.

The fibre inclination was measured using a pointed piece and a tape measure (with an accuracy error of 0.1 mm) and the length of the sides a was determined as the opposite leg and b as the hypotenuse of the triangle formed; applying the expression (1), the angle under study was determined (Figure 2).

$$\left(sen\theta = \frac{catet.opuesto}{hipotenusa} \right) (1)$$

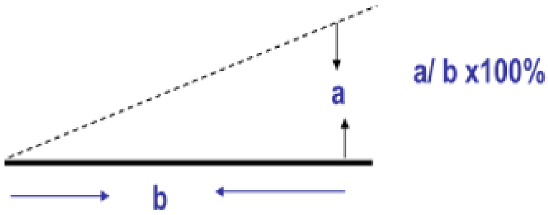

Fig. 2. Inclinación de la fibra.

Repeated measurements were made at three different positions along the sawn piece and the value of this magnitude was taken as the value of the highest frequency. In order to measure the width of the growth rings, the procedure of Kliger (2002) is assumed. A reference position was taken in the horizontal direction, using a caliper foot (with an accuracy error of 0.05 mm) (Figure 3).

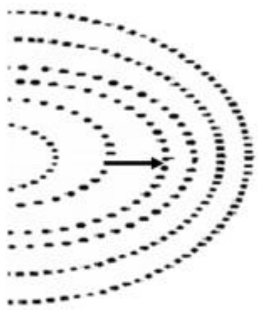

Fig. 3. Ancho de los anillos en dirección radial.

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RESULTS AND DISCUSSION

Analysis of the influence of the inclination of the fibre and the width of the rings on the warp of the sawn wood of *Pinus caribaea Morelet, var. Caribaea* The values of the measurements of the wood parameters are shown in table 1 (Table 1).

Tabla 1. Valores medios de la inclinación de la fibra y ancho de los anillos de crecimiento. Análisis de comparación de medias, según SNK.

Características	Posición A (12cm)	Posición B (24cm)	Posición C (36cm)
Inclinación fibra (cm.)	0, 35211a	0,19263b	0,18333c
Ancho anillos (mm)	8, 78263a	5,06526b	2,63737c

Results with the same letter, there is no significant difference between them for p ≤0,05.

Fiber inclination

As shown, the fibre inclination decreases towards the cortex in the radial direction (see figure 4 and table 1).

The correlation coefficient between warp and fibre inclination is 0.372; similar values have been found in studies carried out by Perstorper, (2001) which give a correlation coefficient of 0.26 (Table 4).

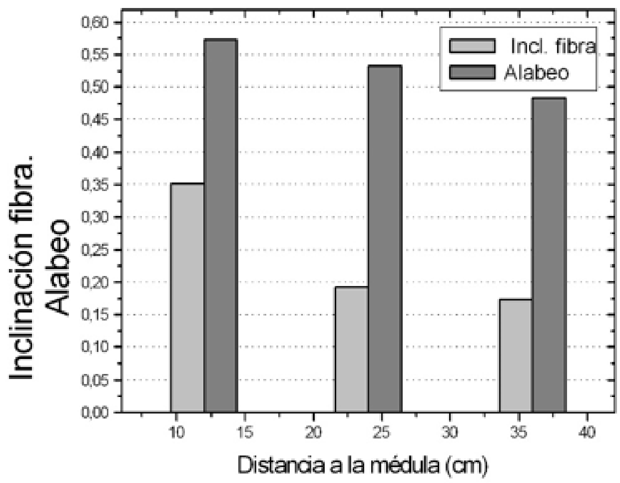

Fig. 4. Comportamiento de los valores medios de la inclinación de la fibra y el alabeo.

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The results of the analysis of variance express that there is a significant difference between the mean values of this magnitude for a significance level of 0.05 (see table 2).

Tabla 2. Análisis de varianza (One-Way ANOVA). Inclinación fibra.

Posición	Media	Varianza	N
A	0,35211	5,73099E-4	100
B	0, 19263	0,02978	100
C	0, 1333	0,07716	100

F = 4, 2666 p = 0, 1187 (At the 0,05 level, the means are significantly different).

Width of rings

Regarding the width of the growth rings, this magnitude decreases from the marrow to the bark, a result similar to that obtained by Coronel, (1994) in studies on Quebracho blanco and Francisco, J., (1999), as well as Álvarez and others, (2013); likewise, deformations behave, specifically warping (Figure 5).

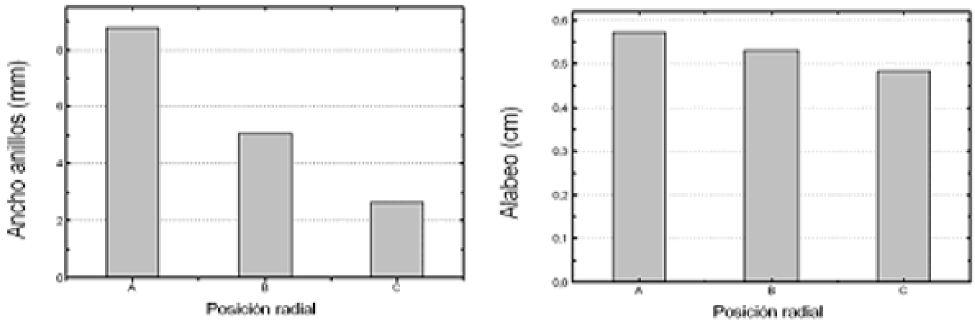

Fig. 5. Comportamiento de los valores medios del alabeo y el ancho de los anillos de crecimiento.

In the analysis of variance for a level of significance of 0.05, it was obtained that there is a significant difference between the values of the width of rings measured in the referred positions.
(See table 3).

Tabla 3. Análisis de varianza (One-Way ANOVA). Ancho anillos.

Posición	Media	Varianza	N
A	8, 78263	1, 37435	100
B	5, 06526	0, 5988	100
C	2, 63737	0,75264	100

F = 200, 32233; p = 0 At the 0, 05 level, the means are significantly different.

In the correlation analysis between warping and the width of the rings, a coefficient r = 0.859 was obtained, which indicates that there is a strong (positive) relationship between these variables; that is to say, with a decrease in the width of the rings there is a decrease in the values of warping, a result that coincides with those obtained by Forsberg, (1997) (See table 4).

Tabla 4. Análisis de correlación.

		Alabeo	**Distancia**	**Anillos**	**Incl. Fibra**
Alabeo	Pearson Correlation	1,000	-0,878	0,859	0,372
	Sig. (2-tailed)	X	0,000	0,000	0,004
	N	76	76	57	57
Distancia	Pearson Correlation	-0,878	1,000	-0,932	- 0,361
	Sig. (2-tailed)	0,000	X	0,000	0,006
	N	57	57	57	57
Anillos	Pearson Correlation	0,859	-0,932	1,000	0,395
	Sig. (2-tailed)	0,00	0,00	X	0,002
	N	57	57	57	57
Inclinación Fibra	Pearson Correlation	0,372	-0,361	0,395	1,000
	Sig. (2-tailed)	0,004	0,006	0,002	X
	N	57	57	57	57

This result can be explained bearing in mind that the decrease in the width of the ring, as it moves away from the pith, implies a decrease in early wood (less percent of early wood than late) with respect to the wood of the first rings, according to Coronel, (1994), Francisco, J., (1999), Álvarez, D and others, (2013); therefore, the predominant properties are those of this type, which conditions greater mechanical resistance, greater density and, therefore, less tendency to deformations.

In the sawn wood of *Pinus Caribaea Morelet*, *var. Caribaea* there is a marked relationship between the inclination of the fibre and the width of the growth rings with the magnitude of the warp. A decrease in the width of the growth rings and inclination in the fibre corresponds to a decrease in the warping values.
The inclination of the fibre and the width of the growth rings increases in the radial direction towards the medulla. The highest quality wood for first and second processing in the

timber industry is that which is close to the bark.

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