ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

EVALUATION OF ALIGNMENT OF WOOD FIBER STRESS IN BENDING STATIC THROUGH OPTICAL

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Abstract. *The correct use of wood can only be achieved by assessing the physical and mechanical properties that are critical in determining its use. Several tests may be performed to identify these properties and those who stand out are the destructive. The use of non-destructive techniques such as vibration, acoustic wave propagation and optics have been studied as an alternative to invasive and destructive tests. The optical methods have beyond not destroy additional advantage not related to the need for physical contact with the object being examined. The use of lasers and associated optics, as a measuring tool, has excelled in several areas of knowledge. The assessment of orientation angle in the wood grain is one of the applications reported in the literature that promotes the adoption of a routine analysis of the alignment of the wood fibers. This study evaluated the application of laser for monitoring the alignment of the fibers of wood under bending stress as a measuring tool.*

Keywords: *Non-destructive testing. Deformation. Alignment of the fibers*

1. INTRODUCTION

The timber is considered an excellent structural material known for its high strength and low density compared with other materials such as steel, stands KOLLMANN et al. (1968). Knowing the physical and mechanical properties of wood is very important to determine their application in security, performance and resistance to tensile or compressive. For EVANS et al. (2000), the fibers are important for determining the use of the timber. The parameters usually considered studies fibers comprise four basic measures: length, width, wall thickness and lumen diameter.

There are several types of cells having different functions in the plant, such as the sap conduction, support and storage of nutrients. Each of these functions confers a different form for cells. Some are more elongated other cube-shaped. Some have thicker walls, other finer. According TSOUMIS (1991), the fibers in their anatomical constitution represents about 65% to 75% of the size part, the remainder being supplemented by the vessels and parenchyma cells axial and radial directions.

The use of optical techniques for determining parameters of the timber are concentrated in the evaluation work piece surface, such as assessment of wood texture by analyzing speckle patterns formed by the laser light wood, shown by Silva et al. (2005). SORAGI (2009) presented optical technique to access the lighting effect. Already HU et al. (2004), SIMONAHO (2004) and FARIA et al. (2008) presented work using the phenomenon of laser scattering and image processing as a new technique for measuring the orientation of the grain, showing that the laser to focus on the wood tends to form figures rich in information.

According to PEREIRA et al. (2002) to focus the laser beam on the wood surface tends to spread in the fibers, which behave as networks which guide the light. It is noted that the figure formed on the surface of the wood pattern has a nearly elliptical with the major axis aligned with the longitudinal orientation of the fibers and the minor axis aligned in the transverse direction. Figure 1 shows the layout of the laser wood scattering in the fiber of the wood.

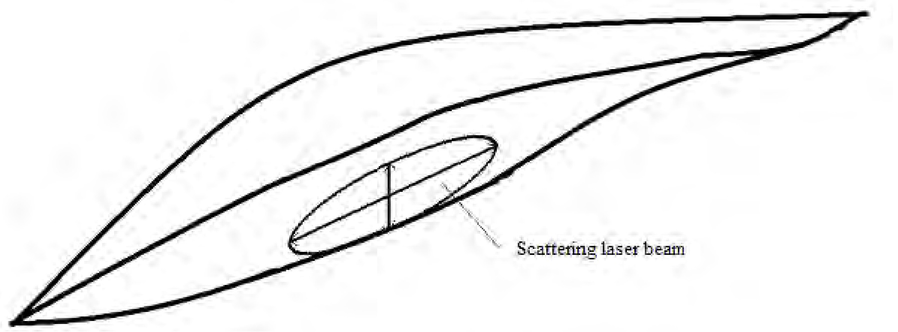

FIGURE 1: Schematic of the scattering of the laser wood on fiber

Because of the nearly elliptical shape when a change occurs in the fiber alignment is possible to note the rotation axis of the ellipse formed. Considering the major axis of the ellipse as "x" and the lowest as "y" and using the geometric properties of the ellipse may be calculated using the technique of the moment of inertia of the rotation angle between these two axes. As the laser beam tracks the internal walls of the fiber is the measure deformation in aligning the microstructure of the wood.

2. EXPERIMENTAL METHOD

We used pieces of Eucalyptus sp. shaped beam belonging to the same batch. According to NBR 7190 (ABNT, 1997), the bodies of the test piece shall be free of defects and the size of the longitudinal section should never be less than 300 mm. The bodies of the evidence presented dimensions of 420x20x20 mm (length, width and thickness, respectively). In Figure 2 is shown the detail of the piece.

FIGURE 2: Detail of wooden beam

The experiments were performed in two steps:

- Development of an experimental setup for validation and calibration of the method;
- Application of tests for monitoring the alignment of the fibers of the wood.

The first stage aimed to verify the optimal configuration for the assessment of fiber alignment. A piece of Eucalyptus sp 20mm thick and 80mm diameter was attached to a tool to enable rotation of the fibers. A He-Ne laser beam forming an angle of incidence of 20° was positioned to illuminate the point where the predominant rotation without the presence of translation. From a point of reference taken as 0 ° rotation has been applied to achieve the angles of 5°, 10°, 15°, 20° and 30°. The image corresponding to each angle was captured by a CCD digital camera then binary and processed to calculate the moment of inertia and the rotation angle. Were not performed technical notes as the focal length, having as main objective only the quality of image that allows good visualization of incidence of the laser beam. This mounting configuration can be seen in Figure 3.

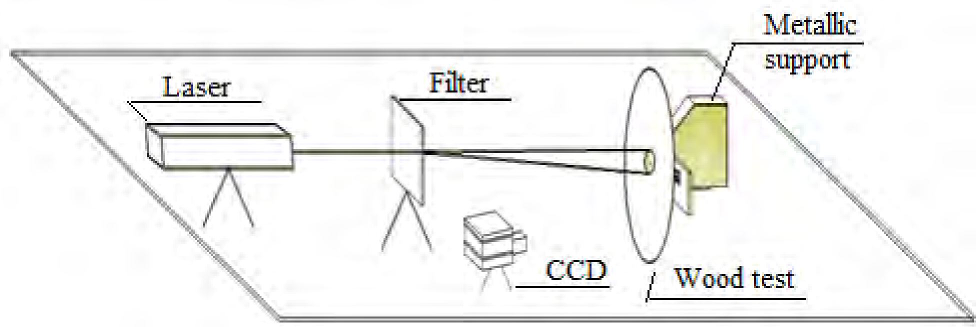

FIGURE 3: Detail mounting validation experiment

ISSN 2176-5480

In the second step, we performed the test stress application of bending, where we opted for simple bending supported with concentrated load at the midpoint of the span, Figure 4.

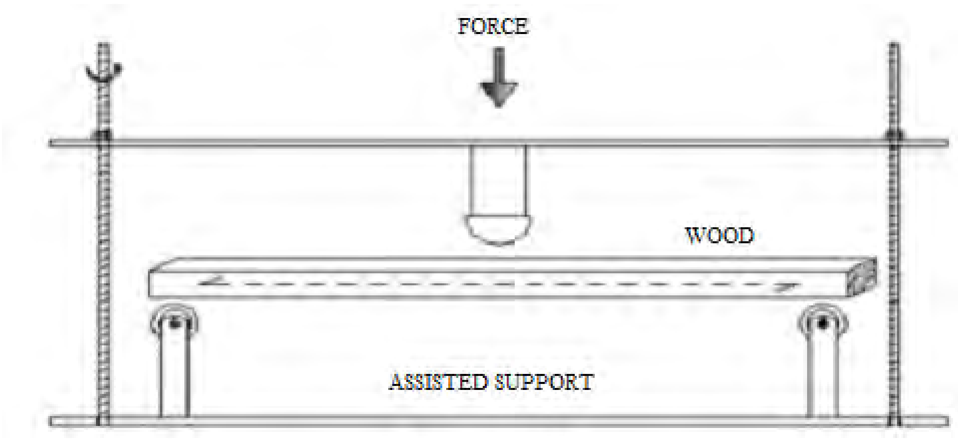

FIGURE 4: Bending simple supported

We used 6 pieces of Eucalyptus sp-shaped beam, with dimensions 420x20x20 mm (length, width and thickness, respectively). Next, the laser gun was turned on and the beam is directed across the part surface closest to the neutral zone is considered in this case the support zone, with the angle of incidence of 20° Figure 5.

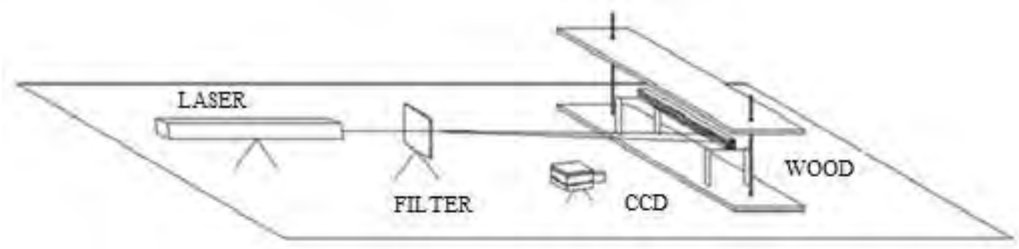

FIGURE 5: Setup of the experiment

During rehearsals were recorded 3 images for each load, which is applied to cause a vertical displacement of 2.5mm in the middle of the span. Stored images were digitized and analyzed by means of an application in the public domain. We applied a Gaussian Blur filter with a radius of coverage equal to 6 pixels to reduce the grainy effect. The result can be seen in Figure 6, namely an image with smoothed edges and well defined.

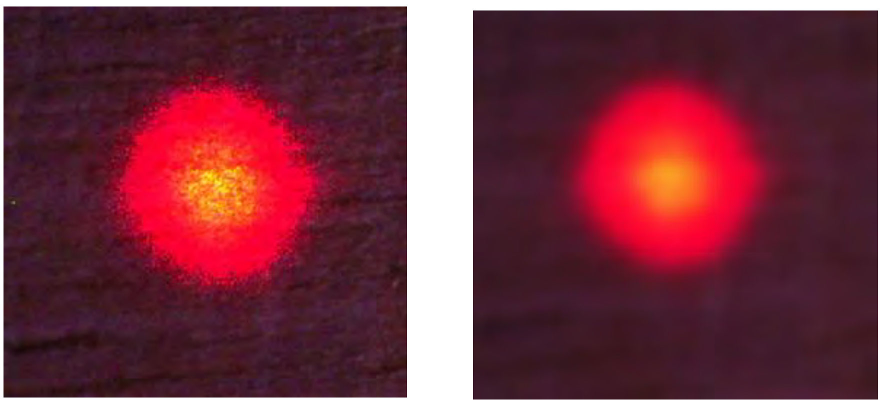

FIGURE 6: Image formed by the laser beam (a) without the filter, (b) with the Gaussian filter

Next, we performed a conversion of 8 bits and applied to image segmentation to isolate the beam in the shape of an ellipse. With the values of the major and minor diameters of the ellipse and its orientation in space, calculates the angle of inclination relative to the vertical axis of the image. The image is now undergoing a process of binarization

ISSN 2176-5480

Thresholding (Fisher, 2010b), which consists of transforming the gray tones in black and white. As a result, the image approaches a figure elliptical. This is important information that can demonstrate how steep is the wood fiber, by calculating the smallest and the largest diameter. With these values, it calculates the angle of inclination relative to the vertical axis of the image. For this purpose, I used the app Fit Ellipse Image J (WAYNE, 2010) that adjusts the ellipse by least squares (Ellipse-specific Direct Least-Square Fitting). Figure 7 shows the result.

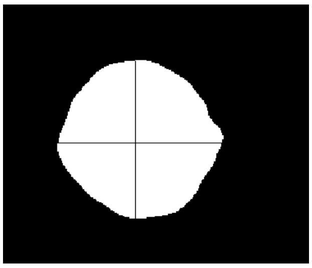

FIGURE 7: Image formed by the laser beam binary

2.1. Experiments planning

The results indicated that scattering of the laser fiber accompanying the rotation. Given the findings presented in Table 1 can be observed and measured the angles vary according to the rotation.

TABLE 1: Angles formed in the ellipse rotation function

Angle of rotation	Angle of the figure formed	Angle corrected	Angle calibrated
0	75,48	0	0
5	80,86	5,38	3,2604
10	93,43	17,95	10,8783
15	156,11	80,63	17,8735
20	175,47	99,99	22,1900
30	197,5	122,12	27,1012

Calculating, Pearson correlation of Angle and Angle of rotation of the figure formed = 0.954 and P-Value = 0.003. Confirmed negative correlation (0.954) Pearson between the angle of rotation of the work piece and the rotation angle of the fibers. The hypothesis H: £ (X, Y) = 0 was rejected because the descriptive level of the test (P-value = 0.003) was small. We conclude then that there is a dependency between X: Y and rotation angle: Angle of fibers. This difference can be explained taking into account the variability of the microstructure of the wood, as reported by Hu et al. (2004) when he says that some wood species and surface roughness affect the accuracy of measurement of angles when using optical scattering of the laser wood beam. Figure 8 presents a straight approach and the equation for the corrected values using a simple linear regression model showing the trend between the values.

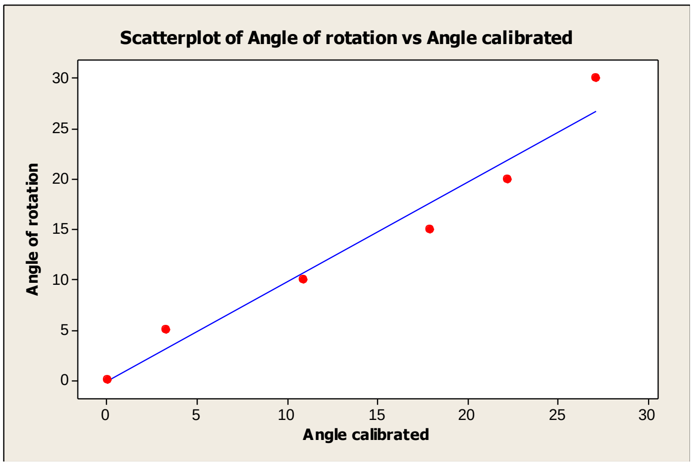

FIGURE 8: Dispersion and trend line of the actual angle of rotation and corrected

ISSN 2176-5480

The coefficient of correlation allowed the use of this technique in the experiments bending step. In the second step, the tests were divided according to the initial angle of the fiber alignment from the reference position. The groups were made with 0 ° as the threshold. The data in Table 2 correspond to the angles of less value, between 90° and 103°, and Table 5 shows the measured angles of greater value, above 109°. The division into groups was made just for clarity, but the factor correction was used only one. Once done the group, began the statistical treatment within each group by applying the correction factor obtained in the previous step. In Tables 2 and 3 shows the results.

Table 2 Angle calibrated alignment of wood fibers

Applied strain	Angle alignment of fiber		
	2ª Sample	4ª Sample	5ª Sample
0	0,000	0,000	0,000
0	0,327	-0,931	0,048
0	1,214	-0,707	0,011
1	3,461	-0,980	0,774
1	4,032	-1,070	0,615
1	3,862	-1,054	0,581
2	3,511	1,267	1,860
2	2,259	1,443	1,683
2	1,956	1,740	1,770
3	4,580	1,287	3,245
3	3,411	1,375	3,113
3	3,841	1,645	3,144
4	5,116	2,871	3,542
4	5,708	3,321	broke
4	5,476	3,464	-------

Table 3 calibrated angle of alignment of the wood fibers

Applied strain	Angle alignment of fiber		
	1ª Sample	3ª Sample	6ª Sample
0	0,000	0,000	0,000
0	0,141	0,323	0,015
0	0,034	0,353	1,787
1	1,668	1,720	0,864
1	1,761	0,925	-0,492
1	2,126	1,146	2,497
2	1,441	1,803	2,442
2	1,608	1,608	4,476
2	3,234	1,831	2,736
3	3,282	3,510	3,789
3	3,302	3,524	2,325
3	3,248	broke	3,425

A statistical linear regression was performed in each group to describe the behavior of the evolution of the angles measured Table 2 shows the linearity of response between applied strain and the measured angle for angles smaller value.

Correlations: 2ª Sample; 4ª Sample
Pearson correlation of 2ª Sample and 4ª Sample = 0,584
P-Value = 0,022

Correlations: 2ª Sample; 5ª Sample
Pearson correlation of 2ª Sample and 5ª Sample = 0,699
P-Value = 0,008

Correlations: 4ª Sample; 5ª Sample
Pearson correlation of 4ª Sample and 5ª Sample = 0,862
P-Value = 0,000

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In Figure 9, presents the straight approach, using a simple linear regression model showing the trend between the values.

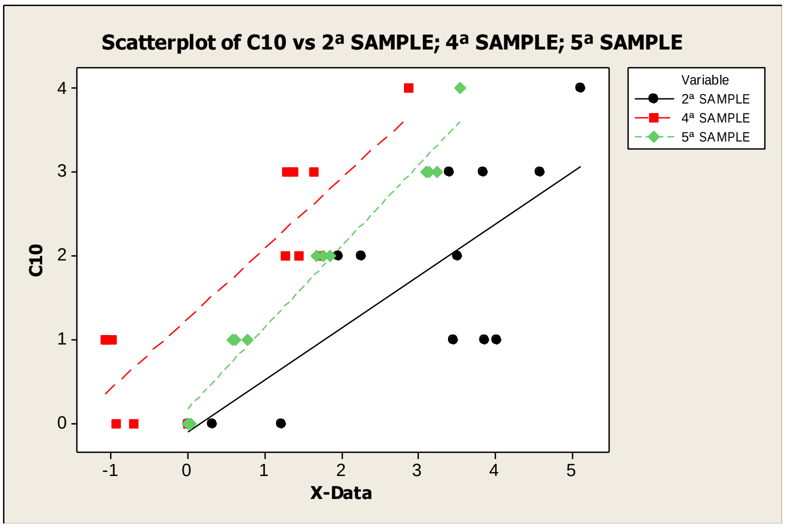

FIGURE 9: Graph fit to the linear regression model as a function of angle and effort (2st, 4rd and 5th sample)

The graph. Figure 9 it is evident that the linear model adjusted to the trend of the measured values. Where we can see that P-value (descriptive level of the test),indicates a strong correlation between experiments, the displacement of the fibers were observed. A plying the same statistical analysis for angles of greater value, Table 3:

Correlations: 1ª Sample; 3ª Sample
Pearson correlation of 1ª Sample and 3ª Sample = 1,000
P-Value = *

Correlations: 1ª Sample; 6ª Sample
Pearson correlation of 1ª Sample and 6ª Sample = 0,593
P-Value = 0,042

Correlations: 3ª Sample; 6ª Sample
Pearson correlation of 3ª Sample and 6ª Sample = 0,593
P-Value = 0,042

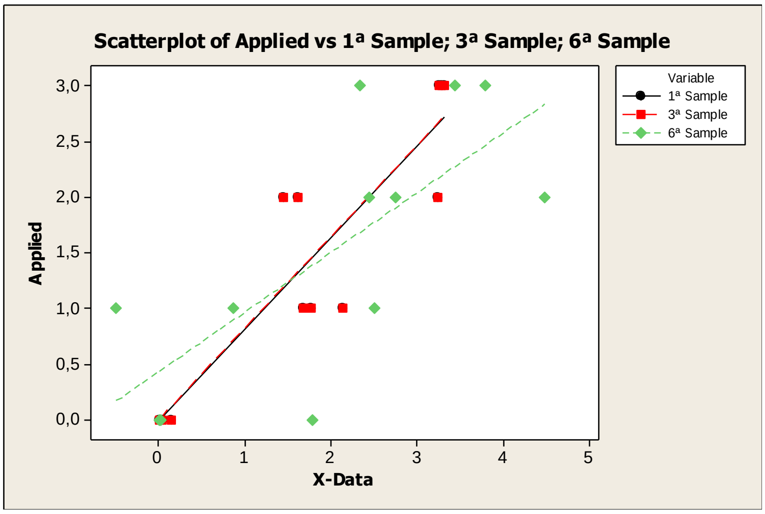

FIGURE 10: Graph fit to the linear regression model as a function of angle and effort (1st, 3rd and 6th sample)

In this case no longer P-value indicates a strong correlation, indicating that the technique provides good results for angles of less value. In Figure 10, represents the degree of linearity of response between applied stress and the measured angle for angles of less value. Consistently for all graphs, the first notable feature is the linearity between the applied stress and the measured angle. This means that, within the ranges studied, an increasing effort causes a deformation proportional to the fiber. Interestingly, the variability around the lines, justifying the need to analyze a greater number of points. This number variation is mainly due to the non-uniformity of the geometric fibers of the body-of-proof, similar situation observed by FARIA et al. (2008). Consistently for all angles, the first notable feature is the linearity between the applied stress and the measured angle. This means that, within the ranges studied an increase in stress causes a deformation proportional to the fiber.

This aspect to be considered is the value of the coefficient of determination R2 found in the two treatments, where the linear model set with satisfactory values for biological materials. Thus, the variability of biological materials can be overcome with the realization of repetitions, in this case showed the technical capability to follow the deformation of the timber non-destructively.

3. CONCLUSIONS

It was shown in this work that the use of the phenomenon of scattering of the laser is a useful technique that can assist in verifying the deviation of alignment of the fibers of the wood, when subjected to bending stress. The technique has the potential to be exploited, not being destructive and, in conjunction with traditional techniques, can improve the quality of evaluations and tests. Correlation analysis between the variable effort and the angle of the grain suggests the sensitivity of the configuration indicating:

a) the need for different settings for different angles of deformation and

b) the need for observation of a higher amount of points in one piece.

c) It is also necessary to explain the change in sensitivity to angles of 90 ° to 103 ° and angles above 109.

It should be noted that the scattering of the laser beam follows the deformation of the fiber and image analysis allows conclusions angle variation. One can observe in this work that the sensitivity obtained by optical technique depends directly on the angle of incidence of the laser lighting plan. It was found that the angle of incidence of 20 ° provided a good response, thereby allowing qualitative and quantitative measures. One can therefore conclude that the results indicate the possibility of using the proposed configuration in evaluating the alignment of the wood fibers.

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