DETERMINATION OF WOOD SPECIMENS USING ISOSTRAIN PATTERNS GENERATED FOR *MOIRÉ* TECHNIQUE

DETERMINAÇÃO DE ESPÉCIMES DE MADEIRA UTILIZANDO PADRÕES DE ISODEFORMAÇÕES GERADOS PELA TÉCNICA DE *MOIRÉ*

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ABSTRACT

Brazilian forest's wood characterization requires very complex tasks due to the large number of species available throughout the whole national territory. Available wood characterization methods demand relatively long test timing or they are quite costly and sometimes they exhibit a lack of precision. This research work reports a new method for wood characterization based on a *moiré* photoelastic technique. Such family of methods is able to generates the microtopography of the object under study and also the stress-strain distribution under a specific loading condition. *Moiré* means *wave like pattern* generated when screens of same mesh density are superposed. It is reported the application of a *moiré* technique in magnifying displacements, being also suitable as a photoelastic method. Three specimens of different wood species were submitted to axial loads before failure meanwhile a grid of specific mesh density was projected onto the object. The experimental setup this work included a digital camera to capture the *moiré* patterns generated by the projection of a regular grid onto the object and processed by involving software named Gimp and Idrisi. Tests were conducted in the Faculty of Agricultural Engineering at Campinas University, Campinas, SP, Brazil.

Keywords: brazilian forest's; interferometry; photoelastic technique; shadow Moiré; isostrain maps; digital pictures.

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RESUMO

A caracterização das madeiras das florestas brasileiras requerem um trabalho muito complexo devido ao grande número de espécies disponíveis em todo o território nacional. Os métodos de caracterização existentes demandam muito tempo e tem custos muito altos além de não terem muita precisão. Esta pesquisa descreve um novo método para caracterização de madeiras baseado na técnica fotoelástica de Moiré. Esta família de metodos são hábeis para gerarem microfotografias do objeto de estudo, assim como de determinarem a distribuição de tensão e formação em objetos a partir de uma carga controlada, isto ocorre devido a padrões de regiões claras e escuras geradas por uma grade sobreposta. A técnica de moiré aumenta os deslocamentos sendo considerado uma técnica fotoelástica. Três amostras de madeiras diferentes foram submetidas a cargas axiais antes da falha enquanto um padrão de difração foi projetado nas amostras. O arranjo experimental foi formado por uma câmera digital para capturar os padrões de moiré gerados, e estas imagens foram processadas pelos softwares Gimp e Idrisi. Os testes foram conduzidos na Faculdade de Engenharia Agrícola da Universidade Estadual de Campinas.

Palavras-chaves: florestas brasileiras; interferometria; técnica fotoelástica, Moiré de sombra, mapas de isodeformação.

INTRODUCTION

Since ancient times forest's wood has been employed as manufacturing material, including rustic tools, weapons, furniture, housing, bridges, structures, machine components, airplanes, etc. It is noticeable that wood has been present in a significant majority of mankind engineering projects. However, several material properties should be well known in order to recommend wood species for specific applications under required mechanical behavior. BERALDO et al. (1991) states that wood characterization includes macro and micro anatomical identification, dichotomy key, moisture content, specific mass, compression parallel and normal to the fibers, static bending, resistance to impact loading, traction parallel and normal to the fibers, cracking, resistance to shearing stress, hardness, nail extraction as well as NDE tests. To identify wood specie among specimens belonging to a same botanical family is not a simple task since remarking anatomical similarities contrast the large range of encountered mechanical properties. The main problems are the great variation in light intensity and the shadows on the images, the variability in shape, dimensions and colors of the agricultural product and the work environment for the equipments (SENA et al., 2003). Properties surveying requires very time demanding procedures, excepting macro identification, since they require special laboratory equipment. In this research work, a new method to identify wood specie named shadow *moiré* which consists in generating interference patterns between a grid and its own shade projected onto an object *is* proposed. This technique is suitable to determine contour lines onto a surface, obtaining, that way, its topography and geometry. These phenomena are well understood and described by the wave theory, discarding the quantum as well as electromagnetic theories.

THEORETICAL CONSIDERATIONS

The wave function describes the light propagation as waves (SALEH, 1991). When two waves of same frequency and amplitude exist simultaneously in the same space region, the total wave function is the summation of theses waves and their phase relationship will generate fringe patterns of different light intensities (SALEH & TEICH, 1991). When two grids or screens are superimposed, fringes are generated as a result of these grids line combinations. These fringes are named *moiré* patterns or *moiré* fringes and the phenomena called *moiré* effect. HU (2001) reports that projecting and shadow *moiré* are the mostly employed shape surveying techniques due to their simplicity and quickness. *Moiré* fringes can be sought as a superposition of two plane waves which keeps an angle between their traveling directions. In the regions where the waves are on phase, a constructive interference is generated, showing clear patterns and in the case of destructive interference, dark patterns are formed (MALACARA, 1992). Such an approximation is derived from the interference between fringe patterns by means of the relations so called initial transition model (PISAREV & BALALOV, 2001). TAKASAKI (1970) employed the superposition of a grid onto its own shade to measure the contour of some objects. The objective of this work is to develop a shadow *moiré* technique to produce a qualitative deformation pattern on wood testing samples, since the relative fringes magnification will generate different patterns during a continuous compression loading. For each different wood sample a specific *moiré* pattern would be generated due to their different mechanical behavior allowing a closely specie identification. By employing the whole field subtracting method as defined by POST et al. (1994), an isostrain field could be defined which would indicate the occurrence of stress concentration. ALBIERO et al. (2004) affirm that technique of shadow moiré allied with whole field subtraction method allows determining deformation imposed to the sample between two different loading levels, characterizing a precise isodeformation map.

MATERIAL AND METHODS

The experimental phase of this research work was held in the Materials Laboratory, Faculty of Agricultural Engineering, State University of Campinas, Brazil. Figure 1 exhibit the setup employed which consists in a light source, a digital camera and of a grid. Topographic map contour lines on a wood specimen is shown on Figure 2. POST et al. (1994) states that sharp fringes are obtained when the width of the bars and of the spaces are the same, the grid is well defined at the edges of the bars, the intersection angle between the light beam and observer lines are small and the ratio between the spaces and bars is less than 1.05:1.

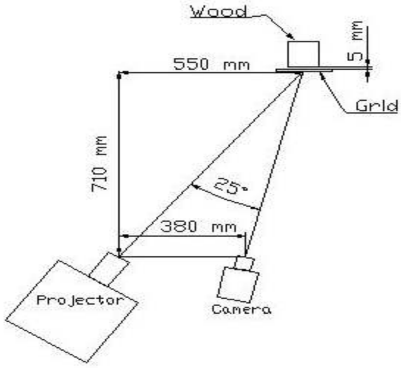


Figure 1. Experimental setup to obtain Moiré fringes.

Figure 2. Contour lines generated from moiré fringes on Jatobá wood (Hymenaea sp) testing samples .

Testing samples of Brazilian woods Garapeira (*Apuleia leiocarpa*) as well as Jatobá (*Hymenaea* sp) and Pinus (*Pinus caribaea*) wood species were axially loaded. Table 1 shows the mechanical characteristics of these testing samples. Figure 3 shows the experimental arrangement. For each testing sample it was obtained two digital pictures corresponding to two different loading levels. A pre-loading procedure was carried to stabilize the testing samples, beyond which pictures have been taken, up to the maximum load. Table 2 shows the loading values applied to the testing samples.

Table 1. Physical and mechanical properties of tested wood species.

Wood specie	Jatobá (Hymenaea *sp*)	Garapeira (Apuleia leiocarpa)	Pinus (Pinus caribaea)
Apparent Density at 12% of Moisture Content kg m^{-3}	1074	892	579
Compression Parallel to the Fibers MPa	93.3	78.4	35.4
Compression Normal to the Fibers MPa	157.5	108.0	64.8
Traction Normal to the Fibers MPa	3.2	6.9	3.2
Shear Stress Loading MPa	15.7	11.9	7.8
Modulus of Elasticity in Compression MPa	23607	18359	8431

(Source: www.brasilis.pro.br)

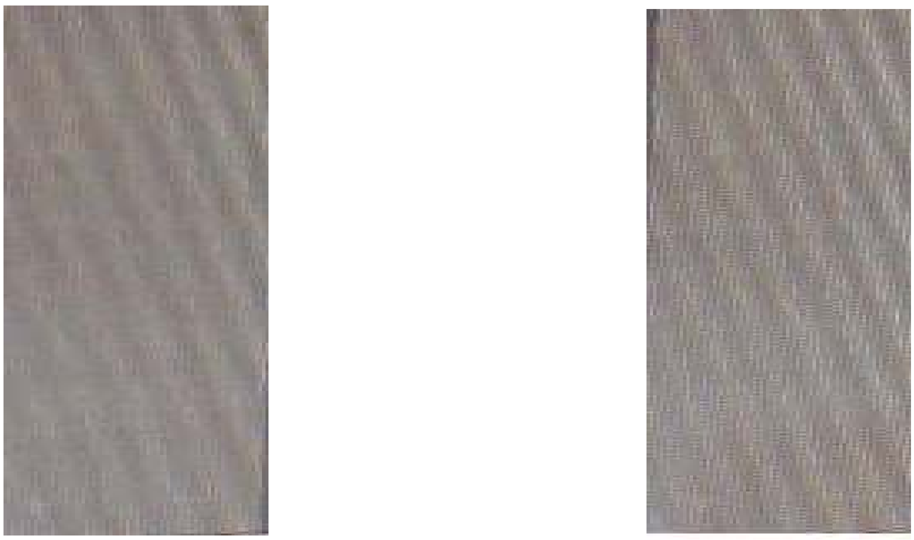
Table 2. Stress Applied on the Testing Samples.

Wood Specie	**Area mm^2**	**Initial Force Loading kgf**	**Final Force Loading kgf**	**Initial Tension Loading kgf/mm^2 (kPa)**	**Final Tension Loading kgf/mm^2 (kPa)**
Garapeira (Apuleia leiocarpa)	2192	100	2128	0.045 (456)	0.971 (9706)
Pinus (Pinus caribaea)	2788	100	2128	0.036 (360)	0.763 (7632)
Jatobá (Hymenaea *sp*)	2437	100	2128	0.041 (410)	0.873 (8731)

All pictures were obtained in JPEG format and transformed to BMP format followed by a gray level transformation by means of the GIMP software, where the 0 gray level is defined by the black color and 255 for white color. IDRISI software was employed to eliminate noise as well as errors. Whole field subtraction method was employed as defined by POST et al (1994), by subtracting pixel to pixel of a picture referring to a X_i loading from a picture at X_{i+1} loading level. That method allows determine deformation imposed to the sample between two different loading levels. The equipment employed in this research work included a Sony Mavica digital camera with 800 kpixels, a testing press, a grid of 0.4 mm period and a overhead projector.

RESULTS AND DISCUSSION

Figures 4, 6 and 8 represent the results of the experiment, while figure 5, 7 and 9 are the resultant images of the processing. These scales qualify the specimens regions with different deformation levels. Plus and minus signals indicate more or less deformation levels and not positive and negative deformations. These scales do not quantify the undergone deformations indicating that new research efforts should be programmed.



(A) **(B)**

Figure 4. Fringe patterns for Garapeira wood (*Apuleia leiocarpa)* testing specimen loaded to : A) 456 kPa and B) 9706 kPa.

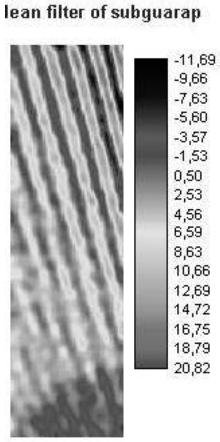
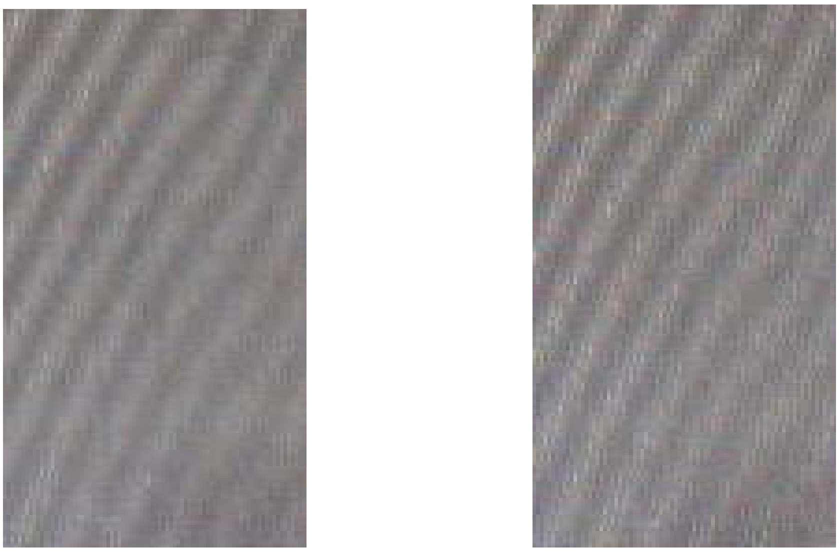


Figure 5. Isostrain map for the Garapeira wood (*Apuleia leiocarpa)* testing specimen*.*



(A) (B)

Figure 6. Fringe pattern for Jatobá wood (*Hymenaea* sp*)* testing specimen loaded to: (A) 360 kPa and B) 7632 kPa.

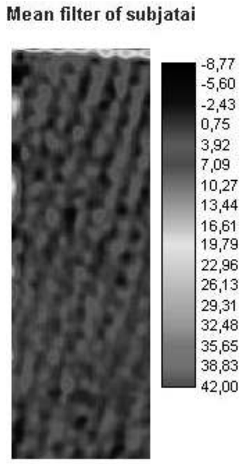
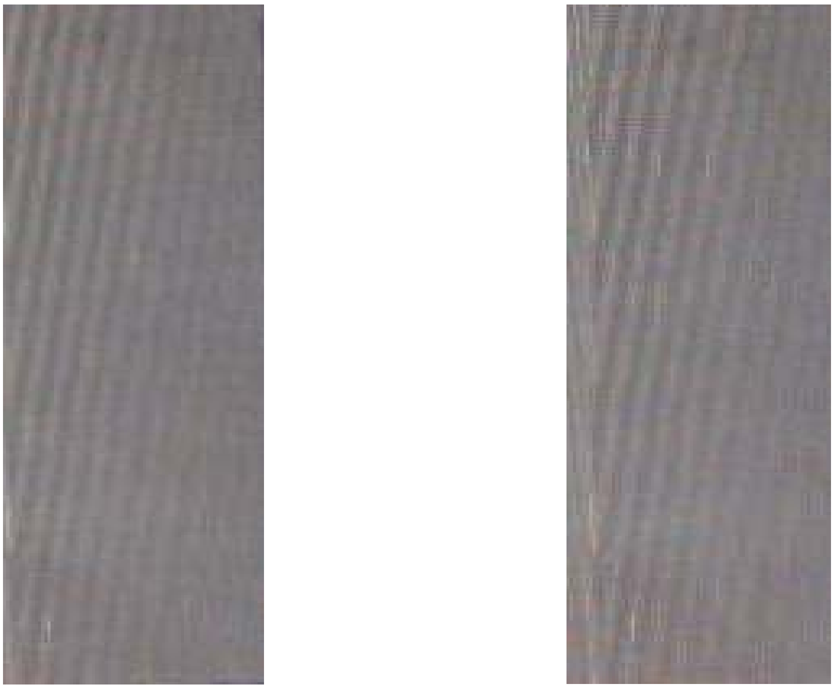


Figure 7. Isostrain map for Jatobá wood (*Hymenaea sp)* testing specimen*.*



(A) (B)

Figure 8. Fringe pattern for the Pinus wood (*Pinus caribaea)* testing specimen loaded to: A) 410 kPa and B) 8731 kPa.

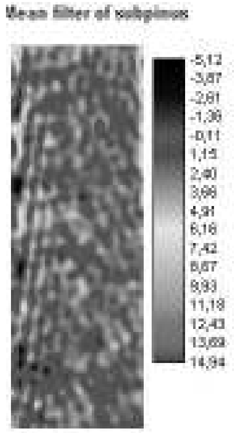


Figure 9. Isostrain map for Pinus wood (*Pinus caribaea)* testing specimen.

Isostrain map for Garapeira wood, shown on Figure 5, indicates a high load concentration at a certain region at the base of the testing specimen due to a slight inclination of the body. Strain maps for Jatobá and Pinus wood, respectively on Figure 7 and Figure 9, are very different, seeming to be proportional to their modulus of elasticity, as shown on Table 1. Fringes for Pinus wood exhibits a non continuous pattern indicating a non isotropic behavior and a low density wood when compared to the more continuous fringes showed by the Jatobá wood which also exhibits higher density. Garapeira wood shows an intermediate behavior as indicated by the fringes continuity as well by the modulus of elasticity. POST et al.(1994) states that Shadow *Moiré* captures out of deformation plane indicate that non isotropic materials as wood would have out of plane deformations registered. These deformations would generate different patterns, according to their mechanical characteristics. Figures 5, 7 and 9 can be presented in color codes to represent the isostrain for Garapeira, Jatobá and Pinus wood as result of a pixel to pixel subtraction from the matrices which generated these images. Each pixel of these images is defined at a light intensity referring to a scale of gray, from zero to 255, and the subtraction of a pixel from an unloaded testing specimen by a loaded testing specimen pixel will generate a pixel that indicates the amount of deformation experienced by the specimen. These scales qualify the specimens regions with different deformation levels. Plus and minus signals indicate more or less deformation levels and not positive and negative deformations. These scales do not quantify the undergone deformations indicating that new research efforts should be programmed.

CONCLUSION

From the exposed before, it is concluded that the shadow *moiré* technique is appropriate in identifying wood species by means of the isostrain patterns which characterizes each studied specie. The Stress distribution on testing specimens is forwarded from isostrain maps since regions exhibiting strain concentration will also exhibit high stress concentration, showing the complexity of non symmetric bodies (non trivial situation).

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