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Application of a Shadow Moiré Optical Technique to Generate Isodeformation Curves on Cashew Nuts Surface

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Abstract-*Moiré* techniques are based on optical interferometry which is capable of generating fringes on the body surfaces under study. These fringes present similar pattern distribution to isothermal curves or even to contour lines drawn on farm land or on the ground surface maps. These lines are named *moiré* fringes which can be captured and processed to reproduce a three dimensional view of the testing body. However, in case the testing body is experiencing traction or compression these fringes can also be associated to the imposed stress which generated a certain strain distribution. By capturing the fringes for further digital processing, a complete three dimensional picture of the stress and strain distribution mapping on the testing body surface will be generated. The stress and strain relations can also be interpreted through elastic as well as viscoelastic laws. The objective of this research work was to identify the stress concentration on cashew shells to support the development of machine elements capable of breaking the shell but preserving the nut. Tests consisted in imposing variable loads to the fruit in order to generate stress concentrations at the points which will provoke shell breaking. Optical grids were projected with four different wavelengths, i.e., blue, yellow, white and red colors, permitting fringes contrast optimization. Higher deformations were observed to occur on nut top meanwhile lower deformation levels were observed on the fruit top border. Results demonstrated the feasibility of the proposed method in determining stress and strain concentrations on cashew nut under mechanical load.

Keywords- *cashew nuts, shadow moiré, strain and stress concentrations, nut shelling*

I. INTRODUCTION

Cashew nuts industrial processing includes several topics as, shelling to liberate the endocarp which exhibits low yielding and causes bruising at levels of 40% to 50%. Farm machineries development requests a complete understanding about mechanical behavior, including stress and strain association [3].

The proposed optical technique is based in generating contour lines on the nut surface, following by image capture by means of digital camera for further processing in order to generate the object topography as well as the stress and stress mapping. The *moiré* phenomenon is generated when screens of certain mesh density are superposed, producing waves like patterns or fringes, which move when its relative positions are displaced [11]. Fringes are generated with different period and angle of the two initial screens [7]. *Moiré* fringes can be generated through the shadow or projection *moiré* techniques [9]. In the shadow *moiré* method a optical grid is projected onto the object surface generating a second grid. Costa et al. recommend that technique photomechanical tests because it generates well detailed pattern fringes. The polychromatic light, despite some inconveniences it indicates the regions undergoing high stress values.

This research work aims to study the cashew nuts in order to determining the points of higher stress during mechanical loading to support the development of shelling mechanisms.

Several authors reported the application of *moiré* methods in determining qualitative stress state on bodies of simple geometry. [8] determined a complete displacement field on discs in modeling sugarcane cutting. [1] determined points of isodeformation on nut shells. [5] and [7] determine stress distribution on wooden beams under flexural loading. The pertinent literature emphasizes the necessity in studying the parameters to support equipment deployment and design enabling to improve working conditions. It worth to emphasize that cashew nuts extraction process is mainly carried by women and children. [10] have no significant differences between the biological material samples destructive testing, associated with the short time interval between tests. This justifies the use of optical techniques for analysis of biological material.

II. MATERIALS AND METHODS

The selected experimental setup includes a digital camera, a 10 cm x 60 cm and 0.2 mm optical grid, a testing press and a PC. The optical grid was held by a frame and positioned in vertical position before de object as it is shown on Figure 1.The multimedia projector was connected to the PC which was working as white, yellow, blue and red light source by means of the PowerPoint software. The object was painted with white opaque color to improve contrast with the fringes and the room was kept dark, but only with multimedia illumination. The nut was positioned on the testing press behind the optical grid meanwhile the images were captured during loading test. A statical loading of 5 N was applied.

Image processing was divided into two parts and carried by means of the ImageJ *software.* In the first part all the images have been mutually and equally processed. In the second part the isoclines and isochromatic lines generation took place. The total image processing is detailed bellow: (1) The higher loading image was processed by means of the ImageJ *software*. (2) The **Record** command was open to generate a routine to register all the commands executed in the image processing for further application to the remaining loaded images. (3) The image was converted from RGB (color) to gray gradient (8 bits) (4) Then the command **Polygon selections** was activated to select the area of interest on the fruit surface. That area covered all the fruit surface. Following, the mask creation procedure is supported by the **Create Mask** command, generating a vectorial secondary image named "Mask" which is composed by two distinct areas. The first area was presented in dark color (vector modulus = 255) which corresponded to the area of interest. The second area, presented in white color (vector modulus = 0), corresponding to the non-selected area. (5) Following, the mask was converted to a binary image containing modulus of **0** and **1**, by means of the **Math** command. That step had the support of the **Divide** command which divided by **255** the pixels of the image. (6) The area of interest was separated from the background by means of the **Image Calculator** command by multiplying the mask by the image. May noises were removed at that step. Image was then filtered by the "Gaussian Blur" filter at intensity of **3.0** which improved the fringes contrast. The routine was finally recorded in TXT extension and denominated as "Macro". Then the image was recorded in BMP extension as displayed on Figure 2.

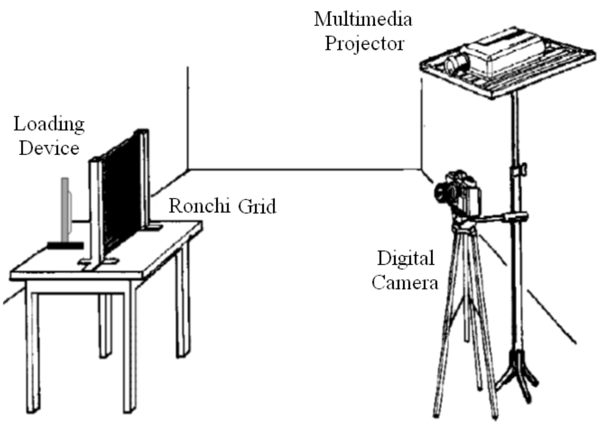


Figure 1. Experimental setup for shadow *moiré*. Hertz *et al*., 1.995

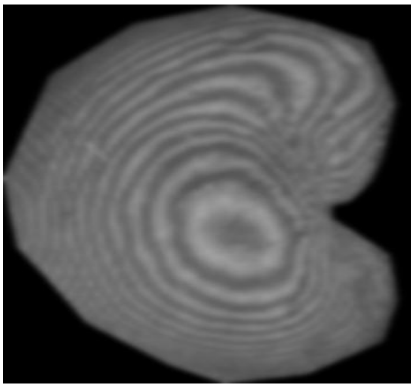


Figure 2. Part of the image processing, define the contours in the object

The procedure as described above was individually and automatically repeated at increasing loading increment order for the images captured in the tests. The second part of the image processing generated the isoclines and isochromatic fringes, as it was referred above. The sequence of that procedure included the following steps. (1) An average of the images resulting from loading **2** and loading **1** by means of the **Image Calculator** command and the resulting image was transferred to the **Interactive 3D Surface Plot** to generate the isoclines plot. Isoclines distribution depends on the adjustment of certain parameters, as **Size Grid**, **Smoothing**, **Perspective**, **Lighting**, **Scale**, **Z-Scale**, **Max** and **Min**, which adjusted only once and fixed for all other replications. That procedure was carried in order of obtaining a variable line distribution according to loading conditions and not according to ImageJ adjustment differences. (5) The data were saved in BMP as it is shown on Figure 3.

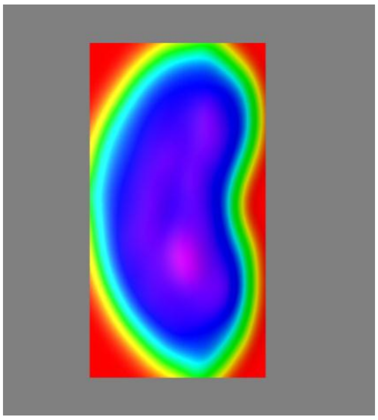
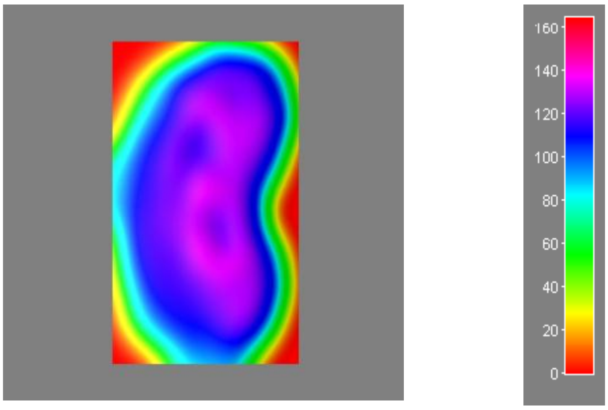


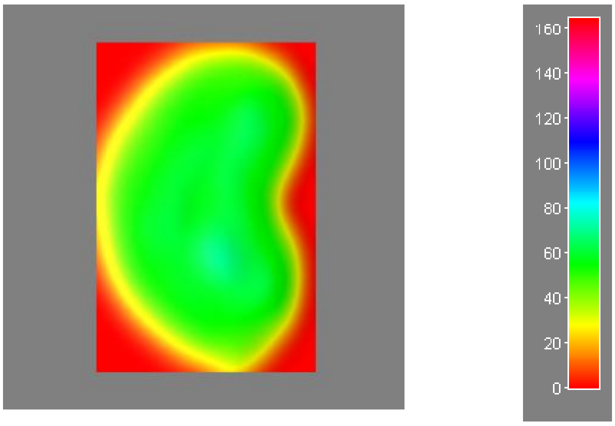
Figure 3. Image after processing figure 2 with Software ImageJ

III. RESULTS AND DISCUSSIONS

The screen generated by the PowerPoint *software* acted as white, yellow, red and blue light sources to obtain the image of each fruit in order to obtain the best contrast of the fringes for the ImageJ *softwareI* processing. These figures 4a, 4b, 5a, 5b, 6a, 6b, 7a, 7b exhibits the isochromatic fringe map as generated by the ImageJ *software* for each light source used in the experimental tests. ImageJ produced a qualitative color scale, based on its pixel modular, to demonstrate points since lower deformations to higher deformations for whole field.

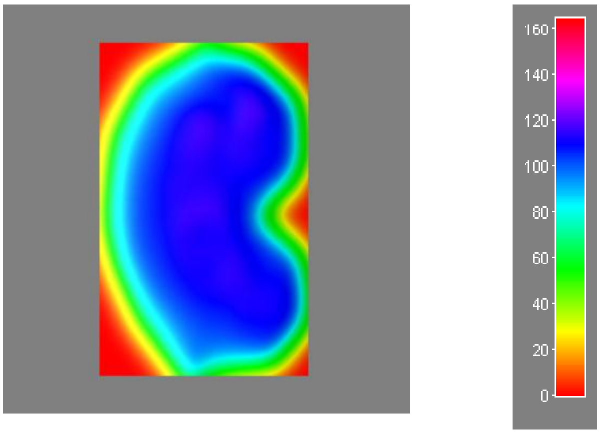


(a)

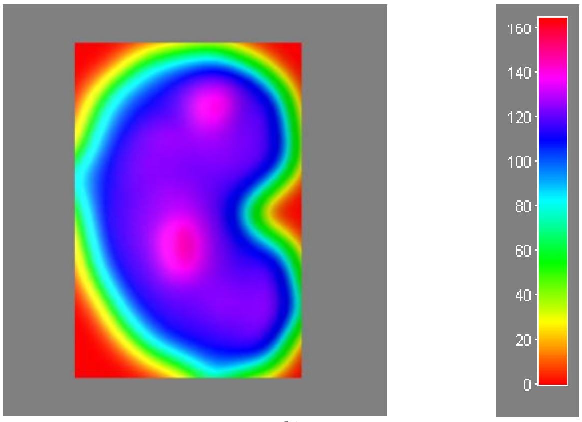


(b)

Figure 4. (a) Isochromatic lines map generated by the ImageJ software with white light, (b) Isochromatic lines map generated by the ImageJ software with white light.

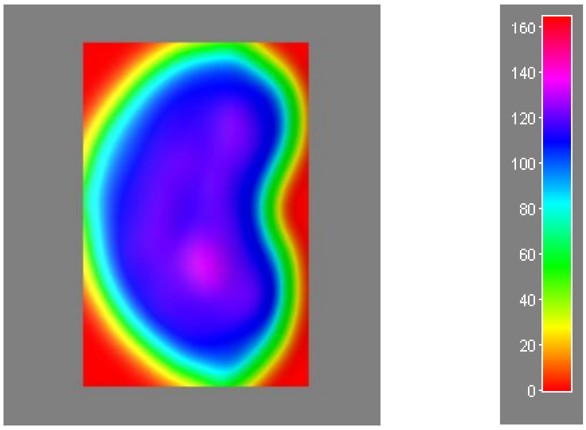


(a)

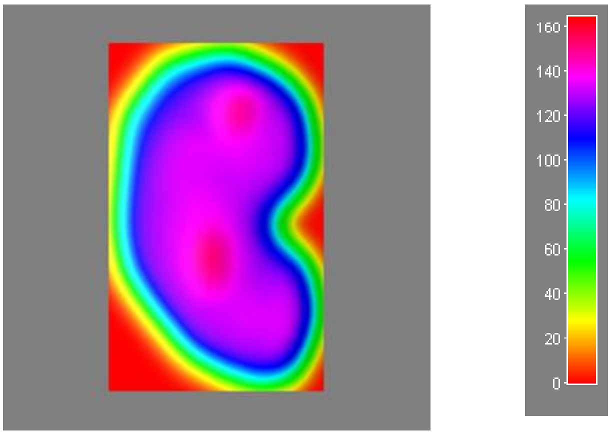


(b)

Figure 5. (a) Isochromatic lines map generated by the ImageJ software with yellow light, (b) Isochromatic lines map generated by the ImageJ software with yellow light

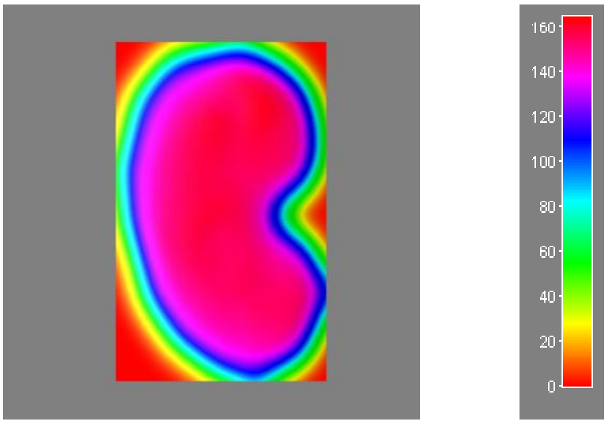


(a)

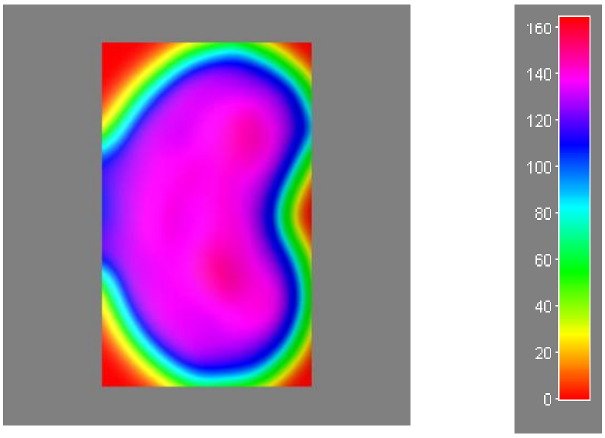


(b)

Figure 6. (a) Isochromatic lines map generated by the ImageJ software blue light, (b) Isochromatic lines map generated by the ImageJ software blue light.



(a)



(b)

Figure 7. (a) Isochromatic lines map generated by the ImageJ software red light. (b) Isochromatic lines map generated by the ImageJ software red light

The images processed by the ImageJ *software* have been analyzed and compared according to light source color and area of higher deformation concentration including several replications. It was observed that the beyond the white light, the red light and yellow light presented good fringe contrasts, followed by the blue light, which permitted higher quality of the final results. Color scale as exhibited together with the images processed by the shadow *moiré* method defined the complete isodeformation mapping to cashew nuts under compression loads. Analyzing these dates is able to observe that the regions exhibiting higher deformations are concentrated at the sample center, meanwhile the lower deformations are concentrated on the nut board. Furthermore, the nut mechanical behavior demonstrated that the higher concentration can be occurred in isolated points, as observed on Figure 5.b, 6.a, 6.b and 7.b or more homogeneous deformation distribution as observed on Figures 4.a, 4.b, 5.a and 7.a. This observed behavior is due the irregular cashew nut shape which is variable among samples, as well as, heterogeneities promoted by issues variation.

IV. CONCLUSIONS.

Based on what it has exposed *moiré* method showed to be very efficient in identifying stress and deformation on cashew nuts. Results demonstrated that the higher deformations are placed on sample center. The mechanical behavior determined two different situations of stress and strain distribution. These dates are very important to apply in equipment development for cashew nut extraction. For future research works, is recommended the analysis of mechanical behavior of nuts, through *moiré* technique, on higher compression modulus to determine its rupture.

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