

Research Article

Image Processing Algorithm for Fringe Analysis in Photoelasticity

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Abstract: Photoelastic fringe patterns recognition are carried out using a circular polariscope on a four point beam loaded by pure bending and they are processed with image processing algorithm in a personal computer. The aim of the present paper stress analysis of the photoelastic fringe in a rectangular cross section beam using digital image processing technology. An algorithm is developed to visualize the stress pattern acting in photoelastic models using fringe sharpening in conjunction with MATLAB software. Photoelasticity is a non-destructive experimental tool can be used for visual representation of stress patterns allowing for stress analysis. The present paper presents an image processing algorithm executed in a personal computer and obtained stress pattern recognition using digital image processing with histogram.

Keywords: Experimental stress analysis, Image processing, Isochromatic fringe, Isoclinic fringe, Photoelasticity.

INTRODUCTION

Photoelasticity is non-destructive technique for stress analysis that utilizes a polariscope in conjunction with optical system [1, 2]. The polariscope takes the benefit of the optical system that is having two-dimensional signal process and non-contact visualization. The polariscope makes fringe patterns based on birefringent phenomena that fringe patterns depend on external load applied to the specimen. The fringe patterns are captured by digital camera and can be analyzed in a personal computer to obtain information about the stress produced in the specimen. Full field information is available on the whole area of specimen through digital camera (non-contact) method in the photoelasticity experiment as compared with point-by-point technique[2]. Recently digital photoelasticity made a significant growth attributed advancement of computational technique in conjunction with digital image processing methods to analyze stress patterns. The progress of computational methods in conjunction with digital image processing methods and applications has been described in detail by Ramesh [3].

Harrow [4] has carried out interactive computer graphic and data visualization to create a technique for analysis of photoelasticity of shoulder orthoplasty glenoid components. Algorithm procedures have been developed by them for image acquisition, calibration, contouring and calculating effective stress and mode viewing.

Lawrence [5] has developed technique for determining the forces acting on a single diametrically compressed photoelastic disk by analyzing the fringe pattern disk exhibits when viewed in a crossed circular polariscope illuminated with monochromatic light.

Li [6] has investigated experimentally infrared transmission technique to extract the full stress components of in-plane residual stresses in thin multi crystalline silicon wafer that find application to measure residual stress for large cast wafers.

Surendra and Simha [7] described digital characterizing the fringe topology in order to enlarge the scope of digital photoelasticity including the ideas of the digital pattern recognition. The digital image processing tools rely on statistical [8] evaluation of intensity data and syntactic methods of pattern recognition. Photoelastic analysis of models has been analyzed by combinations of software packages and computer platforms requiring operator input data. Baek, Kim and Hong [9] have reviewed image processing for better analysis of fringes in photoelasticity and found that fringe patterns obtained in the polariscope consist of broad bands width and they have limited fringe orders.

The purpose of paper is to utilize digital data, interactive computer graphics, and data visualization to create an algorithm for analysis of stress analysis. The algorithm would be used for capturing stress patterns

viewed through the polariscope, through data analysis, working in an inexpensive personal computer platform. A four point loaded photoelastic beam fringe patterns is viewed in a crossed circular polariscope illuminated with mono-chromatic light source. The present paper describes digital photoelastic algorithm simulated on MATLAB software [10] in a personal computer.

EXPERIMENTAL SET-UP

The experimental setup of photoelasticity with polariscope consists of a monochromatic light source, polarizer, analyzer and load frame is shown in Fig. 1. The plane polariscope is an optical instrument that can produce a plane-polarized light and can measure the resulting phase difference when the polarized light passes through a stressed photoelastic model. It can resolve a light vector into transmitted and absorbed orthogonal components. The axis parallel with the transmitted component is called the axis of polarization. The plane polarizer near the light source is called the polarizer and its axis of polarization is called the axis of polarizer. Since the two axes are perpendicular to each other, no light will be transmitted through the analyzer when the transparent model is stress free, and dark field will result.

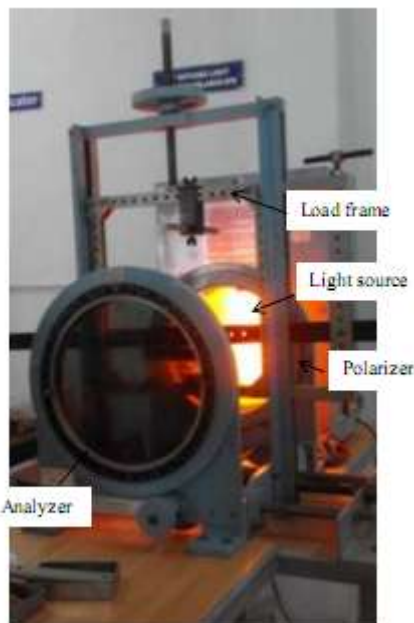


Fig- 1: Experimental set-up of polariscope

The dimensional detail of the beam is described in Fig.2. There values are as $a = 20\text{mm}$, $l = 130\text{ mm}$, $h = 25\text{ m}$, and $t = 5\text{ mm}$. Material of the beam is Araldite CY-230. The setup is attached to a digital camera of specification as Model – Nikon-D3200, Megapixel - 24.2 megapixels, Image processor – Expeed 3.

FRINGE SHARPENING

Photoelasticity involves analyzing the polarized light that passes through a stressed model of

polymeric material. Deformation of the polymeric material causes change of the reflective and refraction of the light wave proportionally to the magnitude and direction of applied load. For a two-dimensional model the applied load can be separated into two-orthogonal principle stresses and shear stress allowing a relationship between the stress magnitude and the index of refraction. One of principle stresses using stress-optic law[1] can be written with non-zero principle stresses σ_1 and σ_2 as

$$\sigma_1 - \sigma_2 = \frac{N \cdot f_\sigma}{t} \tag{1}$$

where N is the fringe order that can be determined from the fringe pattern of the model, t is the thickness of the material, f_σ is the material stress fringe value. The value of f_σ depends on photoelasticity materials. The determination of f_σ , the material stress fringe value is the essential to find out the principle stress of the model in photoelasticity experiment. In this experiment, we are using the four point beam to find out the material stress fringe value. Dark field in chromatic pattern using a monochromatic light source was captured in a circular polariscope setup with polarized analyzer. The fringe constant is calculated using the following expression

$$K = \frac{12P \cdot a}{t \cdot h^3} \cdot \frac{y_i}{n_i} \tag{2}$$

where K is constant of the photoelastic model, P is external load applied to the beam and y_i is coordinate of the n_i order isochromatic fringe as depicted in Fig. 2. Original stress pattern ($P = 49.05\text{ N}$) captured by digital camera and depicted in Fig. 3(a). The stress pattern in grey format is displayed in Fig. 3(b).

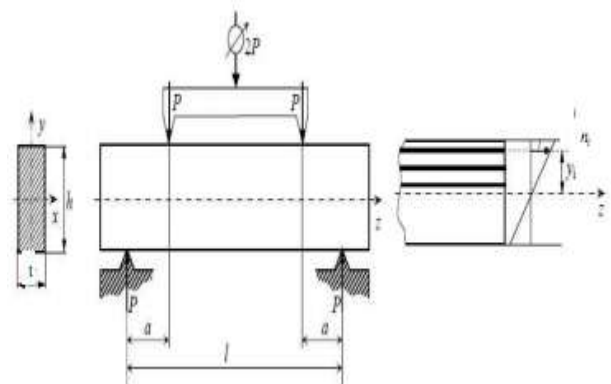


Fig-2: Schematic sketch of four point beam loading

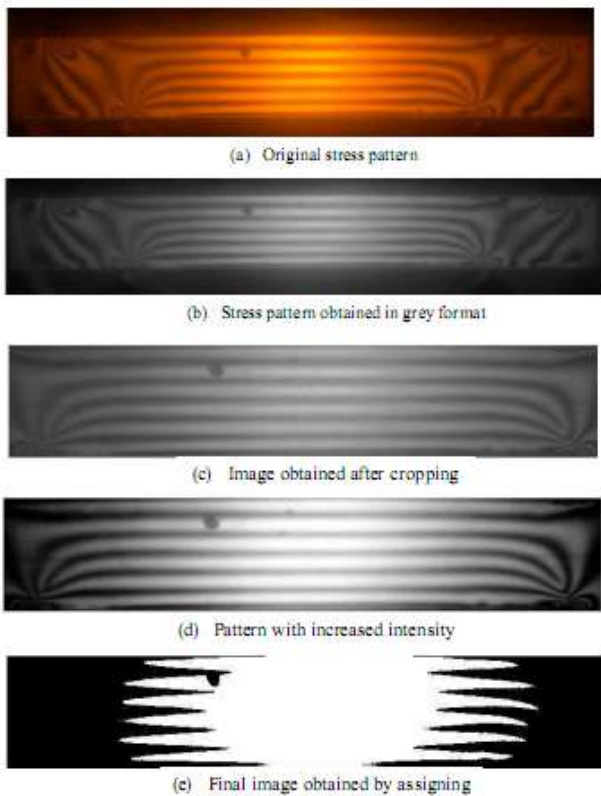


Fig-3: Stress pattern with and without image processing

ANALYSIS PROCESS

The focus of developing an analysis program was to provide an inexpensive and easy to use alternative for photoelastic analysis. The goal was to develop a single PC based program that could be connected to an image database for input, provide image capturing and processing and final analysis viewing methods. An ideal algorithm would have functions for reading a calibration beam image and applying the calibration to other images to obtain stress information from pixel color values. The program would provide the ability for stresses of model of the one effective stress model.

The development of the image processing tasks were completed through the use of external software as a time and cost savings. The functions used in the processing are available in code form from an image processing library and can be combined with the remaining analysis program in the future if desired. The analysis process is having image processing, development of the analysis program providing spacing, alignment, and rendering and then the calibration function. The pixel intensity array of an isochromatic pattern viewed by the digital camera is input to algorithm and run using on MATLAB [10] software. A computer program is written and compiled and executed using MATLAB in a personal computer. We have carried out digital photoelasticity with different

external loading. For the sake of brevity we are presenting results of one test case.

The MATLAB[10] is intended for numerical computing; an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink adds graphical multi-domain simulation and model-based design for dynamic and embedded systems. Figure 3(c) and (d) shows the image obtained after cropping and increased intensity. The stress patterns are sharp and can be recognized through the image processing algorithm.

HISTOGRAM

A histogram is a graphical representation of the distribution of numerical data. It is an estimate of the probability distribution of a continuous quantitative variable. To construct a histogram, the first step is to "bin" the range of values. The bins are usually specified as consecutive, non-overlapping intervals of a variable. The bins (intervals) must be adjacent, and are usually equal size. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram [8]. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. The histogram will illustrate error distribution during the image processing. Figure 3(e) shows final digital image of stress patterns adapting the pixel intensity. Figure 4 shows histogram of the number of pixel versus intensity. The distribution is skewed and more or less display Gaussian distribution. Figure 5 depicts the histogram equalizer. The statistical information is very useful for digital image analyzer using MATLAB software.

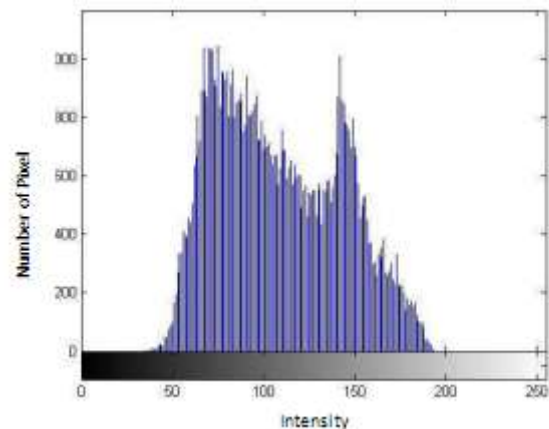


Fig-4: Histogram of pixel intensity

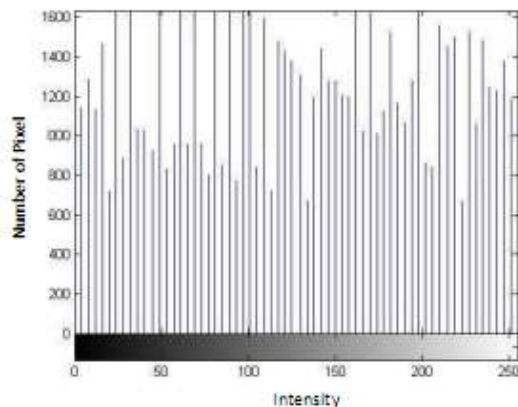


Fig-5: Histogram equalization of pixel intensity

CONCLUSIONS

Image processing techniques are employed to stress analysis of fringes in photoelastic specimens. Photoelasticity experiments with a polariscope are conducted on a four-point beam which is made up of material araldite. The standard four-point load bending test is carried out in the polarized light stream and fringes of isoclinics and isochromatics are extracted. The stress fringes were captured using a digital camera. The input data of the digital camera are used for pattern recognition with MATLAB software. The algorithm is executed on a personal computer to do image processing with MATLAB. It shows that advances in digital image processing techniques can enhance photoelastic techniques. Histogram analysis is carried out to determine the error distribution.

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