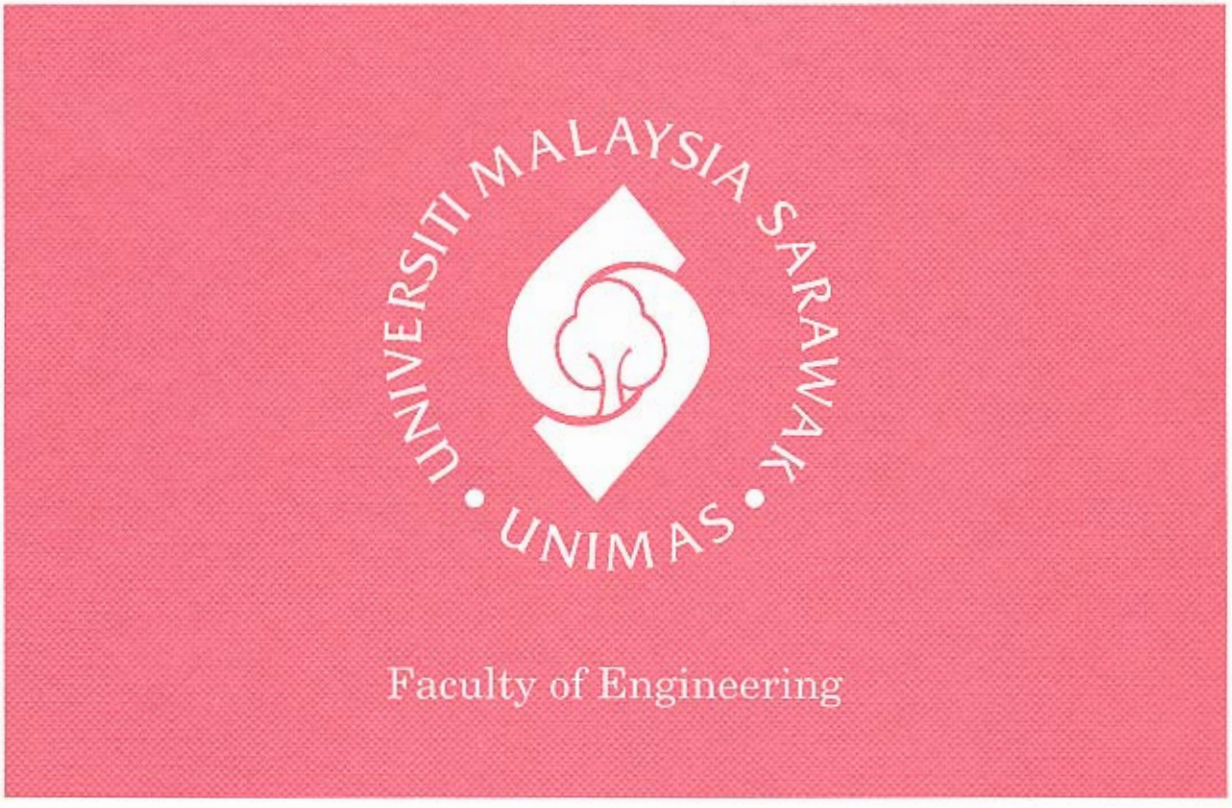

DEVELOPMENT OF PHOTOELASTIC EXPERIMENT

Noraizah Binti Ugang

TA
405
N822
2006

Bachelor of Engineering with Honours
(Mechanical Engineering and Manufacturing Systems)
2006

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DEVELOPMENT OF PHOTOELASTIC EXPERIMENT

NORAIZAH BINTI UGANG

This project is submitted in partial fulfillment of
the requirements for the degree of Bachelor of Engineering with Honours
(Mechanical Engineering and Manufacturing Systems)

Faculty of Engineering
UNIVERSITI MALAYSIA SARAWAK
2006

Dedicated to my mama, my sisters

and my supervisor

ACKNOWLEDGEMENTS

Alhamdulillah, Thank God for all His blessing and permission I was able to complete this Final Year Project. First and foremost I would like to express my thanks for my special supervisor Dr Mohd Shahril Osman, for his superb and brilliant ideas, valuable advices, his patience, his cares and willingness to assist me complete this report. Without his support and time, the work would never have been finished. I would like to mention my special thanks to my beloved mama Pn Bisnah Muris, my sister Noraini Ugang, and to all my younger sisters for their continuous encouragement and support in my life. I am forever grateful to them for that.

I would like to thank to all technicians especially Sabariman, Mr Masri and kak Miza for their cooperation. They have always been exceptionally helpful whenever I faced any problem in developing the experimental set up.

I am grateful to my supportive friend Noraini Asakil for her helps and ideas. Also thanks to all my friends and mechanical lecturers, for their supports and helps. Last but not list for some one special thanks a lot for the uncounted cares, loves, support and patience, and I pray for our everlasting love.

ABSTRACT

Measurement techniques in determining the strength of a material usually employs conventional method where testing is performed by means of tensile or compression test. In most engineering applications, this would means that the sample is required to be mounted onto the testing equipment. One of the available techniques to measure directly the sample is the photoelastic measurement. Furthermore, the technique is non destructive and employ white light to illuminate the sample. The sample for photoelastic experiment must be a transparent material or coated with a transparent resin for which light is emitted to reveal the stress contour. In this work, the experiment will employ the sample to be a transparent perspex material which was shaped like a hook type. The sample shows clearly visible contour for across the thickness of the hook. The calibration can then determine the amount of the fringe contour occurring when load are applied. In calibration experiments, successive loads of 10g, starting from 10g up to 200g was performed. From the calibration experiments, this can then be tabulate such that an unknown load can then be determined simply by using the techniques. The technique describe here is a simple measurement techniques which can be further developed. The result shows an 8.6% difference between experiments and simulation. The sample can be varied using the clear resin type material coated onto the interested region.

ABSTRAK

Ujian ketegasan atau ujian mampatan perlu dilakukan dalam teknik pengukuran untuk menentukan kekuatan atau daya pada sesuatu bahan. Dalam aplikasi kejuruteraan keadaan ini memerlukan sampel diletakkan pada radas experimen. Satu daripada teknik yang mudah untuk mengukur sampel tersebut ialah dengan experimen Photoelastic. Experimen in ialah teknik ujian tidak musnah dimana cahaya putih digunakan untuk menerangkan sampel. Sampel untuk experiment ini mestilah daripada bahan lutsinar atau sampel yang dibalut dengan lutsinar 'resin' bagi membenarkan cahaya melaluinya untuk mendedahkan 'stress contour'. Dalam tugasan ini, sampel berbentuk cangkuk digunakan yang diperbuat daripada perspex lutsinar. 'Stress contour' nyata dapat dilihat dari sampel tersebut. Kaedah pengukuran dilakukan untuk menentukan bilangan 'fringe contour' yang terbentuk apabila beban dikenakan kepada sampel. Dalam experiment ini beban yang dikenakan bermula dari 10g sehingga 200g dalam turutan 10g. beban untuk 500g dan 1000g juga dikenakan kepada sampel untuk memvariasikan pergerakan 'fringe contour' sampel tersebut. Keputusan menunjukkan 8.6% perbezaan anatra eperimen dan simulasi experimen. Kaedah experiment ini juga boleh digunakan untuk menentukan nilai beban yang tidak diketahui dikenakan kepada sampel. Teknik ini adalah teknik pengukuran yang mudah dan boleh dimajukan lagi. Sampel yang digunakan juga boleh divariasikan dengan mengunakan 'resin'lusinar untuk membalut kawasan yang dikehendaki pada suatu sampel atau binaan lain.

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NOMENCLATURES

σ = Stress Engineering

F= Load applied

A= Cross-sectional area

E= Young's modulus

ε =Strain

G= Shear modulus

n= Index of refraction

θ_p= angle of transmitted light to the normal

θ_r= angle of light to the normal

$V_{material}$= Speed of light in material

C_b= relative stress-optic coefficient

N=fringe order

f_s=Fringe value

h= the phase difference or relative retardation

Þ= the sample thickness

$s1$-$s2$= the principle stress difference

h= tensile specimen thickness

ø=angular phase shift

CHAPTER 1

INTRODUCTION

1.0 Introduction

The current method in analysis problem in engineering usually involves measurement either destructive or non-destructive testing. The analysis present here is a non-contacting method called photoelastic method.

The MATLAB software analyse the experiment result and ANSYS applied for simulation technique.

1.1 Photoelastic Method

The photoelastic method is cheap rapid and yields very full information [1]. The method consists of examining by polarised light to the part of sample. The photoelastic method is based on the fact that many materials, notably certain plastics become doubly refractive when subjected to the stress. The amount of this birefringence may be studied with a polariscope and the characteristics of the stress system obtained. A model of a machine part or structure may therefore be made from such a materials and subjected to an appropriate loading systems and the state of stress within it can than be determined.

Photoelasticity is an experimental method to determine the stress distribution in a material. The method is mostly used in cases where mathematical methods become quite cumbersome. Unlike the analytical methods of stress determination, photoclasticity gives a fairly accurate picture of stress distribution even around abrupt discontinuities in a material. The method serves as an important tool for determining the critical stress points in a material and is often used for determining stress concentration factors in irregular geometries.

A model of the actual part or the structure of interest is usually required since special optical behaviour is needed to observe the stresses in material. In term of identification of stress acting over a model, it is necessary to recognise the stress mechanism subsequently that understands the relation between its initial cause and deformation phenomenon.

Since the technique or the method required, special optical behaviour, the material employed for the model must be able to review the photoelastic. For this project, the material will have elastic properties. This will enable the experiments to give the required stress-strain field.

1.2 Stress-strain Relations

The concept of *stress*, defined as force per unit area, was introduced into the theory of elasticity by Cauchy in about 1822. It has become universally used as an expedient in engineering design and analysis, despite the fact that it cannot be measure directly and gives no direction of how forces are transmitted through a stress material [1]. When solid body is subjected to applied forces, these forces are transmitted from one part to another of the body by means of internal forces between the particles of the body [2]. Stress engineering, σ defined as the instantaneous load applied to a specimen divided by its cross-sectional area before any deformation [3].

$$\sigma = \frac{F}{A} \tag{1.0}$$

in which F is the instantaneous load applied perpendicular to the specimen cross section, in units of newtons (N), A is the original cross-sectional area before any load is applied (m^2). The units of engineering stress are Pascal, Pa . The magnitudes and directions of these internal forces vary from point to point of the body, and the tendency to disruption at any point is measured by the intensity of the forces in which the materials has to transmit at the point.

Strain, or elongation, in a solid may be considered as a displacement of the particles relative to one another [2]. It can be elastic (instantaneous, reversible), anelastic (reversible, time dependent), inelastic (irreversible, time dependent) or permanent. The deformation process is a complex phenomenon [5]. This is because of the many changes in the sample shape size and direction of axes. These changes may be either highly visible or practically unnoticeable, without the use of equipment to make precise measurement. For example, a rubber band will undergo a very large deformation when stretched. The deformation occur when the load or stresses is subjected to the sample.

For the sample case of one –dimensional loading, direct *stress and strain* are related by Young's modulus E, as reference [4].

$$E = \frac{\sigma}{\varepsilon} \tag{1.1}$$

And shear stress and strain are related by the shear modulus, G

$$G = \frac{\tau}{\gamma} \tag{1.2}$$

The ability of a material to come to back to the original shape called elastic deformation. The stresses subjected to the material can be measure or observed by using photoelastic technique. The means that, the structural behaviour can be examined.

1.3 Objectives

The objective of this experiment is to setup an experimental method in order to develop photoelastic experiment. The experiment will show the distribution of stress strain in mechanically stressed body by using circularly polarized light. The stress strain monitors and appears as a fringes pattern in the screen of the photoelastic equipment.

The proposed method will be able to determine the stress distribution under loading. The experiment result will employed MATLAB software and the modelling will use ANSYS. Both data will be compared so as to check and validate the result. The stability of complex component under load can also be analysed. The photoelastic experiment can also be used to check the material behaviour in term of changing of structural change under stress.

The project is to analyse the stress distribution for either transparent or coated material for which individual load at any point can be determine.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

The phenomenon of temporary double diffraction induced in amorphous transparent materials by mechanical stresses as in reference [5]. The development in turn makes photoelasticity into a powerful stress analysis tool. Photoelastic technique can be used to investigate the physical properties of materials under the influence not only mechanical but also electrostatic, magnetic and electromagnetic fields.

2.1 The Theory of Photoelasticity

To begin to understand photoelasticity, it is necessary to review the properties of light, based on Maxwell's electromagnetic wave theory, and the polarization and refraction of light [6]. In photoelasticity, stresses measure by describing light as a wave.

2.1.1 Electromagnetic Wave Representation of Light

A monochromatic light source emits light rays of one particular wavelength λ, which propagates at the speed of light c. When illuminated by monochromatic light, alternate bright and dark regions are observed, and the positions of the bands shift as the color of the monochromatic light is changed.

This phenomenon can be practically seen from double-slit interference. Figure 2.1 show the diagram of double-slit interference.

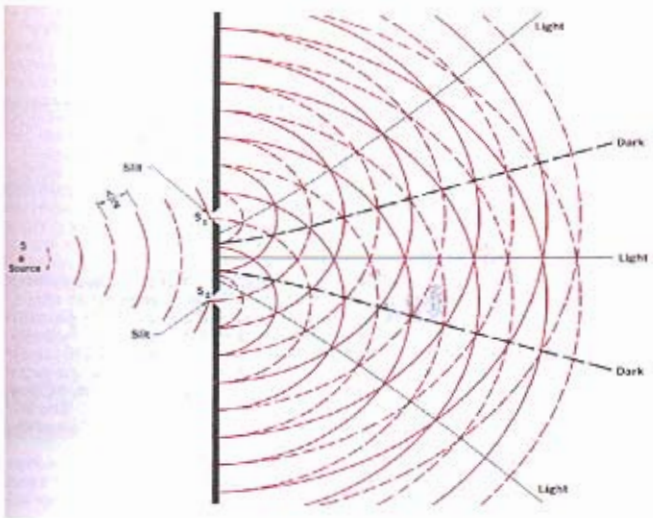

Figure 2.1: Wavefront diagram of double-slit interference with a monochromatic light source

The source S separated into slits S_1 and S_2 at the same distance. The light producing new wave fronts in phase with each other. These waves travel out from S_1 and S_2 producing bright bands of light due to reinforcement where constructive interference occurs and dark bands due to cancellation. The patterns composed from dark and light field called birefringence. Thomas Young explained this thin-film phenomenon in terms of the interference of light waves [10]

2.1.2 Polarization

One of the resultant waves can be cancelled by placing a polarization filter in the light path. The filter which polarizes the light is called polarizer. If a second polarization filter is placed in the light path, the light polarized by the first filter will be completely absorbed when the polarization axes of the two filters are perpendicular to each other, this phenomenon is shown in Figure 2.2.

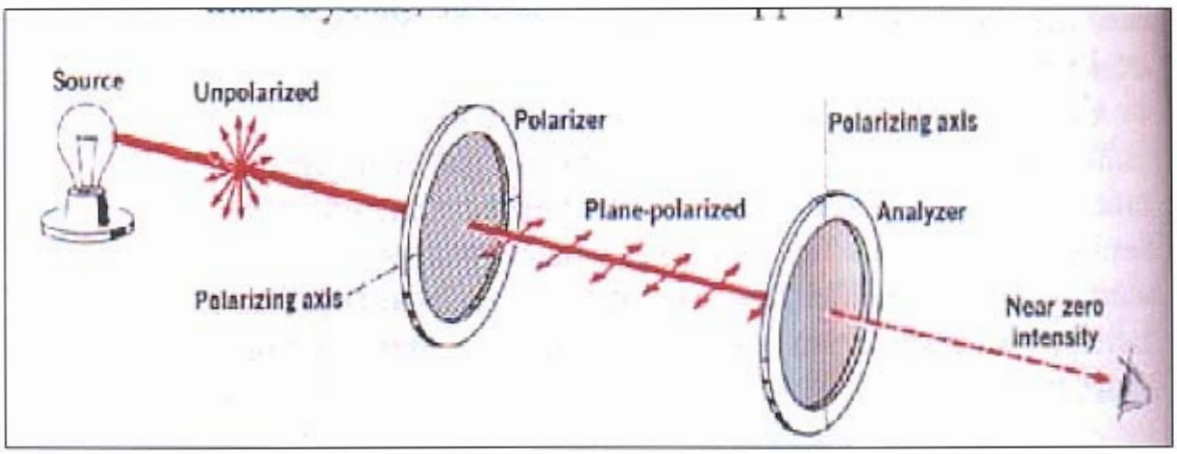

Figure 2.2: polarizer and analyzer