DOWNLOAD PDF PHOTOELASTIC EFFECT AND ITS APPLICATIONS

Chapter 1 : Photoelastic modulator - Wikipedia

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By studying the fringe pattern one can determine the state of stress at various points in the material. For materials that do not show photoelastic behavior, it is still possible to study the stress distribution. The first step is to build a model, using photoelastic materials, which has geometry similar to the real structure under investigation. The loading is then applied in the same way to ensure that the stress distribution in the model is similar to the stress in the real structure. Isoclinics and isochromatics[edit] Isoclinics are the loci of the points in the specimen along which the principal stresses are in the same direction. Isochromatics are the loci of the points along which the difference in the first and second principal stress remains the same. Thus they are the lines which join the points with equal maximum shear stress magnitude. However, examining photoelasticity in three-dimensional systems is more involved than two-dimensional or plane-stress system. So the present section deals with photoelasticity in a plane stress system. This condition is achieved when the thickness of the prototype is much smaller as compared to dimensions in the plane. Thus one is only concerned with stresses acting parallel to the plane of the model, as other stress components are zero. The experimental setup varies from experiment to experiment. The two basic kinds of setup used are plane polariscope and circular polariscope. The working principle of a two-dimensional experiment allows the measurement of retardation, which can be converted to the difference between the first and second principal stress and their orientation. To further get values of each stress component, a technique called stress-separation is required. Plane polariscope setup[edit] The setup consists of two linear polarizers and a light source. The light source can either emit monochromatic light or white light depending upon the experiment. First the light is passed through the first polarizer which converts the light into plane polarized light. The apparatus is set up in such a way that this plane polarized light then passes through the stressed specimen. This light then follows, at each point of the specimen, the direction of principal stress at that point. The light is then made to pass through the analyzer and we finally get the fringe pattern. The fringe pattern in a plane polariscope setup consists of both the isochromatics and the isoclinics. The isoclinics change with the orientation of the polariscope while there is no change in the isochromatics. Transmission Circular Polariscope The same device functions as a plane polariscope when quarter wave plates are taken aside or rotated so their axes parallel to polarization axes Circular polariscope setup[edit] In a circular polariscope setup two quarter- wave plates are added to the experimental setup of the plane polariscope. The first quarter-wave plate is placed in between the polarizer and the specimen and the second quarter-wave plate is placed between the specimen and the analyzer. The effect of adding the quarter-wave plate after the source-side polarizer is that we get circularly polarized light passing through the sample. The analyzer-side quarter-wave plate converts the circular polarization state back to linear before the light passes through the analyzer. The basic advantage of a circular polariscope over a plane polariscope is that in a circular polariscope setup we only get the isochromatics and not the isoclinics. This eliminates the problem of differentiating between the isoclinics and the isochromatics.

Chapter 2 : The photoelastic effect and its applications: symposium Ottignies/Belgium - Google Books

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However, certain new and novel developments and applications have revived the use of photoelasticity. Among them are image processing for fringe analysis, polarimetric fiber optic sensors, infra-red photoelasticity, low cost dynamic photoelasticity and photoelastic applications in stereolithography. This paper will, after a brief introduction to photoelasticity, highlight some of these advances and developments. As the name implies, photoelasticity was developed to apply optical photo principles to solve engineering problems of elasticity. The method relies on the birefringence property exhibited by transparent plastics. In particular, the phenomenon of stress or load induced birefringence is utilized where the material becomes birefringence under the influence of external loading. The phenomenon was first observed by David Brewster in the early nineteenth century in glass and he foresaw the potential of this for stress analysis. However, glass was far from the ideal material although photoelasticity of glass 1 has generated great interest. The technique was ,however , systematically developed into a viable experimental stress analysis tool only in the second quarter of this century. Works by Coker and Filon 2 , Frocht 3 and Jessop and Harris 4 are particularly noteworthy in this regard. The potential of 3-D stress analysis was also developed by Oppel 5 and Hetenyi 6 and to this day remains one of the very few experimental methods for 3-D stress analysis. With this background, photoelastictiy found widespread application in many industrial applications. In particular, determination of stress concentration 7 in front of notches and holes was and still is one of the premier forte of photoelasticity in design of machine elements. The simplicity and black box nature of FEM was particularly inviting to designers who did not have to get their hands dirty. However, while one cannot ignore the power of FEM, one has to realize the limitations of the method in it being as good as the model used. Indeed, critics of photoelasticity did mention that photoelasticity requires a birefringent model to be used instead of the actual structure. The same applies to FEM since it relies on a numerical model of the actual structure and loading to generate the stress and displacement distribution patterns. A new school of thought is the use of hybrid methods where advantages of both experimental and numerical methods are exploited. Nevertheless, recent needs such as continuous on-line monitoring of structures, residual stresses in glass plastics and microelectronics material , rapid prototype products and dynamic visualization of stress waves have brought photoelasticity into the limelight once again. This paper will highlight some of these advances and developments in photoelasticity. The principles of photoelasticity can be succinctly elucidated by the following two laws: For stress or strain induced birefringence, the normally incident polarized light is split into two components along the principal stress directions in a plane perpendicular to the direction of light propagation and are transmitted only along these planes through the model. The velocities of light transmission along these directions is directly proportional to the intensities of the respective principal stresses. These laws imply that the input linearly polarized light emerges as an elliptical polarized light where the degree of ellipticity depends on the principal stress directions and the magnitudes of the principal stresses. The required phase difference or fringe order is determined by placing the birefringent model in a Polariscope as schematized in fig. The standard plane polarsicope consists of the light source and Figure 1: Schematic of Crossed Plane Polariscope a pair of polarisers, termed the polariser and analyzer, with crossed polarization axis on either side of the model. The polarisers are generally tuned for the visible region, with infra-red photoelasticity requiring special polarizers. Imaging of the fringe patterns have also changed from the traditional film based systems to digital imaging system with increased versatility both in image capture and processing. Based on the optics of the plane Polariscope it can be shown 8 that the recorded light intensity emerging from the analyzer can be written as: Traditionally, regions where the intensity of light was zero were analyzed. From figure 1, this condition is satisfied when either principal stress direction coincides with the axis of polarization of the polarizer. Indeed, since a is wavelength dependent, these fringes have been referred to as isochromatics - lines of the same colour. If the incident light is monochromatic dark and bright fringes will be observed. Conventional photoelasticity used black and white fringes for processing since they were easily distinguishable by the human operator. Colour imaging and processing is now being revived with the ready access to digital colour imaging and image processing. Nevertheless, regions of high fringe gradient might still call for gray level processing. The standard plane Polariscope will thus show both the isoclinics and isochromatics intertwined. From a stress analysis point of view this is quite inconvenient. Visualization of only isoclinics can be achieved by reducing the number of isochromatics by applying a smaller load or using a material with a high material fringe constant. Visualization of isochromatics alone can be achieved by using a circular Polariscope which in addition to the plane Polariscope elements , has two opposing quarter wave plates on either side of the model. Figure 2 shows typical isochromatics around an inclusion and a crack at a bimaterial interface. Figure 2 Isochromatics at the interface of a bimaterial with an inclusion and a crack Having obtained the isochomatics, the next stage is the analysis for stress determination. Photoelasticity, as mentioned above provides the direction of principal stress at every point and the magnitude of principal stress difference. By themselves, these are not sufficient for a complete 2-D stress analysis. However, in most engineering applications, maximum stresses occur at boundaries where one of the principal stress components is known a priori. Hence the separation of stresses is trivial. At other locations additional data is required either through another experiment oblique incidence method 8 or by numerical means shear difference method 8. Furthermore, from the considerations of eqn. Fractional fringe order determination would greatly assist in this extrapolation and various schemes have been proposed for the same with the Tardy method 8 the traditional favourite. Advances and Applications 1. While the optical elements are essentially the same, changes in the illumination and imaging systems have been quite novel and interesting. Current light sources that have found favour for their versatility are the Light Emitting diodes and the laser diodes. Schematic of a typical current Polariscope. A typical pattern 10 from a two colour LED is shown in fig. The LEDs emit at nm and nm and their compact construction enables them to be mounted on a PCB board in such a way as to allow for independent control of the two wavelengths. For improved diffusivity, an HOE diffuser can be used. However, due to their limited power, the intensity for such a short duration may not be sufficient to expose the film. The digital recording system helps out in this regard. The CCD cameras are fairly sensitive to low light imaging and can be used to record the short bursts of light. Conventional CCD cameras however have to be triggered at the right moment in order to image the small duration flash. External triggering can cause problems, since the image will be recorded at the start of the next field which can be upto 20 milliseconds later, by which time the event is history. Asynchronous triggering or keeping the shutter open for the entire frame duration can be used to solve some of these problems. The TDI camera is the electronic equivalent of the drum or the moving film camera, in which unlike the film the charge collection sites are translating from one end to the other. Hence by keeping the film running during the course of the event and the pulsed LED provides the illumination at the required time. Figure shows a typical set of isochromatics corresponding to the impact of a plate. The LED pulse duration was 1m s and the individual frames were recorded at specified delays after impact. Instead of an LED, a laser diode could be used. The advantage of the laser diode is that it provides a higher light intensity; however the laser diode is coherent resulting in speckle noise and they are relatively more expensive than the LEDs. Figure 5 b shows a similar set of isochromatics using a pulsed laser diode light source. This is the norm for traditional photoelasticity. However in the microelectronics industry the material commonly used is silicon which is opaque to visible radiation but birefringent in the near infra-red. In this case an infra-red LED or laser diode would be the preferred choice. Both these are widely available since the infra-red emitting laser diodes were the first solid state laser to be developed. However, the polariser and analyzer has to be replaced with ones operating in the infra-red. These polarisers are relatively more expensive with the cheaper ones or poorer quality. Nevertheless the potential exist for use of infra-red photoelasticity for inspection and determination of residual stress in micro-electronic components. Figure 5 c shows a typical example of dynamic photoelasticity using an infra-red source and corresponding polarisers but the same CCD camera to record the stress wave propagation across a bimaterial interface with a crack due to impact. Figure 5 c Infra-red Digital Dynamic Photoelasticity In all these examples, each frame had to be individually recorded at the preset time delay following impact. While this would be acceptable for experiments which are repeatable, in other examples such as crack propagation studies this approach would not be suitable. The recording in this was not digital but made use of high speed Polaroid film to capture the multiple images. While a digital recording system has been proposed, the current cost is fairly high. The film based system works fairly well and the image can be seen within a few minutes. Low cost development of a digital system should not be too distant in the future. Figure 6 shows a schematic of the LED based Cranz Schardin system and the corresponding fringe patterns that were obtained. Image Processing in Photoelasticity The current trend of digital imaging of photoelastic fringe patterns also augurs well for image processing to delineate the required information from the fringe patterns. The three basic image processing techniques as applied to fringe patterns in experimental mechanics - fractional fringe method, Fast Fourier Transform method and the Phase Shift Method, have also been applied to photoelastic fringes. However, unlike other interferomteric methods where, in general absolute fringe orders are not necessary as long as the fringe sign is available, in photoelasticity, the absolute fringe order and the fringe sign are essential. Of the three methods the phase-shift method has the most potential particularly in respect of fringe sign determination. However, the starting fringe order has still to be assigned manually. The advent of colour image processing can possibly overcome this problem as only the zero order fringe is black and should be readily identifiable, if present. The phase shift method as applied to photoelasticity is not as simple as it appears. The principle is based on the Tardy method. Whereas the traditional Tardy method was applied for single point determination - since only dark fringes were being analyzed, digital Tardy method can make use of all the gray levels present. However, for the Tardy method to be applied, the points being analyzed should fall on the isoclinc corresponding to the current polarization axis of the polariser. The isoclinics are not necessarily straight lines and identifying the corresponding points for use can be quite cumbersome. Solutions to this are available by recording more than the required number of images compared to the traditional phase-shift methods However, for lines of symmetry 14 , the method can be readily applied in the traditional sense. Phase shifting is achieved by rotating the analyzer through equi - angles , noting that the fringe pattern is repeated every degree rotation of the analyzer.

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Chapter 4 : Recent Advances in Photoelastic Applications

Photoelasticity describes changes in the optical properties of a material under mechanical deformation. It is a property of all dielectric media and is often used to experimentally determine the stress distribution in a material, where it gives a picture of stress distributions around discontinuities in materials.

Chapter 5 : J Kestens (Author of The Photoelastic Effect and Its Applications)

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Chapter 6 : Photoelasticity - Wikipedia

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