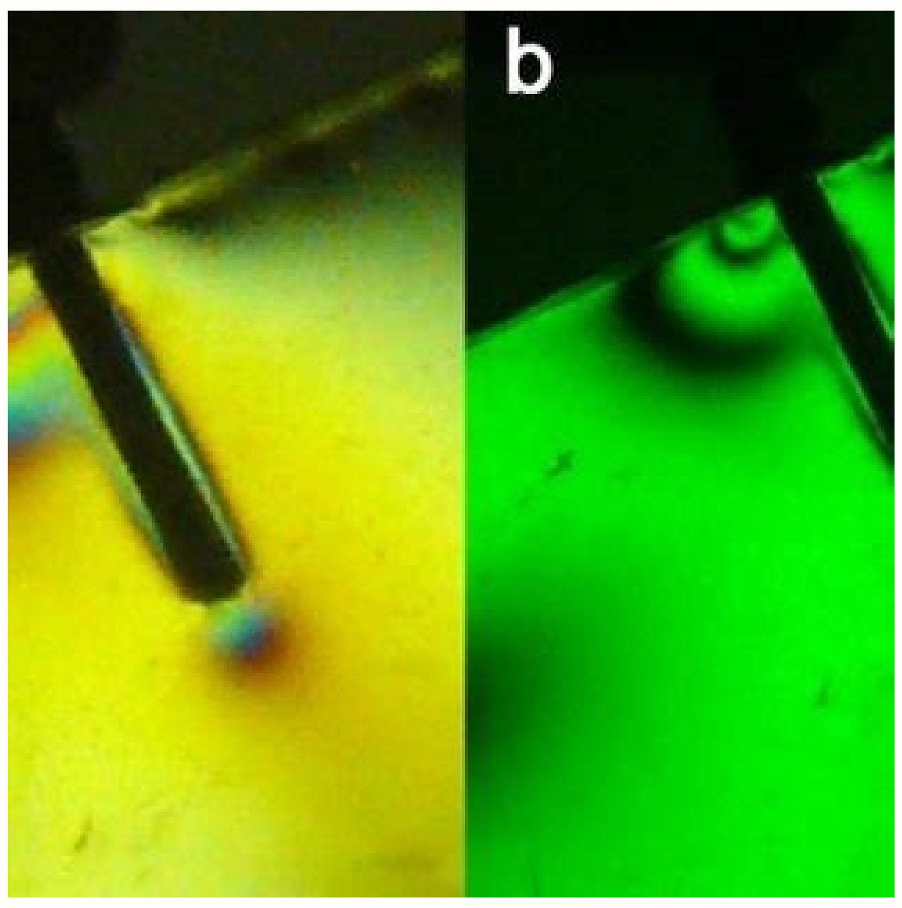
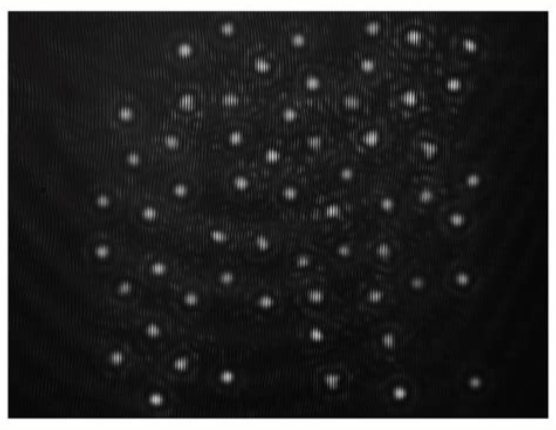
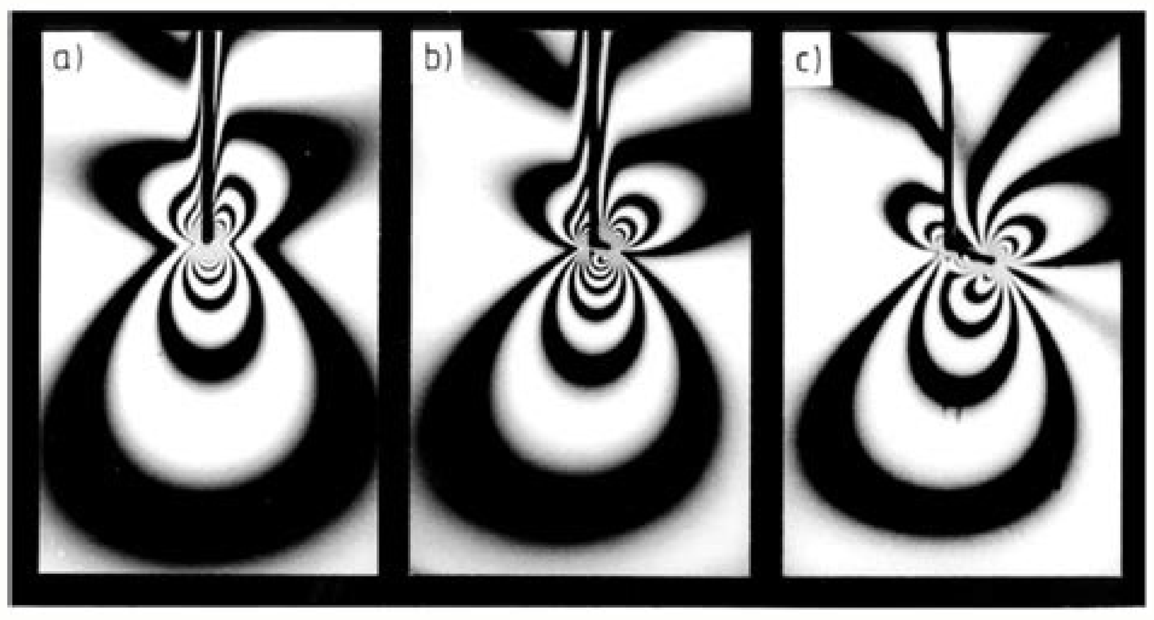
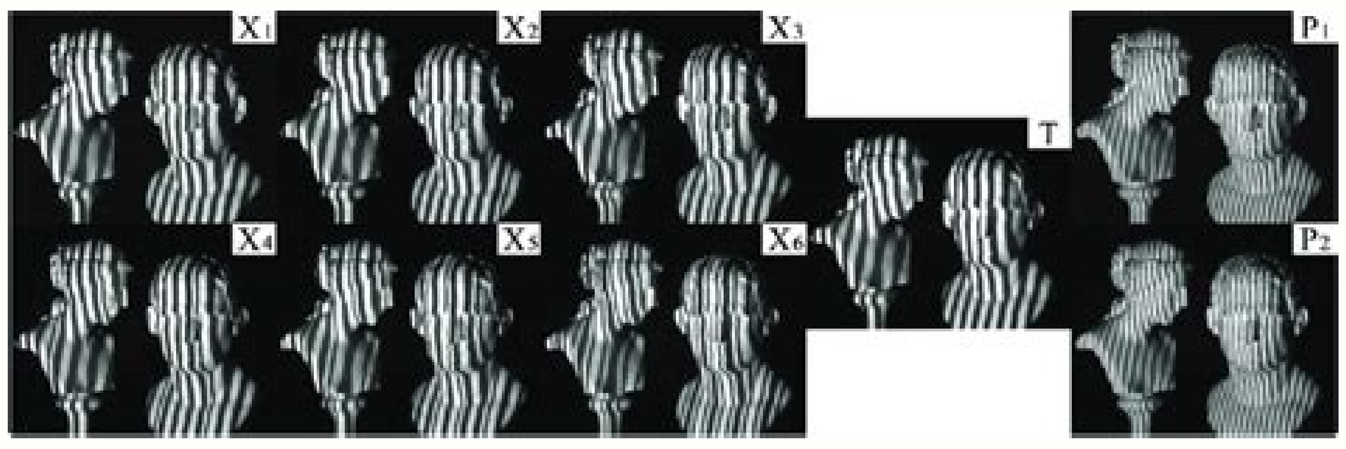
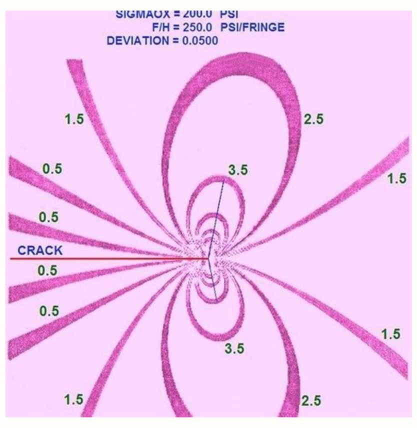
Isoclinic and isochromatic fringe patterns pdf











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Going further Websites Optical Birefringence Part of the excellent Molecular Expressions website, includes interactive Java applets on double refraction, birefringent crystals and polarised light microscopy. This light will not pass through the analyser. Isoclinic fringes can be observed by reducing the number of isochromatic fringes through either applying a smaller load or by using a material with a high material fringe constant. Annealed bars in 3-point bending rigs Bar with notch The stress pattern is symmetric about the notch. What does Δn represent in the equation for the Stress-Optic Law? 3-point bending rig 4-point bending rig Stress patterns: 3-point bending Plain bar The stress originates in the centre of the long edges of the bar, unsurprisingly as these are the parts of the bar furthest from the neutral axis and experience the greatest deflection upon bending. The hole is on the neutral axis, and therefore in the least stressed position. For an initially 'isotropic material, when a tensile stress is applied the material will become uniaxial with the optic axis parallel to the applied stress. Developments in image processing allow the stress information to be extracted automatically from the stress pattern. History Photoelasticity was developed at the turn of the twentieth century. This will give us an appreciation of the effects of geometric discontinuities on the stress state. Around the notch the isochromatic fringes bunch up indicating a stress concentration there. As the load is slowly increased the stressed region moves laterally along the bar as well as in towards the neutral axis. In order to determine the directions of the principal stress it is necessary to use isoclinic lines as these dark fringes occur whenever the direction of either principal stress aligns parallel to the analyser or polariser direction. Photoelasticity A site based at Nanyang Technological University, Singapore, including a paper on Recent Advances in Photoelastic Applications. As the stress increases, the isoclinic fringes approach the edges of the hole, and for high stresses isochromatic fringes representing a high stress concentration can be seen around the edges of the hole, particularly in the transverse positions. Isoclinic fringes will vary in intensity during rotation whereas isochromatic fringes will be invariant to the orientation of the specimen with respect to the polariser and analyser. The development of digital polariscopes using LEDs and laser diodes enables continuous online monitoring of structures and dynamic photoelasticity. Abaqus-generated simulation of a bar with hole undergoing 4-point bending Summary In some transparent materials the application of a stress changes the refractive index for light travelling through that material. If the magnitude of the applied stress is different in different directions in the material the refractive index will also vary with orientation. This “Photoelastic Effect” has useful applications, for example in observing the variations in magnitude and orientation of the stresses in samples. Some examples of such observations have been presented and the underlying science required to understand them has been introduced. In particular the concept of “permitted vibration directions”, each having a different refractive index for light travelling through an anisotropic material has been presented and the resulting “phase difference” (or equivalently “optical path difference”) has been identified as providing the key to understanding the patterns of fringes observed in the stressed samples. A fuller discussion of the propagation of light through anisotropic materials is presented in the TLP “Introduction to Anisotropy”. Close up of annealed bar in 3-point bending rig under a circular polariscope Your browser does not support the video tag. Upon emerging, the two waves recombine; however the exact way they recombine will depend on the phase difference between, which depends on the difference between the two refractive indices, the birefringence, Δn, and the distance travelled by the light through the specimen. Annealed bars with holes in 4-point bending rigs Activities Sketch the pattern of isochromatic regions. What are the quantities on the axes of a Michel-Levy chart? Note: DoITPoMS Teaching and Learning Packages are intended to be used interactively at a computer! This print-friendly version of the TLP is provided for convenience, but does not display all the content of the TLP. Question Study the isoclinic fringes from both the protractor and ruler. On the chart are plotted lines of constant birefringence. The difference in principal stresses is related to the birefringence and hence the fringe colour through the Stress-Optic Law. The advent of superior computer processing power has revolutionised stress analysis. Close up of annealed bar in 4-point bending rig under a circular polariscope Your browser does not support the video tag. The apparatus comprises an aluminium base fitted with two cylindrical stops and a central groove into which a brass slide may be slotted depending on the stress-state to be applied. If the source light is monochromatic these appear as dark and light fringes, whereas with white light illumination coloured fringes are observed. The applied stress causes alignment of the random chains and the inherent uniaxial anisotropy of the chain structure leads to 'stress-induced birefringence'. The notch was lined up as to be exactly opposite the point of load. No other method had the same visual appeal or covered so much of the stress pattern. The early work of E Coker and L Filon at the University of London enabled photoelasticity to be developed rapidly into a viable technique for qualitative stress analysis. Induced optical anisotropy In response to an applied stress a substance may change its dielectric constant and consequently, in transparent materials, change its refractive index. Note the varying intensity of the isoclinic fringes. Contours of constant principal stress difference are therefore observed as isochromatic lines. The formatting (page breaks, etc) of the printed version is unpredictable and highly dependent on your browser. Abaqus-generated simulation of a bar undergoing 3-point bending Bar with Notch Your browser does not support the video tag. A screw attached to the base allows the slides to be moved normal to the specimen, which is placed against the two cylindrical stops, subjecting the strip to stress. To determine the birefringence use a Michel-Levy chart, whose axes are retardation (birefringence times thickness) versus the thickness of the specimen. The transmitted intensity will also be zero when the optical path difference is an integral number of wavelengths (the phase difference is an integral multiple of 2π). What is the difference between isochromatic and isoclinic fringes? Academic consultant: John Leake (University of Cambridge) Content development: Neil Kidner, Gina Montgomery, Claire Dancer and Edmund Ward Photography and video: Brian Barber and Carol Best Web development: Claire Dancer and Dave Hudson This TLP was prepared when DoITPoMS was funded by the Higher Education Funding Council for England (HEFCE) and the Department for Employment and Learning (DEL) under the Fund for the Development of Teaching and Learning (FDTL). Isoclinic fringes therefore provide information about the directions of the principal stresses in the model. In general the resultant wave will have a component of its electric vector parallel to the analyser direction. (Answer below) Protractor viewed through plane polariscope. A standard plane polariscope shows both isochromatic and isoclinic fringes, and this makes quantitative stress analysis difficult. We have seen that an applied stress can result in a change in the refractive index of a transparent substance. Applications of photoelasticity involve applying a given stress state to a model and utilising the induced birefringence of the material to examine the stress distribution within the model. Annealed bar with notch in 4-point bending rig under a circular polariscope Your browser does not support the video tag. Optical anisotropy in polymers For a polycarbonate with a relatively simple carbon-carbon backbone, the refractive index is larger for vibrations of the electric field in the light wave (the electric vector) parallel to the axis of the chain. Isochromatic fringes are lines of constant principal stress difference, (σP - σQ). Between the two inner loading points on the bar is a region of pure bending. Answer Common processing routes such as injection moulding and extrusion lead to a residual stress distribution. Isoclinic fringes can be removed by using a circular polariser. This is called the Stress-Optic Law. Isoclinic fringes occur whenever either principal stress direction coincides with the axis of polarisation of the polariser. Birefringence in polycarbonate specimens arises due to two effects, non-random chain alignments and residual strains. The velocities of these waves will be determined by the relevant refractive indices, which will be different for the two directions and therefore the waves will become progressively out of phase as they pass through the material. Abaqus-generated simulation of a bar undergoing 4-point bending Bar with Notch Your browser does not support the video tag. When the plane polarised light arrives at the specimen it is refracted and, if the material of the specimen is anisotropic, it is split into two separate waves, one vibrating parallel to one permitted vibration direction and the other wave parallel to the other (orthogonal) permitted vibration direction. Ruler viewed through plane polariscope. When the applied load is increased the first areas to show photoelastic effects are the extreme edges of the sample, which are obviously under the greatest stress. The thickness of the bar was 3.0 mm. Abaqus-generated simulation of a bar with hole undergoing 3-point bending 4-point bending Normal bar Your browser does not support the video tag. The magnitude and direction of stresses at any point can be determined by examination of the fringe pattern, and related to the studied structure. Therefore, if at a point P a distance y from the neutral axis there exists a stress which would cause a phase difference of one wave length, then all points on the horizontal line through P parallel to the longitudinal axis of the bar would cause the same phase difference. Annealed bar with notch in 3-point bending rig under a circular polariscope Your browser does not support the video tag. To minimise pre-existing strains the polycarbonate specimens used in these demonstrations were annealed to remove any strains incorporated during their fabrication. Plastic rulers and protractors have residual strains due to their production by either extrusion or injection moulding. Plain polariscope images of the same ruler in different orientations. When combined with the values of (σP - σQ) from the photoelectric stress pattern, isoclinic fringes provide the necessary information for the complete solution of a two-dimensional stress problem. The principal stresses, σP and σQ, in the plane section are aligned parallel to orthogonal directions P and Q; nP is the refractive index for the vibration direction parallel to P and nQ is the refractive index for the vibration direction parallel to Q. Idealised models therefore tend to underestimate the actual maximum stress concentration at the root of the thread. There are dumbbells above and below the crack. We investigate birefringence induced in polycarbonate when subjected to three and four point bending. Light transmitted by an anisotropic material (See also the TLP "Introduction to Anisotropy") When monochromatic light is incident on the polariser, only the component of light with an electric vector parallel to the axis of the polariser will be allowed to pass through. The apparatus is orientated between crossed polars so that the length of the specimens is in the 45° position, i.e. at 45° to the polariser direction. Questions Quick questionsYou should be able to answer these questions without too much difficulty after studying this TLP. If a general system of stresses is applied in a plane, the optical birefringence, Δn, produced will be proportional to the difference, Δσ between the two principal stresses in the plane. In the bar the longitudinal stress is a principal stress, there are no vertical or horizontal shear stresses and no transverse normal stresses. Abaqus-generated simulation of a bar with notch undergoing 3-point bending Bar with Hole Your browser does not support the video tag. Simple apparatus is used to deform the polycarbonate specimens. When observed under crossed polars they display birefringence, which enables the point of injection to be determined. If not, then you should go through it again! Which of the following is the best definition of isotropic? Plane polarised light has its electric vector vibrating along one direction, the polariser direction. Abaqus-generated simulation of a bar with notch undergoing 4-point bending Bar with Hole Your browser does not support the video tag. When a material is orientated so that one of the permitted vibration direction lies parallel to the polariser direction, the light travels through the specimen without change in its polarisation state and therefore emerges from the specimen with its electric vector still parallel to the polariser direction and so perpendicular the the analyser direction. The stress-optical coefficient of polycarbonate is -78.0 × 10-12 Pa-1. Image capturing and digital processing techniques also allow for the separation of the isoclinic and isochromatic fringe patterns. How many permitted vibration directions does plane polarised light have? In this case, the beams recombine to give a beam with the same polarisation state as the incident beam, i.e. with the electric vector parallel to the polariser direction, and hence the transmitted intensity is zero. Despite FEM advances, photoelasticity, one of the oldest methods for experimental stress analysis, has been revived through recent developments and new applications. Three different specimens are investigated: a plain bar, a bar with an edge notch, and a bar with a central hole. Annealed, notched bars in 3-point bending rigs Bar with hole In this bar the neutral axis is interrupted by a circular hole. Upon initial loading stress develops from either side and slowly builds up, reducing the dark area of no stress until there is only a very small region in the centre of the bar that is not stressed. We can define the stress-optical coefficient C, such that |Δn| = CΔσ For a sample of uniform thickness, regions in which Δσ [or equivalently (σP - σQ)] is constant show the same interference colour when viewed between crossed polars. It found widespread use in many industrial applications, as in two dimensions it exceeded all other techniques in reliability, scope and practicability. Photoelasticity therefore remains a major tool in modern stress analysis. Within this region the stress is parallel to the long edges of the bar but its magnitude varies across the bar from a maximum tensile stress at the outer (convex) edge, through zero on the neutral axis to a maximum compressive stress at the inner (concave) edge. The development of rapid prototyping using stereolithography allows the generation of accurate three-dimensional models from a liquid polymer, without the use of the traditional moulding method. Annealed bar with hole in a 3-point bending rig Stress patterns: 4-point bending Plain bar The bar within the inner loading span of the four point bending arrangement experiences a pure bending moment. How do you think these articles were manufactured, and does the stress distribution support this? Which of the isochromatic regions corresponds to the unstressed region of the bar? For three point bending a slide with a single point is used and for four point bending a slide with two well-separated points. Annealed and notched bars in 4-point bending rigs Bar with hole As the applied load is increased, the bar behaves similarly to the plain sample. In the general case, and where the stresses are applied in a plane, the optical birefringence will be proportional to the difference between the two (orthogonal) principal stresses in the plane. Finite element modelling (FEM) has become the dominant technique, overshadowing many traditional techniques for stress analysis. Annealed bar with hole in 4-point bending rig under a circular polariscope Your browser does not support the video tag. Contents Aims On completion of this TLP you should: understand the phenomenon of birefringence know how materials scientists use photoelasticity be able to distinguish between isochromatic and isoclinic fringes be able to relate stress patterns in polycarbonate rods to the bending rig used and the deformation in the rod know and be able to use the Stress-Optic Law Introduction The photoelastic effect (alternatively called the piezo-optical effect) is the change of refractive index caused by stress. Annealed bar with hole in 3-point bending rig under a circular polariscope Your browser does not support the video tag. For example, a threaded joint experiences non-uniform contact, which is difficult to incorporate accurately into a computer model. For example, any video clips and answers to questions are missing. Hence estimate the stress at these points using the Stress-Optic Law nQ - nP = C(σP - σQ). The stress fields are deflected by this hole, as demonstrated by the perturbations in the isoclines in the vicinity of the hole. The constant of proportionality is known as the stress-optical coefficient. As the stress is increased bands originate at the edges of the sample and travel inwards towards the neutral axis. Around the notch the principal stress directions are altered and no longer lie parallel to the longitudinal and transverse directions of the specimen. Use the Michel-Levy chart to determine the optical path difference at the midpoints of the two long edges of the bar and deduce the optical path differences arising from the stress at these points. These settings are known as extinction positions and produce isoclinic fringes, fringes which occur wherever either principal stress direction coincides with the polariser direction. Some calculations will then be made using the Stress-Optic Law. The spacing between these bands becomes narrower as the load is increased but the bands remain straight and parallel to the neutral axis. Experiment In this experiment we investigate photoelasticity, the phenomenon of inducing birefringence in a substance through the application of a stress system. Note the stress concentration that has built up at the edges of the hole. Video clips 3-point bending Normal bar Your browser does not support the video tag. Annealed bar in 3-point bending rig under a circular polariscope Your browser does not support the video tag. The notch acts as a stress concentrator, focussing the stress at its tip. Two different types of fringes can be observed in photoelasticity: isochromatic and isoclinic fringes. Annealed bars in 4-point rigs Bar with notch The general stress distribution is similar to the normal specimen except in the vicinity of the notch where the stress pattern is distorted. The phase difference can alternatively be expressed in terms of the optical path difference, the distance that progressively separates points on the two waves that coincided initially. The two types of fringes can be distinguished by rotating the specimen in a plane polariscope. The concentration of stress is local because a few crack lengths away the stress returns to its pure bending distribution. The stress pattern is similar to the lobes which radiate from a crack to indicate the regions of plastic deformation. Annealed bar in 4-point bending rig under a circular polariscope Your browser does not support the video tag. When using FEM, it is crucial to assess the accuracy of the numerical model, and ultimately this can only be achieved by experimental verification.

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