Polarization of Light and Photo Elasticity

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The paper discusses the phenomenon of Polarizations and its various applications, especially stress elasticity Polarization was studied by Sir David Brewster, a Scottish physicist (1781-1868). Bu it took about hundred years to find the application of polarization here we shall discuss how polarization can help structural and mechanical engineers to make transparent models of plastics (generally "Perspex") and with experimentation using polarized light passing through loaded structures or components the variations of intensity of stress can be found out. Thus it is possible to find out weak areas of a structure or of a component so that corrective action can be taken before undertaking production or proceeding with the project. Sometimes it is complex structures or components it is not possible to find out mathematically that which areas cannot with high stresses. Hence with the aid of cellulose transparent models of plastics and using polarized light it is possible to predict weaker areas.

Index Terms—Polarization, Cellulose, Plastics, Polarized Light.

I. INTRODUCTION

We all know that light travels as a transverse wave motion the vibrations constituting light occur in a plane which is perpendicular to the direction of propagation of the wave. The vibrations take place in all directions in this plane in ordinary or natural light Natural light does not favor any particular side or directions however it is possible using proper equipments to arrange that these vibrations are confined to one directions only in this plane polarized. This plane polarized light when passed through loaded structure made of glasses perplex celluloid Bakelite etc make different coloural potters differing in intensity (more in highly stressed or low stressed components) the stress in the main parts where stream in concentrated will be shown by colors of very high intensity and portions having low stresses will be of low intensity colors these can be captured by using good quality camera.

II. DESCRIPTIONS

Before we go ahead to study the applications of polarizations let us first study the basic principles of it as described below:

Polarization of light waves: When light is passed through a crystal called tourmaline occurring in nature the phenomena of polarization occurs suppose the light is made to pass through a pair of tourmaline crystals C_1 and C_2 with their planes at right angles to the directions of light. The intensity is maximum in this position. Now if we rotate the crystal C_2 through 90^0 angles then the plane of C_2 is horizontal as shown in fig 2 thus the plane of C_1 is vertical in this case the polarized light is intensity in minimum.

That means that light is a transverse wave motion. It is obvious that light offer passing through the crystal C_1 that light vibrates only in one direction i.e. it is polarized because it has acquired the property of one sidedness. The kind of light is called polarized light. The polarization is used to do stress analysis in transparent plastics glass Xylonite bask elite etc As light passes through theses plastics models each color of visible light is polarized with its own orientation when the component of plastics is placed between two polarizing filters, a pattern of different color depending upon intensity of stress appear when we rotate the top plate the color pattern changes to new color some brighter whereas some lighter this is easy to show in laboratory by placing plastic protractor between two Polaroid plates and placing them on top of an overhead projector (or using a good camera photo can be taken for analysis) This fact can be easily demonstrated by taking a piece of clear plastic demonstrated by taking a piece of clear plastic newspaper wrapped between two polarizer's. If newspaper wrapped between two polarizes. If we pull on the newspaper wrapped to create stress one can see that the color appears. It is well known that structural stress in plastic is significant at locations where there is a large concentration of bright colored bands this location of stress where the color is bright is usually the location of weakness where structural failure has chances to occur.

III. EXPERIMENT

If a plastic transparent shell beam is centrally loaded with simple supports then the intensity of stress can be qualitatively determined on the basis that it is high where fringes are red in color and low where the fringes are blue in color naturally the maximum deformation will occur in red color fringes and minimum deformation in blue color fringes. The magnitude of the stress concentration factor k_t depends on the geometry of the member in the vicinity of the discounting the diagram after polarization of transparent simply supported been loaded centrally is shown in fig 3 :-

If we look at the cross section of beam we observe that stress distributions across the section have following characteristics

1. It is zero at the neutral axis of the cross section that is half way from the top or the bottom of the beam
2. It is a maximum tensile stress at the bottom surface.
3. It is a maximum compression stress at the top surface
4. It varies linearly from the top to bottom Remember greater number of fringe lines represents a higher stress gradient. This clearly supports the theory that the bending stress is proportional to the bending moment which in this case is maximum under the load and zero at the supports for loading pattern shown below.

5. It is possible to determine the stress level at any section if one knows the characteristics of the photo elastic material As we can see in the diagram if starting at the midpoint of the cross section and counting the number of fringes from there to the top or bottom surface would allow us to find stress level at that particular section. As shown in the fig .4

It is interesting to note that more complex fringe pattern occur near consent rated load this makes us realize that the material if the beam can withstand these local stresses by using relatively large area of bearing supports.

As we observe the photo we find that these local efforts near the support dissipate quickly as we move away from the support which posses' principal of St Venant the renowned French Scientist who discovered the fact in 1855.

Here it must be made clear that a good quality camera is used to take colored photograph of model after polarization of the analysis of the stress level of structure or mechanical components.

To clarify further that during polarization the model(specimen made of transparent plastic) are placed between two crossed Nicols so that field of views is not changed (Nicol prism falls normally on a calcite crystal cut with its optic axis parallel to its faces for maximum efficiency of phenomenon of photo elasticity) When stress is applied to these specimen the emergent light m general is elliptically polarized and therefore partially transmitted the analysis Nicolssss Thus the field of view is changed and hence after polarization of stressed structure or component different fringe at different intervals are produced which are then photographed for further study

As earlier described the stress distribution in complex engineering structures such as girders boiler plates' gear teeth bridges crane hook etc can be analyzed by photo elastic studies of transparent models. By studying the photograph of different interference pattern the position and the extent of stresses in various parts are calculated. This facilitates in anticipating the expected nature and extent of stresses. It may be noted that sometimes

For more accurate results the photo elastic determination is compared with the result of electrical strain ganger which are very accurate but the advantage of Photo elastic method is to get a clear visualization of concentration of stress distribution in a structure.

IV. CONCLUSION

Thus we see that how the phenomenon of polarization can be usefully employed in elasticity stresses in complex structure and mechanical components which otherwise to calculate mathematically it would be very complex This is the tool which is used these days quite often for stress analysis in bridges boilers and other complex mechanical and civil engineering applications. Of course care should be taken by employing electric strain gauges.

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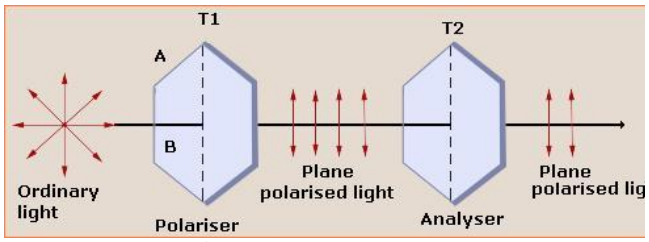

Fig. 1. Phenomena of polarization through tourmaline crystal (plane is 90°)

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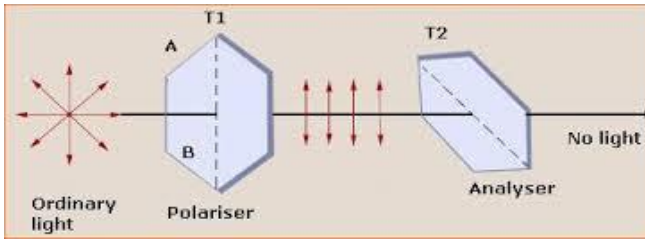


Fig. 2. Phenomena of polarization through tourmaline crystal (crystal is 90^0)

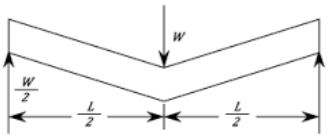
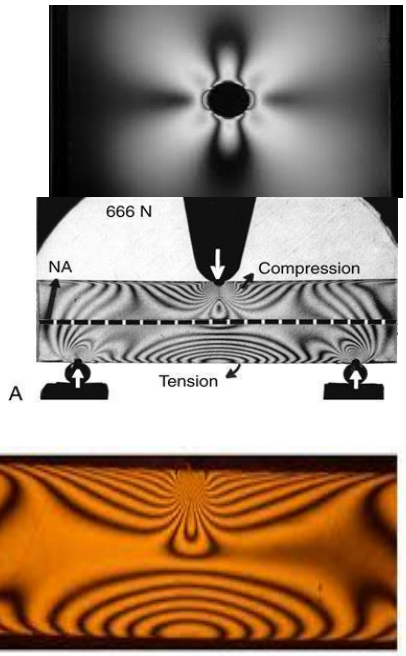


Fig. 3 Simply supported beam with central load W.



(c)

Fig. 4 (a) Photo elastic model of a flat bar with an axial load and a central hole(b) Photoelastic model of a simply supported beam with a concenterated central load. (c) Photoelastic model of a beam with stress