Experimental Physics - III
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Lecture – 49
Photoelastic Property of Materials

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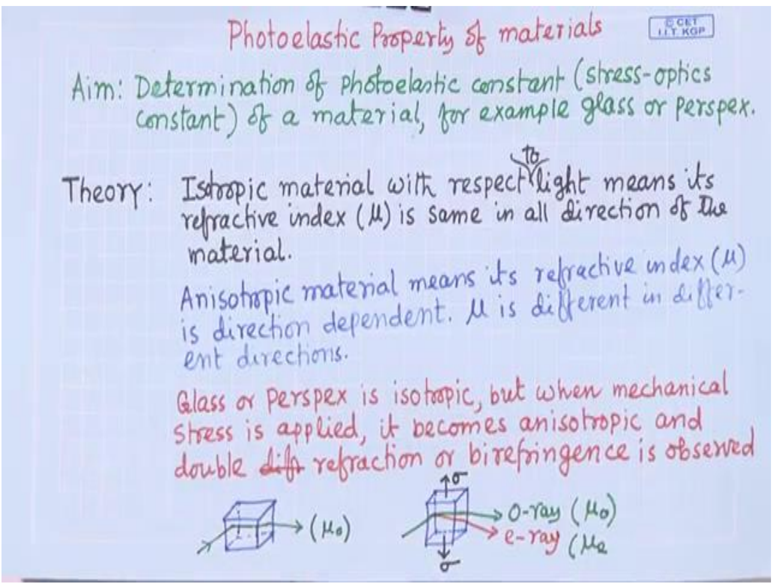

Today I will demonstrate Photoelastic Property of Materials. Aim of the experiment is to determine the photoelastic constant that is stress optic constant of a material. As for example, glass or a perspex, it should be a transparent material. In our laboratory, we will use this glass. for glass what is the photoelastic constant that we will determine.

Theory for this experiment is one has to understand properly for doing this experiment. isotropic material with respect to light means, its refractive index is same in all direction of the material. We tell this material is isotropic; isotropic with respect to some property. in case of light, we will tell the material isotropic when it is refractive index will be same in all directions.

And an isotropic material means, its refractive index is different or it depends on the direction of the material. mu is different refractive index is different in different direction of the materials. then we tell the material is anisotropic with respect to light property with respect to light. Glass or perspex is isotropic, but when mechanical stress is applied, it becomes anisotropic.

When it is anisotropic means, its refractive index is different in different directions. This when a light ray falls on this material if it is anisotropic then it is shows the double refraction or birefringence or bi birefringence is observed. This is the crystal say it is a glass if a cube like shape we have taken. when light will pass through it say, its refractive index when it is isotropic refractive index is mu 0.

And this refractive index is same in all direction, when this material is under stress if we apply stress say, we have apply stress along this direction, then this incident ray when it will pass through it. We will see two rays one is called o ray and another is called e ray. This is double refraction or birefringence this is because the refractive index are different for o ray and e ray

Applying the stress on a material, we can make it anisotropic. These the change of the change of refractive index because of the stress there is a relation between these two. From that, relation it is a proportional kind of things is change of refractive index is proportional to the change of stress. That proportionality constant that is it is the photoelastic constant what is the relation between stress and the refractive index in a photoelastic material.

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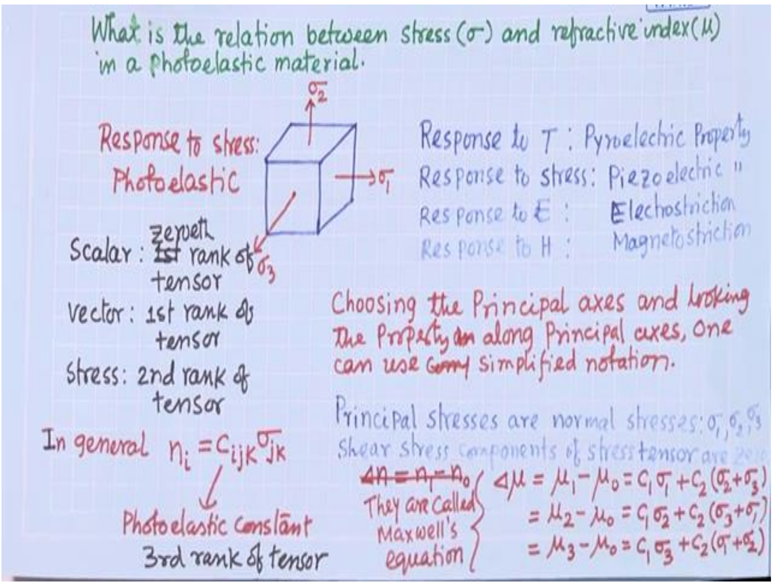

I can discuss it. this is material in shape of cube. Response to stress that we express that is we tell that is the photoelastic property of the material. in general, response of a material to the temperature. Then that property we tell pyroelectric property of that material response to the stress that we tell piezoelectric property response to electric field.

We tell the electrostriction response to the magnetic field we tell the magnetostriction response to stress also it is called the photoelastic property external parameter if you change of a material it shows different kind of property. we study the property of a material as a function of external parameter as for example, it can be temperature, it can be electric field, it can be stress it can be magnetic field ok.

In this case, our external parameter stress and material, we have taken that is photosensitive material what is the response of this photosensitive material to the stress that is what we want to study the elasticity that stress is that tensor of rank 2, second rank of tensor.

One should have knowledge of tensor. you know that scalar vector. That is zeroth rank of tensor: the scalar, 1st rank of tensor this vector and stress is 2nd rank of tensor. in vector you know that we use these one index to express this component say p i means p 1 p 2 p 3 ok.

Once an index is used for expressing the vector. That one is the 1st rank of tensor. In case of stress it is, 2nd rank of rank of tensor means, two index will be used in general refractive index here relation between the refractive index and the stress. Refractive index at different direction this if we express it is by n i. it is an equal to it is a relation with the sigma stress.

Sigma as I told second rank of tensor. This is sigma j k. two index we have to use. this is one index parameter and this is two index parameter. Coupling between these two is expressed by a constant. It will be; it will be it will have the 3 index i j k. that is why this C i j k it's the 3rd rank of tensor. it is a C is nothing, but the photoelastic constant.

Photoelastic constant is a 3rd rank of tensor but you can reduce you can reduce this index i j k choosing the axis properly an applying the stress in a proper direction. choosing the principal axes and looking the property along principal axes one can use simplified notation. Like principal stresses are normal stresses sigma 1 sigma 2 sigma 3 x, y z direction principal axes sigma 1 sigma 2 sigma 3.

And shear stress components other components is shear stress component that component one can make 0. If you choose the principal axes and your stress if we apply along the principal axes that is called normal stress. Then there will not be other components other components are shear stress. East or west if you write in a matrix of diagonal are shear stress and diagonal.

Here sigma 1 it is sigma 1 1 sigma 2 2 sigma 3 3. And other component are sigma 1 2 sigma 1 3 sigma 2 1 sigma 2 3 etcetera other are shear stresses. That component you can make 0 choosing the principal axes and applying the stress along the principal axes. other components you can make 0 ok.

Anyways there are relations they are called Maxwell's equation it is not electromagnetic equation of Maxwell. this is a relation between the stress and the refractive index. This it is expressed in 3 by 3 equation. This change of a refractive index del mu equal to say mu 1 minus mu 0 ok.

that equal to C 1 sigma 1 plus C 2 sigma 2 plus sigma 3, then mu 2 this del mu it can be equal to mu 2 minus mu 0 equal to C 1 sigma 2 plus C 2 sigma 3 plus sigma 1 and also del mu equal to mu 3 minus mu 0 equal to C 1 sigma 3 plus C 2 sigma 1 plus sigma 3 This 3 equation when you are applying stress say applying stress along the principal axes and you are looking you are seeing the refractive index change of refractive index along axis 1 x axis

Then what will be the; what will be the stress and the refractive index relation? it is this. If you look the reflective, index along the y-axis 2 then this relation. For axis 3 this relation depending on the arrangement of the experiment, you can choose you can choose particular equation out of this 3 you can choose particular equation depending on your experimental setup. in general when you are choosing the principal axes, that stress as well as your refractive index you are looking along this principal axes. This is the 3 equations one can use ok.

Further you can change you can simplify this equation depending on your experimental setup.

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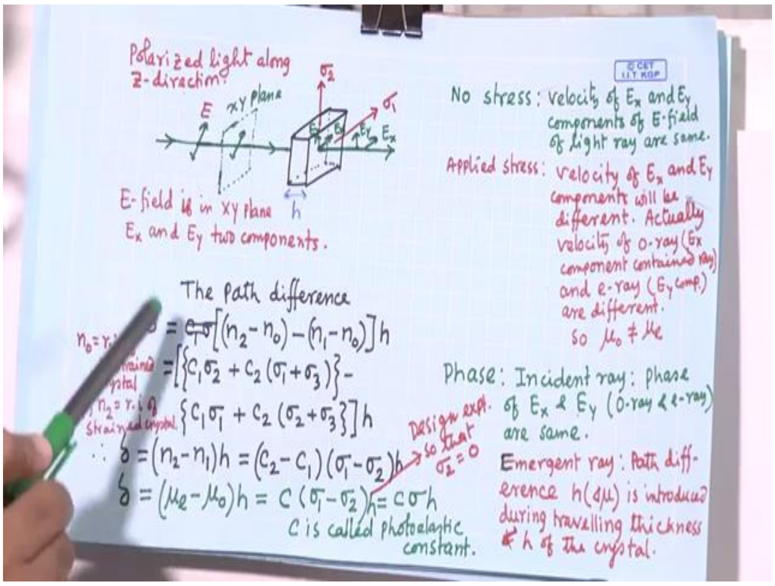

Let me tell you. now, you see that light is coming and falling on the crystal. Now, this is polarized light linearly polarized light how to be linearly polarized light that generally we use polarizer? polarizer have optics axis light passing through the along the optics axis means light is going, but light has electric component and magnetic component.

magnetic component generally, we ignore we consented on the electric component because electric component is responsible for the interaction with the electron charge of the material and this effect is very strong compare to the magnetic effect. Anyway this electric component. un polarized light means the electric component or in all directions on the plane of a on a plane perpendicular to the direction of the propagation ok.

Now that change of the electric vector in a plane in all directions; this is unpolarized light. If we can fixed it in a particular direction then we tell it is a polarized light for that we use the polarizer have optic axis. Electric component only can pass through this along the optics axis those will get a light which will have the; which will have the electric component in a particular direction.

That direction is fixed by the axis of the polarizer. this is such this is such an polarize light it is the electric component in this direction. Now, this direction here I have drawn a plane if this is the direction of light propagation if it is Z direction if it is Z direction. Plane perpendicular to the direction of the propagation is x y plane.

Therefore, this electric component is in x y plane now, when it will enter when it will enter into this crystal. this one this E you can divide into two component one is Ex component and another is Ey component E x component and another is E y component. Now, when it is passing through it. This E x and E y they are perpendicular to each other this two electric component are perpendicular to each other ok.

When this material is isotropic when this material is isotropic, then these two component will pass through this crystal with same velocity when this material is anisotropic; that means, the velocity of light will be or this electric component it will depend on the velocity of light it will be direction dependent. Here you can think that two rays; one ray having electric component x another ray is having electric component E y ok.

These two ray actually one is called o ray another is called E ray. For isotropic material velocity of these two ray o ray and E ray will be same when these two ray will come out. they will have whatever at the incident, whatever the phase difference between these two ray when it is coming out from the crystal its phase difference will remain same ok.

You will get original electric component original direction of the electric film. there is no phase change between incident light and the outgoing light from the crystal. Now, if you apply stress on this material, if we apply stress on this material then what will happen? Then this material will be anisotropic optically anisotropic.

Its refractive index will be different will be different in different direction. what about the E ray and o ray that one is having E x electric component another is having E y electric component. They will have different velocity means; they will have different refractive index. when they will come out. E ray and o ray they will not come out at the same time ok.

There will be retardation there will be phase difference there will be path difference between these two when they will come out then this E x and E y these two between these two rays, there will be phase difference or path difference and when they will combine; when they will combine and give the result and ray. Then now that E x E from Ex and Ey it will be different from the other incident one that outgoing ray it will have the electric component.

So initially whatever the direction of the electric component the outgoing that electric component direction will be different. And it can be; it can be it will defend; it will defend what will be the direction of this electric component. If phase difference; if phase difference is pi if phase difference is pi, then whatever the direction if phase difference is 2 pi then. Then if it is pi then we tell it is the outer phase and if it is 2 pi then we tell it is in phase.

When it will be two pi then it will be same direction as the incident on if it is pi. It will be just opposite direction of the incident one whatever the incident direction that that will be opposite direction there will be path difference. what will be that path difference that will depend on the refractive index mu E and mu 0 for E ray and o ray as well as it will depend on the thickness of this material the distance travels through this material

In general, whatever the Maxwell equation we have seen. there this path difference will be delta equal to delta equal to this here I have written n 2 minus n 0 minus n 1 minus n 0 into h what is n 2 minus n 0? n 2 minus n 0 this n 2 this is the here I as I told this x y plane. It has the x corresponds to 1 and y corresponds to 2.

n 2 refractive index along the y direction. This is for e ray and for in that direction for o ray what would be the or for isotropic case for isotropic case refractive index is n 0 now because of stress now it is n 2. What is the change of the refractive index is this and for x component what will what is the refractive index change because of the; because of the; because of the stress.

that will be n 1 minus n 0 now, this is for this change is for E ray and this change is for o ray and this is n 0 is it’s a for o ray in the sense that for isotropic case. There is no E ray o ray velocity are same. now, n 2 minus n 0 that is C 1 sigma 2 plus C 2 sigma 1 plus sigma 3 as from Maxwell equation And n 1 minus n 0 is suppose minus this minus here.

the C 11 sigma 1 plus C 2 sigma 2 plus sigma 3, it’s a h of course, h will be there from here you can get delta path difference is equal to n 2 minus n 1 Path difference will be for n 2 is for E ray and n 1 for o ray I as I told x component for o ray and y component E y component for E ray so; that means, along the two second direction y corresponds to 2 and x corresponds to 1. Path difference will be the change of the refractive index between these two directions into h, h is the thickness of this crystal.

This will be equal to from here. From here, I can get this and from here, I can get C 2 minus C 1 sigma 1 minus sigma 2 h this will be the path difference. Now here this this I have written n because this in Maxwell equation I use n. this is the general case from there delta power for our purpose I am considering instead of n I am considering mu and defining o ray and E ray.

I can write delta equal to mu e as I told n 2 is for e ray mu e minus mu 0 this for o ray in to h equal to this is a constant C 2 minus C 1. These are constant I can write C, sigma 1 minus sigma 2 into h now, here sigma 1 and sigma 2 what is sigma 2 sigma 2? Stress along the x-axis along the axis 1 and sigma 2 stress along the y-axis means axis 2 ok.

Now, if I design the experiment in such a way. I will apply the stress only along the x direction ok, y direction I will not apply any stress or I will not apply stress any diagonal direction. That it will have component x component, y component and z component I can design the experiment in such a way that sigma 2 is 0. I will not apply any stress along the y axis, I will apply stress only along x axis.

then it will be C now in general I will write instead of sigma one that I can write sigma because the just I am applying the stress along a particular direction C sigma h. here you can see this simple equation ok, if you design the experiment apply the stress considering the principal axes there will not be any complicacy of the stress and tensor ok.

simple direction you will get this path difference is equal to the change of the refractive index for E ray and o ray into the thickness of the crystal it is a traversing that is h that is equal to C sigma h. forget h from here clearly you can see del mu is equal to C sigma del mu is proportional to sigma that proportionality constant is C ok.

This is our; this is our; this is our working formula. how we have derived this working formula ok? That we have to remember, when we set the experiment. if using this equation your apply stress in not in a along a path along a particular principal axes, you are applying in different direction.

here condition is light is propagating along the axis 3 z axis you are applying the stress along the x axis then this and the polarized light and the polarized light of course, it will be; it will be its this electric component it will be on x y plane it then under this condition, we can use this equation now, now this will be the our working formula for the experiment.

I will stop here I will continue in next class.

Thank you.