Optical Methods for Solid and Fluid Mechanics
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Module No # 08
Lecture No # 30

So far we have been discussing techniques for 2 dimensional imaging for measuring deformations specifically for measuring strains and displacements. So this limited correlation was something we discussed at length we will change track a little bit and move on to another technique that I introduced at the very beginning called photoelasticity.

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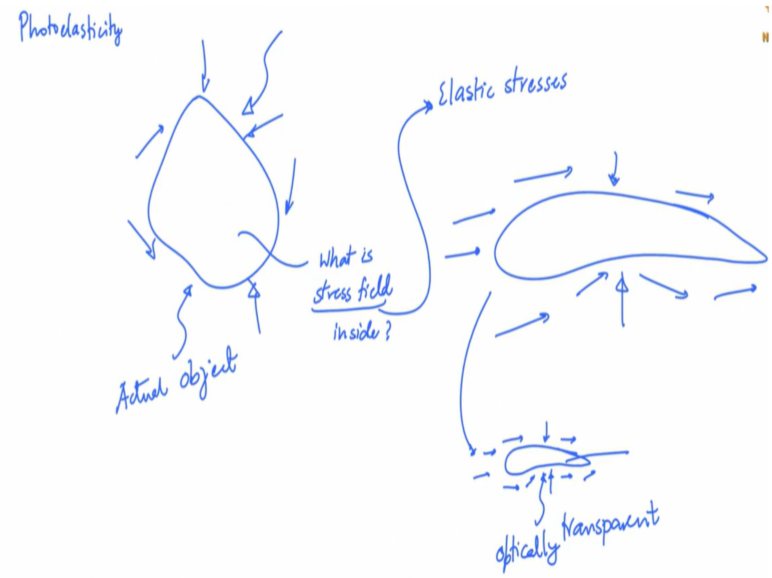

Now photoelasticity is a very old technique it is, been around for a very long time as a phenomenon it was identified a very long time ago and it is also been exploited quite a bit for mechanics for studying deformations stresses and so on. And so some of the stuff that we will discuss are fairly well known. At the very end I will discuss a technique called integrated photoelasticity which is little bit more contemporary to developed maybe in, the seventies and eighties which deals with 3 dimensional fields.

Now photolasticity just like DIC is also an essentially two-dimensional technique but instead of relying on strains and displacements it directly measures or gives you an estimate of the stresses. Now if you have seen photolastic fringes or if you have seen glass within what; are called polarizer sheets you probably have seen colorful, patterns and images and so on. Before even if you have not heard the term photo elasticity you have probably seen some variant of this at some point in your life.

For example if you are if you have worn sunglasses you have seen a polarizer directly and you know what the effect of the polarizer is it cuts off some of the radiation and so on. So essentially this phenomenon draws on several disciplines, and puts all of that together for extracting information. So today I will just start with an introduction to what photoelascity is for those of you who are uninitiated and then will slowly build up some of the techniques.

Some of the basic principles and some of the mathematics behind how; to interpret stress fields and so fringes and obtain stress fields and so on. So the idea is very simple you, have an object which is a replica of typically photoelascity at least historically it is been used for studying stresses in objects which are otherwise optically opaque. So for example if you had let us say if you had an actual object so this is your actual object and it was subject to some loads let us say like this and you wanted to know what the stress field is inside.

Now notice we are asking, what the stress field is not what the deformation field is so this directly relates to the properties of the object. And typically when you say stress field your top talking mainly about elastic stresses. Some of this has been extended for slightly other situations residual stresses for example which are also elastic. But have a slightly different complication we will talk about it briefly at the end.

But you want to know what the elastic sensors are in the material and your interest in this perhaps is to see if under this particular loading condition whether this body fails whether it yields and so on and that is of practical interest. So for instance this could be an aircraft wing subject to some type of forces just making it up and you want to know if any part of the wing fails or any part of, the wing yields right and if it yields.

That means plastic deformation is going to start occurring there more and more it is going to accumulate more and more and which means that eventually that part will be or that section of the wing will be where failure will start where cracks will start and so on. So this was historically why photonicity was used and people would make a smaller scale version, of this something that look like this.

And this would be made out of an optically transparent material then you would subject this to the same forces scaled down of course as the original model and then you would see if the stresses here exceeded the yield strength and so on right. So this was used as an experimental way for determining the elastic surface in an object.

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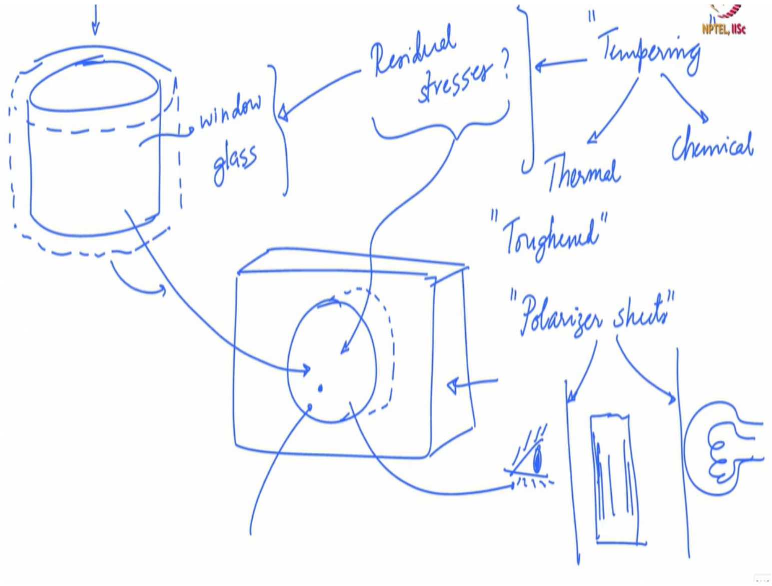

Now subsequently quite a few, other applications have emerged so for instance if you have a piece of glass let us say you made a thick window glass okay for some space application let us say and it has to sit inside a hub like this. So this is the whole inside which the glass is placed and it is completely sealed in let us say with some silicon sealant or something. You want to know if this glass has any residual stress, inside which means when the glass was being made was it made in such a way that there were stresses baked inside the glass which could affect the performance of the glass.

So for instance if this was the window of an airplane so you had or a window of a space shuttle it looked like this let us say in the top view. And if you had into other three-dimensional view actually if this was your glass. And if let us say you had some projectile come and hit the glass from the outside then this will tell you whether this glass will fail under this type of projectile impact or whether it will survive this type of physical impact.

What types of physical impacts it could survive and under what conditions it will fail right. So things like this are not easy to determine from strain fields but the, relatively easy to determine from stress fields right. So that is why photelasticity becomes important in a situation like this now incidentally this is allied to the field of what is called tempering. Most of you if you have metallurgy if you have taken a course in metallurgy physical metallurgy you probably are aware of this term.

But tempering is also done for glasses there is something, called thermal tempering and something called chemical tempering and basically tempering induces residual stress. And so there are various ways of controlling what the stress distribution is actually what this is distribution actually is in the glass and measuring it using photolacity. So that gives you some background for where some of these techniques find use we will discuss a little bit more as, we go along.

But first we will show you a few videos of typical glass samples and what tempered glass looks like what thermally tempered glass looks like or thermally toughened that is another phrase that is/has often used toughened glass. And if you look at this through 2 sheets we will call them polarizer sheets again within codes I will/shall discuss what these are what they are useful, for and so on.

But if you take a piece of glass like this I am now going to draw the side view this view and if you put one of these polarizer sheet over here and another polarizer sheet analogous polarizer sheet here and when you put a light source here. And you look from here then you will see a fringe pattern through the glass right and the fringe pattern will depend on whether the glass is, toughened whether it is thermally different or it is chemically toughened un toughened untreated and so on right.

So we will show you some of these next so that you at least have some idea of what this looks what the stuff looks like practically before we start a more detailed discussion of this phenomena.

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So let us look at some examples of photoelasticity so for this demonstration I have this, linear polarizer sheet and some glass samples which are prepared differently. So based on the orientation of this polarizer sheet we will see that the fringes which are representative of the stress in the glasses will change and you will see the details of why this happens and what the all this represents in coming lectures.

So the glasses shown on the screen although they all look the same but if, you just put these glasses under the folder the sheets will see that their stress sticks are different. Glass number 1 is a normal glass which has no stress state inside well class number 2 is a thermally tempered glass so when we put this glass in between polarizer sheet we will see that all colored fringes appear.

And third and fourth glasses are toughened with a different process which, is called as chemical tempering. So we will see all these classes one by one in between polar other sheets and we will compare and see the difference what happens when we rotate the polarizer sheet in different orientations. So the configuration that I am showing you on the screen on the left I have a normal glass while on the right I have a glass which is thermally tempered.

And there are 2 sheets, one on the below which is polarizer and on the top there is one more linear polar laser shade which is called as analyser. And we are passing white light throw these sheets and observing from the top using a camera. So we can see that there are different colorful fringes appearing on the thermally tempered glass that is because of stresses which are trapped in this glass.

Now if we just rotate this, sheet to a slightly different orientation that is 45 degree to the like bottom sheet you can see that this fringe patterns are changing. Now when we go in detail of this of why this happened and what this implies this will be covered in our upcoming lectures. And also this orientation gives us the information about direction of the principal stresses in this class samples.

Now let us look at what, happens when we keep a chemically tempered glass in the same configuration. So, on the left we have chemically tempered glass while on the right we have thermally tapered glass. We can see that depending upon the stress state again we are getting 2 different types of fringe patterns. Now the next a sample that I am showing you is a very interesting and very famous sample this will call as Rupert's, drops.

So these are basically glass drops which are solidified by melting the glass and dropping that molten glass into water. So because of this rapid cooling what happens on the solidification that stresses gets stabbed inside and this drops show very different properties. So when this class drop head is hit by hammer they do not break but if you just split the tail of this drop this drops, shatters into fragments instantly.

So we can see that when we keep these jobs in between this polarizer sheets there are fringes in the drops which represent the stresses which are trapped inside the drop. So, on the surface of this drops which is a compressive in nature while inside there are tensile stresses. So when crack reaches the tensile region it grows and instantly the drop shatters into, fragments. So this simple experiment showed you how you can visualize the stresses using photoelasticity? Now analysis of this stresses in detail will be there in following lectures.

(Video Ends: 13:18)