Experimental Stress Analysis - An Overview
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Lecture - 2.6
Elegance of Photoelasticity

Let us continue our discussion on overview of Experimental Stress Analysis.

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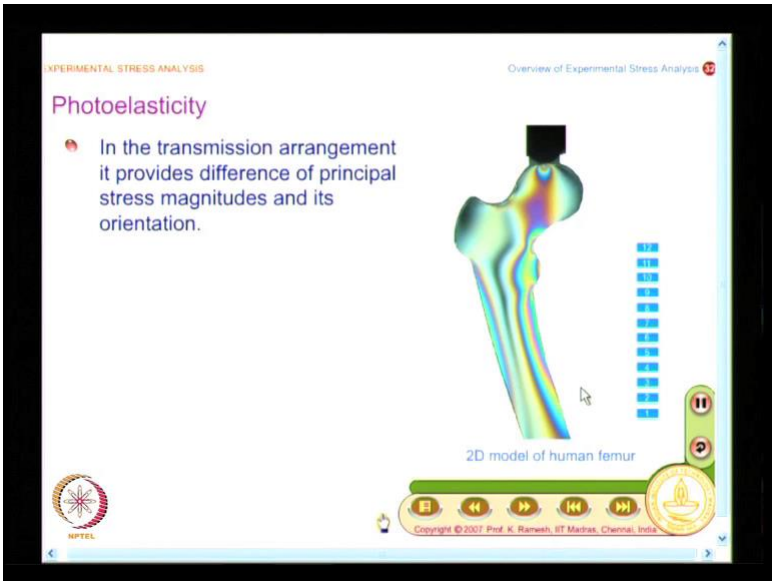

Now, we move on to Photoelasticity. Right now, we will confine our attention only to the physical principle. Also bring out you have a transmission arrangement and this you had seen in the beginning of the lecture also that you have a 2D model of human femur which is analyzed by transmission Photoelasticity. And you also have a reflection arrangement. The reflection arrangement is useful for prototype analysis.

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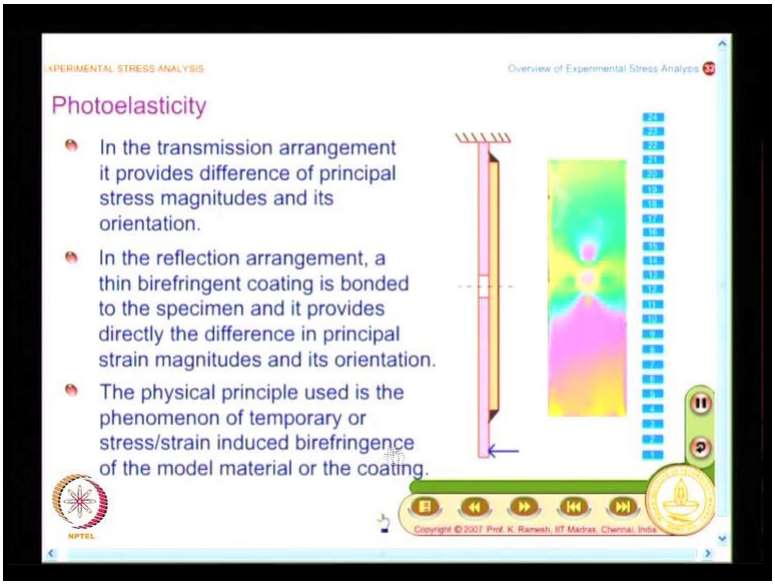

And what you have here is, I have a cantilever beam and I have a hole and I put a coating, the coating has the property of stress strain induced birefringence. So, I can get the fringe patterns like this. So, the basic physics behind Photoelasticity is temporary or stress or strain induced birefringence.

It is the physical principle used is the phenomenon of temporary, because it does not stay once the stresses are removed, this birefringent effect is also removed. So, it is what you are having is, you have to understand birefringence. All that will come when you understand crystal optics and what we had seen in the last class was, without getting into crystal optics, you have plotted for the problem of a Beam under four point bending. How the contours are sigma 1 minus sigma 2 be look like. You saw them as horizontal lines and it matched with what you had seen in the experiment. So, what you have here is the physical principle is stress or strain induced birefringence, which is temporary. The moment I remove the loads these effects vanish.

And you have many developments that I have taken place in photoelasticity. The Photoelasticity is the very versatile technique like strain gauges and. In fact, in 1930's people when they were developing theory of elasticity, many of those solutions were actually verified by experiments using Photoelasticity. And that is what we are going to

see and what you have here is, you need crystal optics is desirable to for appreciate, but we have already said that you can do it by this one.

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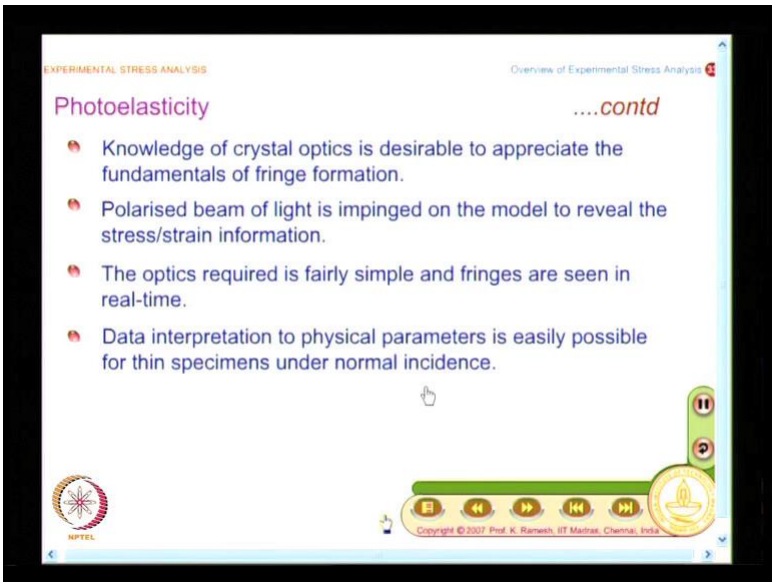

And what you do here is you use a polarized beam of light, for revealing the stress information and the optics required is fairly simple and fringes are seen in real time. This is very important.

If we go to any one of the experimental technique; for example; if you go to holography, you will have a double exposure only after processing you will know how the fringes are. So, you do not have any guidance on while applying the load, whether the load symmetry is maintained all that you will not be able to know, but the developments with computer based processing, you could make even those techniques in real time. So, when you look at any of the whole field optical techniques, one of the aspects you look forward is; is it providing fringe information in real time, Photoelasticity does that.

Data interpretation to physical parameters is easily possible, for thin specimens and a key point here is under normal incidence that will have to keep in mind. If you are having a curved object then what you need to do is, you must immerse it, an liquid which as a same refractive index as that, and ensure that you have normal incidence. See when you

go to the final aspects of any of the technique there will be restrictions. So, it is a tool and how good you use the tool you get the information.

So, whatever the experimental technique you look at you have to look at it is positive aspects as well as is limitation. Within that constrain you should employee those experimental techniques and I have mentioned the data interpretation is easy for thin specimen under normal incidence; you will appreciate only when you go to other techniques how difficult the data interpretation is. In this case it is. So, simple we have already seen from solid mechanics point of you that you get sigma 1 minus sigma 2 contours.

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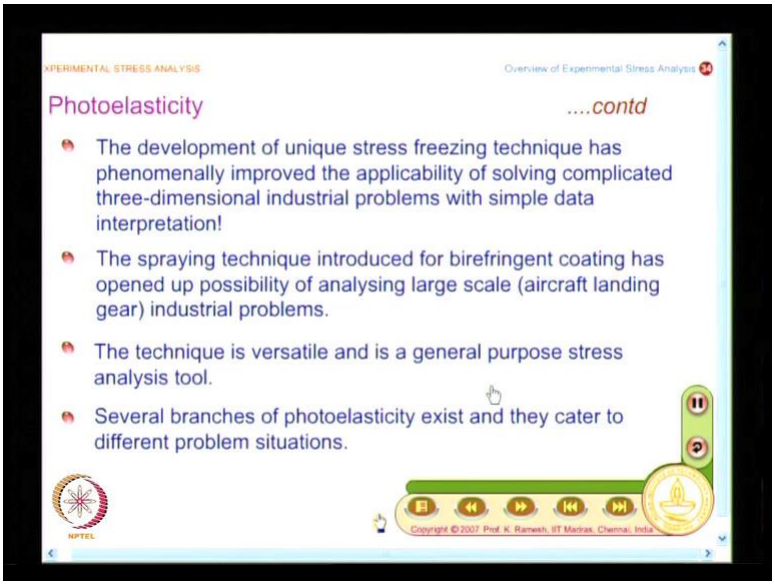

And this technique as advanced, mainly because you have a unique technique call stress freezing very interesting, very interesting aspect and that has make the application of this technique to three dimensional industrial problems. You know analyzing the problem as a whole is very difficult. And what you do here is you take the advantage of analyzing the problem as a hole at the same time, from analysis point of view you still in live in two dimensions by slicing the model into thin slices.

So, what you have here is many industrial problems. Whatever the engines that you see

across whatever, the nuclear reactors you come across they have all gone through mandatory three dimensional photo elastic analyses. That is why the designs have become perfect and designers particularly once the design has stabilized they would be very hesitant to change anything, because for any changes they would have effected there would be a history.

Once it is optimized and stabilized they do not want to change it. And in those stages you need very good tools for you to give the pertinent information. If somebody copies your design that is a different matter he does not require any test. A person who develops a design from fundamentals he needs go through experimental methods, he need to worry about analytical understanding, he needs to use even numerical technique appropriately and arrive at a final design. And if you look at in early stages three dimensional Photoelasticity has placed a very significant role, and particularly because of a very interesting phenomena called stress freezing.

Now you are being sensitized on what are the possibilities. So, this is what in the case of transmission Photoelasticity, On the reflection Photoelasticity side, people will have also developed a spraying technique, to put the birefringent coating on large industrial components. One of the components that people do is aircraft landing gear which is very huge. And they still do structural optimization based on photo elastic analysis. And this model will typically cover a two to three story building height.

It is not a small model you are actually working on you know suppose they want to develop A3 80 they would have only rig for a the previous version A3 20 or A3 30 or A3 70 and they would use that loading jig to make a three dimensional photo elastic model put of a coating and do some structural optimization. Then finally, developed the landing gear and put it in loading rig and finally verify. So, it is done for huge problems, on one spectrum.

On the other spectrum in dental mechanics, if you find they put flask, they put a wire which goes round your tooth to hold it in place. Those clamps are also analyzed by Photoelasticity. So, it is a very small model on the other hand you have a very huge aircraft landing gear. So, the range is very vast, and it depends on the user how he uses

the technique. And like strain gauges it is versatile general purpose stress analysis tool. And when you go to each of the technique, what you will find there are many, many branches because, each technique by itself is very vast.

If you take Photoelasticity, we have looked at only two variations; one is transmission Photoelasticity, another is reflection Photoelasticity.

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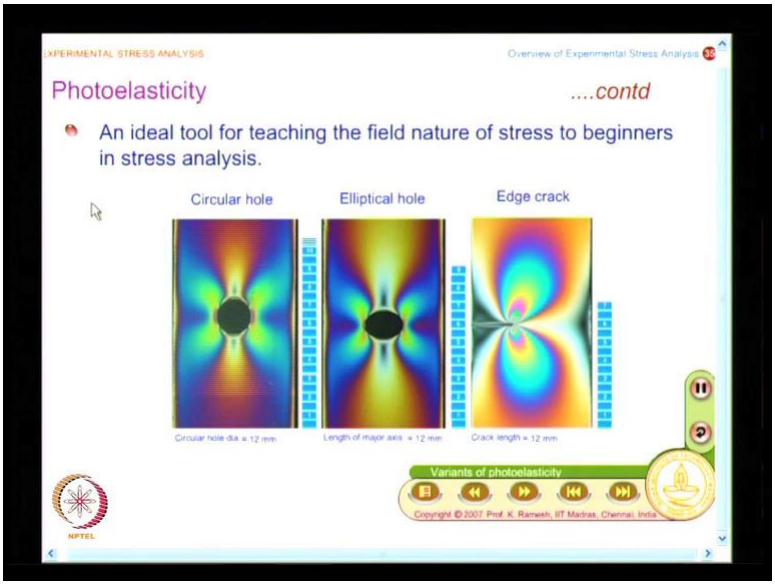

Photoelasticity is always an ideal tool for, teaching the field nature of stresses to beginners. Here I must tell you, you know stress concentration you all know right now. I have a plate with a circular hole, I have a plate with an elliptical hole and I have a plate with the crack.

Now, anybody in engineering will know what is stress concentration is, but if you look at the history, people had mathematicians and stress analysis had acrimonious debate. Mathematician used to say, infinite plate with a small hole is equivalent to a plate without a hole. And only with experimental judgment and other aspects they were able to convince, whole lot of things happen the moment I introduce the stress concentration. So, people understood there is something stress concentration which you cannot neglect it and really when you look at, what you find here is I have a uniform stress field. If I do

not have a hole the moment I have a hole, the stress field becomes bi axial.

The stress field is also the stress magnitudes are very high in this zone, and also in this zone. This is one thing stress concentration means stress magnitudes increased that is one thing. Just not that, even the stress field essentially changes. And it was English in 1913, who said that when he analyzed an elliptical hole. He could do that by theory of elasticity his result showed, crack is not innocent and crack is potentially dangerous.

At that is that is the time that fracture mechanics has not developed, and a new branch of a engineering fracture mechanics came into existence, once people understood that cracks are more dangerous and what you see here is you know, I have a crack and crack where you have the least amount of material is removed.

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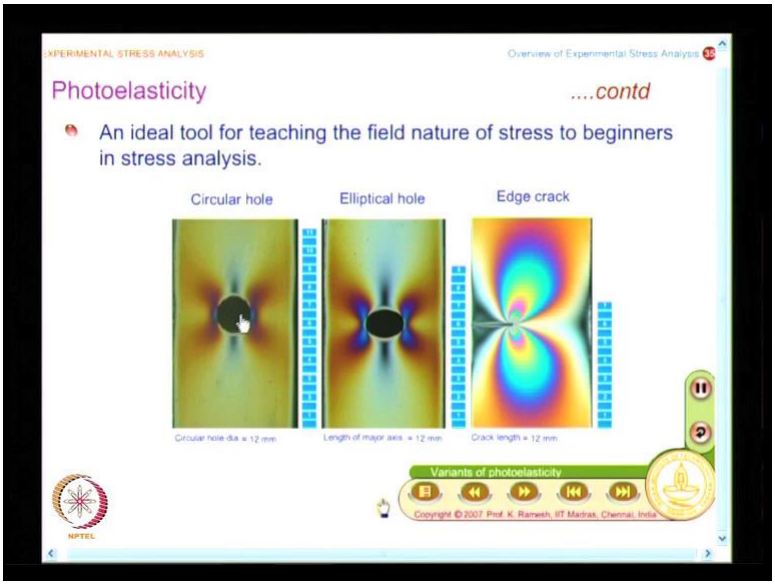

Suppose, I take the load as 6 in all the cases, I have a plate with a circular hole. I have a plate with an elliptical hole. I have a crack, and you do not need to explain, you see you see very few fringes here, you see slightly more number of fringes here, and you see a I have not put that as 6, I put at a 7. I this when I put at 6 you have a large number of fringes here. So, if you have an appreciation of looking at fringe information. The density indirectly indicates the stress levels are high.

So, for a beginner you get the field nature, you understand what is stress concentration. And you may wonder, you know I have an elliptical plate all these cases are finite geometry. I have a finite width and I have a circular hole. Analytically what I could do is, I could do infinite plate with a very small circular hole and here I will have a polar coordinates to determine the boundary condition on the inner surface. And when I go to elliptical hole, you have elliptic coordinates to specify the boundary condition on the inner surface.

At infinity you could considered it has a large ellipse, you could consider as a large circle that is a way you can approach the solution. So, for infinite plate with small circular hole; infinite plate with small elliptical hole, you have analytical solution possible and this goes by the person who has first solve the problem. You have this as a (Refer Time: 13:03) problem.

In theory of elasticity this as English problem and once you come here many has contributed, western guard solution is very prominent, William solution is very prominent. So, in theory of elasticity when they analyze infinite geometry with any one of these defects, or a cut outs you have a name attached to those problems.

So, Photoelasticity is very good to understand stress concentration, to understand the field nature, without much effort you are able to get it and you get up closer picture when I have a look at it like this. Make some of you have already made the sketch, and I would like you to make a sketch of it. And the essential features, you know, you have this kind of a fringe field. And you have a fringe field like this. You have fringes forward tilted and so on and so forth.

In this class we have mainly looked at the elegance of Photoelasticity, and we have also seen how effectively the photo elastic fringes can be used as optical comparators.

Thank you.