Experimental Stress Analysis - An Overview

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Lecture - 1.3
Optical Methods Work as Optical Computers

What ever discussion, on the overview of experimental stress analysis and in the last class I said, that when you say stress analysis in the complete sense it means, determination of six stress components, six strain components and three displacement components. However, I said determining all these 15 quantities maybe a luxury from a design point of view you may not need a full complete solution. So, depending on the problem on hand, you may want to find out only the relevant parameters and then you sit for your design.

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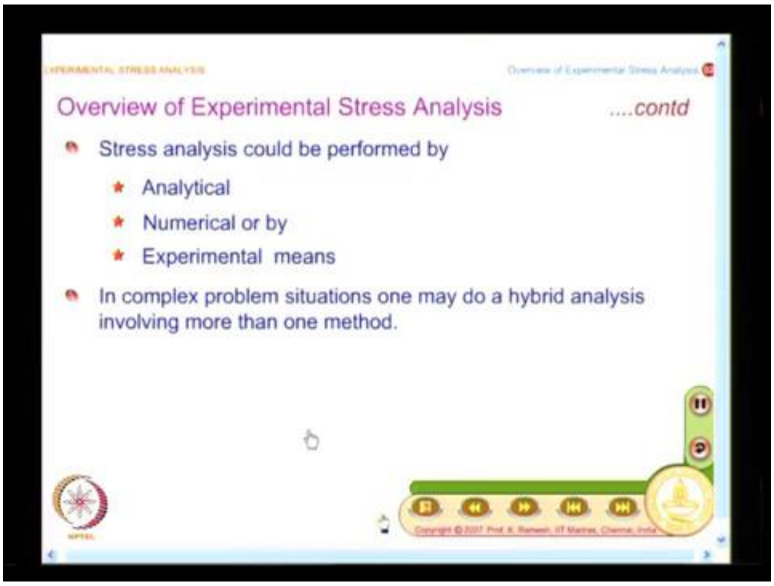

To do the stress analysis, we have also seen that you could do it by analytical methods, numerical methods or by experimental means. In complex problem situations, we may want to use more than one technique, so that we get the problem on hand solve satisfactorily and if you get into analytical methods, what we find is you get a conceptual understanding on the nature of stress fields.

For example, can I have one of the students come here then, show this model and one of the simplest problem that is first taken in, course in strength of material says a slender bar pulled in tension and in this zone away from the grips you all know that is stress is constant and that is given by P by A and what I emphasized yesterday was, you evaluate only a component, you have to learn that you have to put it in a 3 by 3 matrix and put the relevant zero's and understand this as a stress tensor not just as a stress component.

A problem of this nature you have ready made solution without solving differential equations from strength of materials. The moment, you take another problem for the same plate if you introduce a hole; it is just not possible to solve from strength of materials because the moment I put a hole, plain sections do not remain plain before and after loading. Before and after loading plain sections do not remain same. So, your assumption of strength of materials approach will not help you to solve. If you ask a question can this at least be solved by theory of elasticity, which is also not possible, because the size of the hole is comparable to the width of the specimen However, you can still attempt to solve by theory of elasticity.

If the hole size is very small like this for the same width of the member if the hole is very small, though physically this is a finite body from a mathematical sense this could be considered as at infinite distance away and you could invoke theory of elasticity solution and then get a close form expression. So, the size of the hole is very small compare to this. Suppose I have a complex object, what do I do? I have a complex object like spanner and this is a down to earth object, you use it at many of your day today activities, do you get a solution from analytical methods? You do not get this, if such a routinely used specimen, a tool if you want to solve it from your course in strength of materials, it is just not possible to solve. Let it tighten a nut, and what you find here, I have this spanner and I have the nut here and when I start tightening the nut; obviously, you will find stresses are developed.

Do you see the stresses here? You do not see the stresses here. You what you can say from strength of materials because this is constrained here and you are applying a load here, some sort of a bending takes place in the member. Since you all know something about stress concentration you could at best say there will be stress concentration with this zone and this is the load application point. So, certain general observations you could make from your knowledge of strength of materials. Because the geometry is complex you cannot solve it by strength of materials, even theory of elasticity will not help, the only recourse that what we can do is you have to do it only from a numerical technique or an experimental method. What we are going to see is?

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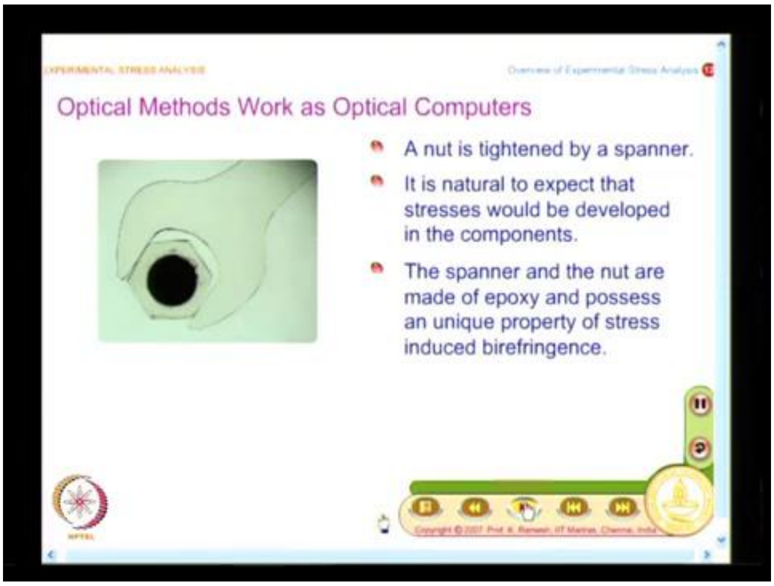

We are going to introduce a new concept that optical methods work as optical computers. This is what we had seen physically, a nut was tightened by a spanner and it is natural to expect that stresses would be developed in the components. You do not see them, the difference what I have shown in the previous live exercise and what you see on the screen, right now the spanner is made of epoxy and nut is also made of epoxy. I have a reason for it because I have an interest to show even the stresses as they developed when the nut is tightened by the spanner.

So, what you find is a very simple problem, down to earth problem, you do not have solution from strength of materials after full course on strength of materials. You can only at best conjecture what could be the stresses not the actually magnitudes. What you have is why I have taken epoxy is, the spanner and the nut are made of epoxy and it possess an unique property of stress induced birefringence. See early I have told you that each of the experimental technique utilize a particular physical principle, which is exploited to reveal a particular kind of information. It will not give all the stress components, all the displacement components, all the strain components and here what we have done is, we have taken a spanner and nut, which is made of epoxy and it possesses a unique property of stress induced birefringence. What I do now is, I introduce appropriate optics and view the same combination with the optics.

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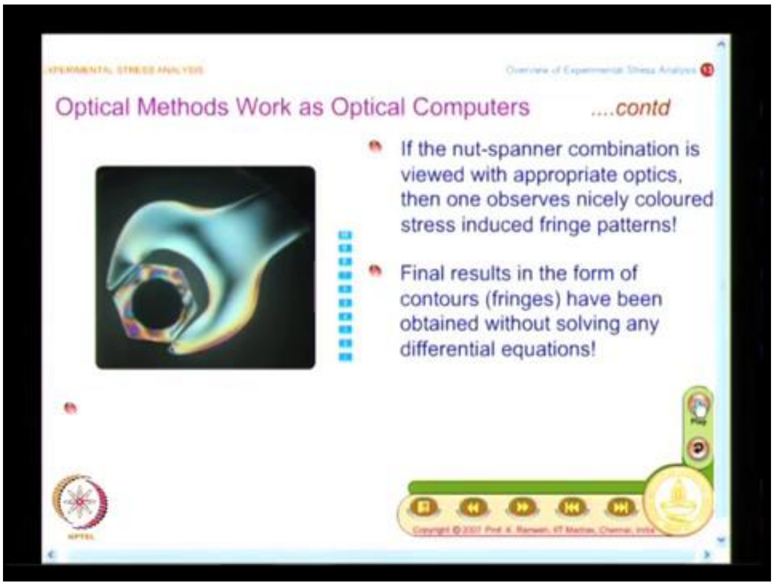

Optics is not shown here in the screen, but you will see the effect of optics seen on the image, and what you have here is?

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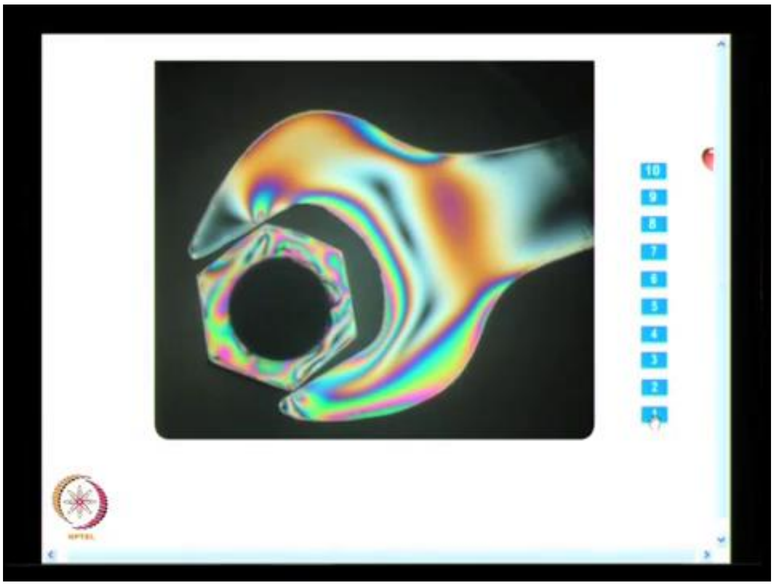

As I change the load, as I keep increasing it, you find that more and more colors are emerging and it is seen. So, what it shows is whatever the colors that you see, are a function of the load applied. I would like you to make a sketch of this, in a reasonable manner at least for the spanner. Forget about the nut at least for the spanner, you make a reasonable sketch of the spanner. You should thank the nature, these are not artificial colors it reveals the stress information in the form of such rich colors. The colors are very nice and normally when you go for a computer plot, you usually plot to indicate what is of a high value as red and a low value as blue and you have a gray scale suitable for different application.

But here the colors are seen naturally and nature wants to reveal the stresses in colors to enthuse the experimental mechanics person to conduct the experiment. I would like a reasonable sketch of it, capturing the silent features. What you have here is you have stress concentration this is the load contact point and you have stress concentration here and you have the fringes developed on the edges and you have seen very clearly, that all these colors have emerged as a function of what you have applied as load. For your benefit I will repeat it again. So, when I have the least load, it is like this as the load is increased in stages you find the fringes are formed and we call these as fringes, and what you get here, I get first information I get is, I get this over the entire spanner I get information.

So, I get whole field information from an experiment, the whole field information from an experiment. What I have here is the results in the form of contours have been obtained and I have got it without solving a differential equation because what is the effort that I have done is I have to make the model of the spanner, as well as the nut and then put it in a appropriate optics and reveal the pattern. I had to do a similar exercise as a numerical approach.

What I will have to do is I will have to formulate the problem as set of differential equations, solve it either the in closed form or at least in the form of a approximate approach then, re plot go to a computer use a plotting software and re plot the values.

Then, I will get these contours. So, in that sense what I could say is that, optics has done the job for you. So, I could call this as optical methods working as optical computers. The effort that you will have to do is you have to make the model, you there no escape. There is some price you have to pay for it.

In a case of numerical method, you have to pay a prize and formulating the problem in the experimental method, you have to pay a price in fabricating the model. Now, what is important is, I have seen this rich contours and what this contours? How do I know what these contours represent? So, here only you have to look at what is a physics behind the problem. So, physics is very important in understanding and interpreting the results given by an experimental technique. If you do not know the physics you will not be able to interpret the fringe patterns and that is what is summarized here, and what you have is one need to know what physical principle does an experiment exploit to reveal the physical information.

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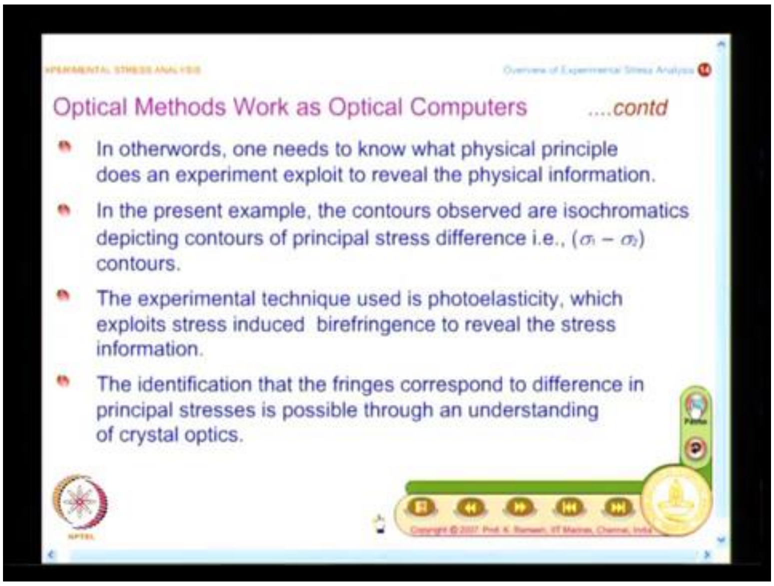

In fact, the purpose of this course is get into the physics of the problem and understands for yourself, completely that this physics is exploited and what I see is this is the contour. But, what I will do now is you take my words for granted at this stage of the course and in the present example the contours observed or isochromatics, depicting contours of principal stress difference. For you to understand this we have to develop special optics, the technique that is used is photo elasticity as I said which exploits stress induced birefringence to reveal the stress information. That is why I have taken a specimen which behaves like a crystal when it is loaded that is what the epoxy that has a phenomenon of stress induced the fringes and because stress as induced the changes in the optics. So, by analyzing the optics information, it is possible for you to relate the effect of optics in terms of stress matrix. So, that is what we have done in this simple exercise.

If you want to have a complete understanding, you have to have a basic understanding of, what is special optics? That also will develop later in the part of the course currently the interest is to focus, when you look at any experimental technique you need to understand the physics behind it. Physics would be different for different techniques. Only if you know the physics, you would be able to interpret getting colored contours that too colored contours is very nice, but experiment does not stopped there. After getting the colored contours, you should know how to interpret it. The interpretation is possible only when you have understanding of physics and many instances interpretation itself will be very challenging and this is where people would like to take the assistance of automated data acquisition and processing methodologies. Where, they would like to minimize the interaction of the person conducting the experiment and you have to understand you will be surprised.

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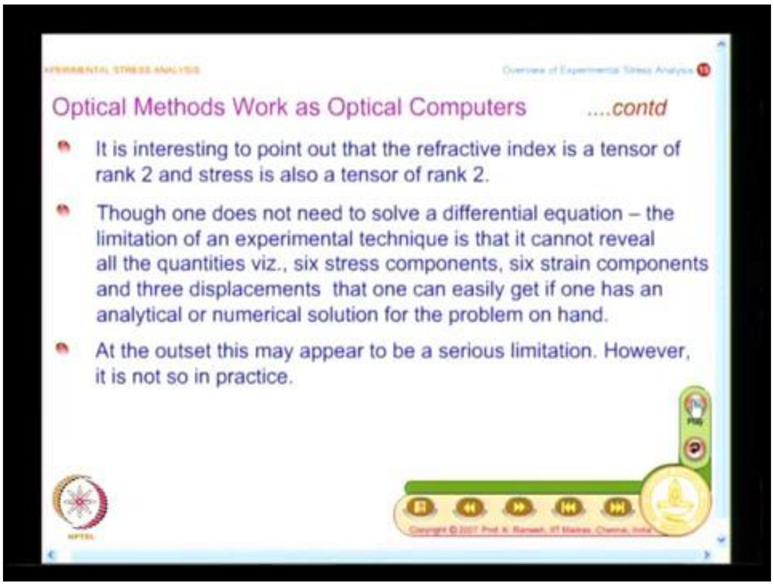

Many of you have done in your physics course, you would have done an experiment on finding out the refractive index of a glass and you would have just got a number and you would have thought, like in the case of introducing strength of materials. You take a slender member and then pull it and then you find out stress introduced is P by A you think that it is a scalar because you are only looking at the component where you are looking at the value, you are not looking at totality of the stress at a point of interest. Similarly, you tend to think that refractive index is also a scalar.

In fact, it is not so. Refractive index is also has direction dependence and it is a tensor of rank 2. Stress is also a tensor of rank 2. So, whatever modification on the refractive index if you are able to capture it by optics, you could relate that to stresses and if you look at this was developed way back in 1816 or so in Brewster, read it in first set of experiments. So, this is what I would like to emphasize again, we do not solve a differential equation from that point of view it is advantage is, but the limitation of an experimental technique.

It cannot reveal all the six stress components, it cannot reveal all the six strain components, it cannot reveal all the three displacement components. In this particular experiment, we have been able to get only sigma 1 minus sigma 2. So, to start with, it will appear, I do an experiment, I do not get everything under the sun, it may look like a limitation but this is not a serious limitation and this is where, as an engineer you have to apply your engineering acumen to choose an appropriate experimental technique or a combination of them to solve a problem on hand.

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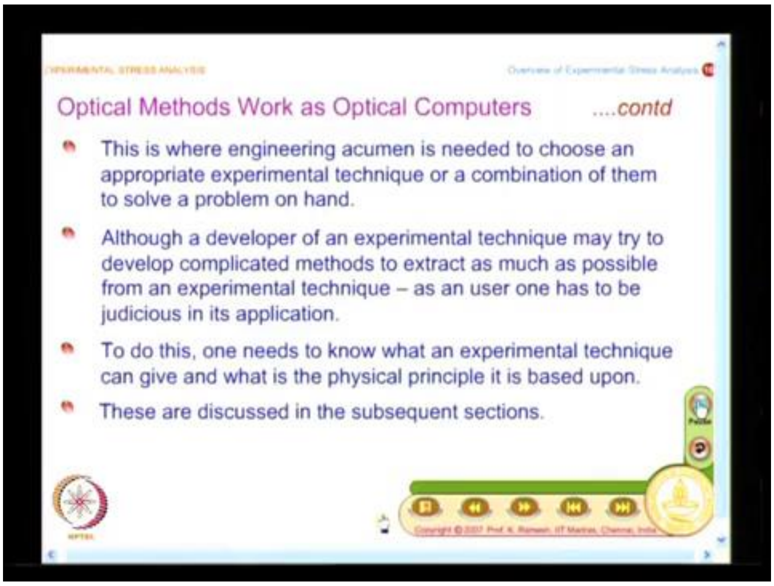

You know this is where the engineering acumen is required and that comes only by practice. See, complicating a problem is very simple. Simplifying a given problem on hand is a most difficult aspect and that comes only by experience. Sometimes, very simple methods can solve the complex problem. So, you should be open to new ideas and you should know what kind of facilities that you have based on that, based on the time constrained, you decide an appropriate combination of techniques to solve it. Another word of caution I would like to say another word of caution, which I would like to say what I would like to say is, see as an experimental person, the person may be interested in developing as much as possible from a given experimental technique.

So, in the process we may do more than what is really required and then try to say, you use complicated steps to extract maximum from a given experiment. Because when a new methodology is proposed he would like to get that methodology established and you would like to show that it can be used for a variety of problems, but from my user point of view, a particular feature of an experimental technique may be more appropriate. That is enough for you to solve without getting into the ramifications of using that with a constraint. So, as an user, you should also use only those aspects of exponentiation technique which are appropriate for your problem on hand. That is what I said to do this one needs to know what an experimental technique can give and what is the physical principle based upon and these will be discussed as we go by.