Experimental Stress Analysis - An Overview

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Lecture - 1.4
Basic information provided by
Various Experimental Methods

In the last lecture, we have seen how optical methods provide, whole field information in the form of contours without explicitly solving any differential equations. What you need to know now is, for each of the experimental technique, what is the information that it gives directly.

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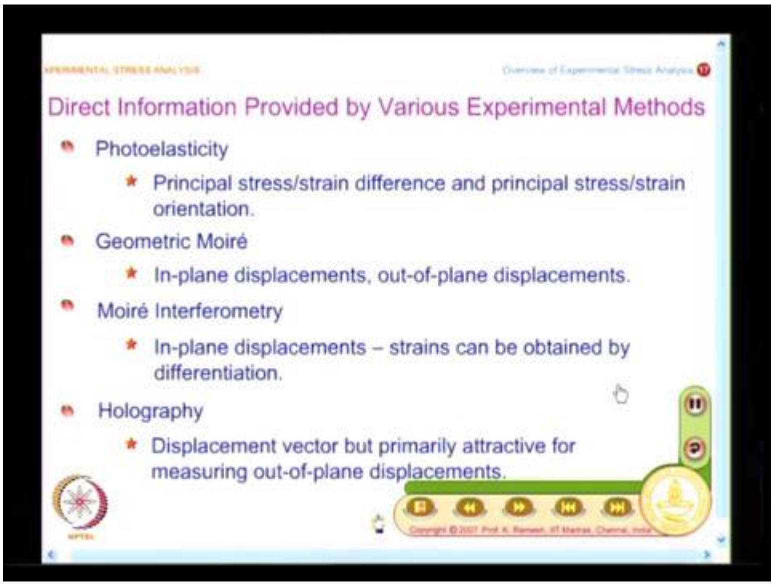

You may want to use this information and use your mechanics of solids or other methods to process this information, to get additional data that is a different aspect, but basically when you exploit the physics, what is the information that we get out of it? That is you need to know and in photoelasticity you get principal stress or strain, because photoelasticity has transmission approach you get principal stress difference if we use a reflection methodology for analyzing prototypes you can get the principal strain difference, and you can also get the principal stress or strain orientation. So, if you look at photoelasticity it can give only these information it cannot give you normal stress components or shear stress components.

But shear stress components if you know principal as difference and the theta you can process it and get it. But directly what it gives depends on the physics because the physics, we are already seen at least partly that it uses stress induced birefringence and some that you will be able to find out difference and principal stresses directly, so you get only stress information from photo elasticity and if you go to Geometric Moiré. Geometric Moiré provides directly only in plane displacements or out-of-plane displacements. What will have to do is if you want to get in-plane displacement, you should go for a particular optical arrangement. If you want to go for out-of-plane displacement you should have some modifications the optical arrangement.

And even if you want to get displacement you should have gratings oriented in a particular way. So, you are an exploit in the physics, you should also know what is a how you use it. So, at a time you will get only one information by enlarge, but there are also techniques which uses more than one combination and you get combined information as comfortably as possible.

The next is Moiré Interferometry. In Moiré Interferometry you can get in-plane displacements. Here, you can go and make very precise measurements compared to Geometric Moiré because the displacements is very accurate, strains can be obtained by differentiation. Like I said, in the case of photo elasticity, you could get in-plane shear stress, if you know the principal difference, principals orientation in Moiré Interferometry. Because the displacement information is very precise because, we have use high density gratings strains can also be obtained by differentiating the displacement.

Now, you should know numerical differentiation is error prone than integration. So, even my small errors in displacement will get more, will become more. When you do a numerical differentiation and you have Holography and essentially it gives a displacement vector and you all know that as a security device but, from a stress analysis point of view it is a displacement vector, very attractive for out-of-plane displacement. In fact, in the early days when they were developing turbine blades, the vibration modes of turbine blades were recorded by Holography and it was very revealing and Holography is very sensitive as well the amount of effort that you need to do Holography is, much more than you do an experiment using Photoelasticity and you have another experimental technique.

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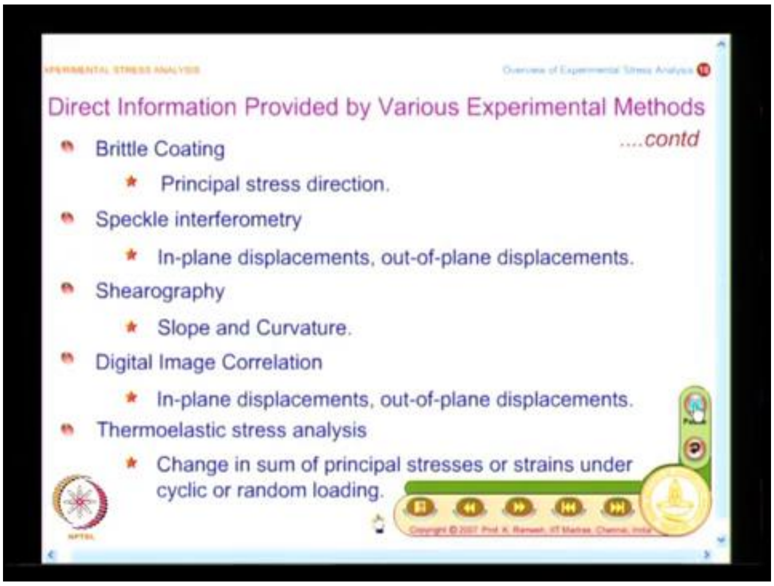

The name itself signifies I use the coating which is brittle and this directly provides principal stress direction. So, I think, right now you will know that we have seen variety of experimental techniques; some give only stress information, some give only displacement and some give only principal stress direction. So, depending on what you want. So, from as an analyst, you should know what you want and based on that you should select the experimental technique. Then you have Speckle interferometry, which is a variation of a Holography and which gives in-plane displacements and you can also get out-of-plane displacements, yes.

see when you are looking at three displacement components UV and W in plane displacement means you are essentially looking at U and V displacements. If you are looking at, if you want out-of-plane displacements that is a W component then, it is out-of-plane displacement. Particularly in a mode shape you have essentially vibration perpendicular to it. Then you will see that easily captured by Holography and for each of this you need to have appropriate optics. The optical arrangement is very important which tells you which one you get and we will definitely spend time on each of this techniques, later to see what is optical arrangement? The initial exercise nowadays, to know in our mind that what an experimental technique can give directly and then you have a Shearography, which is a radiation of a speckle interferometry and which is very popular in non destructive testing where you can find out slope and curvature

For example, when they make honeycomb panels for satellites, all of this, honeycomb panels have to go through a screening test before it is assembled on the satellite, where you do not want to have any surprises when the satellite is launched. You have to see whether that honeycomb panel, the top sheet is gloved properly with the honeycomb and if there is not gloved properly you have to use non destructive testing and shearography is a very ideal tool where you could do the test on the complete panel, satisfy yourself, that it is free of defects or defects within permissible limits then you allow the satellite to be fabricated.

Then the next technique you have which is a very recent origin it is about 10 years old is digital image correlation and this again gives in plane displacement out of plane displacements. You may also wonder I do not have one experimental technique which gives only in-plane displacements. I have many experimental techniques to measure in plane displacements and for example, even you go on yesterday I mention that you have to measure the length, you can measure by tape, length you can measure by scale, you can measure by vernier. When you are using a vernier, you have a least count when you go to screw gauge you have a much finer least count and when you go to optical methods you still talk in terms of wavelengths.

Similarly when you look at experimental techniques also you can get information of varied accuracies from each one of this. So, you will also have to know see, suppose I want to work on rubber I going to have large displacements, digital image correlation is very ideal I do not want to measure large displacement with a very fine measuring instrument. Suppose, I want to work on nano structures and I want to see in nano devices what is the kind of displacement I would naturally go to Holography and then find out the displacements. Though each technique gives seemingly similar information, the physics what we have used or what we have exploited dictates the possible level of accuracy and what I would say is physics as well as the technology. Physics may be same, but the technology is improved then also you can improve the accuracy of evaluation.

Another non contact technique what you have is Thermoelastic stress analysis. This gives only change in sum of principal stresses or strains under cyclic or random loading and you all know fatigue loading is very common in actual structures. So, for handling problems of this nature, thermoelastic stress analysis as come into play particularly, for high temperature measurements you want to have non-contact measurement, this method has been developed. So, directly it can view change in sum of principal stresses. Photo elasticity gave difference in principal stresses; thermoelastic will give in only change in difference sum principal stresses that means, the physics what you have used demands or it gives it is capability of doing that only information. Here, it uses the temperature developed because of stress applied that is what you will basically the information is used, yes.

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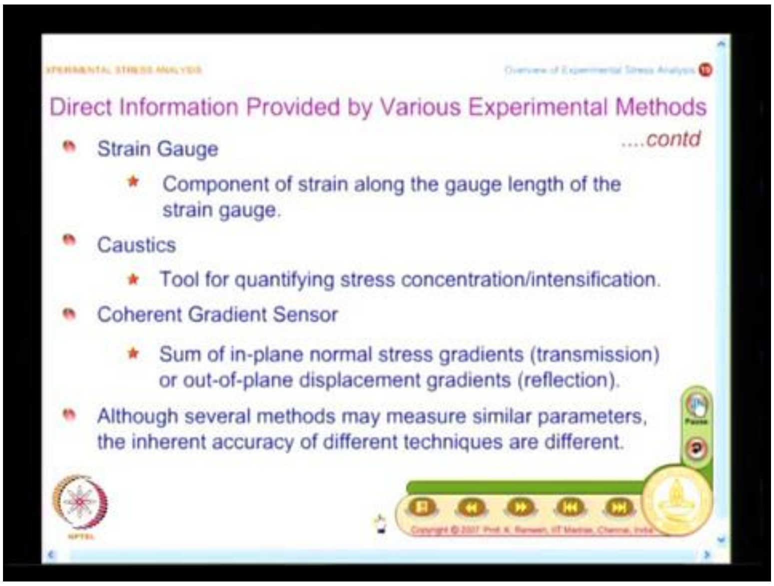

Student: What are non-contact techniques?

See most of the optical techniques are non-contact. If you look at the optical techniques, they are all non-contact techniques. Now, I am showing strain gauges, when you go to strain gauge, what you do? You actually take a strain gauge, paste it on the specimen. So, if you paste it on the specimen you are disturbing it. Any coating technique whether, it is brittle coating or photo elasticity coating or strain gauges, it modifies a stress pattern to an extent.

On the other hand, if I do not make any contact with this specimen or I just send only light waves and then receive the light waves like, what I do in transmission photoelasticity or what I do in digital image correlation or in Holography, you have a non-contact application. This is what I would like to emphasize. See when you look at strain gauge people think strain gauge give strain. They talk loosely it does not give strain, it gives component of strain. There is a fundamental difference between strain and component of strain. Strain is a tensor of rank 2, when you say strain, you indirectly imply it is strain tensor, but a strain gauge, a single strain gauge can give you only component of strain along the gauge length of the strain gauge. This is a very subtle and very important information.

So, if I have to find out strain tensor in 2 dimensional situations, I need to use three strain gauges, I cannot measure strain tensor with one strain gauge. So, if you, only if you understand a single strain gauge give component of strain. So, you have to come out of your earlier understanding or strength of material. You have looked at as components many of you may not even recollect that stress is a tensor and strain is a tensor. You still think in terms of that as one in numbers and the danger is that you may even think that it is scalar like a temperature, it is not so, it is a tensor, tensor of rank 2 whether, you understand or not.

Material understands are tensor because if you break the material the failure planes are dictated by whatever the failure criteria that depends on stress is a tensor. We have also noted what a caustic is; we saw the caustics in a tea cup. I said caustics is the name of the physics behind it. This is particularly used for stress concentration and stress intensification problem. See, if I take photoelasticity I can do it on regions which is not under stress concentration, uniformly loaded also I can get information. Only when I have stress concentration that is suppose I have a load application point, near the load application point you have a concentration of stress and for only in that zone, I would be able to get information by caustics. Because what it uses is it uses the specimen becomes divergent. The specimen become divergent because of poison effect and what over the light you send the light is deflected, you would see that.

So, in a sense it is also localized information you get and a variation of caustics what you see is coherent gradient sensor. In this, it is an optical method and sum of in-plane normal stress gradients you get it in transmission arrangement or out-of-plane displacement gradients in reflection arrangement. As I said earlier, although several methods may measure similar parameters, the inherent accuracy of different techniques is different. So, is any question at this stage? So, the key point here is although several methods may measure similar parameters, the inherent accuracy of different techniques is different and this knowledge you need when you want to solve a problem on hand.

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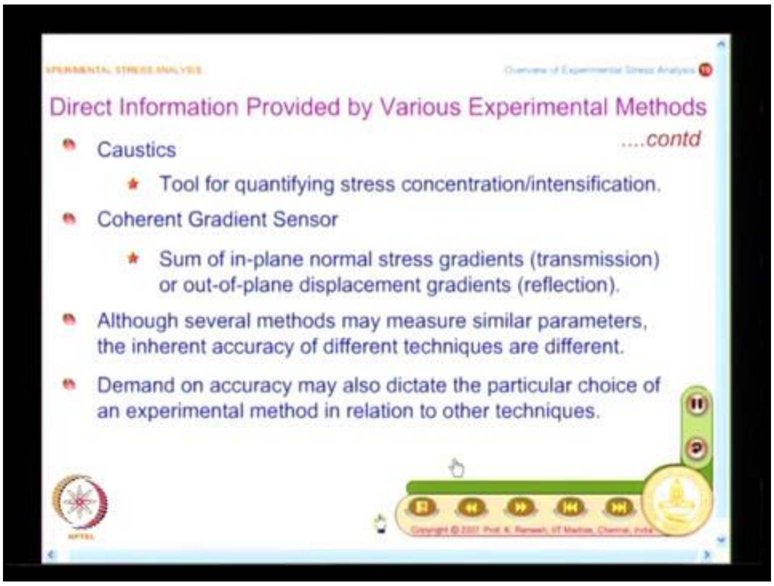

Sometimes you may want a high accuracy. So, demand on accuracy may also dictate the particular choice of an experimental method in relation to other techniques. And everything cost money, if you want more accuracy, you need to pay more. It may also take little more time for you to get the result. So, the idea is there is a fundamental difference, if you are able to solve the problem analytically there is nothing better than like that, but reality is the number of problems you can solve analytically methods are very much limited. You cannot live with analytical methods alone it has definitely given you an understanding that trust you have axial force members where the material is fully utilized in load sharing the moment you come to bending the inner core or the material is not contribute into load sharing.

So, you can have I beams for rails and when you go to torsion the inner core can be removed and you have hollow shafts and if you go and look at is it human beings which are intelligent enough who have understood a mechanics of solids, and they are able to say for a bending member you do not have to have material in the core. If we go and look at nature, it is very surprising nature is much more intelligent than what we think of. You have bones which have hollow portion which actually you have the bone marrow where you have hemoglobin developed, you have birds they fly because of hollow bones and if you look at nature. You have a new branch of science biomimetics, if people go on do look at various natural creatures as well as plants and how do they function and we will only mimicate in our engineering.

And you should not feel, yes, nature is great, in it is own merit human beings also great in their own merit because I always consider all this stress analysis, you are understanding a fluid mechanics, solid mechanics, vibration if we look at what is the product that you can really think proud of is an aeroplane, a huge metallic bird flies and comes back with a such a heavy weight is not a joke.

In fact, all these techniques have contributed to it is development. You have taken certain advantage from numerical techniques you have verified many of this from experimental approach only. Now, people want to fly composite aircraft because they would like to have the least weight, it has it is own advantages as well as problems. So, this class what we have covered is basic information which each experimental technique. I have focused only on basic information; if we use mechanics of solid or combine combination of more than one experimental technique we could derive many of the quantities, that is not the issue here. Why we look at direct information provided by experimental technique is, we would like to know and relate what is the relationship between the physics and what is the information we get.