Experimental Stress Analysis - An Overview
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Lecture - 1.2
Introduction to Stress Analysis: Experimental Approaches

In the last lecture, we have looked at the Analytical and Numerical Approaches for Stress Analysis.

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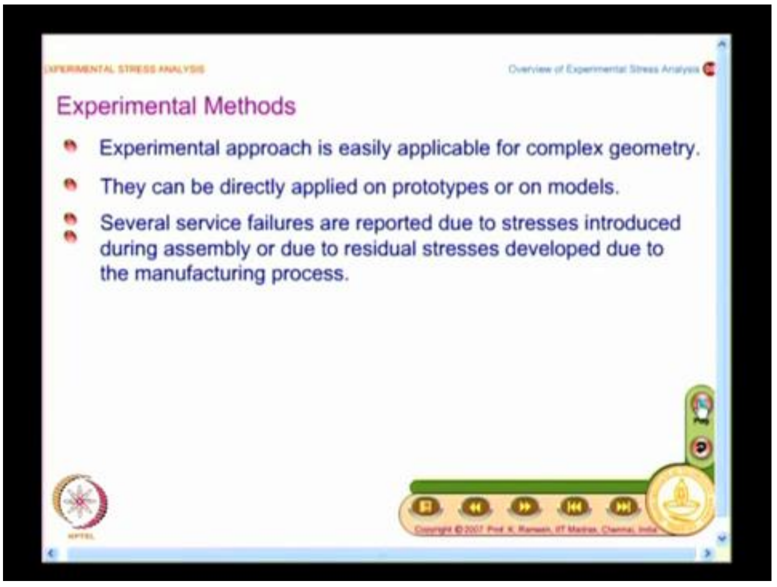

Once you come to experiments, what do you see? Very similar to numerical methods, experimental method is applicable for complex geometry. Absolutely, no problem and once you come to experimental, you will also have to look at two different things, am I working on a model or I am a working on a prototype? So you can do the experimental approach on prototypes or on models. Another area where experimental methods are the ideal choice is in the area where you have assembly stresses or resolution stresses.

Now, I take a very simple example of a chain and this you have it in your bicycle this is also used in a power transmission and in practice what you have? You have two sockets on either side and this is subjected to essentially tension and actual service. Now, what I have here is, I have an element taken out of this chain. I have not, I am just holding it, are the any stresses in this chain? How many of you say no? How many of you say yes?

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There is one person who says is stress, the rest of the class say it has no stresses. See you have to know how this component is fabricated? Suppose, I take a block of material and then I go to c and c machining and then machine out this, that is one thing. And how it is done is? You have essentially plates and these plates are brought together by putting the appropriate bush and the bush has to stay in place, so you have an over sized bush and this has to be inserted so this is done with an interference fit. So, apparently I do not have any external load on this chain link, but because of the way it is manufactured you have stresses developed, you have a bush here, you have stresses developed very prominently here and it is comparable to the service loads. The stresses developed are not small in value comparable to the service load.

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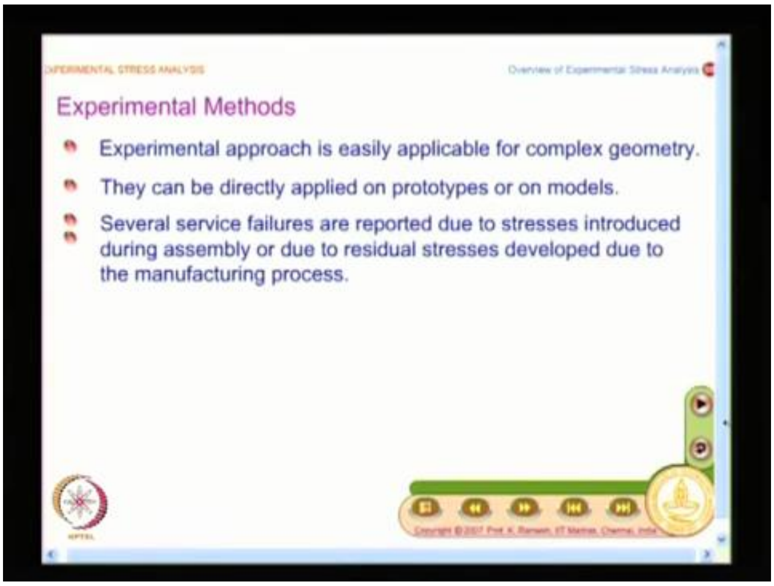

So, what you need to understand here is? It is a very complex problem, and this is where many service failures are reported. Service failures in the field are reported because of residual stresses and also assembly stresses and experimental methods come in very handy for solving problems of this complex nature. Because many issues that go into this you have the bush and bush maybe may not be perfectly cylindrical. And another one is this is a body which has finite geometry, you have a finite geometry and this is an arbitrary shape. Finite geometry I cannot go and approach by finite element by theory of elasticity, definitely I can approach it by finite elements absolutely no problem, but there I have to apply the boundary conditions.

What is the information I may not know for a production shop is this may not be perfectly cylindrical, this will have a variation. So suppose, I put it and then do a experimental analysis on this component directly which acts like a prototype, then I capture all the manufacturing variations that has gone into the fabrication of this. Whereas I do a numerical analysis, I would take this as a perfect cylinder I would not have model if there are any fine undulations on the surface and such variations do exists in actual practice. So, what you find here is? For conceptual understanding numerical analytical methods are needed, for complex geometry you have to go in for numerical methods, but to know the truth you will always have to depend on experimental methods.

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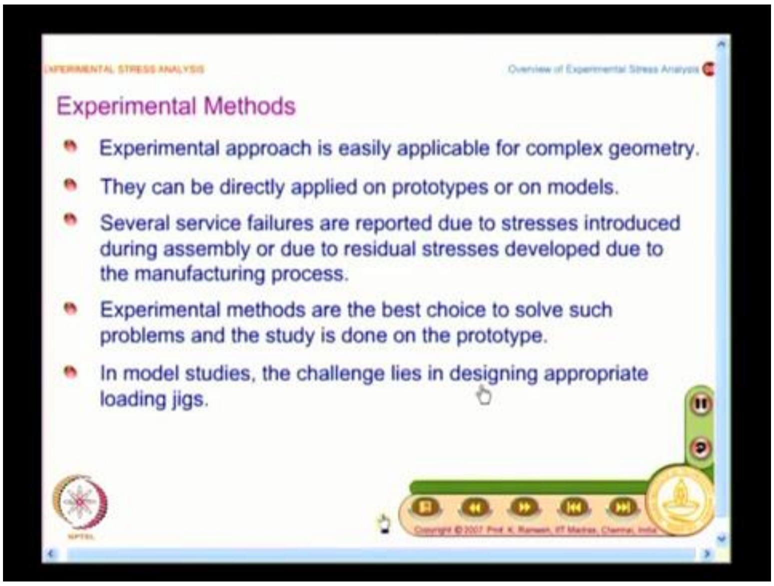

Experimental methods are the best choice to solve such problems and the study is done on the prototype. In model studies, you have difficulty because in model studies the challenge lies in designing appropriate loading jigs. So, if I do not design the loading jig appropriately, then I am not solving the problem that I have to solve even by experiments. I said in numerical techniques if you do not specify the boundary conditions you are not solving the problem that you have to solve, the same defect exists even in the case of experimental methods when you have to work on models. When you have to work on prototypes, the approximation is as close as possible to reality, but when you have to work on models you have to load the model.

Now, let us see one simple example. I have this rod and I want to pull this, I can pull it by grips I can have solid grips and then pull the rod. I can also pull the rod by another method which is what usually do, what you do is? You have a sling, you have a pin so you pull it with the pin it also has a certain level of self alignment. If you really look at what is the stress distribution near the close vicinity of the hole and the way I grip it these two are different, but our interest is I want to have axial force in this member which could be done by numerous ways and one way of doing it is putting a pin and sling and then pull it, another is put a grip and do it. So I am not really solving a problem that I have to do what I have in actual practice and this is where you have this famous St Venant principle that is required.

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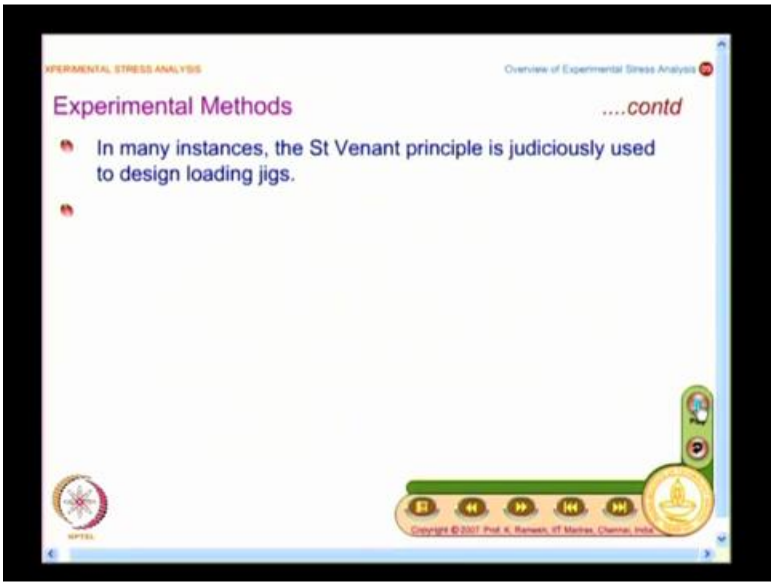

In many instances in designing loading jigs, you use St Venant principle. What it says is? At distances away from the point of loading the distribution is similar to what we finally want. So you will have to use St Venant principle and design your loading jig appropriately so that it simulates service load condition as closely as possible.

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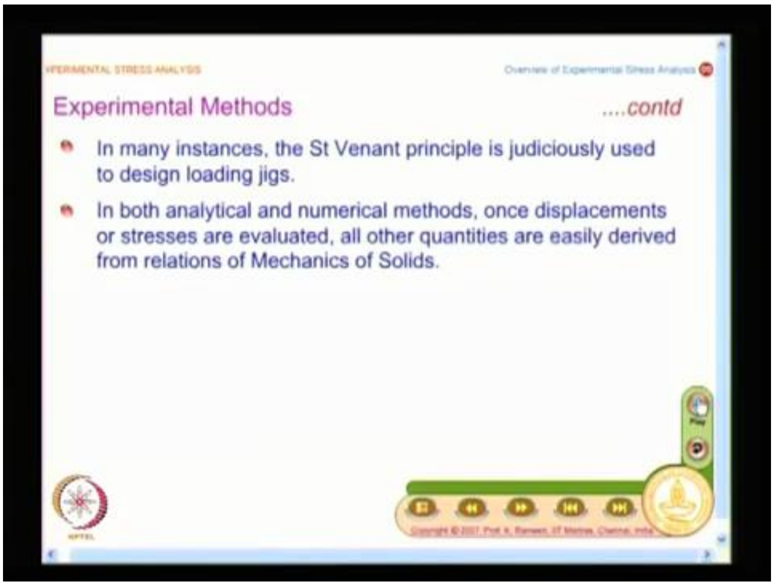

Then what you have? There is also another difference. See in the first, I showed axial member pull you have p by a, you have the stress component, rest of the stress components are 0. If you want to find out strength and you can easily find out because you have this.

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You have readily available Mechanics of Solids equations, you have a stress strained relations, strain displacement relations. So once I find out stress components, I can find out the strain, I can find out the displacements both more in analytical and numerical methods. This is primarily because, I know all the stress components by analytical method then I proceed. In a numerical method also when I solve I get all the stress components evaluated, then I go for strain and displacement, which is not the case, in the case of experimental technique.

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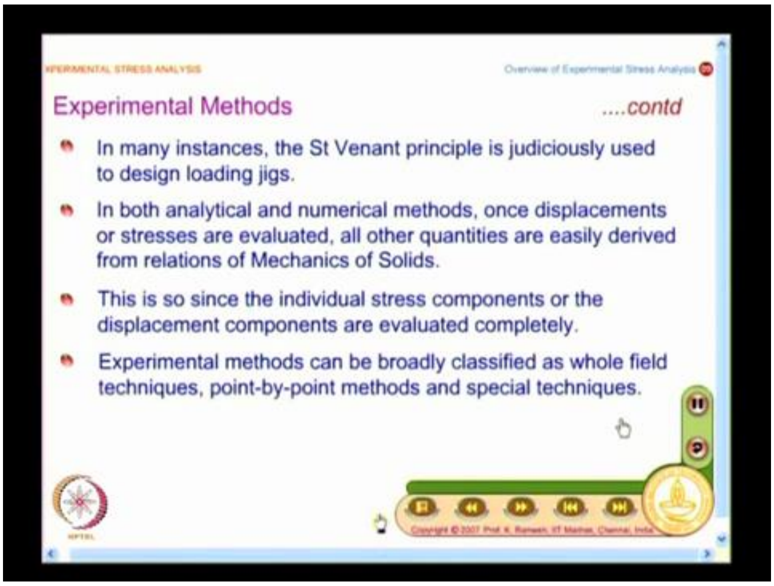

Because experimental technique exploits a physical principle for measurement, so that physical principle impose certain restriction, what you can measure in an experimental technique. Suppose, I measure stress, I cannot measure all six stress components. I can measure only a particular stress component or a combination of them which is dictated by the physical principle employed in the technique. On the other hand, you have an advantage, it can work on prototype, it can work on arbitrary geometry, it can find out (Refer Time: 09:00) set, it can find out assembly stresses, but the restriction is I do not get all information in one go.

So, this is one restriction that you have to live with and once you come to experimental methods there are many experimental methods available they have broadly classified as whole field techniques and point by point methods. If you look at whole field techniques, they are essentially optical techniques, and you have a great many of them and newer techniques are also being developed day after day.

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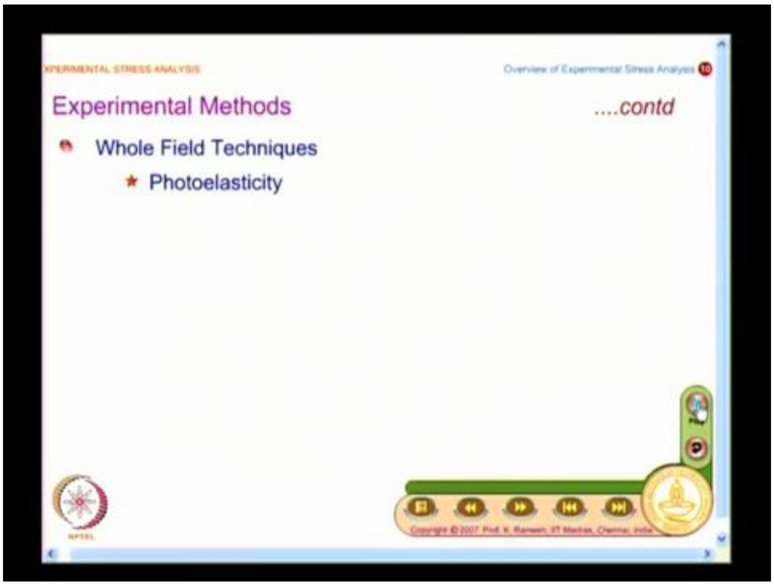

When you look at whole field techniques, one of the very popular and widely used experimental methods is technique of Photoelasticity. We would see later what these experimental techniques give directly the information, what information it can give directly? Essentially, photoelasticity gives sigma 1 minus sigma 2 contours and you have Moiré that essentially gives displacements, and you have Brittle Coatings that gives you direction of principle stress.

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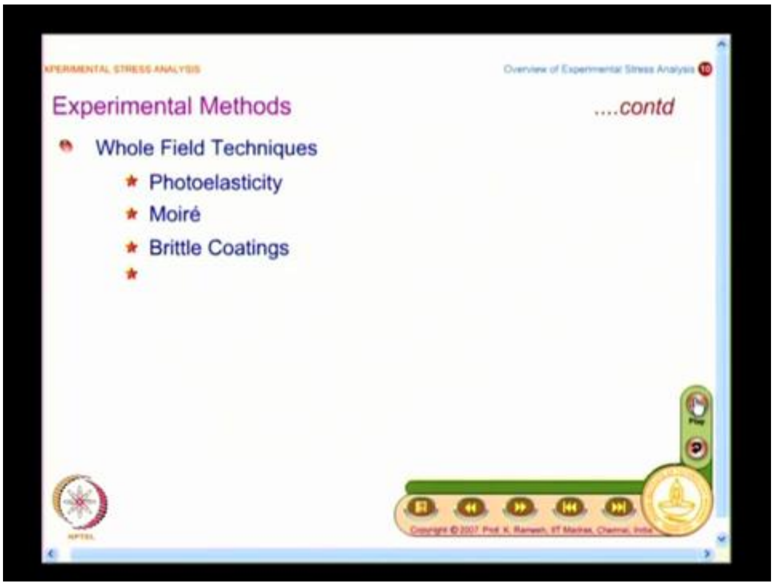

So, for each one the experimental technique you get a particular kind of information, and even if you when I use that the particular experimental technique if it is gives more than one information you should use different optical arrangements to get it. You do not get anything free you know you have some advantage some disadvantages that they go together. So, it is a user who was to decide what aspect you will exploit and then find out which combination you will try to use for solving a problem on hand. You have Holography, many of you must have seen holography as a sticker on many one of the products it is used for a mostly as a security device but it is also a very good experimental technique and you would essentially get the displacement vector. You have Spectral methods, which is the variation of holography and one of the very recent experimental techniques is Digital Image Correlation.

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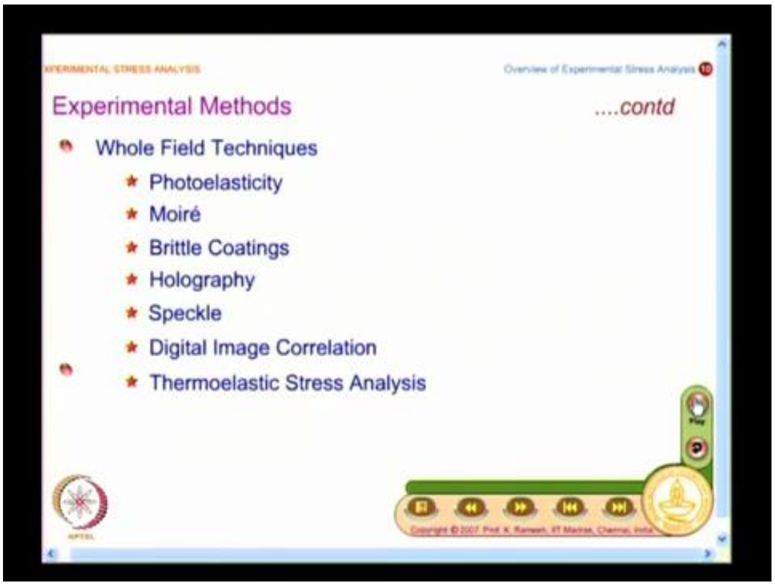

These are as advantage of working at multi scale. Specimen preparation is very simple, surface preparation is very simple and it exploits the computers to the full of extent for measurement of displacement. Then you also have a technique called Thermoelastic Stress Analysis. What you have is, when you have a model and then put a load when I put a cyclical load the temperature change is very, very small and those are measured by a non-contact approach and you have a Thermoelastic Stress Analysis. You have a Point-by-Point Technique and what you have here is the widely used Strain Gauges.

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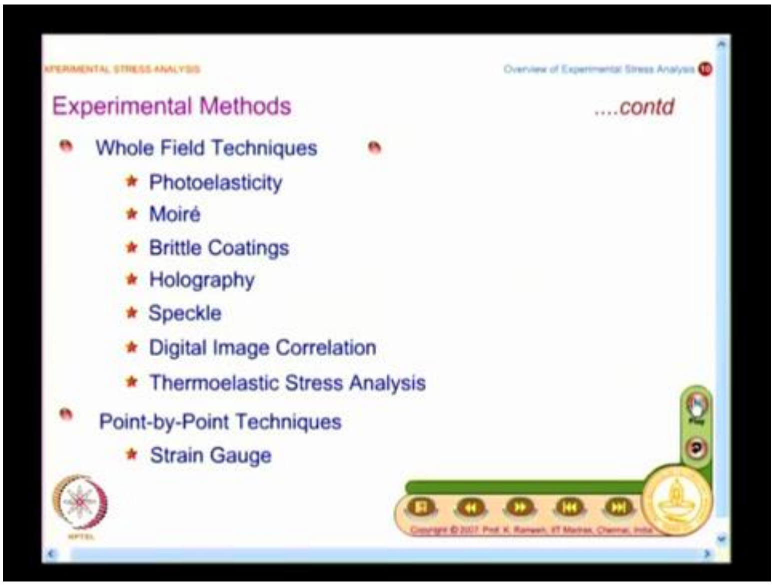

I say it is widely used. I also caution, it is a widely abused technique, because you know people in a strain gauge people have to paste a strain gauge and pasting a strain gauge is such a boring exercise, you have to be trained in pasting strain gauges. We do not paste the strain gauges properly you measure anything under the sun. So, you do not really measure what the system shows, you have error sources so unless you handle the technology behind strain gauge instrumentation right from pasting onwards you would not measure the quantity that it has to be measured correctly.

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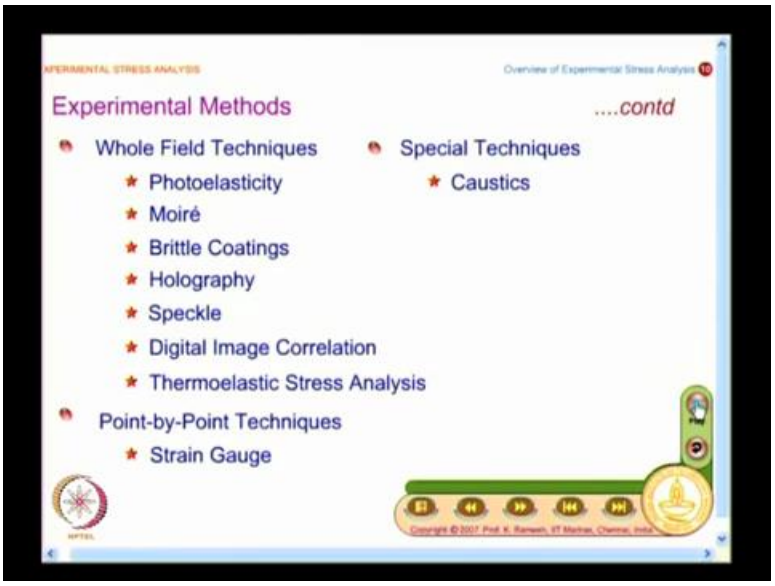

You also have Special Techniques. As I mentioned in the beginning of the class, we saw there is a optical phenomena where light gets reinforce and you get a silver line, you have this as phenomenon of caustics which is used in high stress bearing problems, like when I want to find out what is the stresses developed in the vicinity of a crack? This is a very useful technique and because of Poisson effects the specimen behaves like a divergent lens. Caustics is can be classified as a point-by-point technique because it gives only one information and you have field information in a Coherent gradient sensor which is the variation of caustics.

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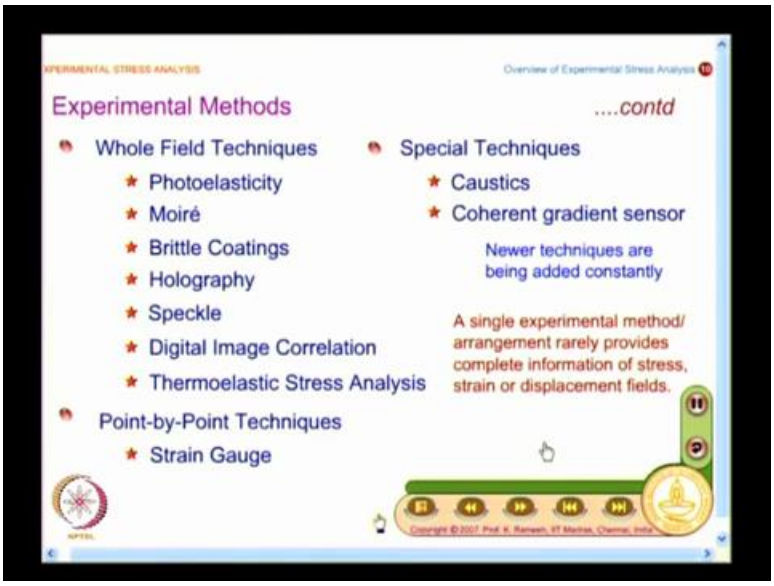

You should also appreciate that newer techniques are constantly added, as I said earlier a single experimental method or arrangement rarely provides complete information of stress, strain, or displacement fields. It may a particular kind of information, if you are satisfied that that information is good enough then one experiment is sufficient for you to get the answer you wanted. If not, you may have to use a combination of different experimental techniques and go and evaluate the parameters that you want to do it for your analysis.

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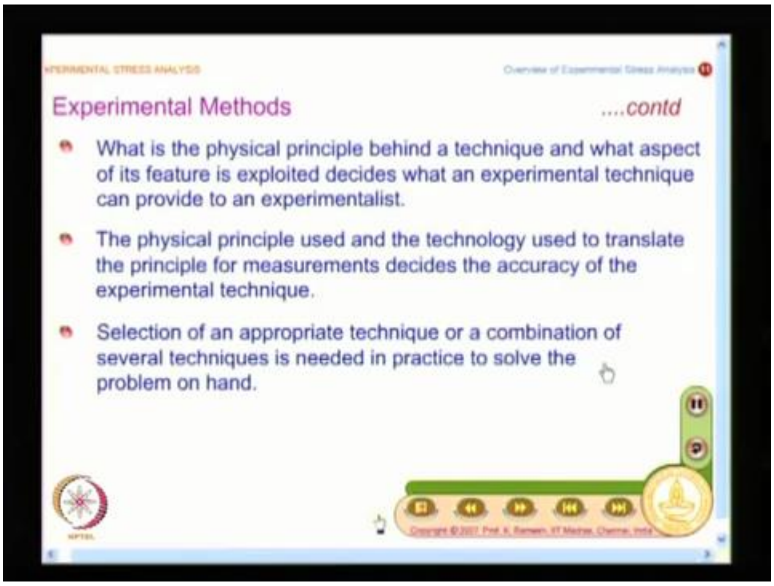

As I have mentioned earlier also, what is the physical principle behind a technique and what aspect of its feature is exploited decides the, what an experimental can give. So I need to know the physics behind it. Another aspect is, what is the physical principle used and the technology used to translate the principle of measurements decides the accuracy of the experimental technique, because if we go to photoelasticity earlier we were making measurements manually, now you have image processing techniques available. So with the technology I can refine the measurements further. You need to know, what the physics behind it is.

Suppose, I go to image correlation the size of the speckles matters and there is inherent difficulty when you want to go for very low value of strain measurement. So you have the physics, what is the physics that you use and what is the technology that is used to exploit this both have to be in synchronization for you to arrive at accuracy of particular kind. I can make measurements using, suppose I want to measure the length of this room I can go and take a tape and measure it, when I take a tape and measure it I am go on to say so many centimeters.

On the other hand, if I want to have very fine measurement then I can go for a laser based measurement technique, where I will say in terms of nano meters the accuracy of the length, same length measurement by depending on whether you use a scale, whether you use a tape or whether you use a vernier or whether you use a screw gauge or whether you got a optical method. The level of accuracy is inherent in the measurement approach, and also the tool that you used for it. As a stress analyst you have to decide whether you want all the six stress components, all the six strain components, all the three displacement components at a every point in the model, or only a particular kind information at a few locations. So this decides a selection of an experimental technique. And for this course, I would essentially use my book on Experimental Stress Analysis 'e-book on Experimental Stress Analysis'.

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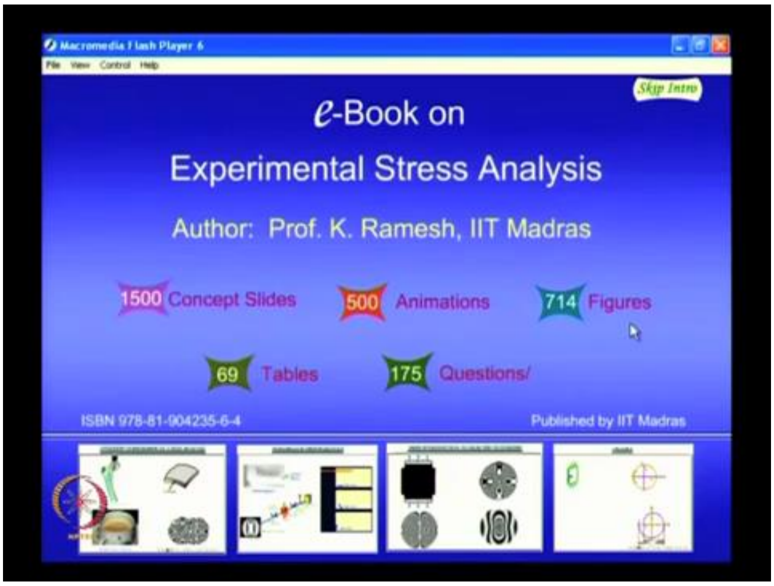

This has been a developed at IIT Madras and published by IIT Madras, and this contains a more than 100 hours of teaching and learning material.

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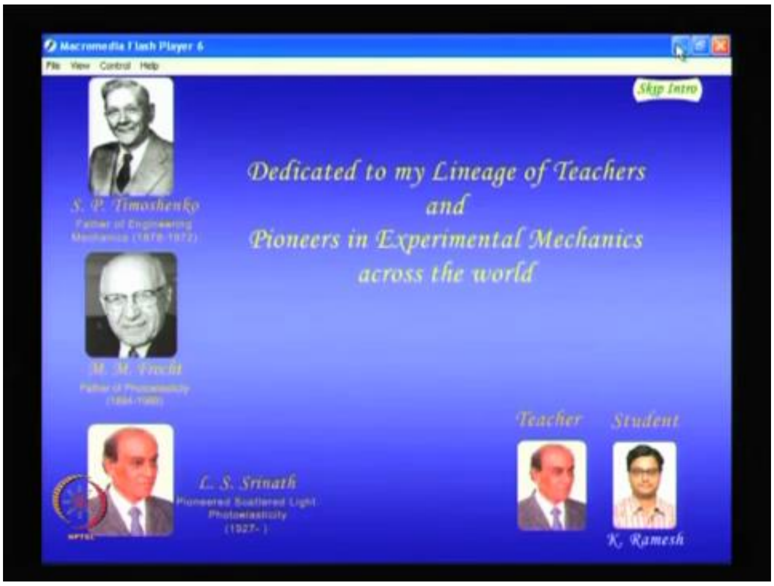

And this book is dedicated to my lineage of teachers and pioneers in experimental mechanics across the world and this will be the core book that I will be following it. Other books that you require for self reading and reference, I would give you as we go by in the course. If you use the experiment technique very carefully, you really get the truth. You can work on prototypes, you can work on models, and when you work on prototypes you are very closer to reality.

In model studies, you have to be very careful in designing the loading jigs; if they are not designed properly you may not really simulate the actual service loads so that will also be erroneous. But you need both, you need to have a prototype studies you also need to have model studies and you will also have to look at whether a particular experimental technique can be applied for both prototype and model studies because if we look at a photoelasticity, one version of it can be applied on models. A variation of that can be applied on prototypes.

So the technique can be applied both on models as well as the prototypes. You have to choose depending on the problem on hand, what is the way that you would go and select this experimental technique. An experimental technique by itself will not give all the information of what the basic stress analysis is all about, it will not give all the 15 components. What component I get is dictated by the physics behind the experimental techniques.