Experimental Stress Analysis - An Overview
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Lecture - 4.7
Selection of an experimental technique- Part 1

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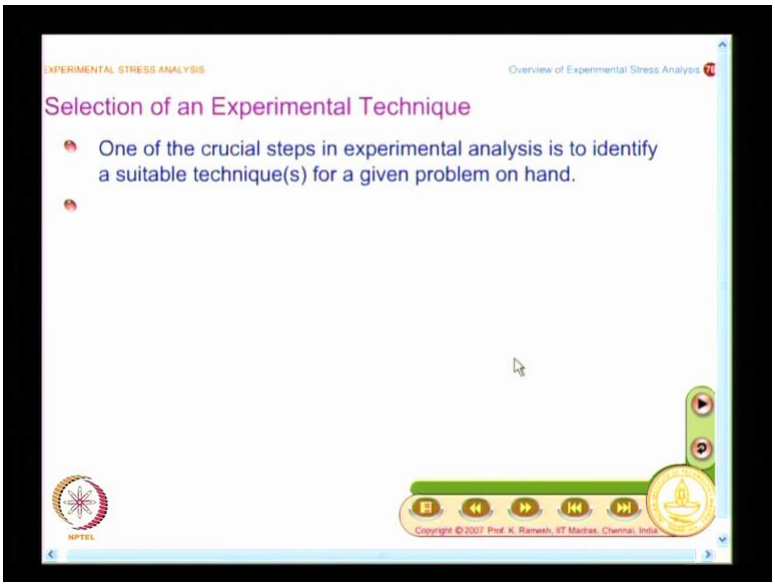

In this lecture, we will look at a very important topic, how to select an Experimental Technique for a given problem? And this is one of the crucial steps whether I can choose one technique or combination of techniques to solve a problem on hand. And you have reasonable information now, though we are discussing only overview you already know what are the information an experimental technique can give directly. And you also know the physics behind the technique. Now when you are confronted with a actual problem, so you will have to find out if you want to get strain information you will definitely go to strain gauges, if your focus is on displacement information you will go and choose among the many displacement methods which one you would like to select for a given application. In all this you could give certain guidelines, these have only guidelines, these are not like you know definitive steps that this is the way you will go about. And we will have a look at some of these guidelines systematically.

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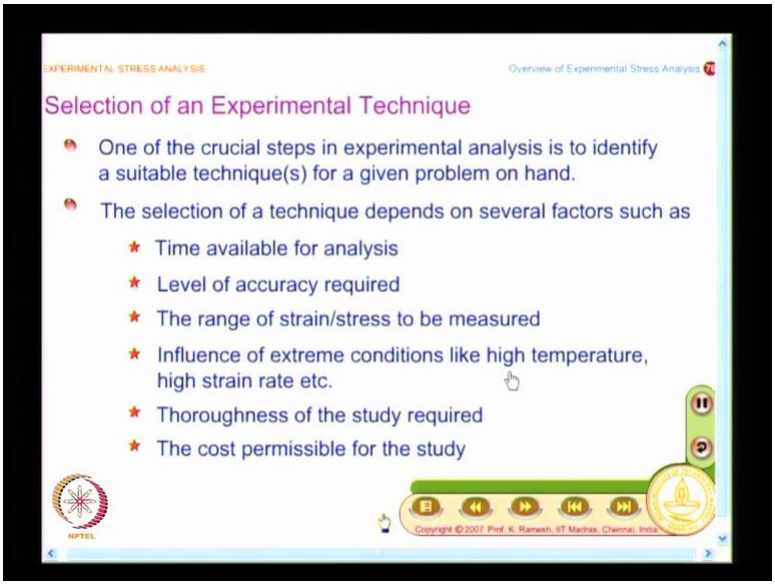

And what you should understand is, selection of a technique depends on several factors. One of the first factors, what is the time available for analysis. If you have time at your disposal you can take your most elaborate method and then accurate method and find out the values. But if the time available is short, then you will have to find out which technique is appropriate. So, time available for you to do the analysis is one of the very important steps that you should consider. Then you have level of accuracy. That is what I said, if you want higher level of accuracy then you will require more time for you to do it. If you want to get quick results, suppose I want to go and look at an industrial component and I want to find out approximately which are all the stress concentration zone, I would apply a brittle coating technique and then find out where the cracks have formed. So that gives me quickly in a huge structure where to identify, but if I want refined quantitative information then I have to pay strain gauges, and strain gauges you know it will take some time for you to cure and then make the measurement.

On the other hand if you want to do online monitoring then even the pasting of strain gauges will require more time for you to it, but you may allow the strain gauge to remain on the structure for months together. Particularly in civil engineering bridges they do such type of studies over a period of time what happens. So, time available, level of accuracy required both are important. Then the range of strain or stress to be measured.

In any measurement technique range is very important, because that dictates. Suppose, I work on large deformation then I will choose a technique of a particular kind, but on the other hand if I have to look at small strain levels then I will have to look at for a different type of experimental technique. So the range is very important. And extreme conditions, like high temperature, high strain rate, etcetera. Suppose, somebody wants to analyze reentry vehicles which is becoming very common these days, several countries are trying to develop such technologies. And you need to find out what is an appropriate technique. People have attempted digital image correlation for such applications. And suppose, somebody wants to find out what happens in an offshore platform which is an a very aggressive corrosive environment you have the sea water, so when you have that you have to select a technically strain gauges obviously.

What is a thoroughness of the study required? And what is a cost permissible for the study? See for a conventional industry which is doing the consumer goods. You will look at cost permissible in a particular fashion you will factor it in a manner. On the other hand high tech applications cost is not a consideration, their safety is the main consideration. A nuclear power plant, if you want to find out what could happen then cost is calculated in different way what is a damage is going to create and what is a kind of human suffering. So, there you have to look at it differently. So all these factors are very important.

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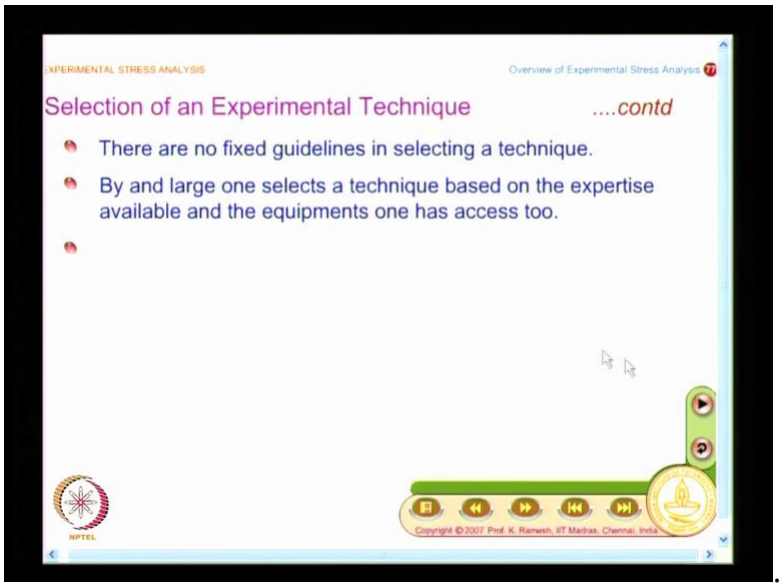

And when you have looked at these factors, what way should be go about. As I have mentioned earlier there are no fixed guidelines in selecting an experimental technique. And by and large what will you do, you will select a technique based on the expertise available and the equipments one has access too. So this also indirectly dictates. You may have several techniques that are suitable for a given problem on hand, but you would definitely choose those techniques that you have access to and also you have personal trained in employing those techniques. See one common draw back what I find in the minds of people is, people think anybody can go and do experiments it is not so. You need to have proper training and you need to be very sensitive right at the beginning of the experiment.

You have 5 steps in an experimental analysis each of this steps you should do it very carefully only then you are guaranteed with accurate information at the end of the experiment. You cannot suddenly wake up at the stage 4 or stage 5 from now on wards I will make the measurements accurately. If you have not followed the steps, For example in the case of speckles if you do not have good characteristics of speckles, whatever the measurement that you do later will be erroneous depends on the quality. Similarly, if you are not pasted the strain gauge then anything you measure is what you want, it is not what the system says that this is the strain value I am experiencing. So you have to have

an approach that you need to have an expertise to do an experiment keep that in mind. When you become managers you train your people to acquire this expertise.

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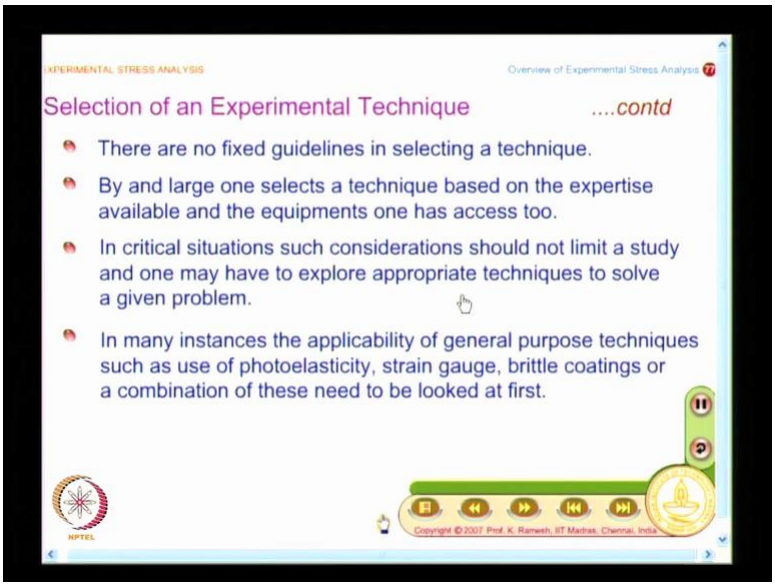

And what you have to look at is, I have already mentioned in critical situations you should not limit a study based on what we have or what is expertise we have. One has to explore appropriate techniques to solve a given problem. So that is always the case. In many instances the applicability of general purpose techniques such as photoelasticity, strain gauges, brittle coatings or a combination of these need to be looked at first. In fact, for many of the industries several day to day problems can be conveniently handled by these tools, these are essentially tools you have to use your human intelligence to innovatively combine aspects of these techniques and try to attack the problem. They are also very fast, very simple to do and you have reasonable expertise available for you to employ these techniques comfortably.

The first step in the general guidelines is, look for general purpose techniques whether they could be employed to solve your problem.

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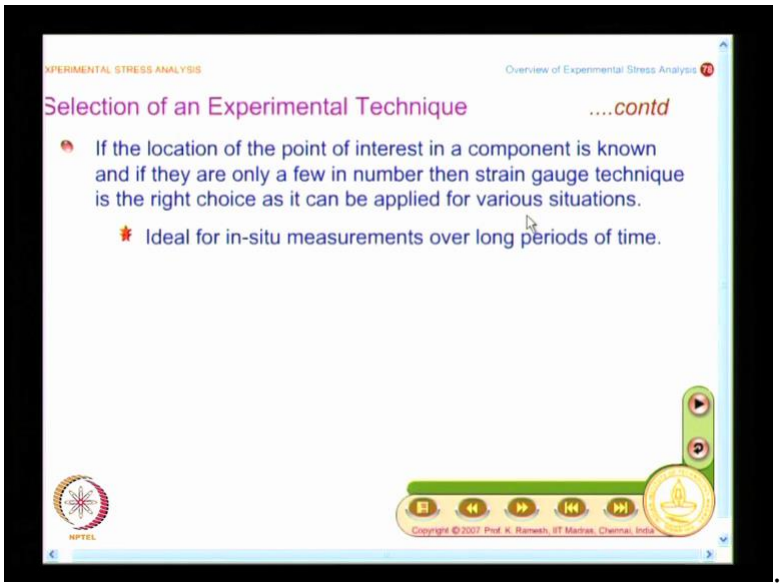

And let us look at what are all the class of problem that they can do. If you know a priori the point of interest where you have to get quantitative data, and these are only a few in number then strain gauge technique is the right choice as it can be applied to various situations. In many instances identifying which are all the point that I need to do you may have to have a priori knowledge. If there is a failure that indicates where you have to analyze more and you can take some clue from brittle coatings and so on and so forth. The beauty of strain gauge is their ideal for in-situ measurements over long periods of time. Suppose, I want to monitor what happens in a bridge I could do it as a function of time.

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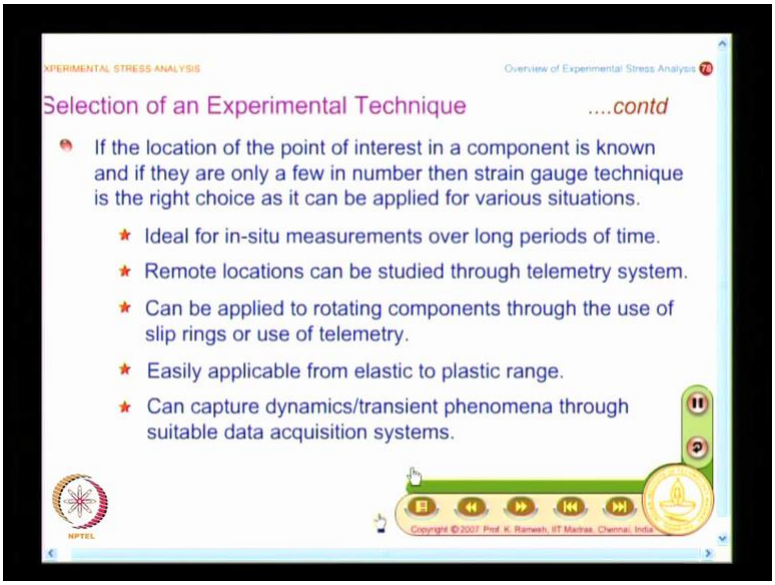

Remote locations, that is what I said suppose I want to find out what happens on the top of the tv tower, because you have wind loads and you want your tower to be safe and you want to find out some measurements there I can have telemetry to do this. And you know you always want to study rotating components, you have compressors, you have turbines, you have many rotating components which require thorough study. I can use strain gauges. By the use of slip rings or use of telemetry I can mound them on rotating components. Here the accessibility is very crucial, unless you take special steps you cannot employ optical methods here. And strain gauges are ideal choice when visibility is not there when it is interior and you know fairly well. See the problem becomes complex it is also becoming expensive. One simple example what I would suggest is, anything hidden it is always a difficult problem. If some portion of the components are visible for optical analysis then well and good. If anything is hidden it is always much more complex to do, (Refer Time: 11:41) not seen out side so you have to have special methods to reveal it. Similarly, when you have a component the interior assembly has a problem then you have to put a strain gauge and take it out and do the analysis comfortably.

In another one I have also said, we have to look at the range. Some problems you will able to access that I leave within the elastic region. But in some experiments you may

want to go up to the failure, so you may also get into the plastic range. So you should know the range. If you have to go from elastic to plastic range then strain gauge is ideal. Another advantage is, it can also capture dynamics and transient phenomena through suitable data acquisition systems. So what this side shows is, what are all the special features of the strain gauge instrumentation. You can do it for dynamic studies, you can do it for rotating components, you can do it on in-situ measurements, you can do it on remote locations, you can do it on locations where you have aggressive environment. So, all these cases you are able to get. So that is why it is a general purpose technique. So, look for whether this could be employed for your problem on hand.

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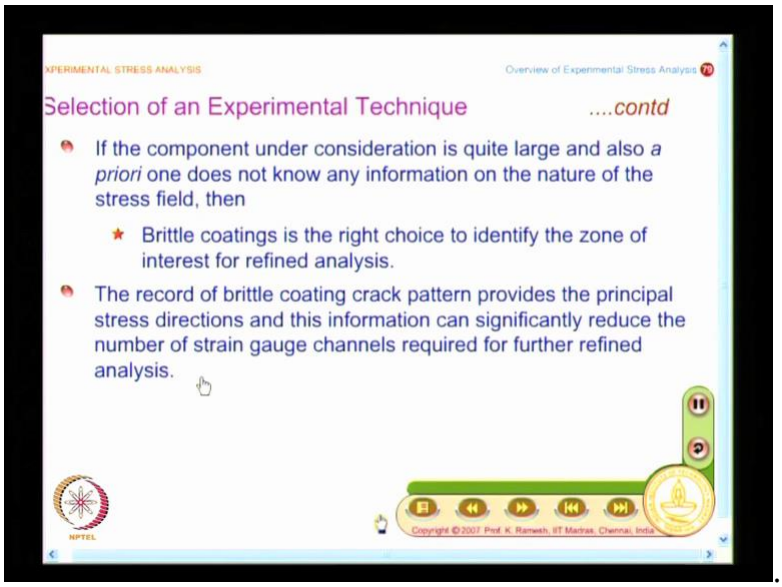

On the other hand, if the component under consideration is quite large and also a priori one does not know any information on the nature of the stress field. then combine brittle coatings ion strain gauges. So, use brittle coatings to identify zones of interest for refined analysis. Continue to the refined analysis based on strain gauges. There is also another advantage, the record of brittle coating crack pattern provides the principle stress directions and this information can significantly reduce the number of strain gauge channels required for further refined analysis, and this is used. In large structures people take the advantage of knowing the principle stress direction. On a free surface if the principle stress directions are known instead of three strain gauges I place only two strain

gauges, so instead of 3 channels I need only 2 channel per point. So, that way if my measurement system has only 1000 channels I can now handle 500 points rather than around 300 points if I have to use 3 strain gauges.

So, you take advantage of an optical technique. A brittle coating provides a whole field information. You visually inspect, here the optics is nothing but visual inspection.

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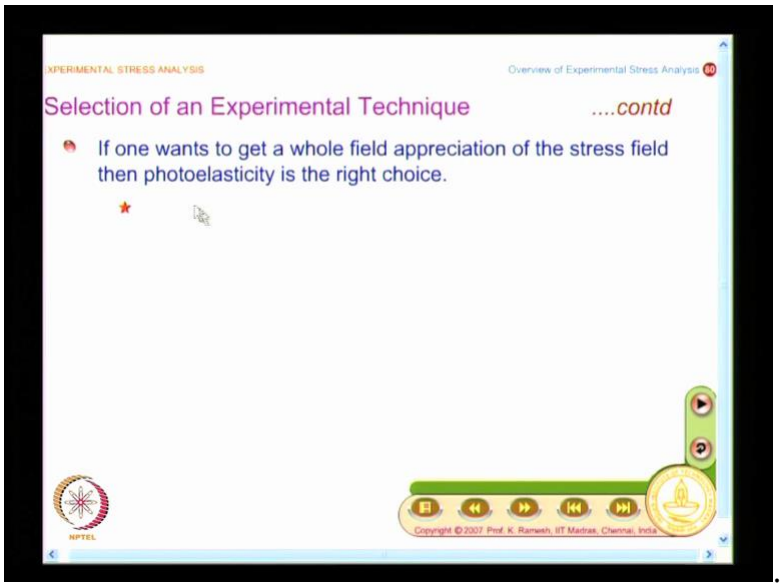

The choice is very clear. If one wants to get a whole field appreciation of the stress field then photoelasticity is the right choice. If I use photoelasticity I get sigma 1 minus sigma 2 contours. In fact, we have looked at for different problems of stress concentration how do the fringe field look like. We could see for a circular hole, elliptical hole and a crack. And we could quickly appreciate crack is more dangerous, it gives you that information you get a feeling for it.

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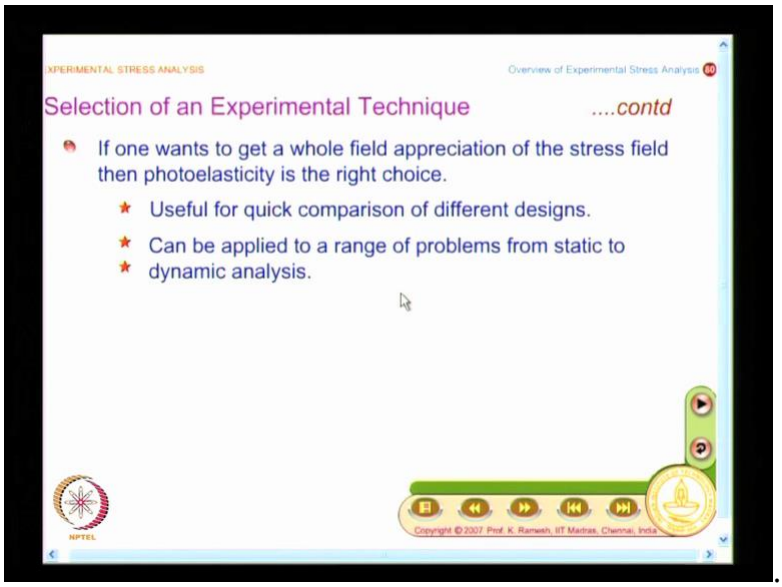

And we have also seen it is useful for quick comparison of different designs. Which we have looked at we have taken the example of a streamline fillet, I introduce the concept that when you are looking at castings or forgings I do not have the restriction of only circular fillets I could relax that and going for non circular fillets and this is one example. When I have to compare designs a (Refer Time: 16:08) photoelasticity if it is possible for you to apply it is a very good candidate, I do not have even have to do a quantitative analysis. Even a qualitative picture can help you to quickly identify among various options which option is better.

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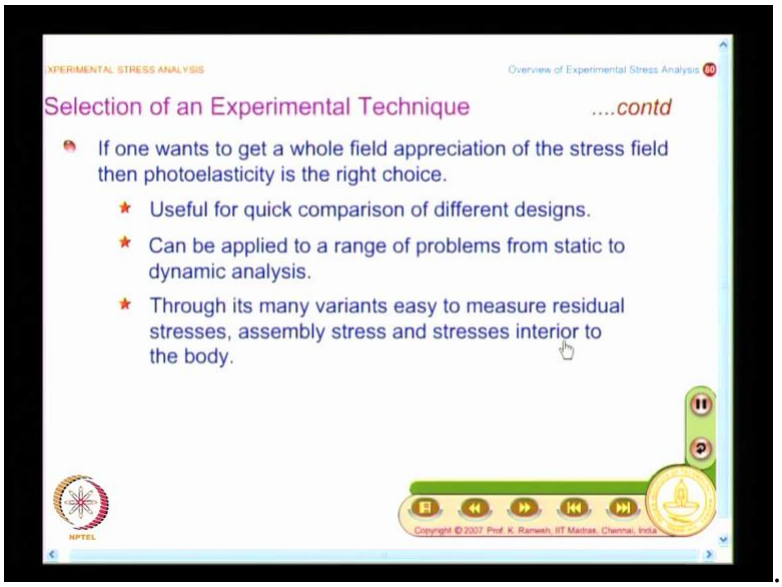

We have also seen with different methods of photoelasticity, you can go from static to dynamic analysis. Through it is many variants easy to measure residual stresses, assembly stresses and stresses interior to the body. In fact, among the various experimental techniques it is only photoelasticity that has been successfully used for a variety of problems to find out stresses interior to the body through it is unique process of stress freezing and slicing, which we will see when we discuss on photoelasticity. But from the point of view of selection, if my problem on hand demands stress analysis interior to the body then I would find out whether I could go for 3 dimensional photoelastic analysis. Because certain class of problems I can handle certain class of problems will not be in a position to handle.

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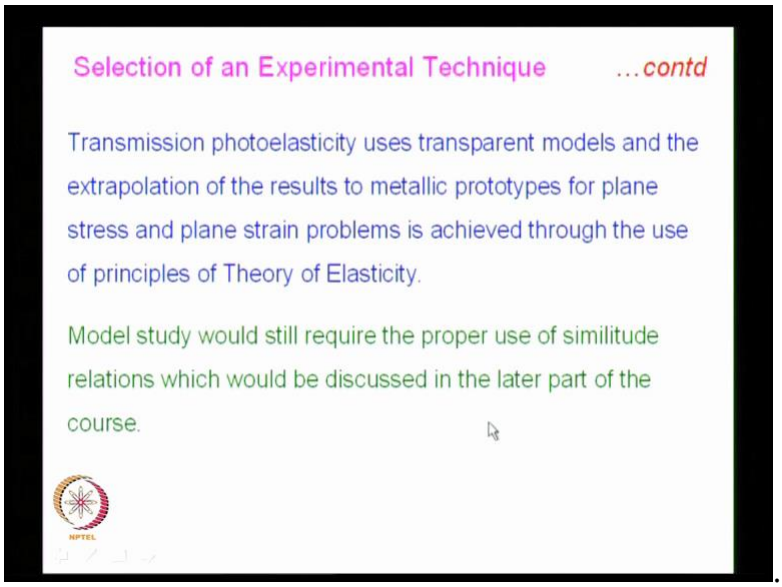

Transmission photoelasticity uses transparent models and the extrapolation of the results to metallic prototypes for plane stress and plane strain problems is achieved through the use of principles of Theory of Elasticity. You are actually using a model, and model study would still require the proper use of similitude relations which would be discussed in the later part of the course.

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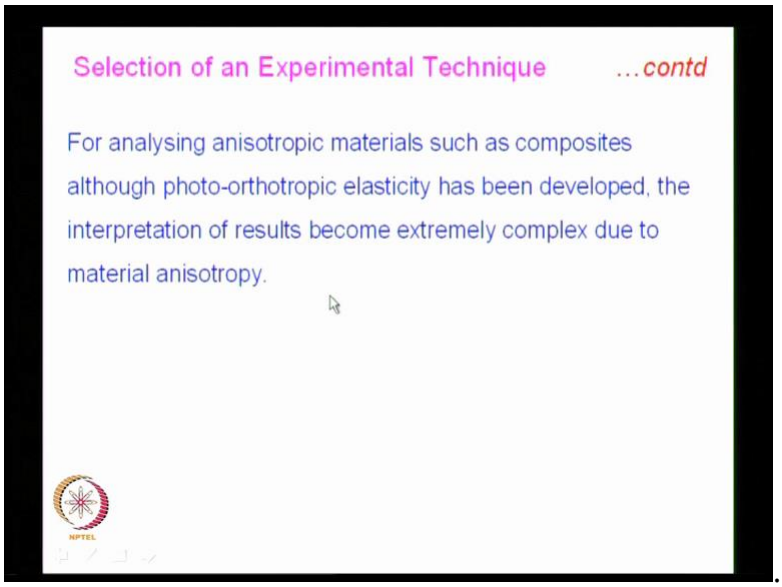

For analysing anisotropic materials such as composites although photo-orthotropic elasticity has been developed. The interpretation of results become extremely complex due to material anisotropy.

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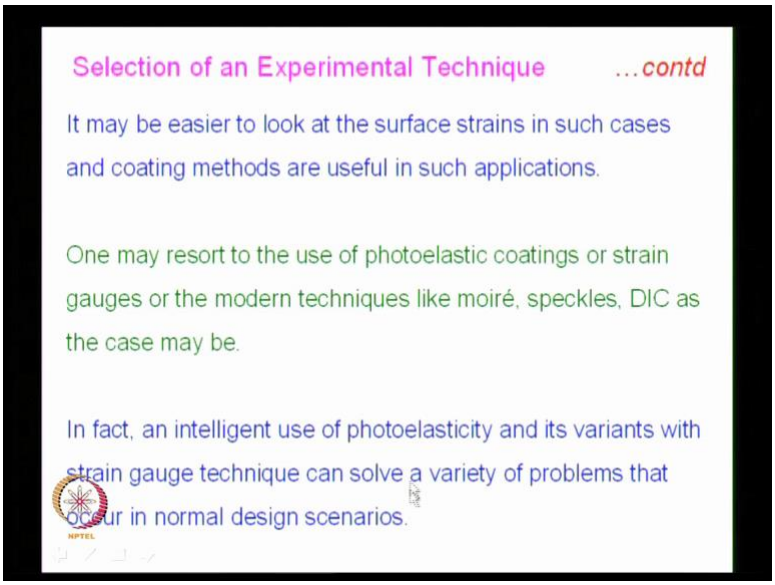

It may be easier to look at the surface strains in such cases and coating methods are useful in such applications. One may resort to the use of photoelastic coatings or strain gauges or the modern techniques like moire, speckles, digital image correlation as the case may be. In fact, an intelligent use of photoelasticity and it is variants with strain gauge technique can solve a variety of problems that occur in normal design scenarios. That is a reason why in this course we would focus more on photoelasticity and strain gauges, because it is general purpose technique and the overview you looked at variety of techniques. So with this background you can do a self study and if you have to look at any one of those particular techniques you will be able to appreciate what is the physics, How to exploit the physics? How to go about and so on and so forth.

So, what you find here is selection of an Experimental Technique is a very important step, although we are only looking at Overview of Experimental Stress Analysis. Since you have looked at what each technique can give directly, right now you are in a position to at least look at which technique you may want to use. To use interpret and improve

data you need to know the experimental technique completely, that we have to look at the details. If you actually look at, when we were introducing many of these techniques I have mention these techniques are applicable for certain class of problems. Like I said, in the case of moire for electronic packing you find moire was very extensively used. So some how this you have to keep remembering it so that when you confront with the problem situation you would be able to find out which technique to adopt.

In fact, I have set of questions which gives certain specific situations and which will prompt you to find out how to identify an experimental technique. Say in normal books on experimental stress analysis, people only discuss the details of each of the experimental technique they do not go about and explain you how to select a technique. Because what is the purpose of this course, the purpose of this course is when you confront with the problem you should be able to go and tackle the problem with the knowledge that you have gained. And it is not that you learn what is strain gauges but you do not know which class of problems you will select and apply if that knowledge is not gain whatever the knowledge that you have on strain gauges will not be used optimally.

This comes only from experience. People burned their fingers in the field. You know there are problems where when they had to find out interference fit, what is the level of stresses developed people use strain gauges and in the process of interference introduction itself strain gauge pealed off. So you will have to use a different technique and you have to have a care in finding out how this stresses are developed. It is not that any industry should have all the methods available to their R and D group. They need to have at least the basic techniques like photoelasticity and strain gauges, and if there are special requirements they can always consult organizations which have this capabilities. And you need to have an appreciation, how to select an experimental technique? That does not come on one day you will have to look at, listen to this, and then have this background while looking at the technique and when we get into the details of the technique you reflect this is the physical principle behind it, this is how physics is exploited, and in which class of problems this could be advantageously used.

This kind of thought process should be there in your minds that is a reason why I thought that I would have some discussion on Overview of Experimental Mechanics in which we also had a brief discussion on selection of an experimental technique.