Experimental Stress Analysis

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Lecture No. # 09
Multi-Scale Analysis in Experimental Mechanics

We are continuing our discussion on over view of experimental stress analysis stress analysis. And what we have done was, we are initially look at what is the difference between an analytical method, numerical method and experimental method. Then we moved on to find out, what the experimental methods directly give the information. Because in each of the experimental technique, we employ a physics - the physics what we employ dictates what is the information that it can give directly. Then we had a reasonable discussion on what is the physical principle behind each of this techniques; the idea is if you understand the physics behind it, you will be able to appreciate the technique better. And also interpret the results with understanding, because interpretation of result is equally important.

In most of the optical techniques you get the fringe feel, and we have a reasonable discussion on what is the richness of qualitative information you get? Our ultimate objectively it is to get quantitative information, but certain decisions which required the immediate attention could also be obtain by looking at qualitative information. Then we also discuss, that all these techniques have been rarely influence by technological development.

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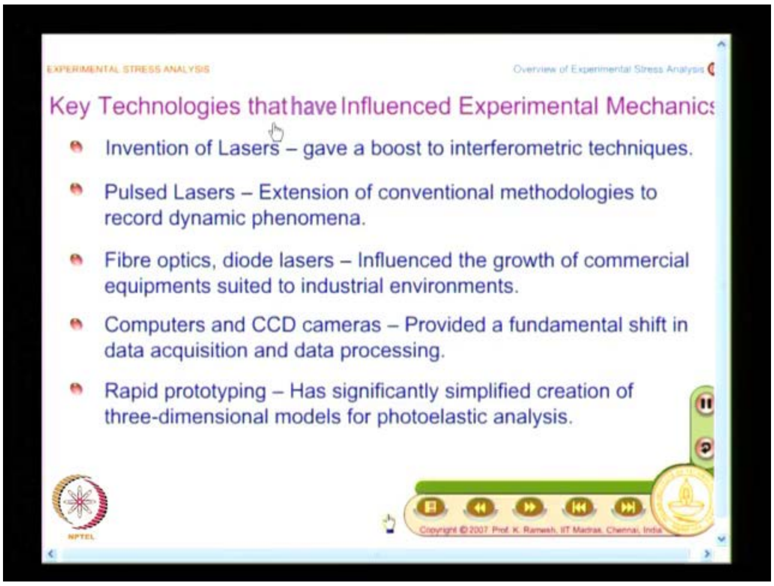

So, what we solve in the last class was, what are the key technologies that have influence the experimental mechanics. We saw that invention of invention of lasers gave the boost inerferometric techniques, then pulse lasers extended method, conventional methods for dynamic phenomena. And not only pulse laser that have also other method by which people could record dynamic phenomena, you had the cram shade in camera - particularly for stress wave propagation. And we also saw that use of fiber optics, and diode lasers help people to develop equipments to suite industrial environments.

So, with the development of CCD cameras, human eye is replace by the electronic eye. And I said in 1930's, most of the designs have been verify by performing a three-dimensional photo elastic analysis. And for three-dimensional photo elastic analysis model making is the crucial step; where involved step. And model should be as precise as possible to mimic the three-dimensional object. And with the development of rapid prototyping, what you find is a process calls sterile (( )) provides models that are photo elastically sensitive. So, rapid prototyping as significantly simplified creation of three-dimensional models for photo elastic analysis.

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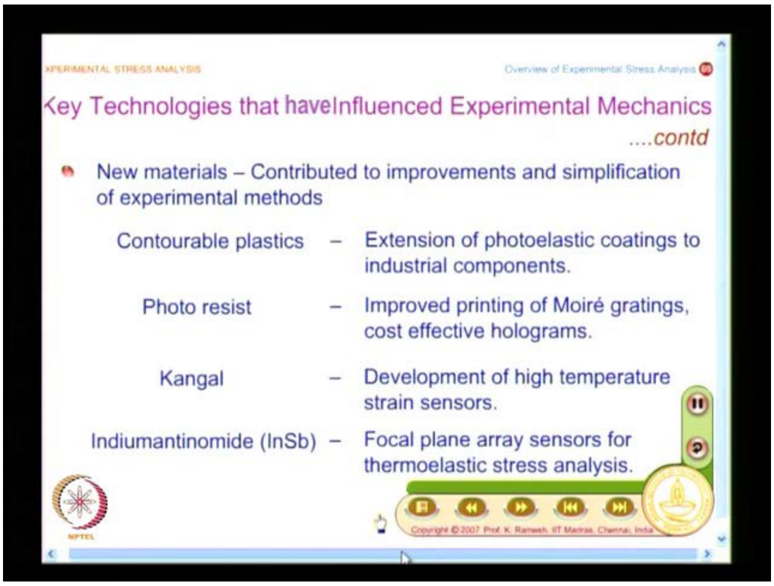

And what I said, if you look at closely the development of science, material research has always played a very key role. And what you find here is, new materials have contributed to improvements, and simplification of experimental methods. So, new material development is the key technological advancement for newer and newer designs, and simplified approaches. Earlier you did not have composite aircrafts with development of composite materials, now boeing as gone and gone for a fully composite fusel edge. So, it is a technological advancement reduces the load of the - dead weight load of the air craft; thereby saving fuel. And if you look at photo elasticity, the development of contourable plastics really made photo elastic coatings to industrial components.

So, what we find here is, the application of reflection photo elasticity was mainly possible for complex objects, because of the development of contourable plastics. Here what you do is, you make a polymer that is flexible enough apply to on the model - it will take the same contour as the model. Then allow it to cure. So, the contourable plastics has help in industrial use of reflection elasticity; and the development of photo resist as greatly influenced improved printing of Moire gratings, and also cost effective holograms - All this holograms stickers, have some form of photo resist material. So, any material development has always influenced advancement of technology. Then, if you come to high temperature, strain measurement development of Kangal has help, and you have high temperature strain gauges and finally, what you find is indium antinomide as help in the development of focal plane array sensors for thermo elastic stress analysis.

See, if you look at one are the earliest method for thermo elastic stress analysis used, and equipment call spate stress pattern analysis by thermal emission, which use only a single infrared detector, the technology was at that time was possible to have only a single infrared detector. And they had the scanning mechanism to record the phenomena, because it was meant for non contact special type of experiments, people were happy whenever you make a development, you start somewhere; and once the technology develop, you also bring in more and more features of it.

Similar to a normal CCD camera at the visual range; now, you have infrared cameras which has the array of sensors. And these arrays of sensor was possible with the development of indium antinomide.

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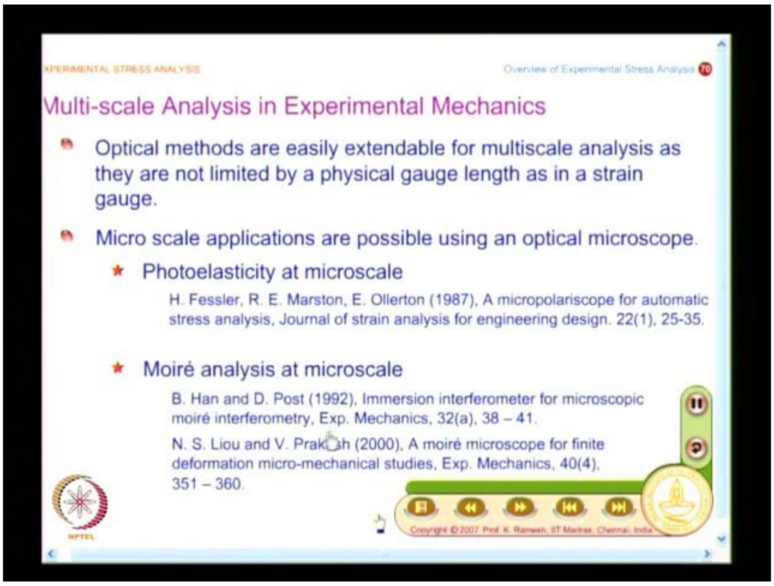

So, what you find material research as contributed to the advancement of methodologies for experimental evaluation: And what we will also look at is - another important aspect, whether you could do multi scale analysis in experimental mechanics. This is also very very important, because now (( )) is the order of the day, people would like to make it as small as possible; and you will also like to find out whether from a stress analysis point of view, this (( )) components are stable, and whether they will do the intended scurvies, whether they come for the life that will to talk about. So, multi scale analysis becomes important. Suppose, you take a strain gauge technique; what happens, the physical gauge lengths determines the size on which I can operate. I want to do it for a single point. So, I want to have the gauge length as small as possible; and for very (( )) components, strain gauge itself when you pasted, it will reinforce the specimen. So, we do not want to use, we will not be in a position to use in such applications.

On the other hand, when you come to optical methods, it is the optics which dictates, what is the scale in which I can operate. And once you get in to this, researchers have develop specific equipments; and you have that available in the literature, and it is very important that you need to have some of this in your notes. So that you know, how these are used? So, what I am going to give you is, for each are the technique what is the key paper that will give an idea, that this is also applied at a different scale. And in order to save time what you could do is rather than writing the journal known completely, you can write it as an abbreviation; and also write the first author and put at all for you to access it.

So, photo elasticity at micro scale, you have H Fessler at all, it was published in1987, and you have a micro Polariscope for automatic stress analysis. This was published in journal of strain analysis for engineering design, you just write it as JSA, and a issue number and page numbers are noted. So, you abbreviate this reference, and this also gives an idea, what are the journalize that you should look at for you to get additional information on experimental mechanics. So, that information also you get indirectly from the list of references you have, and you should also know photo elasticity is applied at micro scale; we have already seen moiré, we have already seen holography being applied at micro scale. And these are all very important information for you to know, how experimental mechanics can be apply. So, moiré analysis at micro scale, you have hand and post in 1992, and they have come out with an immersion interferometer for microscopic moiré interferometry; this has been publish in experimental mechanics write it as e m, that is good enough.

So, what you could do is, you could just write the author, year, journal and the page reference. With this it is possible for you to access the information in the library, and you could have a look at those papers and N S Liou and V Prakash in 2000, they have come out with a moire microscope for finite deformation, micro mechanical studies again in experimental mechanics, and you have the page number. So, just write the first author, year, abbreviated name of the journal, and the page number. This information is sufficient for you to look for these journal papers later. And likewise, we are going to do it for each of the technique - each of the technique, what is the available reference, some of the key references.

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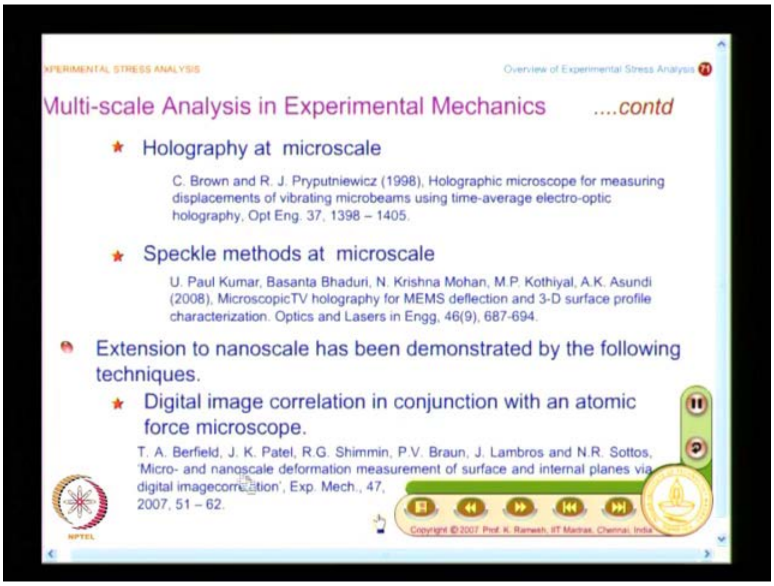

You will have several references given in the end of the paper, that will also give you an idea what way can perform. Then, you come to Holography, you have a paper by C Brown and R J Pryputniewicz in 1998, published in optical engineering, you can put it as OE. And this was for holographic micro scope for measuring displacements of vibrating micro beams using time average electro optic holography. So, micro beams all these have become important from nano level studies now; people are going for (( )). So, you have to find out, whether these components are stable at those scales. And speckle methods, you have U Paul Kumar and others publish in 2008, is publish in optics and lasers in engineering, you could abbreviate it as O L E N . So, publish in O L E N, and these are all the page reference; and this we had is seen when we look arts speckle methods, we were get thing the pressures sensor - it is an rectangular pressure sensor, and you have this out of place displacement was recorded by speckle methodology, and (( )) application.

Then we move on to nano scale studies have been done, and digital image correlation in conjunction with an atomic force microscopic. That is what I have been saying, digital image correlation is an emerging technique; a greatest advantage is, if you are able to control the size of the speckles, and also improve your optics. You could conveniently study at difference scales. And here, you have a papered publish in 2007 by T A Berfield in experimental mechanics, you can put as e m, this is an micro and nano scale deformation measurement of surface and internal planes via digital image correlation. As I mentioned earlier, you need the lead author, name of the journal and page reference. This should be sufficient for you to go on such for the take.

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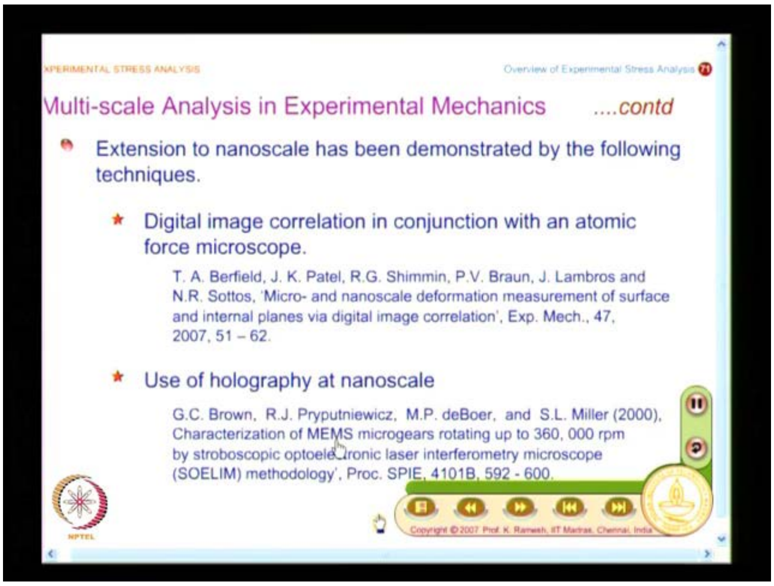

So you have seen, you have to look at experimental mechanics, optics and lasers engineering, journal or strain analysis, and you have you can add to this is experimental techniques; these are all the journals that you would be finding it useful from the point of view of, looking for additional and reasons information. And you also have holography at nano scale; this is the essentially a group led by Pryputniewicz, they have done extensive study on MEMS, and mind you this is about 360000 RPM. You have a microgears rotating at 360000 RPM. People have done experiments on such (( )), and such high speed applications. And this is done by the strobo scopic opto electronic laser interferometric micro scope; so, very very sophisticated methodology; only very few people in the world could achieve such high level of precise experimentation.

So, it is very interesting, I thought that you should know is not few thousand RPM - 360000 RPM - very high speed rotating here. So, here again this is a proceeding of SPIE, so you write that 4 1 0 1 B, there are all online accessible. So, write the lead author, year, and then going for the reference.

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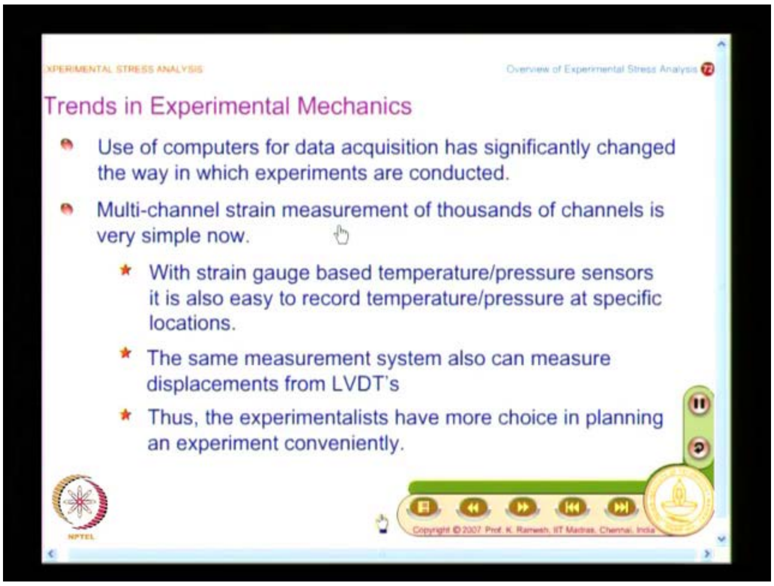

Now the other aspect what we will have to look at is, what are the trends in experimental mechanics. So one of it, ones computers are develop, numerical techniques become very popular. And if you do not use compute as in experimentation, you will also fall back. So, computers are also been employed in experimentation, and what you find is they are been use extendedly for data acquisition, and also has significantly change the way in which experiment experiments are conducted; is the very important aspect, earlier people has have to go on get the hands. Now, it is all parts of a better. So, what you find here is, when you have experiments on large scale structures; collecting data by strain gauge was an (( )) experience. It is no longer so, with computer data acquisition. Multi channel strain measurement of 1000 of channels is very simple one. The technology has so well develop, electronic as so well develop, because the switching and then scanning all this need to be very carefully done, when you are having 1000 of channels. It is one story to have 4 channels, and make measurement, it is totally another story when you have more and more channels added.

The technology is different, and it has to be precise. And another advantage is, it is not only you measures strain; you also need to measure temperature, you may also have to measure in a system pressure. So, what you what you have is this strain gauge based temperature, pressure sensors; it is also easy to record temperature, pressure at specific locations. So, what you have is you measure strain, you are also in a position to measure to temperature, you are also in a position to measure pressure; and some of these we will always come in a combination, you may have to if you are really looking at a structure how it behaves, you may have to have this data. So, now, I can have one data acquisition system which could record in some points temperatures, some points strain, some points pressure. So, I need to identify; which are all the locations where I want to do.

And what was possible? What was made this possible technology, electronics, and you can also measure displacement using LVDT s, they can also be combined to the multi channel strain measurement. So, experimentalists now have more choice in planning an experiment conveniently. I always be mentioning; experiments are plan and executed. You anticipate values; unless you anticipate values you will not know what instrumentation to use, and anticipation of values also helps you to look for surprises. You need to have a open mind when you do an experiment. You will have to have and take the surprises; find out why you have a surprise information. In most cases it may be, because of certain approximation you would have done in your analytical or numerical methods, which would have escape reality. It has several times happen.

Experimental measurements or truth raw data is very very important, but you should record raw data as accurately as possible. When I say raw data is important, you should find out how an experimental technique has to be carried out; follow all the steps and record raw data as accurately as possible. Then raw data is sacrosine; if you take a very casual attitude in doing the experiment raw data is no longer sacrosine. So, if you record the raw data and you find surprises, first thing you go on find out have you made any approximation in your analytical modeling or numerical modeling; which could be improved, so that those results will match with experiment. In fact, if you take a simple cantilever and put an end load, and if the candle never has sufficient depth; you are experimental measurement measurement will definitely be different from your PLQ by

3EA approximation. Because you ignore shear deformation in that formulation; you cannot go and say your experiment is wrong, you are not accommodated shear deformation in your formulation, and your experiment has reveal that is the slight variation - the variation will be small, if the depth of the beam is more; if shear affects are predominant then the deviation will be more. And it again depends on the sensitivity of your measuring system, is the measurement system is accurate enough, you will be able to see the difference.

So, that is how you have to look at it. And now what you have, when you have a complex situation, because you have one multi channel strain measurement can accommodate temperature, pressure, and displacement sensors in one platform it makes your life lot more convenient and help you to plan your experiment much more intelligently.

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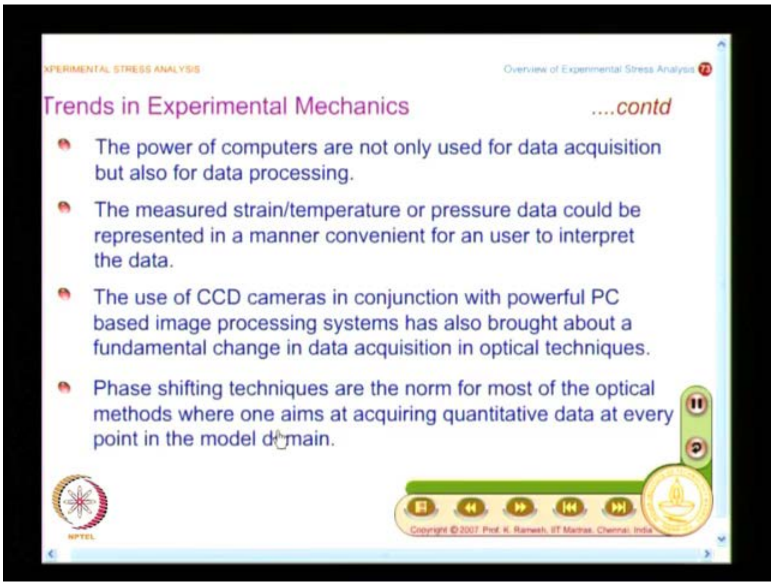

Then what are all other development that has influenced. And what you have here is, there are two aspects. Data processing is now very fast; for example, double exposure techniques, you can make it appear more as real time when will do computer processing, because your processing of computer is very fast in handling large scale images. This is not the only advantage, if you go and look at thermo analysis stress analysis or if you look at digital image correlation, and you can pose process the measure data, temperature strain or pressure they could be represented in a manner convenient for an user to interpret the data. This is not only for the techniques likes image correlation, even strain data when I have. Suppose, I have a multi channel system, I have strain data develop at several places.

I would like to see a visual representation even at point information, if I get. So the colors, if you put it in color, you are able to react better which which you have been doing only in numerical techniques, which can also be done in experimental technique with the availability of computer processing. Then what you have, I have already said the CCD cameras have replace human eye; you know all the optical methods. So, what you find is, it has brought about a fundamental change in data acquisition, in optical techniques. The advantage here is, I could record intense the information using CCD cameras at several frames for second; this as modify the experimental approach developers to find out new ways of process in the (( )) information.

So, what you find now is, you have techniques known as phase shifting techniques have come in to place, and they are the norm for most of the optical methods where one aims at acquiring quantitative data, at every point in the model domain. This was un thinkable earlier; it they have to record interesting, they had a photo multi player cube, and it has to be mode over the model domain. And you have to process data it is time consuming. Now with CCD cameras, I get instancing data; over the feel at several frames for second. So, I could also record slowly varying time phenomena, with high speed cameras it is also possible to record dynamic events with appropriate top ticks, you could record multiple images. So, technology has really advanced with the development of computers; and experimental experimental methods have taken full advantage of it.

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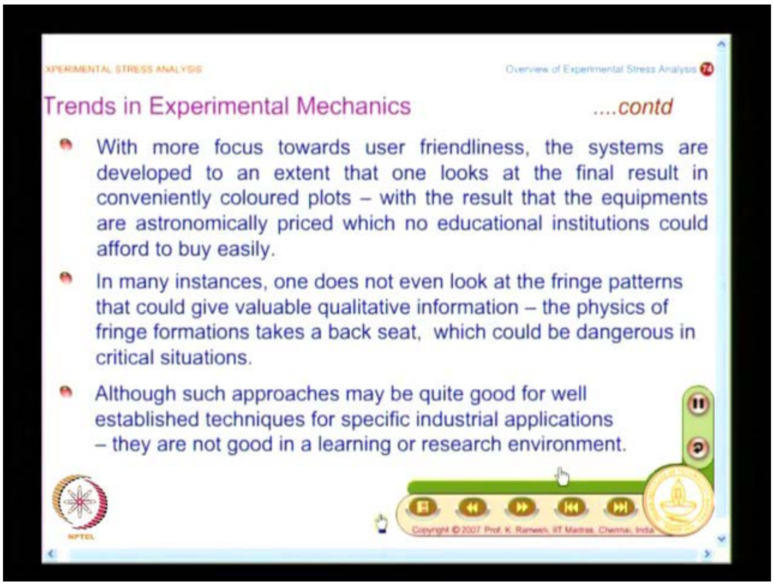

So, this is the positive side of it. What is the other aspect, and you know people want have user friendly equipment. So, when they have goal as user friendly it is equipments, the systems are developed to an extent that one looks at the final result in conveniently colored plots. What is the outcome of these, the equipments are astronomically priced with no educational institutions could afford to buy easily; that is becoming in the trend. This is one aspect of it - the other aspect is now I always saying, there is join looking at fringe pattern. And fringe pattern has lot of information.

And you have this information, you can makes certain judgment based on looking at the appearance of fringes. And with modern developments what has happened one does not even look at the fringe patterns, that could give valuable qualitative information, and in the process the physics of fringe formation takes the back seat which could be dangerous in critical situations. A similar thing happened in development of numerical techniques also, once finite element got stabilized. So, what they found was now, we have very good software which can do all problems. So, no engineers are required; science graduates who know how to run the computer program as sufficient, and that way the industries can bring down the cost of analysis. Then they bond the fingers, they found that boundary conditions are very very important. The science graduate know how to operate the program, but they do not know what to feed to the program.

Then they had a scenario where you have a team leader as the total candidates with background in engineering who with decide on boundary condition, and you will have set of people who will run the software. And a similar situation is also locking on experimental mechanics. So, you need to have user friendly equipments find, but it should not go to the extent that physics of the fringe formation takes a back seat, the physics are the methodology takes the back seat and you press only buttons. So, does not the way the experiment mechanic should go, and the caution here is for well established techniques for specific industrial applications; particularly if you go and look at glass manufacturing, they employ photo elasticity and when they employ the photo elasticity what they do is, they have to control glass process parameters, for this they have well developed equipment, they you have you have to press few buttons and then keep monitor in the process. Let us say specific application where you need some level of automation, some level of fast response for such industrial applications, this kind of user friendliness may be alright.

But they are not good in a learning or research environment environment. So, you need to find out a make a difference, when I am in a research and learning environment, I want to know everything about the experimental technique. I want know it is advantages, I want to know it is limitations, because in a real scenario I may invent a new methodology to extract information in the way I want it. I do not want to go and use it as a black box press some buttons, and report the results; that is not the way a learning and teaching environment should be.

So in this course, we would focus more on physics behind the experimental techniques, and that will give you certain level of confidents, although phase shifting methods are norm of the day in optical methods, we would focus on a conventional approach of looking at fringes. So, that you gain inside into experimental method as well as improve your understanding of solid mechanics. Because many of those things you would have just seen it in the books as equations, and when you see them as fringe patterns you also have an appreciation how the values are at different points on the model. It will also reinforce your understanding of solid mechanics.

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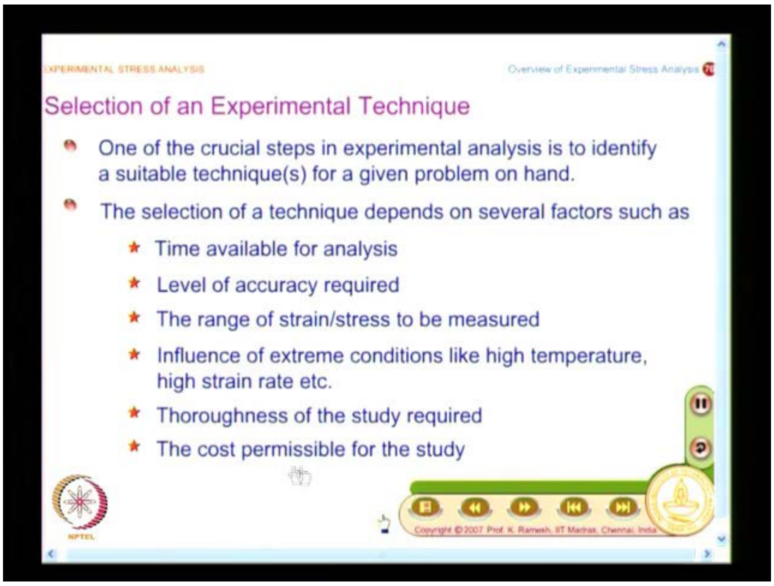

So, that is what we look at. And now, we move on to a very important the topic. How to select an experimental technique for a given problem; and this is one are the crucial steps, whether I can choose one technique or combination of technique to solve a problem on hand. And you have reasonable information now, though we are discussing only overview, you already know what are the information and experimental technique can give directly. And you also know the physics behind the technique. Now, when you are confronted with the actual problem, so you will have to find out, if you want to get strain information you will defiantly go to strain gauges; if you are 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. And in all this you know, you could give certain guidelines; these are only guidelines, these are not like you know definite is steps, that this is the way you will go out.

And we will have a look at some of these guidelines systematically. And what you should understand is selection of a technique depends on several factors. One of the first factors which you 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 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, you want higher level of accuracy, then you will require more time for you to do it.

You want to get thick result, 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 tracks have form. So, that is gives me quickly in a huge structure where to identify, but if I want refined quantitative information then I have to paste strain gauges - And strain gauges, you know it will take some time for you to cure and then make the measurement; and on the other hand, if you want to do online monitoring, then even the pasting of strain gauges will required more times for you do it, but you may allow the strain gauge to remain on the structure for mans together, particularly in civil engineering bridges they do such type of studies for 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 measure; and 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 experiment technique. So, the range is very important, and extreme conditions - like high temperature, high strain rate, etcetera. Suppose somebody wants to analyze re entry 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 half shore platform, which is an very aggressive, corrosive environment, we have the sea water. So when you have that, you have to select a technique like strain gauges; obviously.

And what is the thoroughness of the study required, and what is the cost permissible for the study. See for a conventional, you know 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; there safety is the main consideration. The nuclear power plant, if you want to find out what could happen then cost is calculated in different way, what is the damage is going create; and what is the kind human suffering. So, there you have to look at it different it.

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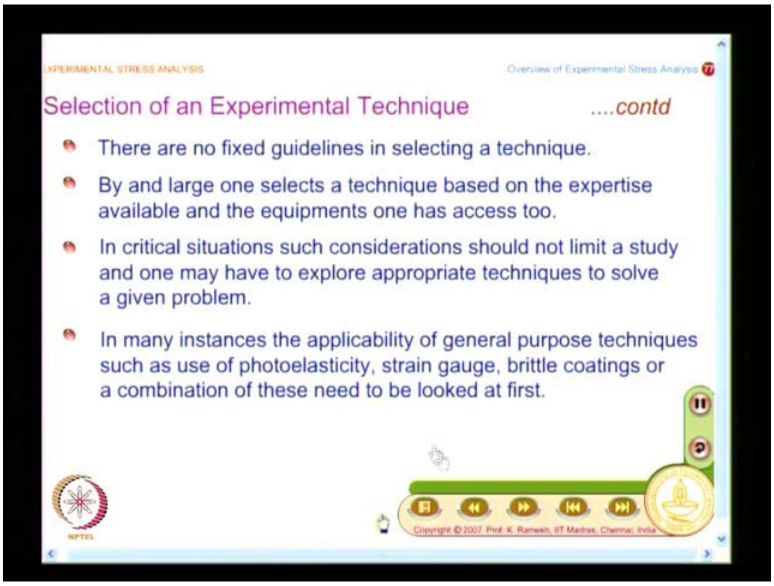

So, all these factors are very important, and when you are looked at these factors what way should be go (( )). And as I mentioned earlier, there are no fixed guidelines in selecting an experimental technique. And by enlarge what will you do, you will select a technique based on the expertise available, and the equipments one has access to. 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 technique that you have access to, and also you have personal trained in employing those techniques. See, one common and drawback what I find, in the minds of people is, people think anybody can go on do experiments. It is not so; you need to have property training, and you need to be very sensitive right at the beginning of the experiment. You have five 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 four or stage five from now onwards I will make the measurement accurately.

If you are not follow the steps; for example, in the case of speckles we do not have good characteristic of speckles, whatever the measurement that to do later will be heronries depends on the quality. And as similarly if you are not pasting the strain gauge, then anything you measure is what you want; it is not what the system says, that this is the strain value and experience. 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 acquires this expertise. And what you have to look at is I have already mention 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. And in many instances the applicability of general purpose techniques, such as photo elasticity, strain gauges, brittle coatings or a combination of this need to be looked at first.

In fact, for many of the industries several day to day problems can be conveniently handle by these tools - these are essentially tools, you have to use your human intelligence to innovatively combined aspect of these techniques, and try to attack the problem. Here also very fast, very simple to do and you have reasonable expertise available for you to employ this techniques comfortable. So, the first step in the general guidelines is, look for general purpose techniques, whether they could be employ to solve your problem.

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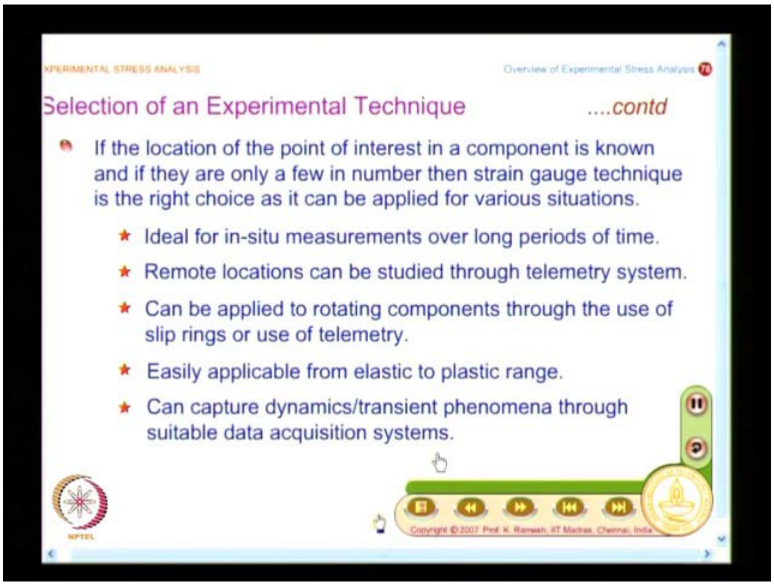

And then, let us look at what are all the class of problem that they can do. And if you know Apriori the point of interest, where you have to get quantitative data, and these are only a few in number. Then strain gauge technique is the right choice as it can be applied to various situations. In many instances identifying which are all the point that I (( )) to do, you may have to have Apriori knowledge. If there is the fail you 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 where 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, and remote location that is what I said suppose I want to find out what happens on the top of the TV tower. Because you have win loads, and you want your tower to be safe, and you want to find out some measurements their; I can have telemetry to do this. and you know you always want to study rotating components; you have compresses, you have turbines, you have many rotating components which required thorough study.

I can used strain gauges by the use of slip rings or use of telemetry, I can mount them on rotating components. Here 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 their, when it is interior and you know fairly well; see, if the problem becomes complex, it is also becoming expensive. One simple example, what I would suggest anything hidden, it is always 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; this will stress is not seen outside. So, you have to have special methods to reveal it. And similarly, when you have a component the interior assembly has problem, then you have to put strain gauges and take it out, and do the analysis comfortably.

And another one I have also said, we have to look at the range. Some problems you will be able to access that I leave within elastic region, but in some experiments you may want to go up to the failure, so you may also get in to the plastic range. So, you should know the range.

If you have to go from elastic to plastic range, then strain gauge is ideal. And another advantage is, it can also capture dynamics and transient phenomena through suitable data acquisition systems. So, what this slide show says what are all the special features of the strain gauge instrumentation; you can do it for dynamics studies, you can do it for rotating components, you can do it on inceptive measurement, you can do it on remote location, you can do it on locations where you have aggressive environment. So, all the cases you are able to get. So, that is by it is a general purpose technique.

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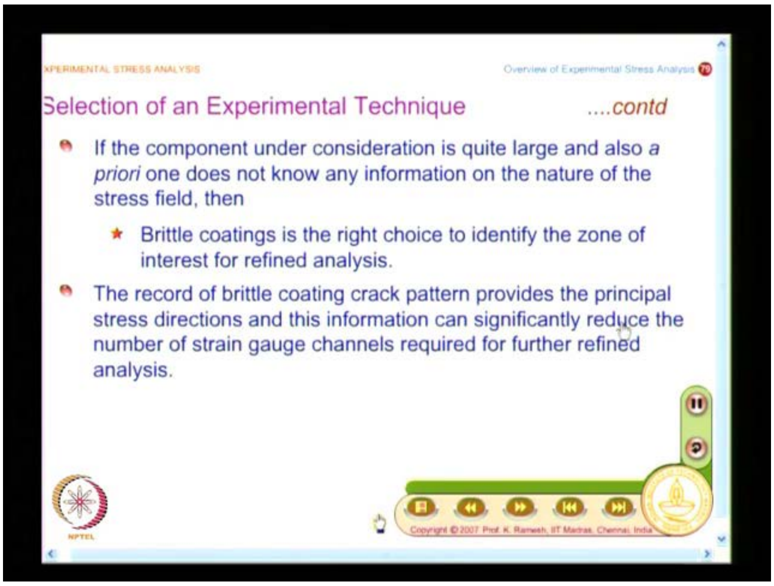

So, look for whether this could be employed for your problem on hand. On the other hand, if the component under consideration is quite large and also Apriori one does not know any information on the nature of the stress field, then combines brittle coatings and strain gauges. So, use brittle coatings to identify zone of interest for refined analysis; continue the refined analysis based on strain gauges. And there is also another advantage. The record of brittle coating, crack pattern provides the principal 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 unknown, instead three strain gauges I face only two strain gauges. So, instead of three channels, I need only two channels per point.

So, that way if I measurement system as only 1000 channels, I can now handle 500 points rather than around 300 points, if I have to use 3 strain gauges.

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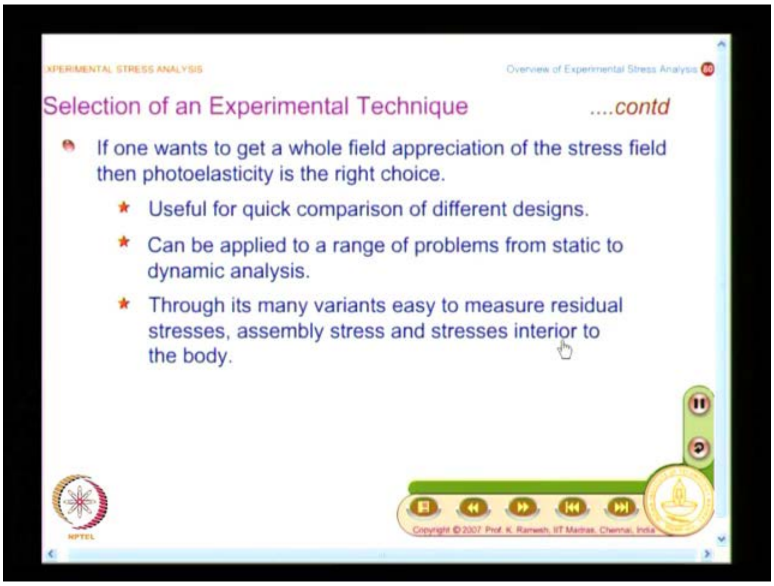

So, you take advantage of an optical technique; brittle coating provides a whole field information. You visually inspect, get optics is nothing but visual inspection. And the choice is very clear is one wants to get a whole field appreciation of the stress field, and photo elasticity is the right choice. If I use photo elasticity, I get sigma 1 minus sigma 2 contours. In facts, we have looked at for different problems of stress concentration, how do the fringe field look like; we could see for the circular hole, elliptical hole in a crack, and we could quickly appreciate crack is more dangerous. It gives you that information; you get a feeling for it. And we have also seen useful for quick comparison of different designs which we have looked at, we have taken example of a stream line fillet, I introduce the concept at when you are looking at casting of forging 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 technical photo elasticity, 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.

And we have also seen with different methods of photo elasticity: You can go from static to dynamic analysis, and 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 photo elasticity that has been successfully used for a variety of problems to find out stresses interior to the body. So, it is unique process of stress reusing and slides; which will see can be discuss on photo elasticity. 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 three-dimensional photo elastic analysis, because certain class of problem is taken handle, certain class of problem will not be in a position to handle.

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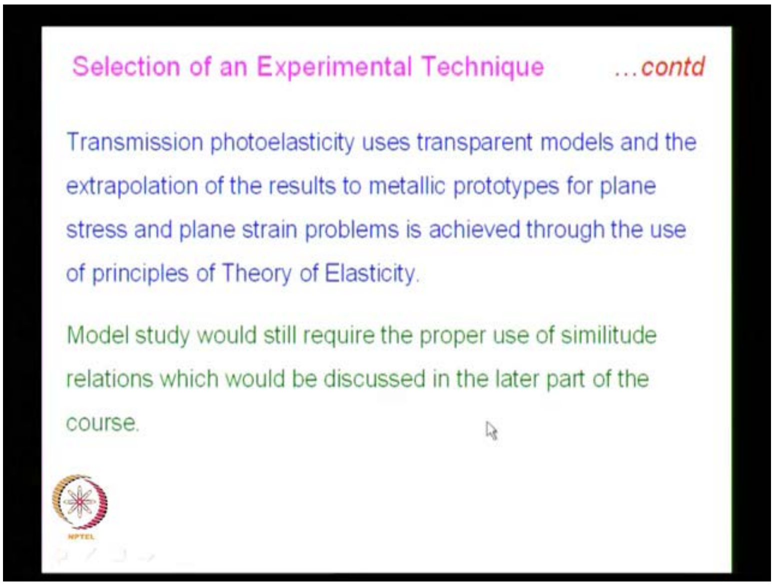

Transmission photo elasticity uses transparent models, and the extrapolation of the results to metallic prototypes for plane stress, and plane strain problems is achieved through the use of principles of theory of elasticity. Your actually using a model, and model study would still require, the proper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

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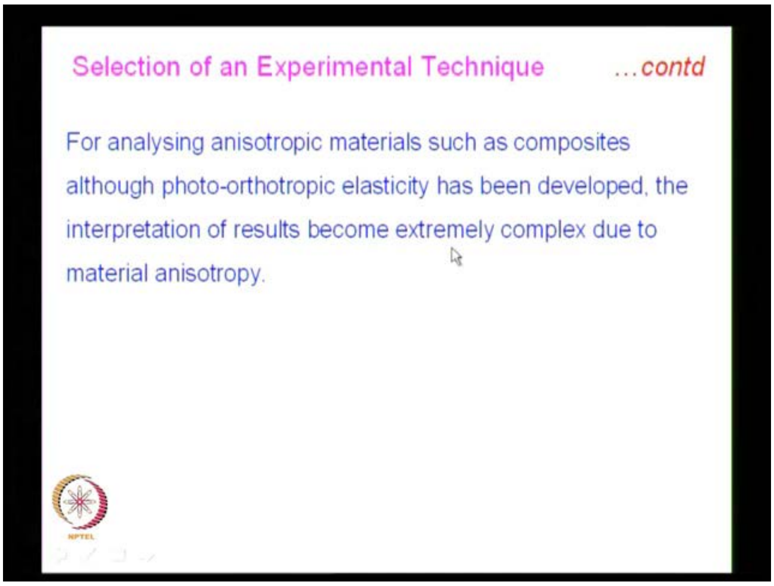

For analyzing anisotropic materials such as composites, although photo orthotropic elasticity has been developed the interpretation of results, become extremely complex due to material an isotropy.

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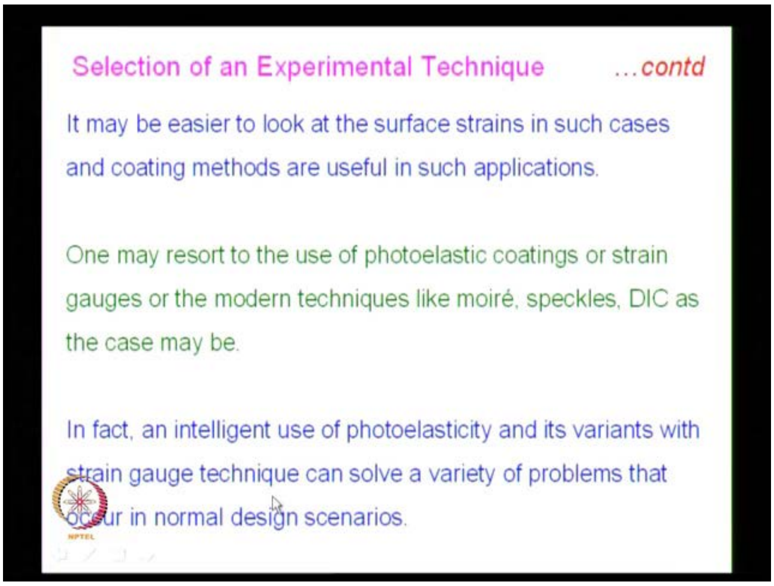

It may be easier to look at the surface strain in such cases, and coating methods are useful in such applications. One may resort to the use of photo elastic coatings or strain gauges or the modern techniques like Moire, speckles, digital image correlation as the case may be. In fact, an intelligent use of photo elasticity, and it is variants with strain gauge technique can solve a variety of problems that occur in normal design scenarios.

That is the reason why in this course, we would focus more on photo elasticity and strain gauges. Because it general purpose technique, and the over view 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 the 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 the very important step, all though we have 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.

The use interpret and improve data, you need to know the experimental technique completely. That we have to look at the details; and if you actually look at when we were introducing many of these techniques, I mentioned these techniques are applicable for certain class of problem; like a said in the case of Moire for a electronic packaging, you find Moire was very extensively used. So, some of these you have to keep remembering it, so that when you comes under with the problem situation, you would be able to find out which technique to adopted.

In fact, I have set of questions which gives certain specific situations, and which will prompt you to find out how to identifying experimental technique. See, 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 scores - The purpose of this course is when we confront with the problem, you should be able to go and tackle the problem with the knowledge that your gain. And it is not that you will learn what is strain gauges, but you do not known 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, and this comes only from experience.

You know people burned the finger in the field, you know there are problems where when they had to find out interference field; what is the level of stresses develop, people use strain gauges and in the process of interference introduction itself strain gauge field of. So, you will have to use the different technique, and you have to have a care in finding out how the stresses are developed. It is not that, any industry should have all the method available to the (( )) group. They need to have at least the basic technique like photo elasticity and strain gauges, and if there are special requirements they can always cancel organization, which have this capabilities and you need to have an appreciation how to select an experimental technique, that does in 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 you get in to the detail of the technique, you to reflect this is the physical principle behind it; this is as physics is exploited. And in which class of problem this could be advantage is the used. This kind of thought process should be there in your mind, that is the reason by 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, and will continue with selection of a experimental technique in the next class also. Because you have to listen to this quite a few times, and also apply your engineering (( )); it is not that you need always newer tool; they existing tools if they are intelligently employ, you can solve a problem. So, you need to develop engineering equipment, and that comes only buy application of your thinking faculty, thank you.