Experimental Stress Analysis - An Overview
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Lecture - 3.1
Principle of Moiré

Let us continue our discussion on Overview of Experimental Stress Analysis. We will move on to the next experimental technique. We have already seen that Moiré is what we have a used for finding out the displacement information, and will see what moiré is all about. And what I am interested to show here is moiré has an effect of magnifying the displacements; that is the way I am going to look at it.

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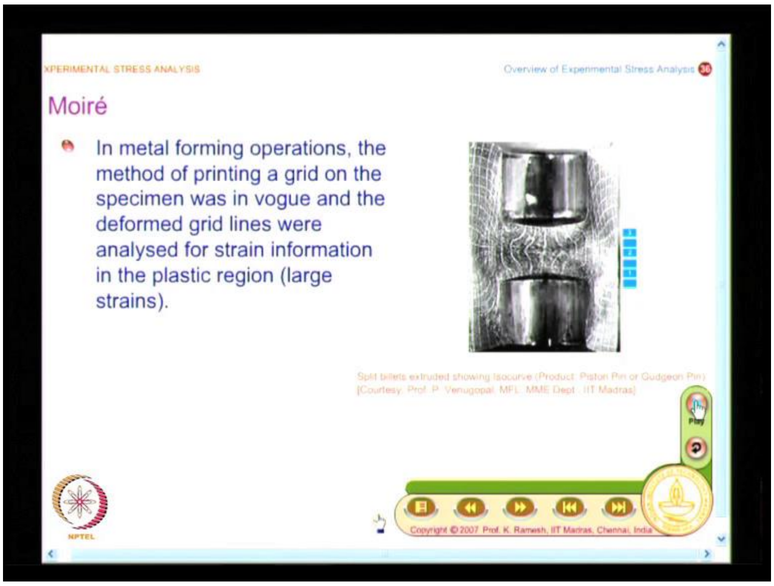

And what you have here is, in the case of a metal forming processes what they have is, they have a billet and they will put a grid you can see the grid here, these are known as grid methods. When I do the metal forming operation, I do a large plastic deformation. I am really talking of a very high value of strain and in this you do not require fine measurements even this grid deforms like this, so you get very valuable information on the nature of strain field from this. You have very large plastic deformation. And for all those metal processing application people use the grid method, because that itself is sufficient to give you some information. You could see here I have the grid initially and I have the final grid so much deformed, so I can really make some kind of quantitative information from this.

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In fact, the credit for this a goes to Prof. P. Venugopal of the Materials and Metallurgical Engineering Department IIT Madras. And what you have seen is the Gudgeon pin that is what this information shows. So people have always looked at they have put a grid, they have always wanted how to go and find out very small deformation if this is for large deformation, it is ok.

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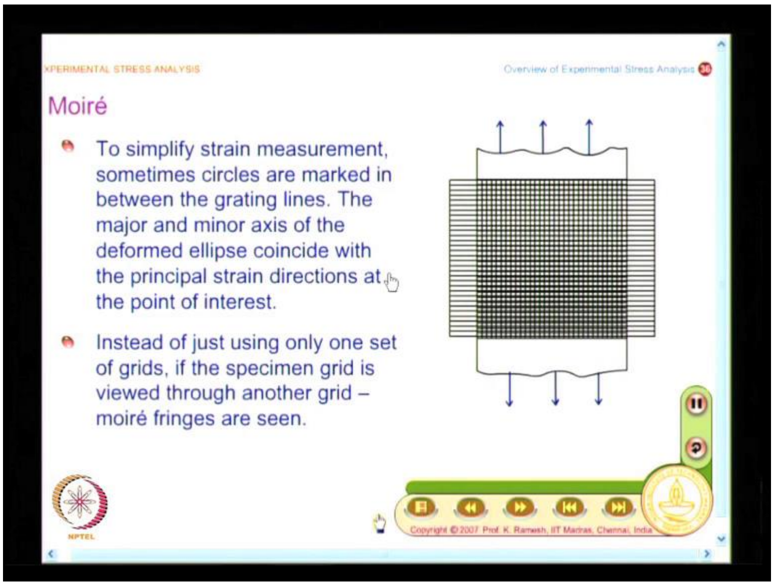

Now what people did is people also to simplify strain measurement what we can do is you can have a not only their grid, in the grid you also put a circle. I will show a magnified view and then you see the animation for a 2 to 3 times, you will have an appreciation. I have a circles marked and they become ellipses. Circles marked become ellipses can you see that.

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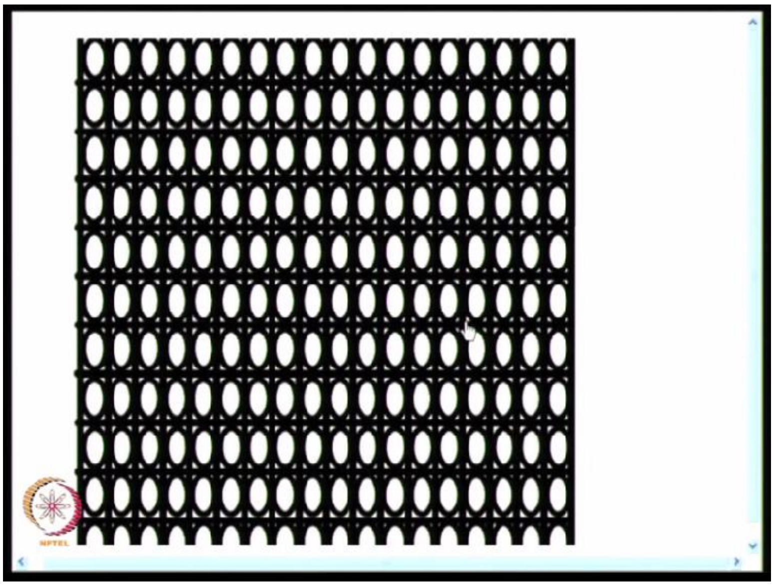

So what you find is, you also find the stretch direction and by looking at the change in the geometry of the circle you will also be able to find out some information about the major strain axis, minor strain axis and so on and so forth. So you are able to, from the grid if you also put a circle it is advantages so I have a circle that gets deform to an ellipse.

And now what I am want to do is people felt that instead of just using a one grid if I have more than one grid it makes it little more comfortable, that is how moiré started developing. And what you find here is, I have a specimen and on the specimen I have a grid and I view it though another grid like this. And what you find here is, I have only stretched it is slightly but I see here a play of fringes on the specimen, I am able to see the fringes they are horizontal fringes. What we have found is people have used initially grids.

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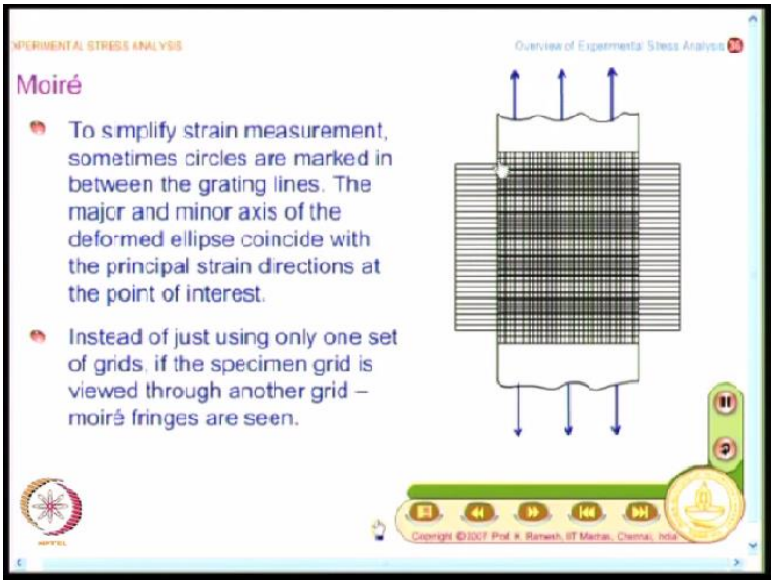

Then they improvised it and put within the grid a circle you get little more information from the deformed picture of the grid, then they realized that if I put not one grid, but I put one grid one the specimen and view it by another grid I get little more information. Somebody ask me what is the grating in one of the classes where we said, what moiré gives you directly? What you have is, this is the grating here and this is nothing but horizontal bars here, and when I put another grating which is very similar you see beautiful fringes, where I rotated them relatively. So, what you have here is, it is by mechanical interference you see these fringes.

Moiré is not optical interferometry technique it is a mechanical interference of the grids that is what you get it. So I get this when I rotate it relative to other, I also get it when I translate it with respective grid. The idea here is, I get this nice patterns and I can interpret it appropriately if I conduct the experiment very carefully. Here I have shown very course grids.

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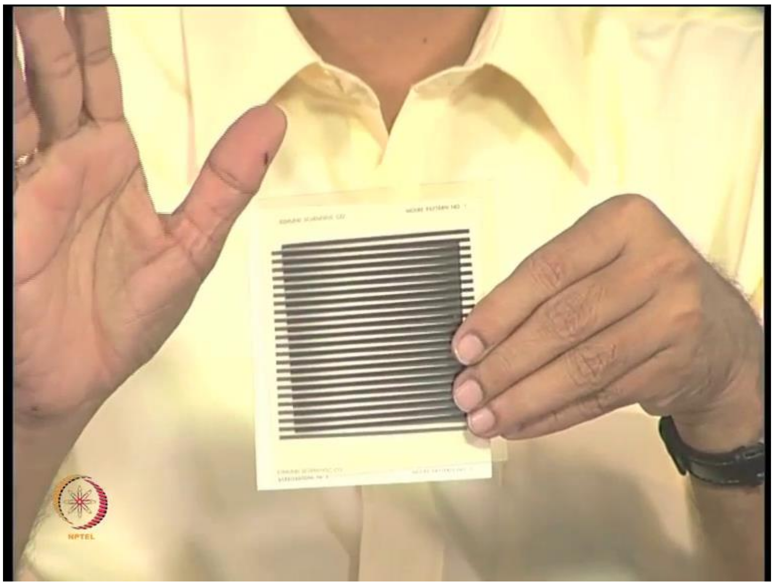

Suppose, I have fine grids; you are not able to see the grid lines at all, and the fringes are lot smoother if I have these grids finer and finer. And here, I am not making any stress analysis I am only showing you mechanical interference of two grid patterns and the grid patterns can be anything.

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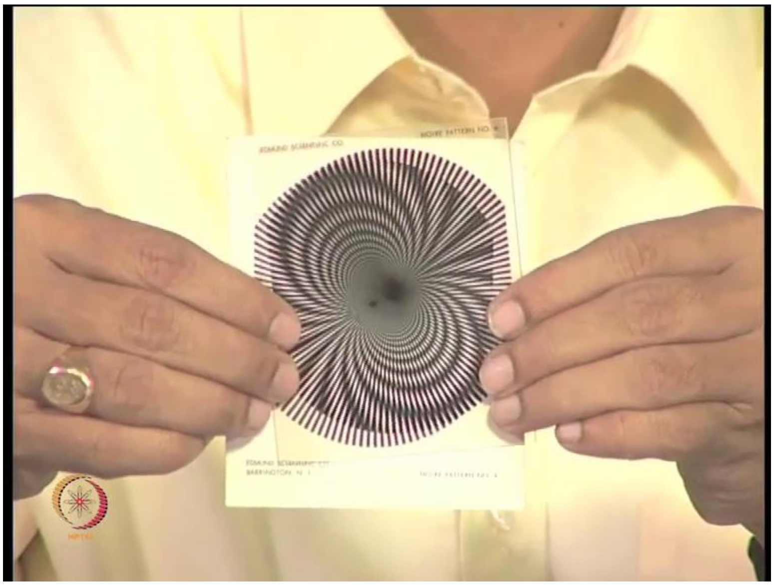

I have this and I have radial lines, and when I put the radial line is so beautiful. May be Tata Salt I think they have this as the pattern for on that cover. If you do saree design or anything if you want to have interesting patterns you could get from some of this information and do it. I am just translating and rotating the grids with respective to each other I get nice play of patterns. And what you will have to look at is, you have to develop this into an experimental technique for you to extract information.

And like friction moiré is new sense. Friction is a new sense in some application, friction is needed in breaking unit friction without a friction you cannot have breaks. So you do not want friction in certain applications where the IC engines you have this (Refer Time: 07:15) moves you want this to as smooth as possible. Now you have another set of grid pattern where I have concentric circle, and when I move the both the grids I get different set of patterns. This is called a grating, and one is pasted on to the specimen and view it with another one. You go have a master grating and specimen grating.

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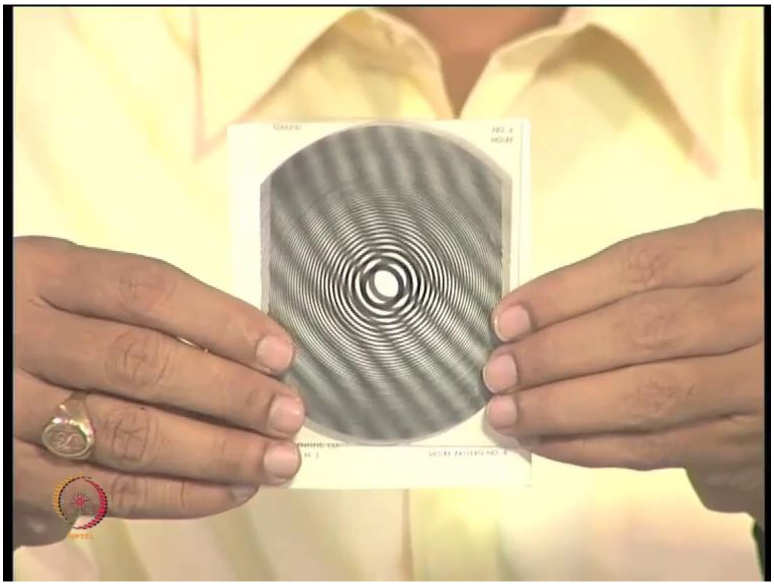

So, what we come here is, if you look at this diagram very carefully compare to that this is a simulation where I have some control on what way I move the specimen grating, and here the specimen grating is a checked pattern. I have reason for it, because I have also mention in some applications I get only one information, in some application I will do one experiment I will try to get two information we will see that. This moves slightly but I see a number of fringes, so indirectly you can understand that it is some sort of a magnification affects that moiré helps you to measure. So I want to measure very small deformations and moiré helps better than the grid.

If I want to go for finer and finer information, I need to have finer and finer grids. So, moiré fringes are spaced broadly indicating a magnifying effect to measure small deformations that cause the formation of the fringes. If I want to improve the accuracy, I need to have a finer and finer grating, that is what I want to do. So, if I have a finer grating I have a better chance of measuring small deformation. And what you have here is, I have two grids; this I call it as master grating, this attached to a specimen which is pulled because a Poisson ratio effect, if the thickness comes down.

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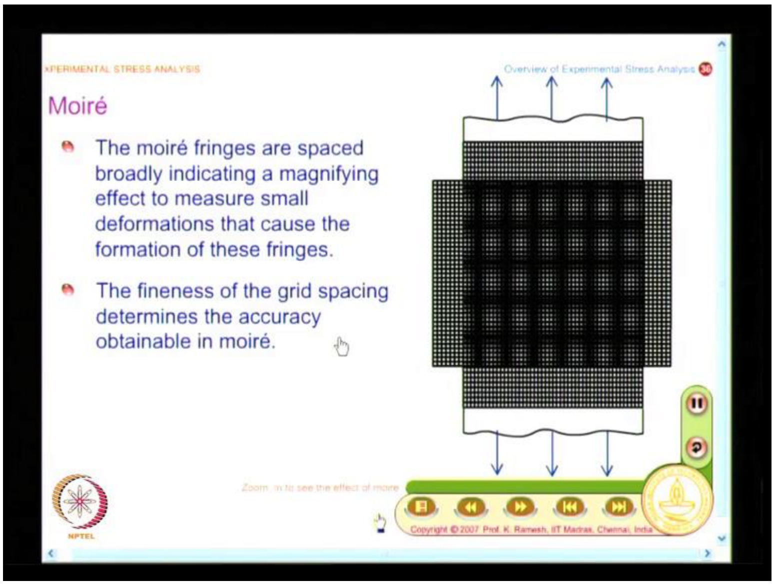

You see horizontal fringes as well as vertical fringes, so that means what you have to interpret horizontal fringes separately because you have always seen I have a grating whatever the fringes perpendicular to the grating direction, you will find out whether if the grating is aligned in x direction and you get the v displacement. If the grating is aligned in the y direction you get the u displacement. Here, I have a cross grating, so I get simultaneously u and v displacement.

And I know strain is a tensor. Once I get displacement information I can also find out the slow, that is nothing but the strain. If I want to strain tensor I need three information, people also have developed a grid at 45 degrees super imposed over that. And I have also caution you know experimentalist when they develop the technique, they develop it and see what maximum information you can get out of it. But from a use a point of view and data interpretation point of view it is always better that you have one information at a time, because you get much better information when you want to do that.

The fineness of the grid spacing determines the accuracy obtainable in moiré, and that is what you shown here. Let us look at some numbers. So what you find is, if you look at the moiré literature the grid line spacing how fine it is was a very big challenge for scientist to develop. When you think of moiré, you cannot forget the contributions by

Daniel Post and his co-workers; they have developed the technique very well. As a grating density is increased I will also have to bring in diffraction effects for interpretation. So what you find is grid, you can easily analyze and I can have some grating I can use just the geometric information and then interpret the fringes that is what you called a Geometric Moiré.

Suppose geometric moiré we find the limitation for me to make final measurement I need to going for finer number of lines then you find from optics point of view diffraction effects have to be brought in and do for interpretation. So the interpretation becomes little involved as you go by. Fortunately, whatever the equation that you develop in geometric moiré is also equally applicable for moiré interferometry.

And what we do is we decide this based on the lines per millimeter. If you have 40 lines per millimeter up to that you can interpret it based on geometric moiré principle. The result displacement resolution is of the order of 25 micrometer. And 40 lines per millimeter is very fine that user is very very fine, it is not you imagine you have millimeter is so small and within that you have a 40 lines, black and white lines. So it is not something very high. It is very fine and you will have to worry about that. What you can do is, from moiré data strain has to be obtained by numerical differentiation. So, it is better that you go for moiré interferometry, where you have finer displacement measurement.

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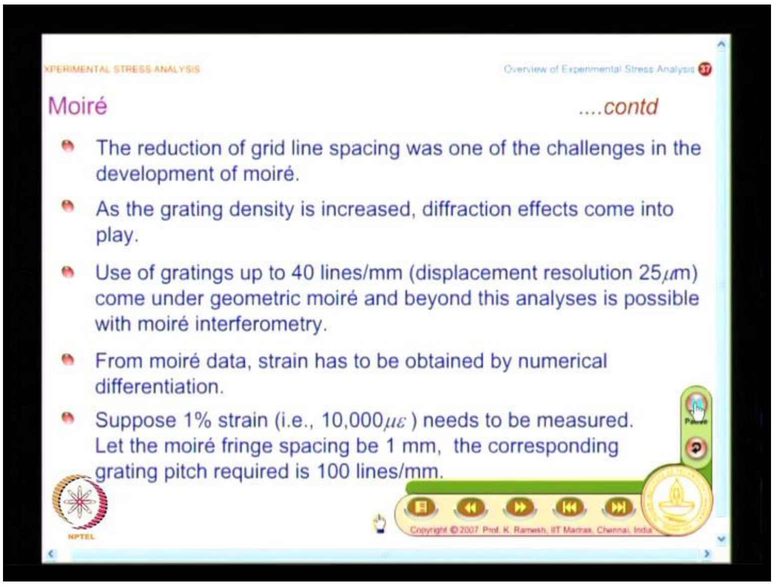

Now let me ask, suppose I want to measure 1 percent of strain. Does 1 percent look a small or big? You go to a bank and ask for a loan if he says 1 percent you will definitely go and take the loan, because you find 1 percent is small. But some of the smart banks what they do is they may say 1 percent per month, that means 12 percent per year. On the other hand, if somebody gives you 1 percent as you are interest for your investment you will never put the money. 1 percent in strain analysis is it small or big. Some say small it is not so.

It is of very huge value. And what I want to caution here is, I said that long time back I said the example of somebody going to a doctor and then finding out whether 105 degrees temperature is small or big it should not refer an encyclopedia. When you have difficulties in finding out the yield point which is not marked sharply, Then what you do is you have the offset method and then you locate the yield point on the stress strained curve. I have an alloy steel which is pulled here, and I have the stress strain data, and this is what I have. I do not see very clearly the demarcation of a going from elastic to plastic it is very smooth. What is usually done is you draw an offset at 0.2 percent.

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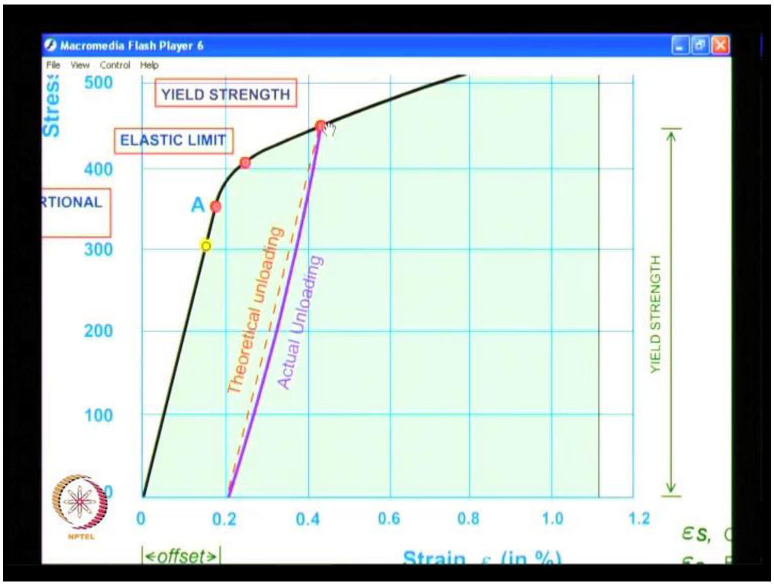

And 0 point 2 percent corresponds to 2000 micro strain. And what you have here is, I have this as the proportional limit, and this has the elastic limit, and you have the yield strength. So what you find is, at 2000 micro strain the material has yielded. But you permit that for you to find out what is the yield strength of the material when you are not able to accurately locate in your stress strain curve. And many actual components they work under you know I have a components interacting with one another and I cannot have large strain. I have to leave much below 2000 micro strain.

So, typically you will leave within 1000 micro strain or so. You will not cross that strain in many of your mechanical and aero space components where you have meeting members and you cannot have large deformation there.

So, 1 percent of strain looks small, but it is not small from strain analysis point of view. Because, at point 2 percent of strain in material has yielded, so many of these techniques you work only regions beyond yield. If I have to come and measure lower strain then I have to improve my experimental refinement, data acquisition, and how do I do the experiment so on and so forth. That is what is done in the case of a moiré. So what you find here is, strain sensitivity can be improved with high density gratings and what you find is 2400 lines per millimeter is now possible. It is a theoretical limit; people have achieved the theoretical limit by real hard work.

And with such high density grating I can measure 0.417 micro meters. But look at the other thing, if I have one fringe is 1 millimeter moiré fringe spacing is 1 millimeter, the strain accuracy is only 417 micro strains. And I said we want to work much below 1000 micro strain. So moiré interferometry has a limitation it cannot go below a certain level so it is good for large deformation problems, it may not be good for small strain measurement. But certain specific applications the method of moiré is very very good. That is where you know domain of application you have to find out. So what you find here is the grating pitch of this high order has been used.

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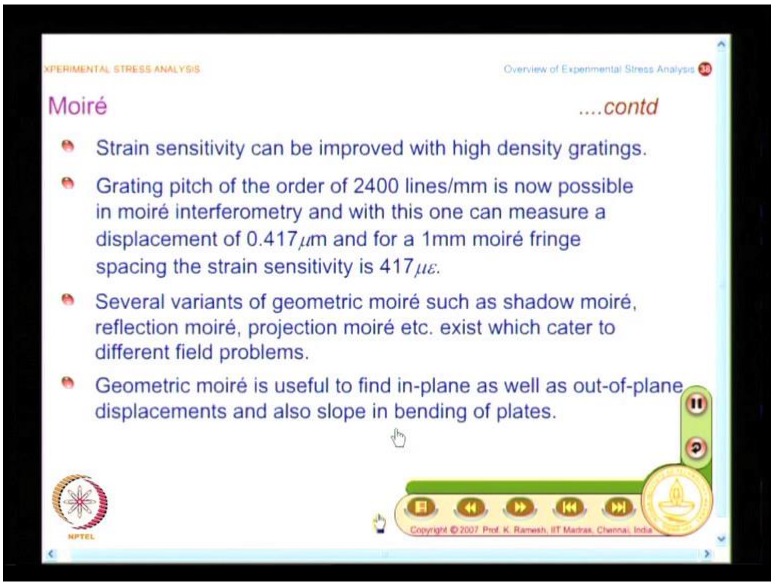

And like I said you have various photo-elastic methods, I have geometric moiré that is what you had seen in some of those a simple examples when you have several variations, you have shadow moiré, you have reflection moiré, you have projection moiré which cater to different field the problems. And if you recall, you had seen reflection moiré has been used for finding about the curvature in the last class. And geometric moiré is useful to find in plane as well as out of plane displacement, and also slope in bending of plates. So, you have to use a particular kind of moiré for a particular application.

Like you use reflection photo elasticity for a prototype analysis you will also use if I want to find out of displacement, I will go for geometric moiré, I will go for shadow moiré. Then if I want to find out a curvature or slope I will have to use appropriate moiré method. If I want to have finer and finer measurement I will go for a moiré interferometry I can go for very small measurement of strain.

Do you have any questions at this stage?

Student: (Refer Time: 19:13)

Yes.

Student: (Refer Time: 19:15)

Yes.

Student: Significant so it cannot used for a (Refer Time: 19:21) elastic.

We will see that later, I mean if you look at IC chips, there are lots of thermal stresses are developed. If you go and look at any one of this electronic packaging, people have now a developed semiconductor technology to extend you can pack as many transistors in a very, very small place. But one of the challenging problems there is the heat generation. How would the heat generation is dissipated? And people have done very interesting experimental approach using method of moiré to find out the stresses on the IC chips the legs and all those electronic packaging components. If you want to look at that moiré is the only technique which can reveal that. So, you have to select a technique for a given application.

Now you have digital image correlation, you have grid method these are all for large deformation problem. But for small deformation you have to use. If you are able to use the strain gauge well and good I can go up to 1 micro strain, but I cannot put a strain gauge on the electronic packaging because that is comparable in size so you will not do that. And if I want still finer measurement I can go to holography and find out very small displacement. For nano mechanics people use holography very well. There is nothing like one technique has to be patronized other technique has to be dropped.

For the problem on hand, which technique is the ideal? that is one issue. Another issue is whether you have the facilities to do that, you may have a technique available in the literature, but you should also have facility because experimental facility is are expensive. And you may want a design answer yesterday. That is how industries come they want result yesterday, when they come today they want result yesterday. So, you have to solve the problem in a very shortest possible time.

We will also discuss towards the end of this overview of experimental stress analysis. A detailed discussion on how do you go about selecting different techniques. Very general guidelines you may not have, there is nothing like one to one matching for you to find out the technique for a particular problem, you can have multiple techniques. So it depends on various factors.

Thank you.