Experimental Stress Analysis

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Lecture No. # 05

Introduction to Moiré, Bridle Coatings and Holography

We are continuing the discussion on overview of experimental stress analysis. And in the last class, we are particularly seen, what is the physical principle behind, some of the experimental techniques. First we saw the method of the strain gauges, and I said stresses alter the resistance of the conductor. And this was the physical principal used in strain gauges it is desirable; however we also found temperature also alters the resistance information. So, this is the nuisance, so you have been very careful in strain gauge instrumentation, to delineate the resistant changes, due to strain and that due to temperature.

So, when we see the experimental technique, we see both, we look at what is the physical principal behind it; and what is the limitation; where does the limitation come from. When we go to photo elasticity, we said that we get whole field information, whereas strain gauge gives up point by point information. The photo elasticity requires normal incidence; normal incidence is a key point, if you have a curve models, then you have to immerse it liquid, which has the same refractive index. Then we had a detailed discussion on moiré and moiré you are able to get the displacement; I said moiré is a nuisance in some applications; for example, in color printing, you do not want to have moiré effects. And secondly, when we all come for this televised lecture, we are advised to wear only plain shirts, you can watch in some of the TV program, if they come with straight shirts, you will have a sort of color banding, because you have a electronic camera, which scans the image.

And that interferes with frequency of your stripes, and you will see a color banding effect. And like I said, friction is needed in some application; friction is not needed in some application. So, moiré is not needed in color printing, moiré is not needed in televised information, where you want to take care, may be with high definition television, some of these effects are fairly addressed. But what you will have to understand is, for every technique, you will have certain kind of limitation, and in moiré what we also saw was, I have a grating, and which I had shown, and what will have to notice it when I have this grating, I make a rigid body translation and rigid body rotation. I see fringes, we get excited to see fringes, but you should implicitly understand, this is the nuisance in moiré, because moiré, I would like to find out, what is the effect of stresses or strains introduced in the material, not rigid body rotation and rigid body translation. So, you will have to be very careful, while performing moiré that you take care of the effect of rigid body translation and rotation. It is very, very important point, it is very (( )).

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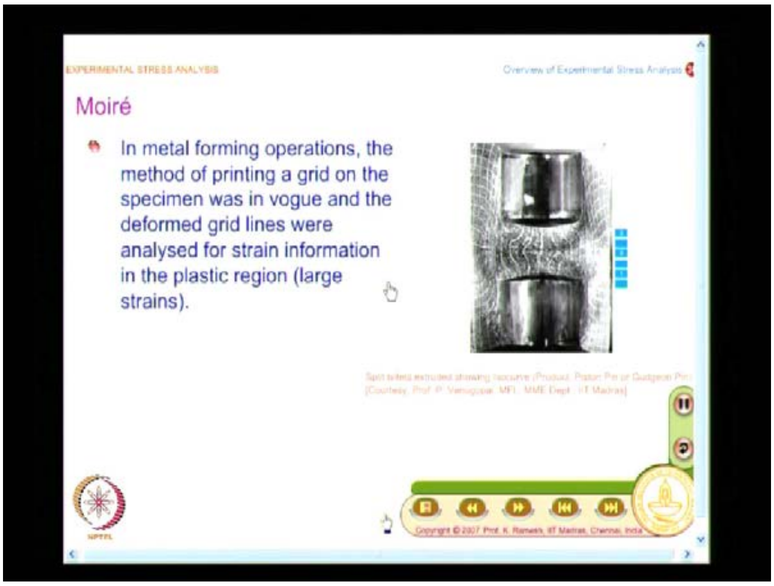

And we will again go back and look at, because of moiré is very interesting technique; we will look at we started moiré by introducing the application of grids in metal forming operations; and what we saw was we had a billet, which is put with the grid, and when you have very high plastic deformation, you see this grids visually distorted and this gives you an information on what is the level of strain introduced and how the material has flood and so on and so forth.

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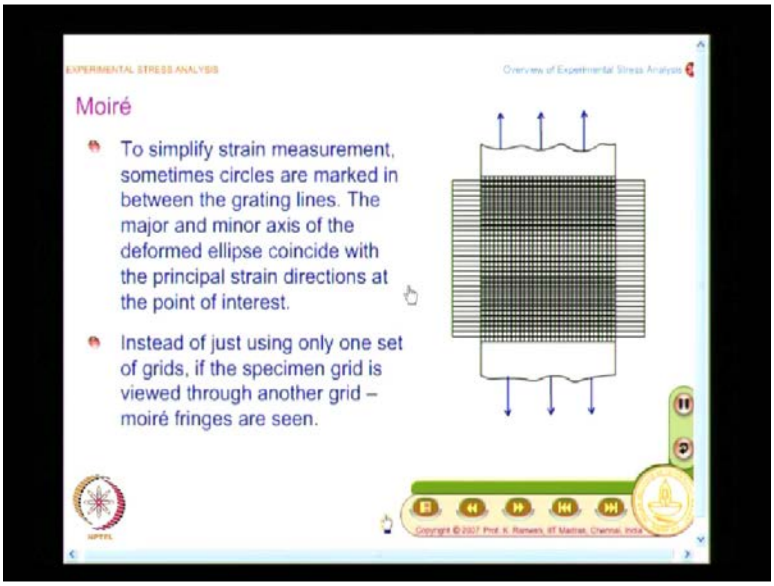

And what we saw was instead of just using a grid; people also had another approach, where in along with the grid, inside the grid, there put a circle. And when you stretch the member, the circle deforms into an ellipse. So, you also get the stretch direction. And later on, what we did was instead of using only one grid, we have used two grids. We call one as a master grating and another as a specimen grating. And here the specimen grating is cross hatched and master grating is horizontal lines; and I pull the material, pull the specimen, so the specimen along x as well as contracts, because of poison effect; and what you see here is the actual specimen deformation is small, but you see a play of fringes. So, what we find is instead of using only one set of grids, if the specimen grid is viewed through another grid-moiré fringes are seen. And these are very coarse fringes.

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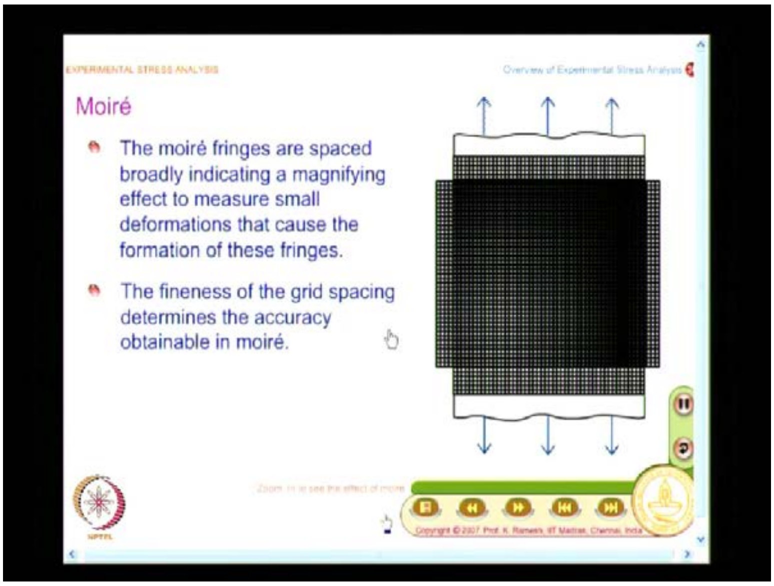

And what we want to see is we want to have fine measurements. And you also appreciate that moiré fringes has a magnifying effect to measure small deformations, because it has a magnifying effect, by making measurement on fringes, you are in a position to find out very fine displacements. And what you find here is the fineness of the grid spacing, determines the accuracy obtainable in moiré; whatever you call it as a pitch, the finer the pitch, finer the deformation measurement that you can do; and here we have a situation, I have the specimen is with very fine, cross hatched pattern and I also have a master, which is also having a cross hatched pattern.

So, I get two sets of fringes; one set of fringes horizontal, one set of fringes vertical. See you should not confuse these horizontal and vertical fringes to the grating lines. We have seen in the problem of a disc, the fringes could be curve. You could get curved fringes, but you interpret whether these fringes belong to u displacement or v displacement, by looking at what was the master grating direction. The master grating direction is horizontal then you get displacement in the vertical direction. Here the problem what we have taken is axially loaded member; here you have uniform deformation, the fringes also at become horizontal and vertical. So, do not carry the mental block that horizontal fringes means v displacements, vertical fringes means u displacement, do not have that confusion that confusion is possible by looking at this picture. This is a very special case.

So, what we look at here is, I can also get two information from one's experiment, thus I said in some experiments, which is time varying you may want to record more than one information. Recording both the information simultaneously is better, but simultaneous recording is not always good. So, you would like to have information obtained separately, and also said that in moiré, it is possible to identify the displacements easily; we will see that in a few slides later.

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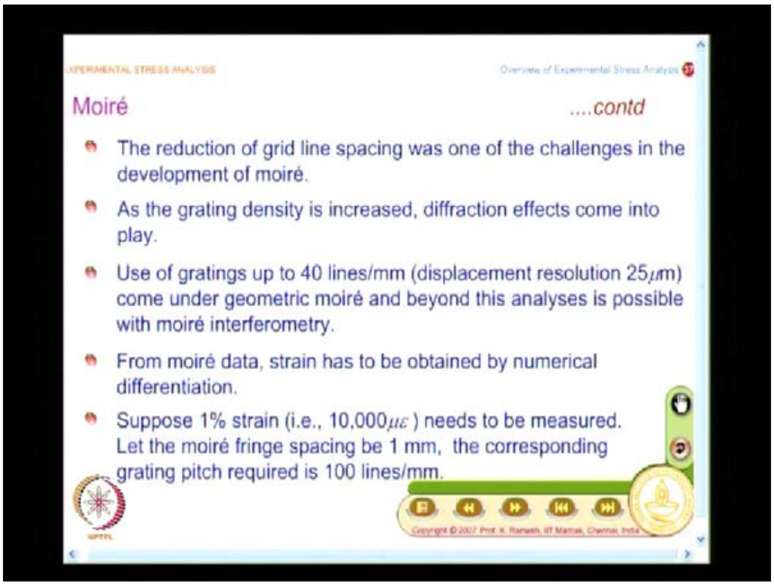

Now we also looked at the reduction of grids line spacing was the challenges and many scientist are contributed to it, and we have also seen as a grating density is increased, increased what you find was what you find was the fringes become finer and finer, and I said a thumb rule, which says up to 40 lines per millimeter, you can call it as geometric moiré, even this 40 lines per millimeter is fairly small, and you are able to get a displacement resolution of 25 micro meters.

And moiré gives you only displacement, and from moiré data, strain has to be obtained by numerical differentiation. And we have seen that numerical differentiation is ironies. So, unless we have very fine information is not worked doing a numerical differentiation. And we also looked at efforts have been aimed at, increasing the density of a gratings, and I pose the problem, I want to measure 1 percent of strain and here it is really shown as 10000 micro strain; obviously, it is a very large value. Even when you want to measure very large strain, what you find here is you required 100 lines per millimeter.

So, from 40 lines per millimeter, if you go to 100 lines per millimeter, which is very, very fine from pitch point of view; from pitch point of view, it is very, very fine; but what you find here is the strain value till very high. So, what you would need to understand is moiré is applicable for large strain problems comfortably.

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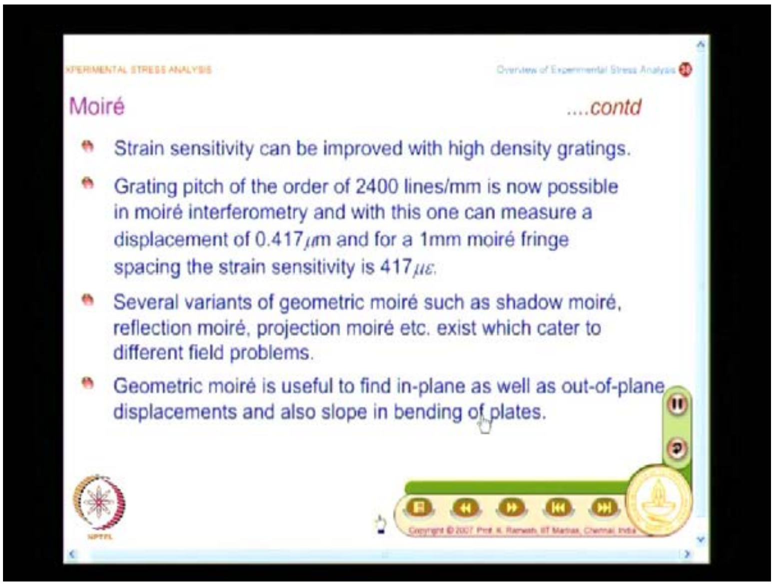

And we have also looked at what is the level of grating pitch that they could reduce, people have gone up to 2400 lines per millimeter and what you find here, if you have 2400 lines per millimeter, the displacement accuracy is of the order of 0.417 micro meter; and suppose, you find that you are able to see a moiré fringe, at a spacing of 1 millimeter, it is a reasonable assumption. The strain sensitivity is only 417 micro strains. It still large, because I said we live much below 2000 micro strains for most of practical requirements. And we may operate around 500 micro strains for many of our strategically important components.

So, if moiré is sensitivity it cannot go below that. So, measurement in those regions, you have to look for other techniques. And we have already seen strain gauges, you are able to measure up to 1 micro strain; now even 0.5 micro strain reliable measurements is possible. So, when you go for very fine small strain measurement, strain gauge is good, but it is the point by point information. The advantage of moiré is I get whole field information. And what we have seen is I also see the fringes in real time. And I also find the digit body rotation and translation; you have to be careful about in moiré.

And I said that once you take any technique you have several variants exist. So, in geometric moiré, you have shadow moiré, you have reflection moiré, you have projection moiré, which cater to different field problems. And Geometric moiré is useful in in plane, as well as find out- out of- plane displacement and also slope in bending of plates. And we have already seen that reflection moiré was used to find out curvature, and you could find out, out of plane displacement by shadow moiré and geometric moiré, can give in plane displacement. And the method of putting the specimen grating is slightly different in shadow moiré, reflection moiré and projection moiré, etcetera.

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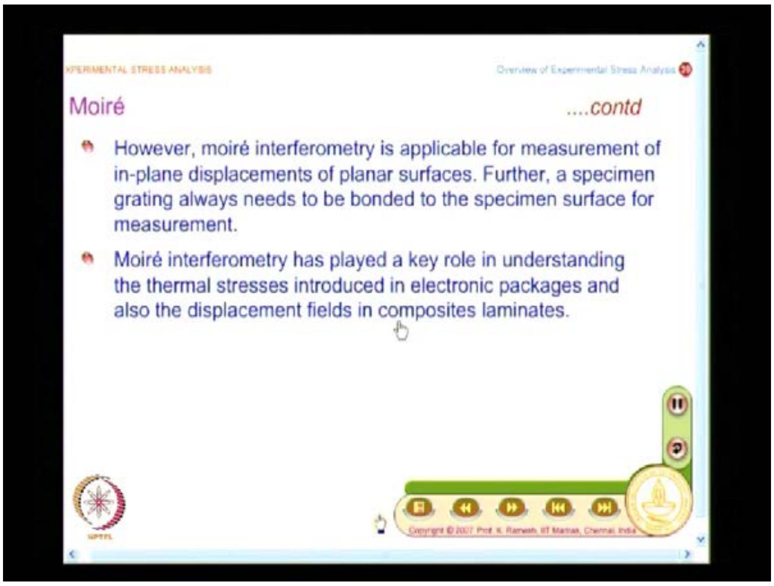

And we have also seen that moiré interferometer is to improve the accuracy. And what you find here is primarily it is applicable for in plane displacements of planar surfaces. This is the very key point, if you have curved surfaces, whether it is photo elasticity or moiré or any other experimental technique will have problem. So, we are happy, we are happy from simple geometric to complex shapes, but once you come to complex shapes, if it is curve, then you will get information, but interpretation became difficulty.

And the greatest advantage of moiré interferometer is whatever the equation that you have developed for geometric moiré, equally applicable. And here, you have to have a specimen grating, always needs to be bonded to the specimen, which is not the case in geometric moiré, I can project the grating on the specimen, I can look at the shadow of the grating on the specimen, and then do the interferometer, but once you come to moiré interferometer, I will have to have the specimen grating firmly bonded to the specimen and there are many techniques that I have been developed. Newer materials are contributed to the improvement and many techniques and these are all very fine grid lines. See the fineness makes the process delicate.

And I have also identify that moiré interferometer has played a key role in understanding the thermal stresses, introduced in electronic packages and also the displacement fields in composite laminates, because composites are becoming very important for structural applications. And because of the material anastrophe, analytical modeling is extremely tedious in at least you get surface information by using techniques like moiré interferometer. So, what is important here is, each technique has a particular domain, where it has served its purpose fully. The moment you think of moiré interferometer, electronic packaging we cannot forget. They go together, very interesting problems in electronic packaging having solved by moiré interferometer.

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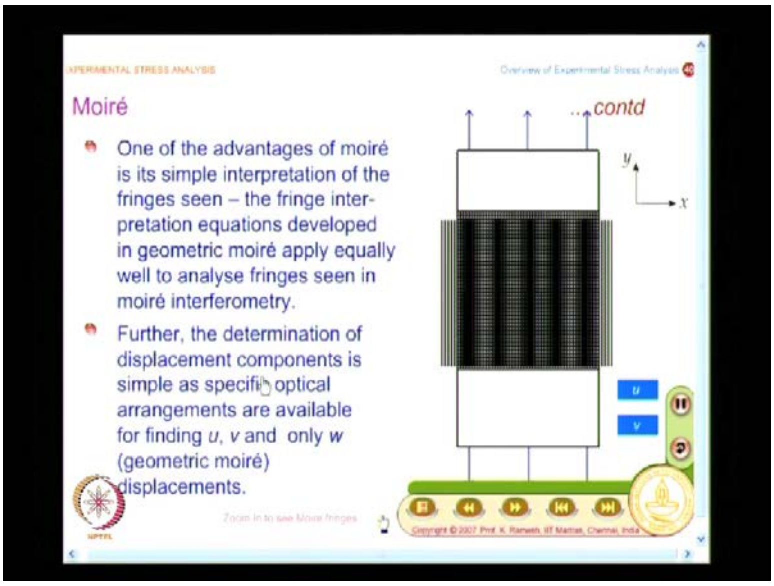

And other concept, which I wanted to say, was that you are able to get the displacement information, comfortably separated in moiré analysis. And purposely this is taken like this, I have a specimen with a cross grating, but I view this specimen with the horizontal grating. So, what is the displacement I get, we have already seen, once you have horizontal grating, what is the displacement you get; you get the displacement perpendicular to that.

So, the fringes what you have here, show u, v displacement. And what I want is suppose, I want to see u displacement; I will change my grating; I will change my master grating, to have vertical lines. So, I will have a U displacement. So, what I have is on the specimen I bond only one grating, which has crossed lines, but I view this with a horizontal grating or a vertical grating. So, I can comfortably switch over from U displacement to V displacement, data interpretation is not difficult. It is a very key important, because the next technique, we I am going to take up this holography; in holography, you will get displacement vector. It will give you u, v as well as w bundle together, separation becomes difficult and in the case of moiré, by choosing the master grating appropriately, I can look at u displacement; separately I can look at v displacement, separately.

And you know all these contours, when you look at they all have special names, you know we have seen in photo elasticity isochromatics; we have seen isoclinics and in moiré, these contours are called as isotechnics; u displacement isothetics, v displacement isothetics, r displacement isothetics, theta displacement isothetics, all those terminologies you will come across. So, what you find here is the determination of displacement componants is simple as specific optical arrangements are available for finding u, v and only W displacements. That is possible from geometric moiré; moiré interferometer gives you only u and v displacement. When you go to geometric moiré, it is variation like shadow moiré, reflection moiré, projection moiré, you get out-of plane displacement you get slope, you get curvature and each case, you need to have specific a optical arrangement, though it appears specifically arrangement is a nuisance in some instances, data interpretation is lot more simpler, it has specific optical arrangement.

See what we have looked at is, we have looked at the method of strain gauges. Strain gauges is able to find out strain, at a particular location. Suppose I have a known situation, I know these are all the regions of stress concentration, I can put a strain gauges and find out the strain comfortably, suppose I have a large industrial problem and the component is so huge, and you have a no clue on how to go about and find out and get started on the problem.

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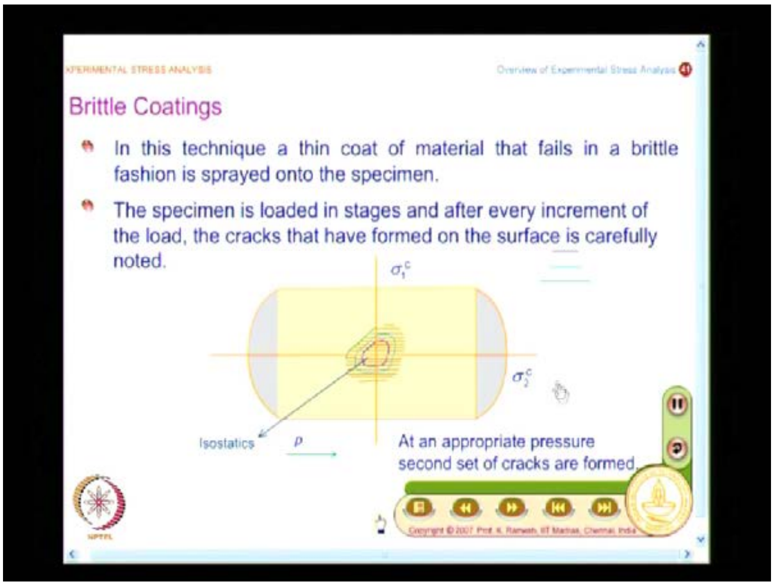

So, in such cases, brittle coating is the first step and the name itself signifies, in this a thin coat of material that fails in a brittle fashion, is sprayed onto the specimen. So, the name indicates, you have a Brittle coating. So, you put a thin spray of material, which fails in a brittle fashion. A brittle material fails by what theory? What is the theory of failure for bridle material? It fails by maximum stress theory or maximum strain theory and you can call it as moiré's theory, which are the ways, you want call it

So, once it fails we are able to get the principal stress direction from that. So, here what you do is, you have a specimen, on which you spray the material, you load the model and allow the coating to crack and very peculiar. And here that accuracy of the technical will be decided by the property of the coating. If the coating fails at a lower value of strain, lot more better, because I can even measure, strains at lower levels. So, that is the principal behind it. And even the experiment is conducted in a slightly different fashion here; see in other cases what you do is, I want to find out strain for a given load, I will go and apply that load and find out, what are the contours that I got and try to interpret.

On the other hand brittle coating is done in a different fashion. What do you do is you take the model, you load it in steps and at the end of each step, I have to go and look at where all cracks of form, go and carefully inspected, mark them, they all carry meaning. And you see that for a pressure vessel, I have a pressure vessel here; and what we will see is you have a pressure vessel is made of steel, that is what the gray color shows and this slight brown is (( )), light brown shows the areas sprayed with brittle coating.

Now what I am go to do, I am go to increase the pressure inside the pressure vessel; and what you find here is, I have first set of cracks formed; I notice that first set of cracks are formed. And I indicate the level of pressure by an arrow and this pressure will keep on increasing. So, what I do is, I do not continuously increase the load, I increase the load to pressure p; stop the test; go to the specimen and look at the crack. And these cracks are labeled as isostatics. Not only I do I notice the cracks, but I also draw the boundary of the crack. So, it is connecting all the ends of the crack, as a contour. And these contours are also named separately, you have those contours has isoentatic. So, what you have here is, you apply the load, go and look at the formation of cracks, mark the boundary, then come back and increase the load.

So, you will do the loading intermittently, in between we have to go inspect the cracks. And if we look at, the many methods develop, how to identify the cracks, you should not escape attention of cracks on the structure. So, you have to inspect the complete structure or recommendation that you should do it this in five minutes time, because you know you are having a coating, the coating should not grip. So, you maintained the load, at the given pressure, go quickly mark the crack, comeback and repeat the load, repeat the experiment. So, what I will do is, I will increase the load, I will increase the pressure, that is what we will see here. So, what you find is the pressure is increased, you have seconds set of cracks formed, and we will see this very closely now.

So, what you find here is, I have increased the pressure. So, for each one of this end of cracks, I noted different color and at this stage, if you are very careful, you would also see there are cracks perpendicular to the original cracks also have appear. And I also mark a isoenthetic around them. So, the whole experiment is little different in Brittle coating. What I do is, I look at the structure for a given load, incrementally raise the load in stages, after raising the load, you stop it, hold it, go and look at the cracks, identify the ends of the crack. And then repeat the next stage and so on and so forth; that is you do it that is you do it the experiment.

And what is important here is this is available at a particular pressure p in the case, this is the set of pressure p, p dash, which is greater than the original p. So, at increasing pressures, you get more and more contours. And if I want to find out quantitatively the information, I need to do it for two different loads, and then find out the numbers. And I have also caution, as experimentalist people develop methodologies to extract (( )).

My recommendation for using brittle coating is to find out the principal stress directories, it is very simple. The moment you get the cracks, the cracks indicate, the principal stress direction. The tangent to the crack is nothing but the principal stress direction, because you have a brittle material and brittle material as failed. Why it got separated, it has reach it is as threshold strain and whole things got separated and this naturally gives you the principal stress direction; but if you want to find out, even the magnitude of the stresses developed, then you need isoentatics. And then do the processing and if really look at those the equations, a very long winding. So, when you want look at Brittle coating, what you will have to look at is these isoenthatic patterns, you have to mark it. You have to use these patterns to find out the quantitative value of stresses.

On the other hand, if I combine brittle coating and strain gauges, I have a lot of advantage. The advantage what I have is, I know the principle stress direction from the isostatics. So, I can align the strain gauge appropriately on an actual test component. Normally on a free surface you require three strain gauges to be mounded, because you want to find out three component of strain tensor; if I know the principle stress direction, I can reduce one strain gauge per point, it is a great saving. And when you are really looking at analysis on a aircraft structure or any one of the realistic structures, you may want to handle 1000 channels, 2000 channels. So, in that you can increase the number of point, by reducing number of channels per point, because each strain gauge occupies the channel.

So, in large scale problem, you combine strain gauges and brittle coatings appropriately, and this better is also little different. You incrementally load the structure, at each level of the load, you identify the outer boundary of the cracks, you call them as isoentatic. And if you look at the equation mindboggling and you also make certain approximations in the processing of the results.

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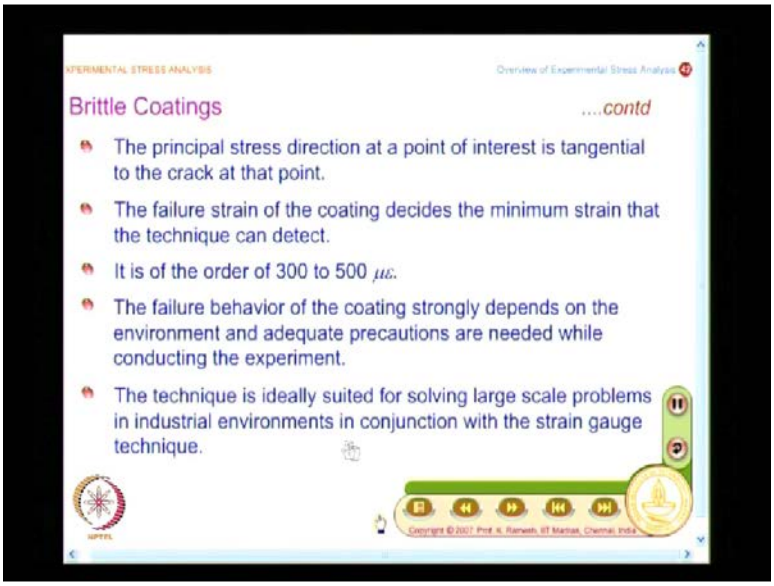

So, the idea is use Brittle coating more for finding out the principle stress direction rather than finding out the magnitude. So, that is what we have to look at it, the principal stress direction at a point of interest is tangential to the crack at that point. And what is the level of accuracy; the accuracy of the test is dictated by failure strain of the coating, decides the minimum strain that the technique can detect. And another thing you will have to keep in mind in all the coating techniques, in all the coating techniques what you find is, in all you will have Poisson ratio.

The Poisson ratio mismatch is the nuisance in all the coating techniques, because one of the assumption, what we do is I have a prototype and I have a coating on it ; and we feel, we assume that whatever the strain of the prototype is faithfully transferred to the coating, you will have a coating with different elastic properties. The specimen will have nu s as the Poisson ratio; the coating will have nu c as the Poisson ratio. You can understand if it is stretched, you can understand you are applying the load and then both the coating and the specimens stretch uniformly.

On the transverse direction, Poisson ratio place in nuisance value. So, this you will have to live with in all the coating techniques in experimental mechanics. What you will finally say is the Poisson ratio effects are minimal at could be neglected or you bring in a correction factor, you have to handle this very carefully. So, Poisson ratio mismatch is a nuisance; that is why you said; experiment gives you information closer to truth. In some cases you will also have to follow a few minor issues, which we are not in a position to solve. And what is the level of strain that this can give, it is of the order of 300 to 500 micro strains. And as technology advances, we are able to get coating, which lower and lower strain; but it is around this region, but you know experimental is I am not start like this, you know once you find that there is a limitation, they have also developed methodology, where they use refrigeration to reveal regions, where you have the strains below and develop the cracks. So, if you get into the technique, there are there are ways to circumference some of these issues.

And another very important aspect of this is we have very much consent about the environment, and here the whatever the materials that used for Brittle coatings, you need to have productive here you know, is not healthy for humans to breath. And not only this the failure behavior of the coating strongly depends on the environment, whatever is the humidity and temperature dictates, how the coatings is to going to behave; that means, the failure strain will change. In the ambient temperature changes, if the humidity changes, because you are going to apply Brittle coating in the field, you are not going to apply the Bridle coating inside the comfortable laboratory; inside the comfortable laboratory, you can control everything; you can control the humidity, you can control the temperature, you can have dust free environment, where Brittle coating is a very industry friendly techniques, it is used in the field.

And it gives the very valuable information in large structures, where you want to identify zones of importance for further study, that is a way at look at, you have to use this technique, more to identify zones of important that needs further attention, then you use either photo elastic coating or you can also use brittle strain gauges and make find the measurements. Now we move on to the technique is suitable for solving large scale problems, which have said and it is to be used in conjunction with strain gauge, and that is the way the technique has on edge, when you want to use it in real practice.

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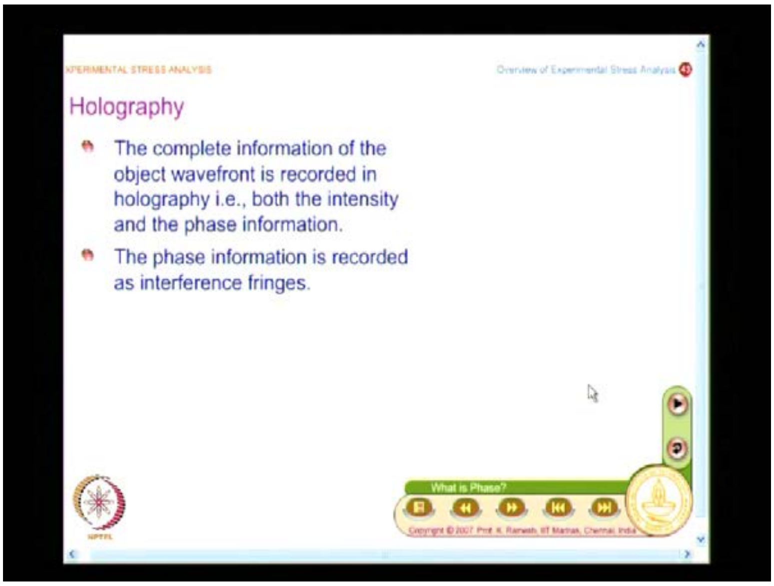

Now we move on to the next technique Holography. And this is very similar to you know, the name is very similar to photography, but what is holography? Holographies rise to provide you complete information; when you say complete information, what complete information? It rises to give you intensity and the phase information. So, we need to understand little more, when we come to holography and the phase information is recorded as interference fringes. And before we get into some of these details, you will just see lasers are used in Holography, you will see look at what we do in conventional photography and we look at, what is that we do in conventional photography.

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And I have the figure of photograph of Athena - Greek Goddess of Wisdom; because I want all engineers to be wiser, occurring knowledge is not sufficient to be a good engineer, you need to have practical experience, knowledge combine with practical experience, constitute wisdom. So, what you see here is, you have a beautiful picture of Athena; it is illumination is white light. Suppose I change the light source what happens? This figure is much better, this figure is not even nice to watch and what you find here is you can see very clearly, there are secular information that is you see dots, red dots, rain (( )) and that. This is what happens with any laser illumination, when you illuminate anything with laser laser is highly monochromatic and highly coherent, but you have this information available only in this fashion and this is your positive.

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Now, we let as look at what is the negative? When I have a positive, when I have a negative, if I look at the negative, I can make out, what does this negative contain? You see intensity is recorded, when you have a black in the original negative, it is white. So, it allows more light, and then you get that has the black in positive. So, in conventional photography, you are able to clearly see, that I record intensity, I record intensity and then you are able to see intensive variation, and you are able to look at this is positive, and then conjecture what a negative could be; or from negative you could see, what is the positive have recorded. So, this is the information I want to you to recognize from conventional photography. Now we go back, and then find out, what Holography is (( )). So, in the Holography what I find is, I record both intensity and the phase information.

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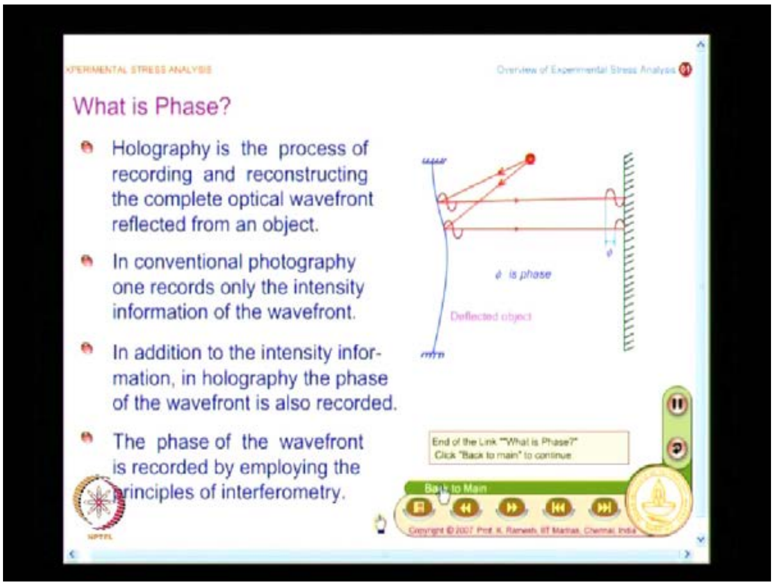

And now you have to know what is phase; what is phase, you need to understand, I have a deflected object here, I have a light in fringes on it and reach as the model. And I would like you to have a fairly neat sketch of this, because this gives you in nutshell on understanding of what is phase; I have shown a deformed object, and I have a laser source, which hits the object, they depth is different. So, when the light scattered from this reaches the screen, it reaches at different values of phase. So, the phase carries the depth information. So, normal photography, you do not record the phase information, you record only intensity, that is what we are see in the positive and negative.

The moment you come to holography, you record in addition to intensity the phase information of the reflected wave (( )). So, that makes holography different, how this phase information is recorded; this phase information recorded based on principals of interferometer. Under what we will see is will see the ideas listed here. So, what we do in holography, it is the process of recording and reconstructing the complete optical wave front, reflected from an object. And I say complete optical wave front, I said intensity as well as phase and we have seen in conventional photography, 1 records only the intensity information of the wave front. In Holography phase of the wave front is also recorded. And phase of the wave front is recorded by employing the principles of interferometry. So, what is the difference and we will go back and see does how the hologram looks like and then what you see in that.

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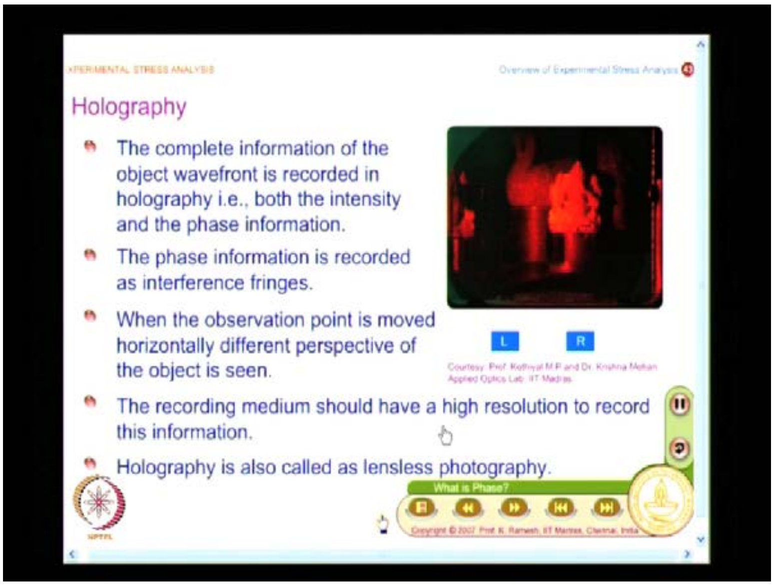

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I have a hologram here. And what is the important point here is first observation is the images not good as, good as what I record in normal white light, but the because I record the phase information, when the observation point is moved horizontally different perspective of the object is seen. So, you you are able to get the three-dimensional effect of the recording. As with the model is in front of you are able to go beep, what it is, you are able to see that I will show you that in my animation, I will also magnify this, I will show you this and this as the hologram was recorded in the lab (( )) and doctor Krishna Mohan at Applied Optics lab, IIT Madras; and now I, move my head and what you see here, I see objects behind, I see this swine is behind and you have a statue of lord Ganesa in front and then I move it to the right; then I you are able to see the depth information; are you able to see the depth information.

As if the objects are kept before you by you are able to see the depth information, you are able to get different perspective this is recorded as is you are moving the head, over the region of hologram. But from from our measurement point of view, we are not looking at only three-dimensional pictures, our (( )) go in for deformation; when metrology application this is useful or you able to see the depth information or you convenience that Holography records depth. Now we go back and then see the other aspects of it. So, what I find is the recording medium should have a high resolution to record this information, because I am recording both the information of intensity and phase. So, I need to have, high resolution to record the information. And holography is also called as lenseless photography and we have to see further, what is the implication of the use of lenseless photography; and how it is the recorded and traditionally they were having a very high resolution, they had holographic plates that show the able to record the holograms.

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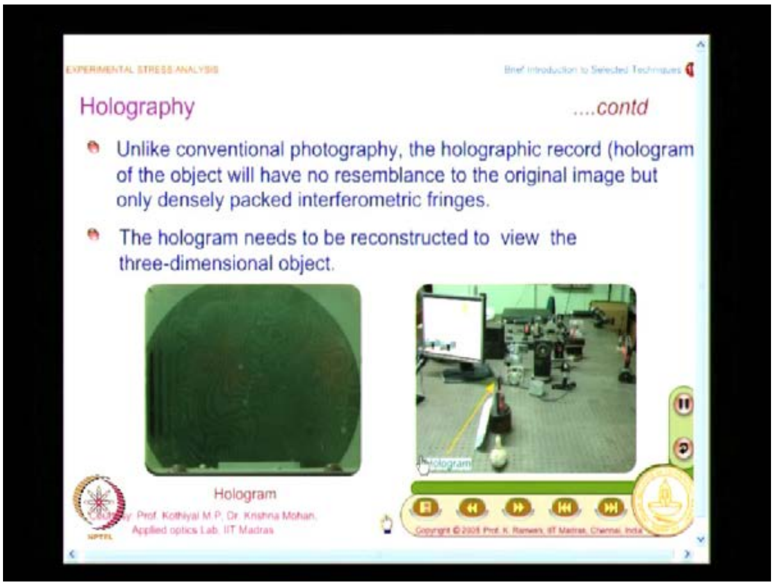

And now we will get into, how does this… So, what we find here is see in the case of conventional photography, the holographic record of the object will have no resemblance to the original image, but only densely packed interferometric fringes; this is my interest show, because in the case of conventional photography, you look at negative, you are able to make up, what is recorded on that; suppose somebody gives you hologram, you will not know what is that unless you reconstruct. This is the fundamental difference. So, what you see here is the hologram needs to be reconstructed to view the three-dimensional object.

And for the set of Ganesa and swan, what is kept? If you look at the hologram the hologram is like this. We will see that is enlarged and this is what I see, do you make out anything here, you see only some funny fringes on this. So, this contains in a information of swan, lord ganesa, kept at different distances, we arrival to beep in to it and then you are able to see that and then able to it by looking at the hologram, give the negate eye, you cannot see the picture, you need to reconstructed, you need an optical arrangement do that. And that optical arrangement is shown next and this is what you see here. And what you have here is, I have the hologram mounded, I have a play of laser, which falls on this and you lot to look at this hologram and then record the three-dimensional depth of the hologram.

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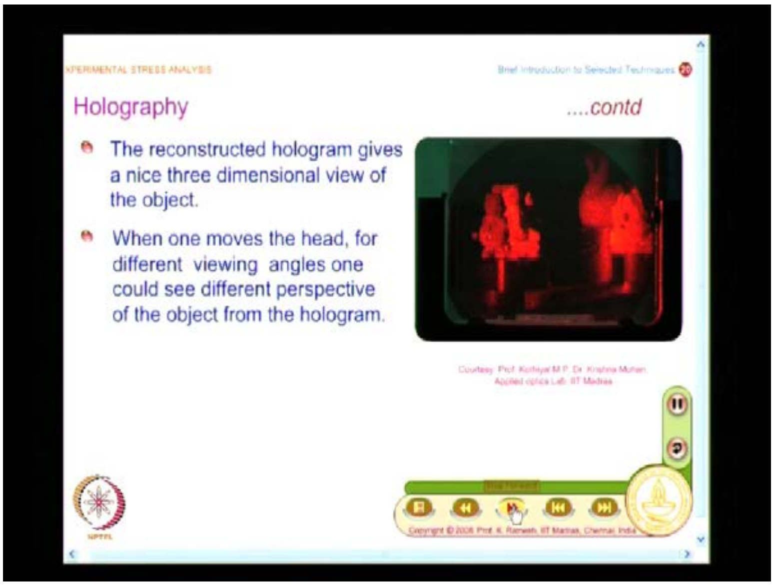

So, it is not a conventional photography, conventional photography you gave a digital camera now, you take a photograph instantly, you see what we have recorded, but Holography, you will have to reconstruct the hologram and view it. But many will desecrate with me, sir we are seeing the hologram day in day out in many of our simple appliances, when I buy a cassette, I have a hologram printed on this. What is this Hologram? Though it is not needed for, you know your stress analysis or strain displacement analysis is better to know, have a common knowledge on what are the holograms; so that is what are going to look at now, what we look at is…

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That is what you have seen reconstruct holograms give on eyes three-dimensional views.

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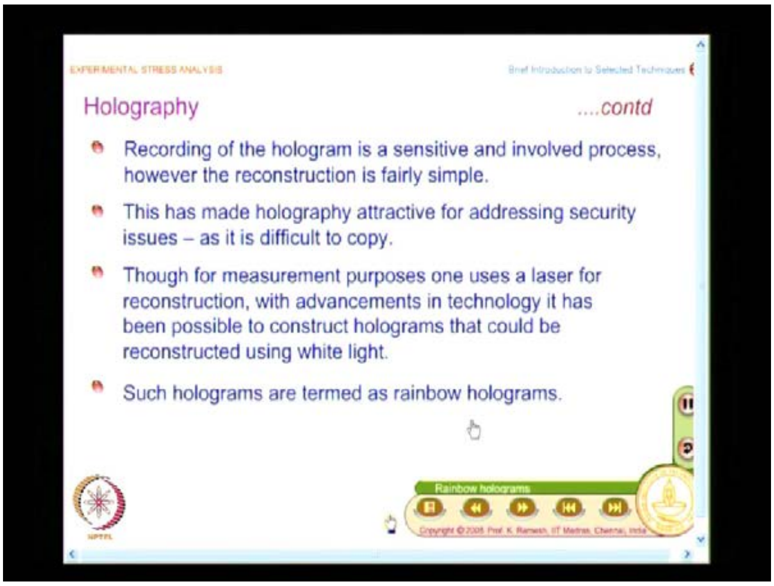

Now, what you want to see is, Recording of the hologram is a sensitive and involved process, it is not a… That is why it is used for a security device; however the reconstruction is fairly simple. Though for reconstruction, I need on optical arrangement good. So, this has made holography attractive for addressing security issues, as it is difficult to copy. That is why people use holograms stickers. Though for measurement purposes, one uses a laser for reconstruction, with advancements in technology, it has been possible to construct holograms that could be reconstructed using white light. So, what you see as holography stickers or nothing but white light holograms.

There is some sacrifices of quality in the process, but at the same time, because holograms are difficult to make, duplication is difficult. So, you are able to give a guarantee to the genuine of this product, if you see the hologram, given by the manufacture. And these holograms are termed as rainbow holograms. Why they are called as rainbow holograms? There is the reason behind it; many times you do not know how to even look at the hologram; how to look for information; and we will see, what are these rainbow holograms?

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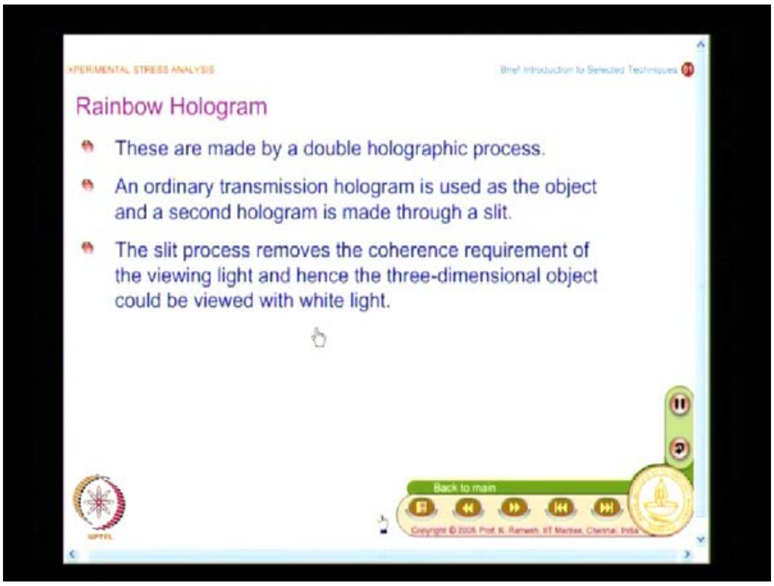

And what you have here is these are made by a double holographic process. An ordinary transmission holograms is used as the object; and a second gram is made through a slit it, is an optical requirement and the focus here is, I want to see the reconstruction, without going into complicated optics, just normal white light should be good enough that is the purpose behind it.

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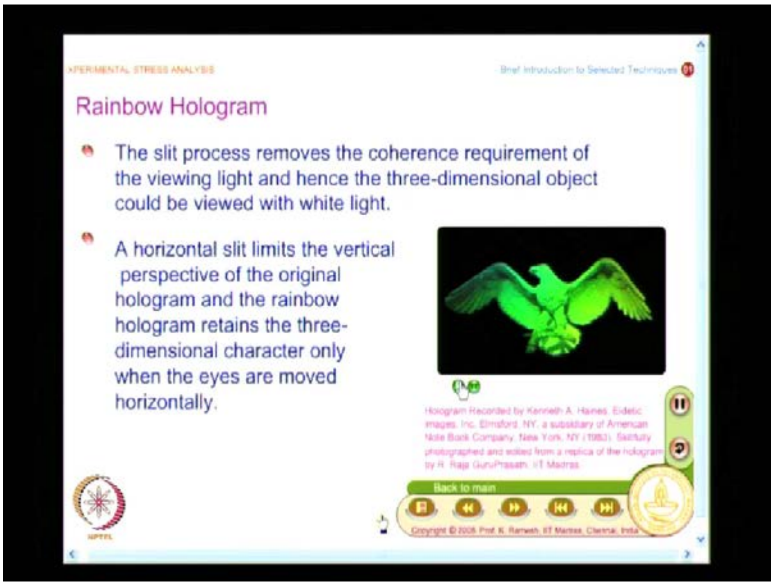

So, what you have here is the slit process, removes the coherence requirement of the viewing light and hence the three-dimensional object, could be viewed with white light.

So, this is the advantage. So, one of the greatest application of holography is in security, which we see it is become so common place, almost anything you buy it comes with the holographic stickers. And if you go back in history, it was in 1983; first the ma the visa card the dough the hologram was used I will just show you that. So, what you have here is you have a visa card dough hologram. This is the dough and you could even see the color change, and what will do is we look at another hologram, which was also released in the same time, how to view a rainbow hologram. What is the difference between a conventional hologram and this this is more from a point of view of appreciating, how you know a holography is used in various applications.

So, what you find here is, I have a beautiful hologram here, and we will have a magnification of this, and then see the demo. And what you have here is, if I move my head horizontally, I will repeat it again, you could see beautifully the three-dimensional depth of the eager. Could you see that? I will repeat again, you are able to see this and this hologram was recorded by Haines of eidetic images. It was done in 1983 and this was published on the national geographic zonal as a cover page, they were popularizing holograms at the time. And what you saw here as a animation, it requires skillful photography to reveal and assemble them together. See in the normal books, what they will show is they, will show one extreme view, one middle view and one another view to show that recording the depth information. And this was done by Guruprasath and done it at IIT Madras and these are assemble to give you a nice three-dimensional view, but still it has not explain, why it is rainbow hologram.

So, you have a horizontal slit, limits the vertical perspective of the original hologram, and the rainbow hologram retains the three-dimensional character, only when the eyes are moved horizontally. When I move my eyes horizontally, I have three-dimensional representation. If I move the eyes vertically, I would not have a three-dimensional representation, I would have only rainbow of colors and here again recording is difficult. It is recording is very difficult and that was done by my student and that is what you will see here, you will see beautifully the play of colors.

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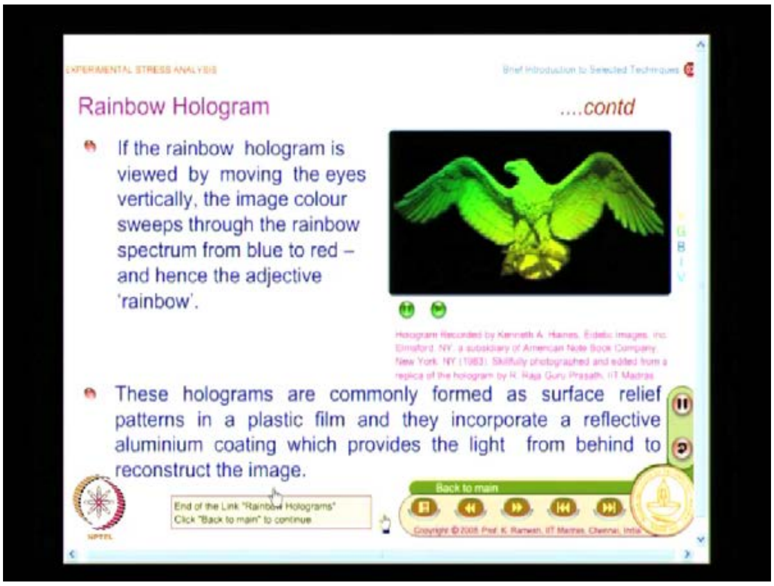

So, I have this on the vertical movement when I do it, I have play of colors and this is what you see, you could see, you could see the whole eagle as green, I will I will move further, you could see the whole eagle as red and this is you know this is because of the operations, it elimination is not already you do not see this comfortably. And so, what you see here is you are able to see different colors of the rainbow and able to stop only at green, I want to stop it at blue, let me see one more, I am able to stop only my reflections are such, I able to stop only at red or blue, I will also want stop it at blue, you know stop it at blue, I will try one more time, now when I will do that so fast.

So, what you find here is you have a nice hologram, what you have the rainbow of colors. And here, because you know the images are not assembled properly, you say assemblance of depth, but it is not actual depth, what do you saw in the earlier one, when you move ahead horizontally, you saw a beautiful depth, here you see only colors are different, that is why it is called a rainbow hologram. And these holograms are commonly formed as surface relief, patterns on a plastic film and they incorporate a reflective aluminum coating, which provides the light, from behind to reconstruct the image.

So, what we saw in conventional holography was, you need to have a laser arrangement to view the hologram, you cannot view the hologram like reading a normal negative, you need an optical arrangement to do that, but people found as advancement develop they could do away reconstruction optics, normal white light can do it, but in the process you are three-dimensional, three dimensionality on both direction is lost, on one direction you are able to (( )) three dimensionality, on other direction you see only a play of colors that is interesting that is very interesting. So, you have a play of colors and that is that is the way you have to verify, that it is a genuine hologram or not; and these days, you know they have multilayer holograms, you will see on one layer one information, another layer another information and this use of holography is more from security point of view, less from stress analysis point of view. So, what we will do is, we will try to look at, what is the use of stress analysis in the next class.

And you will also have to remember, holography was invented in 1948, as recent as 1948 and the person who developed holography or invented holography was given a Nobel Prize for it. So, it is a invention of that fundamental in nature that we got a noble prize is done is gabber, who got noble prize in 1971 and this holography finds numerous applications, but we will focus our attention from solid mechanics point of view, how do I find out the displacement, primarily it gives you displacement. I spend little time on rainbow holograms, yours that is what you have access to easily and you should know at least go and educate your people at home, how to view and hologram. So, if you have a rainbow hologram on horizontal direction, you will saw you will have a three-dimensional representation on the vertical scale, you will see play of colors.

But now you have layered holograms, so many varieties have come, so many varieties of even there they have views, colors, try to bring holography in color, so many developments. So, those are all like more from marketing point of view displays and then public use of holography for fund, we will not get into all that we will only look at how holography can be exploited for stress analysis. That we will take it up in the next class, thank you.