Theory of Elasticity
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Lecture – 54
Photo – Elasticity

Welcome, we are in the next module for this theory of elasticity course.

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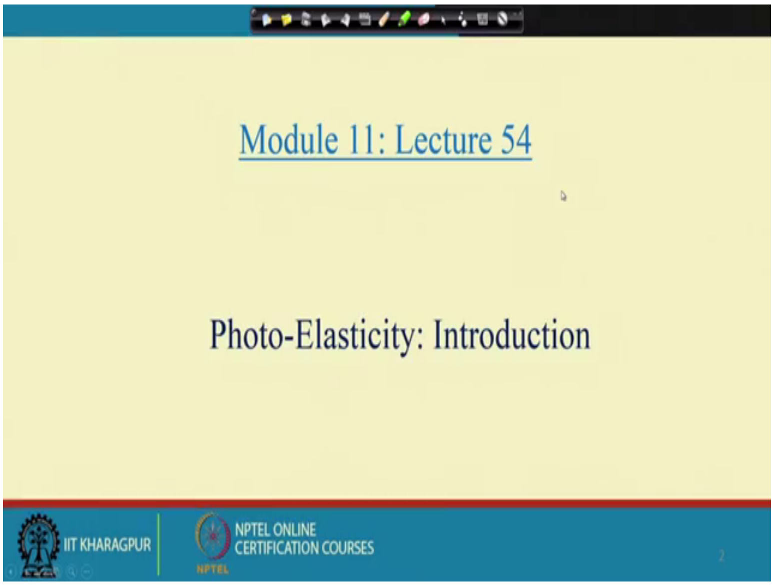

Actually in this module we will briefly discuss about one of the oldest experimental technique known as the Photo Elasticity. So, this Photo Elasticity as the title suggest the photo means it is elasticity using optics. So, the reason we are studying or we are discussing this topic is that till now we have understood or we have gone through the analytical development or analytical approach to the stress measure or the stress analysis in an analytical approach.

So, another approach as I have discussed in the last module also is the numerical approach where basically you use all your theory and theoretical assumptions. And solve the problem in a numerical approach through finite element through finite difference or any other numerical approach where basically you solve the governing differential equation with the help of approximating technique.

Now, so, if I now define it in three basic category of stress analysis is that one is the analytical approach. Where for a simple geometry for a simple boundary condition simple material we can solve this problem analytically or the direct or the sometimes it is also known as the exact solution. Or there are some other technique that semi analytical approach where part of the problem is solved analytically and part of the problem through numerically or any other approximation technique. So, analytical or numeric semi analytical solution is very restricted.

So, we the next step is gone for the numerical approach where we can solve large class of problem; another approach where it is an experimental approach whether we can really see the stress pattern or the deformation pattern or the strain pattern in a body, through an experimental approach.

So, this topic comes under the experimental approach, where essentially we call this technique is in photo elasticity. And this is the one of the oldest method of stress analysis and very early days this technique has been people have been used to view the stress pattern in a complex body.

Suppose you have a very complex body. And in earlier days the numerical approach were not. So, easy because of the computer availability and the computer power basically so, that restriction is not there right now, but still if you have a complex body. And if you want to know the complex stress strain pattern or stress pattern in a complex body, how we can view this.

The one approach is you solve by a numerical approach which is currently very much feasible today and you can visualize it, but there are certain limit to that. One of such limit is that for instance you have learned thus solving effects solving effective or the end effect in a body where the where you constrain the body.

So, there all those assumptions of elasticity certainly not valid so, those things you can observe in an experimental technique very easily. And those effects basically how we observe the observation is essentially.

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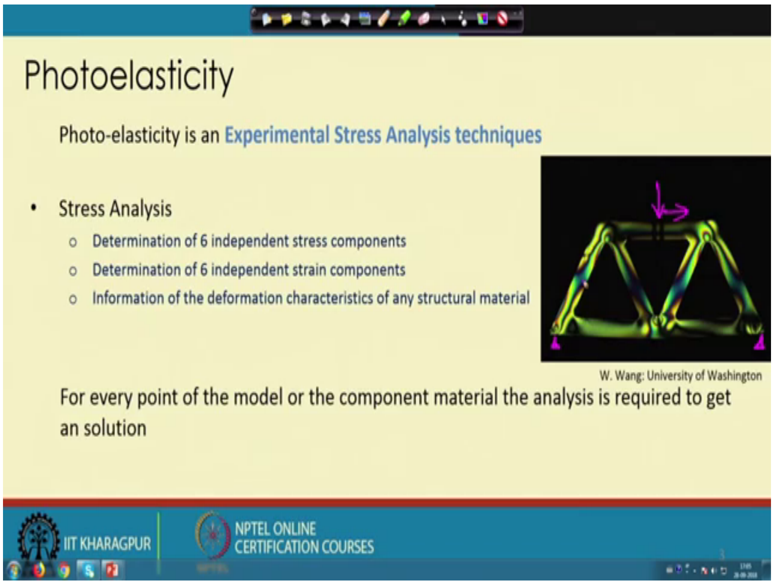

You prepared some material or some prototype of the complex body and then you try to view the stress strain pattern within that body. So, essentially photo elasticity is an experimental stress analysis technique. So, the stress analysis is basically we are interested in depend stress, strain components and deformation characteristics. So, and this pattern of stress and strain is very much heterogeneous within the body in case of a complex body.

So, let us see a simple stress this stress simple very simple stress and if I just put some load into this stress and some load or something like that or some axial load or something some amount of axial load or something like that. And this stress is supported here or here somewhere in the body. And this stress will show some pattern of this some pattern in which that pattern we do not know that pattern, but it has been found that this pattern is very much filler to the stress distribution in this stress. And we will know what this pattern is called. So, this is essentially the photo elasticity naturally. This stress is not made of the actual material that like steel or concrete or whatever it is.

So, there is a the material is essentially different and the material is essentially a non crystalline member by which the light can propagate into the body. So, this technique is essentially known as the photo elastic technique or the photo elasticity.

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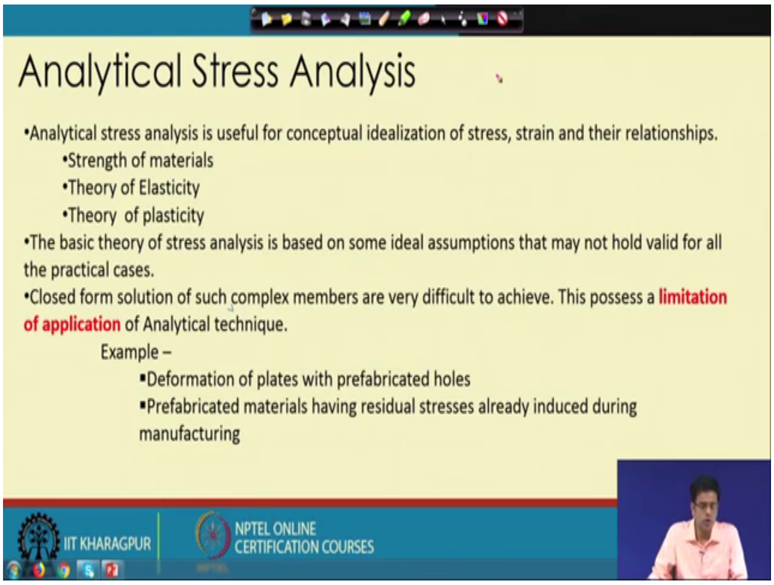

So, analytical technique analytical stress analysis that, I was talking about we have strength of materials theory of elasticity theory of plasticity. So, the basic theory of stress analysis is based on some ideal assumptions and with that may not hold for the realistic case that, for instance the I just discussed the stress analysis at the end of the body which is or the constraint at the point where the constraint is applied. So, that point the stresses are very much non unique and it does not follow the assumptions. So, that is popularly known as the solve in effect.

Now, for instance another issue is stress concentration. So, stress concentration in a body also shows the very much stress jumps. So, these technique are these things we can very much easily see through the photo elastic analysis.

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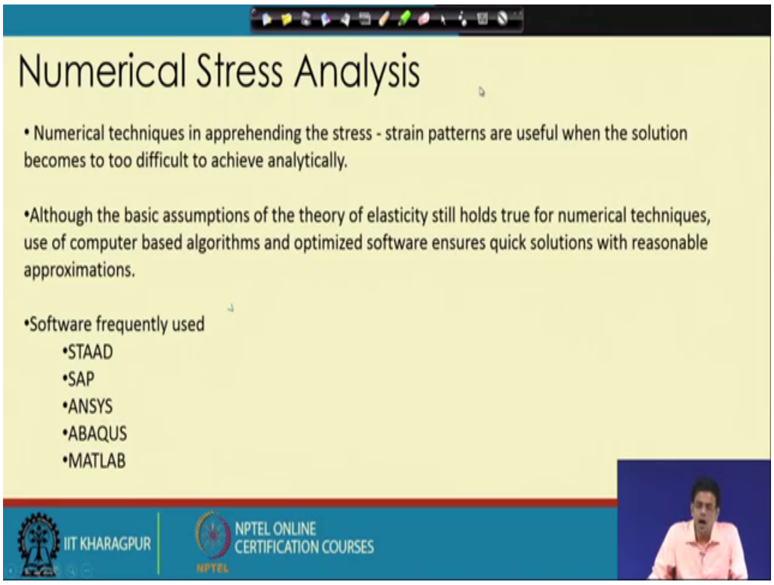

Another approach as I have discussed is numerical technique so, but the in the numerical technique all the assumptions of theory of elasticity is valid and. So, we all take those assumptions to finally, solve the problem. So, and there are some numerical Softwares like STAAD, SAP, ANSYS, ABAQUS, MATLAB some other Softwares which we use to solve this problem numerically.

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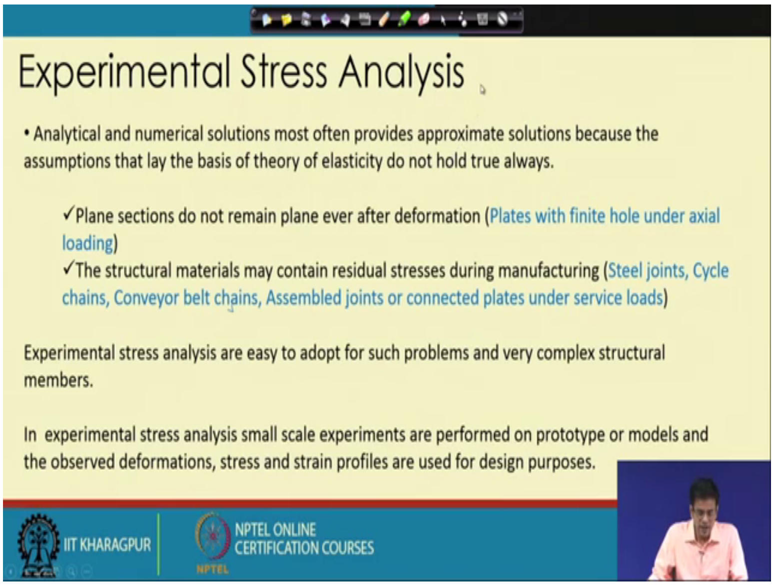

So, in the experimental stress analysis so, analytical a numerical solution most of them provides approximate solutions because of the assumptions in the theory, but these assumptions really may not hold in the actual place.

So, for instance plane section remains planes before bending after bending. So, this is an assumption. So, this assumption is very much true for certain cases of the body, but if this is a when you have the large body or where these highlights you have to use a different theory either or you have to visualize the what is the case or what is the stress distribution within the body.

So, another important issues is that most of the structural material contrary contains residual stresses. So, identification of these residual stresses or estimation of those residual stresses is a very tricky issue. And this residual stress is essentially a lies within the body and when if you do not take these residual stress within the body in your design or design the structure or analyzing the structure.

It may lead to a failure in a later stage because the stress or strain you predict through a through your analysis may not be same, when you take residual stress or residual strain taken into account in the analysis. And identifying or knowing that residual stress or strain is very difficult issue. So, this the stress residual stress we can actually visualize through the photo elasticity or photo elastic experiments.

So, experimental stress analysis and easy to adopt for such problems and very complex structural members; essentially it is not easy rather what we do is that we prepare a prototype of that complex structural model and try to visualize how the stress distribution happens. So, it is a essentially scale transformation. So, for instance you really want to see what is the stress strain pattern or stress pattern in a bridge or in a large complex structure. So, you scale down the model and prepare a prototype of a different material and then you see the stress.

Now, it is very interesting that we are talking about that stresses in a body of a small scale body which is not made of actual material. So, on that how that stress will be same in that body and the actual body which is made of different materials.

So, answer to this question you have encountered this problem for instance that bi harmonic equation we talked about in the elasticity is independent of the material parameter. So, when you actually try to find out strains then you need strains and essentially displacement you need material behavior to comment before that it is not required that stress function approach that we have talked into. So, essentially the stress distribution here the pattern will be remaining same. So, if the load and the boundary condition with the actual body and the small scale body remains same. So, this thing helps us in understanding the stress behavior or stress distribution especially the heterogeneous stress distribution within the body in a complex situation.

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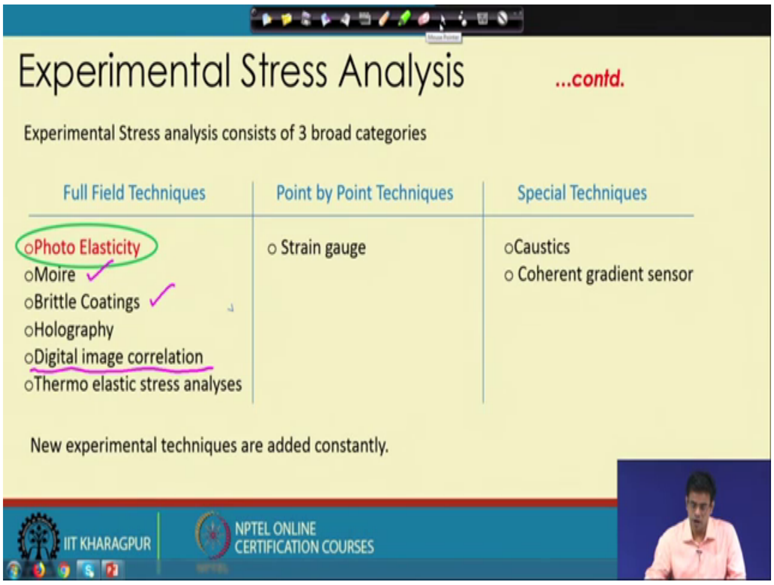

So, the experimental stress analysis basically can be divided into three major part. And the one part is where you is in you are familiar with that is the point to point technique. For instance in your all your B-tech experiments probably you have used the Strain gauges where it measured the strains at a point electrical resistance strain gauges. So, that you have used. So, that essentially gives you a point by point measurement. So, where you figures the strain gauge you get that strain pattern strain at that point it may be time dependent. So, but the spatial location of that point is very much fixed.

Another way if you divide it is fulfill technique whereas essentially you measure everywhere in the body. So, that fulfilled technique involves this photo elasticity.

This photo elasticity also moire fringes brittle coatings holography. Another technique which is very advanced topic is digital image correlation. So, digital image correlation essentially you compare two images and try to infer the displacement and finally, strengths thermo elastic stress analysis and all those things.

So, new experimental techniques are also added very frequently based on the based on the optical thing or any other methods. So, special technique can also be is also there for instance Coherent a gradient tensor and caustics and all those things are also there, but we are interested here in this lecture in the photo elasticity or the photographic or the optical effect or optical using the optical properties how can I understand the stress pattern within the body.

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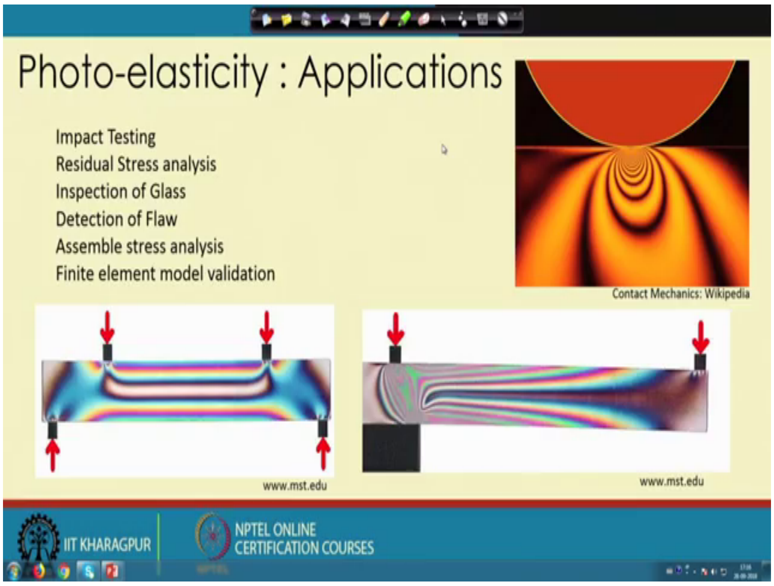

So, the application the application lies in several thing for instance. this if you see this picture that this picture is the 4 whole point winning test. All of you know that that for what is four point winning test. So, you see the stress pattern is very much similar to the theory that we have observed in the elasticity this course. So, this two point loading and these two points are support. So, this is a stress pattern.

Now, if you see the, if this is a cantilever and this is a point load and then how the stress pattern will be. So, this is the support you can see that the supports are very much supports are very much different. Now so, these highlights the. So, when I (Refer Time: 15:36). Now when you apply this thing in a theory you get the similar stress pattern, but this part of the stress pattern will be very much different in the numerical or analytical analysis because to take care of these things you really need to have this whole body into the consideration. This picture shows the contact which is of the one of the important area of mechanics where this the stress pattern in the when two bodies contact each other and then how the stress grows and stress balls propagates within the body this also describes these.

So, there are several application for photo elasticity. And the interesting thing that with the development of the full field techniques this photo elasticity or especially the development of the electronics the photo elasticity is re emerged and till date these techniques are very much valid in experimental stress analysis.

So, another issue that is often we talk about finite element model validation. So, essentially you solve a model through your numerical analysis and then try to see whether your analysis is correct or not this is one of the important way, where we can really validate our numerical model whether it is correct or not. So, this is finite element model validation is another issue or technique where photo elasticity has a large application.

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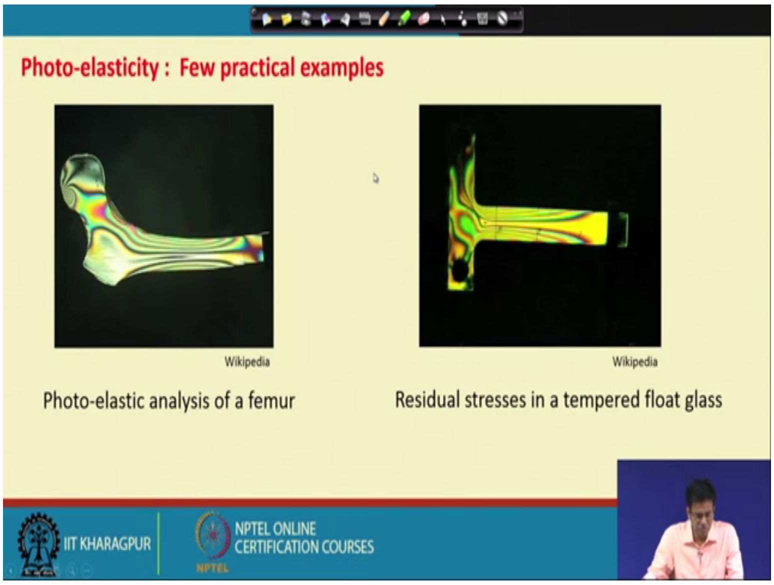

So, now I will show some photo elastic analysis technique photo elastic samples. For instance this is a femur human femur how the stress distribution within the femur can happen. And this is the residual stresses in a tempered float glass. So, this is how the if you see very carefully that these zones are the stress concentration in these zones are very much proper and then these zones where these stress concentration is very much useful for from the analysis point of view. And this is this part where the loading and all those things have been applied.

So, this clearly gives you the how stress varies within the body. And how the complex stress pattern is in special cases where the complex boundary condition is very important. And this boundary condition plays an important role especially.

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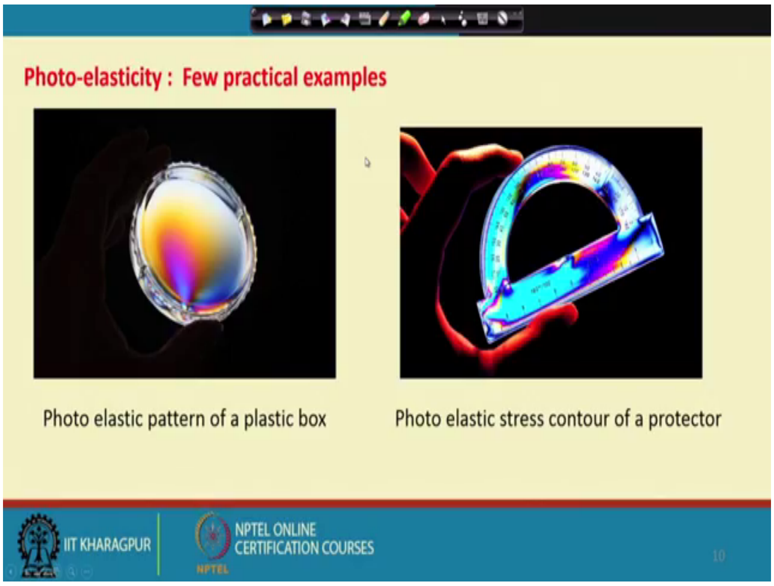

So, now this is a photo elastic pattern of a plastic box how plastic box will look like and then stress distribution and then elastic stress distribution of a protector all those things are very much photo elastic material.

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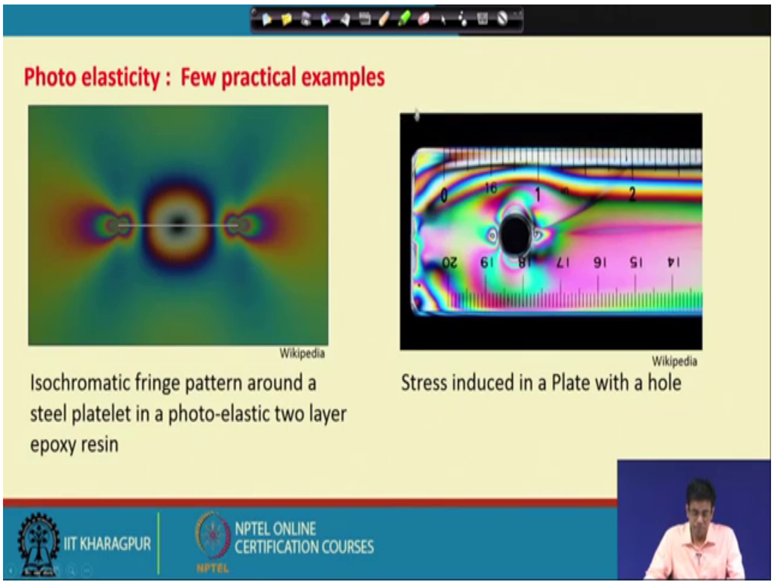

So, through the photo elastic analysis now, this is a fringe pattern around a steel plate late in a photo elastic two layer epoxy resin. Where you can see that and the stress concentration and then played with a hole with the standard problems where you can see that stress concentration is very much prominent. So, this thing we have already seen analytically some of the cases. So, already we have seen analytically in our the theory. So, now the photo elastic stress analysis also can reveal the pattern of the stresses in the present examples.

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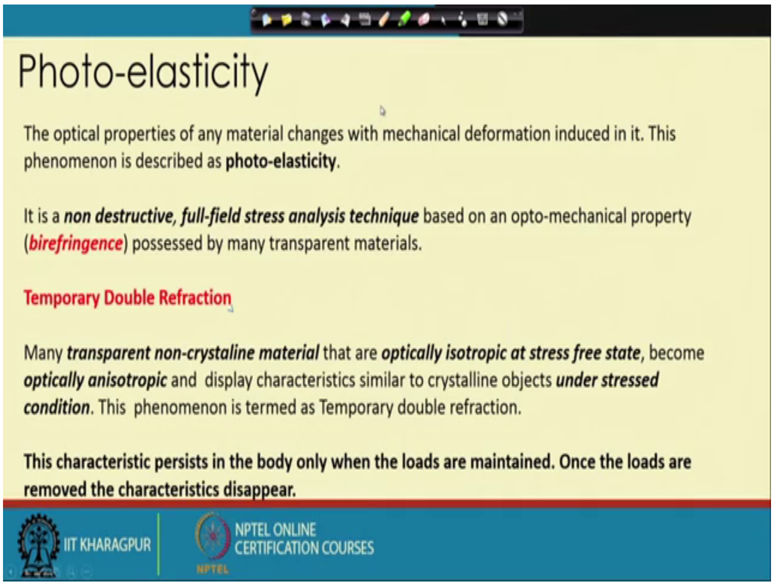

Now what is essentially photo elasticity? Photo elasticity is essentially in optical properties of material changes with the mechanical deformation induced in it. And this phenomena is described as photo elasticity. What is the that means? So, some material property changes due to the load and naturally that is not elastic property.

So, we are not considering the time dependent or the load dependent elastic properties. So, optical properties will changes. And this is essentially some the optical properties, means that some properties are isotropic in before you stress the body. And it becomes an isotropic once you stress the bodies and we will see that and this phenomena is known as actually birefringence.

So, birefringence is that is a phenomena that actually helps us to interpret the stress pattern. So, many transparent to non crystalline material that are optically isotropic at stress free state become optically anisotropic you can display characteristics similar to under stress condition. And this phenomena is actually termed as a temporary double reflection. And this thing actually plays a important part in the optical stress analysis or essentially due to this double refraction characteristics allows us to view the stress pattern within the body. So, this and this is temporary when you remove the load this goes off.

So, essentially this double refraction. So, once the before stress you apply the load to the structure it was isotropic there was no nothing visible in the bodies or the fringes are very visible in the body, but when you give a stress to the body the it is optical property which is earlier isotropic now it becomes Anisotropic. Now due to that there is a changes in the body which shows some pattern which is actually the proportional to the stress pattern of the body. So, this allows us and this phenomena is known as the temporary double refraction. And this phenomena actually allows us to view the stress, stress pattern within the body.

So, ah, but important thing is that when we remove the load again it is not visible. So,. So, that is why this property is temporary.

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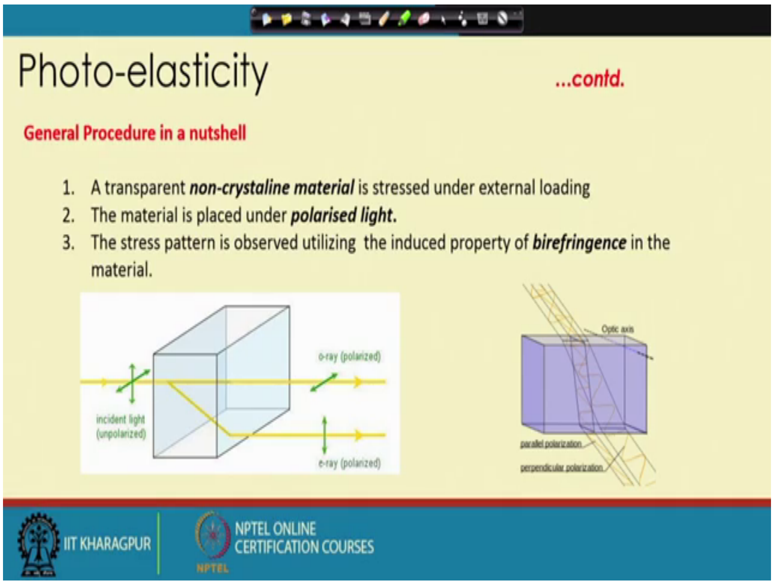

Now what is a general procedure I will describe it in a later lecture, but we have to know that we all are you see the poor unpolarized light. The un polarization the polarization of light also probably you know that is light is vibrating in random different direction, but when you un polarized light when you actually with the un polarized light you cannot really see the thing.

So, essentially you pass a monochromatic light or you filter the polar you use the filter or reflection or refraction those techniques to polarize a light. So, what it is we will also discuss in detail. So, essentially a transparent non crystalline material which shows the property of double temporary double refraction that is the properties were isotropic before stressing and anisotropic after stressing.

So, these non crystalline materials for instance a Plexiglas. So, that is also a non crystalline property which shows the photo elastic which is suitable for photo elastic experiment. So, which the property of birefringence it shows.

So, it transparent on crystalline material in stress under ex loading and the material is placed under a polarized light. So, that the stress pattern comes proper. And then the stress pattern is observed is relying induced property of birefringence in the material.

So, birefringence is why; what is the birefringence I have already discussed that is when you have a certain class of material that is temporary double refractive. So, that changes the optical property your optical property is different in different directions and isotropic means we already know that optical property is different in different direction means elastic and isotropic means we know that optical elastic properties is different in different direction.

So, essentially we chose isotropic optical property. Now it becomes an isotropic. So, anisotropic means it is different in different direction. So, we have a stress pattern visible. So, that is the basic thing.

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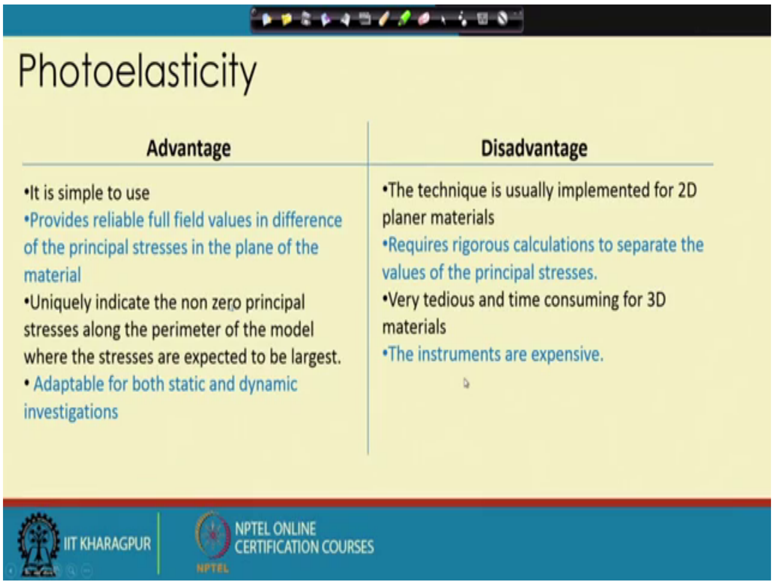

So, the advantage of photo elasticity it is very simple to use and provides full fill value that is very important. So, with the strain gauges we really cannot get the effect because it may and the photo elasticity gives you the total stress pattern of in your body which is stressed. And difference essentially it is the difference of principle stresses in the plane of the material. So, we will see that how it is an uniquely indicate non zero principal stress along the perimeter of the model where stresses are expected to be largest. So, that is this thing and adaptable for both static and dynamic in investigation.

So, but the disadvantage is generally suitable for 2 D not very much suitable for 3 D. So, requires require rigorous calculation of separate. And the values of principal stresses because we will see that how the fringe pattern from the fringe pattern we can actually compute the principal stresses. So, and very tedious and time consuming for 3 D material that I have already told you and the obviously, you need an instrument to really visualize this thing.

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So, this is a our recent Polariscope and what is Polariscope and all those things we will explain there. And this is our old polar Polariscope.

So, this is the main body this is a instrument by which we essentially analyze the photo elastic body.

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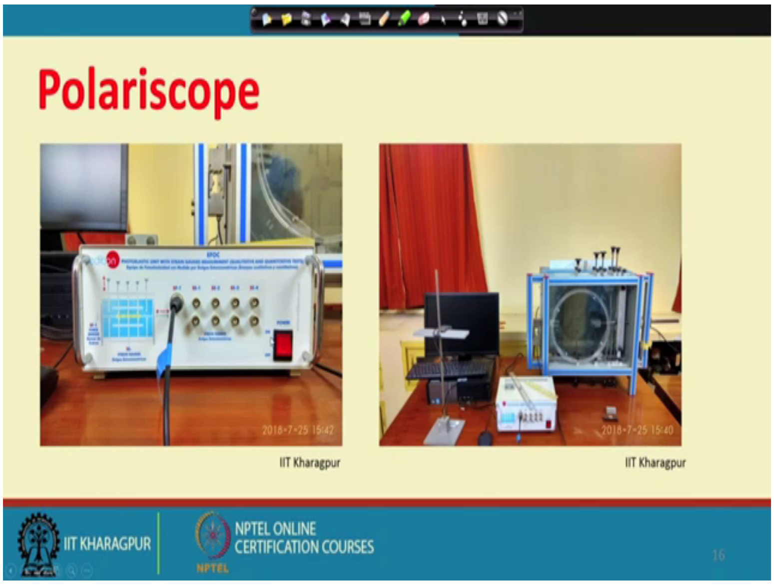

And this is the whole setup here and this is the data acquisition system and all those things. So, strain gauges and all those things are also there with the photo elastic experiment here. So, there here I stopped today. So, in the next class basically will study some of the basics of optics. So, that optics some basics of the optics is required to understand that photo elasticity. And these optics essentially all of us know, but it is a kind of revisiting those essentially the electromagnetic wave that we will revisit in the next lecture. So, here I stopped today.

Thank you.