Experimental Stress Analysis - An Overview
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Lecture – 3.3
Introduction to Brittle Coatings

We are continuing our discussion on different experimental techniques. In the last lecture, we looked at Moiré. Now, in this lecture we will look at Brittle Coatings.

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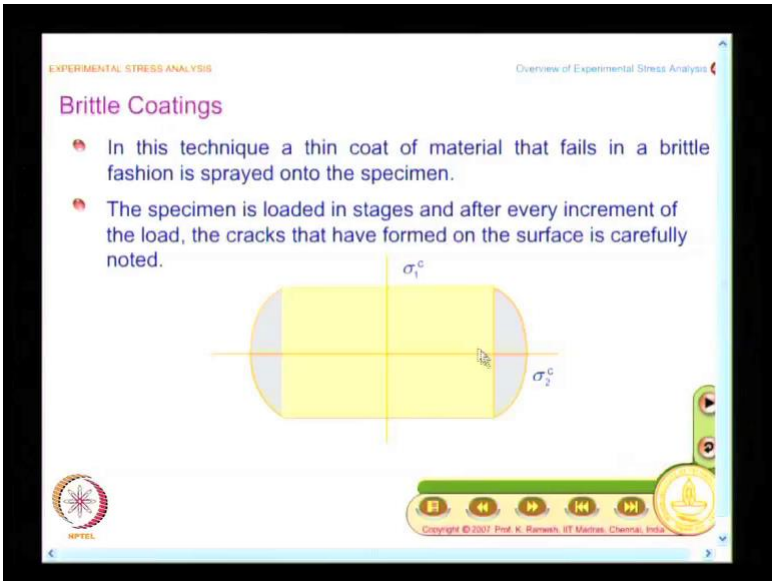

Earlier, we have looked at the method of strain gauges, strain gauges is able to find out strain at a particular location. Suppose I have a known situation, I know these are all the regions of stress concentration. I can put a strain gauge and find out the strain comfortably. Suppose I have a large industrial problem, and a component is so huge and you have a no clue on how to go about and find out and get started on the problem. So, in such cases Brittle Coating is a 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, 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 a brittle material? It fails by maximum stress theory or maximum strain theory and you can call it as Moiré's Theory, whichever way you want to call it.

So, once it fails, it you are able to get the principle 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, a very peculiar. And here accuracy of the technique 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 principle behind it.

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, I try to interpret. On the other hand, Brittle Coating is done in a different fashion. What 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 have formed. Go and carefully inspect it 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 the pressure vessel is made of steel, that is what the gray color shows and this slight brownish tinge, light brown shows the areas sprayed with Brittle Coating.

Now, what I am going to do is, I am going 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 have form 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 a load to pressure p stop the test, go to the specimen and look at the crack and this cracks are labeled as isostatics.

Not only 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 as 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 you have to go inspect the cracks. And if you look at the many methods developed, 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 5 minutes time.

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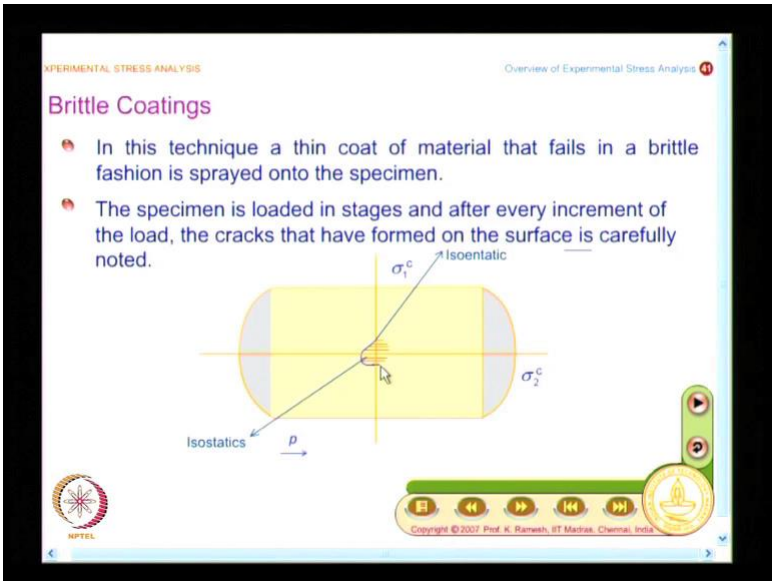

Because, you know you are having a coating, the coating should not crib. So, you maintain the load, at the given pressure go quickly mark the crack come back and repeat the experiment.

So, what I will do is, I will increase the load, I will increase the pressure, that is what you will see here. So, what you find is the pressure is increased, you have second set of cracks formed and we will the 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 appeared. I also marked isoentatic 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 how you do it. That is how you do the experiment.

What is important here is this is available at a particular pressure p in this case. This is at a pressure, p dash which is greater then 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 principle stress directory it is very simple.

The movement you get the cracks, the cracks indicate the principle stress direction. The tangent to the crack is nothing, but the principle stress direction. Because you have a brittle material, and brittle material as failed why it got separated? It has reached, it is stress hold to strain and the whole thing got separated and this naturally gives you the principles 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 you really look at those equations, a very long winding. So, when you want to look at Brittle Coating, what you will have to look at is these isoentatic patterns you have to mark it. You have to use this patterns to find out a 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 aline the strain gauge appropriately on an actual test component.

Normally, on a free surface you require three strain gauges to be mounted, because you want to find out three components 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 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 points, by reducing number of channels per point because each strain gauge occupies a channel. So, in large scale problem, you combine strain gauges and Brittle Coatings appropriately. And this brittle 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 equations, they are mind boggling and you also make certain approximations in the processing of the results.

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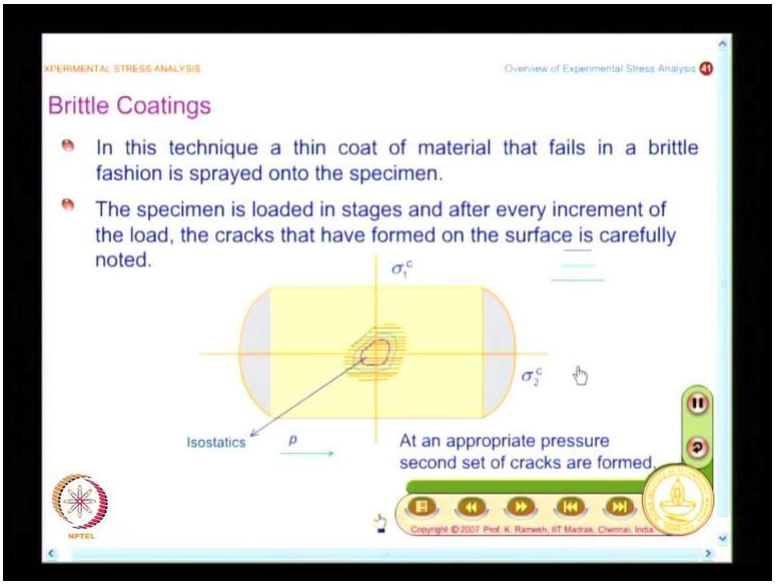

So, the idea is use Brittle Coating more for finding out the principle stress direction, rather then finding out the magnitudes. So, that is what we have looked at it. The principle stress direction at a point of interest is tangential to the crack at that point.

And what is a level of accuracy, the accuracy of the test is detected by failure strain of the coating decides the minimum strain, that the technique can detect. Another thing you will have to keep in mind in all the coating techniques, what you find is in all you will have Poisson ratio. The Poisson ratio mismatch is a nuisance in all the coating techniques, because one of assumptions 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 a Poisson ratio; the coating will have nu c as a Poisson ratio. You can understand if it is stretched, you can understand you are applying the load and then the both the coating and the specimens stretch uniformly. On the transverse direction Poisson ration plays a nuisance value.

So, this you will have to leave with in all the coating technique in experimental mechanics. What you will finally, say is the Poisson ration 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 he said experiment gives you information closer to truth, in some cases you will also had to shallow 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 a experimentalist I have not stop 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 a strains below and develop the cracks. So, if you get into the technique there are ways to circumvents some of these issues.

And another very important aspect of this is, we are very much concerned about the environment and here the whatever the material that is used for Brittle Coatings, you need to have protective gear, you know its not healthy for humans to breath, and not only this failure behavior of the coating strongly depends on the environment. Whatever is the humidity and temperature detects how the coating is to go in to behave. That is means the failure strain will change. If the ambient temperature changes, if the humidity changes, because your going to apply Brittle Coating in the field.

You are not going to apply Brittle Coating inside the comfort of a laboratory. Inside the comfort of the laboratory you can control everything. You can control the humidity, you control the temperature, you can have dust free at the environment, but Brittle Coating is a very industry friendly technique it is used in the field and it gives very valuable information large structures, where you want to identify zones of importance for further study. That is a way you have to look at it.

You have to use this technique more to identify zones of important that needs further attention. Then you use either Photoelastic coating or you can also strain gauges and make final measurements. The technique is suitable for solving large scale problems,

which I have said. And it is to be used in conjunction with the strain gauge, and that is a way the technique has an edge when you want to use it in real practice.

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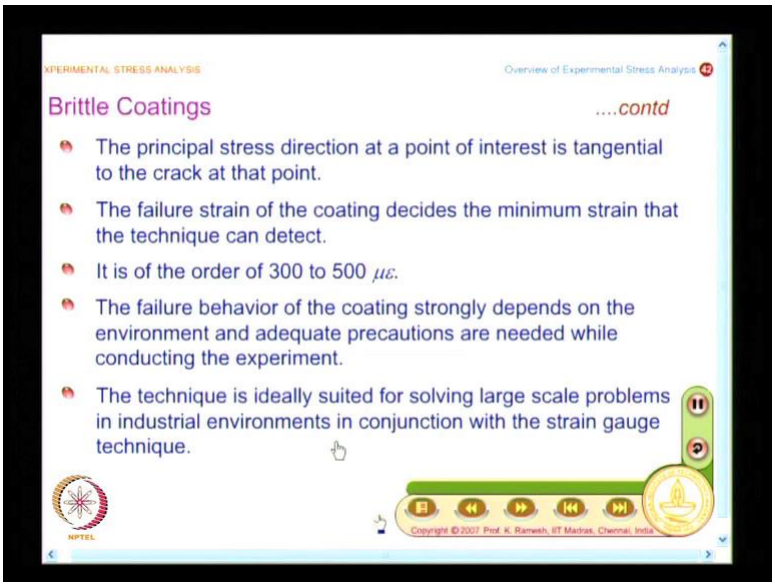

In this lecture, we have looked at physical principle behind the Brittle Coating technique. The methodology to perform Brittle Coating experimental technique is also briefly explained. Brittle Coating is ideal approach to identify zones where you have to concentrate for further investigation.

And, if you look at combination of Brittle Coating and strain gauges makes this stress analysis lot more accurate and fast because, in a large structure you do not know a priory which is the zones that need further attention. Which could be identified by Brittle Coating, followed by a strain gauge technique can give you accurate numbers in zones of importance.

Thank you