Experimental Stress Analysis - An Overview
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Lecture - 4.1
Introduction to Caustics

We have so far seen, quite a few techniques what is the physical principle and what is the essential difference between them.

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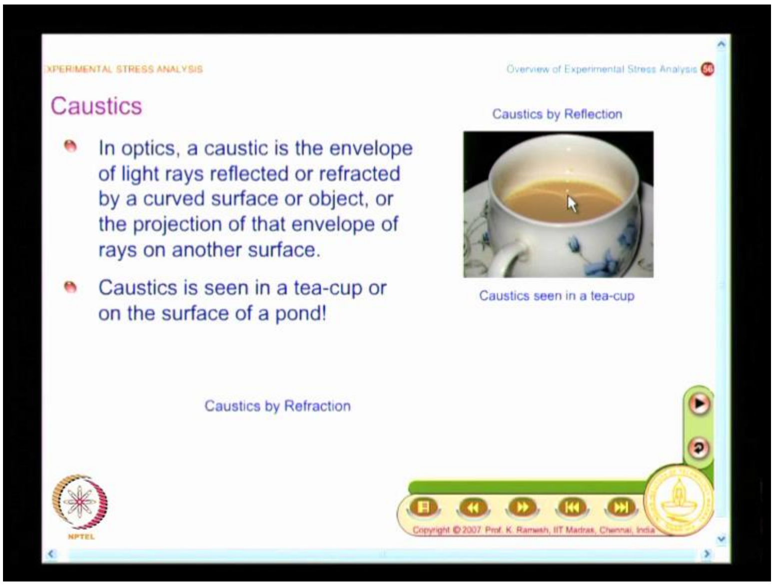

Now, we move on to another interesting optical technique, which is the method of Caustics. What I want to mention here is, caustic is the envelope of light rays reflected that is what we had seen earlier in the beginning of the course. It can also be refracted by a curved surface or object or the projection of that envelope of rays on another surface.

So, what you see here is, I have a caustic by reflection. I have a tea cup and because of this curved nature and with appropriate lighting, light hits on this curved surface. And gets reinforced and you see a silver line as a cusp. This is by whatever the line that you get the principle is called Caustics. The same name is also given to the optical technique we use it for measuring high stress gradient problems, but this is a physical principle.

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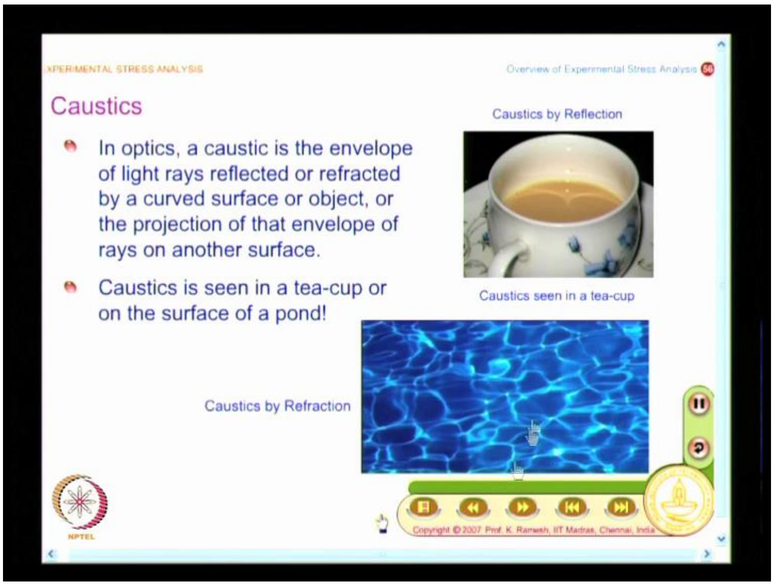

When you go to a pond, you may also see nice structures like this and all these silver lines, what you see them they are all because of the phenomenon of caustics. Now you can go and say you might have noticed it, but you may not have named it. Now you can go and see these are all nothing, but caustics. So, caustics is seen in a tea cup or on the surface of a pond.

What is it is used for me in stress analysis? See if I have to use, there is joy in looking at all this patterns and name them as caustics. But I must also it is utility from the stress analysis point of view. How it is seen, we will have a look at it we will also elaborate upon it.

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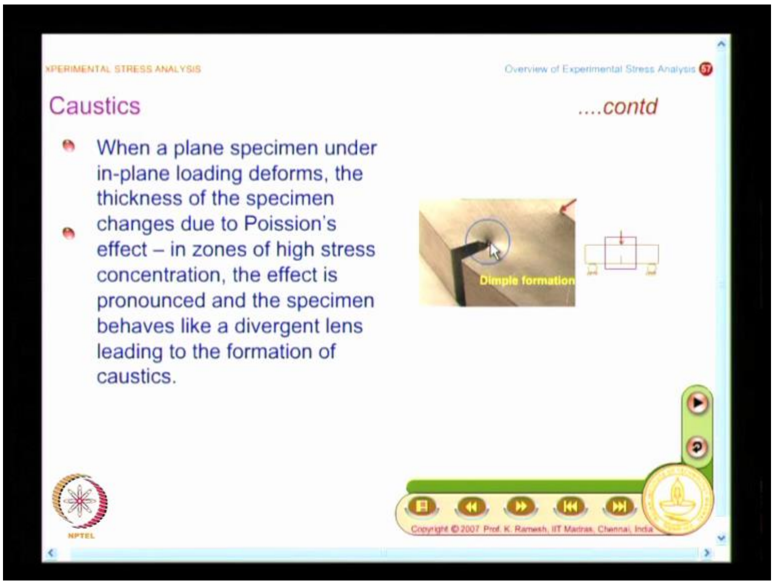

First, we will look at what is a principle. And this is what is a shown here, I have aluminum specimen which has a crack and you see a dimple formation here. First we will see this and then look at the reason behind it. Can you see the dimple very clearly, at the tip of the crack, you see a very large deformation here and this occurs when I apply load. When this is in three point bending, when I apply the load I have a dimple formation.

So, what you find here is, when a plane specimen under in plane loading deforms, the thickness of the specimen changes due to Poisson's effect. If I do not have a crack I would not see the change in the thickness very prominently. Because of the crack which introduces high stress concentration. The change in thickness is also very significant and that is seen as a dimple. So, this is particularly seen in zones of high stress concentration the effect is pronounced.

And when you look at here when I send a collimated beam of light, I can have a transmission arrangement as well as the refraction arrangement. If I have a transparent model, then it behaves like a divergent lens and the light rays whatever I send it gets deflected. And it forms a particular pattern on the screen. Now you relate, what causes the deviation of the rays. By relating these two, you will be in a position to find out what caused this change and hence the level of stress concentration.

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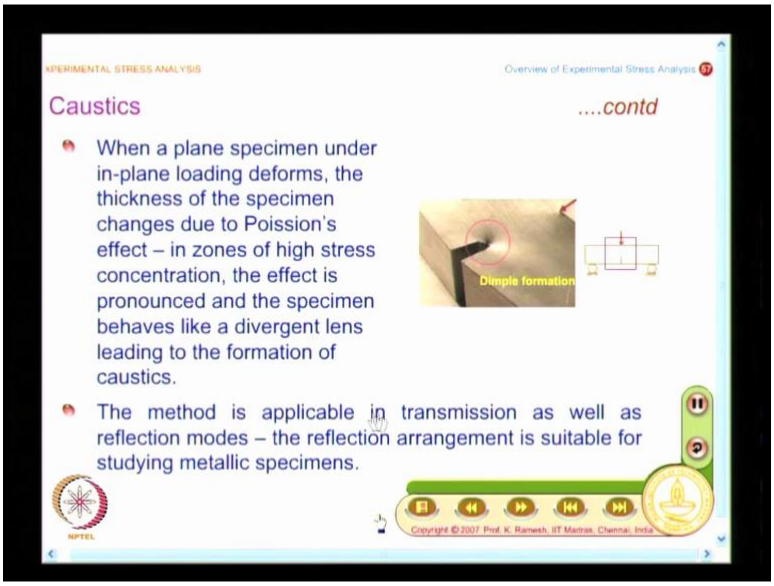

So, that is the basic principle behind it. As I mentioned earlier, it is applicable to transmission as well as reflection modes. The reflection arrangement is suitable for studying metallic specimens. This also I have said that, you need to have techniques to find out for models as well as prototypes. Photoelasticity has transmission photoelasticity and refraction photoelasticity.

So, in method of caustics, you can do it on transparent models, as well as on opaque metallic specimens, and particular in fracture mechanics, when people wanted to understand the plastic deformation at the crack tip; caustic really helped and it really helped for people who know little bit of fracture mechanics, establishing the concept of HRR field, Hutchinson, Rice and Rosengren feel near the crack-tip was very well established with the method of caustics. What I will do is I will elaborate this; this aspect of this specimen becoming a divergent lens, we will have a look at it. And this I am going to the chapter on caustics, I will just show you how this deformation is recorded.

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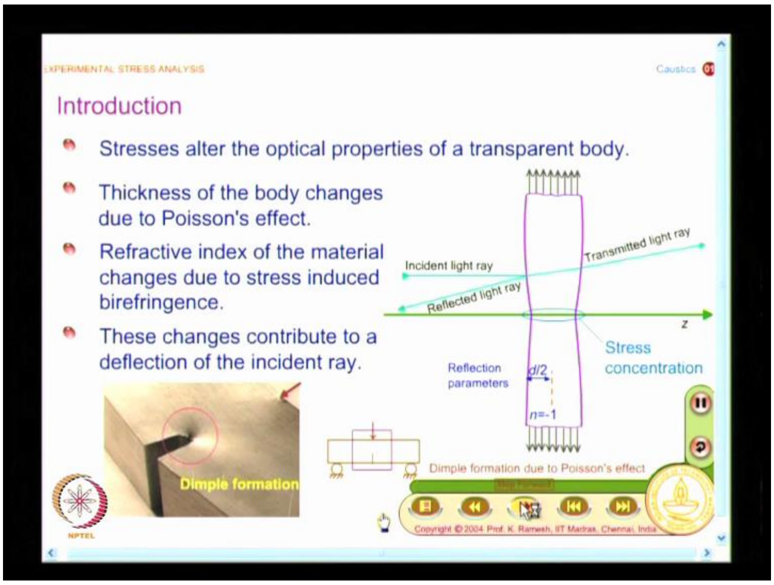

So, this is a specimen I have. I have a stress concentration here, I pull this model and from this it is exaggerated that you see a thickness change very prominently noted near the stress concentration. Stresses alter the optical properties of a transparent body you will also have change in the refractive index. If it is a metallic specimen, there is no question of a refractive index getting changed. The thickness change, because of Poisson effect is very prominent near the stress concentration zone. If I use a transparent model, most of the transparent models which we use also birefringent, so the refractive index also in has an influence, so the combined influence of this, causes the formation of caustics.

So, what I see here is I have an incident ray and it get transmitted it does not go straight it gets deflected, it gets deflected. And because of these changes, when I send a beam of light I will get a shadow essentially behind the specimen. In transmission arrangement and on the reflected this one, you will see on this plane.

And you have certain parameters, you do not have to worry about them now when we go in to mathematical development which we may not do in this first level course. So, you have to take those parameters appropriately and here again you have shown, for a transmission arrangement this is very clear. For the reflection arrangement you have this dimple very prominently seen. So, when I send the ray it will get reflected like this, and because of this you will have a family of rays emerging and that forms a shadow.

And if possible, I will also illustrate it by a simple experiment. But before we go into the experiment we will also see, take a specimen with crack and make a very simple sketch of it and look at what happens. I will just show that animation for a minute then we move on to the experiment. This formation of caustics is very clear, just observe the specimen.

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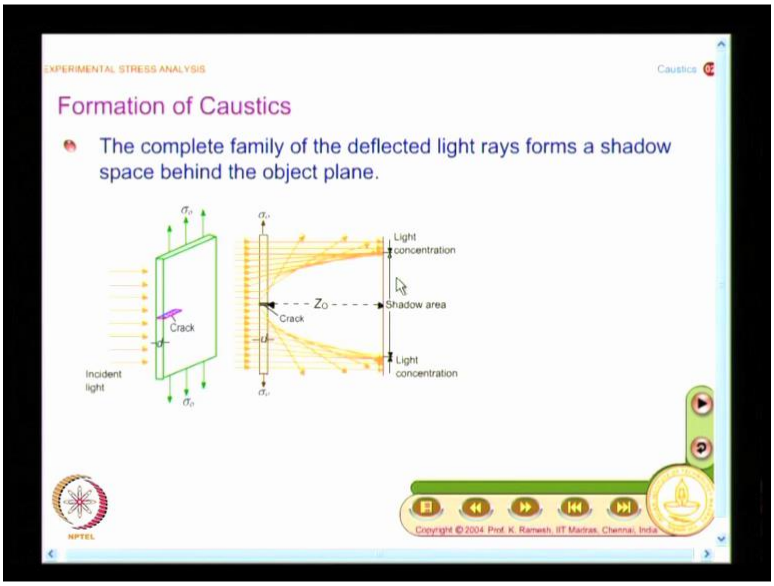

So, what I have here is, I have a specimen with a crack. I have parallel beam of light impinging of the specimen, and because of the Poisson ration effect. The light does not go straight. If I do not load the model the light will go straight. Light gets deflected like this. And because this gets deflected, you get a shadow region on the screen and you have reinforcement of these rays form a silver line enclosing the shadow line. Because that is found because of the principle of caustics, you call the entire methodology as method of caustics. It derives a name from that. So, you have a family of rays, which reinforce and give you a silver line. Is the idea clear?

And what we will do is you can actually illustrate caustic by a very simple experiment. Even in the lecture class and what I have here is I have a polyurethane specimen because this I can a stretch easily, and I have a crack. I do not think it is very clear maybe I will put a white background. I will put a white back ground you are able to see the crack here. You are able to see the crack here, and I do not know whether the camera is good enough to show the, if I stretch it. I will see a dimple that is getting formed. I will get a dimple being formed at the crack tip. Even visually you can see you can have a dimple formed at the crack tip. when I will pull it you will see the dimple. And if you are not able to see the dimple, we will see we will send a laser beam of light and then find out what happens.

So, what we will do is can I have one person come and help me? What I have here is I have the model here. And I send the laser beam of light, it is not loaded I see that has a point you just load the specimen. And you will find that the rays are getting deflected. The rays are getting deflected. Rays are not going because I am just doing it with hand I am not able to show you the shadow completely, but this is what happens. You are able to see that the rays are not going straight, but that they get deflected. And if you come here, if you look at the sketch again what you have here is, you have this stress concentration and rays get deflected. And if you actually perform the experiment you will get the shadow like this. We will have look at it. Listen a moment, I will show you this.

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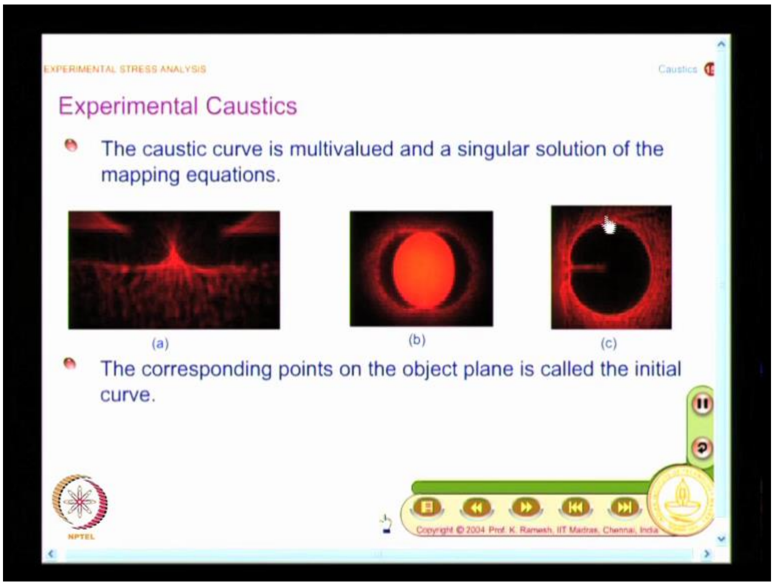

This is a caustics is shown for different problems of a stress concentration. It is a semi infinite page with a concentrated load. This is a plate with a whole you have a figure of 8 and this is a plate with a crack. I have the crack here and I have a caustic envelope like this. So, you have a shadow, bound by a silver region and you can see very clearly I have a shadow this is bound by a sliver region; that is what you have. And this is the caustic shadow for a mode one crack. So, you send a beam of light, you get a shadow you do not get light passed through.

And that is mainly because you have the specimen behaved in a fashion where you have thickness change, so whatever the light rays impinged on it. It diverged, it behaves like a divergent lens and you do not have light here and that become a shadow and that is what you have seen in the screen. And this is what I tried to show and in fact, if you do it very carefully you will be able to see it. Because hands are shaking you are not able to see that in the class. So, it is a very interesting phenomenon. So, what you will have to keep in mind is, if people find out physics. They are waiting to exploit and develop a new technique and this has found very good application. In the early development of fracture mechanics, to establish HRR field this was a very ideal technique.

So, in this class you have looked at how caustics is employed to reveal high stress gradient information. It is not a general purpose tool. If you use image correlations it is a general purpose tool. If you use photo elasticity it is general purpose tool. If you use strain gauges that is also a general purpose tool. The moment you come to caustics, it is particularly sensitive to high stress gradient information. And I have shown the caustics shadow for three problems, one is for the semi infinite plate with a concentrated load, plate with a hole and the third one is plate with a crack stretched.

Thank you.