Experimental Stress Analysis
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Lecture - 19
Fringe Ordering in Photoelasticity

Let us continue our discussion on transmission photoelasticity. I had mentioned that one of the key parameters that you need for comparing the results of photoelasticity with analytical or numerical methods is the materials stress fringe value. And in the last class we had seen how to evaluate this parameter as accurately as possible, we initially saw a single point method which is a conventional approach to find out the material stress fringes value.

And since we are in the digital era where computers are very well used for many applications which you also find photoelasticity is not lagging behind, and people have tried to utilize the whole field information in finding out the parameters of interest. So in that direction we have also developed a linear least square approach which collects data from the fringes field, utilizes this information and then find out the materials stress fringes value as accurately as possible.

We have also looked at the methodology so well developed that the collection of data points should not influence the final result, so you do a statistical conditioning, and I said for any of those procedures it is better that we go and utilize digital image processing techniques for extracting the data for you to analyses. What is the data that you require? You need the positional coordinates and the fringe order.

So you need to identify the fringe skeleton and for finding out fringe skeleton people only had techniques in the initial stages to mimic what we do manually, so one of the earliest techniques in that direction was identify the fringe areas as binary information black and white and within the fringes identify the skeleton by removing the outer pixels progressively, and they essentially extended principles of optical character recognition to process the fringes pattern.

And the whole process depends on what is the maximum thickness of the fringes in the field, you have to do scanning left to right, right to left, top to bottom, bottom to top, and is this essentially and iterative process, and at the end of the iterative process though you get a skeleton you are not guaranteed whether these skeletons merge with minimum intensity points, because in a broader fringes the answer may be slightly different.

So way of circumventing this problem is to go and utilize the intensity information, even while using the intensity information people have developed mass based methods, we have not looked at them in the last class, we have only looked at a global fringe thinning algorithm.

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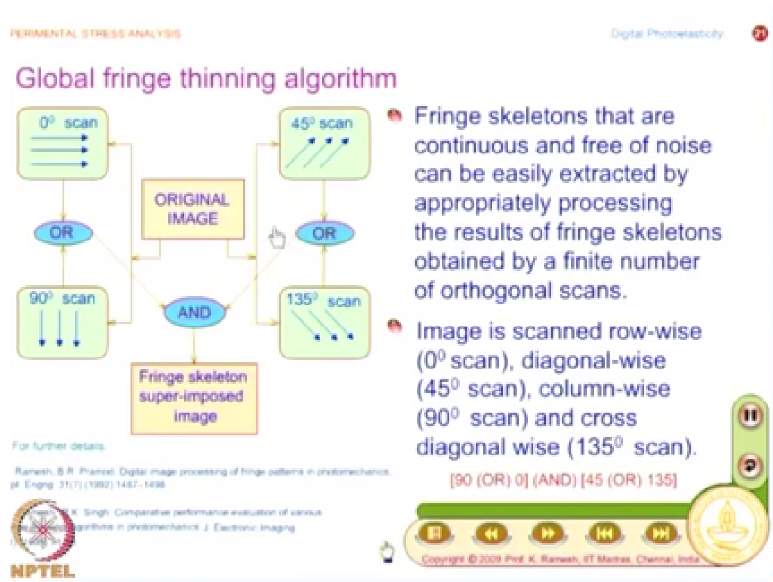

This is of a different approach and what the focus is fringes skeletons that are continuous and free of noise that is very important that could be easily extracted by appropriately processing the results of fringe skeletons obtained by a finite number of scans that is very important, there is no iteration involved and in this case we use only 4 scans. I have 0 degree scan, 45 degree scan and 90 degree scan and finally 135 degree scan.

And if you really look at them they are essentially orthogonal scans, I have a 0 degree scan and 90 degree scan, and what we found was when you do a 0 degree scan it identifies fringe area as well as gives you noise. And if you look at 90 degree scan, it identify some fringes skeletons and also noise but when I do a OR operation, I get complete fringes skeleton but with some noise. And what we found fortunately was when you do the other orthogonal scans, 45 degree scan and 135 degree scan and do OR operation you get the complete fringes skeleton with noise.

But the noise what you get in this orthogonal set is different from what you get in this set, so when I do the AND operation we retain only the fringe skeleton and the noise is eliminated, this is the greatest advantage. So the whole procedure can also be simply labelled as 90 OR 0 AND of 45 OR 135.

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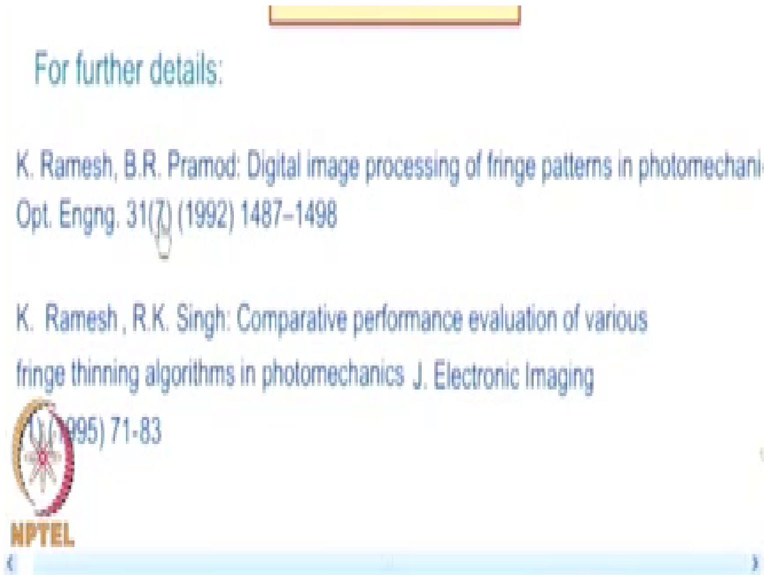

And if you want to get further details you could look at in these differences this were essentially published in the 1990s, and the first paper deals with the essence of this algorithm, the second paper on Comparative performance evaluation of various fringe thinning algorithms in photomechanics really brings out the advantage of global fringe thinning algorithm in comparison to other fringe thinning algorithms, both binary based and intensity based algorithms which are essentially mass based.

So it is a step forward in the direction of finding out fringe skeleton comfortably as far as photoelastic images are concerned, photoelastic images have very high contrast and it makes identification of fringes areas very simple, and use the minimum intensity position to extract the skeleton. And I also mentioned in a complex fringes pattern like what you have in a cracked isochromatics instead of doing the scan orthogonal to fringe area.

I said 4 scans globally can identify the curvature also even with different curvature or the fringes the skeleton could be extracted and here you do intelligently utilize the logical operators and you extract the fringe skeleton. And the next topic what is important is we have N F sigma/H=sigma 1-sigma 2, we have seen how to get an F sigma, now we have to find out how to label the fringes.

It is a very crucial aspect if you look at photoelasticity the arithmetic involved is very very simple for you to find out the stresses the arithmetic is simple, but for you to get the stresses you need F sigma and you need fringe order. And now we take up how to label the fringes?

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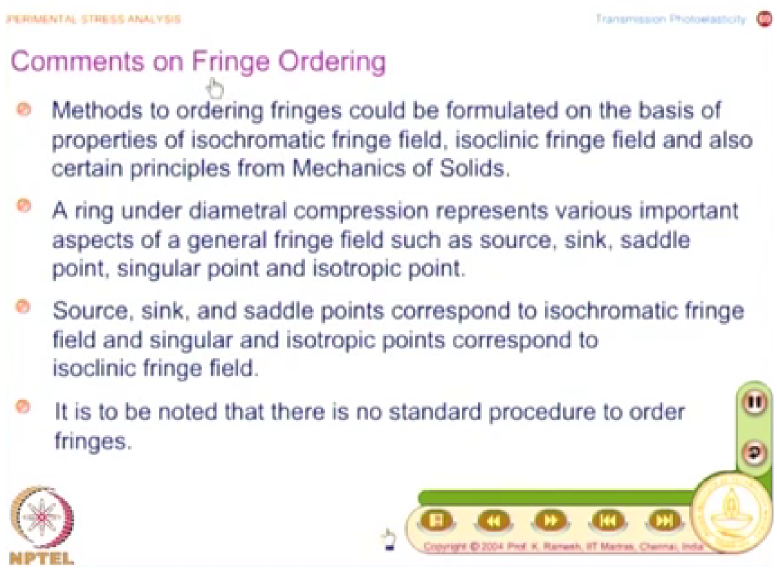

See one of the important aspects in any of the optical techniques is to find out how to label the fringes orders, and in photoelasticity you can get assistance in labelling the fringe ordering by looking at properties of isochromatic fringes field, properties of isoclinic fringes field, and also invoking certain principles from Mechanics of Solids. See what is important is with modern developments you have the advantage of computer based methods which provide you fringe order at every point in the model domain, though they are automated methods.

My recommendation is it is better from learning point of view, you should also know how to look at the fringes pattern and label the fringes, this knowledge would complement your further learning. And we have seen in the case of photoelasticity you have many important fringe field features such as source, sink, saddle point, singular point and isotropic point. And also mentioned that source, sink and saddle correspond to properties of isochromatic fringes field.

Singular and isotropic points correspond to isoclinic fringes field, and it is to be noted that there is no standard procedure to order the fringes, these are only guidelines and it is better that you look at the problem approach in one fashion, and order the fringes verify this by another approach. So I am really giving you more than one method to arrive at the fringe order, and what we will do is we will look at the problem of ring under diametrical compression.

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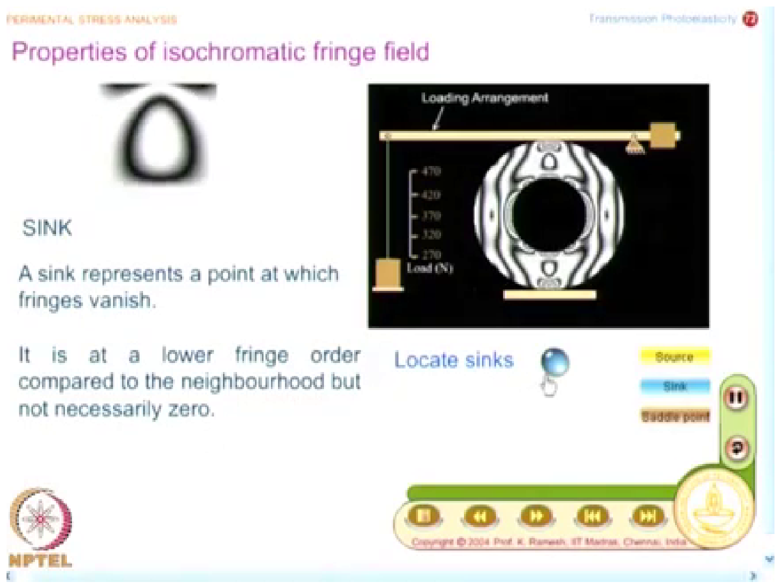

I have already mentioned that fringe ordering in a ring under diametrical compression is really complex, and what is shown here is I have a conventional loading arrangement of a lever on loading, and in this the load is changed. So essentially what you have is load is increased and fringes formed and then move out, and what I have here is I have the inner surface of the ring is a free surface as well as outer ring except the load application points is free surface.

And what you find here the fringes field is very complex do not carry the impression you had seen in the problem of disc under diametrical compression, where you had the outer boundary accept the load application point fringe order was 0, so you should not conclude that any free boundary you will have fringe order 0, it is not so. It was a very special problem even theory of elasticity solution said that outer boundary the fringe order is 0.

Here, I have a ring under diametrical compression I look at the outer boundary and inner boundary I have the several fringes which touch the outer boundary as well as the inner boundary, so you have to find out the fringe order very carefully. And we had seen in the last class a particular feature what happens in these type of zones we have looked at that fringes vanishes at this point as a load is increased fringes appear and they vanish at this point.

And I said akin to your fluid mechanics you could call these points as sinks, so from this knowledge what you get what is the fringe order at sink, one common mistake people will do is sink is 0 it is not 0, it is only at fringe order lower than the neighborhood, because what you find is as the load is increased the fringes develop and they go and vanish at the sink, so this is what you are really looking at.

And the other feature what we have looked at is we have points where fringes originate, I have the fringe originate here, I have fringe originate here, I have load application point, and they move out. And I also caution that you have a fringe vanishes here and you have another situation where this fringe does not vanish it remains in its place and as the load is increased the density in its neighborhood increases.

And I would also mentioned that such a fringe is essentially a 0th fringe order it does not move as a function of the load application, and we would find out this identification of 0th fringe order by other methods also. If I take a color image of the fringe pattern using white light as a source then a black spot in a circular polariscope will definitely say it is 0th fringe order, if we have white light source if you able to look at it, it is well and good.

But if you do not have you should also have methodologies to identify what is this 0th fringe order, but in this case even if I know the 0th fringe order we do not know how the gradient is along this direction, there is no way I can label the fringes, understand how complex this fringe field is. So what we will see is we will look at the definition of this sink that is what we have seen first, and you have a sink here you have a sink at the bottom also.

A sink represents a point at which fringes vanish, and how do you get this only when you gradually increase the load, you would be able to identify whether it is a source, sink or a saddle point. These are all functions of fringe formation as the load is increased, otherwise by giving a static picture you would not be able to identify unless your eyes is tuned here there could be a possibility of sink, possibility of a source, possibility of a saddle point, you would not be able to quickly say that this is so.

So if you want to reconfirm this gradually increase the load and decrease the load, and find out whether it is a sink or a source or a 0th fringe order that you have to find out very carefully. And what you will have to keep in mind is sink only says it is at a lower fringe order compare to the neighborhood but not necessarily 0, if the load is such you may have 0th fringe order there is no bar that sink should not be a 0th fringe order, it depends on the particular load that is applied, it is at a lower fringe order.

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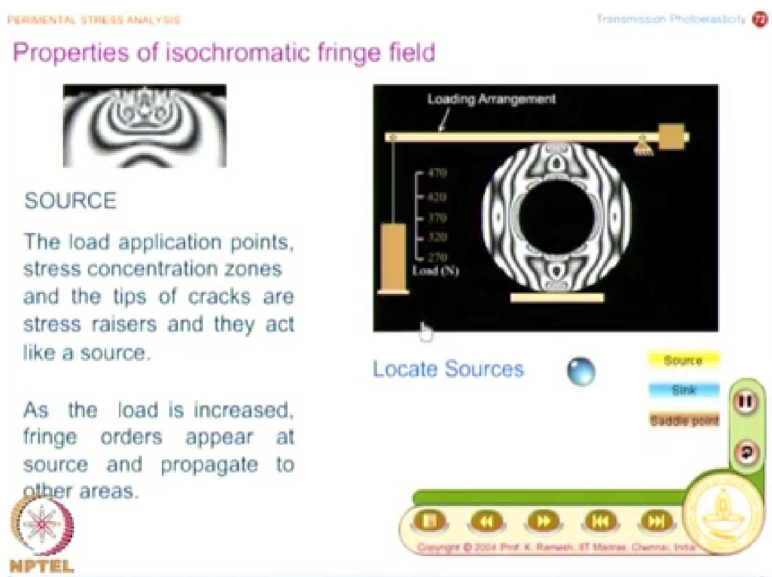

And we have also look at what is the source, source by definition you have the load application points, you have the stress concentration zones, and the tips of cracks are stress raisers and they act like a source. So what happens is when you increase the load the fringes start to appear from the source and move out as the load is increased, so these are the fringes that comes first when load is applied.

As the load is increased fringes originate and if you label the fringe order and the fringe order moves with the fringes as the load is increased, and you have many such sources in the case of ring under diametrical compression, and you can also locate the sources I have not located all of them this gives you an indication how to go about and locating the sources. And this is the key point as the load is increased fringes orders appears at source and propagate to other areas.

So if I labelled the fringes I can trace it label as it moves out. And finally you have another fringes feature which you could have identified in isochromatic fringe field it is a saddle point, that comes directly from how does the saddle is? In a saddle you have a one direction the curvature is like this, so the fringe order should increase on either side and on other side the fringe order should decrease.

So you sit in a horse saddle similarly, you have a saddle point with this definition can you recall is there anything special about circular disc under diametrical compression, we have looked at circular disc the fringe pattern was very, very simple it is very academic, we had only the minimum number of fringes loops it is easy for you once identify the 0 you have a point where load is applied the fringe order is increasing and labelling was so simple 0, 1, 2, 3.

You would see that was simple only when you comparing it with ring under diametrical compression, if you do not see ring under diametrical compression you would not be able to appreciate that, and we have actually used circular disc to find out the materials stress fringes value, we also found out what is the fringe order at the center of the circular disc. What happens in the center?

If you go diametrically up I have load application point so fringes orders increase on either direction, so it is like you know I have this bass fringe order is increasing like this on one direction fringe order is increasing on other direction, on the horizontal diameter you have a situation fringe order this is the base fringe order decreases, so center of the circular disc is the saddle point fine. And in that case I could find out this has 2 orthogonal lines, it is not necessary it is always orthogonal.

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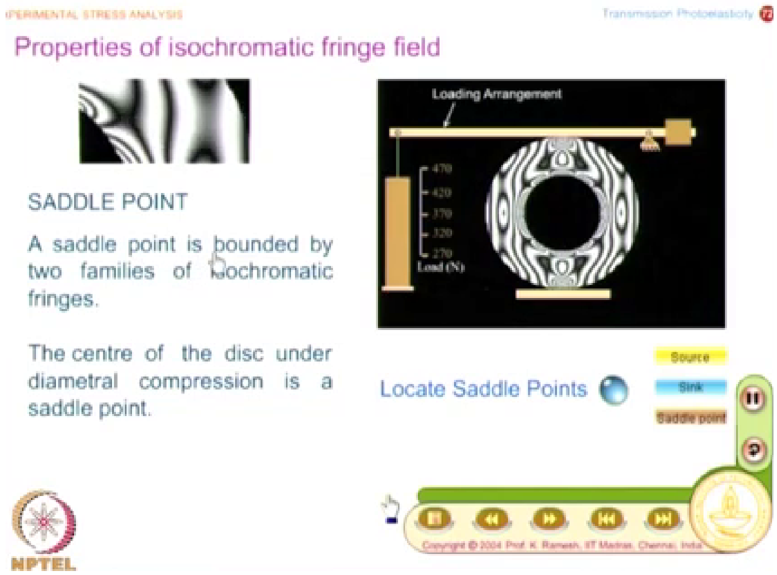

So we will see what is the saddle point? Having looked at circular disc center is the saddle point, a saddle point is bounded by 2 families of isochromatic fringes, so in one direction you will have fringes increasing, in another direction fringes will be decreasing, so it is essentially gives you the gradient information. So I should identify saddle points in the field and this is more to check suppose, I have ordered the 0th fringe order and then I am moving from 0th fringe order and I label it.

If I identify a saddle point and if we count a check from the saddle point what I do both should match, if it is not matching then you will have to go back and find out what mistake you have done, so it acts more from a verification point of view. And what you have here is we will also look at some of these aspects, what I will do is I locate saddle points and then magnified this picture, and then look at the feature.

So what I have here is you now the fringes merge like this, so you have this kind of a feature so wherever you have this feature you have a saddle point located, I have another feature saddle point is located, and you know this is the source, and this is also like a source, if you look at a line like this fringe is increasing, if you look at a line like this fringe is decreasing and similarly, fringes are decreasing in this direction.

So it is like a curve here it is not like a perpendicular line like what you see in a circular disc, so you can quickly appreciate that wherever the fringe appears like 2 branches they merge and go all those points are behaving like a saddle point. So how many saddle points I have now? I have 2, 4, 6, 8, 10 and 12 saddle points we have identified in a ring under diametrical compression, and this is more like verifying how to check the ordering of fringes.

Because saddle point we know in one direction the fringes should increase, in another direction fringe should decrease, so whether this feature is captured is what we will have look at, and all along you know we have not bothered about what is the sign of the boundary stresses, we have looked at beam under bending, we have looked at ring under diametrical compression, how do you identify whether a sign change we will have a methodology to find out separately, we can also look at from a fringe feature.

Suppose, I have a 0^{th} fringe order on the boundary, how can you pass through 0, when I pass through 0 I need to have sign change, so we will also identify certain points on the outer boundary as well as certain points on the inner boundary where the fringe order is 0, I would be able to do if I look at the isoclinic fringes field. On the other hand, in the case of a circular disc you had the entire outer boundary was 0th fringe field.

Here, you are not having the entire outer boundary as 0th fringe order, you only find out just 4 points I have a 0.1 here, 0.2, 0.3 and 0.4 if you look at very carefully as load is increased you know this fringe order remain as such if your eye is tuned that is the reason why I keep this animation for such a long duration you find this is getting compressed into this that is becoming sharper and sharper still have a fringe.

So any fringes that does not change as a function of the load is a 0th fringe order, and a similar fashion you also have 0th fringe order on the inner boundary it is difficult to observe, if you look at here as the load is increased the density of the fringe is increases, and this is again a 0th fringe order. We will verify this by a property of the isoclinic fringes field, and what you find here is I have 4 points in the inner boundary 1, 2, 3, 4, and 4 points on the outer boundary 1, 2, 3, 4 where the fringe order is 0.

And fringe order is also 0 at these 2 points, whenever I cross the fringe order 0, the sign of the boundaries stresses changes on the boundary you have to understand that, when I cross 0 I can cross only when there is a sign change, and you have 2 sinks in the ring under diametrical compression. So now what we will look at is we will look at what are all the properties of the isoclinic fringes field.

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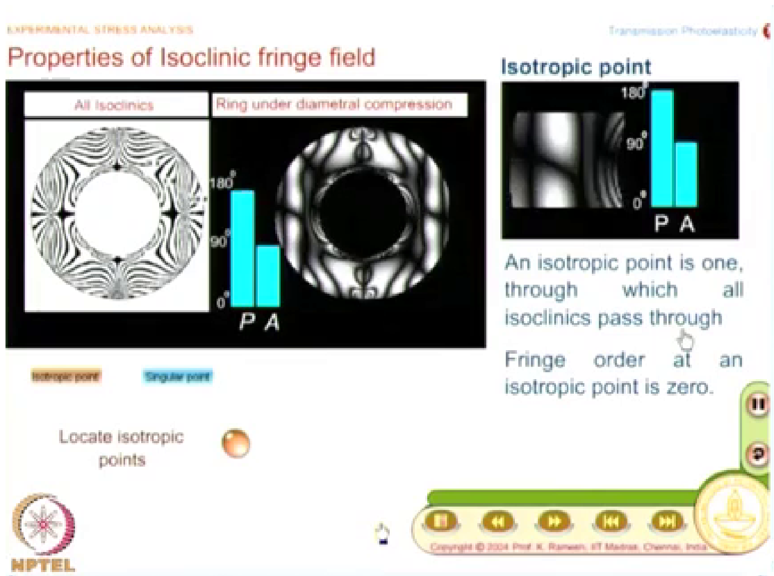

And here again I have nice animation for a fixed load, you have the polarizers which are kept crossed are rotated, and what I want you to see is look at the animation, in this class there are more of observation and less of notes taking, you have to appreciate how the whole fringes appear. There are many features you find you know what is happening at this point? And what is happening at this point? Very interesting there is something is happening.

What is happening to this branch of isoclinic? The isoclinic actually rotates in an anti-clockwise direction, I have all the isoclinics passes through the point do not you find that, because here I have I am continuously rotating the polarizer analyzer combination crossed, and what do you find is you always have an isoclinic passing through this point of interest, and you also find the 4 points which I said in the outer boundary here also all the isoclinic passes through the point of interest.

The many things you can understand you know this is happening in the particular fashion, you know the way as the polarizer analyzer combinations rotated here all isoclinics pass through, but it moves in a particularly different fashion, then what you find in this, here it is anticlockwise here it is clockwise okay. And similarly, even if you look at the points which are in the inner boundary can you see this point, this point was difficult to locate in a isochromatic fringes field.

And here I have one point where all isoclinics pass through do you see that, this is the observation I want you to make, and this is possible in an animation like this, it is difficult to do it in actual laboratory class unless you very intently see this, can you see this point I have the cursor located at this point you find all isoclinics pass through this, when I rotate the polarizer analyzer combination. Suppose, I take a point here one isoclinic comes and goes that is all.

A particular isoclinic comes and goes at this point, on the other and you always have a isoclinic at this point, so this itself gives you an indication how to identify the 0th fringe order, you have an appreciation on that we will see that in detail. So to aid your visualization I have also plotted the isoclinics in steps of 10 degrees and this summarizes some of the observation you will see those observation.

And what I find here at this point all isoclinics pass through, at this point all isoclinic pass through, and at this point you have all isoclinic pass through, likewise you will see. But I also have another 2 points where the isoclinic originate, suppose you look at the load application points there are also all isoclinic merge, so you have made these observations, first you make the observation then we find out and classify what are all the different fringes features.

And this animation also shows that I have the polarizer analyzer crossed and they are rotated that is how you are seeing these isoclinics moving through the fringe field. Now what we will do is we go and see, what is an isotropic point? An isotropic point is one through which all isoclinics pass through, you have already seen I have already help you to tune your eyes to see that there are points in the model domain where all isoclinics pass through.

Since you have seen that now you can appreciate this point, and you have the advantage fringe order at an isotropic point is 0, see here I tried to find out property of an isochromatic fringe field by looking at an isoclinic fringe field. I can verify I can switch back and forth and then verify this is 0th fringe order, there is also methodologies to verify 0 order even in a circular polariscope.

But if you have a confusion you can always verify it, you always need some verification. So what we find here is isotropic point is one through which all isoclinic pass through, and whenever you have a rule there will be an exception. The load application points are not to be considered as isotropic points.

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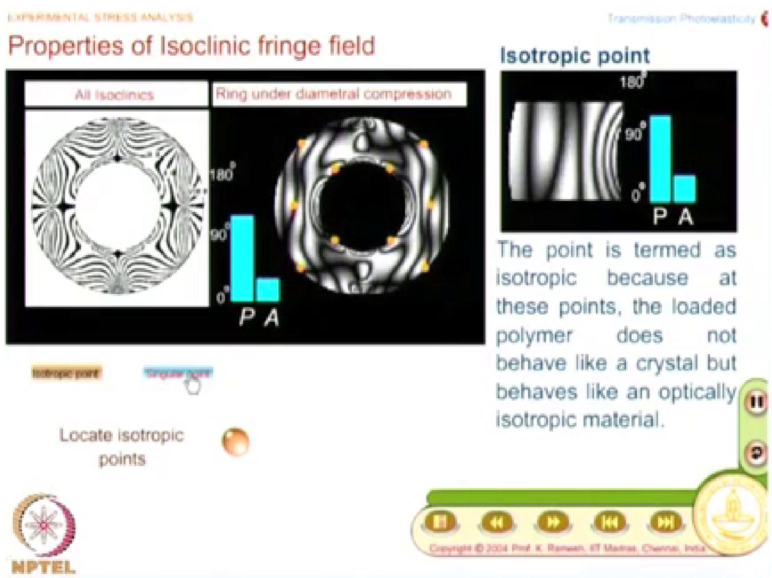

And why do you call this as isotropic point? It is termed as isotropic because at these points the loaded polymer does not behave like a crystal but behaves like an optically isotropic material, every axis is principal stress direction. You have even when you do the principal stress direction evaluation you can have a situation every direction is a principal stress direction that is what is happening in an isotropic point, so you have several isotropic points located.

The isotropic points are also now marked in the fringes field, and you can have a look at it, so what I have here I have 4 of them 1, 2, 3, 4 on the outer boundary, I have 4 of them in an inner boundary 1, 2, 3, 4 and 2 in the horizontal diameter of the ring. So you have only at this points fringe order is 0, look at here the complexity is manifold in a ring under diametrical compression.

“Professor - student conversation starts” yes, (()) (32:02) do we have this isotropic point? You do not have an isotropic point. We do have 0th fringe order, that is not the intention there, see the definition of the isotropic point is where all the isoclinic passed through, in fact I given you this as the home exercise where the circular disc is so special I said isoclinic will be meet the boundary at what angle. So each point on the boundary you will have 1 fixed isoclinic meeting.

Whereas in an isotropic point all isoclinic pass through do not carry the information that 0th fringe order means all isoclinic pass through know, the contrary is not true, when all isoclinic pass through fringe order is 0 you take that statement, do not look at the other statement. I take the beam under bending I have 0th fringe order at the horizontal, you have only one isoclinic there is no isoclinic.

Because isoclinic is horizontal in case of a beam 0th isoclinic only pass through, so if you want to find out the 0th fringe order takes the queue that if all the isoclinic pass through that point is 0th fringe order, do not use this for 0th fringe order, do not look for more isoclinic to pass through in every 0th fringe order. There are special situations, the special situations are what you see in a beam under bending and disc under diametrical compression, these are exceptions.

You should not mix up exceptions with the general rule, it is good that you ask that question, it is a very valid confusion that you can come across **“Professor - student conversation ends.”** And so I have 10 isotropic points have been identified, and you know we also sub classify you know what you look at here is when I have an isotropic point lying on the boundary I will label it by another name, I call it as the singular point.

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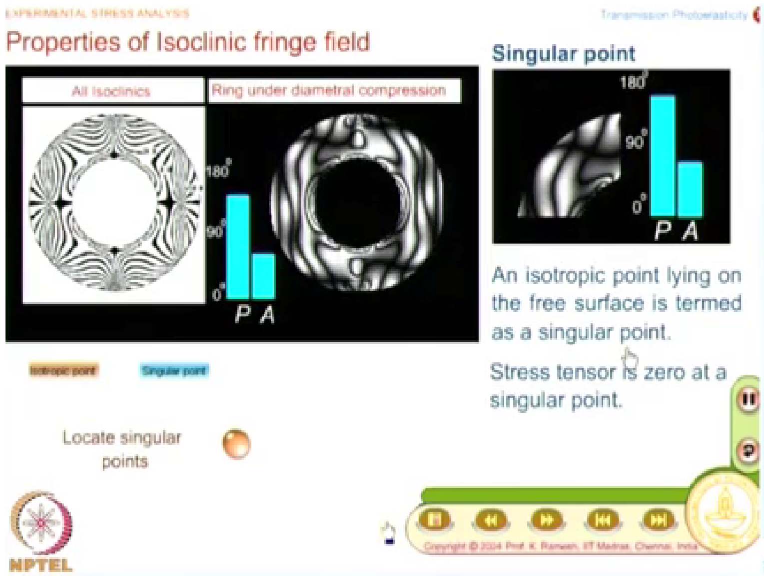

So what we say is an isotropic point lying on the free surface is termed as a singular point, so what happens in a singular point? We not only have fringe order 0 but stress tensor is also 0, why it is 0? Because it is a free surface there is no stress acting perpendicular to the direction it can only be tangential and you do not have anything perpendicular that is 0, when fringe order is 0 it only implies sigma 1=sigma 2.

The students will have a confusion when I say 0th fringe order everything is 0 this is one wrong conclusions you can think of; it only implies sigma 1=sigma 2. Suppose, I have a 0th fringe order on a free boundary stress tensor is also 0, and that is indicated by a singular point, and if I locate the singular point you itself know there are 8 such singular points in the ring under diametrical compression.

So now you have a fairly good idea, what is the source? What is the sink? What is the saddle point? And what is the isotropic point? And what is the singular point?

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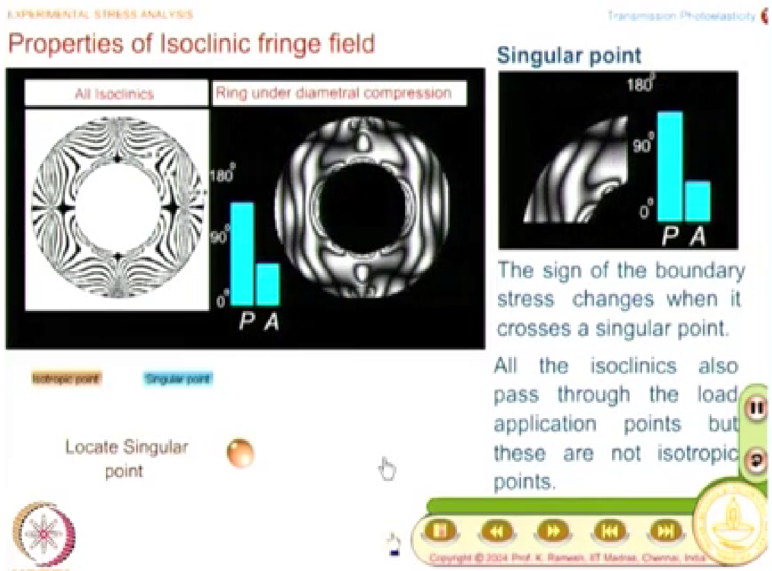

And we have also made one small distinction that when you look at the isotropic points, you find that the isotropic fringes move in a particular fashion we will see what it is.

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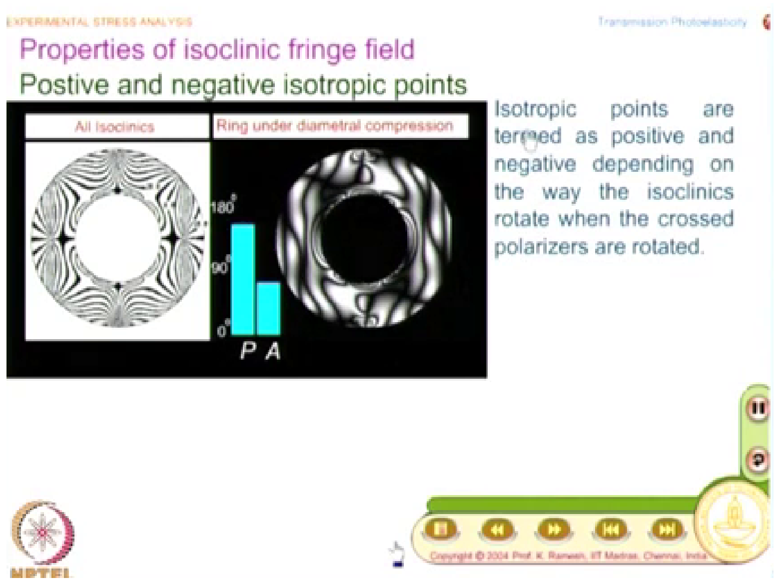

There is a special distinction you also classify them as isotropic points are positive and negative depending on the way the isoclinics rotate when the cross polarizer is rotated, and that is what you have seen very carefully there is a particular aspect happens at this point when I rotate they rotate in a same fashion as the polarizer analyzer combination, and you have a simple labelling you know you called this as a positive isotropic point.

And I will call the other one has negative isotropic point, I just classify I only want to record my observation that in one cares when I rotate the polarizer as a combination the isoclinic also changes in the same fashion in the point of interest, there is a synchronization between the way I rotate and the way you see the labelling of isoclinics you have that as positive isotropic point. And you have to have what is the ultimate use of it, see all this is to verify your labelling of fringes.

I can label the isochromatic fringes, I can also labelling the isoclinic fringes. In a isoclinic fringes you have to plot them separately and then do it you can take a photograph, you have taken multiple photographs extract isoclinic and separately prepare a composite image, and in the process you may make an error, and what you find here is I can zoom it and then show, see if you look at I have a point here, I have another isotropic point here, I have another isotropic point here.

Here, something interesting happening, when I move from this isotropic point to another isotropic point in between the sign changes that is how it will appear, so this is a nice queue for you to verify whether you have label the isoclinics correctly, and it is very interesting to know you know it is better to know some of these aspects.

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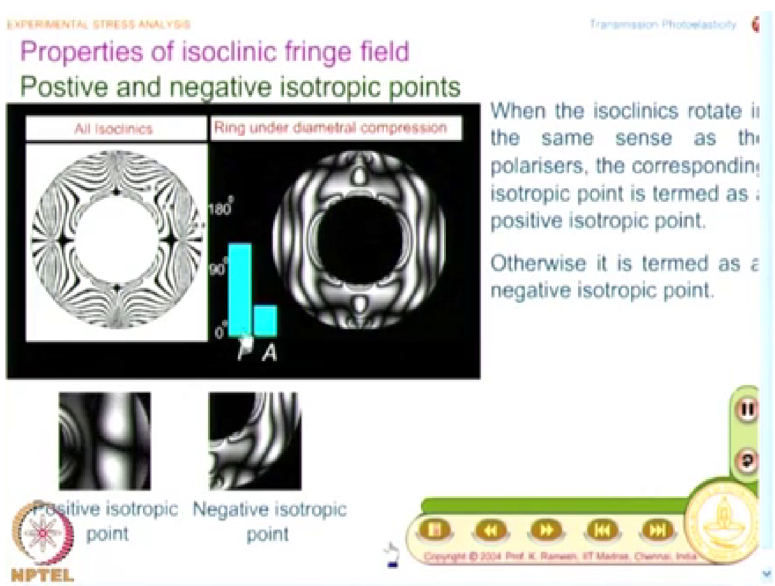

So you will always have these isotropic points in a combination, we have seen what is the positive isotropic point, we have also seen what is the negative isotropic point. This is rotating anticlockwise and this is rotating clockwise, and I rotate the polarizer analyzer combination in an anti-clockwise fashion, so when that sense and this sense matches I called that as a positive isotropic point, I called the other one as a negative isotropic point. Are there any questions at this stage?

You know fringe ordering is the most complex, and we would see further what are all the other aspects of Solid Mechanics that I can employ? Now you have seen the fringes field they are very rich animations, and I am sure you would have got a gist of what this fringe orders are.

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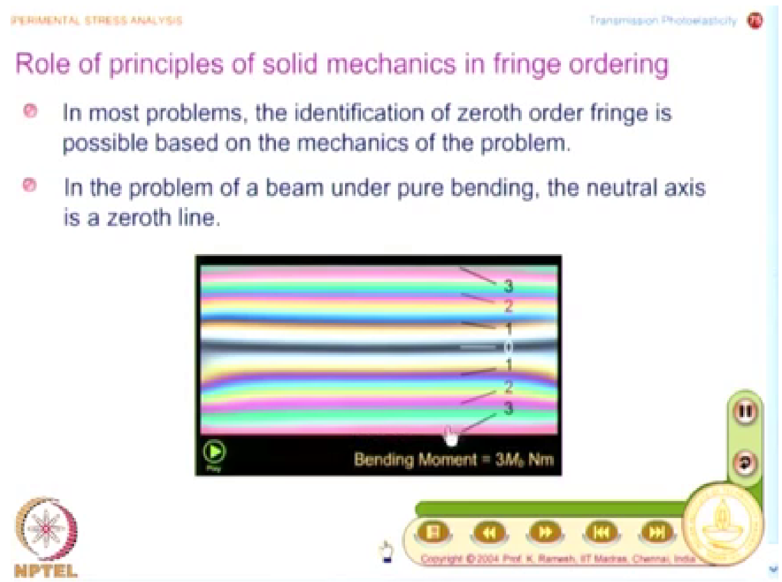

And this is what I have said that in most problems identification of 0th fringe order is possible based on the mechanics of the problem, see if I have this 0th fringe order, and if I know the gradient information it is possible for me to label the fringes. And I can get the gradient information by looking at a color code, and once I mentioned 0th fringe order let us also look the exceptions, because that was also discussed briefly when we looked at properties of isochromatic and isoclinic fringes fields.

So in the problem of a beam under pure bending, the neutral axis is a 0th line, it is not just a point you have a complete line which is a 0th fringe order. And because of the luxury of the multimedia you can quickly see what is happening in a beam under bending, and what I have here I have the 0th fringe order at the center, while we looked at beam under building we never bothered to look at as the load is increased this remains stationery.

Now you have seen this ampliclear for the case of a ring under diametrical compression, now I increase the load, the density increases in this zone, whereas fringe order 1 has moved, fringe order 2 has appeared, but fringe order 0 does not move, this is a very important observation. And another question we have not raised all along, I said you have fringes orders only has positive integers in photoelasticity, neither you ask me how to find whether it is tension side or compression side by looking at the fringe order alone.

We will see a methodology experimentally, but because it is a simple problem if you know how you have applied the load, if you applied the load like this it is bend like this, so the top fibre is compression bottom fibre is tension that we know, but in general you have to do auxiliary methods to find out the sign of the boundary stress, because as such fringe order has no negative sign fractional fringe order has not the total fringe order.

Total fringe order you may say 1.23, 1.24 you will always attach a sign as positive, because sigma 1-sigma 2 is always positive, so this also you need to learn as part of fringe ordering as part of understanding what is the stress analysis information, we also need to know whether it is tension or compression we will postpone that discussion for the time being.

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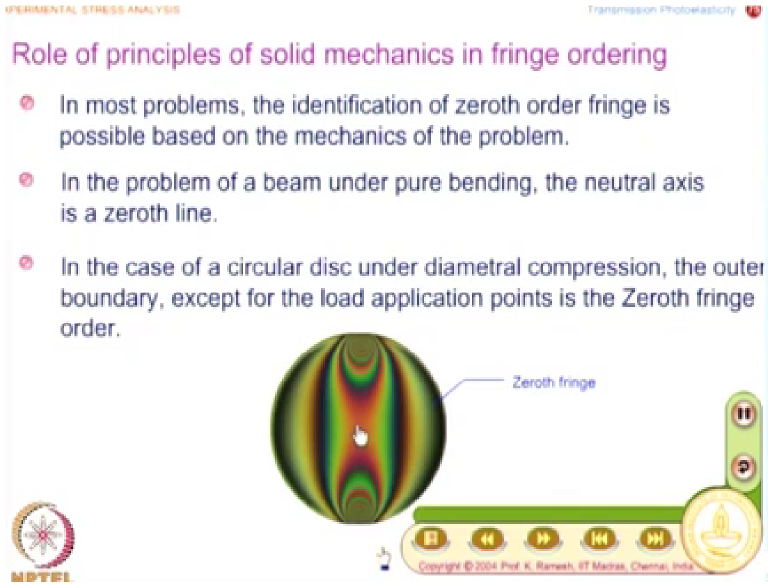

And what are we seen in the other case we also look at circular disc under diametrical compression it is again a special case except the load application points you have the outer boundary as 0th fringe order that is again special case, do not confused special case with the general rule. So this turned out to be a very simple problem for fringe ordering very simple beam under bending and circular disc are the simplest problems you can think of.

Where I have multiple fringes and I can also label them one after another comfortably, so I have this as 0, 1, 2, 3 and so on, and this is your saddle point because fringes increase in this direction, fringes increase in this direction, fringes decrease in this direction and fringes decrease in this direction. So this is also like an indirect check.

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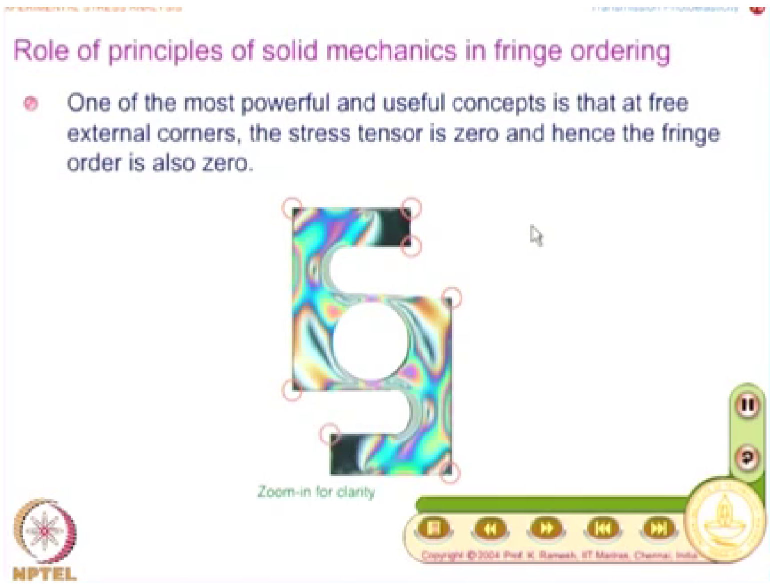

And you know we have seen as part of your assignment I have asked you to find out what happens in free external corners, and you had seen mathematically from the definition of stress vector and also you have identified stress tensor has to be 0 on free outward corners, and this is the very useful information in complex problems. So I am also taking you from simpler fringe field to more and more complex fringes fields.

In fact, I am going to show you a load cell 2 dimensional model, where you have taken the fringes with white light, even with white light the fringes are very complex. I said if you use white light you have use rich colors, and it is easy to label the fringes even there the fringes field is complex, we will see that. I have this here and you know I have this fringes field and this is used in many popular load cell design this is the spring element and they would have strain gauges put inside this boundary of the hole and this also can be hermetically sealed.

And what I have here is this is subjected to the compression along this direction and this direction that is what you see here, and there is no load applied here so I have a free external corner, I have a free external corner, I have a free external corner, and look at carefully in all these free external corners I have the fringes as black. And you see a black line here, so this is again a 0th fringe order, this is again a 0th fringe order here, and in between you see a point where there is a 0th fringe order.

So this gives you an indication it is not that 0th fringe order you have a line all along the model or line all along the boundary like in a circular disc you may have pocket certain points has 0, you may also have some line some points, so fringe ordering becomes extremely complex. And I have a nice color code and you know all know, if I have a blue red transition what is the fringe order here? This is fringe order 1, I have 0 I have 1, I have 0 I have 1.

Because this is the source so fringe order increases in this direction, and if you look at here the fringe order also increases in that direction, so this is how you find out and you find out how to label the fringes. And let me ask one more one more question, you had also seen long time back fringe order in the case of a plate with a crack, you had seen color fringes, you go back and see your notes where was the 0th fringe order.

I have a tension strip, I have a crack, and I have loaded it, because you know when you learn some of these concepts you only see what you want to see. I have not asked you to certain features in those classes, I had only forecast that when I have a plate with a circular hole, when I have a plate with an elliptical hole, when I have a plate with crack, the fringes density will be very high at the tip of the crack that was emphasized.

But we have not looked at numbering the fringes, now we had discussion on numbering the fringes, go and look at your fringe pattern and find out what should be the 0th fringe order, take this as a home exercise, and then label the fringes in the case of crack, in the case of a crack problem if you know 0 you know the stress concentration point, so it is easy to label the fringes you do not need anything beyond that.

But on the other hand if I have to go and identify the fringe order in the case of plate with a hole it is little tricky, plate with a crack is simpler to label the fringes, plate with a hole it has certain features common with ring under diametrical compression. So this is the way you have to go about. So in this class what we are looked at was, we had reviewed, what is the advantage of using intensity information in identifying the fringes skeleton?

How the methodology becomes very simple and computationally efficient in the beginning, and you need to find out F sigma, so we have looked at F sigma a methodology utilizes the field information, and we also looked at the digital technique which provides you the field information. Then we moved on to finding out the fringe order, we looked at the isochromatic fringe field, we looked at the isoclinic fringe field. And we saw certain aspects of isochromatic fringe field can be understood by looking at the isoclinic fringe field.

And later we also developed what concepts of Solid Mechanics you could utilize to identify the 0th fringe order, if I have the 0th fringe order and if I also know the gradient it is easy for me to label the fringes, and once a labelled the fringes as a verification you can utilize the properties of isochromatic fringes field, properties of isoclinic fringes field, to double check whether your labelling is indeed correct, though this may look redundant in these days, where you have software to provide you information.

Like I said both in finite element technique and in experimental methods computer should be used to assist you, you should not blindly believe what the algorithm says, because if you have done wrong boundary conditions or wrong interpretations of your experimental results, you can go wrong, you should know how to do and verify the results. So the methodology of fringe ordering will help you to verify even your result from an automated software that provides you fringes order.