

Experimental Stress Analysis
Prof. K. Ramesh
Department of Applied Mechanics
Indian Institute of Technology, Madras

Module No. # 02

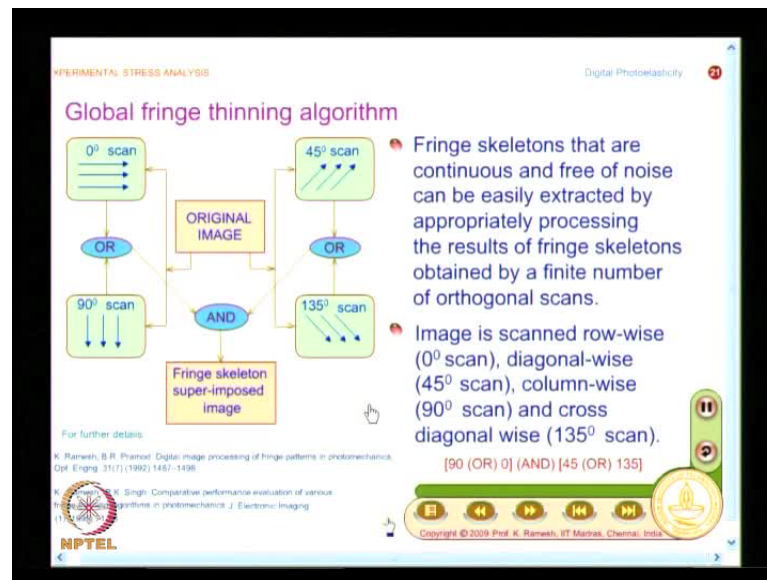
Lecture No. # 22

Fringe Ordering in Photoelasticity

Let us continue our discussion on transcription 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 fringe value. And since we are in the digital era, where computers are very well used for many applications, 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 the direction, we have also developed the linear least squares approach, which collects data from the fringe field, utilize this information and then finds out the material stress fringe value as accurately as possible. We have also looked at the methodology so well developed, that the collection of data points should not influence a final result. So, you do a statistical conditioning, and I set for any of those procedures, it is better that we go and utilize digital image processing techniques for extracting the data for you to analyze. 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 the fringe skeleton, people only had techniques in the initial stage as to mimique what we do manually. So, one of the earliest techniques in that direction was to identify the fringes areas as binary information black and white and within the fringe to identify the skeleton by removing the out of pixels progressively.

(Refer Slide Time: 03:40)



They essentially extended principles of optical character recognition to process the fringe pattern. And the whole process depends on what is the maximum thickness of the fringe in the field, you have a do standing left to right, right to left, top to bottom, bottom to top and this is essentially in iterative process. And at end of the iterative process, though you get the skeleton, you are not granted whether these skeletons merge with minimum intensity points, because in a broad of fringe, the answer may be slightly different. So, one way of 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 and we have only looked at a global fringe thinning algorithm. This is of a different approach, and what the focus is, fringe 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 four scans, I have 0 degree scan, 45 degree scan, and 90 degree scan and finally, one 35 degree scan, and if you really look at them, they were essentially orthogonal scans. I have 0 degree scan, and 90 degree scan, and what you found was when you do 0 degree scan, it identifies fringe areas, as well as gives you noise. And if you look at 90 degree scan, it identify some fringe skeletons and also noise, but when I do OR operation, I get complete fringe 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 the OR operation, you get the complete fringe 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 have written only the fringe skeleton, and the noise is eliminated, this is the greatest advantage. So, the whole procedure can also be simply labeled as $90^\circ \text{ OR } 0^\circ \text{ AND of } 45^\circ \text{ OR } 135^\circ$. And if you want to get further details, you could look at in these references; these are essentially published in 1990s.

And the first paper deals with the essence of the algorithm, the second paper is 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 photoelasticity images are concerned, photoelasticity images are very high contrast and it **is** make identification of fringe areas **are** very simple and used the minimum intensity position to extract the skeleton. And I also mentioned, in a complex fringe pattern like what you have in a chreptipsochromatics, instead of doing the scan orthogonal to the fringe area, I set four scans, globally can identify the curvature also, even with different curvatures of the fringe, the skeleton could be extracted.

(Refer Slide Time: 07:52)

EXPERIMENTAL STRESS ANALYSIS

Transmission Photoelasticity

Comments on Fringe Ordering

- Methods to ordering fringes could be formulated on the basis of properties of isochromatic fringe field, isoclinic fringe field and also certain principles from Mechanics of Solids.
- A ring under diametral compression represents various important aspects of a general fringe field such as source, sink, saddle point, singular point and isotropic point.
- Source, sink, and saddle points correspond to isochromatic fringe field and singular and isotropic points correspond to isoclinic fringe field.
- It is to be noted that there is no standard procedure to order fringes.

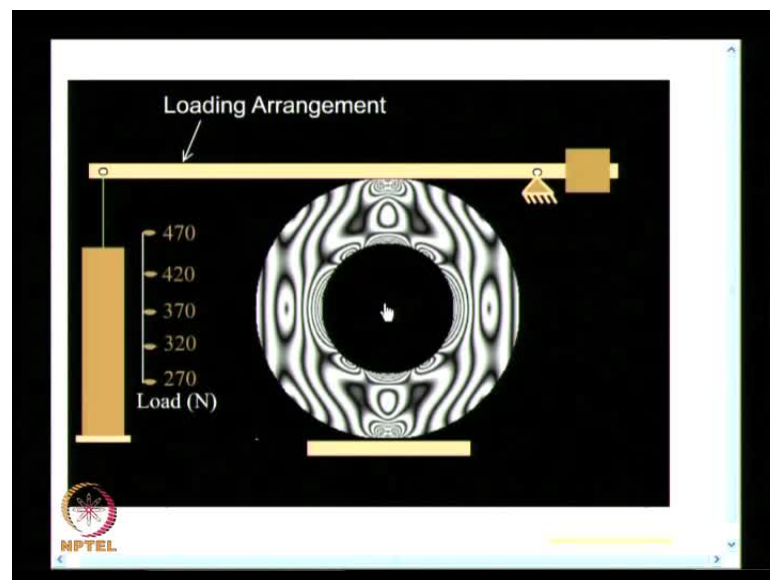
NPTEL

Copyright © 2004 Prof. K. Ramesh, IIT Madras, Chennai, India

And here you do intelligently utilize the logical operators, and you extract the fringe skeleton. And the next topic, what is **the** important is, we have $n F \sigma$ by h equal to σ_1 minus σ_2 , we have seen how to get $F \sigma$, 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 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.

See, one of the important aspects in any of the optical techniques is to find out how to label the fringe orders. And in photo elasticity, you can get assistance in labeling the fringe ordering by looking at properties of isochromatic fringe field, properties of isoclinic fringe 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 fringe pattern, and label the fringes; this knowledge would complement your further learning.

(Refer Slide Time: 09:48)



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 fringe

field, singular anisotropic points, correspond to isoclinic fringe field. And it is to be noted that there is no standard procedure to order the fringes, these have 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 diameter compression. I had already mentioned that fringe ordering in a ring under diametric compression is really complex. And what is shown here is, I have a conventional loading arrangement of a reverlong loading, and in this, the load is changed, so essentially what you have is the load is increased, and fringes form and then moves out. And what I have here is, I have the inner **the** surface of the ring is free surface, as well as outer ring except the load application points, it is a free surface. And what you find here, the fringe field is very complex, do not carry the impression, you have seen the problem of disk and diametral compression, where you have the outer boundary, expect the load application point, fringe order was 0.

So, you should not conclude that for any free boundary you will have fringe order 0, it is not shown, it was a very special problem, even theory of elasticity solution is said that in outer boundary the fringe order is 0. Here, I have ring and diametral compression, I look at the outer bound and inner boundary, I have several fringes which touch the outer boundary as well as inner boundary, so you have to find out the fringe order very carefully. And we are seen in the last class a particular future, what happens in these type of zones, we are looked at that fringe vanishes at this point, as load is increased, fringes appears and they vanish at this point. And I said kin your fluid mechanics, you could call these points as sinks.

So, from this knowledge what you get? What is fringe order at the sink? One common mistake people will do is sink is 0, it is not 0, it is only at a fringe order lower than the neighborhood. Because what you find is as the load is increased, the fringes develop and **the** go and vanish at the sink, so this is what we are really looking at. And other future what we have looked at is, we have points where fringes originated. I have the fringe originate here, I have fringe originated here, I have the load application point and they move out. And I also caution, but you have a fringe vanishes here, and you have another situation, where this fringe does not vanish, it remains in it is place, and as the load is

increased, the density in its neighborhood increases. And I also mentioned that such a fringe is essentially a zeroth fringe order, it does not move as a function of the load application. And we would find out this identification of zeroth 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 the zeroth fringe order. If you have white light source, you were able to look at it, it is well and good, but if we do not have, you should also have methodology to identify what is the zeroth fringe order. But, in this case, even if I know the zeroth fringe order, if I 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 had seen first.

(Refer Slide Time: 13:57)

EXPERIMENTAL STRESS ANALYSIS

Transmission Photoelasticity 12

Properties of isochromatic fringe field

SINK

A sink represents a point at which fringes vanish.

It is at a lower fringe order compared to the neighbourhood but not necessarily zero.

Locate sinks

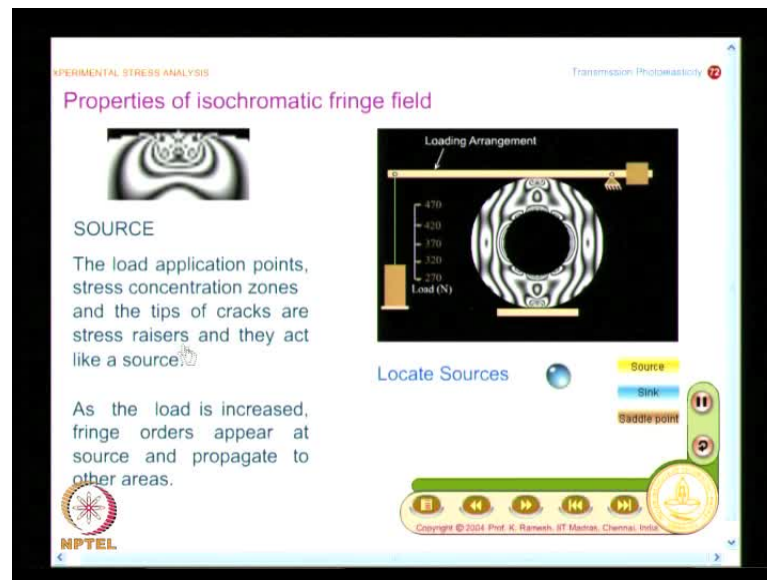
- Source
- Sink
- Saddle point

NPTEL

Copyright © 2004 Prof. K. Ramesh, IIT Madras, Chennai, India

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 eye is tuned, here there could be a possibility of a sink, possibilities of a source, possibility of a saddle point, you would not be able to quickly say that this is source.

(Refer Slide Time: 15:45)



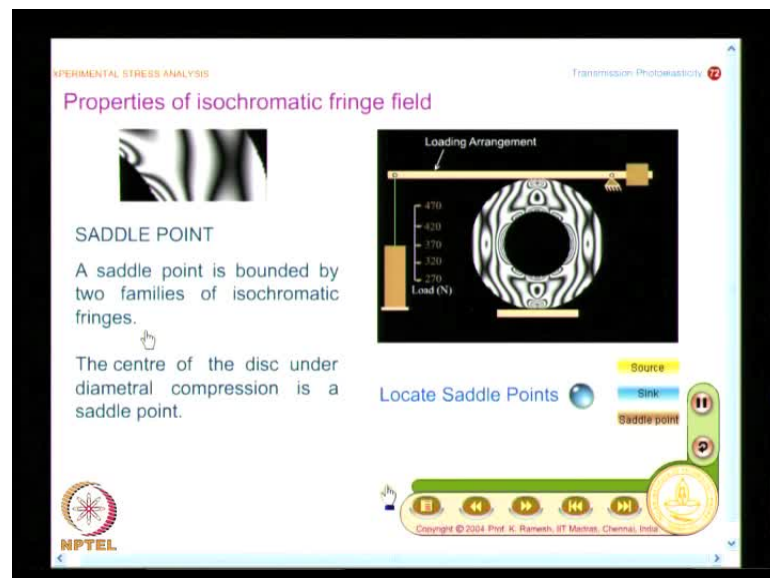
So, if you want to reconfirm this, gradually increase the load, decrease the load and find out whether it is a sink or source or a zeroth fringe order that you will have to find out very carefully. And what you will have to keep in mind is, sink only says it is at a lower fringe order compared to the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

And we have also looked at what is a 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 this source and move out as the load is increased. So, these are the fringes that come first when load is applied, as the load is increased fringes originate. And if you label a fringe order, and the fringe order moves with the fringe as the load is increased. And you have many such sources in the case of ring under diametral compression, and you can also locate the sources, I am not located all of them, this gives you an indication how to go about in locating the sources.

And this is the key point, as the load is increased fringe orders appear at source and propagate to other areas. So, if I label the fringe, I can trace its label as it moves out and finally, you have another fringe feature which you could identify in isochromatic fringe field, it is a saddle point that comes directly from how does a saddle is. Saddle you have

on one direction, the curvature is like this, so the fringe order should increase on either side, on other side fringe order should decrease. So, is it in a saddle, horse saddle, similarly you have a saddle point, with this definition can you recall is there anything special about circular disc under diametric compression. We have looked at circular disc, fringe pattern was very simple, it is very academic, you had only the minimum number of fringe loops, it is easy for you, once you identify 0, you have a point where load is applied, the fringe order is increasing and labeling was so simple 0 1 2 3. You would see that was simple only when you compare it with ring under diametral, if you do not see ring and diametral compression, you would not be able to appreciate that. And we have actually used circular disc to find out the material stress fringe 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?

(Refer Slide Time: 19:02)



I have loaded application point, so fringe orders increase on either direction, so it is like I have this base, 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, fringe order decreases, so center of the circular disc is the saddle point, fine, and in that case, I could find out this as **to** orthogonal lines, it is not necessary that it is always orthogonal. So, we will see what the saddle point is. Having looked at circular disc, center is a saddle point. A saddle point is bounded by two families of isochromatic fringes, so in one direction you will have fringe

is increasing, in another direction fringes will be decreasing, so it essentially gives you the gradient information.

So, I should either identify saddle points in the field, and this is more to check. Suppose I have ordered this zeroth fringe order, and then I am moving from zeroth 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 the saddle point, and then magnify this picture, and then look at the feature.

So, what I have here is, 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 here, where saddle point is located, and you know this is a source, and this is also like a source, if you look at, if you look at a line like, this fringe is increasing, if you look at a line like this fringe is increasing, and if you look at a line like this fringe is decreasing, and similarly fringe is decreasing in this direction. So, it is like a curve here, it is not like a perpendicular lines like what you see in a circular disc. So, you can quickly appreciate that wherever the fringe appears like two branches, they merge and go, and all those points are behaving like a saddle point.

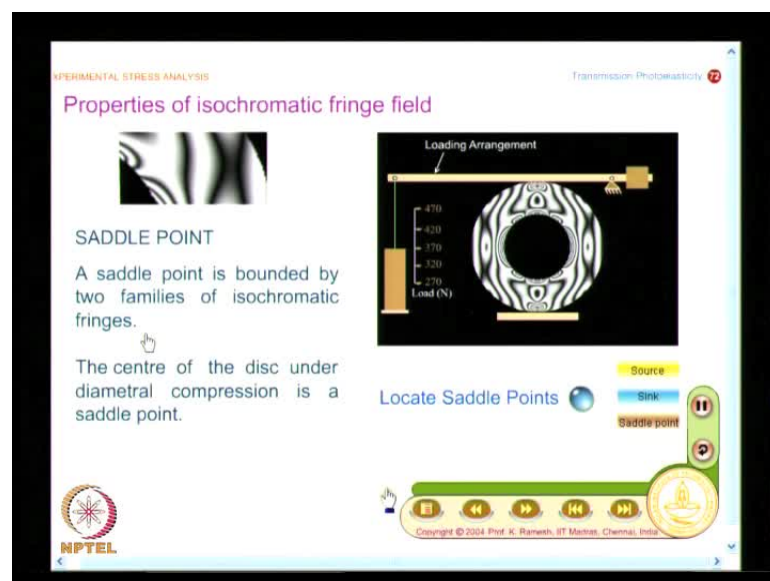
So, how many saddle points I have now, I have 2 4 6 8 10 and 12 saddle points, we have identified in a ring under diametric compression. And this is more like verifying how to check the ordering of fringes, because saddle point we know in one direction, **it** the fringe should increase, in another direction fringe should decrease. So, whether this feature is captured is what we will have to look at, and all along we have not bothered about what is the sign of the boundary stresses. We have looked at beam at the bending, we have looked at ring under diametric compression, how you identify **whether the** whether the sign change, we will have a methodology to find out separately, we can also look at for fringe feature.

Suppose, I have a zeroth 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 the certain points on the inner boundary, where the fringe order is 0. I would be able to do that if I look at the isoclinic fringe field, on

the other hand, in the case of a circular disc, you had the entire outer boundary was zeroth fringe order. Here, you are not having the entire boundary as zeroth fringe order, you will only find out just 4 points, I have point 1 here, point 2, point 3 and point 4. If you look at very carefully, as a load is increased, this fringe order remains 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 it is becoming sharper and sharper, you still have a fringe.

So, any fringe that does not change as a function of the load is a zeroth fringe order, and in a similar fashion also have zeroth 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 increases, and this is again a zeroth fringe order, we will verify this by a property of the isoclinic fringe field.

(Refer Slide Time: 19:02)

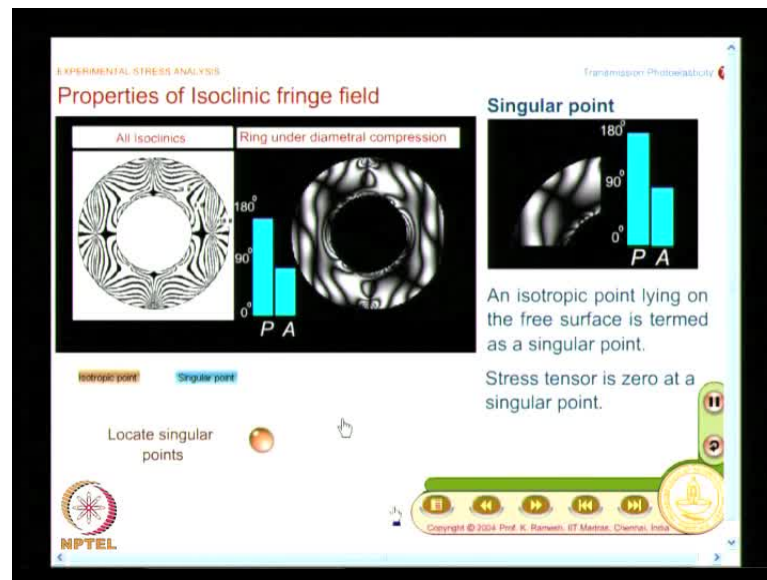


And what you find here is, I have four points in an inner boundary 1 2 3 4, and four points on the outer boundary 1 2 3 4, where the fringe order is 0, and fringe order is also 0 at these two points. Whenever I cross the fringe order 0, the sign of the boundary stresses changes on the boundary, you have to understand that. When I cross 0, I can cross only when there is a sign change and you have two strings in the ring under diametral compression.

Now, what we look at is, we look at what are all the properties of the isoclinic fringe field. And here again, I have a nice animation, for a fixed load you have the polarizers, which are kept crossed or rotated. And what I wanted to see is, look at the animation, observe, in this class there is more of observation, and less of notes taking. You have to appreciate how the whole fringes appear, there are many features you find, and what is happening at this point, very interesting, there is something happening, what is happening to this branch of isoclinic? The isoclinic actually rotates in an anticlockwise direction, I have all the isoclinics pass through the point, don't define that, because here I have, I am continuously rotating the polarizer analyzer combination crossed. And what you find is, you always have an isoclinic passing through this point of interest, and you also find the four points which I said in the outer boundary, which I said in the outer boundary, here also all the isoclinics passes through the point of interest. Many things you can understand, this is happening in a particular fashion.

The way as the polarizer analyzer combination is rotated, here all isoclinics pass through, but it moves in a particularly different fashion than what you find in this, here it is anticlockwise, here it is clockwise. And similarly, even if you look at the points, which are on the inner boundary, can you see this point; this point was difficult to locate in an isochromatic fringe field. And here I have one point where all isoclinics pass through, do you see that, this is observation I wanted 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 isoclinic pass through this. When I rotate the polarizer analyzer combination, suppose I take a point like here, one isoclinics comes and goes that is all. A particular isoclinic comes and goes at this point; on the other hand, you always have isoclinic at this point. So, this itself gives you an indication how to identify the zeroth fringe order, you have a appreciation of that, we will set that in detail.

(Refer Slide Time: 28:07)



So, to aid your visualization, I have also plotted the isoclinics in steps of 10 degrees, and this summarizes some of the observation, we will see these observations. And what I find here, at this point, all isoclinics pass through, and at this point you have isoclinic pass through, likewise you see, but I also have another two points, where the isoclinic originate. Suppose you look at the load application points there also all isoclinics merge, so you **are** made these observations. First you make the observations and then we find out and classify what are all the different fringe features. And this animation also shows that I have the polarizer analyzer cross and they are rotated, that is how you are seeing this isoclinic moving through the fringe field. Now, what we will do is, we will go and see what an isotropic point is. An isotropic point is one through which all isoclinic pass through, you are already seen, I have already help you to tune your eyes to see that there are points in the model domain, where all isoclinic pass through. Since, you are seen that now you can appreciate this point, and you have the advantage fringe order at an isotropic point is 0. See, here, I try to find out property of an isochromatic fringe field by looking at isoclinic fringe field.

I can verify, I can switch back and forth, and then verify this is zeroth fringe order, there is also methodology is to verified 0 fringe order even in a circular polariscope, but if I have a confusion, you can always verify it, you will always need some verification. So, what we find here is an isotropic point is one through which all isoclinics 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, and why do you call this is isotropic point; it is termed as a 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 stresses 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 fringe field, and you can have a look at it. So, what I have here, I have four of them, 1 2 3 4 on the outer boundary, I have four of them inner boundary 1 2 3 4 and 2 in the horizontal diameter of the ring. So, you have only at these points fringe order is 0, look at here, the complexity is many foal in a ring and a diameteral compression, yes.

Other one

Yes

doing have this isotropic point

You want have an a isotropic point

Do have zeroth fringe order

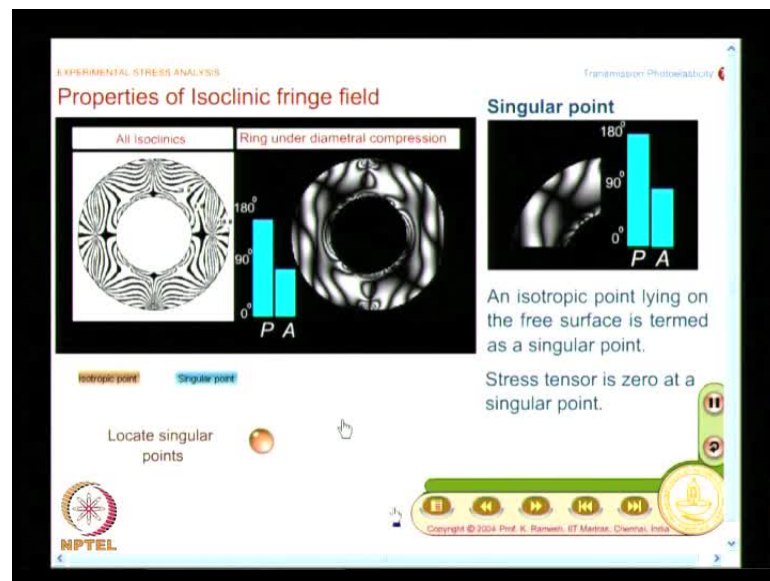
That is not the intension there, see the definition of an isotropic point is where all the isoclinic pass through. In fact, I had given you this as the home exercises, where the circular disk is so special I said the isoclinic will meet the boundary at what angle. So, each point on the boundary, you will have one fixed isoclinic meeting, whereas in an isotropic point, all isoclinics pass through. Do not carry the information, that zeroth fringe order means all isoclinics pass through, no, the contraries is not true, when all isoclinic pass through the fringe order is 0, you take that statement, do not look at the other statement.

I take the beam under bending, I have a zeroth fringe order at the horizontal, you have only one isoclinic, there is no isoclinic, because isoclinic is horizontal in the case of a beam, zeroth isoclinic is only possible, pass through it. So, you if you want to find out the zeroth fringe order, take the queue that is if all isoclinic pass through, that point is zeroth fringe order, do not use this for zeroth fringe order, do not look for more isoclinics

to pass through an every zeroth fringe order, there are special situations, the special situations are what you see in a beam under bending, and disk under diametral compression. These are exceptions, you should not mix-up exception with general rule, it is good that you ask that questions, it is it is very valid confusion that you can come across.

And so I have ten isotropic points identified, and you 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, label it by another name, I call it as a singular point. 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, not only have fringe order zero, but stress tensor is also zero, why it is zero?

(Refer Slide Time: 28:07)



Because it is a free surface, there is no stress acting perpendicular to direction, it can only be tangential, and you do not have any perpendicular that is 0. When fringe order is 0, it only implies σ_1 equal to σ_2 , the students will have confusion, when as a zeroth fringe order, everything is zero, this one wrong conclusion you can think of, it only implies σ_1 equal to σ_2 . Suppose I have a zeroth fringe order on a free boundary, stress and solids are 0, and that is indicated by a singular point, and if you locate at the singular point, you as self know there are eight such singular point in the ring under diametral compression.


(Refer Slide Time: 35:56)

EXPERIMENTAL STRESS ANALYSIS

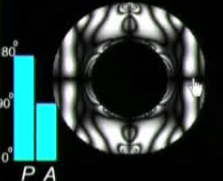
Transmission Photoelasticity

Properties of Isoclinic fringe field

All Isoclinics



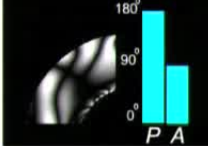
Ring under diametral compression



180°
90°
0°

P A

Singular point



180°
90°
0°




P A

The sign of the boundary stress changes when it crosses a singular point.

All the isoclinics also pass through the load application points but these are not isotropic points.

Isotropic point Singular point

Locate Singular point



Copyright © 2004 Prof. K. Ramani, IIT Madras, Chennai, India

(Refer Slide Time: 36:08)


EXPERIMENTAL STRESS ANALYSIS

Transmission Photoelasticity


Properties of isoclinic fringe field

Positive and negative isotropic points

All Isoclinics





Ring under diametral compression



180°
90°
0°

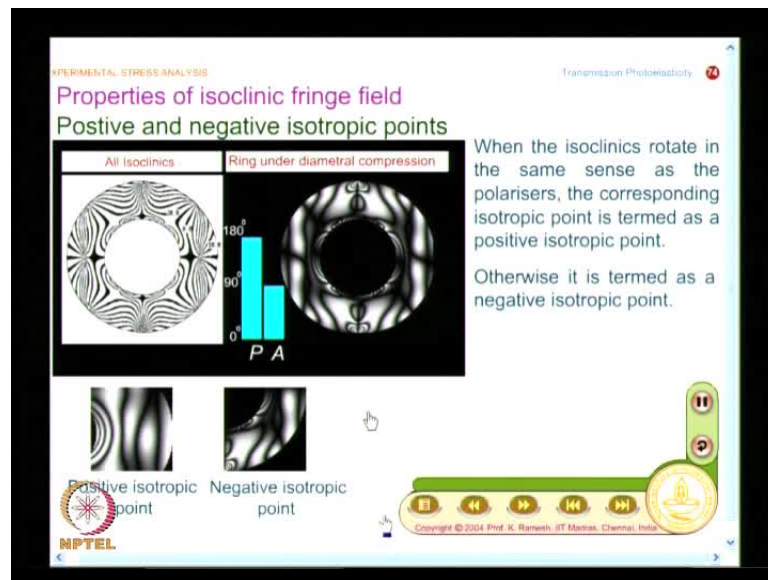
P A

Isotropic points are termed as positive and negative depending on the way the isoclinics rotate when the crossed polarizers are rotated.



Copyright © 2004 Prof. K. Ramani, IIT Madras, Chennai, India

(Refer Slide Time: 36:45)



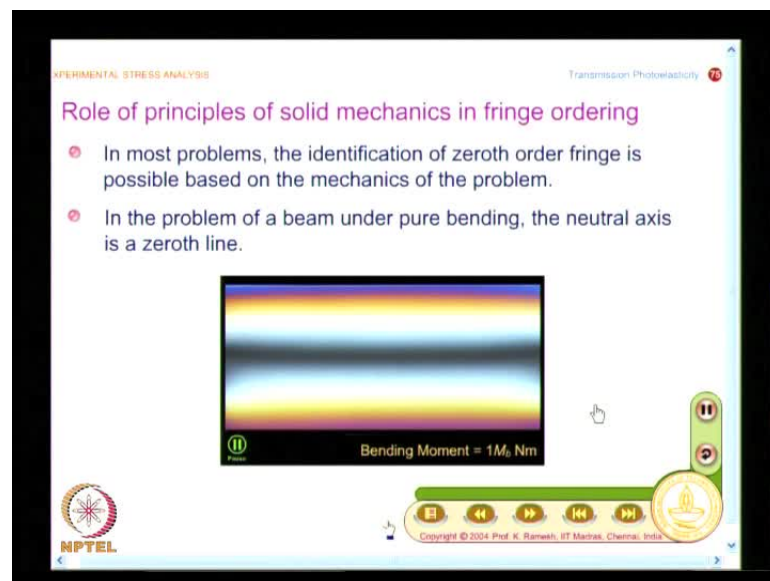
So, now you have a fairly good idea, what is the source, what is the sink, what are the saddle points, and what is the isotropic point and what is the singular point. And you also made one small distinction, that when you look at the isotropic points, you find that the isoclinics fringes move in a particular fashion, we will see what it is. 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 crossed polarizers are rotated. And that is what we have seen very carefully, there is a particular aspect happens, at this point, when I rotate, they rotate in the same fashion as the polarizer analyzer combination. And you have a simple labeling, you call this as positive isotropic point and I will call the other one is negative isotropic point.

I just classify, I only want a record my observations, but in one case when I rotate the polarizer analyzer combination, the isoclinics also change in the same fashion in the point of interest, there is synchronization between the ways I rotate, the way you see the labeling of isoclinics, and 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 labeling of fringes, I can label the isochromatic fringes, I can also label the isoclinics fringes. In a isoclinic fringes, you have to plot them separately and then do it, you can't take a photograph, you have to take multiple photographs, extra isoclinics 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 is 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 the nice queue for you to verify whether you have labeled isoclinic correctly, and very interesting to know, it is better to know some of these aspects, so I will always have this isotropic points in a combination.

We are seen what is the positive isotropic point, we also see what is the negative isotropic point, this is rotating anti clock wise and this is rotating clock wise, and I rotate the polarizer analyzer combination in a anti clock wise fashion. So, when that sense and this sense matches, I call that as positive isotropic point, I call the other one as a negative isotropic point. Any other question at this stage, you know fringe ordering is the most complex and we would see further what all the other aspects of solid mechanics that I can employ are.

(Refer Slide Time: 39:31)



Now, you have seen the fringe field, very rich animations, and I am showing you, you would have got a just of what the fringe orders are. And this is what I have said, there in most problems identification of zeroth fringe order, is possible based on the mechanics of the problem. See if I have the zeroth 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 the color code, and once I mention zeroth fringe order, and let us also look the exceptions, because that was also discussed briefly when we looked at properties of isochromatics and isoclinic fringe field. So, in the problem of a beam under pure bending, the natural axis is a zeroth line, it is not just a point, you have a complete line which is a zeroth fringe order, and because of this luxury of the multimedia, you can quickly see what is happening in a beam under bending. And what I have here? I have the zeroth fringe order at the center, why we looked at beam under bending? We never bother to look at as the load is increased this remains stationary, now you have seen thus amply clear for the case of a ring and diametral compression, now I increase the load, the density increases in this zone, whereas fringe order one is more, fringe order two has appeared, but fringe order zero does not move, this is the very important observation.

And another question we have not raised all along, I said you have fringe orders only as positive integers in photo elasticity, neither you ask me how to find out whether is a 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 apply the load, because we have applied the load like this, **we have** it is bend like this, so the top fiber is compression, bottom fiber is tension, that we know. But, in general, you have to do axillary 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 have is a 1.23, 1.24, you will always attach a sign as positive, because σ_1 minus σ_2 is always positive. So, this also you need to learn, as path of fringe ordering, as path 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.

(Refer Slide Time: 39:31)

EXPERIMENTAL STRESS ANALYSIS Transmission Photoelasticity

Role of principles of solid mechanics in fringe ordering

- In most problems, the identification of zeroth order fringe is possible based on the mechanics of the problem.
- In the problem of a beam under pure bending, the neutral axis is a zeroth line.
- In the case of a circular disc under diametral compression, the outer boundary, except for the load application points is the Zeroth fringe order.

Zeroth fringe

NPTEL Copyright © 2004 Prof. K. Ramesh, IIT Madras, Chennai, India

The slide features a central image of a circular disk under diametral compression, showing a color fringe pattern. A blue line points to the outer boundary, labeled 'Zeroth fringe'. The slide includes a navigation bar at the bottom with icons for back, forward, and search, and the NPTEL logo in the bottom left corner.

And what are we seen in the other case, you also looked at circular disk under diametral compression, it is again a special case, except for the load application points, you have the outer boundary as zeroth fringe order, that is again a special case, do not confuse the special case with general room. So, this turned out to be very simple problems for fringe ordering, very simple beam under bending and circular disk are **the no** the simplest problems you can think of, where I have multiple fringes, and I can also label them one after another comfortably.

(Refer Slide Time: 39:31)

EXPERIMENTAL STRESS ANALYSIS Transmission Photoelasticity

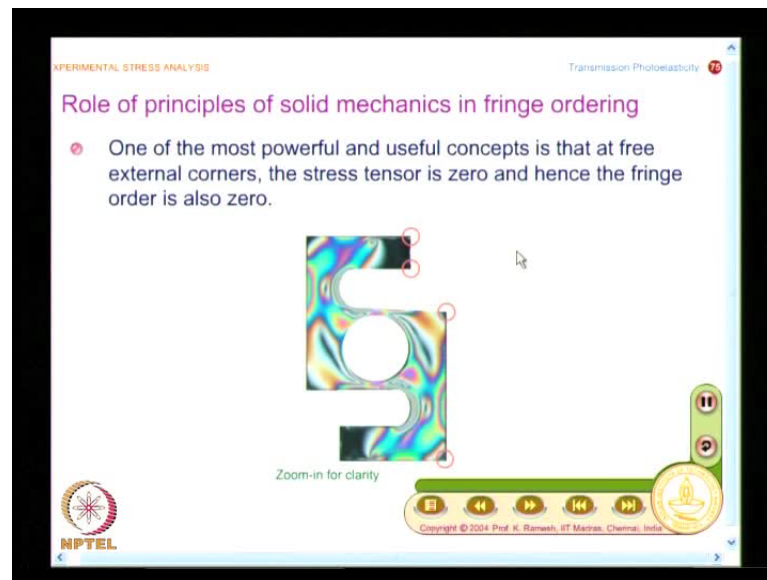
Role of principles of solid mechanics in fringe ordering

- In most problems, the identification of zeroth order fringe is possible based on the mechanics of the problem.
- In the problem of a beam under pure bending, the neutral axis is a zeroth line.
- In the case of a circular disc under diametral compression, the outer boundary, except for the load application points is the Zeroth fringe order.
- One of the most powerful and useful concepts is that at free external corners, the stress tensor is zero and hence the fringe order is also zero.

NPTEL Copyright © 2004 Prof. K. Ramesh, IIT Madras, Chennai, India

The slide features a central image of a circular disk under diametral compression, showing a color fringe pattern. The slide includes a navigation bar at the bottom with icons for back, forward, and search, and the NPTEL logo in the bottom left corner.

(Refer Slide Time: 45:12)



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. And you know, we are seen as a path of your assignment, I have asked you to find out what happens in free external corners, and you are seen mathematically from the definition of stress vector, and also we have identified stress tensor has to be 0 on free out word corners, and this is the very useful information in complex problems.

See, I am also taking you from simpler fringe fields to more and more complex fringe fields. In fact, I am going to show you a loads cell two dimensional model, where you have taken the fringes with white light, even with white light the fringes are very complex. I said if I have white light, you have rich colors, and it is easy to label the fringes, even there the fringe field is complex, we will see that.

I have this here, and I have this fringe field, and this is used in many popular load cell design, this is the spring element, and they would have strain edges put inside **the** this boundary of the whole, and this also can be hermetically shield. And what I have here is this is subjected to 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 this free external corners, I have the fringe as black, and you see a black line here, so this is again

a zeroth fringe order, this is again a zeroth fringe order here, and in between you see a point where there is zeroth fringe order.

So, this gives you an indication, is not that in zeroth fringe order you have a line all along the model, or align all along the boundary like in a circular disk, you may have packets, certain points are 0, you may also have some line, some points, so fringe ordering became extremely complex, and I have a nice colored code. And all know, if I have a blue red and transition what is the fringe order here, 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 increase in the direction, and if I look at here, the fringe order also increase in their direction, so this is how you find out.

And You find out how to label the fringes, let me ask one more question, you could also seen long time back, fringe order in the case of a plate with the crack. You are seen color fringes, you go back and see your notes, where was the zeroth fringe order? I have a tension strip, I have a crack and I have **a** loaded it, because you know, when you have learned some of this concepts, you only see what you want to see. I want to ask, to see certain future at in those classes, I have to only focuses that when I have a plate with a circular hole, when I have a plate with a elliptic hole, when I have a plate with a crack, the fringe density will be very high at the trip of the crack, that was emphasized, but we are not looked at numbering in the fringes.

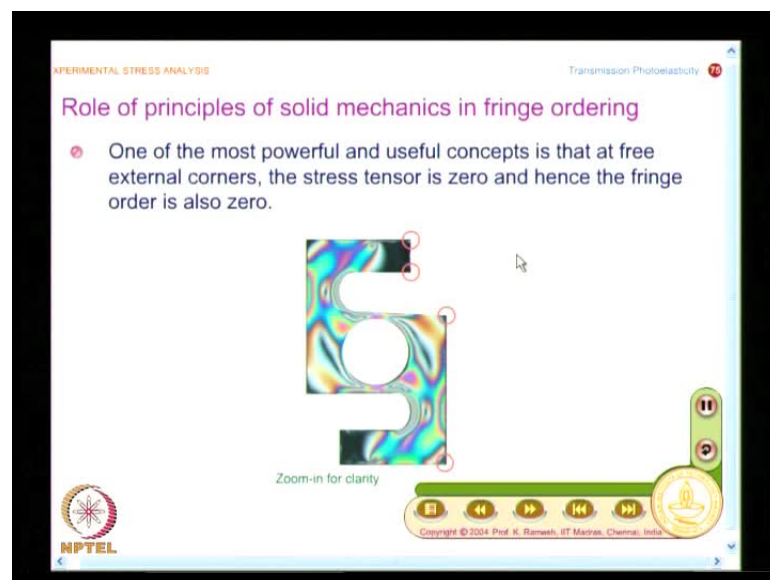
Now, we are having an discussion on numbering the fringes, go and look at your fringe pattern, and find out what should be the zeroth fringe order, take this as home exercises, and then label the fringes in the case of crack, in the case of crack problem. If you know 0, you know the stress concentration point, so it is easy to label the fringes, **you** no need anything **to** beyond that. But on the other hand, if I have to go and identify the fringe order in the case of plate with the whole, it is little tricky, plate with a crack is simpler to label the fringes, plate with the whole it has certain future common with ring and diameteral compression.

So, this is the way you have to go about, so in this class what we are looked at was we have reviewed what is the advantage of using intensity information in identifying the fringe skeletons, how the methodology becomes very simple and computationally efficient in the beginning. And you need to find out F sigma, so we have to looked at F

sigma a methodology utilize the field information, and we also looked at a digital technique which provides to the field information. Then we moved on to finding out the fringe order, we looked at the isochromatic fringe field. We look at the isoclinic fringe field and we saw certain aspects of isochromatic fringe field can be understood by looking at an isochromatic fringe field.

And latter we also develop what concepts of solid mechanics you could utilize to identify the zeroth fringe order. If I have the zeroth fringe order, and if I also know the gradient, it is easy for me to label the fringes, and once I label the fringes as verification, you can utilize the properties of isochromatic fringe field, properties if isoclinic fringe field to double check whether you are labeling is indeed correct.

(Refer Slide Time: 45:12)



Though this may look retardant in this days, where you have software to provide your information, like I said, both in finite element technique, and in experimental methods, computer should be used to assistive you, should not blindly believe what the algorithm says. Because, if I have done wrong boundary conditions or wrong interpretation 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 automated software that provides its fringe order.