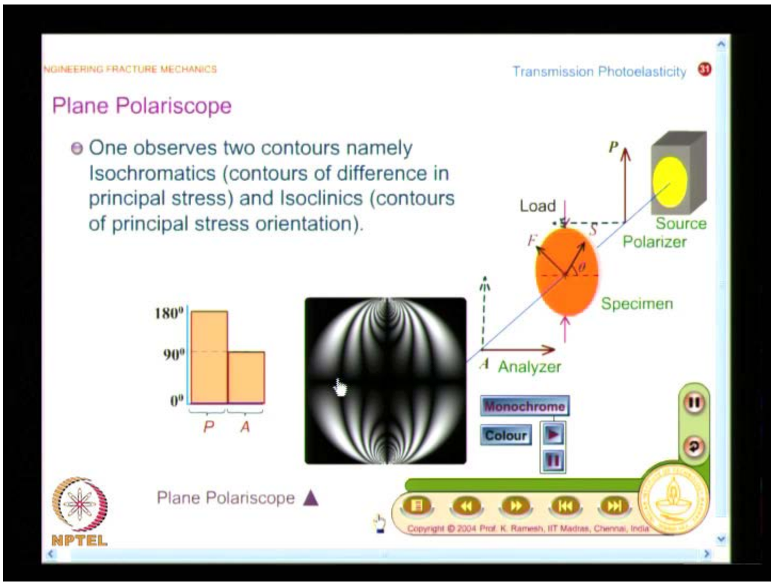
Experimental Stress Analysis
Prof. K. Ramesh
Department of Applied Mechanics
Indian Institute of Technology, Madras

Module No. # 02
Lecture No. # 17
Circular Polariscope

We have been discussing on various aspects of photo elasticity. After looking at stress optic law, we said to quantitatively determine the difference in principal stresses, I need to find out the fringe order n and also the material stress fringe value F sigma. For us to find out the fringe order, we need to go for suitable optical arrangements. We have looked at elaborately plane polariscope, and we have just started looking at circular polariscope, nevertheless we again go back and see what is the plane polariscope and immediately see what is the circular polariscope and identify the difference between the two.

(Refer Slide Time: 01:00)



In a plane polariscope, what we did? I have the source of light which is monochromatic, I have the first optical element as polarizer, then I have a loaded model, then I have the analyzer. And when you see the screen, you see two sets of fringe pattern. So, one observes two contours, namely isochromatics which represent contours of difference in principle stresses and isoclinics which represent contours of principle stress orientation. And what we saw? From a logical explanation, when the model behaves like a full wave plate, the input polarized light is cut off by the analyzer which is kept at 90 degrees to the polarizer access.

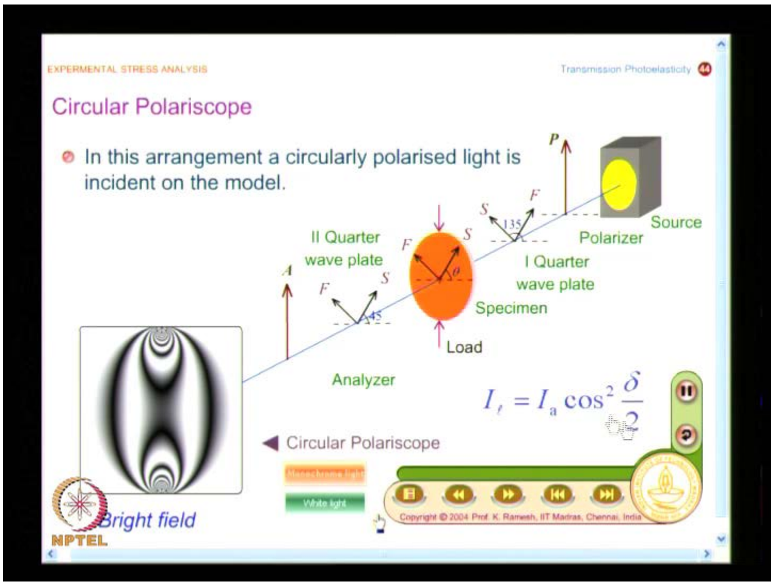
We also saw another possibility, when the polarizer and analyzer axis coincides with the fast and slow axis of the model, then also whatever the light that comes is cut off by the analyzer and you see the contours of isoclinics. And what we saw, when we rotate this polarizer analyzer combination crossed, we find the isoclinics move over the model. But you have to ask, see you have done a course on strength of materials, when you do a course on strength of material, people start with a simple tension number. Once you go to finding got the bending moment, shear force diagram, you have a simple four point bend, we have left these two examples, but we have taken a complex problem of a circular disk and a diametral compression. What is the reason behind it? If I have a simple tension number what will happen? You will have, whatever the retardation will be uniform for the entire cross section away from the point of loading. So, I will not able to see set of isochromatics, I will see one isochromatic at a time, it may be a fractional fringe order also.

And if you look at the principle stress direction, you have only one principle stress direction, it is not varying from point to point. On the other hand, when I go to a beam under bending, you have seen that you saw a neutral axis and you have fringes above and you have fringes below. So, to illustrate isochromatics it was a very nice example problem, but if you want to look at isoclinics, even in the beam you will have only one isoclinic for the entire beam cross section, when you are having a four point bending, because I do not have shear.

So, we take an example problem, which is good enough to illustrate all aspects of the technique that we are looking at. And we have taken a circular disk, because we look at a circular disk what you need is a perfectly circular specimen, and if it is put between two horizontal platens, then you have a diametral compression easily initiated. And not only this, the stress field is very simple, I have an analytical expression for stress field, I see isochromatics as well as beautiful play of isoclinics.

So, the reason why we go for a circular disk is mainly because, when I want to develop the concept of photo elasticity, I want to show you isoclinics, I want show you isochromatics and emphasize the fact when I rotate the polarizer analyzer combination, the isoclinic sweeps the model. Not only this, later we will develop compensation techniques to find out fractional fringe order at a point of interest, there again circular disk comes very handy. And we have already seen in the chapter one what is the stress field equation for a circular disk and a diametral compression, using theory of elasticity it is possible for you to get the solution.

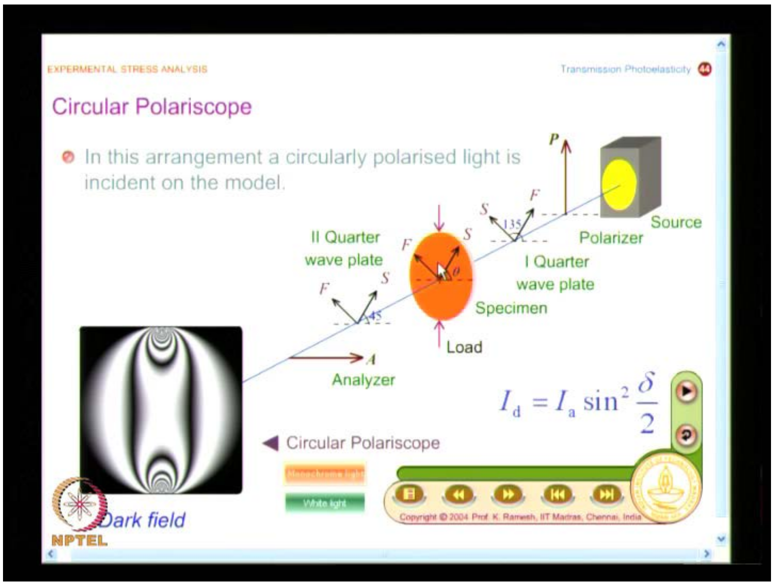
(Refer Slide Time: 05:42)



So, now what we do? We go and look at what is the circular polariscope. In a circular polariscope, I am going to have two addition elements. And what is the advantage of those two additional elements? The two additional elements serve the purpose of removing the isoclinics.

So, what I have here is, I have a light source, I have a polarizer, I have a quarter wave plate, I have the model, then I have the second quarter wave plate, then I have the analyzer. And you should be able to sketch this schematically, you may leave this portion, at least this portion you should be able to sketch for different optical alignments systematically. And you should also note down here, I have the first quarter wave plate, the axes are labeled as slow and fast, and you have the second quarter wave plate, again slow and fast.

(Refer Slide Time: 06:43)



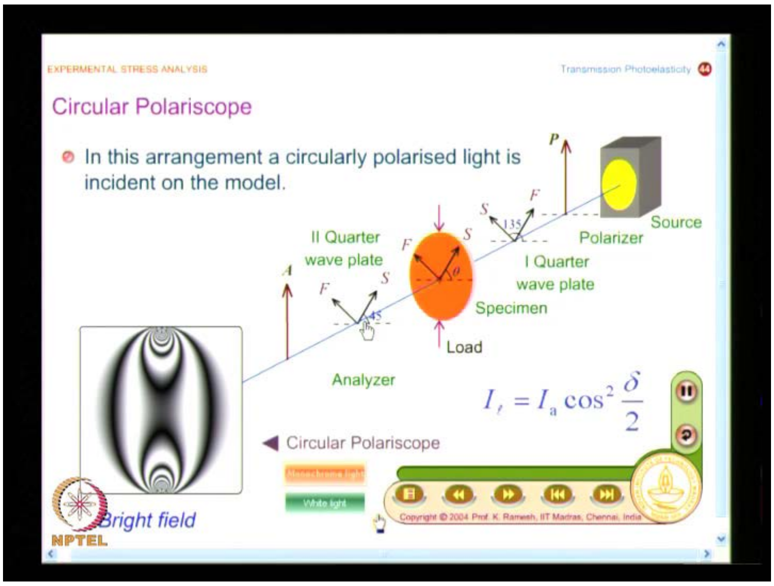
If you look at these two are crossed positions, the quarter wave plate one and quarter wave plate two are kept crossed. Suppose I keep the analyzer horizontal, the quarter wave plates are crossed, you also have the polarizer analyzer crossed, and I see a dark field. And I said in the last class, you can analyze trace of light passing through the model in a circular polariscope using trigonometric resolution, and I said you have element number one, you have element number two, you have the model. So, whenever you have the quarter wave plate or a specimen, you will have to consider the incident plane as well as the exit plane. Similarly, you will have an incident plane on the model and exit plane on the model.

On the exit plane you will also add the appropriate retardation, and I said this kind of an approach would be very cumbersome and you will find it will take quite a few pages of your note book to put the derivation completely, and on the other hand, Jones calculus will be lot more simpler in handling a problem like this. But even before Jones calculus, we have already seen what way the light will change when it passes through the model, and we have looked at different retardation plates, we have said what a quarter wave plate will do, what a half wave plate will do, what a full wave plate will do. We can also have a logical explanation and the logical explanation becomes simple for a dark field arrangement. Let us look at that. So, what I have here, I have the polarizer, I have the quarter wave plate, and if you look at the angle between the slow axis and polarizer is 45 degrees.

So, I have along the axis of the quarter wave plate, the amplitude of light is same. And being a quarter wave plate, it introduces a retardation of phi by 2. So, what you get after the quarter wave plate? You get essentially a circularly polarized light. How many of you are able to see this? I make the amplitude of vibration same and it introduces 90 degrees as the retardation. So, I get a circularly polarized light, directly comes from your light ellipse analysis, and it impinges on the model. The moment I have a circularly polarized light, the directional dependence has no role to play. If I have a plane polarized light, when the plane polarized light coincides with one of the reference axis, we saw isoclinic. The moment you send a circularly polarized light, the light extinction because of directional dependence no longer exist. So, that is why you see in a circular polariscope only isochromatics, you do not see isoclinics. It is an advantage. When I have two information super imposed, data collection becomes cumbersome, and if I find an optical arrangement which eliminates one of the contours, my data collection would be simpler.

Now, let us understand, when I have the model, the model behaves like a full wave plate. So, what will happen? Whatever the light incident on the model, it will come out with the same characteristics. I send a circularly polarized light, then I get a circularly polarized coming out, and this circularly polarized light comes out and hits the second quarter wave plate, and this is where you have to note down what is the advantage of keeping these two quarter wave plates crossed. So, what will happen here? You have a fast axis in the place of slow axis of the first quarter wave plate, and slow axis in the case of fast axis of the first quarter wave plate. So, what will happen is, the amplitude of light is same, and the slow and fast axis are interchanged, so whatever the retardation introduced in these two components, they are cancelled. So, in essence after the quarter wave plate, you will get only a plane polarized light. Are you able to see this? If you are cable to see this, when the model behaves like a full wave plate the incident polarized light comes out as incident polarized light after the second quarter wave plate, because I keep the analyzer horizontal, this light is cut off.

(Refer Slide Time: 12:43)



So, I see fringes, zeroth order fringe, fringe 1, fringe 2, fringe 3, fringe 4 and so on. So, a logical explanation is lot more simpler and straight forward in this case. It is not difficult, if you understand what is the meaning of a full wave plate and also understand basics of how a retardation plate operates, you are able to conjecture, I will have only one set of contours, I will not have isoclinics, I will see only isochromatics, this is what we saw. And what happens when I keep the analyzer vertical, I see a background light, background becomes white. Because we have seen, when it model behaves like a full wave plate, it comes out as linearly polarized light, earlier the analyzer was kept horizontal, so the light was cut off, now the analyzer is kept vertical, the light is passed. And I also mentioned you see complementary fringe pattern between dark and white field. What was appearing as dark in the dark field, will appear white. So, the fringe areas which were dark, they appear white in a bright field. And it is possible to show that this is fringe order 0.5, 1.5, 2.5, 3.5 and so on.

And you also note down, the intensity of light transmitted takes the form I a cos square delta by 2 and this will go to 0 only when delta I is phi, 3 phi, 5 phi and so on. So, even without getting into trigonometry, we have been able to logically explain how in a circular polariscope you see only isochromatics, and you also have a dark field and bright field gives you physical information which you can interpret. In the case of a plane polariscope, we only used dark field, we do not use a bright field in conventional photo elasticity.

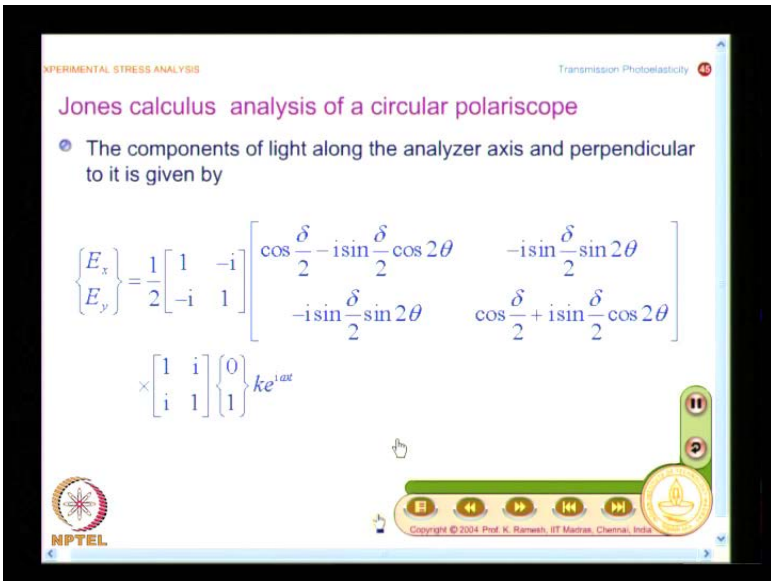
Let us look at one more statement. I made a statement, in a conventional photo elasticity, what is important is, the first quarter wave plate and second quarter wave plate need to be kept crossed. We are not really concerned about whether I had kept slow axis at 135 degrees or slow axis at 45 degrees for the first quarter wave plate. Because when you look at logical explanation, I have this, and if I have this as the complimentary arrangement, you get a plane polarized light when the model behaves like a full wave plate. And this is the reason why in conventional photo elasticity people never bothered about calibrating a polariscope. Calibration of model material everybody knows. The moment you come to digital photo elasticity, I must also calibrate the polariscope to the mathematical expression you have.

If in the mathematical expression I have slow axis at 135 degrees, I must adjust my polariscope until my analytical expression and what I seen in the experiment match one to one. Why this is so? Because in digital photo elasticity people process intensity information. In conventional photo elasticity you only worry about fringe contours, as long as I get the fringe contours formed, I find information only on the fringe contour essentially, later on we also have compensation techniques which will find out fringe order in between the fringes, and in view of such simplified approach the real need for calibrating a polariscope never arose as long as you keep them crossed. And there is also a thumb rule, we have said any retardation plate is a function of the wavelength used. So, what you find is a commercially available quarter wave plate may not exactly match with the light source you have.

So, you will always have some mismatch of quarter wave plate with the wave length, even when I use a monochromatic light source. And what people have found is, if I keep the quarter wave plates crossed, the error introduced because of mismatch of quarter wave plate is minimal. I can show you the graph without proof, but this is the thumb rule and that is how many conventional photo elastic analysis is carried out and the same knowledge extends even in digital photo elasticity.

So, now what we will do is, we will go and look at how to analyze this mathematically. We will look at Jones calculus and what we will do is, we will go along with the light, we will see what is a natural light, then we will see the polarizer, then we will see the first quarter wave plate, then you look at the model, then you at the second quarter wave plate, and then find out what is the light coming out, because after the second quarter wave plate I can keep looking at the horizontal component and vertical component to find out when the analyzer is horizontal or when the analyzer is vertical. That is what we need to do.

(Refer Slide Time: 18:09)



We do not have to find out the light after the analyzer, if I stop after the second quarter wave plate, it is lot more convenient. And you have the necessary rudiments for you do that. So, what I have here? I have to find out what is the exit light ellipse, I want to see E x and E y, and this I will find out after the second quarter wave plate. And I know in my optical arrangement I have the natural light which is impinging on it, then I have this polarizer which makes it polarized in one direction, then I have the first quarter wave plate. I have said, once you look at the quarter wave plate, label the slow axis angle and the retardation, the retardation is phi by 2, and the labeling is 135 degrees, we have already plugged in these values on a general expression of retarder, and we have got what is the matrix representation of quarter wave plate with it's slow axis at 135 degrees. You already have the result, so you can directly plug in that result. So, I had this as 1 i i 1 into 1 by root 2.

So, I have now come up to the model. When I have these three elements, that is I have the light, polarizer, I have the first quarter wave plate. Now, what will I write as the model? You will simply write the representation of retarder as a matrix form, because we do not know what is the value of the delta of the model at the point of interest and what is the value of theta at the point of interest. The only assumption you make here is, theta what we are representing is a slow axis representation, whatever the value of theta I get, it corresponds to slow axis of the model. So, you write the general expression of the retarder and that you should remember. You know at this stage of the course since you have derived it and it is worth remembering it, it is very easy to remember also, it is not difficult at all. You take a minute and then if you are not remembering it, at least look at the previous pages and then translate that matrix to displace. And it is worth remembering it, this will make your understanding of photo elasticity faster, when you are doing any mathematical calculation, you will have to live with representation of retarder in various forms, write down that matrix completely.

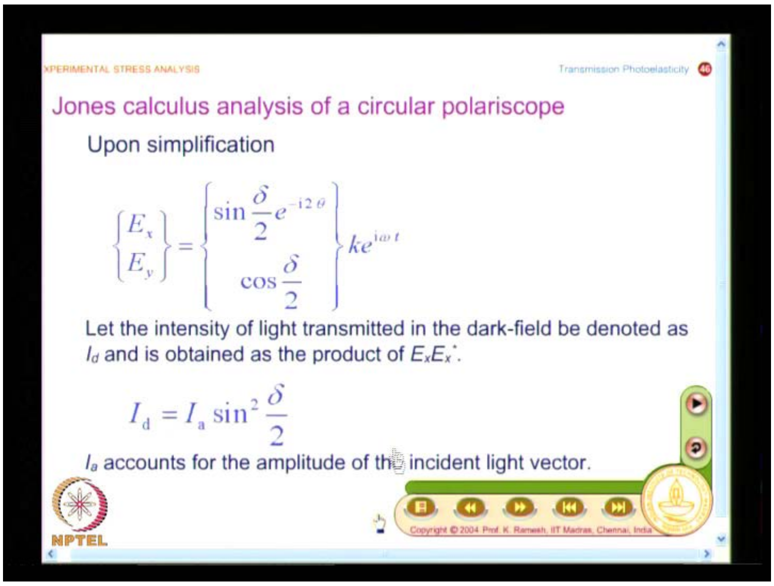
So, I have the matrix here. I have this as cos delta by 2 minus I sin delta by 2 cos 2 theta and the diagonal term I have to just change the sign, that is all I have to do. Compared to the first term, the diagonal term is simply a change in sign, I have a cos delta by 2 plus I sin delta by 2 cos 2 theta. Then I also mentioned, these two cos terms are not difficult, instead of cos 2 theta you have sin 2 theta here, I sin delta by 2 sin 2 theta and I sin delta by 2 sin 2 theta, it is a symmetric matrix, from the imaginary quantity point of view it is symmetric, if you put the real part it will be skew symmetric.

So, this is representing the model, because our goal is to find out delta and theta of the model. Now, after the model what I have? I have the second quarter wave plate and second quarter wave plate you will have to find out that matrix. You take a minute, it is very similar to what you have got as a first quarter wave plate, instead of 135 degrees you are going to put it as 45 degrees. What is the change does it make in the quarter wave plate matrix, it is straight forward. Even if you do one term you will able to find out how to fill in the matrix, you look at the 1 comma 2, you have 1 1 1 comma 2 2 comma 1 2 comma 2, you look at the 1 comma 2 term there is slight change in that term, that is all the difference is.

You have to look at trigonometric identities and also matrix multiplication, if you want to carry on with analysis of optical arrangements in photo elasticity, you must be conversant with using trigonometric identities and matrix multiplications. You must pick up speed, that speed comes when you work it out yourselves. So, please work it out, this is fairly simple, and I think some of you have got it. It is as simple as 1 minus i minus i 1, a small change is this sign change happens, when I have 1 by 2.

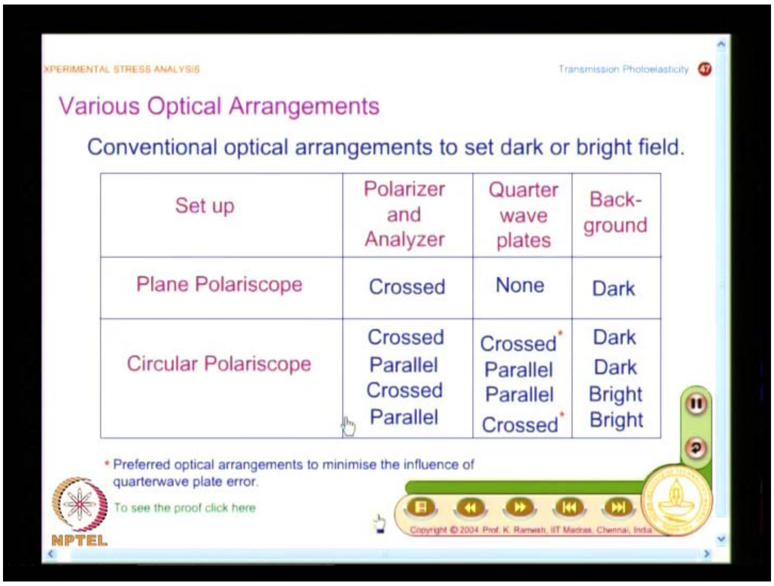
So, now what is the simple expression? I have a set of matrices, you multiply them in the way it is written, and you know what is the light transmitted after the second quarter wave plate. The reason why I stopped after the second quarter wave plate is, I can look at keeping the analyzer horizontal or keeping the analyzer vertical; that means, for me to get the expression for dark field and bright field I can do it in one stroke. Do the matrix multiplication, you have do that matrix multiplication, it is not difficult, it is fairly simple. And you must keep doing this sort of multiplications off and on and you become comfortable in handling these kind of expressions. So, what I will do now is, in order to cut time short, I will go and show you the final expression and verify these expressions with your calculations.

(Refer Slide Time: 24:54)



So, what I have here is upon simplification I get the expression in this fashion. So, what I have is, I have sin delta by 2 and cos delta by 2. So, I will have the expression for dark field, I get this as E x into E x star, where E x star is the complex conjugate and I simply get this as I a sin square delta by 2, and I a accounts for the amplitude of the incident light vector. And what you find here is this expression is independent of theta. This is same as, the first term is same sin square delta by 2 was appearing in plane polariscope dark field also, in addition you also had sin square 2 theta, you also had a theta term there and here you are not having a theta term, otherwise you label the fringes as 0, 1, 2, 3, in plane polariscope dark field as well as circular polariscope dark field, there is absolutely no change between the two. And this expression is very clear, when I keep the analyzer vertical it will allow the y component, then this expression will change to I a cos square delta by 2. And we label fringes as dark contours, so this will happen when in dark field when it is a full wave plate, it behaves like a full wave plate, you have delta taking 0, 2 phi, 4 phi, 6 phi. You have fringes, you call them as 0, 1, 2, 3. In the case of bright field, you will have 0.5, 1.5, 2.5 as the fringe orders.

(Refer Slide Time: 27:01)



As I mentioned earlier, you have multiple optical arrangements, you do not have only one optical arrangement. In a plane polariscope, I use only polarizer and analyzer, there is no quarter wave plate, and you always have them crossed and the background is dark. And in a case of a circular polariscope I can have many arrangements, but only popular ones are labeled here, I can have the polarizer analyzer crossed, then when I have quarter wave plates crossed, I get the background as dark. Suppose I keep the polarizer analyzer parallel and also quarter wave plates parallel, I get this as dark. Suppose I have this polarizer analyzer crossed, if I have parallel quarter wave plates I have bright field, I have parallel polarizer and analyzer crossed quarter wave plates I have this as bright. And the list does not end here. You have a longer list and if you look at the book on digital photo elasticity by me, you have the other expressions available, because what you find here is multiple optical arrangements are possible, and among the multiple optical arrangements, which one will be good from an experimental point of view, you to have to look at.

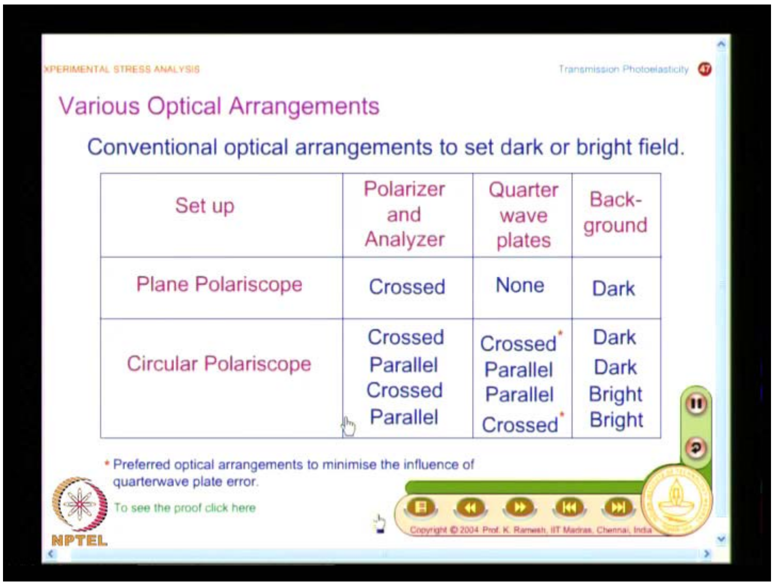
Let us see a commercial polariscope. Now, this is the commercially available polariscope, this has the light source and what you have is monochromatic light impinging on the model, you have the first optical element, namely the polarizer, you have the second optical element which is the first quarter wave plate, then you have the loading frame, in the loading frame you have the model loaded, here you have a circular disk and diametral compression, then after the model you have the second quarter wave plate, and finally you have the analyzer.

The advantage of a sheet polarizer is, you have a very large field of the order of three hundred millimeters in dia and they can be easily rotated by a simple mechanism. And what you see in the polariscope is the fringe patterns in dark field for a circular disk under diametral compression. The fringes have to be labeled as 0, 1, 2, 3 etcetera. This shows the loading frame, how the model is loaded and what you have is hydraulic cylinder which is controlled by a pump, by selecting the valve position appropriately it is possible to change from tension to compression. And what I have here is a load cell which measures the load, and you have the model placed between two horizontal platens and the disk is kept under diametral compression.

This shows the load that is applied and this reads it in kilogram force. See, the basic optical arrangement of the polariscope is in dark field. So, what we will have is polarizer analyzer are crossed, first quarter wave plate and second quarter wave plate are crossed. When you have both the pairs are crossed, you will essentially see a dark field. Suppose I rotate the analyzer and keep it at 90 degrees, then what I will have is polarizer analyzer are parallel, I will essentially see a bright field. Rotate the analyzer now.

So, what you now see is, you see the bright field fringes. Now what we will do is, we will go back and keep the quarter wave plates also in parallel position, they were originally crossed, now we will keep it parallel. Rotate the quarter wave plate two. So, when I have both the quarter wave plates parallel as well as polarizer and analyzer are parallel, I essentially get a dark field fringe pattern. Suppose I keep the polarizer analyzer crossed, I will have a bright field fringe pattern. Now rotate the analyzer. So, when I kept the analyzer parallel, I essentially see a bright field fringe pattern. So, in this demonstration we have seen how bright and dark fields can be obtained by keeping the quarter wave plates parallel or crossed and appropriately keeping the polarizer analyzer combination.

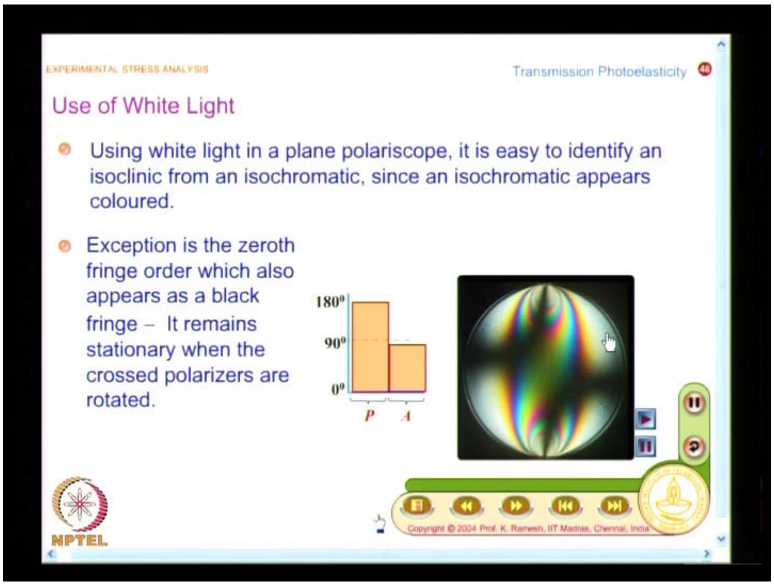
(Refer Slide Time: 27:01)



All the elements in the polariscope can also be rotated by this knob and you use this for making the polariscope to function as a plane polariscope, in this what you do is, you keep the quarter wave plate axis along the polarizer, so you optically cancel the first quarter wave plate, similarly optically cancel the second quarter wave plate. Now, the polarizer analyzer are kept crossed and they can be rotated to find out the isoclinics in a plane polariscope. Rotate be on now. You can now see all the elements are rotated appropriately, so you can use this for plane polariscope as well as for circular polariscope.

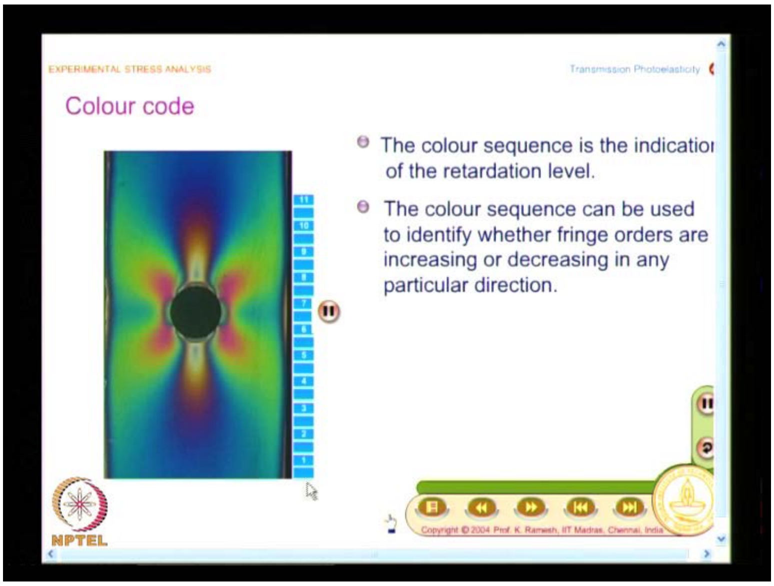
In the case of a plane polariscope, there is no wavelength dependence problem from the arrangement point of view. Whereas, in a circular polariscope since you have a quarter wave plate, the retardation introduced by it is a function of wave length, you have all the likelihood there could be small deviation of matching this wave length to the actual light source, so you will always have a small error. And how to minimize this error? Experimentalists have found out that if you use crossed quarter wave plate combination, that is what I have represented it in my line sketch, we moved from dark field bright field by keeping the quarter wave plates crossed, we kept the polarizer analyzer initially crossed, then we kept them parallel, so I move from dark to bright field by simply modifying the analyzer position, and this is supposed to give the least error, when the quarter wave plates are not perfectly matched with the light source, which is in all likelihood possible.

(Refer Slide Time: 35:29)



So, a crossed quarter wave combination is what you should always look for arranging in a conventional circular polariscope. And you know, use of white light has lot of advantages. For example, even though I say the quarter wave plate is matched for a particular wave length, though it introduces an error, viewing the model in white light for an unknown situation gives you a wealth of information. In conventional photo elasticity, people used it to find out the fringe gradient direction and also for integer fringe orders. In digital photoelasticity, you have well developed techniques now called three fringe photo elasticity or r g b photo elasticity, which can extract quantitative information from colored data, it is no longer a problem now, it is lot more simpler. And you have already seen, in the plane polariscope if I have a white light source, it is advantageous, because I can distinguish between isochromatics and isoclinics by distinguishing the color and the black isoclinic. The only difficulty comes in delineating the zeroth fringe order and isoclinic, which you have already seen and which you have already learnt, it is not something new.

(Refer Slide Time: 37:10)

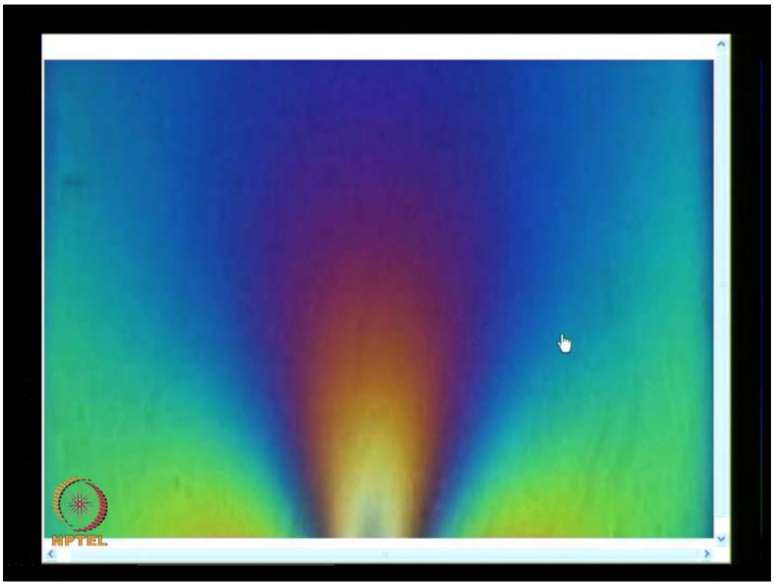


So, color helps. And let us look at a very nice example, you all know stress concentration, we look at for a plate with a hole, how do the fringes develop, so beautiful. We will see one after another, I have this, I have the load gradually applied, when I gradually applied the load, you have colors start appearing and also observe where the colors start appearing, it starts appearing at a point where you have very high stresses. So, colors start appearing and then they move as you go by. So, this is how you have.

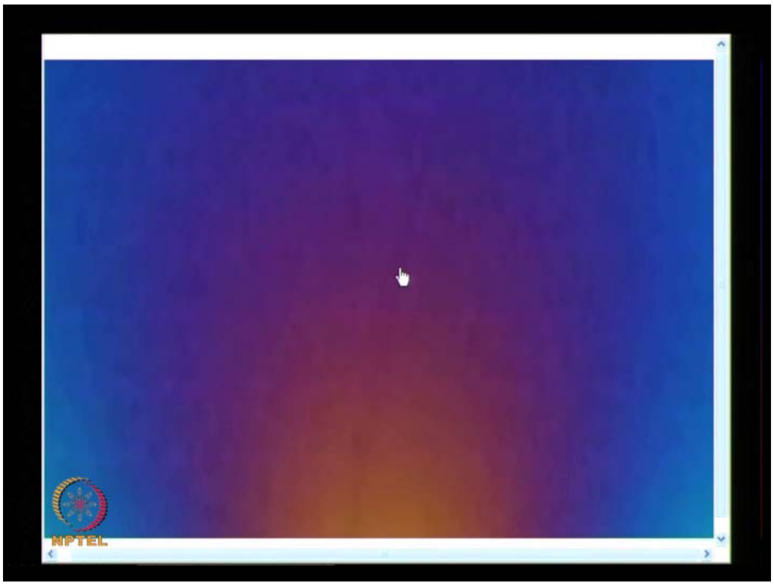
And this is a very complex problem because it is a finite geometry and I can find out stresses only from an experimental approach. You see a very bright a blue, very rich blue. And as the load is increased, you see beautiful play of colors. So, the color sequence is the indication of the retardation level. So, if I know the color sequence I can identify the gradient, whether it is increasing or decreasing in any particular direction. See, in a conventional photoelastic analysis, I may still do quantitative data extraction using a monochromatic source. You have seen only simple fringe patterns so far, you have seen for a circular disk, where the outer boundary is free boundary and the stresses increase as you go to the load application point, you have not seen complex fringe pattern, I have kept it deliberately away for the time being, we would spend time on a ring and diametral compression, how the fringes appear and if you know how to label the fringes in ring and the diametral compression, you are fairly learnt enough how to identify fringes in any general problem. They serve in two extreme conditions, disk is very simple and ring is very complex.

We will see those fringe pattern also latter. Right now what we are looking at is, even when I use a conventional photoelastic analysis, for me to find out quickly what way I have to label, suppose I know the zeroth fringe order I know which way the fringes are increasing, then I can go to monochromatic light source, identify zeroth fringe order and then in the direction of increasing value I can put 1, 2, 3 and so on, I can do that. That is the way in conventional photoelasticity color information was used, color information was not used to precisely find out the fractional fringe order, which is possible with digital photo elasticity, but we may not look at it as part of this course for the time being.

(Refer Slide Time: 40:25)

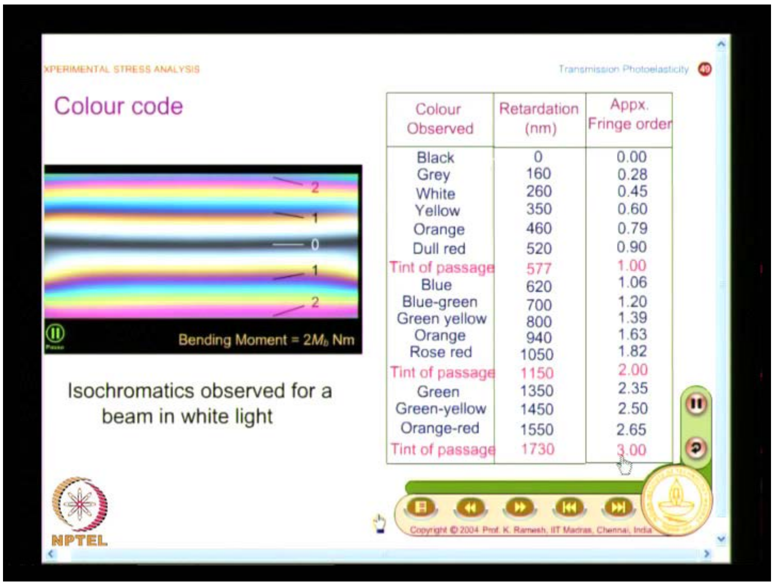


(Refer Slide Time: 40:56)



And what you find here is this is how the fringes develop. And you also have, I want your eyes to get tuned to these rich colors and then have a look at it, the color is so good, I have a beautiful color and this is nature that has given it, like what you see in a peacock feather you see such beautiful colors, you are not gone and. And if you watch here, you have shades of gray and you have a white also in between, then you have yellow, then you have color changes. I could do the zooming and you can see how rich the colors are, the colors are very rich. Now, we will go and attach numbers to these colors approximately, that is what we will do. So, I have a color code.

(Refer Slide Time: 41:10)



So, what I have is, I have a black, gray, white, yellow, orange dull red, and we call something as tint of passage, this happens at 577 nanometers, tint of passage again occurs when this is doubled approximately, 1150 and you have 1730 and so on. So, you have this as fringe order 1, fringe order 2 and fringe order 3. So, what I am going do is, I am going to have one zeroth fringe order and then we will see closely some of this colors. So, what I have is, I have black, grey, white, yellow, orange, then dull red and tint of passage. You see here I have black, I have grey, and then I have white, I have tint of yellow, I see orange, I see dull red.

So, I see this color sequence here and which is labeled. And I have what is known as tint of passage, where there is a change between dull red to blue for the fringe order one. And you will also notice this is the top portion of the beam which is subjected to compression, which is bottom portion of the beam which is subjected to tension, and because of the Poisson effect you see a slight change in color. If I actually look at with black and white, you may not notice this color change so well and this is also a magnified picture.

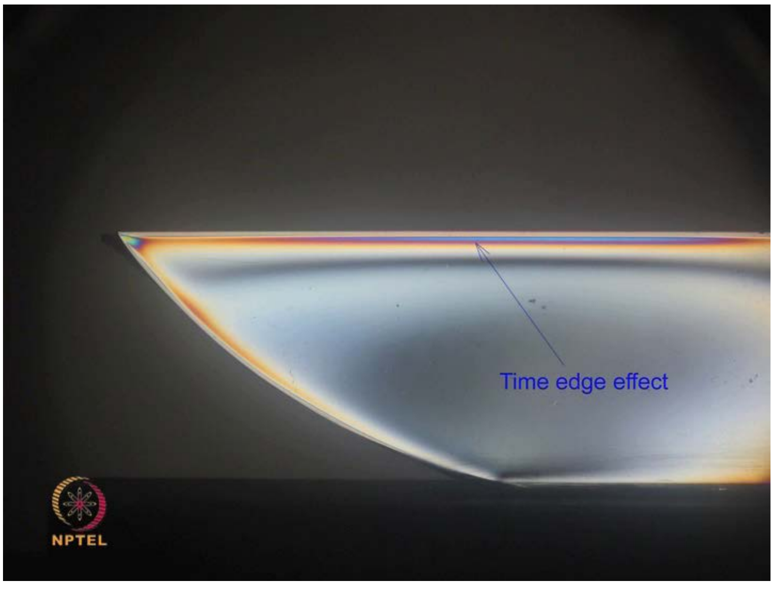
So, you see the color change. So, experiment is truth. When the thickness changes because of Poisson ratio, you see that in your fringe pattern, you cannot hide anything from experiment, experiment only looks at what actually happens to the model, it does not look at your approximations. So, you have to correct your approximation based on experimental result. And what you see here? I see a dull red to blue and that is what you see here. My interest is to show you what is the difference between fringe order one and fringe order two. We will see the fringe order two here and this is fringe order one. I will just magnify, before I magnify you look at here, I will have a blue, blue green, green yellow, orange and this is labeled as rose red.

See in the case of a first fringe order, you have a transition between dull red to blue, and in the case of second fringe order, it is rose red to green. And these are easily disguisable, when I magnified the picture. And I want to you do have an appreciation of this. You see here this is zero and see this is the dominance of blue here; whereas, the red is also different, here only you see the red, though it is said as dull red, when I magnify it further you may see the dull red. You see the red here, but the red here and what you see here, there is a definite change and you see a strong blue color, you see a shade of green here. And you know your eye needs to be tuned to this, eye need to be tuned to this. So, this is for your fringe order 1 and this for your fringe order 2, you notice the difference in the red between the two.

I will also show this very closely. So, you see that tint of passage is different, we will go and look at up to three fringe order what happens. I will have magnify this further, and this is how you find. So, it is easy to distinguish fringe order 1 and fringe order 2, this is zeroth fringe order, this is fringe order 1 and this is fringe order 2. Your eye needs to be tuned to these subtle color changes. Blue dominance is seen in fringe order 1 and pinkish red is seen in fringe order 2. And fringe order 3, there you know, the red and green are slightly different, your eye needs to get tuned. And beyond fringe order 3 you do not see distinction in colors, they all merge. And that is why we also name the color based technique as three fringe photo elasticity.

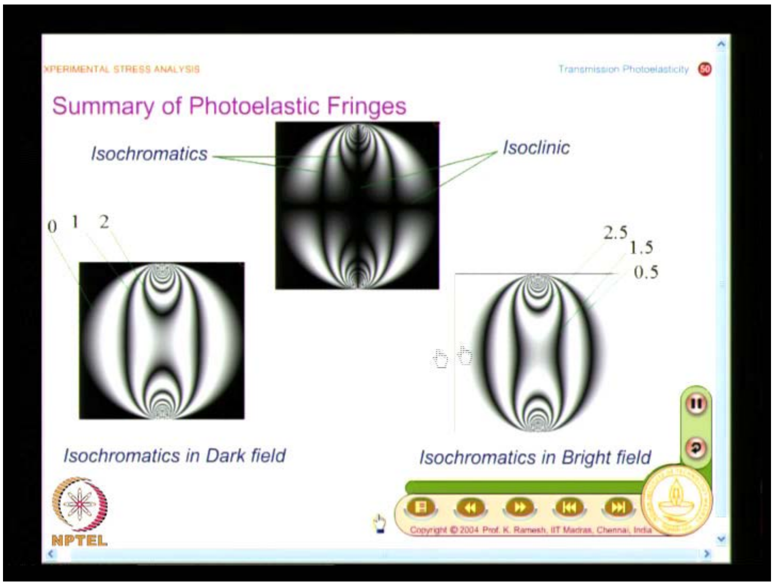
Let us now see how photoelastic models are preserved. This is a desiccator which is used for storing the photoelastic models. And what you see at the bottom in blue is a silica gel which observes the moisture. And even the lid is put very carefully on the desiccators. The interfaces put with layer of grease, so you prevent any fresh air entering into this. And any air inside is observed by the silica gel and the model is kept in an environment free of moisture. And this is particularly needed when you want to preserve the model for future experimentation. And can you open the lid.

(Refer Slide Time: 48:37)



So, it is done by a shading action that shows that this gap is completely filled with the grease. And this is how you keep the model. And when you hold it, you need to hold it like this. You should not touch the edges. When you touch the edges, the edges are particularly sensitive to absorb moisture and what you will eventually have is what are known as Fourier's fringes, because of an effect called time edge effect. And you need to avoid this for quantitative extraction of photoelastic data. So, hold the model only like this, keep it in a desiccator and put it with silica gel and periodically monitor that silica gel is in good condition, and this is very important. And if you do not follow these practices, you will see formation of Fourier's fringes at the edges, which will spoil the model for future use.

(Refer Slide Time: 48:45)



To summarize, let us see what all we have seen in these two optical arrangements. We have seen a plane polariscope, we have seen a circular polariscope, and we find two fringe contours in a plane polariscope, we see only one contour in a circular polariscope. And we will see for a circular disk, what are these fringe contours are. So, what I have here is, this I seen in a plane polariscope, I have background as dark, I have isoclinic as well as isochromatic. And if you look at this and dark field of a circular polariscope, the fringes of isochromatics are same, only the isoclinics are different. Isoclinics are seen in a plane polariscope, isoclinics are absent in a circular polariscope. And I labeled the fringes are 0, 1, 2, 3, 4 like this. And same thing I also do here 0, 1, 2, 3, 4 like this, because the fringe gradient is like it is increasing in this fashion.

The moment I come to bright field, I labeled the fringes as 0.5, 1.5, 2.5. And comparing these two figures, you can see that these two are complementary fringe pattern. So, what was white here is dark here, and what is white here is dark here. So, in the case of a bright field, you label the fringes as 0.5, 1.5, 2.5 and so on. In the case of a dark field, you label them as 0, 1, 2, 3 and so on. So, that is how we have seen the ordering of fringes. And ordering of fringes is a very tricky task in a generic problem, we need to learn more and I will postpone it for a few classes, because I would like to see how to find out the fringe order in between fringes, we will see what are compensation techniques. After learning compensation techniques, we will go and learn how to calculate F sigma. So, once I know F sigma and if I know how to find out the fringe order N and theta at the point of interest, I can find out certain quantities. Later on, we will reserve the discussion for a full class on how to label the fringes in complex problems, some guidelines.

That alone is not sufficient, you also need to pick up experimental equipment to label the fringes. And some cases you may have to gradually load the model, observe how the fringes develop or use the color code, all those circus we will have to do. And what we have also seen is, we have also had a look at how an actual polariscope is constructed, and we had a feel of what are the elements in an actual optical arrangement, and we also looked at what a desiccator is and why a desiccator is needed, and how do we find out what are Fourier's fringes, why these Fourier's fringes are caused and this is obtained by time edge field. We will see the details how to find out the fringe order for any arbitrary point as well as theta for any arbitrary point in the next class.