Experimental Stress Analysis
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Lecture - 14
Circular Polariscope

We have been discussing on various aspects of photoelasticity, 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 back and see what is the plane polariscope? And immediately see, what is circular polariscope? And identify the difference between the 2.

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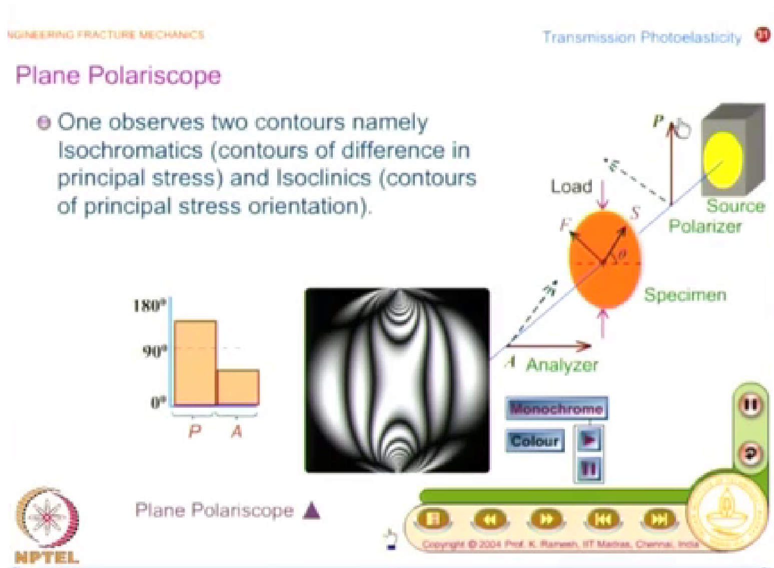

In a plane polariscope what we did? I have the source of light which is monochromatic, I have the first optical element as polarizer, then I have a loaded model, then I have the analyzer. And when you see the screen you see 2 sets of fringe pattern, so one observe 2 contours namely isochromatics which represents contours of difference in principal stress, and isoclinics which represents contours of principal stress orientation.

And what we saw from a logical explanation when the model behaves like a full wave plate, the input polarizer blade is cut off by the analyzer which is kept at 90 degrees to be polarizer axis. We also saw another possibility when the polarizer and analyzer axis coincide 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 polarized analyzer combination crossed, we find the isoclinics move over the model, but you have to ask, see you have done a course in strength and materials, when you do a course in strength and materials people start with the simple tension member, once we go to finding out the bending moment shear force diagram you have a simple 4-point bend, we have left these 2 examples.

But we have taken a complex problem of a circular disc under diametrical compression, what is the reason behind it? If I have a simple tension member what will happen? You will have retardation whatever the retardation will be uniform for the entire cross section away from the point of loading. So I will not be able to see set of isochromatics I will see only one isochromatic at a time, it may be a fractional fringe order also.

And if you look at the principal stress direction you have only one principal 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, you had fringe above, you had fringe 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 have only one isochromatics for the entire beam cross section when you are having a 4-point bending.

Because I do not have shear, so we take a example problem which is good enough to illustrate all aspects of the technique that we are looking at, and we have taken a circular disc because if you look at circular disc what you need is a perfectly circular specimen and if it is put between 2 horizontal flattens then you have a diametrical 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 circular disc is mainly because when I want to develop the concept of photoelasticity, I want to show you isoclinics, I want to show you isochromatics and emphasize the fact when I rotate the polarizer and analyzer combination the isoclinic sweeps the model, not only this later we will develop compensation techniques, to find out fractional fridge order at the point of interest, there again circular disc comes very handy.

And we have already seen in this chapter 1 what is the stress field equation for a circular disc under diametrical compression using theory of elasticity is possible for you to get the solution, so now what we will do? We go and look at what is the circular polariscope. In a circular polariscope I am going to have 2 additional elements.

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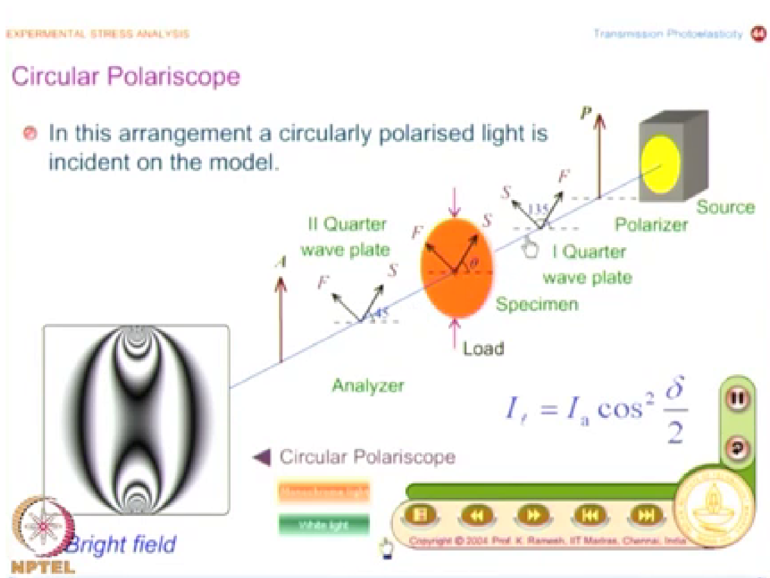

And what is the advantages of those 2 additional elements, the 2 additional elements serve the purpose of removing the isoclinics, so what I am have here is I have a light source, I have polarizer, I have a quarter wave plate, I have the model, then I have the second quarter wave plate, then I have the analyzer. And you should 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 axis are labelled as slow and fast, and you have the second quarter wave plate again slow and fast, if you look at these 2 are crossed positions, the quarter wave plate 1 and quarter wave plate 2 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 screen.

And I said in the last class, you can analyzer trace of light passing through the model in a circular polariscope using trigonometrical resolution, and I said you have a element number 1, you have element number 2, 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 the incident plane on the model and exit plan on the model.

On the exit plane you will also add the appropriate retardation, and I said this kind of an approach could be very cumbersome and you will find it, it will take a quite 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 the problem like this, but even before Jones calculus we have already see 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 a 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 the polarizer is 45 degrees.

So I have along the axis of the quarter wave plate amplitude of light is same, and being a quarter wave plate it introduces a retardation of pi/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 circular polarized light, the directional dependence has no role to play, if I have a plane polarized light then the plane polarized light coincides with one of the reference axis we saw isoclinic. The moment you send the circularly polarized light, the light extinction because of directional dependence no longer exists, so that is why you seen a circular polariscope only isochromatic you do not see isoclinics, it is an advantage.

When I have 2 information superimposed 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 the 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 2 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 this slow and fast axis are interchanged.

So whatever the retardation introduced in these 2 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 able to see this, when the model behaves like a full 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.

So I see fringes 0th 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 the retardation plates operates, you are able to conjecture I 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 when we see the model behaves like a full plate it comes out as a linearly polarized light earlier the analyzer was kept horizontal so the light was cut off, now the analyzer kept vertical the light is passed, and I also mentioned you see complementary fringes pattern between dark and bright 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 Ia cos square delta/2, and this will go 0 only when delta is pi, 3 pi, 5 pi 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 dark field and bright field gives you physical information which you can interpret.

In the case of a plane polariscope we only use dark field, we do not use the bright field in conventional photoelasticity. Let us look at one more statement, I made a statement in a conventional photoelasticity what is important is the first quarter wave plate and second quarter wave plate need to be kept crossed, they need to be kept crossed. We are not really concerned about whether I had kept slow axis at 135 or slow axis at 45 degrees for the first quarter wave plate.

Because when you look at logical explanation, I have this and I if I have this as a complementary arrangement you get a plane polarized light when the model behaves like full wave plate, and this is a reason why in conventional photoelasticity people never bothered about calibrating a polariscope, calibration of model material everybody knows. The moment you come to digital photoelasticity I must also calibrate the polariscope to the mathematical expression you have.

If the mathematical expression I have no axis at 135 degrees, I must adjust my polariscope until my analytical expression and what I see in the experiment match one to one why this is so? Because in digital photoelasticity people process intensity information. In conventional photoelasticity you only worry about fringe contours, as long as I get the fringe contours form 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 arouse as long as you keep them crossed, and there is also a Thumb rule you know 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 light source you have, so you will always have some mismatch of quarter wave plate with the wavelength even when I use the 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 photoelasticity analysis is carried out, and the same knowledge extends even in digital photoelasticity. 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 the 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 look 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 the analyzer is vertical that is what we need to do.

We do not have to find out the light after the analyzer, we stop after the second quarter wave plate it is lot more convenient, and you have the necessary rudiments for you to do that.

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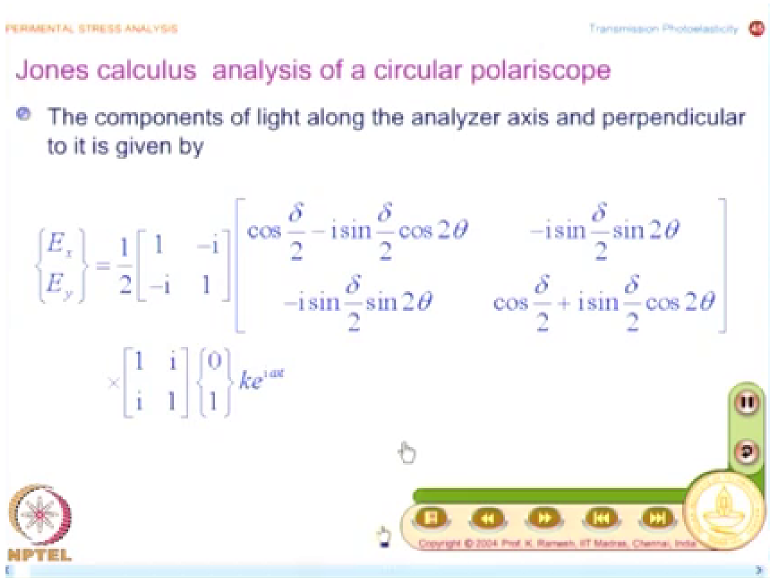

So what I have here, I have to find out what is the exit light ellipse, I want to see Ex and Ey and this I will find out after the second quarter wave plate, and I know in my optical arrangement I have the natural light which is impinging on it, then I have this polarizer which makes it polarized in one direction, then I have the first quarter wave plate. I have said once you look at the quarter wave plate labelled the slow axis angle and the retardation, the retardation is pi by 2.

And the labelling is 135 degrees, we have already plugged in these value on a general expression of retarder and we got what is the matrix representation of quarter wave plate with its slow axis at 135 degrees, you already have that result, so you can directly plug in that result. So I had this as 1 i i 1*1/root 2, so I have now come up to the model when I have these 3 elements that is I have the light, polarizer, I have the first quarter wave plate.

Now what will I write as the model, we will simply write the representations of retarder as a matrix form, because I do not know what is the value of the delta 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 as the 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 this place, and it is worth remembering it, this will make your understanding of photoelasticity faster.

When you are doing any mathematical calculation, you will have to live with a representation of retarder in various forms write down that matrix completely. So I have the matrix here I have this as cos delta/2-i sin delta/2 cos 2 theta, and the diagonal term I have to just change the sign that is all I have to do, compare to the first term the diagonal is simply a change in sign I have a cos delta/2+i sin delta/2 cos 2 theta.

Then I also mention these 2 cos terms are not difficult instead of cos 2 theta you have sin 2 theta here, i sin delta/2 sin 2 theta and i sin delta/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 asymmetric. So this is representing the model because our goal is to find out delta and theta of the model, now what I have? 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 got as the 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 be able to find out how to filling the matrix you look at the 1, 2 you have 1,1 1,2 2,1 2,2 you look at the 1,2 there is a slight change in that term that is all the differences.

You know you have to look at trigonometric identities and also matrix multiplication, if you want to carry on with analysis of optical arrangements in photoelasticity you must be conversant with using trigonometric identities and matrix multiplications you must pick up speed, the speed comes when you work it out yourself, so please work it out this is fairly simple, and I think some of you have got it, it is as simple as 1 -i -i 1 a small change is this sign change happens and I have 1/2.

So now what is the simple expression, I have 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 stop after 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 1 stroke.

Do the matrix multiplication you have to 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 you know to cut time short I will go and show you the final expression and verify these expressions with your calculations.

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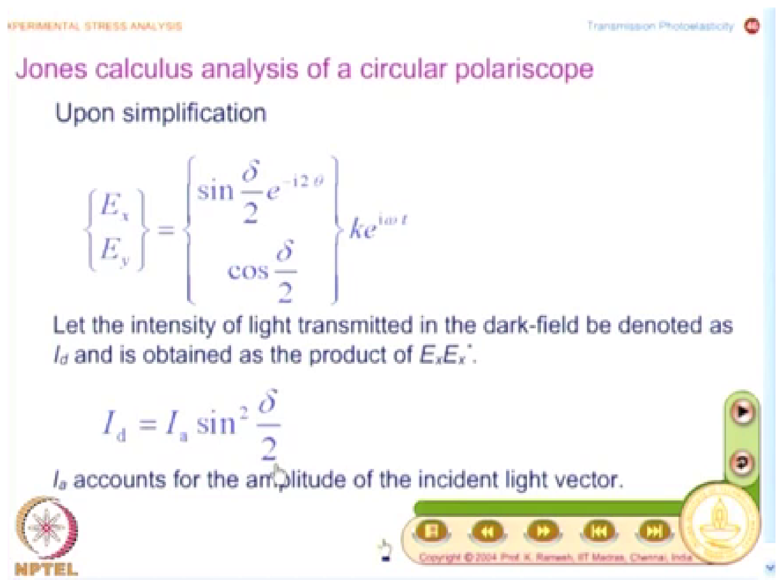

So what I have here is upon simplification I get the expression in this fashion, so what I have is I have sin delta/2 and cos delta/2, so I will have the expression for the dark field I get this as Ex*Ex star, a Ex star is the complex conjugate and I simply get this as Ia sin square delta/2, and Ia accounts for the amplitude of the incident light vector, and what you find here is this expression is independent of theta.

This is same as you know the first term is same sin square delta/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 2.

And this expression is very clear, when I keep the analyzer vertical it will allow the y component then this expression will change to Ia cos square delta/2, and we label fringes as dark contours, so this will happen when it in dark field when it is a full wave plate it behaves like a full wave plate, you have you have delta taking 0, 2 pi, 4 pi, 6 pi 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.

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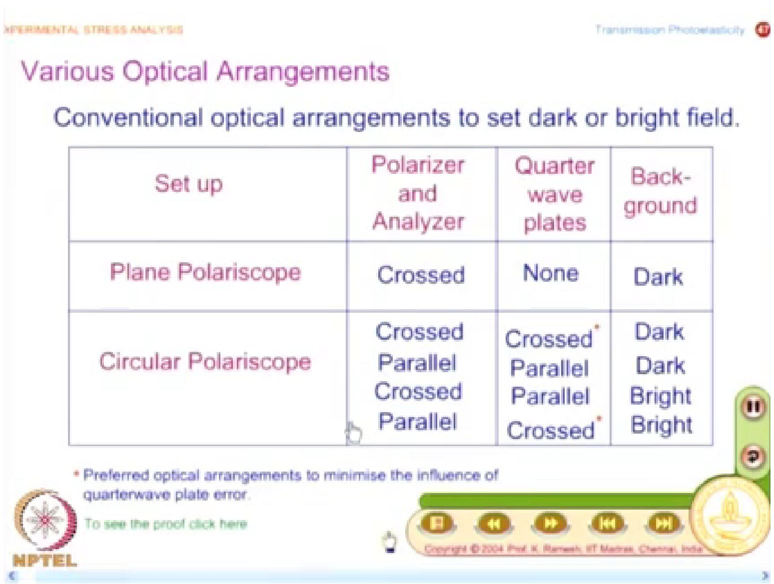

As I mentioned earlier you know you have multiple optical arrangements, you do not have only one optical arrangement in a plane polariscope I use only polarizer and analyzer there is no quarter wave plate and you always have them crossed and the background is dark. And in the case of circular polariscope I can have many arrangements but only popular ones are labelled here, I can have the polarizer analyzer crossed.

Then when I have quarter wave plate crossed I get the background dark, suppose I keep the polarizer analyzer the 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 analyzer crossed quarter wave plates I have this bright. And the list does not end here, you have a longer list and if you look at the book on digital photoelasticity 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 will have to look at, let us see a commercial polariscope now.

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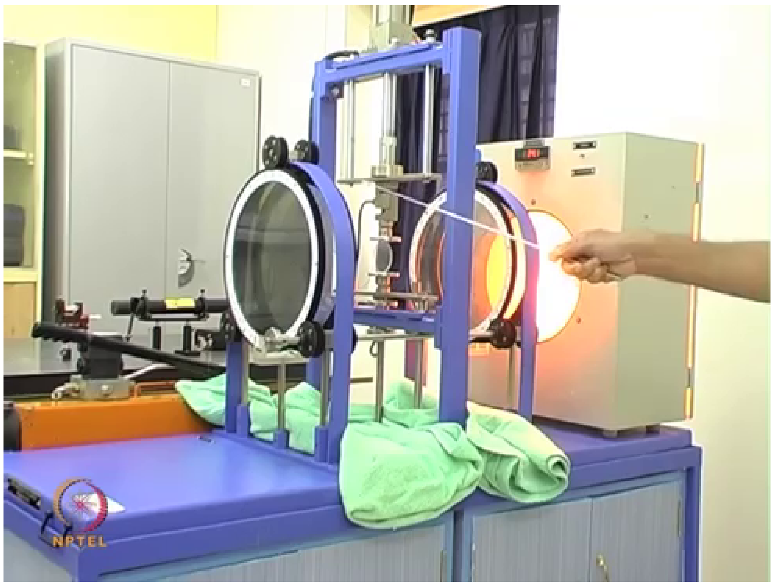

This is a commercially available polariscope, this has a light source and what you have is a monochromatic light impinging on the model, you have the first optical element namely the polarizer, you have the second optical element which is the first quarter wave plate, then you have the loading frame in the loading frame you have the model loaded, here you have a circular disc under diametrical 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 300 millimeters in dia, and they can be easily rotate by a simple mechanism. And what you see in the polariscope is the fringe patterns in dark field for a circular disc under diametrical compression, the fringes have to be labelled as 0, 1, 2, 3 etc. this shows the loading frame how the model is loaded, and what you have is the hydraulic cylinder which is controlled by a pump by selecting the wall 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 2 horizontal patterns, and the disc is kept under diametrical 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 and analyzer are crossed, first quarter wave plate and second quarter 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 and analyzer are parallel I will essentially see a bright field, rotate the analyzer now. So what you now see is you see a 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 2, 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 get 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, all the elements in the polariscope can also be rotated by this nob and what you will do is you use this for making this 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 kept crossed and they can be rotated to find out the isoclinics in a plane polariscope, rotate the nob. 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 wavelength, you have all the likelihood that will be small deviation of matching this wavelength to the actual light source, so you will always have a small error, and how to minimize this error, experimentalist are 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 to 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 lights source, which is in all likelihood possible. So a crossed quarter wave plate combination is what you should always look for arranging in a conventional circular polariscope.

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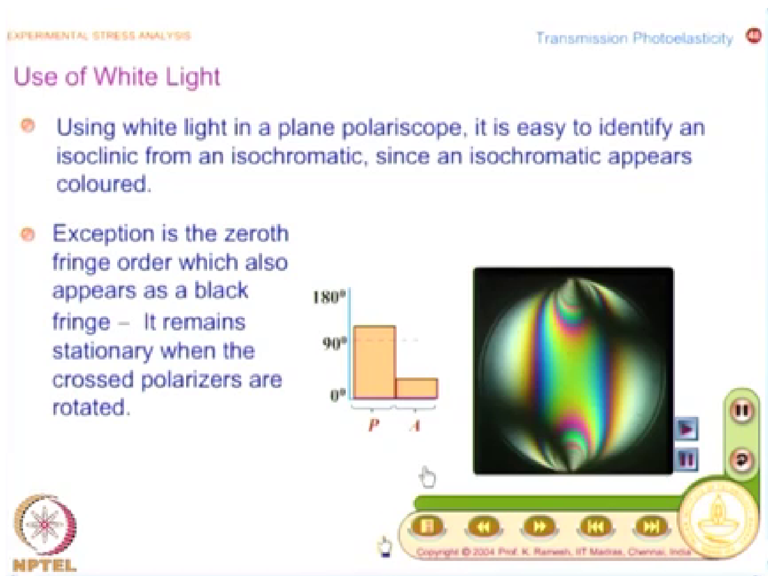

And you know use of white light has lot of advantages, for example even though I say the quarter wave plate is match for a particular wavelength, though it introduces an error during the model in white light for an unknown situation gives you a wealth of information. In conventional photoelasticity people used it to find out fringe gradient direction and also for integer fringe orders.

In digital photoelasticity you have well developed techniques now called 3 fringe photoelasticity or RGB photoelasticity, which can extract quantitative information from color data, it is no longer a problem now, it is lot more simpler and we have already seen in the plane polariscope if I have a white light source it is advantages because I can distinguish between isochromatics and isoclinics by distinguishing the color, and the black isoclinic.

The only difficulty comes in delineating the 0th order and the isoclinic, which we have already seen and which we have already learnt, it is not something new. So color held and let us look at a very nice example you all know stress concentration, we will look at for a plate with a hole, how do the fringes develop?

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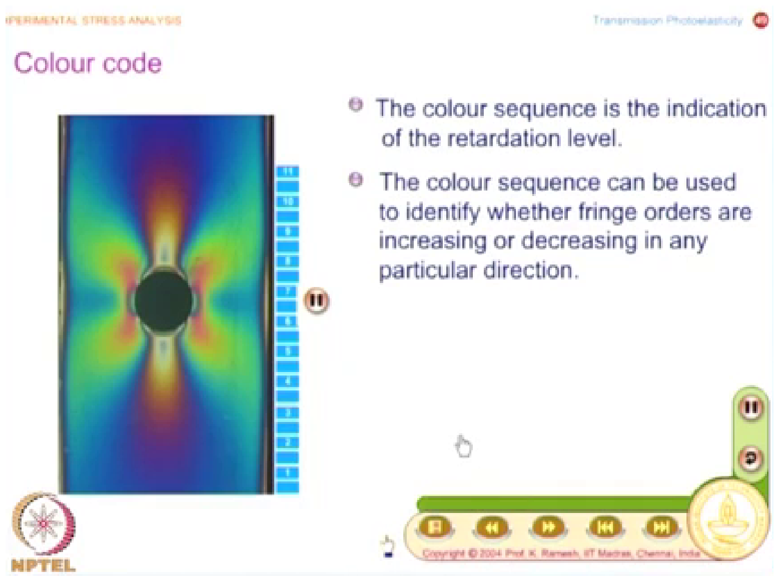

So beautiful we will see one after another I have this, I have the load gradually applied, when I gradually applied load you have colors start appearing, and also observe where the colors start appearing, it is start appearing at a point where you have very high stresses okay. So color start appearing and then they move as we go by, so this is how you have and this is a very complex problem because you know it is a finite geometry and I can find out stresses only from an experimental approach.

You see a very bright blue very rich blue, and as the load is increased, you see beautiful play of colors, so the color sequence is 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 I may in a conventional photoelastic analysis I may still do quantitative data extraction using a monochromatic source fine.

You have seen only simple fringe pattern so far, you have seen for a circular disc where the outer boundary is free boundary and stresses increases as we go to the load application point, you are not seen complex fringe pattern I have kept it deliberately away from the time being, we would spend time on a ring under the diametrical compression, how the fringes appear and if you know how to label the fringes and ring under diametrical compression you are fairly learnt enough how to identify fringes in any general problem.

They shelve in 2 extreme conditions, disc is very simple and ring is very complex, we will see those fringe patterns also later. 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 0th fringe order I know which way the fringes are increasing, then I can go to monochromatic light source identify 0th fringes 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 photoelasticity, but we may not look at it as part of this course for the time being, and what you find here is this is how the fringes develop and you also have you know I want your eyes tune to this rich colors.

And then have a look at it the color is so good, I have a beautiful color you know this is nature that has given it, like what you see in a peacock feather you see a such beautiful colors you are not go on, and if you watch here you have a shades of grey and you have white also in between, then you have yellow, then you have color changes, and you know I can do the zooming and you can see how rich the colors are? The colors are very rich.

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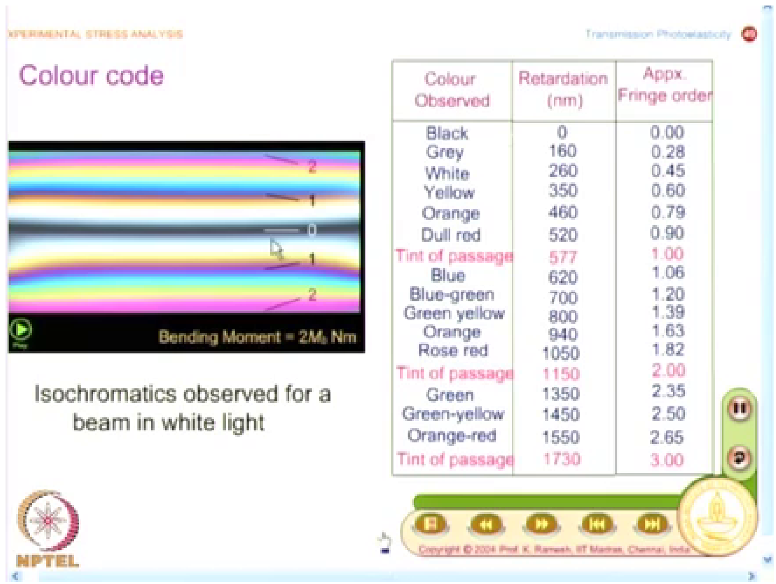

Colour Observed	Retardation (nm)	Appx. Fringe order
Black	0	0.00
Grey	160	0.28
White	260	0.45
Yellow	350	0.60
Orange	460	0.79
Dull red	520	0.90
Tint of passage	577	1.00
Blue	620	1.06
Blue-green	700	1.20
Green yellow	800	1.39
Orange	940	1.63
Rose red	1050	1.82
Tint of passage	1150	2.00
Green	1350	2.35
Green-yellow	1450	2.50
Orange-red	1550	2.65
Tint of passage	1730	3.00

Now we will go and attach numbers to these colors approximately that is what you will do, so I have a color code, so what I have is I have a black, grey, 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 to do is I am going to have one 0th 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 tinge of yellow, I see orange, I see dull red. So I see this color sequence here and which is labelled and I have what is known as tint of passage, where there is a change between dull red to blue for the fridge order 1,

And you will also notice this is the top portion of the beam, which is subjected to the 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 the Poisson's 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 approximation, so you have to correct your approximations based on experimental results. 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 1 and fringe order 2?

We will see the fringe order 2 here, and this is fringe order 1, I will just magnify before I magnify you look up here I will have a blue, blue green, green yellow, orange and this is labelled 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 a second fringe order it is rose red to green, and these are easily distinguishable when I magnify the picture and I want you to have the appreciation of this.

You see here this is 0 and see this is a dominance of blue here, whereas the red is also different here only you see the red, though it is 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, so this is for your fringe order 1 and this is for your fringe order 2.

You notice the difference in the red between the 2, I will also show this very closely, so you see that tint of passage is different we will go and look at up to 3 fringe order what happens?

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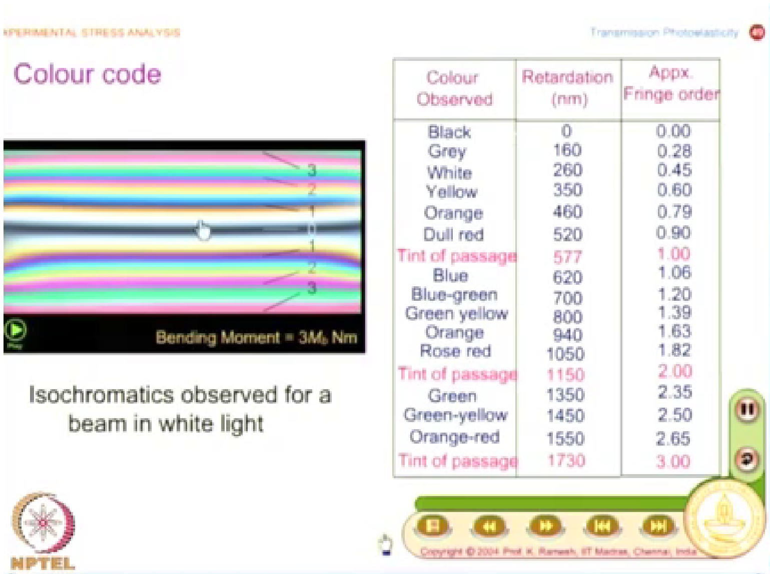

I will have magnified this further and this is how you find, so it is easy to distinguish fringe order 1 and fringe order 2, this is 0th fringes order, this is fringe order 1, and this is fringe order 2. Your eye needs to be tuned to this shuttle color changes, blue dominance is seen in fringe order 1, and pinkish red is seen in fringe order 2, and fringes order 3 you know the red and green are slightly different your eyes 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 3 fringe photoelasticity. Let us now see how photoelastic models are preserved.

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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 absorbs the moisture, and even the lid is put very carefully on the desiccator the interfaces put with a layer of grease, so you prevent any fresh air entering into this. And any air inside is absorbed 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 that lid, 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 not particularly sensitive to absorb moisture and what you will eventually have is what are known as spurious fringes because of an effect called time edge effect.

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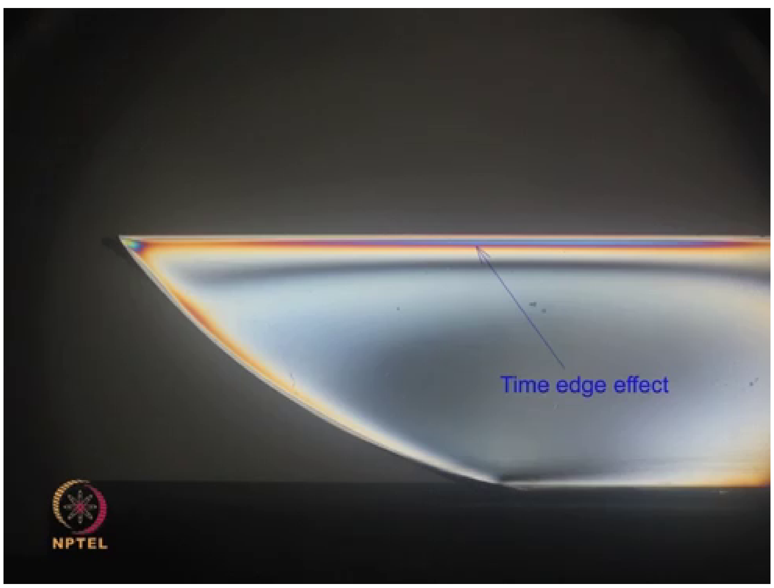

And you need to avoid this for quantitative extraction of photoelastic data, so hold the model only like this, keep it in the desiccator, and put it with silica gel, and periodically monitor that silica gel in good condition, and this is very important. And if you do not follow these practices you will see formation of spurious fringes at the edges which will spoil the model for future use.

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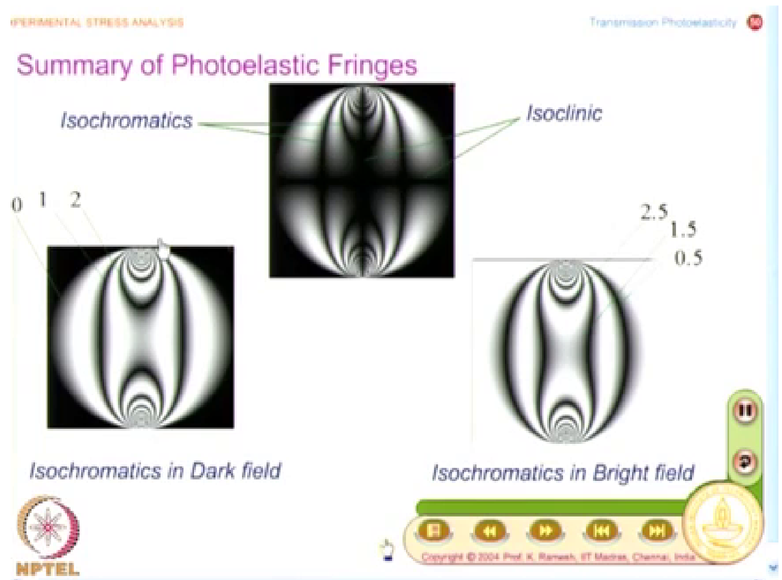

To summarize let us see what are all we have seen in this 2 optical arrangement? We have seen a plane polariscope, we have seen a circular polariscope, and we find 2 fringes contours in a plane polariscope, we see only one contour in a circular polariscope, and we will see for a circular disc what this fringe contours are. So what I have here is this I see in a plane polariscope, I have background as dark, I have isoclinic as well as isochromatics.

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 will labelled the fringes as 0, 1, 2, 3, 4 like this, and the same thing I will also do here 0, 1, 2, 3, 4 like this, because the fringe gradient is like increasing in this fashion, it is increasing in this fashion.

The moment I come to bright field I labelled the fringes as 0.5, 1.5, 2.5, and comparing these 2 figures you can see that these 2 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 case of a dark field label them as 0, 1, 2 and 3 and so on, so that is how we have seen the ordering of fringes, and ordering of franchise is very tricky task in a generic problem we need to learn more.

And I will postpone it for the 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 at a point of fringe order N, and theta at 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 fringes, and some cases you may have to gradually load the model observe how the fringes developed or gives the color codes all the circus we will have to do. And what we have also seen is we have also had a look at how one 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 spurious fringes? Why this spurious fringes are caused? And this is obtained by time edge effect. 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.