Experimental Stress Analysis

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Module No. # 02

Lecture No. # 18

Determination of Photoelastic Parameters at an Arbitrary Point

We have been discussing on transmission photoelasticity. And we have said that you need to know stress optic law, to relate the fringe patterns observed to stress information. And to plug in the stress optic law, you need to get the fringe order. And in order to get the fringe order, we need to have appropriate optical arrangements. We have looked at plane polariscope, we have also looked at the circular polariscope. And I said one of the convenient means to quickly identify the fringe order is in white light.

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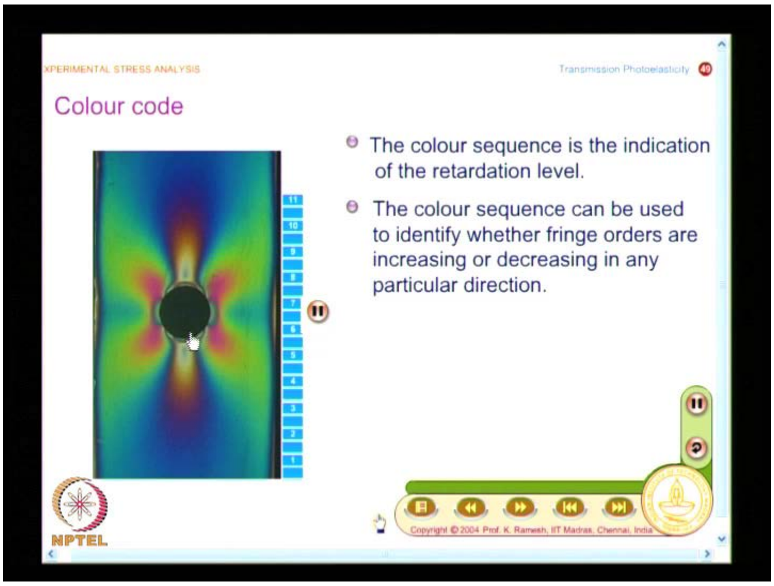

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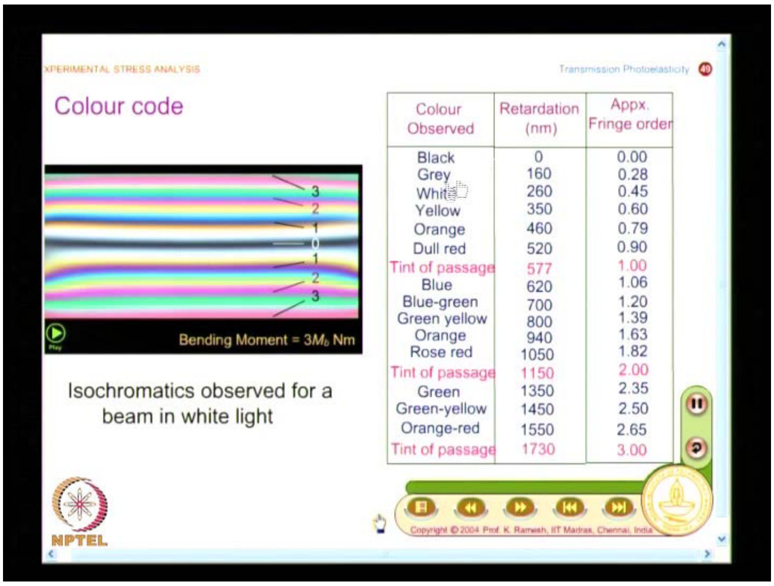

So, in white light, you see a color code, and what I have here is the problem of a plate with a whole, and you have this as a stress concentration region, and I have a color of black here, then you have white and then it moves out. And you see a rich play of colors, and the play of colors give an indication what is the gradient of the fringe variation, here it is 0, here it is 1, so from 0 to 1 it increases in this direction. And we also looked at the color code, wherein we identified for each of the colors an approximate value of the retardation, and I have the color code up to fringe order 3. And what you have was dull red to blue transition, you have a tint of passage, and you label that as fringe order 1 and the corresponding retardation is about 577 nanometers.

The second transition happens between rose, red and green, that is what we have here; this is your fringe order 2. And if we look at the retardation, it is double that of 577 closely. Then you have another tint of passage between orange, red and then green, and beyond fringe order 3 the colors tend to merge. Though it is not shown in this picture, the picture stops at fringe order 3, beyond fringe order 3, the colors merge, it is very difficult to associate to a particular color to a fringe order beyond fringe order 3.

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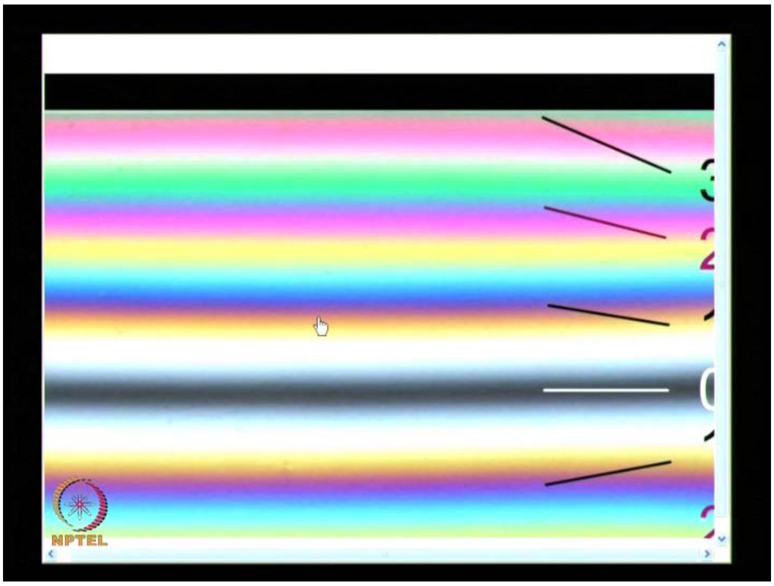

And this gives a fairly good idea, when it is black I have a fringe order 0, and when it is a blue red transition you have fringe order 1, and rose, red and green transition, you have fringe order 2, similarly you have orange red and shade of green, which is fringe order 3. You can tune your eyes to get this and you can have a picture of how these fringes look like. So, you have the variation here and this gives an indication how to find out that gradient direction. In conversational photoelasticity, color was primarily used to find out the gradient more than quantitative estimation.

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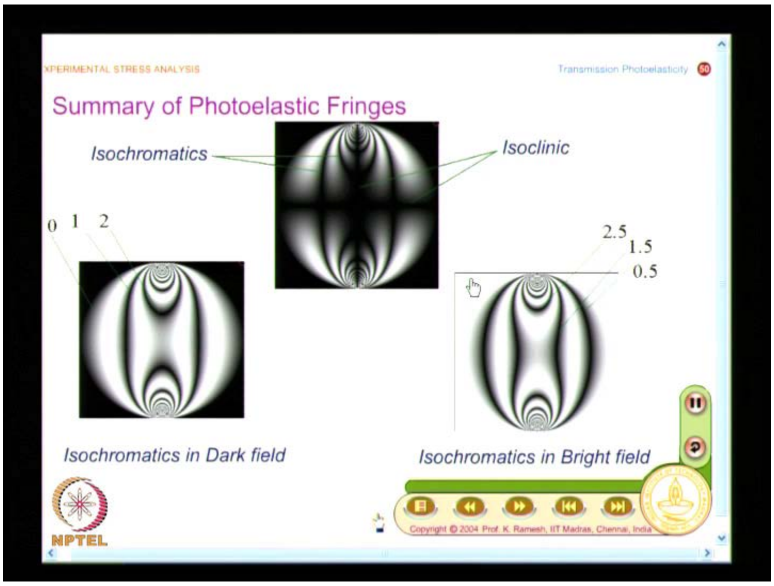

And we have also looked at a summary, wherein we saw what we had as fringes in plane polariscope and what we had as fringes in circular polariscope. In a circular polariscope, you have a dark field, as well as the bright field, and because the way the model is loaded, and also from the theory of elasticity solution, the outer boundary fringe order is 0. This was also seen in the color code when we are looked at circular disk of color, we had shade of gray followed by black on the boundary. So, this is fringe order 0, and this is the load application points, so you know the fringe gradient direction, from 0 it goes to increase towards this.

So, by knowing the zeroth fringe order, and the gradient in the direction it increases or decreases, it is possible to label the fringes. We have not really looked at (( )) fringe order labeling, if somebody gives a black and white photograph, it is extremely difficult to label the fringes; it is not the simple task. On the other hand, if you have an isochromatics is recorded in white light, you can comment on approximate value of the fringe order and also the gradient by looking at the color visually. If you go to three fringe photoelasticity, you can also give quantitative data, but in visual interpretation, you can only say the gradient comfortably, numbers may be error only.

Now, what we will had look at is, in all problems we may not want to know the fringe order at every point in the domain. What I have is, I have a fringe order 1 here, I may have a point in between, for which I need to find out fringe order.

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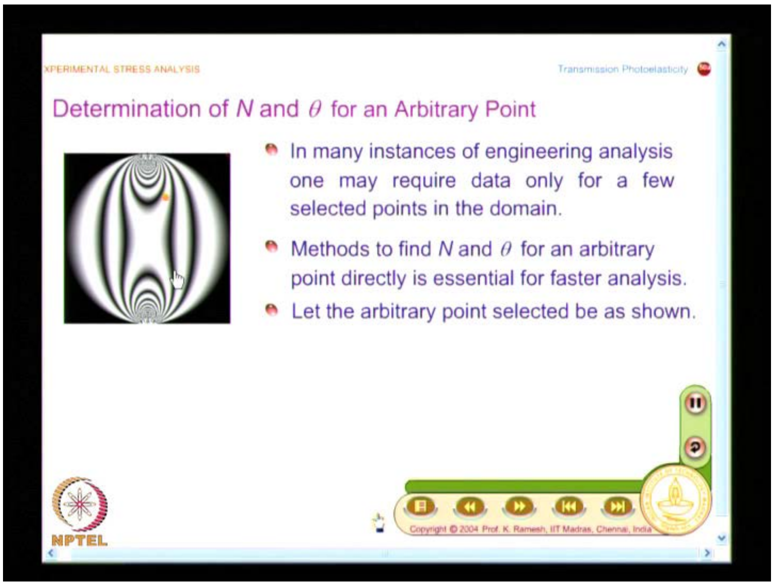

Now, we need to find out how to do this experiment. So, the focus is how to find out determination of N and theta for an arbitrary point. And what you shown here is I have a circular disk and diametric compression, dark field arrangement, I have 0, 1, 2, 3, 4 and so on. This to illustrate, suppose I have a point, which lies between fringe order 2 and 3, I want to know the fringe order at this point of interest, and this is what key for my design scenario, then it is enough that I find out the fringe order at this point or few selected point in the domain.

I need not go and find out, and use the complete whole field information, this I emphasized earlier. Experimental methods, particularly optical techniques, give you whole field information. From a design point of view, you may not require all that information; you may want to know information only at few selected points, particularly when you go for a stress concentration problem. You would like to estimate the stress concentration factor; in that case, you may want to know what the maximum stress is and what the average stress is. So, you may want to find out fringe order at these two locations.

So, in addition to looking at whole field information, there are also requirements where you have to find out the fringe order at selected points. So, methods to find N and theta for an arbitrary point directly, this is the key point, is essential for faster analysis. And you already know, suppose I want to find out N and theta, for N I can go to a circular polariscope, for theta I have to necessarily go to a plane polariscope. And in fact, determination of theta at any arbitrary point is for more simpler and straight forward, then finding out N at arbitrary points.

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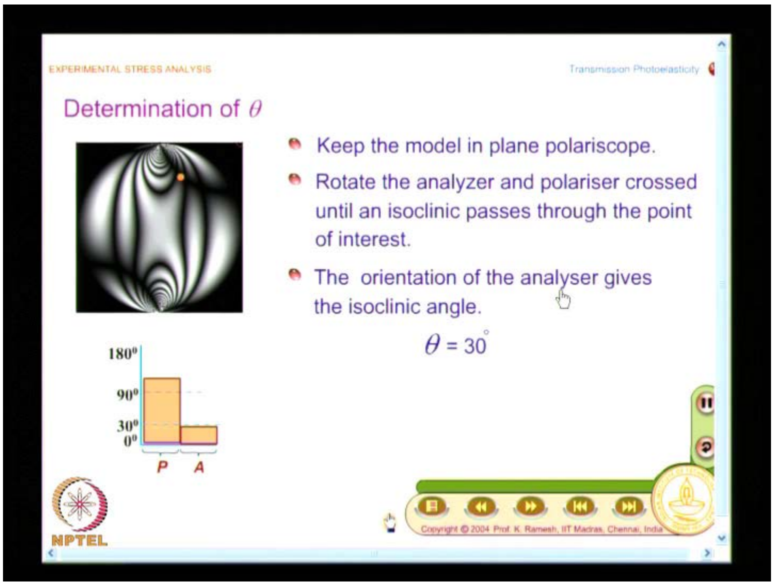

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So, first what we look at is, we look at how to get theta, and then we will go and find out how to get the fringe order N. Now, for the same point, I want to find out the theta. So, what I do here is, I go to a plane polariscope, and I rotate the elements until the isoclinic passes through the point of interest. So, this is very simple, what I need to do is, I need to mark the point on the model, then I keep the model in the plane polariscope, keep rotating the polarizer analyzer combination crossed, you want keep them crossed and then rotate, and you stop it when an isoclinic passes through the point of interest. And what will have to keep in mind is, since we are going to do it visually, you know you have to look at the model perpendicular, error or parallax has to be avoided and you also see, compare to an isoclinic fringe, fringe is very broad.

So, some amount of human judgment is involved in stopping when to identify an isoclinic pass to the point of interest. And there could be an error in the determination of this, this is if you are very careful, you can do it plus or minus 0.5 degrees, if you are casual, you may end up with an error of plus or minus 2 degrees.

So, if your eye is tuned, and if you look at the model perpendicularly, and also stop it at a point where the intensity is fairly minimum, then you will be able to give an accuracy of the order of plus or minus 0.25 degrees, even visual inspection you can do and that procedure is summarized here; what I have explained is summarized here.

So, keep the model in a plane polariscope, rotate the analyzer and polarizer crossed until an isoclinic passes through the point of interest. The orientation of the analyzer gives the isoclinic angle, because we have labeled the analyzer angle with respect to the horizontal and that itself directly gives what is the isoclinic at the point of interest. A 30 degree isoclinic is passed through it and this is pictorially represented in this diagram. So, you will always find the angle polarizer analyzer are separated by an 90 degrees, indicating that they are crossed, and we have stop this crossed position of polarizer analyzer when analyzer has reach 30 degrees, this has passed through the point of interest.

So, the value of theta at this point, after looking at the analyzer, you find it is 30 degrees. And it is simple, suppose I want to find out for another point, mark the point and find out when does the isoclinic fringe pass through it, then stop it, find out the analyzer, and you get the isoclinic angle as simple as that. The only difficulty is, because the isoclinic fringe is very broad, your involvement in interpretation and stopping the crossed polarizer analyzer combination is crucial in deciding the accuracy. And in modern days, you replace your human eye with an electronic camera, and you do intensity processing, and you are in a position to enhance the accuracy.

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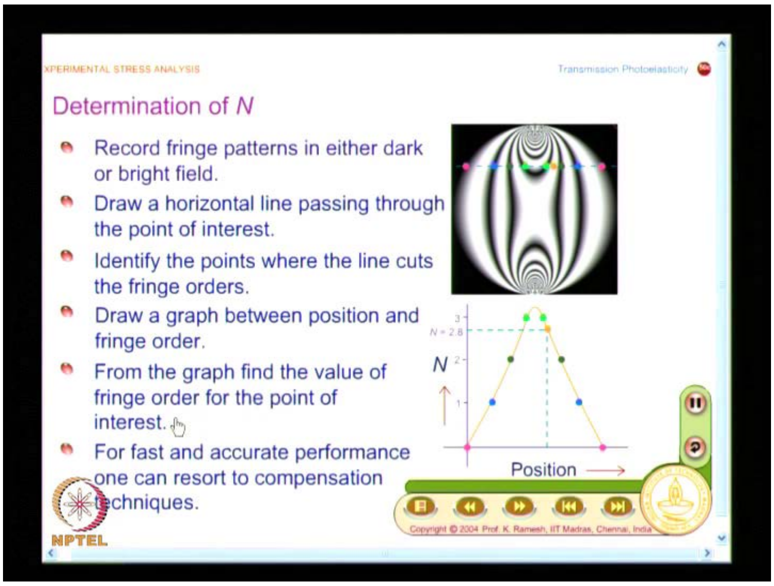

So, determination of theta is fairly simple, now we move on to find out how to get fringe order element. Now, I know for which point I want to find out a fringe order, we have deliberately taken this point not lying on any one of the fringe orders. In this case, I have taken it between fringe order 2 and 3, and this is the dark field recorded image. Suppose you are given a choice, you have to find out the fringe order, this is the data available and how will you proceed? We want to improve the accuracy, you need to have as many data as possible and the simplest thing is try to fit a curve of variation.

Because I know the fringe ordered selected points, and if I know the fringe ordered selected points, joint them and this point lies in between that. So, you can find out from the graph what is the fringe order at the point of interest? Suppose I have sufficient number of fringe orders, even recording dark field alone would be sufficient. If you do not have several data points, you can recorded dark field image, you can record a bright field image, so you have additional data points and from that you can find out what happens at the point of interest. Draw a graph and that is what precisely we will do, and in this case, even a dark field images is sufficient, because suppose I take a line along this passing through the point of interest, it would cut several fringe orders. So, the simplest way to do is, you record the image and then post process the data.

So, what I am going to do is, draw a horizontal line passing through the point of interest, so I have several points that this cuts. So, what I have here is I have fringe order 0 1 2 3, this is 3, then 2, 1 and 0; this I have been able to find out, because I know for sure in the case of a circular disk, the outer boundary is zeroth fringe order. This information is known, so I can count it as 0 1 2 3. And now, I want to find out fringe order on a point, which is lying in between fringe order 2 and fringe order 3.

So, what you need to do is you need to draw a graph, and then identify what is the fringe order at the point of interest and that is what you shown in this slide. So, what you do is, identify the points where the line cuts the fringe orders, draw a graph between position and fringe order and that is shown below. I have the position, and I have the graph drawn, from the graph find the value of fringe order for the point of interest, and it depends on how good you have drawn the graph, and how well you have located this points, your accuracy is dictated by that, and here it turns out to be fringe order at the point of interest is 2.8, that is what you get here.

But, if you want to have a real improvement, you need to resort to what are known as compensation techniques. See, here, what you do is you have to take a picture, draw a line, and then find out the fringe order. Suppose I eliminate even taking the picture and drawing the graph, then I will have a much better technique and that is what you do in compensation techniques.

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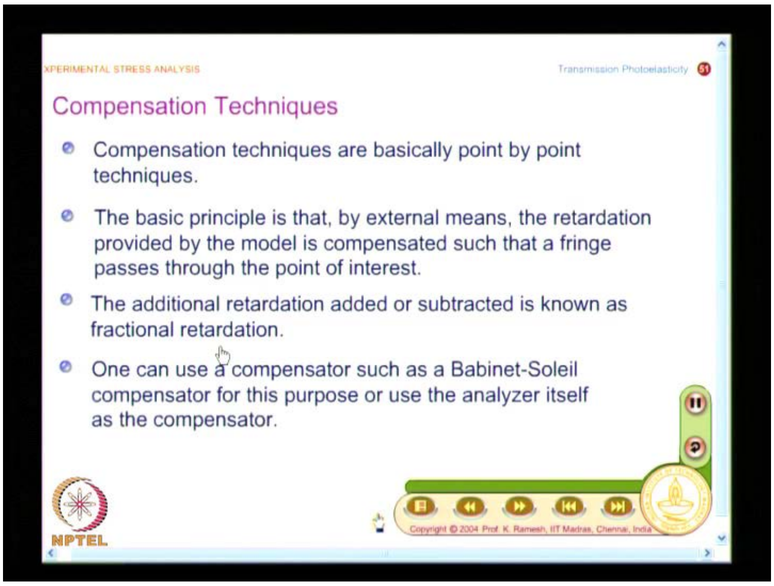

So, once simple approaches is plot a graph and then do it, and if you want to improve the performance, and also improve the accuracy, you have to resort to what are known as compensation techniques and we will see what are compensation techniques. See, the moment you come to compensation techniques, you have to go back and then see how we evaluated the retardation matrix. In Jone’s calculus representation, we have indicated a retarder by a matrix, and I also said, we are adding or subtracting retardation with respect to the reference access. The reference access at the point of interest coincides with the principle stress direction, this is very important. I emphasis even at that point, you need to find out in which access you add or subtract retardation, this is the very key point.

The moment you come to compensation technique, even optical method becomes the point by point, because we are in general, said, when you have a fringe pattern observed, you get the whole field information. If you are in able to interpret from that photograph well and good, the moment I go to a compensation technique, whatever I do pertains to the particular point of interest, I may see in the process of compensation methodology. I may still see some fringe contours away from the point, they do not have physical meaning, the physical meaning is attach only to the point of interest, this will become clear when we look at the technique and how we do it.

So, do not think a whole field technique always gives whole field information. The moment you employ a compensation technique, you reduce this to a point by point method, so this is what you have. Compensation techniques are basically point by point techniques. And what is the principle? By external means the retardation provided by the model is compensated such that a fringe passes through the point of interest.

See, we have also done a logical development of fringe formation both in a plane polariscope and circular polariscope. We set when the model behaves like a full wave plane in a dark field, the light is cut off at 0, 2 pi, 4 pi retardations, at other points you had shades of brightness, you know, from dark fringe to you also go to a bright fringe, so you have an intensity variation. Why that intensity variation comes? Because at those points the model was not behavior like a full wave plate, instead of a plane polarized light coming out, you have an elliptically polarized coming out in the case of the plane polariscope. So, all the light is not cut by the analyzer, so you see some light.

Now, in compensation technique, you find out what is the fractional retardation, we need to add or subtract at the point of interest, so that with the compensating device at the point of interest the retardation, equals 0, 2 pi, 4 pi, 6 pi, this is the basis of compensation techniques. But, for me to apply the compensation I should know the principle stress direction at the point of interest, this is the pre request. So, the principle is, you make it with the compensating device the retardation at the point of interest equal to a full wave plate in the case of dark field, if you employer dark field.

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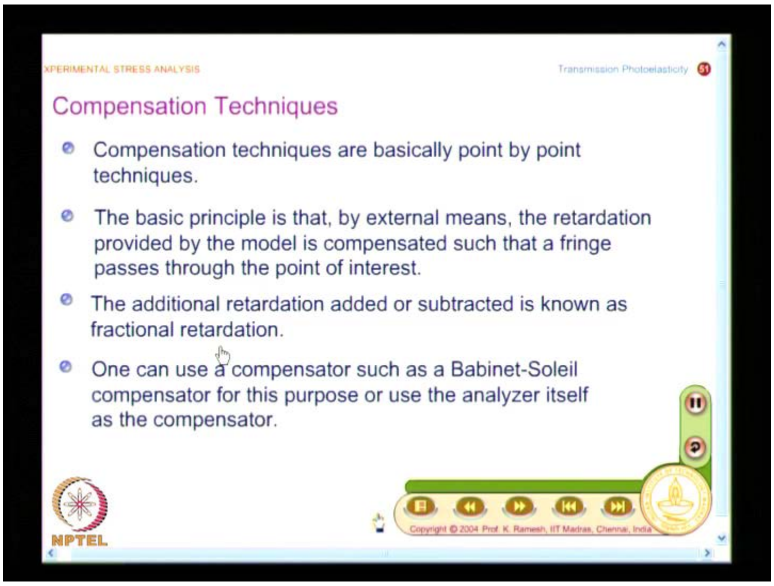

If you employ a bright field, you can also have intermediate values and this is what we have. So, the basic principle is, by external means, the retardation provided by the model is compensated such that the fringe passes through the point of interest. And the moment I bring in compensation, see I also made a statement that in photoelasticity, you get only positive fringe orders, this refers to total fringe order, sigma 1 minus sigma 2 is equal to n s sigma by t or n s sigma by h, because sigma 1 minus sigma 2 is always positive, n is always positive.

But, when I do compensation, the compensation can be positive or negative; you should not confuse these two. Because, at the retardation, may be greater than 2 pi, I may slightly reduce it and bring it 2 pi, so I have to have compensation as negative value, it may be slightly lower than fringe order 1, I may add compensation to increase it to fringe order 1.

So, the moment I come to compensation technique, first is it is the point by point methodology, second whatever I compensate has a sign attach to it, do not confused this with sign of the total fringe order, these are two different issues, because such confusions you know can come.

So, this is what you have here, the additional retardation added or subtracted is known as fractional retardation, so we call this as fractional retardation and fractional retardation can have a sign attached. And in many instances, how to find out the sign is crucial, in fact, in the whole of digital photoelasticity, the sign was ambiguous, and this has really took almost a decade to solve this issue, is not trivial. When you are doing a conventional photoelasticity, you have lot of heuristic information available to you to fix the sign. The moment you go to computer processing, this has to done intelligently and that has been achieved now.

So, what you find here is the fractional retardation will have a sign, and that you have to find it out precisely. And there are many compensation techniques available, one can use the compensator such as Babinet-Solell compensator for this purpose, or one can also use analyzer itself as a compensator. See, when you normally develop a technique, you identify that there is an issue and this needs be sorted out.

So, the first solution will only be sort of at first approximation, you want may want an additional gadget to help you. So, if you look at Babinet-Solell compensator, it is an additional piece of equipment which needs to be attached to the polariscope and then find out the compensation.

On the other hand, as techniques develop, people also device without an additional element, can we do something with an optical arrangement itself, go back to the equations and find out whether you could improve upon and find out one of the elements itself can behave like a compensator, so that is how you have. Analyzer itself is being used as a compensator, this has a special name, you have a person invented it, so you call that as the (( )) method of compensation.

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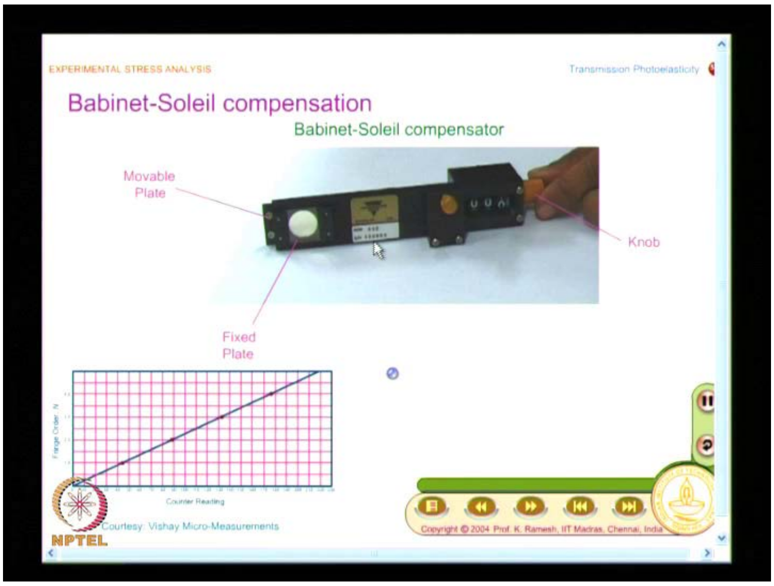

So, what we will do is we look at Babinet-Solell compensator, as well as compensation by using the analyzer. And you have readymade equipment's available for Babinet-Solell compensation. And you can see here, I have a window and I have another plate that is coming out, so I have a fixed plate, and I have another plate which moves and you can also see that there is a counter. So, this is the commercially available Babinet-Solell compensator, this is from a (( )) measurements group.

And what you have here is I have two elements, one element is stationary, other element moves. This can be rotated by rotating this knob and the counter value will change. You need not sketch this; you just observe this, later I have a simpler sketch which you can note it down. And what you have is when they supply a compensator like this, they also supply a calibration graph, so this graph goes with the compensator, this is supplied by the manufacturer himself. So, what is that you need when you want to look at compensation, see you have read elaborately what is the retardation plate, what are wave plates. Wave plates, you know by changing the thickness, if you have crystal plates, by changing the thickness you can adjust the retardation. And if I want to have a plus and minus this is also possible.

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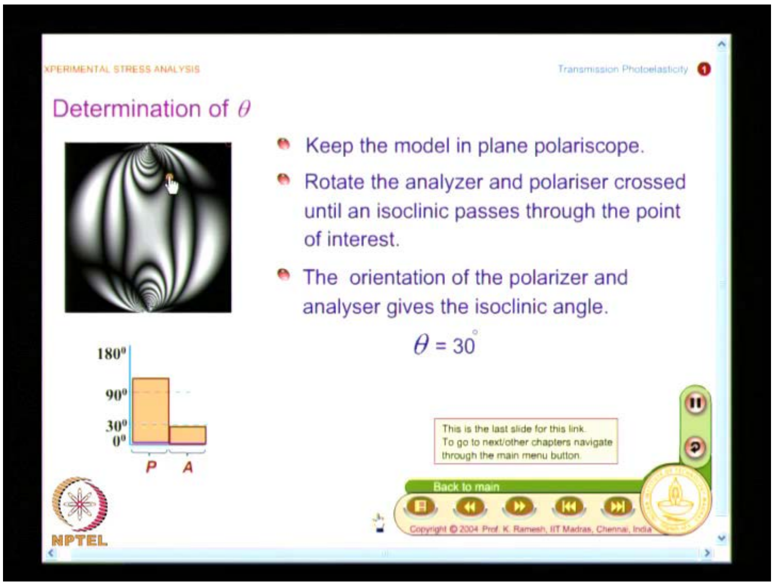

So, the physics behind the Babinet-Solell compensator is I have a provision to adjust what is the effective thickness of the compensator, one could be positive, one could be negative, there are many combination possible, one could be tapered, so the essentially what you are doing is you are trying to adjust that fractional part so that at the point of interest model behaves like a full wave plate and this is very interesting. And how do we go about? See what I have is, I have a kept the same point, which we have found out the fringe order by plotting a graph earlier, and we will find out the fringe order for this point by using Babinet-Solell compensator.

See, when we went and do the graph, you did not want to find out the isoclinic at the point of interest, and what you did was you simply took the photo graph, then you drew the line, and then identify points where the line cuts a fringe order, then you plotted a graph, and picked out what is the fringe order at the point of interest. If you adapt that kind of a method, there is no need to find out the isoclinic angle at the point of interest, but that method is time consuming and also depends on the accuracy with which you have picked out other data points.

On the other hand, in compensation technique, I do not have to take a photograph. Imagine in old days, when they have to take a film, develop the film and then make a print, only then they will be able to do. Now you have a digital camera, instantly you get the pictures. Even processing the picture is not a big issue now, we have several image processing routines also have come and picking out this data is very simple.

But now, with advancement and imaging, why do you go and work on a conventional approach, people thought that they will work intensities, that is how digital photoelasticity developed. Even the basic philosophy in processing the data has changed, but nevertheless you need to know how you can do a conventional approach, that knowledge helps. This also helps in verifying whether your digital photoelastic algorithm is giving with the correct result, because you should always have a secondary method to check, because once you bundle everything as a software, it is a black box, whether it is finite elements, or whether it is explorer mechanics, you are going to ultimately use a software, you should never use it as a black box. You should know how the software has been developed and you should also have methods which helps you to verify whether the software is turning out correct results.

So, from that point view also finding at the fringe order at any arbitrary point, using a compensation technique is useful. Do not think that with digital photoelasticity, in one with press of a button, I get all fringe orders, then why I need to find out and learn compensation technique, even to verify some of those algorithms may fail at some places, there are limitations. In any development there are limitations, so what you have here is I need to find out the fringe order at this point of interest, the moment I go for any compensation technique, I need to know the isoclinic angle at the point of interest. And how do I get the value of theta? And for this point we have already seen the recapitulate in it, so we found that a 30 degree isoclinic pass through the point of interest.

So, I have theta at this point of interest is 30 degrees, this information is needed for me to align the Babinet-Solell compensator at the point of interest to introduce compensation, understand this. Interestingly, even in digital photoelasticity, I need to get theta at the point of interest and then only go to find out fringe order.

Though in a conventional approach, I can find out theta separately and N separately, the moment I come to compensation techniques, I need to find out theta also at the point of interest and then only apply compensation. The same philosophy is extended in digital photoelasticity also, and you will also have to keep in mind when you are looking at compensation technique, when I do the compensation which fringe order has moved and fill the point of interest.

I am telling you in advance, so that when the animation comes, you observe this (( )) points. First thing is, it is applicable only to the point of interest even though I see fringes elsewhere; they have no physical meaning, this you have to keep in mind. And second observation is, which fringe order has moved and occupied this, whether it is the higher fringe order as moved to the point of interest, or lower fringe order has moved to the point of interest, this you have to keep in mind. Now, what we see is we have identified theta at the point of interest.

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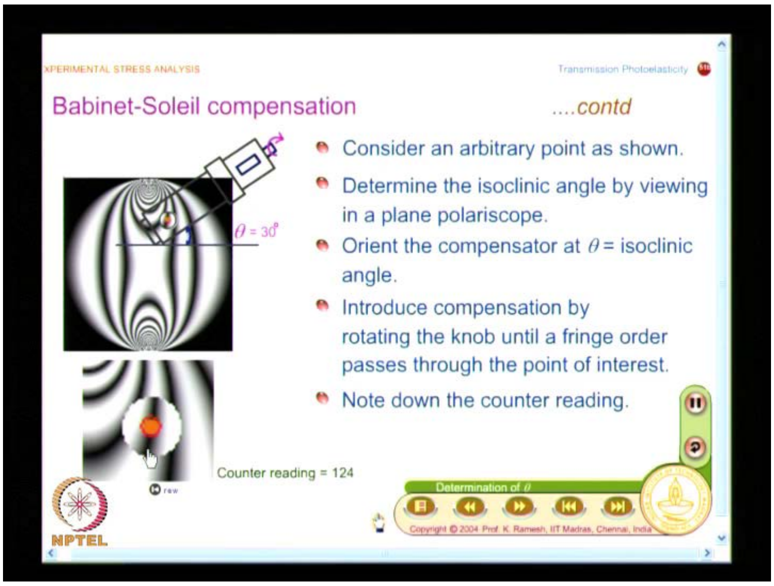

Now, we go back and then see how do I use this information. So, we have determined the isoclinic angle by viewing in a plane polariscope, and what I mean to do is orient the compensator at theta equal to isoclinic angle, so that is what you see here.

So, what I see here is, you see this very carefully, I have oriented at this compensator axis at theta equal to 30 degrees, this is where I use this. And I think you need to sketch this figure, I will give a slightly complete figure here, so I have the fringe pattern, I have to align this compensator at the angle of the isoclinic at the point of interest. Because, this compensation has to be done along the reference axis at the point of interest, the reference axis turn out to be principles as direction at the point of interest, and principle interest at the point of interest at the point of interest has been determined from the isoclinic angle. Now, I align the compensator with that angle, then whatever the compensation I do, it is possible for you to obtain a calibration between the counter riding and the compensation added or subtracted, it as simple as that. And what I have shown here is the compensator is put, and this is the field of you. The field of you is very small in the case of Babinet-Solell compensation.

So, what you see here is, only within this field, whatever the interpretation even within this field, only at the point of interest the interpretation is valid, though you see a fringe background they have no physical meaning when I apply the compensation. Right now, compensation is not applied, right now only I have aligned, even when I have aligned it, there is the base compensation is available. Until I rotate the knob, and then make this fringe to move to this point of interest, I will not know what the way to interpret the data is.

Now, what I will do is, I am going to rotate the knob in such a manner, a fringe passes through the point of interest. So, that is what is shown, you are rotating this knob and you have this in the field of interest, I have a fringe that passes through the point of interest. And we would have a enlarge view of this, and I will do the compensation again, are you able to see? When I do the compensation, here which fringe order as move to the point of interest? Higher fringe order has moved to the point of interest. And I see a fringe here; do these branches have any physical interpretation? They do not have any physical interpretation.

I see a fringe that is why I say in all optical techniques interpretation of recorded data is very crucial. Just because you see a fringe, I cannot say this was fringe order 3, so all this point fringe order is 3, you cannot conclude that way. What we have made observation is a higher fringe order as moved and occupied this position, so that means, what I have done is I have done the compensation in a manner, whatever the fringe order is, 3 minus, in this case is this is the fringe order is 3, so 3 minus that compensation will give the fringe order at the point of interest.

So, you get the heuristic information, what is the sign that you should attached to the fractional retardation. Suppose fringe order 2 has moved, and then you need to add, fringe order 3 has moved, so you need to subtract.

So, whether to add or subtract depends on what observation you make at the point of interest, this will become very important when I go to (( )) method of compensation, because in (( )) method of compensation I can rotate it clockwise or anti-clockwise, and in the counter that have (( )) very user friendly. You rotate it in own manner, whatever the reading that you get, you are in a position to, you have a calibration chart, you have a position to find out what is the fringe order at the point of interest, that is the way the calibration is. The calibration is slightly done differently, but the physics is same, you have to know in all compensation techniques, whether a higher fringe order as moved and come to the point of interest or a lower fringe order has moved to the point of interest. And in this case, the animation clearly shows a higher fringe order has moved to this point of interest.

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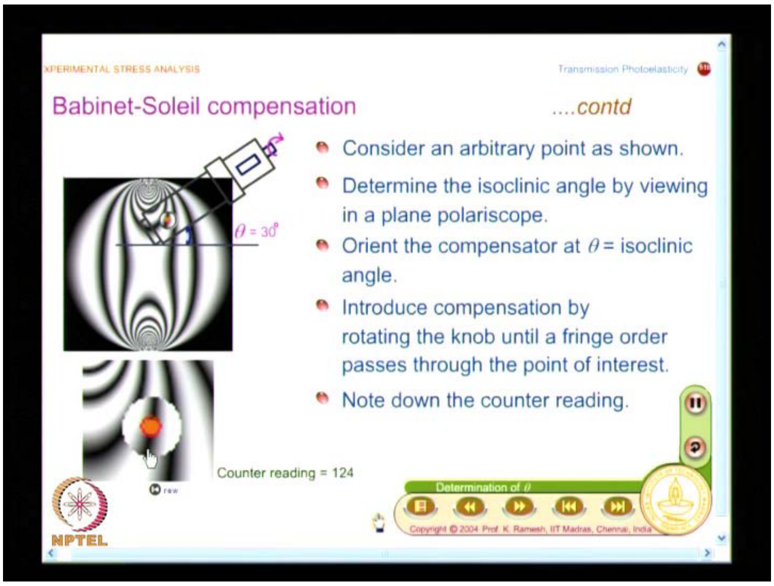

And when I start with, you know, because in a Babinet-Solell compensator the field of (( )) is only this, the other fringes are not affected, other fringes are like what I have in the regular dark field, they still hold the interpretation as dark field fringes. In this region, the interpretation is valid only for the point of interest, for illustration I have shown a big circle; actually it is the center of the circle. So, whatever the interpretation, data interpretation is applicable only to the point of interest when I apply compensation technique.

Even though I see (( )) of fringe else where, they do not hold interpretational value to the physics (( )). In this case, because the field of view is only restricted to this, these are stilled dark field fringes, do not worry about it, they are still dark field fringes, and you can attaches 0 1, I mean in this is 1 2 3 all those values. Within this region, only for the point of interest you must attach the retardation, whatever is the fractional retardation, you should attach only to this point of interest.

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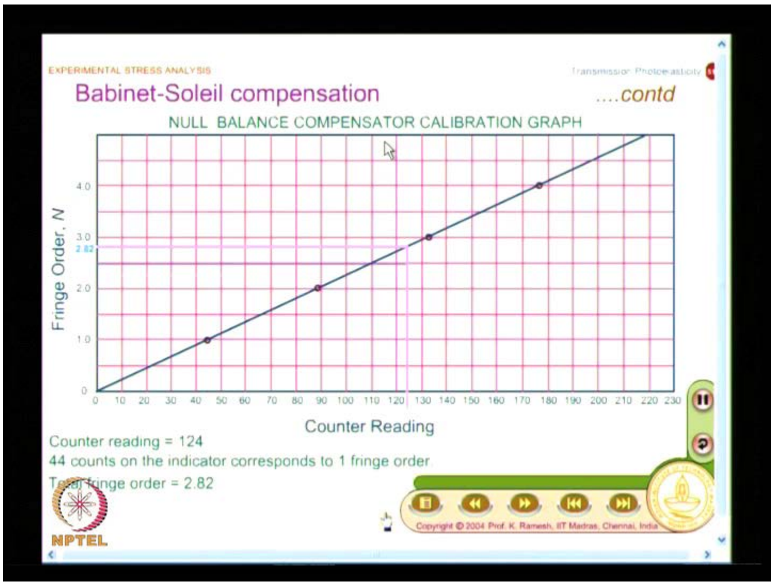

So, this is how you do the Babinet-Solell compensation. So, I stop it, stop the rotation of the knob until a fringe passes through the point of interest and you need to note down the counter reading. And in this case, the counter reading turns out to be 1 2 4. So, is the idea clear? When I go to a compensation technique, I need to know, I need to mark the point of interest in some manner, then I need to find out the principle stress direction at the point of interest, align the compensator axis along the principle stress direction, then rotate the knob until a fringe passes through a point of interest. In a Babinet-Solell compensation, they are made the calibration in the manner that you find out the counter reading, you are in a position to use the graph supplied by them.

So, this gives a null balance compensator calibration graph, now I have the counter reading is 1 2 4, I simply go in this graph and find out what is the fringe order, I get this fringe order as 2.82. So, this is far more accurate than finding out based on plotting your graph, and here I do not need to plot a graph, I have the calibration done just by noting the counter reading. You make a sketch of this graph that is you just, you do not have to put all this fine values, you just show the shape of this linear variation and you have fringe order 1 2 3 4. And if I know the counter reading, it is possible for me to find out from this graph what the fringe order is.

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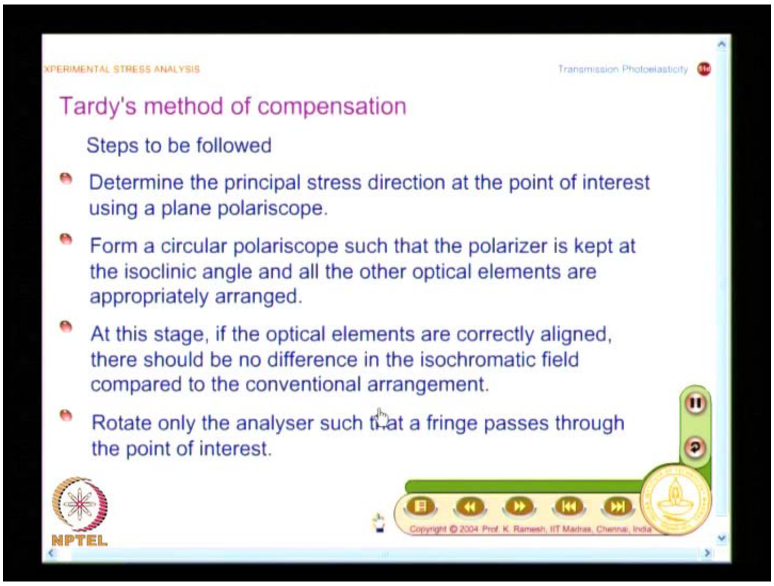

So, it is easier for you to do this, you have this as 2.82, and this is supplied by the manufacturer, he gives you 44 counts on an indicator corresponds to one fringe order, this is for the particular piece that is supplied. So, this may vary from batch to batch or piece to piece, and this will be supplied by the manufacturer. And what I am going to look at is, we have also said, one can find out compensation not by having an external element, but by simply handling the analyzer, and this is known as (( )) method of compensation. And I am going to only list out the steps today and we will see the mathematical development later.

As before, you have to find out the principle stress direction at the point of interest using a plane polariscope. Then what I need to do is I need to form a circular polariscope such that the polarizer is kept at the isoclinic angle and all the other optical elements are appropriately arranged. See this is a very important step; in the case of Babinet-Solell compensation what we saw? We found out the principle stress direction, and we took the Babinet-Solell compensator and aligned it along that access, it was 30 degrees. So, you have the disc, and then you put it like this, put it at the 30 degrees in their particular point of interest, the alignment was fairly simple.

Suppose I want to use the analyzer itself as a compensator, then I need to rotate the entire polariscope to that angle of the isoclinic angle, so that means, the fringe field should not be effective. Here again, we will send this circularly polarized light impinging on the model, then circularly polarized layer, whatever the light that comes out of the model is analyzed by second quarter wave plate and analyzer, that would form the reference access. And this one of the verification is whether you have rotated all the elements appropriately, is to verify after rotating, all these isochromatic fringe should remain same, it should not have any distortions or any changes, that ensures that you have rotated all the optical elements appropriately.

So, it is very similar to keeping the compensator at the isoclinic angle, at the point of interest. Then, the next step what you do is, you simply rotate the analyzer. Rotate only the analyzer such that a fringe passes through the point of interest. And what I have said is summarized with the optical elements are correctly aligned; there should be no difference in the isochromatic field compare to the conventional arrangement, this is the check. Because, you know, when you have a polariscope, where you have to rotate each of the optical elements, they have to be rotated carefully and maintain the parity between the individual elements.

Because we want to have a polarizer and quarter wave plate separated by 45 degrees, and you need to have the slow access at 135 from the horizontal. Now, it becomes appropriately when with respect to the basic isoclinic angle, so you need to keep that parity, quarter wave plates should be crossed. Now, I have the base, whatever the analyzer access, I will take that as the base, and what I need to do is, I need to rotate the analyzer until a fringe passes through the point of interest.

Now, what I will do is, we will be surprised that whatever the angle that I rotate is crucial at itself, will give you what is the value of the fractional retardation and that sign how will you attach? Whether the higher fringe order as move to the point of interest, lower fringe order move to the point of interest, in fact, the conventional photoelasticity, this is the very strong heuristic information, because you visually see higher a fringe order comes or a lower fringe order comes and occupies this.

So, you attach the sign and in fact, we will be doing this as part of your laboratory exercise to find out the material stress fringe value, you need to find out the value of fringe order as accurately as possible, so you resort to a compensation technique.

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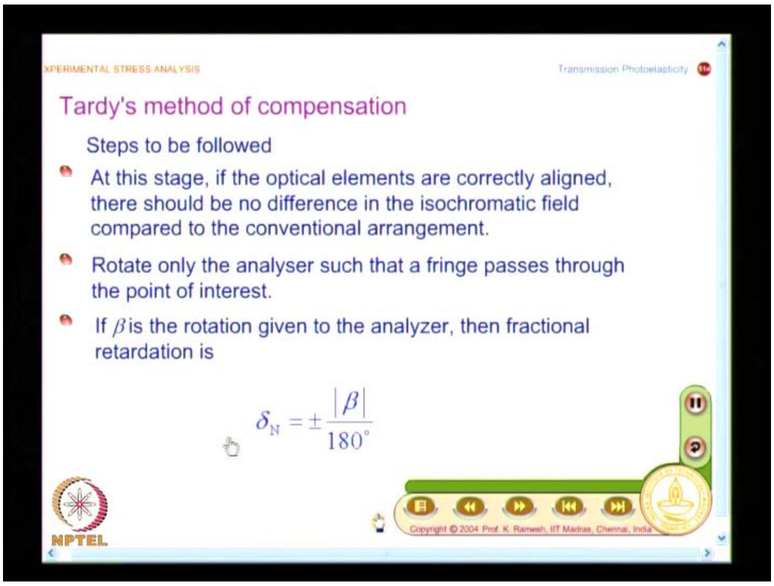

So, what you have here is the optical elements are correctly aligned; there should be no difference in the isochromatic field compare to the conventional arrangement that you should verify and rotate only the analyzer such that the fringe passes through the point of interest. And what you finally have is, I have this as, suppose I have rotated by an angle beta, then you have an expression, the fractional fringe order delta N express in terms of fringe orders, is given as plus or minus beta by 180 degrees.

So, in the Tardy's method of compensation, your focus is to find out the angle beta that is necessary to keep the analyzer, so that a fringe passes through the point of interest and beta is also referred from the isoclinic angle reference. And you have this as beta by 180 degrees, and this sign comes from your observation of higher or lower fringe order passing through the point of interest. See, now as engineers, you need not have to believe my words; you have to go back and then get in to Jone's calculus, repeat this steps and find out whether whatever the statement that I have made, the analyzer behaves like a compensator, you can verify. In fact, we will take it up as part of discussion in the class tomorrow. And in this class, what we focused was we looked at briefly what we saw as color code.

I said color code is very useful in conventional photo elasticity to identify the gradient of fringe, whether the fringe orders are increasing in a particular direction or decreasing in a particular direction, color code is very useful. And I said black is zeroth fringe order, and then blue red transition is fringe order 1, and red green transition is fringe order 2. And if your I is tuned, it is easy for you to identify, fringe order 0 1 2 you can comfortably identify, three will there will be a little difficulty, but there is a distinct change in color between 1 and 2, that is easy for you to identify.

Then, we said, in many problems, in practical interest, it is not necessary that you need to find out fringe order at every point in the model, few selected points are sufficient. And in fact, for you to directly find out the fringe order, compensation techniques are the ideal, but when I want to employ the compensation technique, even to find out the fringe order only, I need to calculate and find out what is the isoclinic angular at the point of interest, and then only we move, want to find out the fractional fringe order, they are inter related.

Suppose I want to take a photograph, and then process it, and find out the fringe order, I do not need two isoclinic angles, because there you take a photograph and then draw a line passing through the point of interest. If you have sufficient number of points, joint them appropriately, and from the graph you will be able to get the value, but that consumes time. On the other hand, compensation techniques give you instantly what is the fringe order at any point of interest and in fact, compensation techniques are useful even to verify the result from your digital photoelastic algorithm.

Sometimes these algorithms fail at certain locations, if the gradient is high or if you have discontinuity and so on, you need to have verification by a secondary technique, where compensation techniques really do a rate help. And we have seen two methods of compensation, one is Babinet-Solell compensator, which is an external compensator, we have seen how to use it. And we have also looked at analyzer itself of a circular polariscope we used as a compensator, we have only looked at this steps, because there are two issues involved, you need to know how to apply Tardy's method of compensation, the basic procedure and you need to have a proof to convince yourself that this basic procedure is quite alright. And this is what we will take it up tomorrow, but I would like you to look at trigonometric identities, and also matrix multiplication, brush these fundamentals and come to the class; thank you.