Experimental Stress Analysis - An Overview

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Lecture – 4.4
Fringe Patterns - Richness of Qualitative Information

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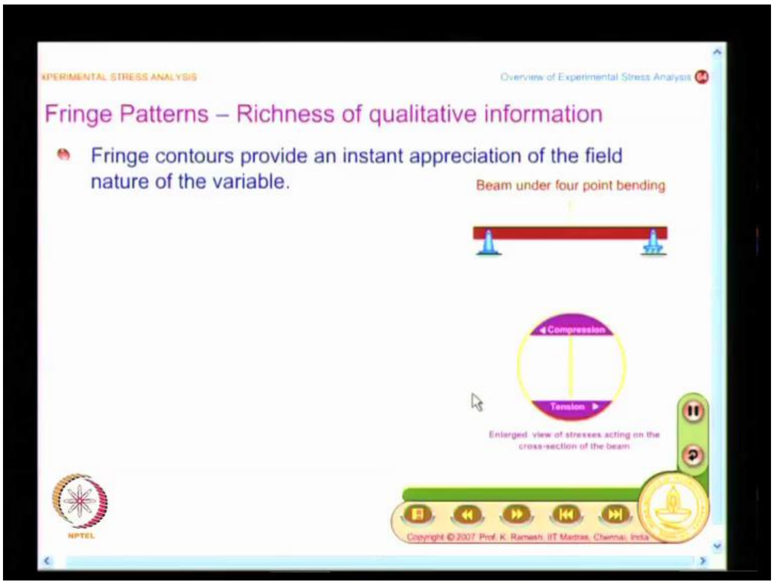

In most of the optical techniques, you get fringe patterns and we need to understand certain issues about how this fringe patterns are? First what I need to do is, I need to find out whether the interpretation, what I do for the fringes is acceptable or not? A simple exercise is, compare it with an analytical solution. If the comparison is correct, then you understand that this is what the technique gives. The other approach is look at the physics of the problem, find out what all the physics can reveal then come and link that this is what the technique is capable of giving.

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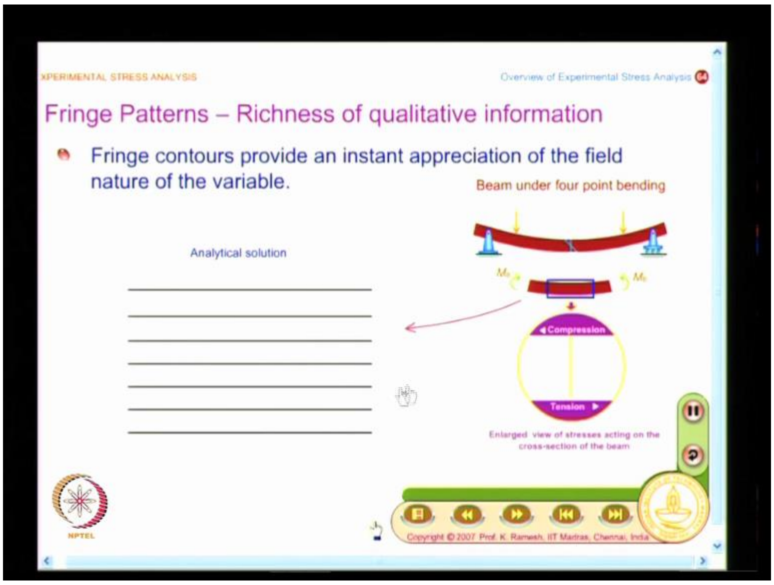

What we find in the case of beam under bending, we have looked at the central portion and then we said we will plot contours of sigma 1 minus sigma 2. The analytical solution turned out to be horizontal lines.

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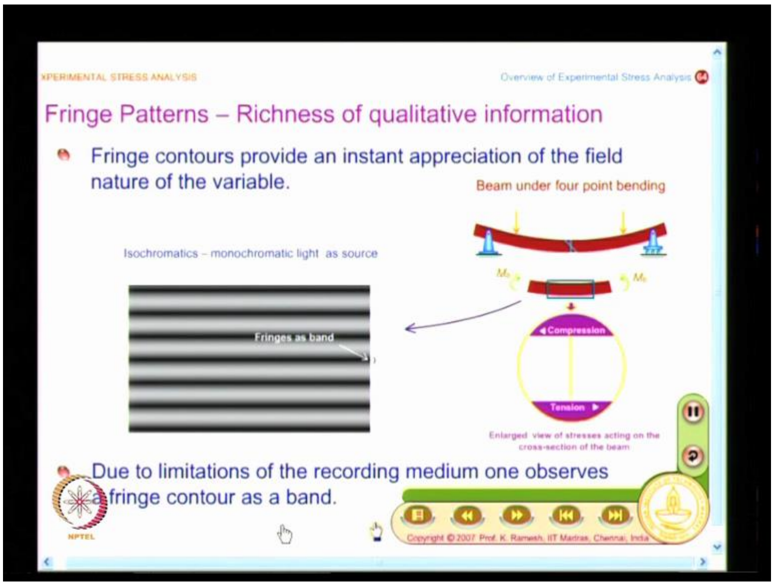

When I look at the experiment what happens? I get this as horizontal lines, but they are not thin lines, I have a band, but nevertheless I got horizontal contours. We said why you see that as a band is because of the limitations of the recording medium, one observes a fringe contour as a band. All optical techniques you will see only a band. One of the most challenging and difficult aspect for any experimental analysis is how to go and number these fringes.

Because I need to know the fringe order, then I need to use the appropriate equation and find out what is it that I will have to interpret on. What you find here in instead of a monochromatic light source, if I view this pattern in a white light source, I get not black and white contours, but contours with distinctive color and this is the specific advantage of photoelasticity. So, what I could do is, by knowing the color it is possible for you to find out the fringe order, its also easy for you to identified how the gradient information changes.

Whether it is increasing in this direction or decreasing in this direction, you can find out whether the color is color sequence is repeating in a particular fashion. Whether the color sequence repeats in a particular fashion, then you can identify positive variant and negative variant, all that you can find out. So, one of the most challenging aspects is qualitative extraction of data from all this experimental techniques, but the focus of our attention now, is to find out richness of qualitative information, that you could get from fringe patterns because this gives you a sense of comfort in looking at an interpreting the fringe patterns.

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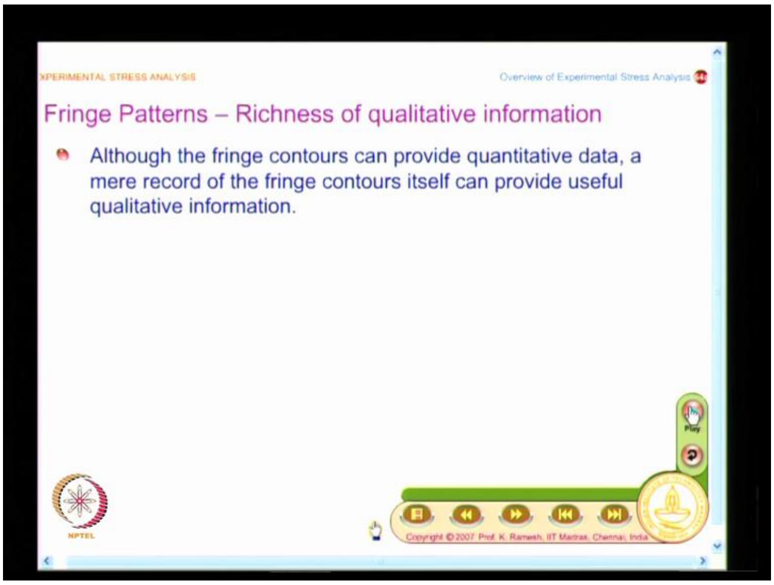

Let us look at, what we have seen is fringe is a band, we have seen it and mere record of the fringe patterns itself can provide useful qualitative information. So, we have to look at what all the qualitative information that you could identify. One of the things what we could see is I get it is a band.

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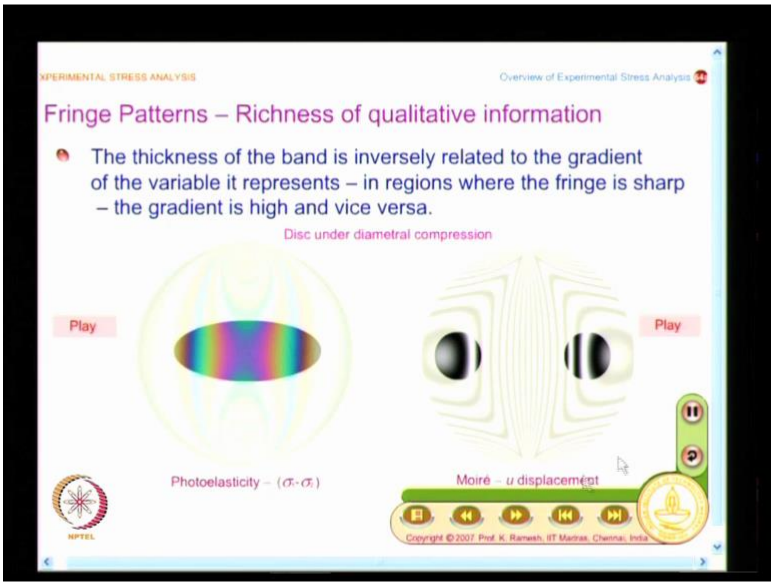

If we look the fringe patterns closely, are the bands of uniform thickness. The thickness of the band is inversely related to the gradient of the variable it represents. So, that we will see, we will, I have a fringe pattern from photoelasticity because photo elasticity has information in color a colored fringe pattern is taken.

I also have a fringe pattern in Moiré, and what we will have is we will have a closer look at how the fringe thickness varies. And this just shows that, for you to draw your attention you have this fringe patterns draw earlier, go back and then look at that fringe contour is not of same thickness, the thickness changes and that is what is tried to be shown in the slide. You have a very broad fringe here and let me repeat I have very sharp fringes here and the same fringe becomes increasing in thickness. So, essentially what you find is that fringe band is not of constant thickness.

I mentioned in one of the classes, you have this fringe plotting by software, when you have to go and mimic what is the way to get the fringe band. One of the information you use it variation in the variable, even if you give a constant variations in the variable, because the gradient changes, automatically the thickness of the fringes changes, when the gradient is small fringe is very broad and the gradient is very high, fringe is very sharp.

So, I can find out by looking at the fringe patterns, whether the gradient of the information is high or low. I can find out from thickness. This is not a property of photoelastic fringes you see a similar one even in Moiré. I go to Moiré and then look at it you see this a very sharp, thickness increases and that is how you find in same fringe has thick and thin it is thinner here, it is thicker at the corner and this becomes much thicker.

So, when you look at the fringe pattern, observe for all these indirect information. The fringe pattern speaks to you. This is how the distribution is. So, take note of it, suppose I have fringes closely packed then, I would say that this is a zone of high stress concentration. Later on, I can go and do a technique, do a quantitative processing and try to get the actual data. That is a different issue, but the moment you look at a fringe pattern. You should react to it you should know that this is stress concentration region. And this is the region where, I can scoop out material, I need to get that kind of information and you get that by looking at the thickness of the band as simple as that. So, this is one of the qualitative information you get.

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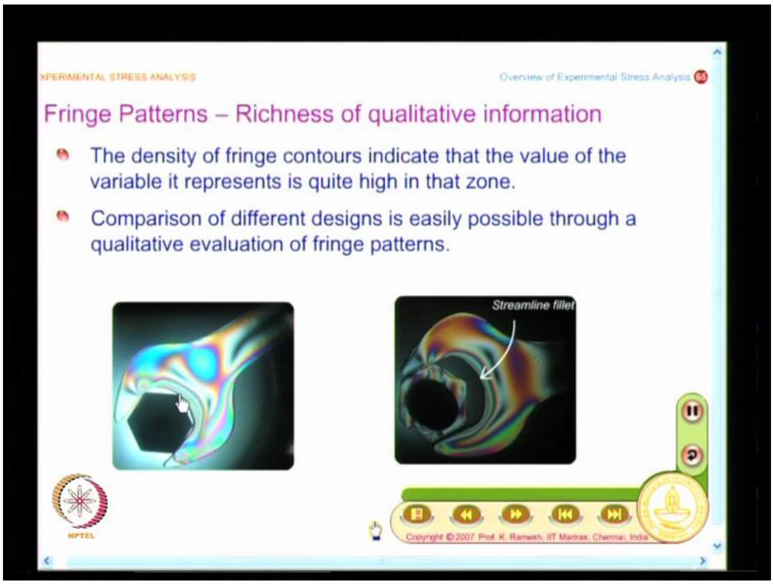

What is the other information that you can think of? I have said that density of fringe contours indicate that the value of the variable it represents is quite high in that zone. Suppose, I want to compare two different designs and the ideal way is take the fringe pattern for both the cases. Compare the fringe pattern and find out based on qualitative appreciation, how you can evaluate the different design. So, its used as a optical comparator and one simple example is given, and what you find here is I have a example of two different types of spanners, and in case I have given this as a streamline fillet.

Let us understand, what is the idea here? You all have; you are all mechanical engineers. So, you know how a fillet is made? How a fillet is made? Suppose, I coat any machining process, it is easier to make a surplus fillet because, the measuring operation is simple. I can go and make a surplus fillet and why do I make a fillet. I would like to minimize the sharp geometric changes and then I would like to have a smooth variation, and this smooth variation you could do by a fillet.

So, you essentially reduce the stress concentration and if you look at forging operations or casting operations, when you look at forging or casting I do not have the restriction of having only a circular fillet. I am not doing a machining; in a machining operation circular fillet simplifies your fabrication of the component. When I go for casting and forging, I have the luxury of choosing any type of fillet I want. Non circular fillets are more common in those applications and how do they arrive at such art shaped fillets, and you have an example here and what you find here I have this contour like this I can also enlarge it further.

What you find here the fringes are many in this zone. They are not tangential to the boundary; I would like you to make a sketch of it. I would like you to make a sketch of it and this is an example problem. That is shown, I have one circular fillet here, I have another circular fillet here, I have another circular fillet here. They are not joined you. So, you do not have a smooth transition here, and when I make a spanner out of it, find in this zone the fringes are not tangential to the boundary. You focus only on this region you do not have to focus on the other regions, make a neat sketch of bring out that the fringes are not tangential.

So, when you have a fringe pattern, you have to look at very closely and try to extract as much information as possible. And obviously, I have a load application point I have fringes originate here. So, it also indicates stress concentration zone, and what I find here is, as such when you seen only one design, you will only see oh these colors are good the fringes are good that is a way you will interpret. Only when you see a counter example, you will find that the knowledge is different. Now, what I will do is, I will go and show the other one, then come back to this.

So, that you will know what is the difference? Now, I take this example and what I find here the contour is the fillet is smooth, it is non circular here and you find more or less these fringes are tangential to the boundary. It merges with the boundary of this and these are called streamline fillets. So, only when you see the difference, you will know what is the advantage, and they are very strong. They are very strong, you need to concentrate only on the, do not worry about the nut. You concentrate only on this region where I am showing the arrow. You need to worry about the fringes, you find the fringes are parallel to the boundary, by and large as some small abrasion is there here, but compare to the earlier one, here the fringes are lot more smoother and parallel to the boundary.

In fact, when people design some of those castings and forgings, they take a photoelastic model which is slightly large in shape and then keep on shaving the material until, for the given loading you get the fringe tangential to the boundary. In fact, there is a famous book by Hayward, designing by photoelasticity where he talks about, how to get a streamline fillet and when you get a streamline fillet the component will have very high strength, nothing happens to the component and I can afford to have a streamline fillet, which is not always circular in a forging and casting, there is no problem and you know this spanners are done by forging. So, l can afford to have a non circular fillet and take advantage of our understanding of stress distribution. So, let us see these fringe pattern one after another, I see this as tangential to the boundary.

I go back and then show the other one, you will find that this is different and this is a fictitious example, you know you do not have a spanner like this. This is done to illustrate I have combination of circular fillets here. So, when I do is, I have lot of deviation from this, and this is not strong. You can have failure initiated in this and in service it can fail. So, what you do is I do not do a quantitative analysis; even a simple qualitative exercise can help you to improve your design. So, this is another aspect of richness of qualitative information.

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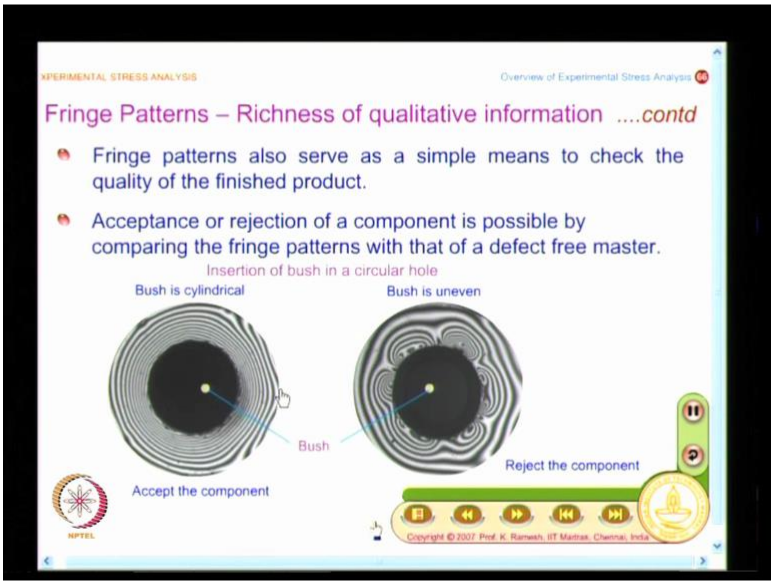

In a production line you know, I like to inspect whether my component is being manufactured correctly or not. I can have an optical comparative, and what we are going to look at is insertion of a bush in a circular hole. This is what we are going to look at as an example. So, what we are going to look at is how fringe patterns help you to check the quality of the finished product.

What I am going to do in a quality checking mode I will accept or reject, based on some evaluation of fringe patterns and I have a example here, I have one example where I have a perfectly circular bush, inserted in another plate and you all know Lamins problem, you need to get concentric fringes I do get concentric fringes. This is not what happens in an actual production line, in an actual production line if you do not maintain the cylindricity of the bush.

You can have surprises like this and what I see here, I see extra flowery pattern. Let us look at little more closely here. So, what I have here is, I have bush is cylindrical you can go and accept the component. While you sketch it what you do is you do not have to draw all these fringes, you say essentially they are concentric. When I have a non circular bush, which has undulation which are not visible to the naked eye, but when I insert I get this flowery patterns on the inner boundary.

I have inserted a bush, in a circular hole. It should behave like a Lamins problem concentric circle I should get, but instead what I get is, I get fringe pattern like this and in this case, the deviation is quite obvious, it is very striking the fringe pattern. What I find is very striking I can quickly say something has gone wrong. If the variations are very subtle then I cannot make a judgment.

In fact, one of the most difficult things is if we have a member and stretch it. Invariably if the member is not stretched correctly, you will always have some amount of bending. If you take a specimen which can respond optically, any small misalignment will show up in the optical fringe pattern. So, simple experiments are really very difficult to conduct even a simple tension. So, one of the ideas what they suggest is if you have a situation where you need to verify the alignment go for optical techniques and improve your alignment based on that.

So, optical elements are very good they are very sensitive to any one of these loading peculiarities, and what we see here you have concentric fringes, and you have the fringes which are coming as a flower. That is what you have; I want you to make a reasonable sketch to bring out this difference that is idea. You have a flowery pattern, and you have a concentric circle and that gives you an idea that something has gone wrong and you can take corrective reaction, you can go and modify your production line inspect the, how the product is made go and improve the process parameters.

So, you can take some kind of corrective action. So, now, you realize that by looking at mere fringe patterns, we have extracted quite a bit of data. We can find out stress concentration zone. We can compare different designs; we can also accept or reject the component, based on some of this information.

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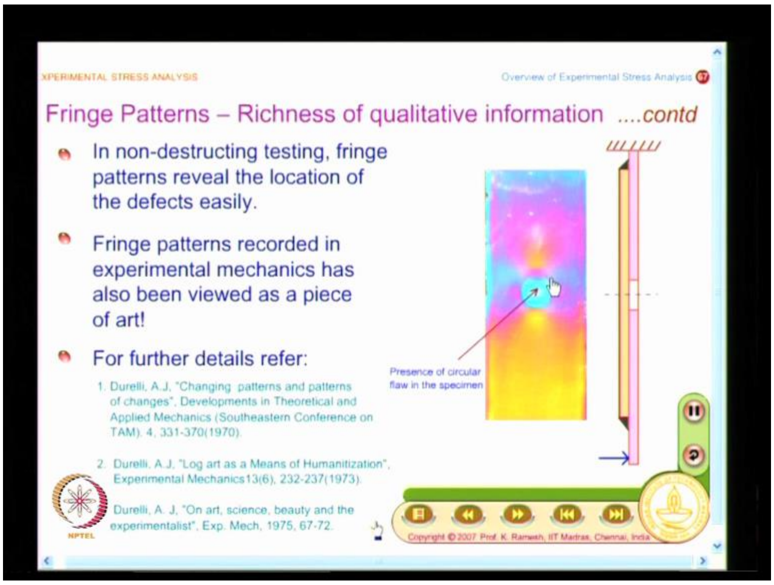

So, that is quite useful I mean we have been able to take note of this. Another advantage what you have is I have a defect here. What I have is I have a plate with the hole, and I have a coating put on this. Here I have taken example. So, I know that there hole present and now I am interpreting that you have a hole that is seen in the fringe pattern.

In fact, to find out internal flaws, people have attempted putting a photoelastic coating. When the model is loaded the fringe signature can identify presence of flaws in the member. So, this is another approach, people have used it and identifying a flaw in a structure, is a very challenging aspect. What is the difference between an ultrasonic techniques; In an ultrasonic technique, even benign flaws will detected, because it will only look at material separation on the other hand, if I have a technique where the model is loaded those flaws which are sensitive which can pose problem to you, only those will be revealed.

See collecting lot of information is not necessary you need pertinent information for a given problem. So, this is one of the reasons they sight if we use acoustic emission technique, your searching a needle in a haystack because you get. So, much information, identifying your pertinent information is extremely difficult. So, on the other hand, if I have a technique, which can reveal those flaws which are going to give you problem, alone will be detected is well and good and I have also emphasized in one of the classes.

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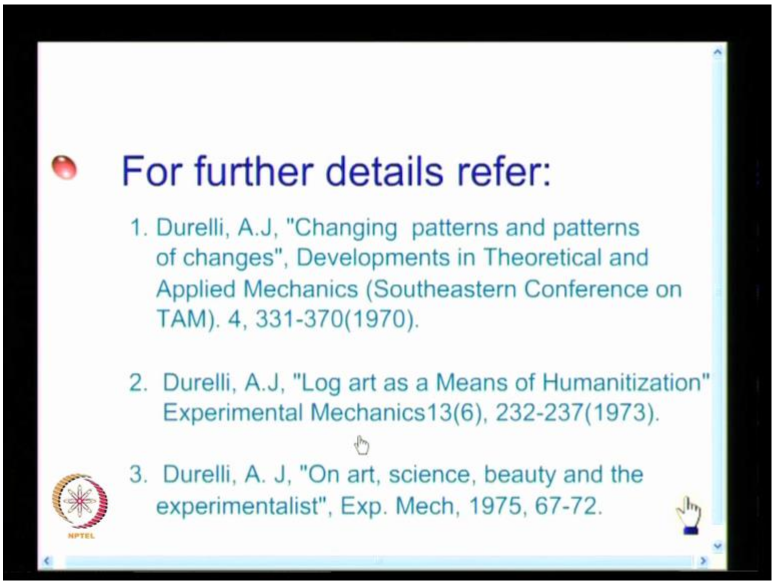

That people also have looked at all this fringe patterns has piece of art. In fact, Prof. Durelli, has made significant contributions in looking at fringe patterns like this. So, my interest is all of you please just note down, some of these reference details, and you do not have to write the full reference. You know he has a paper in applied mechanics developments in theoretical and applied mechanics in 1970. This may be may not be in a position to get it, but at least the experimental mechanics will be able to get it. So, you write down this experimental mechanics, and write the page numbers and the year. You do not have to write that tittle of the article. You can easily search it based on the reference, there is another paper in experimental mechanics on art, science, beauty and the experimentalist.

So, you know people have written not one paper. Three papers he has written. Variety of fringe patterns he has shown. It is very interesting because you know when you are looking at optical techniques you should also look at the other side of it there is beauty attached to it, lot of qualitative information that you can get out of it. So, what you need is you need to have some of these references, you should not just focus only on your stress analysis you should also know related information that makes your learning lot more enjoyable and purpose full. So, this is very interesting that is why I thought that I should show you this.

In this class we looked at, a reasonable extent on how the qualitative information of fringe pattern can provide useful information. See, in an industry people want answers yesterday. When they come to you for a problem, they want the answers so fast. So, you will have to use your engineering judgment and do detailed analysis only when it is required. So, even if you are able to make certain judgment based on qualitative inputs, it can go a long way in solving your problem on hand.