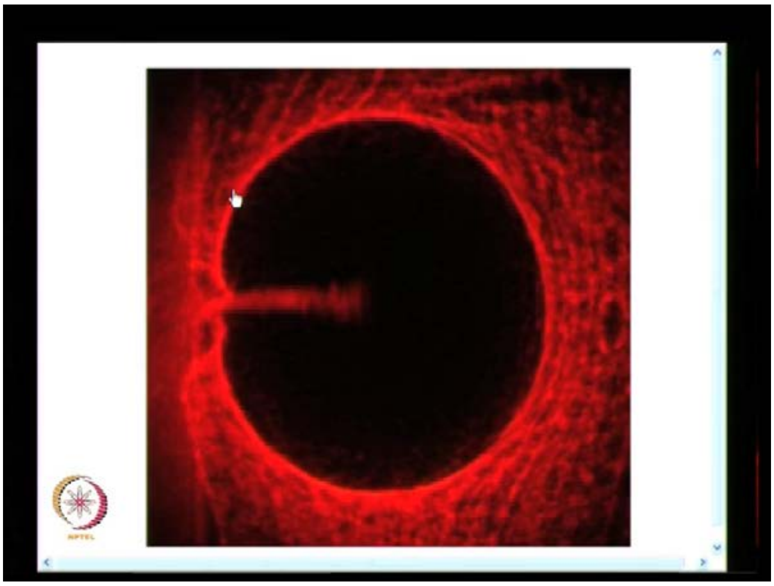
Experimental Stress Analysis
Prof. K. Ramesh
Department of Applied Mechanics
Indian Institute of Technology Madras

Lecture No. # 08
Fringe Patterns – Richness of Qualitative Information

We have been discussing about various experimental techniques, what is a physical principle behind the experimental technique; what are its main features? And also in which class of problems, these techniques could be ideally used. And we have discussed the method of caustic in the last class, and you know when you look at each of the techniques there are pioneer's who have made significant contribution to the development of these techniques; professor (( )) from Germany, was the person who was worked on caustics and made it will perfection and they have been contribution from (( )) and also from (( )) and is grouped cachet. So, many scientists of contributed to development of each of the techniques, if you look at any technique, we to look at strain gauges; we to look at holography; these are all not developed by a single individual. Someone identifies the physics behind it, and the idea is initiated, then people carry on many scientist contribute it.

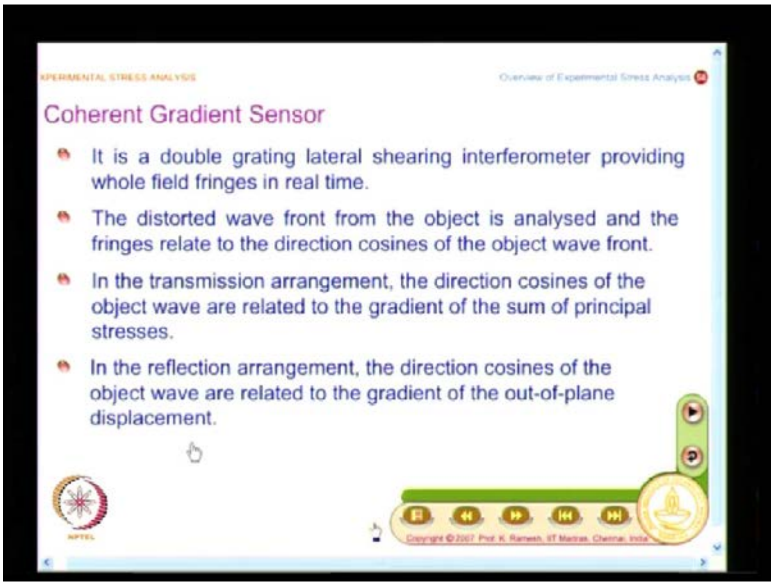
(Refer Slide Time: 01:32)



And what we saw in the last class was we had seen, at the deep of the crack. You have a nice caustic shadow obtained and we explain, how this shadow is formed and we also looked at that the silver line what you have is the caustics. And in actual experimentation, you just measure this diameter, you measure this diameter, and then you have equation, which will help you to find out, what is the parameter associated with this problem.

In this case you will be able to find out the stress intensity factor by measuring the diameter. And I said caustic is not a general purpose experimental tool; it is only a high stress bearing problems; you get information from this; and what you find here, you do not have any information in the shadow region. So, this prompted researchers to find out how to fill in information even in this zone.

(Refer Slide Time: 02:48)



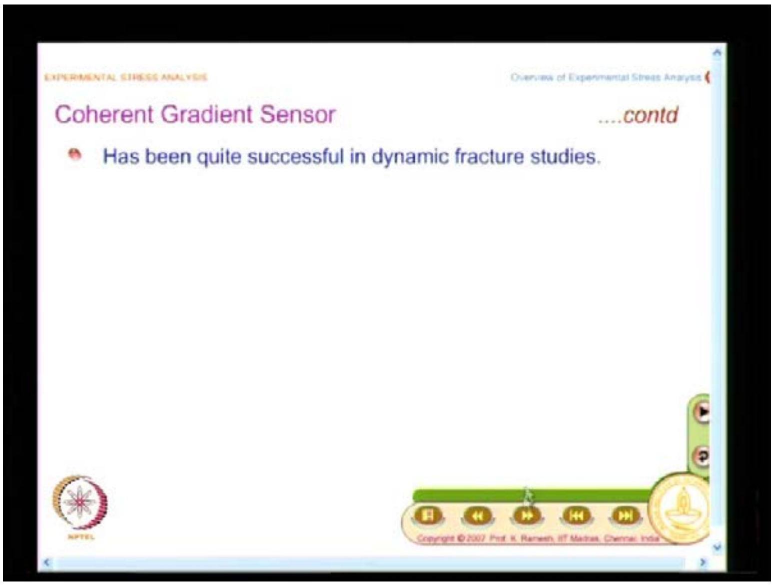
And if you really look at the method of Coherent Gradient Sensor that is what we are going to discuss next, that has originated from this aspect in mind; and what you have here is, it is the double grating lateral shearing interferometer, providing whole field fringes in real time. So, we have emphasis some of these concepts, we have said whenever you look at an optical technique, you have to find out, whether you get information in real time. If you get information in real time, it makes your life lot more simpler; and we have seen any technique, which involves double exposure, you need to do post processing and only then you see the fringes in real time. Whereas techniques like photo elasticity, moiré, you do see fringes in real time. On similar lines you also find Coherent Gradient Sensor gives you fringes in real time. And here the optics is little involved and also the principle is also mathematics are quite involved. So, what we will do is we will have a bird's eye view of what this technique is.

And what you find here is, you have a live, if it is a take model, it gets reflected from the surface, if it is the transparent model, it get transmitted; and you are really looking and the distorted wave front, and you look at the distorted wave front, and you find out the direction cosines of the object wave front. This is what we essentially do in the optics and this has different meanings, when I do a transmission arrangement or when I do a reflection arrangement. So, what you find here is in a transmission arrangement, I relate these to the gradient of the sum of principle stresses. So, this is what I had said; for the each of the techniques, what you find here is, there is the physics is exploited and that physics dictates, what is the information you get from interpreting the (( )).

And here what happens, you are able to get those direction cosines related to the gradient of the sum of principle stresses. This is what happens in a transmission arrangement; and when I go to reflection arrangement, what I get this I relate this to the gradient of the out of plane displacement. So, we have seen a very similar, parallel information, when we are looking at holography; what we said bass, I can find out essentially out of plane displacement. And in fact, when I want to combine photo elasticity and holography, I exploit the feature of holography to measure the change in thickness as because of poison ratio. That is related to sums of principle stresses that we had looked at it. So, they go to gather, when I have out of plane displacement and also it is relation to in prune plane problem, it could be related to sigma 1 plus sigma 2.

So, what we find here is, I can apply Coherent Gradient sensor in transmission arrangement as well as reflection arrangement and in transmission arrangement, I get the gradient of the sum of principle stresses and in reflection arrangement, I get the gradient of the out-of-plane displacement, I get only a gradient, I do not get actual values, I get only the slope.

(Refer Slide Time: 06:42)

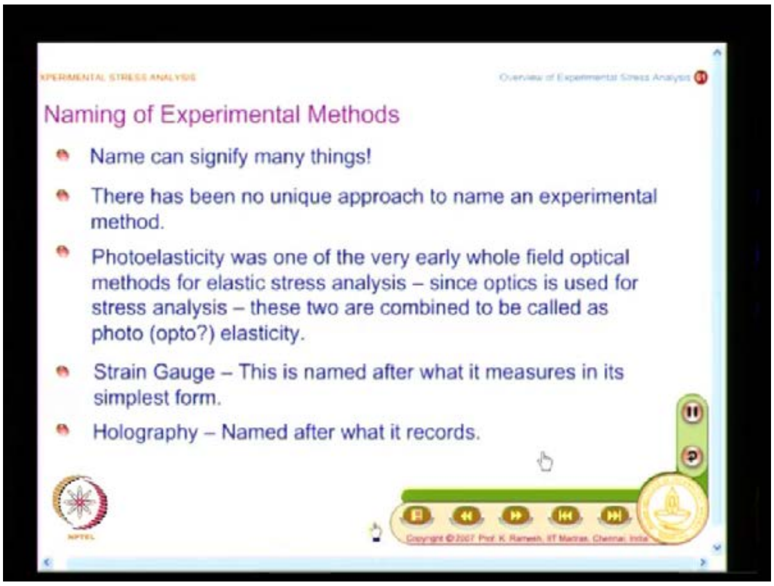


And what you find here is this has find wide application in dynamic studies. So, if you look at dynamic fracture, Professor. Row saw key (( )) and his group and Harish tempure (( )) they have developed this technique; they found it useful for dynamic fracture structure studies. So, what you find is in the caustic shadow, you lose information. Caustic is not a general purpose experimental tool; on the other hand Coherent Gradient Sensor, because it gives information on the entire region this has been used for finding out curvature that is what we had seen in few classes earlier, we had also looked at the shearing interferometer, can be used for finding out slope and curvature.

And in a sense, it complements the data that is given by caustics, if there are also experimental is who have combined, method of caustic and method of Coherent Gradient Sensor to be recorded in one optical arrangement. See I have been saying if you have a problem on hand, you may not be able to solve all the quantities that you want by using one experimental technique. You may have to use multiple experimental techniques in a generic sense; I have shown that people have combined strain gauges and Brittle coatings; so that they could do and solve industrial problem, very quickly; and we have also seen, if I want to find out separation of stresses, interferometric technique and photo elasticity could be combined.

On the other hand, people also thought of recording this information simultaneously, such equipments also have come. One is use and performs experiment separately then processes the information. And once you decide the these are the two information, I want people also device new equipments, wherein they could, either simultaneously record or record one after another with the same of optical arrangement with with modification of what you want to insert, such a development has also been seen in combing method of caustics and coherent Gradient Sensor; so such information available in the literature.

(Refer Slide Time: 09:10)



And now what we move on to do this is that let us have a very interesting discussion on, naming of experimental methods; you may wonder, name can signify many things, you know if you look at the the development of languages, they will look at Sanskrit, even for nouns, they find out the root and then the explain, because of a such and such and as reason reason this is name like this, and it is a very well developed and scientifically, it has a grammar, which is scientifically proven and people find it easy for implementation in the computer; in fact, for natural language processing, Sanskrit grammar is so convenient; you can translate from one Indian language to another language the intermediary Sanskrit and then go to it.

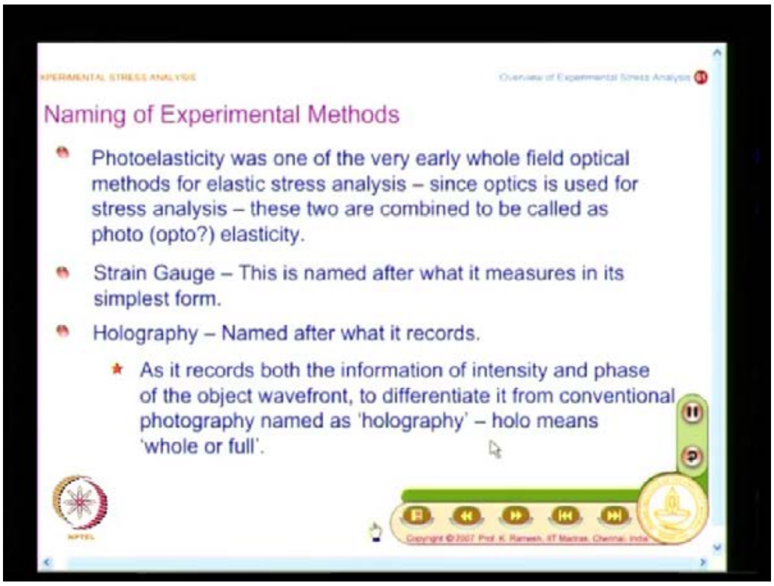
And if you look at, you know because we are looking at naming of experimental technique, let us also look at, what way names are given in Sanskrit. I will you give you one example; in Sanskrit they (( )) is very important and phonetic rendition of the word, has some idea of what the word can notes; and if you want to talk about the tooth, the Sanskrit name for this (( )). And you will be surprise, if you do not have a tooth, you cannot pronouns it. It is very interesting, you know the the why you say a Sanskrit is so perfect I am not getting in to know language division and things like that, when there is the positive and scientific aspect attached to a particular language, as scientist we should recognize that merit. And it is so interesting; it is (( )) you call it; I can call the tooth by several different names; and the phonetic rendition, has the link to the meaning are what it converts.

So, if you are not having an understanding then we can find out and think about and go to the root and find out what the meaning. So, it is not arbitrary name. So, done them you pronouns it, you need tooth for it and it is the tooth it indicates. Now let us look at have you named our experimental technique scientifically. And if you look at one or the first technique was photo elasticity and there is the discussion, you know there is no unique approach to name an experimental method, and if you look at 1930’s.

Another earlier optical method that came into existence was photo elasticity; why call it as photo elasticity, people have used optical methods to reveal the stresses. So, they have combined optics and stresses; and photography was also prevalent that time then they where recording the information. So, they in stuff combining optics and elasticity, they call it as photo elasticity, they call it as photo mechanics and even now there is the debate, should be call it as photo elasticity or photo mechanics or optomechanics. There is the school of scientist, who heal we have to go and rename all the techniques and we call, because we are using optics, why do not we call it as opto mechanisms. So, if you look at photo elasticity, I have just combined the sensor, optics is used as the sensor and you are analyze for elastic problem. So, you call it as opto elasticity, photo elasticity. So, that why we have named it.

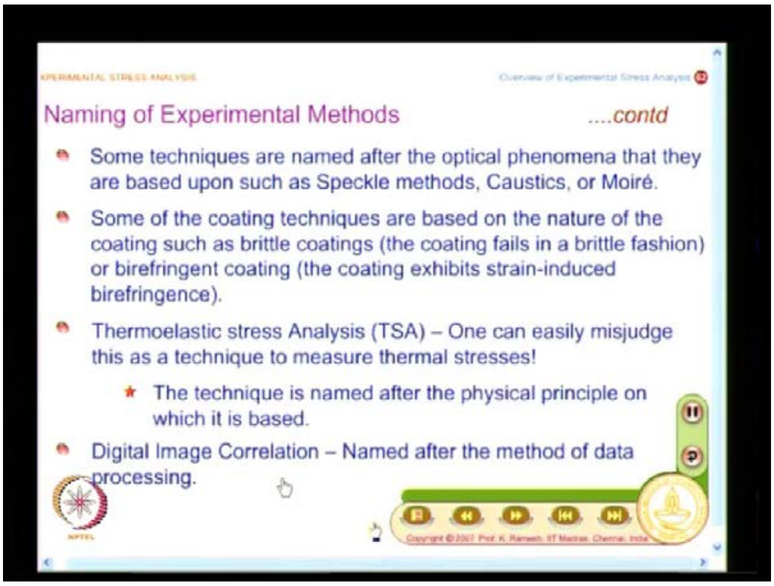
And when I come to strain gauges, what you do? And this is what I caution, because people named it as strain gauges, there is the danger that you gets strain tensor. It is not shown; it measures only a component of strain. Because it basically measures strain, they call it as strain gauge. And if you go to the strain gauge literature, you find special grid configuration, where you find out stresses, so call it the stress gauge, you have shear stress gauge, star gauge, like wise you name it. So, strain gauge as got it is name from this.

(Refer Slide Time: 13:32)



Then you have a holography; and holography, it is named after what it records; and what we find here is, I have mentioned that holography records, both intensity and phase of the object wave front. Hollow means whole or full, because I record both the information together, following the example of photography, they called it us holography; and we have also seen, it is a very fundamental contribution to the scientific community. So, who ever has develops the holography, he got the noble prize for it is, such a very important development.

(Refer Slide Time: 14:27)

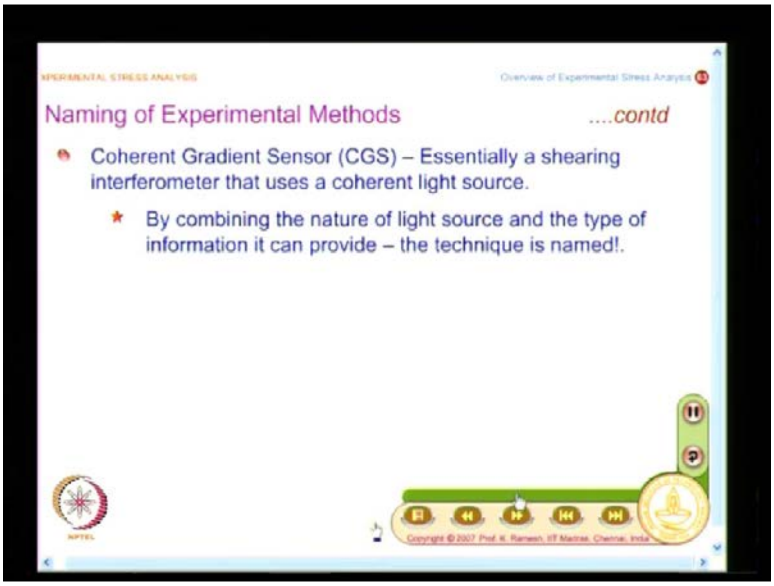


And then what we have, you also have techniques, where you use the physics. I said that in the method of caustics, you employ the principle of caustics in the formation of the shadow, and you name it directly as method of caustics. And whenever you have a two grid super imposed, you get moiré fringes see and you call it that as moiré, similarly wherever use the speckle, speckles are formed on the diffusively reflecting surface, secularly reflecting surface, you qualified the surface and when you used those you call those method as speckle methods, and when we go to digital image correlation, it uses widely speckle, but call it by a different approach.

And we have also same coating techniques, what we have seen we have seen Brittle coatings, we have seen birefringent coatings, why do a call it as Brittle coating, I have a coat that is put on the met on the model, it fails in a brittle fashion. In fact, when brittle coating was originally developed, they were all used for finding out plastic deformation. And when you have rolled steel, you have scale that has formed. So, they flake like a a Brittle coat. So, they were able to identify, zone of plastic deformation that is how the whole technique developed. So, you name that technique based on how the coating behaves, I said photo elastic coating; other name of photo elasticity coating is birefringent coating. And I said in photo elasticity the physics use this temporary or artificial by the fringes and that is what exit exhibited by the coating. So, you call it as photo elasticity coating as well as birefringent coating.

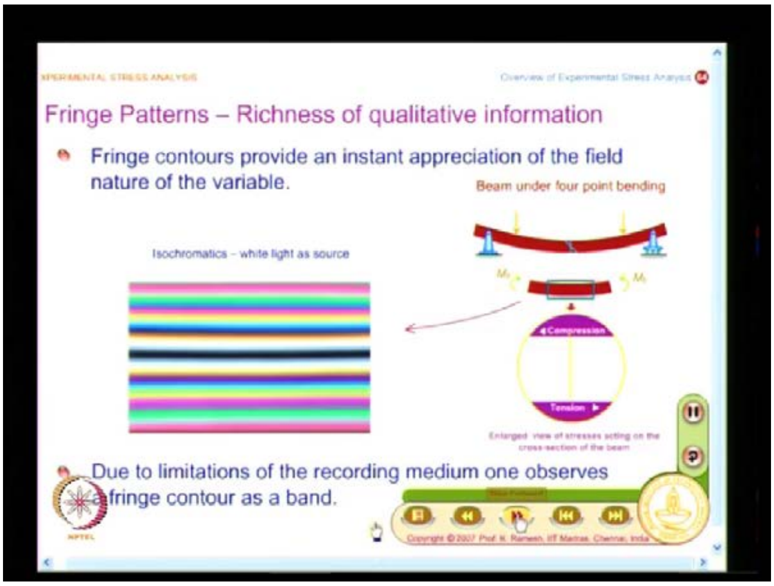
And we also have another technique thermo elastic stress analysis; and I caution do again and again do not misconstrue that is this technique can measure stresses due to thermo elasticity, it is not so; the physical principle used employs measurement of temperature, which is very, very small and we call this as a thermo elastic stress analysis. So, it is based on the physical principle and I said I have one or the emerging technique now is digital image correlation. It uses light weight speckles; however, this is name after the method of data perfection, I have digital images, and then I look at and deformed and deformed configuration, and then do a correlation; so I call it this as digital image correlation. So, techniques are named differently, I do not have the unique approach and it somebody wants to develop new technique, he coins what is more appropriate, and what you seen Coherent Gradient Sensor, why the technique is call it Coherent Gradient Sensor.

(Refer Slide Time: 18:13)



If you look at that, I use the coherent source of light. It is essentially sharing an interferometer by combined the nature of light source and the type of information it can provide, the technique is named; and you know you know researchers also want attention to their work. So, one of the recent why they coined a technique is to attract the attention of others, to look at what this technique is all about it; so, Coherent Gradient Sensor this very famously known as CGS, which essentially a shading interferometer, now people call it as shading interferometer. That is how they, because it has become a general purpose analysis tool; people do it for the thin wafers in, when you go for names application, thin wafers for analyzed for out of plane displacement, slope, curvature. So, you have this. So, I combined the type of radiation that I use, I have a Coherent Source of life and I measure the gradient. So, I call it as Coherent Gradient Sensor.

(Refer Slide Time: 19:28)



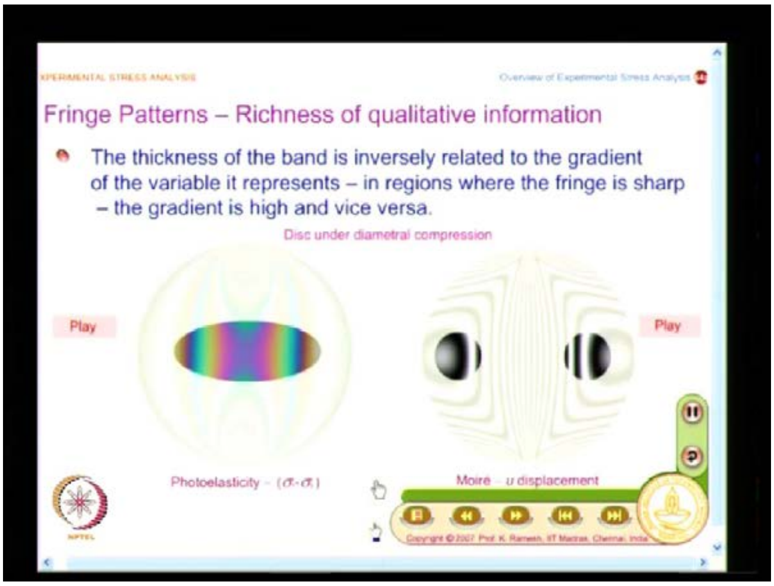
Next we move on to a very important aspect, which we have also seen and discussed we little bit earlier, what we looked at was in most of optical techniques, you get fringe patterns; and we need understand certain issues about how this fringe patterns are; first what I need to do it, I need to find out whether the interpretation what I do for the fringes is acceptable not not a simple exercises compare a 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 is the what the technique is capable of giving. And 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.

When I look at the experiment what happens, I get this as horizontal lines, but they are not thin lines, I have a band I have a band, but nevertheless, I got horizontal contours and we said, why you see that has the band is because of the limitations of the recording medium, one observes a fringe contour as a band, and all optical techniques, you will see only a band. And one or the most challenging and difficult aspect for any experimental analysis is how to go and number these fringes, because I need for the fringe order, then I need use the appropriately equation and find out, what is it that I have to interpret on; and what you find here, instead of mono chromatic light source, if I view this patterns in a white light source, I get not black and white contour, but contour with color, contour with this distinct pick color and this is the specific advantage of photo elasticity.

So, what I could do is by knowing the color, it is possible for it find out the fringe order. It is also easy for you identified, how the gradient information changes, how the gradient information change, whether it is increasing in the 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, when you can identify positive gradient, negative gradient, all that you can find. So, one of the most challenging aspect is quantitative 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, but this gives you a sense of comfort in looking at and interpreting the fringe patterns.

(Refer Slide Time: 23:00)



Let us look at; what we have seen is fringe is the 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 are all the qualitative information that you could identify, one are the things what we could see is I get it is the band, and if you look we fringe patterns closely are the bands of uniform thickness. The thickness of the band is inversely related to gradient of the variable it represents. So, that we will see, will I have a fringe pattern from photo elasticity, because photo elasticity as information in color, a colored fringe pattern is taken, and 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 various; and this shows that for you to draw your that attention, you have this fringe patterns drawn 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 this play, and you have a very broad fringe here.

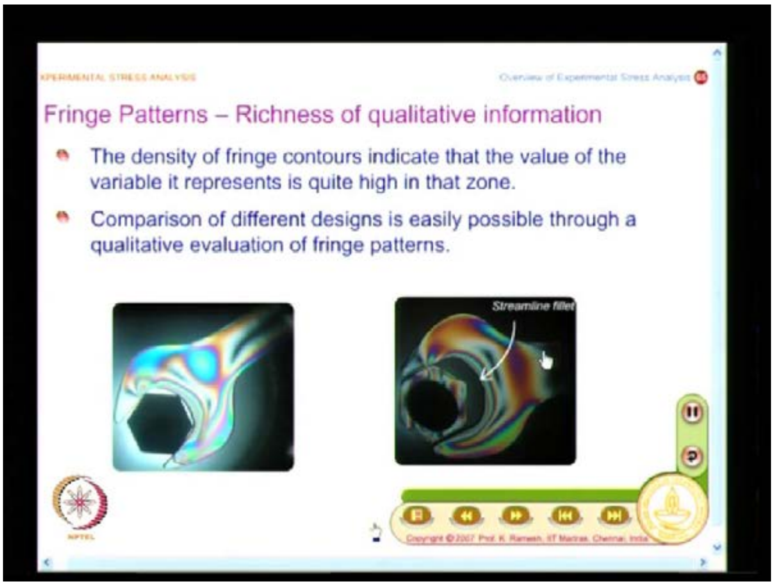
And let me repeat, I have very sharp fringes here and the same fringe becomes increasing in thickness. So, essentially what you find is that fringe band is north of constant thickness, and I mention in another class, you have this fringe plotting by a software, when you have to go and mimic, what is the wave to get the fringe band; one of the information you use it, variation the variable, even if you give a constant variation the variable, because the gradient changes, automatically the thickness of the fringes changes, when the gradient is small, fringes very broad, when the gradient is very high, fringes 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; and this is not a property of photo elastic fringes, you see a similar one, even in moiré. I go to moiré, and then look at and you see is the very sharp, thickness increases, thickness increases and that is why, you find; and same fringe has thick and thin; it is thinner here, this is thicker at the corner, and this becomes much thicker.

So, when you look at the fringe pattern, observe for all these indirect information. This fringe pattern, speaks to you this is how the distribution it is. So, take note of it, suppose I have fringes closely packed, then I would say that this is the 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 the different issue, but the moment you look at the fringe pattern, you should react to it, you should know that this is stress concentration, the region and this is the region, where I can super 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 and, what is the other information that you can thing of?

(No audio from 26:56 to 27:03)

(Refer Slide Time: 26:44)



I have said that density of fringe contours indicate that the value of the variable it represent is quite high in that zone. Suppose I want to compare two different designs and the ideal way is take the Fringe Pattern for the both the cases, and compare the fringe pattern and find out based on qualitative appreciation, how you can evaluate the different design. So, it is used as the optical comparator; and one simple example is given and what you find here is, I have a example of two different type of facts. And in one case, I have given this as a surface streamline fillet.

Let us understand, what is the idea here, and you all have, you are all mechanical engineer, so you know, how the fillet is made; how the fillet is made? Suppose I go to any machining process, it easier to make a circular fillet, because the machining operation is a simple, I can go on make a circular fillet and why do a 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 can do by a fillet; so, we essentially reduces the stress concentration; and if you look at forging operations or caustic operation. When a look at forging are 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 (( )), I have a luxury of choosing any type of fillet I want, non circular fillets are more common in those applications.

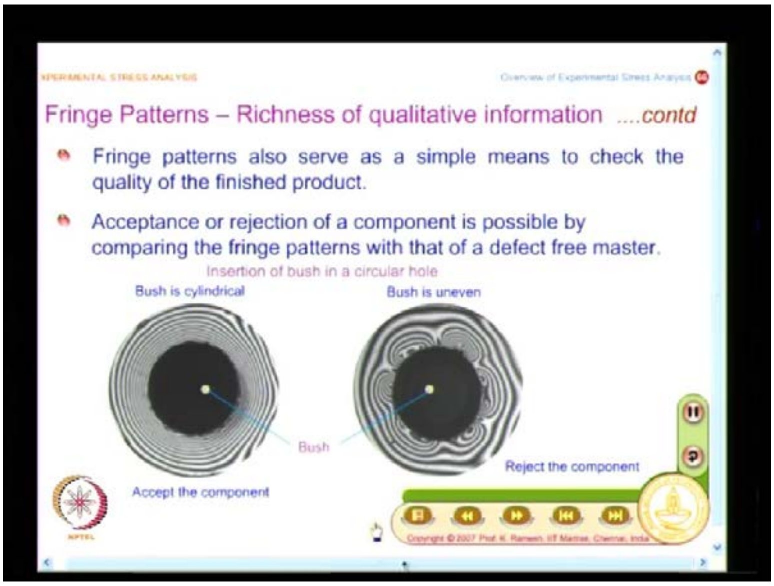
And how they arrival at such art shaped fillets, and you have an example here and what you find here, I have this contour like this, and I can also a enlarge it further. And what you find here, the fringes are many in this zone; they are not tangential to boundary. I would like to make it a sketch of it; I would like to make it a sketch of it; and this is a 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 join, because you do not have a smooth transition here, and when I make a spanner out of it, I find in this zone the fringes are not tangential to the boundary, and you focus only on this region, you do not have to focus on the other regions, make a neat sketch of bring out that 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 see only one design, you will only see over this color are good, the fringes are good that the 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 go and show the other one, then compact to this. So that you will know, what is the difference? Now I take this the example, and what I find here the contour leaves the fillet is smooth, its non circular here, and you find more or less the fringes are tangential to the boundary. It merges with 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 are very strong, they are very strong; you need to concentrate only on the… Do not worry about the nut, the 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 are some small operation is there here; but compare to the earlier one here the fringes are lot more smoother and parallel to the boundaries. And in fact, when people design, some of this casting and forgings, they take the photo elasticity 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 that there is the famous book buy favor designing by photo elasticity, where it talks about, how to get as streamline fillet. And when you get streamline fillet the component will have very high stress, nothing happen to the component. And I can effort have a streamline fillet, which is not always circular in a forging and casting. There is no problem and you know, these spanners are done by forging. So, I can afford to have a non circular fillet and take advantage of our understanding of stress distribution. So, let us see this fringe pattern one option another, I see this as the tangent to the boundary and I go back, and then show the other one, you will find that this is different, and this is the effectives examples, you know you do not have a spanner is the like this, this is done to illustrate, I have a combination of circular fillets here. So, when I do is, I have a lot of deviation from this. And this is not strong, you can have failure initiated in this and in service, it is can fail. So, what you do as 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.

(Refer Slide Time: 33:55)



In a production line you know, I have a pro I would like the inspect, whether my component is being manufacture correctly or not; I can have a optical comparator. And what we are going to look at it is insertion of a bush in a circular hole; this is what we are going to look at of an example. So, what we are going to look at is how fringe patterns, helps you to check the quality of the finished product. What I am going to do in a quality checking more, I accept or reject based on some evaluation of fringe patterns.

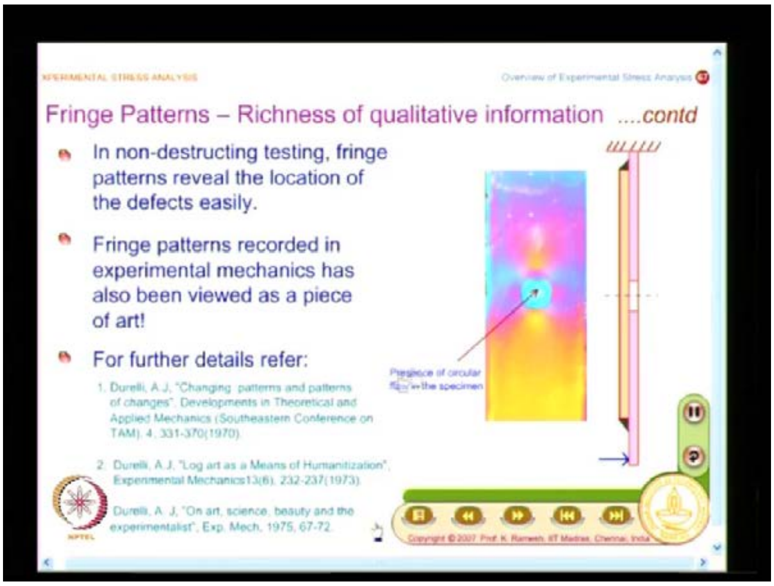
And I have example here, I have one example, where I have perfectly circular the bush in certain (( )) another late and you all know lane is problem, you need to get concentric strangers, I do get concentric it and this is not what happen in an actual production line; in a actual production line, if you do not maintain the cylindricity of the bush, you can have surprises like this and what I see here, I see extra flower it back and let us look at little more closed here. So, what I have here is I have bush is cylindrical, you can go and accept the component.

And why use sketch it what you do is you do not have this draw all the stringers, you say essentially they are concentric and when I have and non circular bush, which as undulation, which are not visible to the make a die, but when I insert, I get this clever a patterns on the inner boundary, I have a inserted the bush in a circular hole, it should behave like a lane is problem concentrate circle by 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 they fringe pattern, what I find is very striking, I can quickly is a something is a gone drawn, if the variation are very curtail (( )), then I cannot make a judgment. In fact, one are the most difficult thing is if you have a member and stretch it. Invariably if the member is not stretch correctly, you will always as some want of bending and if you take a specimen, which can response optically any small misalignment will sharp in the optical fringe pattern. So, experiments simple experiments are really very difficult to calculate, even a simple tension. So, one are the idea is what the suggestion is if you have a situation, where you need to verify the alignment go for optical techniques. And improve your alignment based on it.

So, optical elements are very good very sensitive to any one of this loading peculiarities, and what we see here, you have concentrate fringes and you have the fringes, which are coming a effect level and that is. So, you have I want you to make a reasonable sketch to bring out this different that is idea. You have a flowering pattern and you have a concentrate surface and that gives you an idea the something as gone drawn and you can take corrective action and you can go one modifier production line; and 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, near fringe pattern. We have extract a quite a bit of data. We can find out stress concentration zone, we can compare different designs; we can also accept or reject a component based on some of this information.

(Refer Slide Time: 38:19)



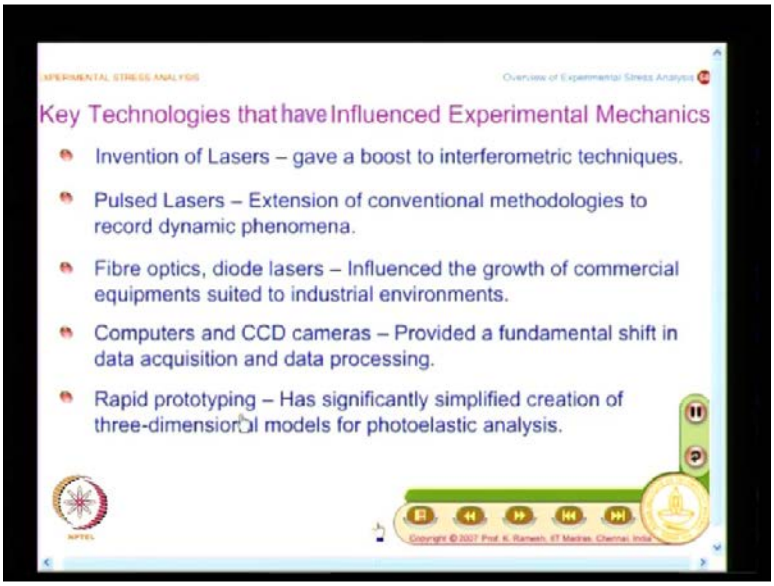
So, that is quit use for the eleven (( )) behave mean able to take note of this. And another advantage, what you have is I have a defect here, what I have I have a plate with a hole and I have a coating put on this. And you know here I have taken example. So, I know that there's the hole present and now an interpreting that you have a whole that is seen in the fringe pattern. In fact, to find out internal flaws, people have attempted coating of photo elasticity coating and when the model is loaded the fringe is signature, can identify presence of flaws in the men.

So, this is another approach, people have used and identifying a flaw in a structure is the very challenging aspect. And what the different between ultrasonic techniques in an ultrasonic technique, even behind flaws will be greater. (( )) 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 reveal see collecting lot of information is not necessary. You need personate information is for a given problem. So, this is one of the reasons they side, if the use the acoustics becomes a technique, you have searching and needle in a here stack, because use you get so much information, identifying your pertinent information extremely difficult.

So, in the other hand if I have a technique, which can reveal those flaws, which are going to give you problem, alone will be redacted is valiant tool. And I have also emphasized in one are the classes that people also have look at all the fringe patterns has piece of art. In fact, the process direly has made the significant contribution, looking at fringe pattern like this. So, my interest is all of you please just note down, some of this reference detail. You don't have to write the full reference, you know he have the paper in applied mechanics, developments in theoretical and applied mechanics in 1970.

This may be even on being a position to get it, but at least experimental mechanics will be able to get it. So, you write down this experimental mechanics and write the page numbers and the year, do not have to write the title of the article, you can easily search it based on the reference that is another paper in experimental mechanics, on art science beauty and the experimentalist. So, now people have written not one paper, three paper they as return and variety of fringe pattern we are shown. And 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 attach to it, lot of qualitative information that you can get out of. 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. So, this is very interesting that is why I thought that I should Show you this.

(Refer Slide Time: 41:58)



And now let us look at Key Technologies that have influenced Experimental Mechanics; obviously, invention of Lasers - gave a boost to interferometric techniques. I said then holography as invented then is gab or had only mercury or clams. So, you could not take the advantage of technology, the moment laser scheme into picture all over in interferometric techniques. As become refined a lot more, sensitive and you could go for long phase difference calculation. Once you have lasers you also had development of pulsed lasers. So, you have intermittent elimination, you could extend conventional methodologies to record dynamic phenomena.

And dynamic phenomena recording reveal lot of interesting information, if you go and have a water that getting boil, it looks as if it is random, it is not really random, you have bubbles formed at periodic intervals and come out and then they burst, people do research on how this bubble formation so on and so forth, and recording dynamic phenomena, like you have a microscope, which optically magnifies, you have a time magnification here. You are able to record at very minute intervals and see it as a slow motion film; you understand the physics behind it better. You know stress waves in solve its were reveal beautiful a photo elasticity, until then people where not what has stress waves.

When you see the fringe pattern, when you see the fringe patterns move at gives lot of understanding on the phenomena and you need, it the process is very fast then I need ultra fast recording and one of the issues in ultra fast recording is I should have a lights source, which is strong enough to eliminate, because when I have a long exposure, I am not worry about the intensity of light, given at dim lid condition, if have long exposure I can record. When I want a record dynamic phenomena, there has to be a perfect match between your amount of light available and the shortest time that you want to the record. So, they go together and pulse lasers the very intense, and you could achieve some of these advantages.

So, what you find here is pulsed lasers have helped in recording dynamic phenomena. Then what you have right now you have very sleek equipment and fiber optic as done the trick, I can have a light source and take the light, where you want throw a fiber and then going to your elimination. In hazards environment, where I want to where I cannot go near and do it, suppose I want to test the pressure vessel, I cannot go to near the pressure vessel and testing, I have to away after barrier, and I want an elimination, I can have a fiber optics to do that. And you have plenty of laser printers around they all used diode lasers.

So, whatever the technological development that influences the way that you do the experiments. So, what you find is the availability of fiber optics, diode lasers has influenced the growth of commercial equipments suited to industrial environments. You want some kind of robustness and you would like to have and this is possible is such developments. And all the optical techniques, you know if you really look at the development of image processing, earlier they had use the late bed on which they will put a photograph and then you will on the tool post they will have optical sensor, which will pick out the information and the whole thing will traverse and that is. So, the digitize digitization itself may take several hours.

Then we go to the computer and do extraction of features other things people have done, now you have charge couple device cameras, you instantly get the digitize information. So, all optical techniques now replace human eye, no one does in the feel inspect in the component with a human eye have electronic eye, which records this information then you process. So, it has provider of fundamental shift, because I can record intensity data.

So, I can have new ways of data processing possible. So, this is the particular the influence of technology, but for the technology, you could not think in this direction at all and for op optical technique people used a shifting method. And parallel you also had development in manufacture; you have what is known as rapid prototyping and this as significantly reduce the lead time in fabricating a prototype. And fortunately one are the rapid prototyping technology, known as serial orthography uses certain kind of resin, which are also photo elastically sensitive. And I have told you earlier in 1930's and people where devising different components they all gone through mandatory three-dimensional photo elastic analysis.

So, one are the challenge in photo elastic analysis was fabricate a three-dimensional model. And now with rapid prototyping fabrication has become lot more simple, not only it is lot more simpler; I have a cad model to fabricate the prototype the same cad model can be used for finite element analysis. The same cad model could also be used for photo elastic analysis; because I fabricate the model I do the slicing.

And then I am able to bridge numerical analysis and experimental analysis that way I will have more confident in solving complex problems. And what you find here is technology has the very important role to play and you have to observe technology in that experimental technique will survey only when it is open to development of technology and observes those aspects. If you stay away from computer processing no experimental technique is going to be use full. So, what we have looked at it this class was we have started with a brief look at what caustics where then I said in the caustic shadow, you do not get information. So, you have Coherent Gradient Sensor, which provides information that is shadow then we moved on and look at briefly, how to name an experimental technique some discussion on why a particular technique is given a particular name so on and so forth.

Then we looked at a reasonable extend on how the qualitative information of fringe patterns, can provide useful information. See in an industry people want answers yesterday; when they come to you for a problem they want answer 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. Then finally, we looked at technology is played very significant roll and we have looked at how interferometric techniques, got a boost from lasers and we will see in the next class, how material research. See if you look at any scientific advancement, it is the invention of new materials that contribute to it and what we would look at it is in which way experimental mechanics has gain because of material research.

Every advancement of science in a, if you look at hot walls, it has the root from you has space technology. They had titanium based allies, which had which are also found to be bio compatible that is how peculates. When you do high tech research, it peculates down to human suffering alleviation. So, we will see material research development, how it is helped experimental mechanics in the next class. .