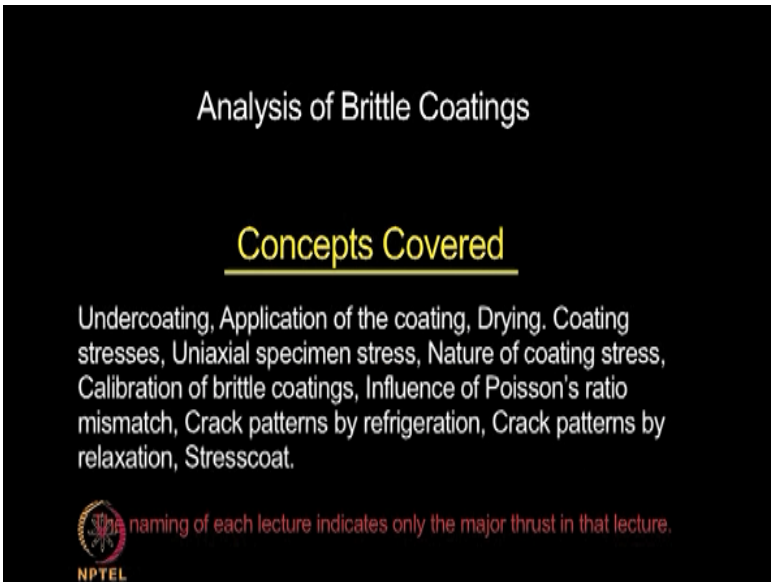
Experimental Stress Analysis
Prof. K. Ramesh
Department of Applied Mechanics
Indian Institute of Technology- Madras

Lecture - 27
Analysis of Brittle Coatings

(Refer Slide Time: 00:07)

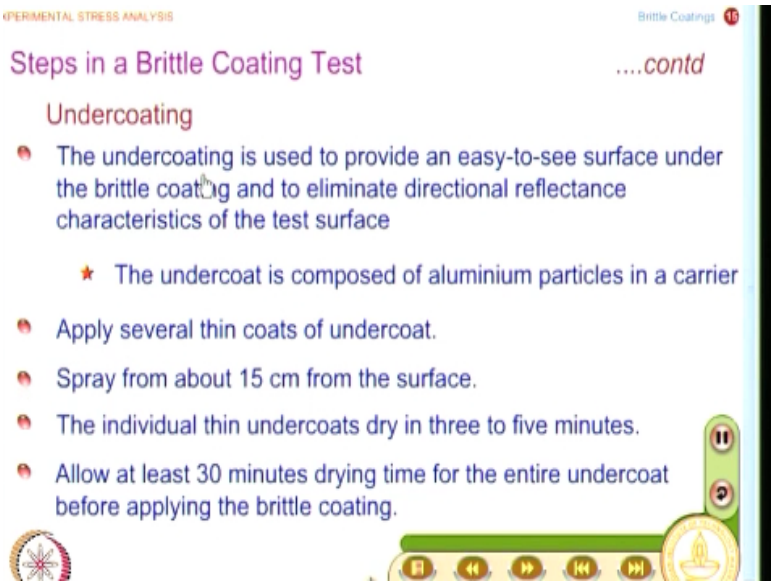


Let us continue our discussion on brittle coatings we saw one of the earliest brittle coatings was naturally formed scales on hard cold steel and the author saw even the oxides that were formed on surfaces there were also used as a brittle coating. And primarily those coatings fail to indicate the presence of plastic deformation in the component. Only later with advancement in material research people developed sensitive coatings which fail at strains much below the yield strain.

That is about 2000 micro strain is when the yielding takes place so people develop coatings which can fail even at 300 micro strains and in all the coatings techniques you need to follow your specific procedure for bonding the coating over the specimen surface. So, in the last class we saw what are the steps in performing a brittle coating test we saw the first step was to select a suitable coating.

The second step was how to claim the specimen surface and now we will see the third step.

(Refer Slide Time: 01:41)



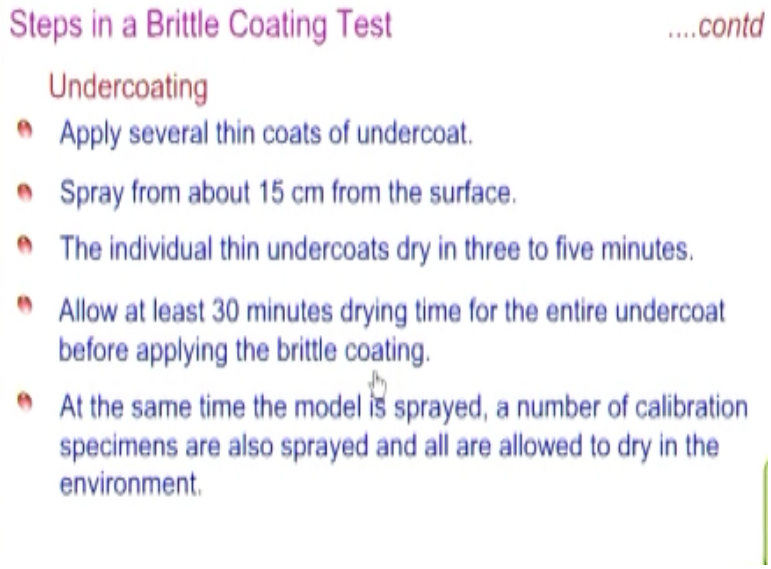
The third step is to provide them undercoat and what is the use of the undercoat, undercoating is used to provide an easy to see surface under the brittle coating and to eliminate directional reflectance characteristics of the test surface. It is very important because you have to go and identify the cracks and you must have the convenience in detecting the cracks and what is the type of undercoat they have the undercoat is composed of aluminum particles in a carrier.

And you know in order to make some of these procedures systematic you know the manufacturer give you detailed set of instructions because it is all skill development and after trial and error they find out typical values for each of the operations. So, what you will have to do is you have to apply several thin coats of undercoat and the recommendation is spray from about 15 centimeter from the surface so that you will have a uniform layer of coatings being formed.

And you must allow after each spray the individual thin undercoats to dry and they take about 3 to 5 minutes. So, you have a recommendation of what kind of a cycle that you need to follow and after you have made several thin coats of undercoat. Allow at least 30 minutes drying time for the entire undercoat before applying the brittle coating. You know what you will have to keep in mind this though these procedures looked very detailed.

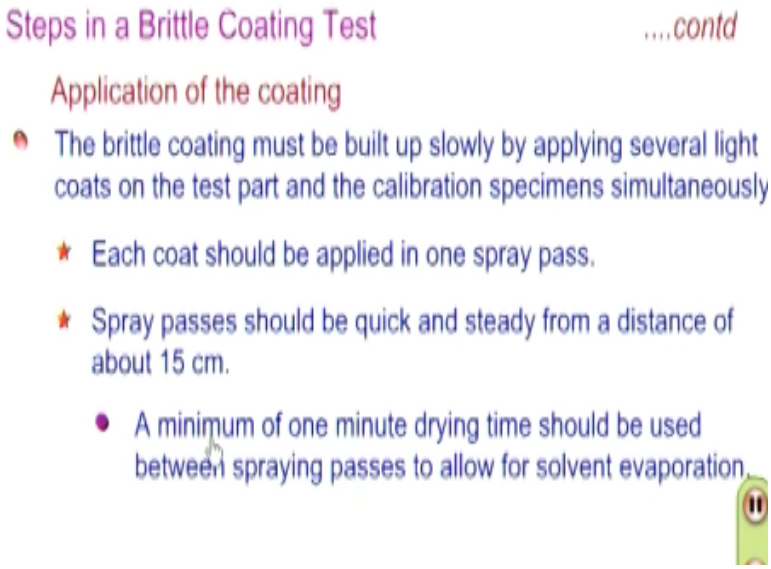
This has come about by several iterations operated by the manufacturer and it is better that they follow these recommendations.

(Refer Slide Time: 03:55)



And what you learn to also keep in mind this when you prepare the undercoat of the model you must also keep a number of calibration specimens spray them with undercoat and allow them to dry in the same environment. Because in all these techniques calibration is equally important unless I find out the failure strain of the coating for each test my data interpretation becomes difficult and this you have to keep in mind.

(Refer Slide Time: 04:33)



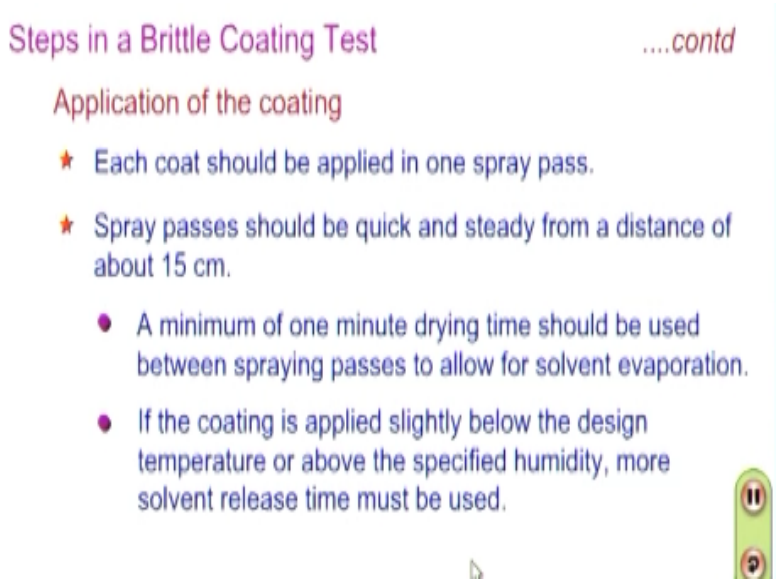
And after undercoat now you get on to application of the coating and how do you apply the coating you have to built up the brittle coatings slowly by applying several light coats on the test part and the calibration specimen simultaneously. So, you are also taking care of preparing good

calibrations specimens which are identical to the way that you have prepared the model. And like the undercoat each coat should be applied in one spray pass.

And you should also do this quickly and do it with a steady hand from a distance of about 15 centimeters so the spraying technique is very similar as undercoat and what you have is after each spray you must follow 1-minute drying time to allow for solvent evaporation. The reason is also given in you know after every coat you must allow sufficient time for whatever that you have applied to dry.

And what you find is undercoat required little more time for drying whereas the actual brittle coating takes much less it takes just 1 minute where you had about 2 to 3 minutes. And all this information is very important to follow because unless you allow the solvent to evaporate the next coatings that you apply may not stick properly smudges may take place. So, that is the reason why you have to observe these type of procedures.

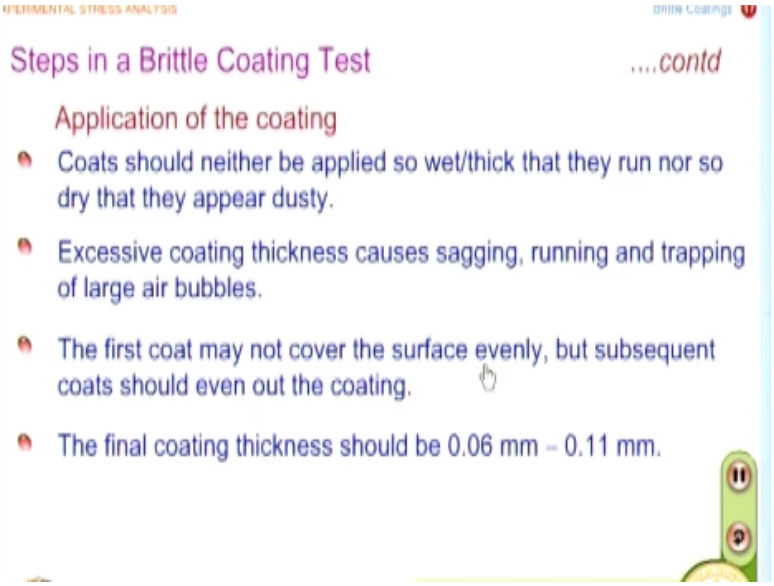
(Refer Slide Time: 06:39)



And you know you will have to be careful when I say 1 minute for each of the coatings the environment is also very important. Suppose you apply the coating slightly below the given temperature design them but they are above the specified humidity more solvent release time must be used. So, you must assess for the given environment are you are in a position to establish that you have provided sufficient time for solvent evaporation.

So, it is more like an art you know you how to develop this be sensitive to what is happening and then apply the coat uniformly.

(Refer Slide Time: 07:35)



And what are the problems that you can come across see you want the coat should neither be applied so wet/thick that they run nor so dry that they appear dusty. So, it has to be in between totally wet and totally dry. And what will happen if you have excessive coating thickness excessive coating thickness may cause sagging, running and trapping of large air bubbles. See this is very important when you are applying coating.

You also ensure that the coating is uniformly applied and there are no air bubbles in trap so that whatever the strain of the prototype is faithfully transmitted to the coat that you have to ensure. So, I want a uniform thickness only if you have a uniform thickness my quantitative estimation would become meaningful. And what will happen when you are putting a coat the first coat may not cover the surface evenly.

So, you do not have to worry about it because you are going to apply the coating by several passes of spray. So, the subsequent coats should even out the coating. So, what you need to look at is when you do the first coat just follow the procedure keep it at 15 centimeters away from the specimen and then make one pass like this allow it to dry and after you make several passes the

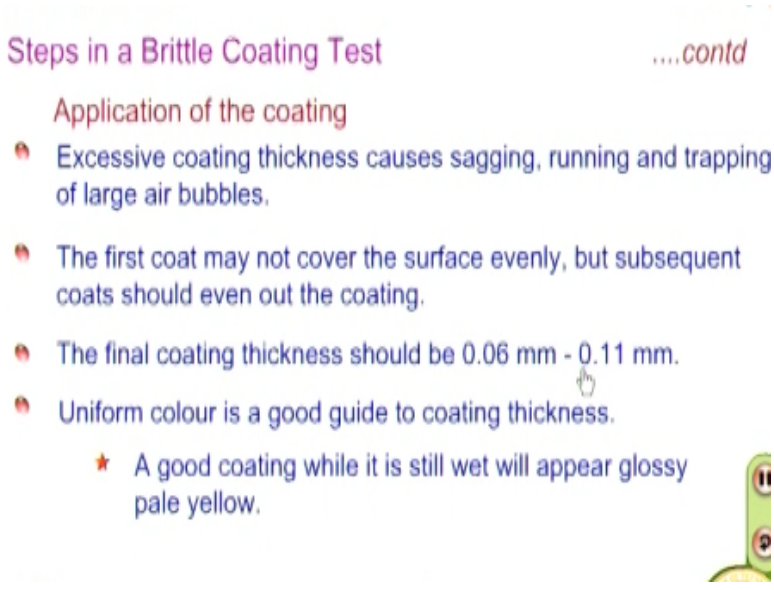
coating will form more or less uniform on the surface.

And what is the typical coatings thickness that you are talking about this is about 0.06 millimeter to 0.11 millimeter. So, here you are the comparison the moment you coat the photo elastic coating I said coatings of 3 millimeters are not uncommon people use less than that but very often you come across 3 millimeter coating. So, that you have sufficient optical response so compared to whatever the thickness affects.

What we discussed in photo elastic coating those effects are not significant in brittle coating and also you are not doing a very careful quantitative valuation of stresses and you are only using this for finding out the principle of direction from the point of view the technique is very robust and industry friendly that is what you have to keep in mind it is industry friendly technique because I can use it for a large structure simply spray.

So, the final coating thickness is very small so the assumption that you have a thin coating is reasonably satisfied in brittle coating technique.

(Refer Slide Time: 10:42)

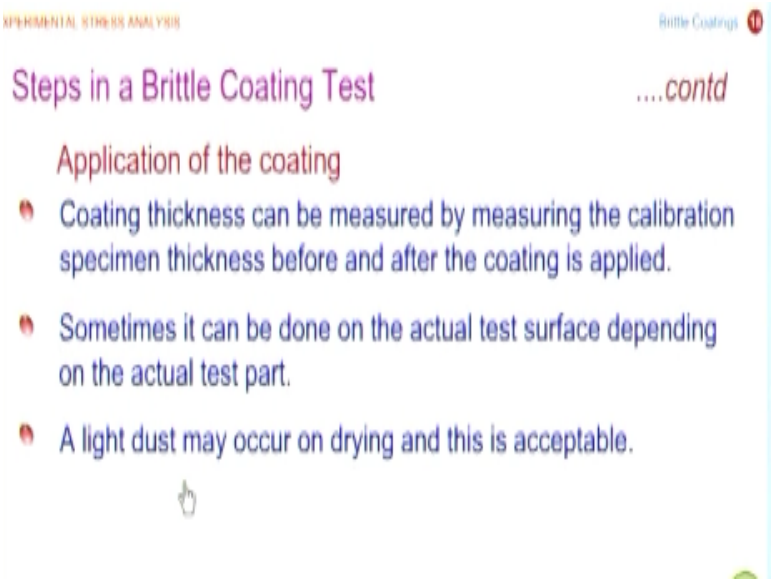


And how do I assess I have reached the final thickness in a color is very very important in the human brain is very sensitive to observing the color. So if you have a uniform color it is a good guide to coating thickness and what is stated is a good coating while it is still wet will appear

glossy pale yellow. Because now you are talking of huge structure you are not talking of a simple cantilever beam that is used for calibration.

When you are having a huge structure we must also have a mechanism by which we quickly check. So, a visual inspection is the first operation that you can do. So, you can visually appreciate whether the coating is uniformly applied on the specimen surface. And the next question is how do you find out the thickness of the coating.

(Refer Slide Time: 11:48)

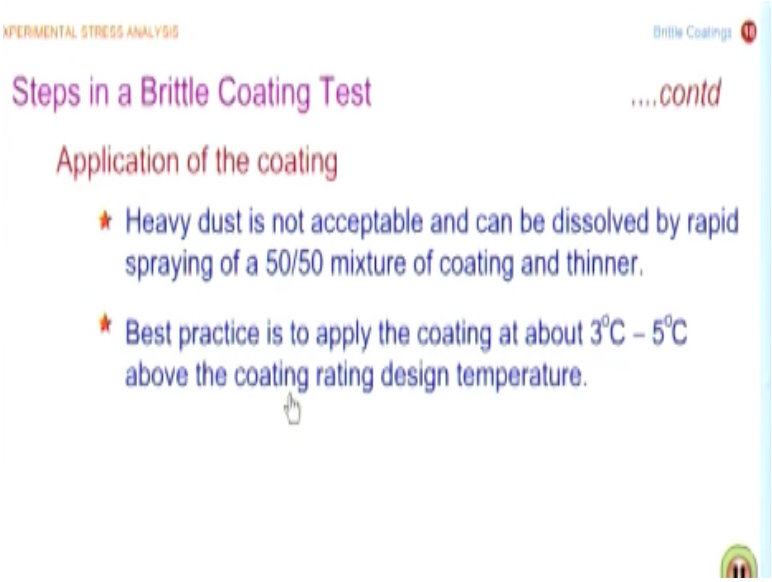


So, one way of looking at that the thickness is to measure the calibration specimen thickness before and after the coating is applied. So, this is straightforward because you are keeping the calibration specimen as part of your specimen preparation. So, whatever the operation that you do for the specimen is evenly done for the calibration specimen. If you have done 5 passes on the actual specimen, you also do 5 passes on the calibrations specimen.

So, that ensures that if I measure the calibration specimen thickness before and after the coating I can find out what is the thickness of the coating on the actual specimen and in critical applications it can be done on the actual test surface depending on the actual test part you also have methodologies that help you to find the thickness and I said it is a industry friendly technique not necessarily you apply the coating in your controlled laboratory environment.

So, you may have a light dust because of the environment and this is acceptable you do not have to be annoyed that I have a light dust what do I do you do not have to get annoyed. Suppose if I have a heavy dust you also have a methodology to handle the situation.

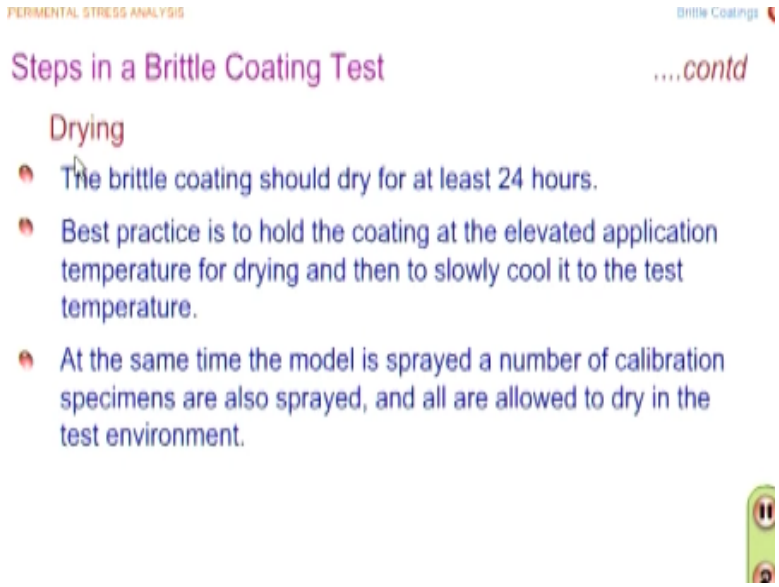
(Refer Slide Time: 13:21)



So, when you face a problem you always have a solution heavy dust is not acceptable and you can dissolve it by rapid spraying or 50/50 mixture of coating and thinner. So, this is the beauty when you look at the procedure you know the manufacturer has looked at all aspects of applying the coating. Because in all coating techniques only if the coating is properly formed data interpretation is meaningful.

This you cannot ignore it you know if it requires skill then you need a skilled technician who helps you to do this or you have agencies which provide you such facility. So, you must pay attention on forming the coating very carefully and there is also other minor recommendation that best practice is to apply the coating at about 3 to 5 degrees above the coating rating design temperature. This helps in curing.

(Refer Slide Time: 14:35)

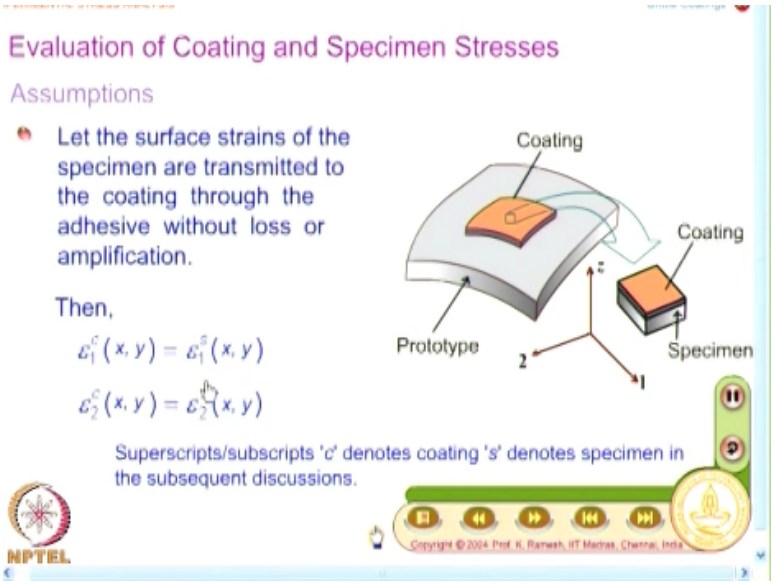


And the final process is how do you do the drying and you should note that brittle coatings takes 24 hours for drying. It is not immediate whereas the undercoat took about 1/2 an hour whereas the actual coating you must allow 24 hours and you also have a suggested practice best practice is to hold the coating at the elevated application temperature for drying and then to slowly cool it to the test temperature.

And like what we have seen earlier at the same time the model is sprayed and number of calibrations specimens are also sprayed and all are allowed to dry in the test environment. So, what you need to ensure is you mimic a very similar process like the actual specimen to the calibrations specimen also. So, now after this process both the calibration specimen and the actual model or prototype are ready for your test.

And now the data interpretation comes and I said when we are discussing photo elastic coating we saw that for all coatings techniques the basic equations are similar. So, I am going to just show those equations for refreshing there are same set of equations there is no difference.

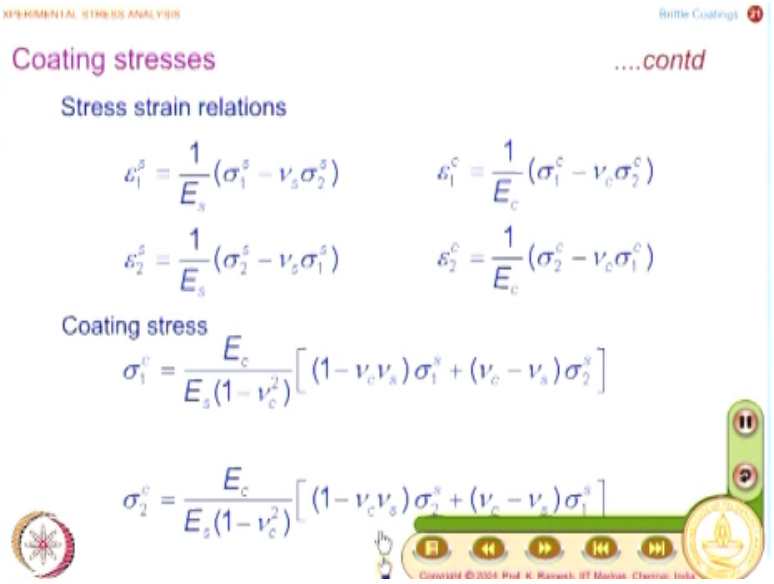
(Refer Slide Time: 16:18)



And the assumptions are also similar so I have a prototype I have a coatings and on the coating a select appropriately a axis for convenience I take axis 1 and 2 they correspond to the principal strain direction at the point of interest and what we assume is the coatings strain=the specimen strain at that point of interest. The adhesive is properly used to transfer the strain without loss or amplification.

That is what is important neither it should amplify nor there should be a loss and then we also looked at how to get the coatings stresses.

(Refer Slide Time: 17:07)



We had looked at stress strained relations for the specimen we also see in this for the coating and

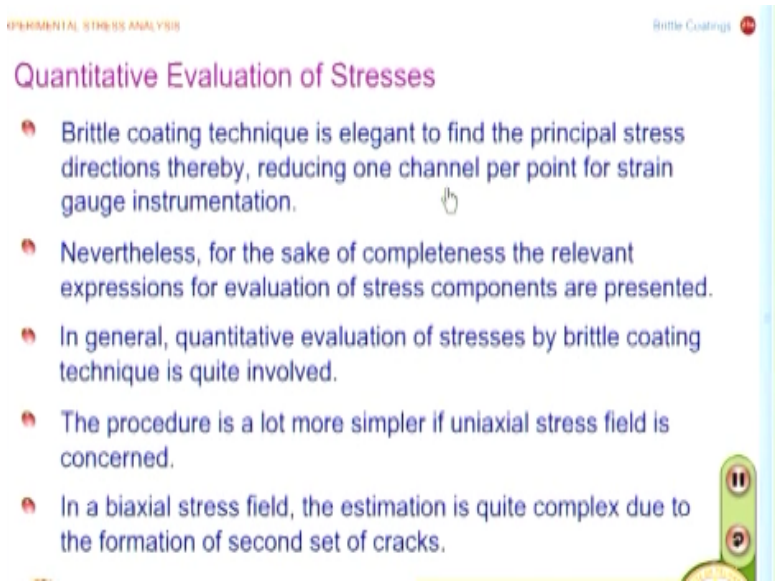
you have also got the expression for coatings stress. Now look at these expressions very carefully you know I have always been saying Poisson ratio plays it spoilsport in all experimental techniques and in this case a very special thing happens suppose I have a specimen is subjected to only a uniaxial state of stress what do these expressions indicate.

The specimen stress is only uniaxial sigma 2s is 0 but what happens to the coating by looking at these expressions what do you infer suppose I have nu c not=nu s when you have a uniaxial specimen stress I will have biaxial coating stress very interesting. You know I have always cautioned uniaxial stress is simpler whereas uniaxial strain is difficult to achieve in experiments and I also caution when I apply a uniaxial stress on this specimen.

The strain would be either biaxial or tri axial depending on the specific geometry of the specimen under consideration. And now what do you see here is because I have a coating applied on the specimen and the Poisson ratio to the coating and the specimen are different which is usually the case you find I will have sigma 1c as well as sigma 2c for a uniaxial specimen stress. So, this makes your data interpretation complex.

See my interest is to bring out and also discourage you from using brittle coating for quantitative evaluation it is left to myself I will use it only for finding on the principle stress direction and reduce the channel and you have to know what are the difficulties. So, you find for a uniaxial specimen stress I have a biaxial coating stress in general suppose I make the Poisson ratio equal then I do not have this problem but you have to appreciate this.

(Refer Slide Time: 19:46)



Now let us look at how do I do quantitative evaluation of stresses. And this is what I emphasize again and again brittle coating technique is elegant to find the principal stress directions thereby reducing 1 channel per point for strain gauge instrumentation. And I have already indicated to some extent that quantitative evaluation of stresses by brittle coating is quite involved. On the other hand, suppose I have only a uniaxial stress field on the specimen.

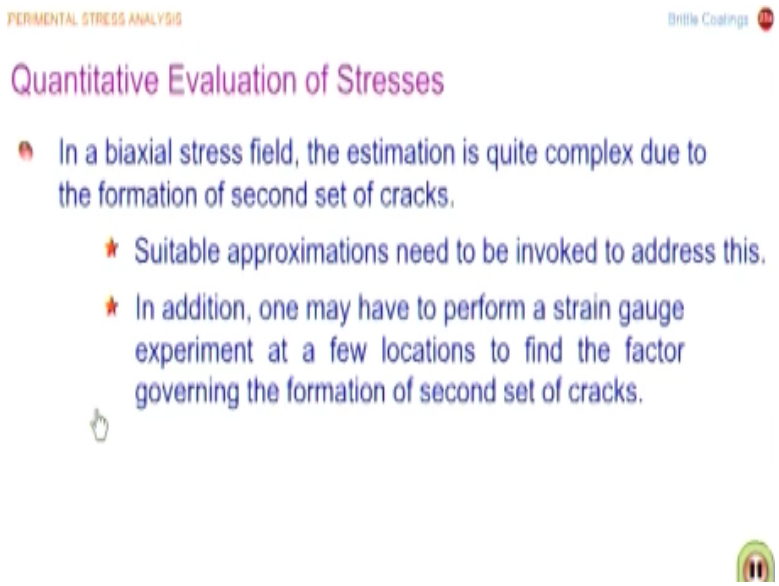
The procedure is a lot more simpler and you have enough examples where uniaxial stress need to be evaluated. On the other hand, if the specimen has a biaxial stress field the estimation is quite complex. See we have seen in some of the examples that you saw 1 set of cracks and you saw another set of cracks formed perpendicular to it and when you want to find out the governing equations.

What causes the formation of second set of cracks you have to bring in a lot of approximations and also information from the actual experimental situation that makes the quantitative evaluation involving? Not only involve but doubtful in its accuracy and I have already said brittle coating is provided + or –20% we are not guaranteeing+or-1%. So, you have to consider that there is an industrial friendly technique.

Where the problem is very complex even a small information will go a long way in improving your design. So biaxial stress field the estimation is quite complex mainly because of the

formation of second set of cracks.

(Refer Slide Time: 22:11)

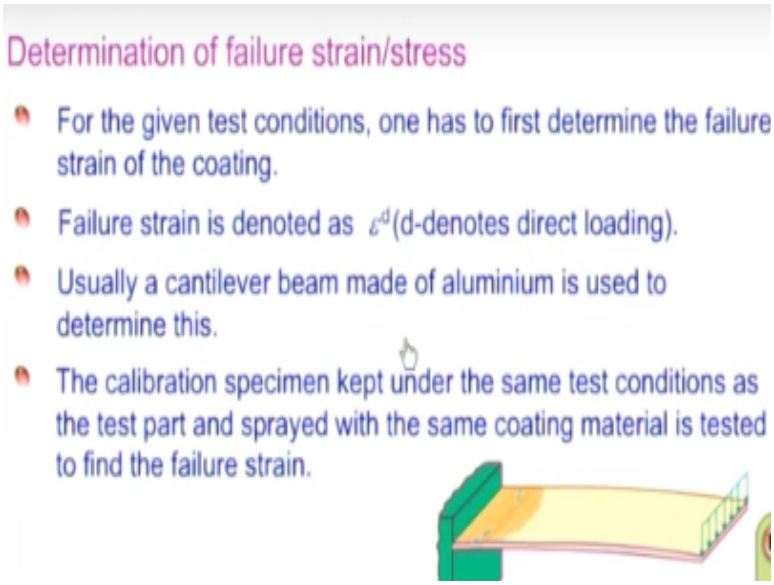


And what kind of information you need from the experiment first is you need to make suitable approximations in addition one may have to perform a strain gauge experiment at a few locations to find the factor governing the formation of second set of cracks. Because in the initial case what we say is the coatings is unperforated you know I have a uniform coating and you can say that being the coating being a brittle material.

It may fail by maximum stress theory or maximum strain theory whatever the theory that you want to have then the cracks form. But if you want to analyze the formation of second set of cracks you do not have a uniform coating you have a coating with cracks. So, that is why you need to bring in additional approximation and you have to say there must be some kind of a factor which governs which may not happen at the actual failure strain of the coating.

There will be a factor and that factor has to be determined experimentally you need to make additional experiment using strain gauges otherwise you will not be in a position to do it. See my interest is I am not going to get in the mathematical details I am going to skip that but I want to give you an idea that when I get into a biaxial stress field what kind of complexities are involved in quantitative estimation of stress magnitude that is where the focus is.

(Refer Slide Time: 24:00)



And what is a first step in the case of brittle coating see we have all along looking at in any of the experimental technique you have to find out what is known as a calibration constant in transmission photo elasticity you had f sigma as a calibration constant that you need to find out. In photo elastic coating you need to find out k once you come to brittle coating I need to find out what is the failure strain of the coating for the given test conditions.

This is the basic information that helps you to get the quantitative data and you need to find out the failure strain and for our discussion we will look at the direct load. So in order to indicate that we are finding out for direct loading the failure stain is indicated with the superscript d. d denotes that it is a direct loading and I have said cantilever beam is the best choice of the specimen configuration that is used for calibrating the failure strain.

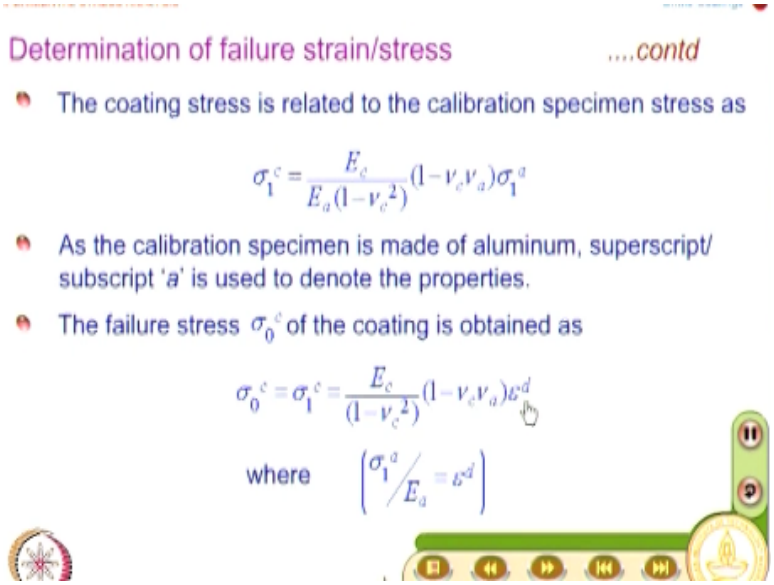
Whatever coating that you have you find out the failure strain by coating a cantilever beam made of aluminum and then estimate it. And we have already seen the calibration specimen has to be kept under the same test conditions as a test part and sprayed with the same coating material and you apply the load and find out when do the cracks form. And now we have to bring in several cases you know you had to bring in I may do it calibration on an aluminum specimen.

So, that becomes a specimen for calibration. So, I will have Poisson ratio of the aluminum, so I will have a new a as Poisson ratio of aluminum then I have a Poisson ration of the coating then I

have the Poisson ration of the specimen. So, I am going to handle 3 different Poisson ratios so that is how the expressions will come and if we actually look at sigma 1c and sigma 2c expression which we have seen earlier it is a play of that only.

But what you need to keep in mind here is because I use a calibrations specimen is made of aluminum and I had to do it on actual test part with material maybe different and I said Poisson ration mismatch is a nuisance and let us see how?

(Refer Slide Time: 26:58)



This is interplay of all these values that are going to see and from whatever the expression that you had seen earlier it is possible for you to write an expression for coatings. So, sigma 1c and I am having only a uniaxial specimen stress the same coating as expression had 2 terms 1 with sigma 1s and sigma 2s. Since I am using aluminum as the calibrations specimen instead of using s as a sub script or super script I use a.

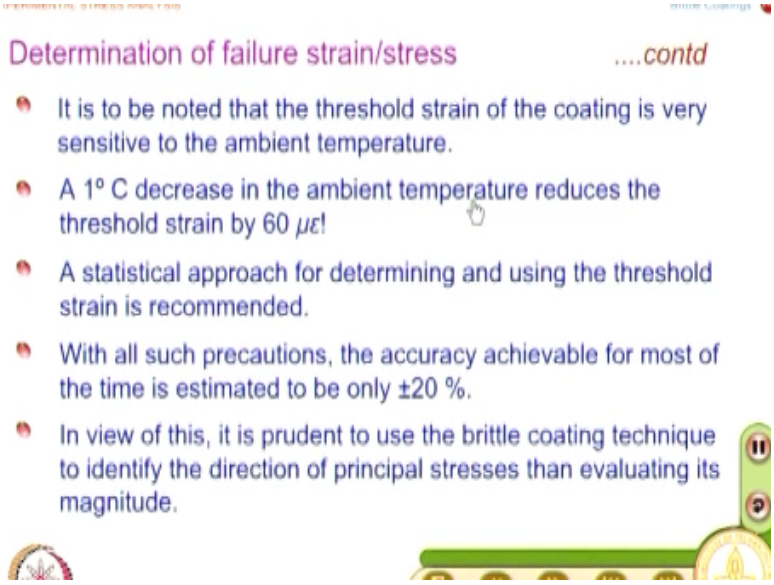
So, what I have here is the coating failure strain can be determined from this expression the coating stress is expressed as Ec/Ea 1-nu c square*1-nu c nu a*sigma1a.We will modify this expression until we get the failure strain or failure stress and the corresponding stress in the specimen it can be expressed in 3 different ways all these different ways we look at it. Now I put at 0 and then say that this is the failure stress of the coating.

And from this expression I write sigma 0c=Ec/1-nu c square*1-nu c nu a*epsilon d, because I have uniaxial stress applied, sigma1a/youngs modulus of the aluminum gives you the strain. So this is the strain for the formation of first set of cracks and I have already cautioned in the brittle coating test the first set of cracks are the most critical one. So, you should not take the incremental loading casually you have to estimate fairly, accurately.

What would be the desirable increment for a particular component on hand. And you are going to find out the failure strain and you roughly know it will fail around 300 to 350 micron strain. So, you can also estimate so you can do experiment very carefully and not miss out this this is what is important so I have what is the failure stress. See that my interest is to go and then show how these Poisson ratio mismatch can affect what I want to do is.

I will also find out what is the corresponding specimen stress when the coating fails there must be some specimen stress for which the coating has failed.

(Refer Slide Time: 30:06)



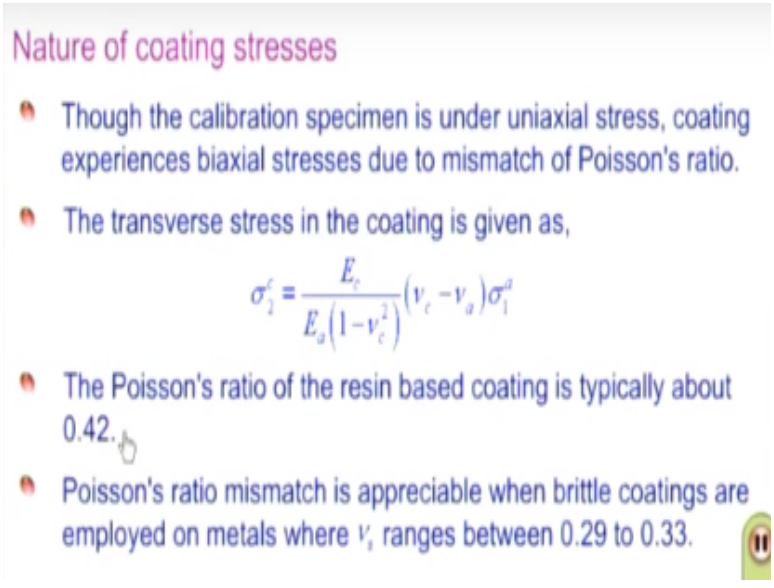
And I can bring in the Poisson ratio of the specimen and look at what way it affects and you must also keep in mind the environment plays a very very important role. And what is reported is even a 1 degree centigrade decrease in the ambient temperature reduces the threshold strain by 60 micro strain. It is very large see what you need to keep in mind is you know when the temperature is lower the coating behaves more brittle.

So, you have to be very careful in that temperature and identifying the humidity relative humidity this is the very important you must maintain that and you must also look at the charge supplied by the manufacturer that you have use the appropriate coatings for a given application. And also ensure that you follow the recommendations and what is recommend is a statistical approach for determining and using the threshold strain is recommended.

Because I may have to do several tests and find out from a statistical approach what is the failure strain of the coating. Even with all such precautions the accuracy achievable for most of the time is estimated to be only+ or –20%. See this is more of a caution you have to keep in mind that all the precautions you do you cannot get a accuracy better than + or - 20%. So, that is the reason why I have always been saying when you are asked to use a brittle coating test.

Use it more for finding out the principle stress direction thereby reduce 1 strain gauge per point. So, in order to establish that also I am showing all this so now after you see all this even a 1 degree centigrade can affect the failure strain by 60 micro strain. So, the quantitative evaluation becomes involved as well as not very accurate when you have this.

(Refer Slide Time: 32:37)



And I already mentioned to you that even for a uniaxial specimen stress the coating in general will have a biaxial stress that is what I am going to look at it. And from whatever the expression

that we have seen for the coating stresses you readily get because this specimen is now used as aluminum you get sigma 2c=Ec/Ea 1-mu c square and you have nu c-nu a*. So the Poisson ratio mismatch becomes important in brittle coating analysis.

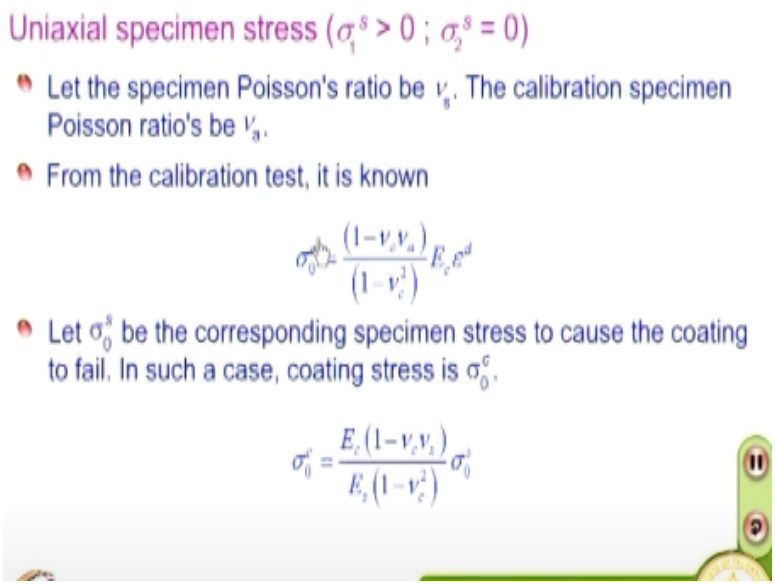
And what is the Poisson ration of the resin based coating it is typically about 0.42 to that is how they have. And the Poisson ration mismatch is appreciable when brittle coatings are employed on metals where mu s ranges between 0.29 to 0.33. So, this is what you have to keep in mind Poisson ratio mismatch has a role to play and what we do here is what way the Poisson ratio mismatch shows up in your equations.

So, one way or circumventing this is what at least in calibration do not do it on aluminum, do it on the specimen on which you do the test. So, in that case what will happen is whatever I do it on the specimen on the calibrations specimen can be easily related to the actual prototype. Now we have not looked at the only looked at the calibrations specimen. We only look at the coatings we are not brought in the actual specimen.

Now I am going to show you the Poisson ration of actual specimen and then you will realize if I use the calibration specimen same as the actual material on which I test I have one problem list that is what they are talking about sound that you are eliminating all problems you have one problem less. So, that is what we are going to look at it now. Now what we have emphasize is for a uniaxial specimen stress the coating experiences biaxial stresses.

So, that is very important to keep in mind.

(Refer Slide Time: 35:14)

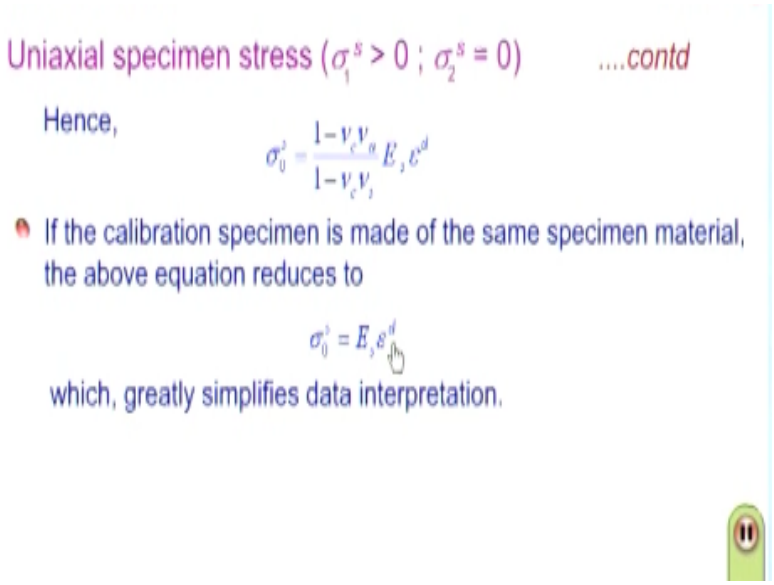


Now I have actual prototype also fails only with 1 specimen stress acting on it the other specimen stress is 0. Now, let us look at how the interpretation can be done and we have done a calibration test from the calibration test what we have found out we have found out the failure stress of the coating and that is written as 1-nu c nu a/1-nu c square youngs modulus of the coating*failure strain Epsilon d.

And I can also go back to my original set of expressions like what we have written for the calibration specimen. I can recast the same expression with specimen Poisson ratio and the specimen stress. So, when I have a coating stress sigma 0c I can also find out when the coatings fail what is this specimen stress that has caused that is given as sigma 0s and what do you have here is sigma 0c=Ec/Es*1-nu c nu s/1-nu c square*sigma0x.

Now I can bring in I can express sigma 0s in a different way.

(Refer Slide Time: 37:03)



Where I will find out that if I use the specimen for calibration same as the actual prototype material then my problem is less and that is what is shown in this slide. So, what you have here is sigma 0s=1-nu c nu a/1-nu c nu s * Young's modulus of the specimen*failure strain Epsilon d. This is simple to derive I am skipping the mathematical steps it is not difficult you can go back and work it out and this brings out the role of Poisson ratio mismatch in this expression.

You have Poisson ration of the coating Poisson ratio of the specimen as well as the Poisson ratio of the calibration specimen. And I said you can reduce the problem by having the calibration specimen same as the specimen material then this equation reduces to sigma 0s=youngs modulus of this specimen*epsilon d. So, this gives you a via media that if you want to have less mathematical calculation.

If you have a very important problem wherein you want to do this repeatedly it is better to use a calibration specimen same as the actual specimen material, you know I have expressions for what happens in uniaxial specimen stress biaxial specimen stress I will not get into those details those equations are very complex. Now what we look at is we will look at for revealing the crack patterns under different type of practical situation that we may come across.

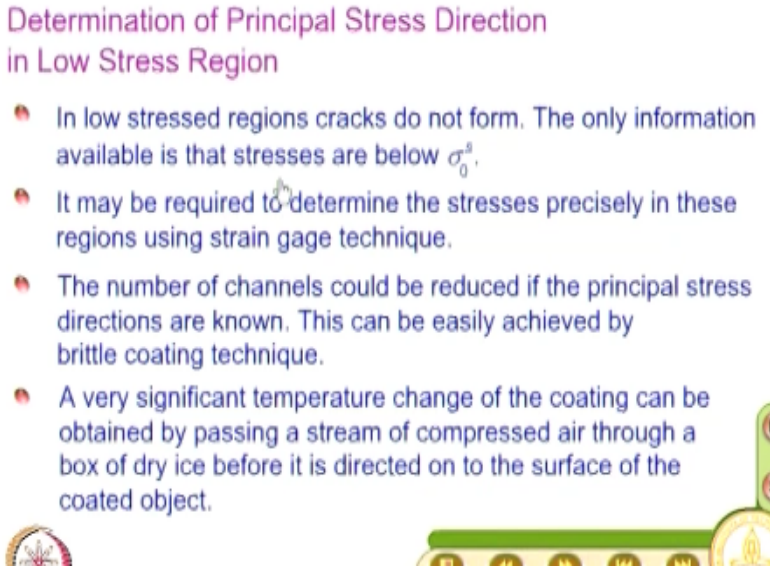
See when you are looking at design you want to optimize you also want to prevent failure. If you want to develop the design to prevent failure, I am interested in finding out the maximum

stresses stress concentration zone and so on. Because that I would like to re-enforce until I am satisfied that it will withstand the operational loads and also any unforeseen exigencies on the other hand when I want to go for optimization I must also look for low stress regions.

You cannot ignore them because I have put an unnecessary weight over it so I have to identify and scoop out material out of it. So, now we look at how brittle coatings technique can be modified to reveal crack patterns in zones where you are not seen cracks fine this is the one situation we look at the other situation is suppose I apply a compressive loading can brittle coating be employed.

You can also employ brittle coating in compressive loading if you restart to a different technique that is very or called as direct loading and the other type of approach will be called relaxation loading. So, you can handle for situations where you do not see cracks how to generate cracks and in situations like compressive loading how to reveal the cracks. So these two aspects we will see.

(Refer Slide Time: 40:38)



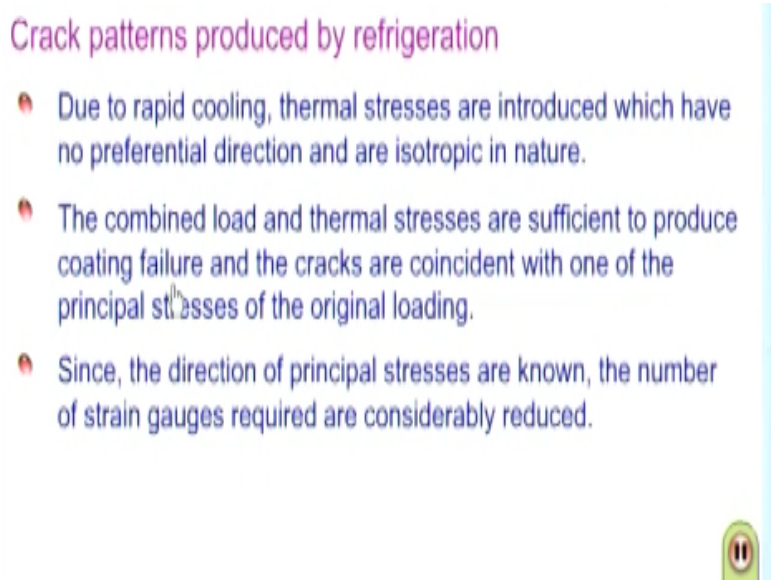
So, we are going to find out the principle stress direction in low stress region that is my interest because when I want to do optimization I need to scoop out material from low stress regions. And what you have is the cracks do not form in the low stress region and the only information that you have in those regions is the stresses are below sigma 0s. Because we have already seen

there is something called the failure strain of the coating?

We have also looked at what is a failure stress of the coating corresponding to the failure strain and we also looked at what specimen stress has caused the failure of the coating we called that as sigma 0s. So, now we know from the appearance of no cracks that the stresses are below sigma 0s and what you can do is the next 2 point say why we need this what you actually do this is a very significant temperature change in the coating can be obtained.

By passing through a stream of compressed air through a box of dry ice before it is directed on to the surface of the coated object. So, what you do is you generate a cool air and then put it so you generate a temperature field which is isotropic in nature and that precipitates crack formation.

(Refer Slide Time: 42:28)

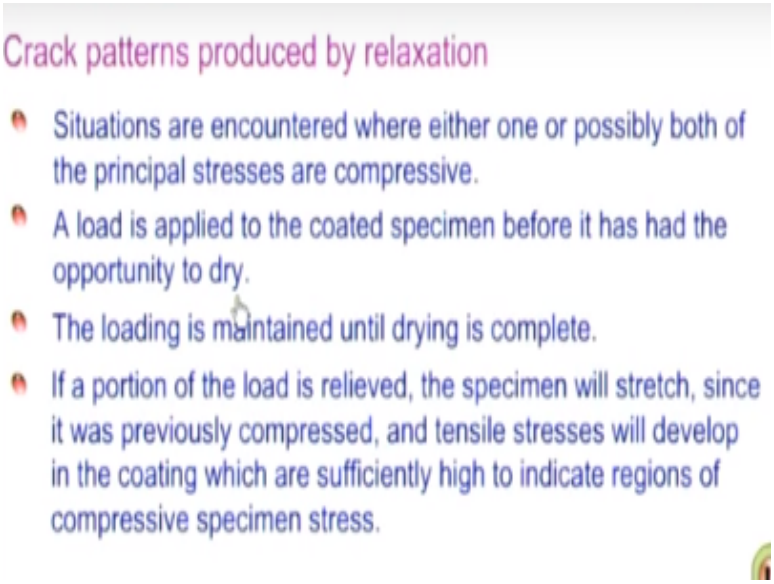


The general level of stress increase and that is what you have. Due to rapid cooling thermal sources are introduced which have no preferential direction and are isotropic in nature and what you have is that combined load and thermal stresses are sufficient to produce coating failure. So, you are able to reveal a crack patterns in regions which are not appeared earlier and this is this approach is known as crack patterns produced by refrigeration.

And once you have got the cracks you have the direction of principal stresses are known. And I can reduce the number of strain gauges. So, it is a very simple extension of basic methodology of

brittle coating and what do I do for compressive stresses you apply the coating differently.

(Refer Slide Time: 43:30)



What do you do is when I go for compressive stresses which is known as crack patterns produced by relaxation, you load the specimen first, a load is applied to the coated specimen before it has had the opportunity to dry. The loading is maintained until drying is complete. So. What will happen, when you release the load whatever the stresses that were compressive, they will behave like tension.

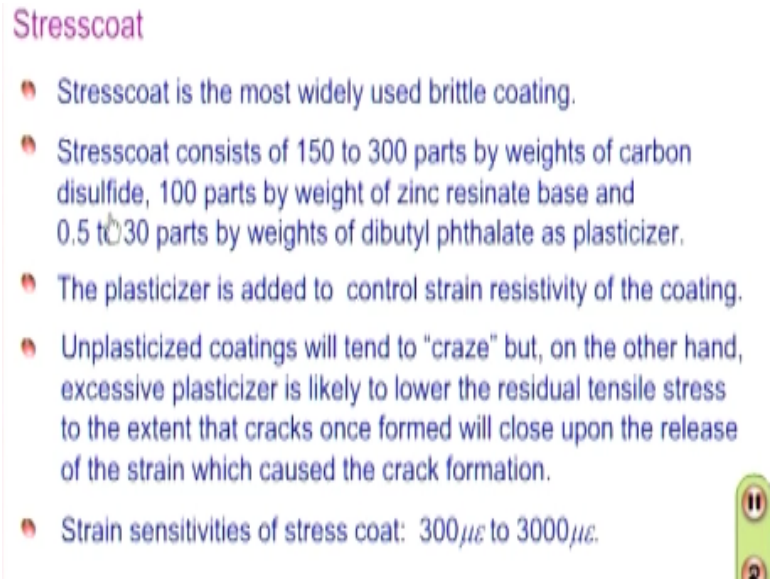
So, you will have cracks formed so you have crack formation very similar to what you saw in direct loading then you can mark those but these are very difficult experimentation you know AJ Durelli and his coworkers have very carefully demonstrated all these techniques and they were also very successful in recording crack patterns in problems like ring and diametric compression Essentially a compressive load applied.

And they have also shown that whatever the isostatic is that you get for these two cases because when they have formation of second set of tracks what it indicates this you get contours corresponding to their first set of crack as well as contour corresponding to a second set of crack and they showed experimentally the principal stress directions are mutually perpendicular. See you have only heard from mathematics that the principle stress direction is orthogonal.

You have not visually seen it even when I do photo elastic analysis I only get contours of isoclinic I do not get contours corresponding to sigma 1 and contours corresponding to sigma 2 and see whether they are mutually perpendicular whereas in brittle coating it is possible to get one set of isostatics because sigma 1 has reached failure strain of the coating and others another set of contours where sigma 2 has increased and cause another set of cracks.

And they have demonstrated that you have 2 families of isostatics, they ae orthogonal everywhere. So, you get an experimental proof that principle stress direction is mutually perpendicular that you only get from brittle coating that is the advantage of brittle coating.

(Refer Slide Time: 45:59)



What is the type of coatings that is available now you have what is known as a stress coat? I said that initial coatings where naturally formed coatings then we saw the first coatings was mixture of shellac and alcohol and what do you have widely now is called stress coat. Stress coat consists of 150 to 300 parts by weights of carbon disulfide, 100 parts by weight of zinc resinate base and 0.5 to 30 parts by weights of dibutyl phthalate as plasticizer.

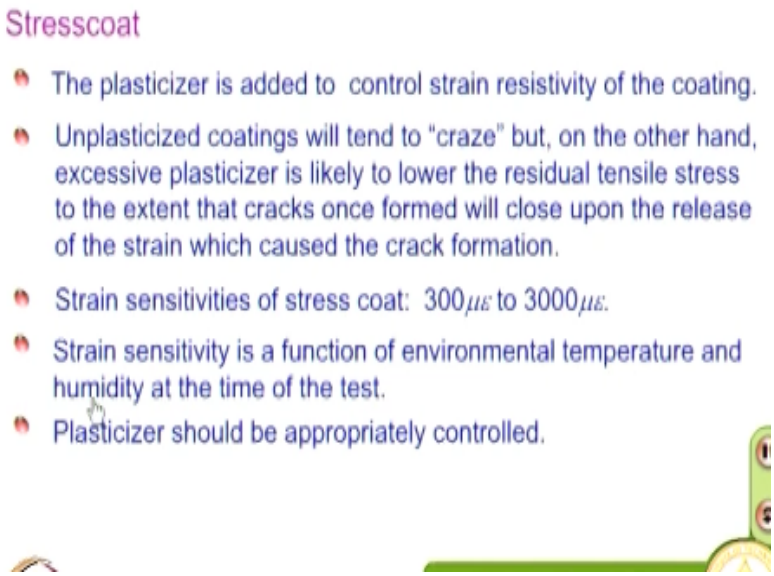
And plasticizer is very very important you know you need to handle it very carefully. Plasticizer added it does the job of controlling the strain sensitivity of the coating and if you do not plasticize the coating the coating will tend to craze that means spurious crack patterns will get form. So, you need some plasticizer to be added and excessive plasticizer if you add what

happens the cracks once formed will close up on the release of the strain which caused the crack formation.

So it is like you have to add it very very carefully it is you cannot remove it completely you need a minimum quantity and what is the minimum quantity it is a function of your requirement and you can also control the strain sensitivity. That is what I said initial coatings were very highly stressed, only when they are very highly stressed they will crack but later coatings with developments in material research.

You have a coating which fails between 300 micro strains to 3000 micro strain so, all this is done by slightly modifying the constituents to suit your requirement.

(Refer Slide Time: 48:12)



And you should also keep in mind strain sensitivities a function of environmental temperature and humidity at the time of the test. Which we have also seen when we are talking about the calibration and plasticizers should be appropriately controlled. You have to have the plasticizers very carefully should handle it. So, what we have seen in this class was we had a decent appreciation of what is brittle coating techniques.

We have looked at what are the conditions for formation of cracks we have also emphasized for a uniaxial specimen stress in general coating experiences biaxial stress. So, it makes the

interpretation and also application of failure theory complex. And like in photo elastic coating here also you have to do a calibration and what do you do a calibration is the failure strain of the coatings.

We also saw we can find out the failure strain of the coating and we can also express it as a failure stress of the coating and we can also find out what is a specimen stress which causes the failure of the coating. So, we also looked at interplay of Poisson ratio of the coating, Poisson ratio of the specimen, Poisson ratio of the calibration specimen and I said you have one problem less if you made the calibrations specimen same as the actual test material.

Then we also saw how to generate cracks in regions where you do not see cracks in the initial test you can do by refrigeration and finally we have also looked at in problems where you apply compression. How do you reveal the cracks which can be done by relaxation? And we also saw what is the material that is available now for brittle coating that is labeled as stress coat, it is a commercial name and that brings it into to a close of what is brittle coating.

But I will still appreciate some of you to look at you know, suppose I have Isoentatic for various loads I have got the Isoentatic, how do you use this Isoentatic for finding out the magnitude of the stresses? Think about it we will have a brief discussion on it in the next class and then we will take it up strain gauges. Thank you.

(Refer Slide Time: 50:53)


Analysis of Brittle Coatings
Next: "Introduction to Strain Gauges"