Experimental Stress Analysis - An Overview
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Lecture – 4.8
Selection of an experimental technique- Part 2

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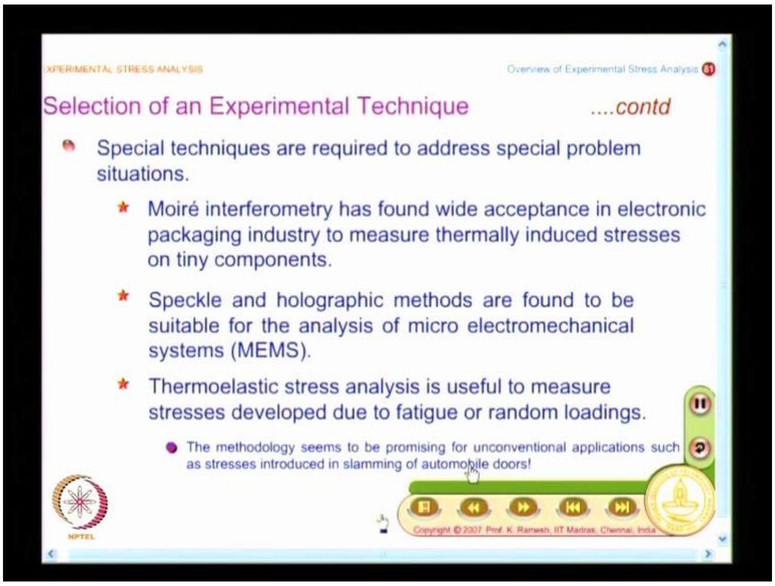

In this lecture, we will continue our discussion on Selection of an Experimental Technique dealt in part one. In fact, you have concord aircraft though it is grounded now after the accident in France. This was one of the aircraft which had very least amount of failures in the field, there were no accidence till it was grounded and it had a tail rudder which was failing repeatedly. In those days about 70's they have all also done a finite element analysis to find out the cost for the rudder failure. From finite element point of view the rudder is found to be reasonably strong to with stand the service loads. But nevertheless it was failing, then what they did, they took a strain gauge and put it on the rudder and made measurements. When they compared their strain gauge values with design calculations it also showed it is within the permissible limits.

Then what they did was, but the component was failing in the field. So you have to find out the cost. Something, what they could not identify from a numerical technique or a point-by-point experimental technique forces them to go for a whole field experimental measurement. They applied a photoelastic coating, then they found the maximum stress point was slightly shifted and strain gauge was reading only two third of it is maximum value. So, the moment they applied photoelastic coating identify the point of stress concentration then they put strain gauges then that design was perfected and the problem was solved.

In many instances, in practical problems identifying what to do? Which is the critical area itself is the challenge. So, a combination of whole field and a point by point technique they go together and they help you to solve a problem. So day to day design problem you can handle and also in special situations. You can always fall back on either photoelasticity or strain gauges. For special situation what you have to do? You have to go in for special techniques.

So you need special techniques to address special problem situations and the moment you think of moiré interferometry you have to think of electronic packaging industry and you find it as found wide acceptance in electronic packaging industry to measure thermally induced stresses on tiny components. In this application, moiré is ideally suitable, mainly because the components are very small I cannot go and paste the strain gauge and moiré gives whole field information and the researchers have convincingly shown that moiré is applicable for these classes of problems.

We have seen for MEMS application, speckle and holographic methods are ideally found to be suitable. We have seen MEMS sensor, how speckle method could be employed? And we also saw in one of the references they have used holographic method to study a micro gear rotating at 360000 rpm. So, MEMS application, if you have the need, then you think of either speckle or holographic methods. Then what you have you have? The method of thermoelastic stress analysis and this is useful to measure stresses developed due to fatigue or random loadings. That is a very special application people have applied using thermoelastic stress analysis. The methodology seems to be promising for unconventional applications such as stresses induced in slamming of automobile doors.

See you may think it is a problem worth analysis. In fact, you know more and more competition on automobile industry people are very particular about the shape. So they keep changing the shape of the automobile and they are all having streamline contours, they also travel at very high speeds and there is also a pressure on them to bring out new variants and this is all sheet metal work. You need to find out for the given life whether the doors will with stand. So, slamming of the door is a random loading and people found, because it is three dimensional problems, it is not two dimensional problem, because you have a contour shape and when you slam it and you need to make the measurement and people found that you can apply thermoelastic stress analysis it is very interesting.

So, as technology advances you also get newer and newer problems. In fact, if you compare the olden days the cars did not have smooth contour they were having box type anythings, I am talking of a 70 to 80 years back. Now what you have, we all have streamline contours, new manufacturing technologies and more and more increase in speed, so all that brings in new class of problems which also require newer techniques to solve.

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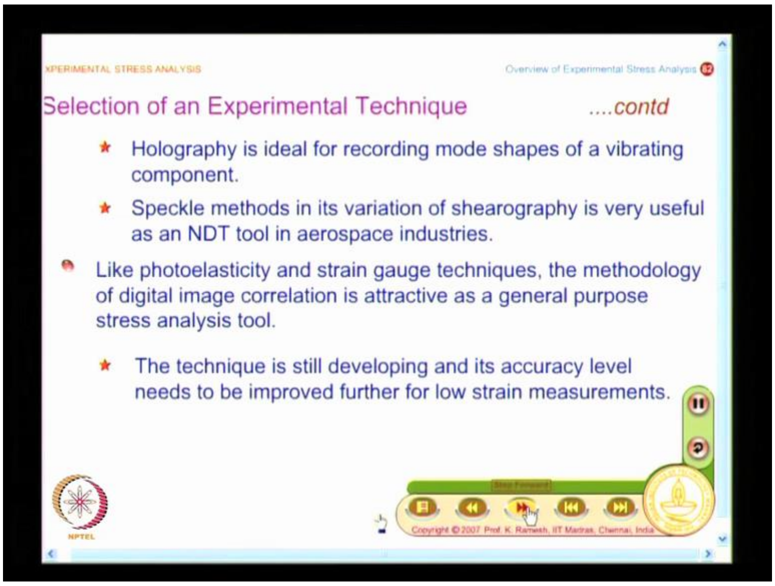

The moment you think of vibration holography is an ideal choice. See I do not know whether you have done some experiments in your laboratory when you want to find out the mode shape, you would normally sprinkle sand or lycopodium powder on a flat object. As long as I am working with the flat plate of different shapes I can do the analysis with a sand or lycopodium powder find out the nodes. Suppose, I want to do it for turbine blade, which as a complex arrow file shape and it is also twisted, so that is where holography came to the rescue because it is essentially out of plane measurement technique it found interesting application on finding out the mode shapes of a vibrating component. And more and more composites and honeycomb panels are used in space technology, so they all have the delamination problem and speckle methods in it is variation as shearography is very useful as an NDT tool in aerospace industries.

I have already caution that if you see butterfly fringes you should not be happy you should be rather sad, that you have so much delaminations and you need to go and repair it, then inspect, then only send. So you have to be very careful about that. And what you need to look at is, I have been saying photoelasticity and strain gauges or general purpose tools. On similar lines methodology of digital image correlation is also attractive as a general purpose tool. The technique is still developing and it is accuracy level needs to be improved further for low strain measurements. Sometime back the low strain was about 160 micro strain, now people say even you can go up to 50 micro strain. So as the technologies improving you are also improving the capability of the technique to measure smaller values of strain, and this as a great potential (Refer Time: 09:00).

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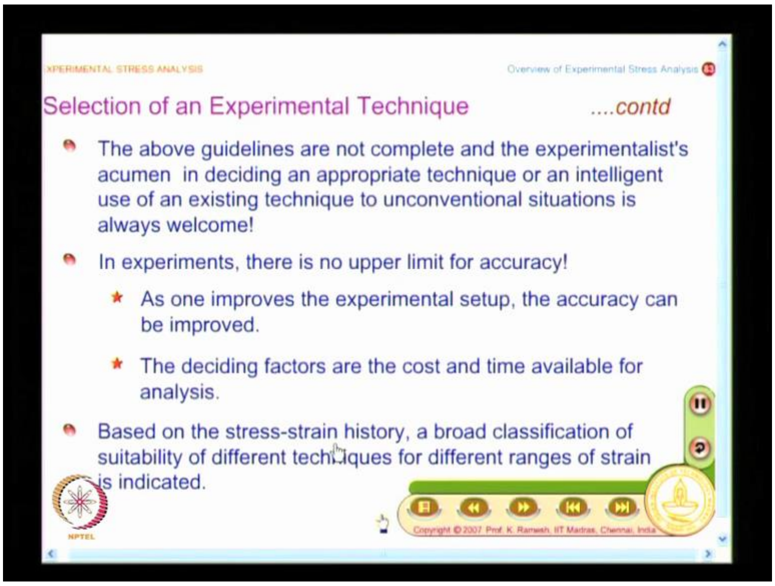

Then what you have, you have to keep in mind that whatever the guidelines that we have discussed so far they are not complete and the experimentalist's acumen in deciding an appropriate technique, is very much essential and you will also have to use a intelligent use of an existing technique to unconventional situations is always welcome. You should never forget that because you know seemingly complex problems you could attack it intelligently with simpler combination of existing methods.

So, your engineering acumen is required. Like doctors have the acumen in detecting what is the disease, people go to only to that doctor when he is able to identify the disease correctly and then solve your problem. Similarly, engineers also have to understand what is a requirement of the given design scenario, select an appropriate technique, and solve the problem. It is not that you are given a problem and you say that you will not be in a position to solve; designers want some answer which they can use. They can always use the factor of safety if there is fuzziness in the answer. But some answer is always required.

Another issue is what is the level of accuracy that you can expect in experiments? And you have to understand there is no upper limit for accuracy. You can keep improving the accuracy in an experimental technique, you may start with the simpler rig and you make some measurements and once you understand this scenario you may want to improve it as much as possible. As one improves the experimental setup the accuracy can be improved. So there is no upper limit for accuracy and you can keep improving the accuracy of an experimental technique.

What decides it is a cost and time. The deciding factors of the cost and time available for analysis. If somebody designer wants a quick answer you could give a number with certain level of accuracy, and you can always use a factor of safety and carry on with the design. If we want a very precise analysis, see normally when people design if they want to make a helicopter to fly they will make it fly first, optimization comes later. So, only when they go for optimization you need refined analysis. And when we are talking about accuracy I would also like to caution, when you compare your experimental results with analytical solution.

For example, if you want to find out the free and displacement of a cantilever. So, you have PLQ by 3EA and what you will do is you will find out what is the displacement from your experiment, and for the moment you consider that there is no sheared deformation the depth is very small. But even then when I make my analytical calculations I need to feed in the value of moment of inertia. Moment of inertia is BDQ by 12, and if you do not measure the depth of the beam correctly then what will happen, you will make an error on analytical calculation of the displacement. Because I have BDQ by 12 it will have a very high error and PLQ by 3EA will not match with the experiment, so you should not always blame the experimental technique when analytical an experimental techniques do not match.

In your analytical calculation have you provided correct numbers for you to do the calculation? That is also very important, people ignore. See if I give thin specimen to a student he uses a scale and measure the thickness, you have to use a vernier and then measure the thickness. When thickness has to be measured small distances have to be measured you should use the precision. This many people ignore, when they compare analytical method results to experiment even for analytical calculation you need to feed in some measurement by making actual measurements on the component of the object. So, these measurements also (Refer Time: 13:47) precise and you should use method Principle of Statistics take few measurements take an average, all that you should employee. People never use statistics, they go and measure once and then say that this is the value. You will always have to have a averaging procedure, so that is also equally important. When we say experiments there is no upper limit for accuracy, you should also caution when you are doing an analytical calculation those calculations have to be accurate enough.

What we will look at now is, based on the stress-strain history we will look at a broad classification of suitability of different techniques for different ranges of strain in the next slide. So this is what we are going to look at. You can broadly classify based on the stress-strain range you want to find out.

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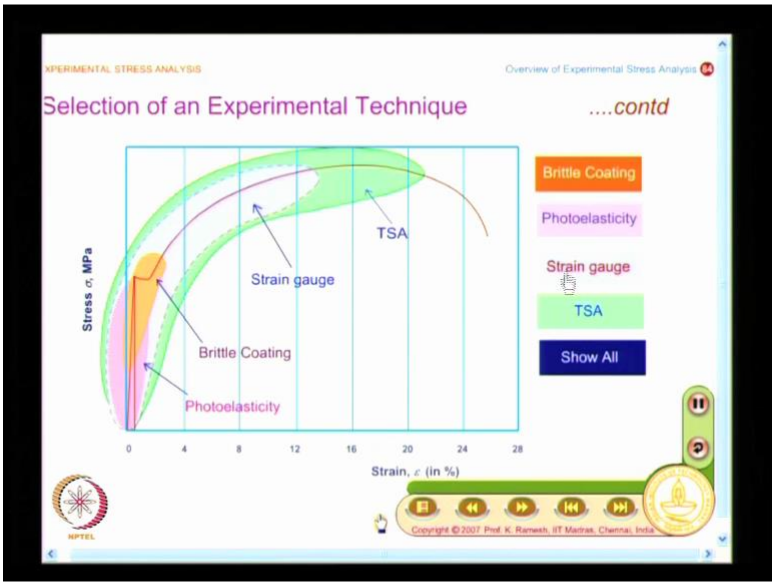

II have taken a typical stress strain graph. The idea is to show that I have a very small elastic region and a very large plastic region and what we will look at is, you make a sketch of this stress strain curve a typical curve. We will go one after another Brittle Coating, Photoelasticity, Strain gauge, Thermoelastic Stress Analysis in which range can we use it because the visual representation always helps to quickly identify am I working on elastic or plastic region.

What way we looked at in brittle coating. Brittle coating as we all said that the failure strain of the coating decides the lower limit, and we saw that it is about 300 to 500 micro strain. As newer and newer materials are developed you may be able to bring it down, but the threshold limit is about 300 to 500. So you will have a brittle coating in this zone, you are operating in this zone. You have to start from this portion to this portion. This shape of the shadow is just for convenience; shape of the color is just for convenience. So, it is about 300 micro strain will be like this, because we always know that when it has this elastic point it is about 2000 micro strain. So, we talk much below that. And we cannot go to lower strain levels in brittle coating. These have been used to identify plastic deformations. This is the typical range where brittle coating can be employed.

What you need to worry about this is the end point and the start point roughly. Roughly this range and when I say photoelasticity what does it indicate, I am essentially living in the elastic region. A photoelastic analysis we will confine only in the elastic region it will give you information. If I have to go for plastic region, I have to go for photoplasticity. Currently we are only looking at photoelasticity, so you will get this information for the elastic region and the moment you come to strain gauge we have seen currently you have techniques which can measure even 0.54 micro strain, so that means almost close to 0. You can also go to the plastic region about 10, 12 percent of strain you can easily measure with strain gauges. You can also understand why we say strain gauge is a versatile technique. So, it has a longer a range I can go from elastic to plastic comfortably.

Thermoelastic stress analysis is proposed as a whole field strain gauge technique that is how they are propagating the technique now. You can go from elastic to plastic region and this is more of a whole field representation. But the instrumentation is very expensive understand that. Strain gauge instrumentation is lot more simpler when you compare it to TSA, but even that instrumentation is a costly it is not cheap.

Now you have relative zones for different techniques shown. So, this is TSA, this is Strain gauge, this is Brittle Coating, and this is Photoelasticity. So, when you are confronted with a problem where you need to find out strain in a particular region this graph you will be able to find out which way you will select the existing technique. I have shown only 4 techniques here. We will have a similar graph for other 4 techniques.

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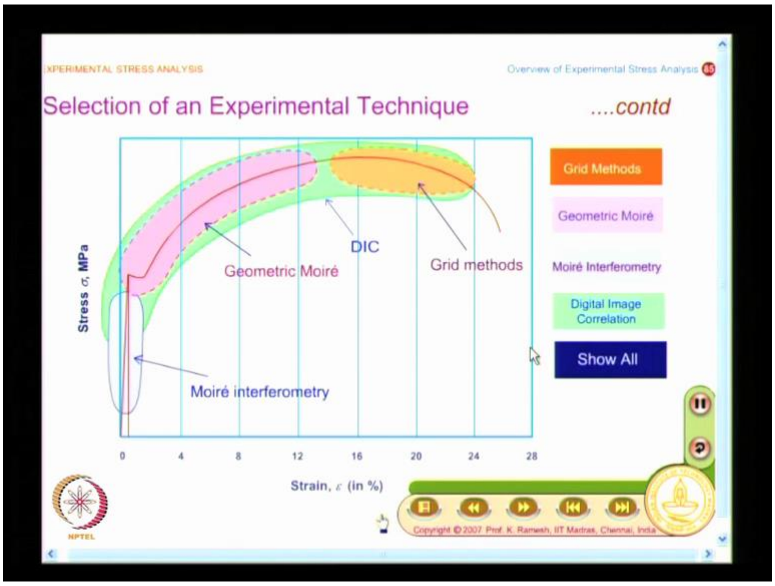

They are Grid Methods, Geometric Moiré, Moiré Interferometry, Digital Image Correlation and you know grid methods were the one which is used for very high plastic region. Then you have geometric moiré, and moiré interferometry is a refinement of geometric moiré. Digital image correlation it as a large range, but it does not have accuracy at lower strain levels. So when you look at grid methods, the range is somewhere here, it is only in the highly plastic region you have the grid methods are applicable.

When you come to geometric moiré I would have it somewhere here this is how I will be able to do this, and if I want to lower this then I can go for moiré interferometry. And what you need to worry about is this end point and start point this shape is for convenience, for aesthetic beauty some shape is drawn. The issue here is, what is the range of strain that you are really looking at? And moiré interferometry cannot measure very small strains it can go down, but it cannot go close to 0 and these are you know pictorial representation numbers are not given so you find that this is the range that you are really working with moiré interferometry.

When I come to digital image correlation, I can go from this to this. I have already said that this can be brought down by improvement in technology (Refer Time: 21:19) researchers are working across the world and they bring down this to as close to 0 as possible. They are now come to the claim is now about 50 micro strains, and it is only question of time that they improve the technique further. Now you have a relative appreciation of various techniques; I have Grid Methods, I have Digital Image Correlation, I have Geometric Moiré, and I have Moiré Interferometry. This gives you a reasonable appreciation on how to decide the techniques based on the strain range.