Experimental Stress Analysis - An Overview
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Lecture – 4.6
Multiscale analysis and trends in experimental mechanics

In this lecture, we will deal with some of the aspects of Multi-scale Analysis in Experimental Mechanics and the Trends in Experimental Mechanics.

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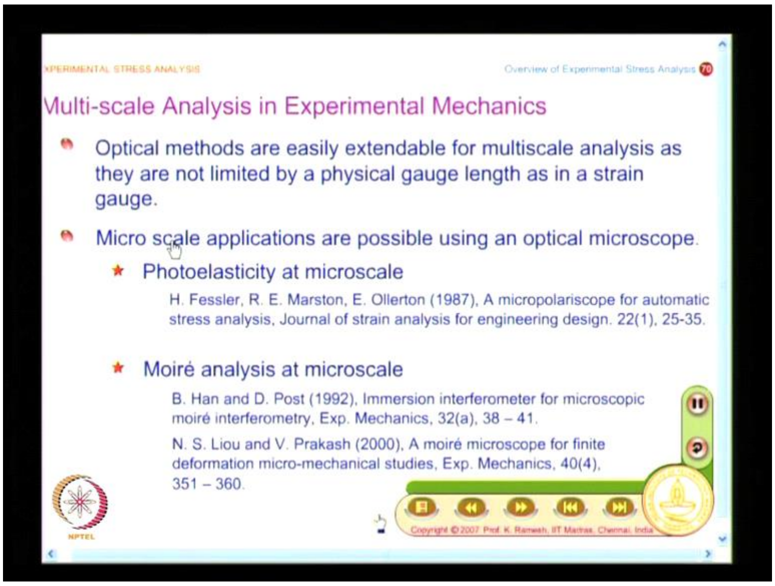

And what we will look at is, important aspect whether you could do multi-scale analysis in experimental mechanics. This is also very, very important, because now miniaturization is the order of the day people would like to make it as small as possible and you will also like to find out whether from a stress analysis point of view, this miniaturized components are stable and whether they will do the intended service whether they will come for the live that you talk about. So, multi-scale analysis becomes important. Suppose, you take a strain gauge technique, what happens? The physical gauge length determines the size on which I can operate. I want to do it for a single point so I want to have the gauge length as small as possible, and for very miniature components strain gauge itself when you past it will reinforce the specimen. We will not be in a position to use in such applications.

On the other hand when you come to optical methods, it is the optics which dictates, what is the scale in which I can operate, once you get into this researchers have developed specific equipments, and you have that available in the literature and it is very important that you need to have some of these in your notes so that you know how these are used. So what I am going to give you is, for each of the technique, what is the key paper that will give an idea that this is also applied at a difference scale. In order to save time what you could do is rather then have writing the Journal (Refer Time: 02:24) completely you can write it as an abbreviation, and also write the first author and put at all for you to access it.

So, photoelasticity at micro scale you have H. Fessler at all it was published in 1987 and you have a micropolariscope for automatic stress analysis, this was published in Journal of Strain analysis for engineering design you just write it as JSA, and the issue number and page numbers are noted. So you abbreviate this reference. This also gives you an idea what are the journals that you should look at for you to get additional information on experimental mechanics? So that information also you get indirectly from the list of references you have. You should also know photoelasticity is applied at micro scale. We have already seen moiré, we have already seen holography being applied at micro scale and these are all very important information for you to know how experimental mechanics can be applied.

So, moiré analysis at micro scale you have Han and Post in 1992, and they have come out with an immersion interferometer for microscopic moiré interferometry. This has been published in Experimental Mechanics; write it as EM that is good enough. So what you could do is, you could just write the author, year, journal, and the page reference. With this it is possible for you to access the information in the library and you could have a look at those papers and N.S. Liou and V. Prakash in 2000 they have come out with a moiré microscope for finite deformation micro-mechanical studies, again in Experimental Mechanics and you have the page numbers.

So just write the first author, year, abbreviated name of the journal and the page number. This information is sufficient for you to look for these journal papers later and likewise we are going to do it for each of the technique, what is the available reference. Some of the key references, you will have several references given in the end of the paper that will also give you an idea what they can go upon.

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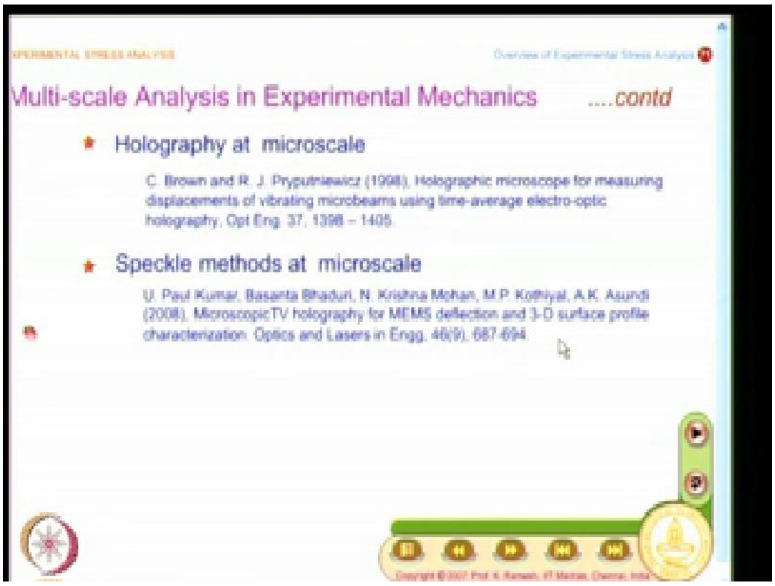

Then you come to holography, you have a paper by C. Brown and R.J. Pryputniewicz in 1998 published in Optical Engineering you can put it as OE and this was for Holographic microscope for measuring displacements of vibrating microbeams using time average electro-optic holography. So microbeams, all these become have become important from nano levels studies now, people are going in for miniaturization. So you have to find out whether these components are stable at those scales. And speckle methods you have U. Paul Kumar and others published in 2008 is published in Optics and Lasers in Engineering, you could abbreviate it as OLEN. So it is published in OLEN and these are all the page reference. This we had seen when we looked at speckle methods, we were getting the pressure sensor it is a rectangular pressure sensor and you have this out-of-plane displacement was recorded by speckle methodology and some application.

Then we move on to; nanoscale studies have been done and digital image correlation in conjunction with an atomic force microscope. That is what I had been saying digital image correlation is an emerging technique. The greatest advantage is, if you are able to control the size of the speckles and also improve your optics you could conveniently study at difference scales. Here, you have a paper publish in 2007 by T.A. Berfield in Experimental Mechanics you can put it as EM. This is on micro and nanoscale deformation measurement of surface and internal planes via digital image correlation.

As I mentioned earlier, you need the lead author name of the journal and page reference. This should be sufficient for you to go and search for the paper. So you have seen, you have look at Experimental Mechanics, Optics and Lasers in Engineering, Journal of Strain analysis, and you have you can add to this list experimental techniques these are all the journals that you would be finding it useful from the point of view of looking for additional and recent information.

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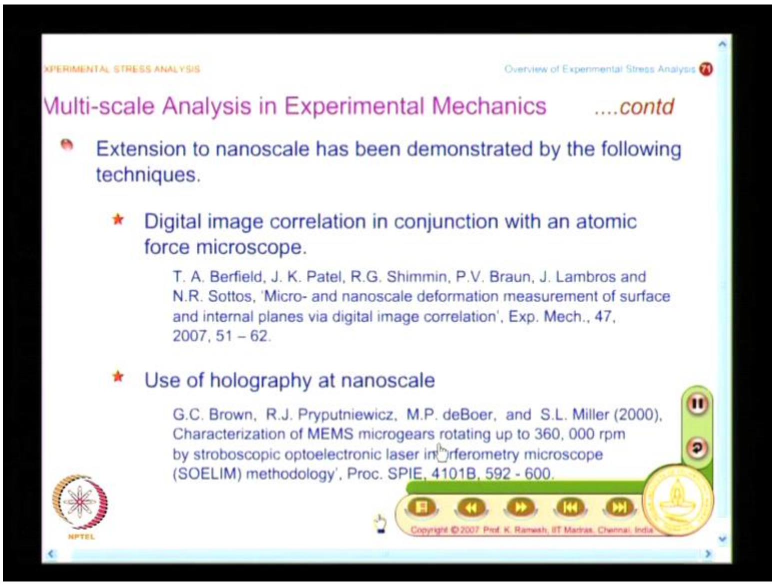

And you also have holography at nanoscale, this is essentially a group led by Pryputniewicz, they have done extensive studies on MEMS, and mind you this is about 360000 rpm. You have a microgears rotating at 360000 rpm. People have done experiments on such miniaturised and such high speed applications and this is done by stroboscopic optoelectronic laser interferometery microscope. It is very, very sophisticated methodology only very few people in the world could achieve such high level of precise experimentation. So it is very interesting, I thought that you should know it is not few thousand rpm it is 36000 rpm, very high speed rotating gears. Here again, this is a proceedings of SPIE so you write that 4101B. These are all online accessible. So write the lead author, year, and then go in for the reference.

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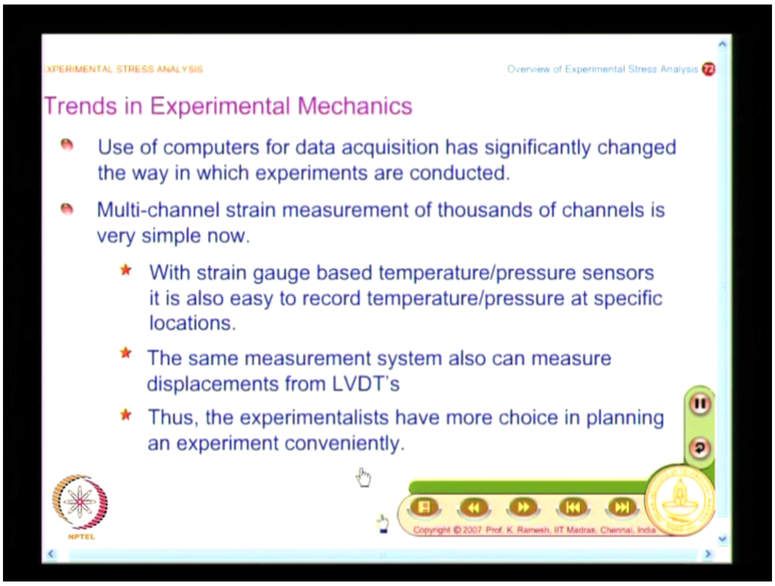

Now the other aspect what we will have to look at is, what are the trends in experimental mechanics? So one of it once computers are developed numerical techniques became very popular, and if you do not use computers in experimentation you will also fall back. So computers also been employed in experimentation. What you find is, they have been used extensively for data acquisition, and also has significantly changed the way in which experiments are conducted. This is a very important aspect.

Earlier people have to go and bet their hands now it is all press of a button. So what you find here is, when you have experiments on large scale structures collecting data by strain guage was a nightmarish experience. It is no longer so, with computer data acquisition multi channel strain measurement of thousands of channels is very simple. The technology has so well developed, electronics are so well developed, because the switching and then scanning all these need to be very carefully done when you are having thousands of channels. It is one story to have four channels and make measurement it is totally another story when you have more and more channels added. The technology is different and it has to be precise.

Another advantage is, it is not only you measure strain, you also need to measure temperature; you may also have to measure in a system pressure. With strain gauge based temperature pressure sensors it is also easy to record temperature, pressure at specific locations. So what you have is, you measure strain, you also in a position to measure temperature, you are also in a position to measure pressure, and some of these will always come in a combination. You may have to if you are really looking at a structure how it behaves you may have to have this data. So now, I can have one data acquisition system which could record in some point temperature, some points strain, some points pressure. So I need to identify which are all the locations where I want to do. And what was possible? What has made this possible? Technology, electronics. You can also measure displacement using LVDT's. They can also be combined to the multi channel strain measurement.

So, experimental is now have more choice in planning an experiment conveniently. I have always been mentioning experiments are planned and executed. You anticipate values, unless you anticipate values you will not know what instrumentation to use and anticipation of values also helps you to look for surprises. You need to have an open mind when you do an experiment. You will have to have and take the surprises find out why you have surprise information, in most cases it may be because of certain approximations you would have done in your analytical or numerical methods which would have escape reality.

It has several times happen experimental measurements or truth raw data is very, very important, but you should record raw data as accurately as possible. When I say raw data is important you should find out how an experimental technique has to be carried out, follow all the steps and record raw data as accurately as possible. Then raw data is sacrosanct. If you take a very casual attitude in doing experiment raw data is no longer sacrosanct. So if you record the raw data and you find surprises, first thing you go and find out have you made any approximation in your analytical modeling or numerical modeling which could be improved so that those results will match with experiment.

In fact, if you take a simple cantilever and put an end load and if the cantilever has sufficient depth your experimental measurement will definitely be different from your PLQ by three (Refer Time: 14:25) approximation. Because you ignore shear deformation in that formulation, so you cannot go and say the experiment is wrong. You are not accommodated shear deformation in your formulation and your experiment has revealed there is a slight variation. The variation will be small, if the depth of the beam is more if shear effects are predominant then the deviation will be more and it again depends on the sensitivity of your measuring system is the measurement system is accurate enough you will be able to see the difference. So that is how you have to look at it.

Now what you have when you have a complex situation, because you have one multi-channel strain measurement can accommodate temperature, pressure and displacement sensors in one platform it makes your life lot more convenient and help you to plan your experiment much more intelligently. Then what are all the other developments that has influenced.

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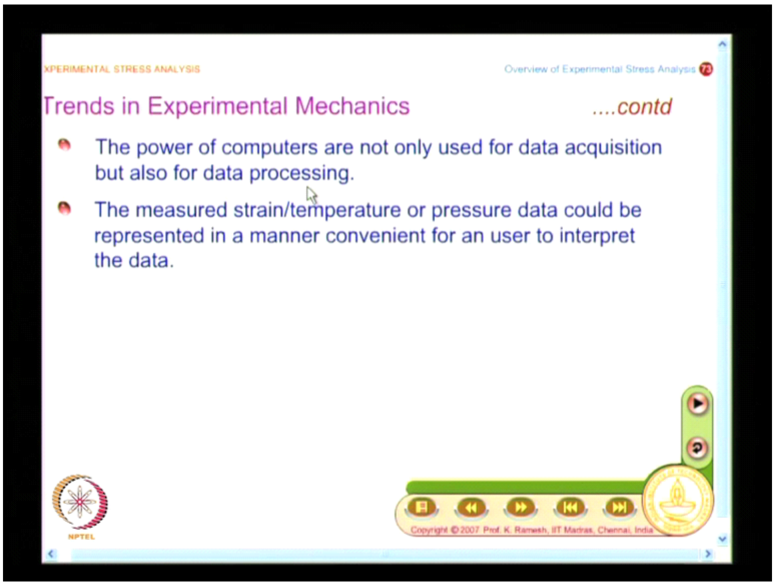

And what you have here is, there are two aspects; data processing is now very fast. For example, double exposure techniques you can make it appear more as real time when you do computer processing because your processing of computers is very fast in handling large scale images. This is not the only advantage. If you go and look at thermoelastic stress analysis or if you look at digital image correlation and you can post process the measure data, temperature, strain or pressure they could be represented in a manner convenient for user to interpret the data. This is not only for the techniques like image correlation.

Even strain data when I have, suppose I have a multi-channel system I have strain data developed at several places. I would like to see a visual representation even at point information if I get. If you put it in color you are able to react better, this which you have been doing only in numerical techniques which can also be done in experimental technique with the availability of computer processing.

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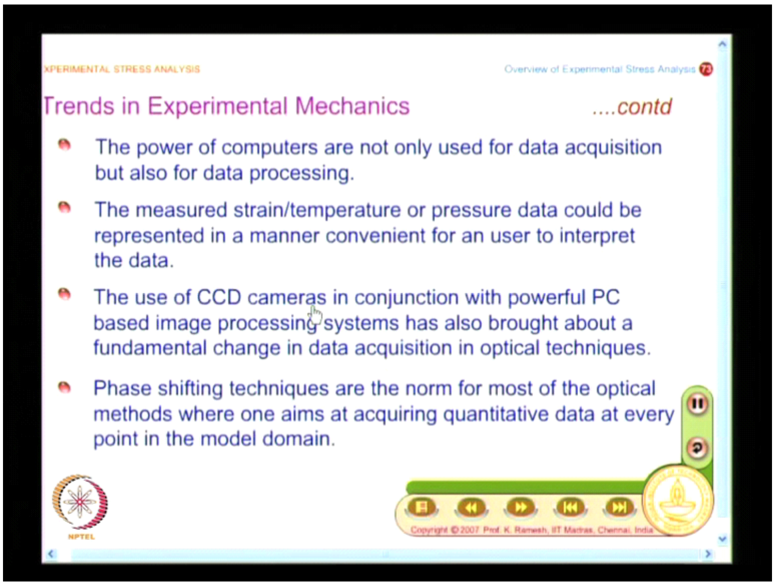

Then what you have, I have already said the CCD cameras have replaced human eye in all the optical methods. So what you find is; it has brought about a fundamental change in data acquisition in optical techniques. The advantage here is; I could record intensity information using CCD cameras at several frames per second. This has modified the experimental approach developers to find out new ways of processing the intensive information. So what you find now is; you have techniques known as Phase shifting techniques have come into place and they are the norm for most of the optical methods where one aims at acquiring quantitative data at every point in the model domain.

This was unthinkable earlier. If they have to record intensity they had a photo multi plate tube and it has to be moved over the model domain and you have to process data, it is time consuming. Now, with CCD cameras I get intensity data over the field at several fringe for second so I could also record slowly varying time phenomena with a high speed cameras it is also possible to record dynamic events with appropriate optics you could record multiple images. So, technology has really advanced with the development of computers and experimental methods have taken full advantage of it. So, this is the positive side of it.

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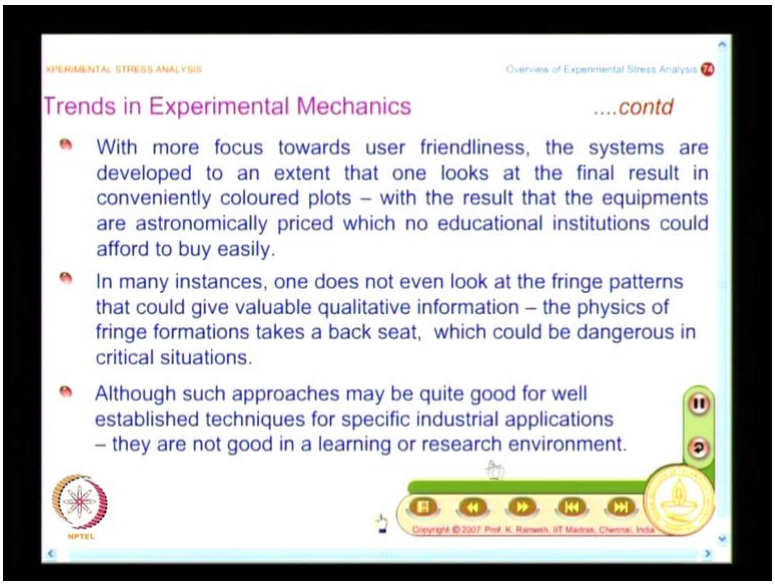

What is the other aspect? You know people want to have user friendly equipment. So when they have goal as user friendly equipments, the systems are developed to an extent that one looks at the final result in conveniently colored plots. What is the outcome of this? The equipments are astronomically priced which no education institutions could afford to buy easily. That is becoming the trend. This is one aspect of it.

The other aspect is, now I have always been saying there is joy in looking at fringe pattern and fringe pattern has lot of information, and you have this information you can make certain judgment based on looking at the appearance of fringes. With modern developments what has happen, one does not even look at the fringe patterns that could give valuable qualitative information. In the process the physics of fringe formation takes a back seat, which could be dangerous in critical situations.

A similar thing happened in development of numerical techniques also, once finite element got stabilized so what they found was, now we have a very good software which can do all problems so no engineers are required science graduates who know how to run the computer program are sufficient and that way the industries can bring down the cost of analysis. Then they burnt the fingers. They found that boundary conditions are very, very important. The science graduates know how to operate the program, but they do not know what to feed to the program. Then they had a scenario where you will have a team leader has a doctoral candidate with a background in engineering, who would decide on boundary condition and you will have set of people who will run the software.

And a similar situation is also looking on experimental mechanics. So you need to have user friendly equipments fine, but it should not go to the extent that physics of the fringe for formation takes a back seat, the physics of the methodology take a back seat and you plus only buttons. That is not the way the experimental mechanics should go and the caution here is, for well established techniques for specific industrial applications. Particularly, if you go and look at glass manufacturing, they employ photoelasticity and when they employ photoelasticity what they do is, they have to control glass process parameters, for this they have well developed equipment where you have you have to press few buttons and then keep monitoring the process. That is a specific application where you need some level of automation, some level of a fast response for such industrial applications this kind of user friendliness may be all right.

But they are not good in learning or research environments. So you need to find out, make a difference. When I am in a research and learning environment I want to know everything about the experimental technique, I want to know it is advantages, I want to know it is limitations, because in a real scenario I may invent a new methodology to extract information in the way I want it. I do not want to go and use it as a black box press some buttons and report the results. That is not the way learning and teaching environment should be.

So, in this course we would focus more on physics behind the experimental techniques, and that will give you certain level of confidence. Although, Phase shifting methods are now of the day in optical methods, we would focus on the conventional approach of looking at fringes so that you gain inside into experimental method as well as improve your understanding of solid mechanics because many of those things you would have just seen it in the books as equations, and when you see them as fringe patterns you also have an appreciation how the values are at different points on the model. It will also reinforce your understanding of solid mechanics.

In this lecture, we have looked at the multi-scale analysis in experimental mechanics and also that trends in experimental mechanics.