Machinery Fault Diagnosis and Signal Processing

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Lecture - 01
Introduction

Welcome to this online certification course on Machinery Fault Diagnostics and Signal Processing which is coming from the Mechanical Engineering Department of IIT Kharagpur. Well, those of you who would have seen the introductory video on this course would have got a feel of what this course is about. This is basically how do we monitor the health of a machine. A very easy way to relate yourself to this course is you become machine doctors instead of human doctors.

So, what do we need to become this so called doctors; that is what we will be covering in this 30 hour lecture, which is being covered in 12 weeks and every week we will have about two and half hours of lecture, every lecture being of an half an hour segment; thus we will have about 60 lectures in all on this online certification course on machinery fault diagnostics in signal processing.

Well briefly to tell you, we will be covering all aspects of a maintenance principles and then we will be talking about how maintenance is done; in particular condition based maintenance and then what are the requirements or prerequisites required by an Engineer to conduct machinery condition monitoring, in particular instrumentation, signal processing, techniques like; vibration monitoring, moto current signature analysis, thermography, wear debris analysis, NDT techniques and so on.

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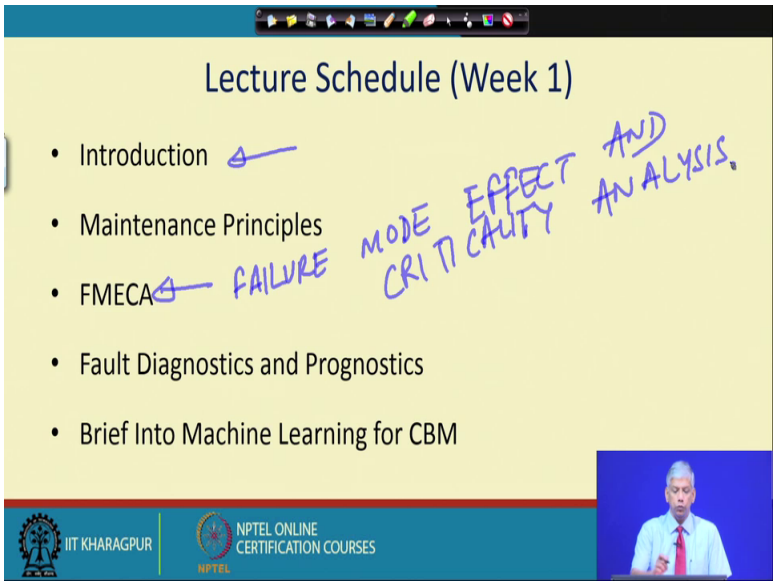

Well, if I go to the week by week schedule of this course; we will have one introduction. This introductory class about half an hour where I will be going over, what we are going to cover in this 60 lectures and what are the principles of maintenance available to us in the industry. And which maintenance techniques to be chosen when will be studied by a method which industrial Engineers use which is known as a FMECA; Failure Mode Effect and Criticality Analysis.

So, because through FMECA we can understand which is the best maintenance technique to be used; in a machinery fault diagnostics. Well, then we will come over certain definitions of using fault diagnostic like what is the fault? What is detection? What is isolation? And what is Prognostics?

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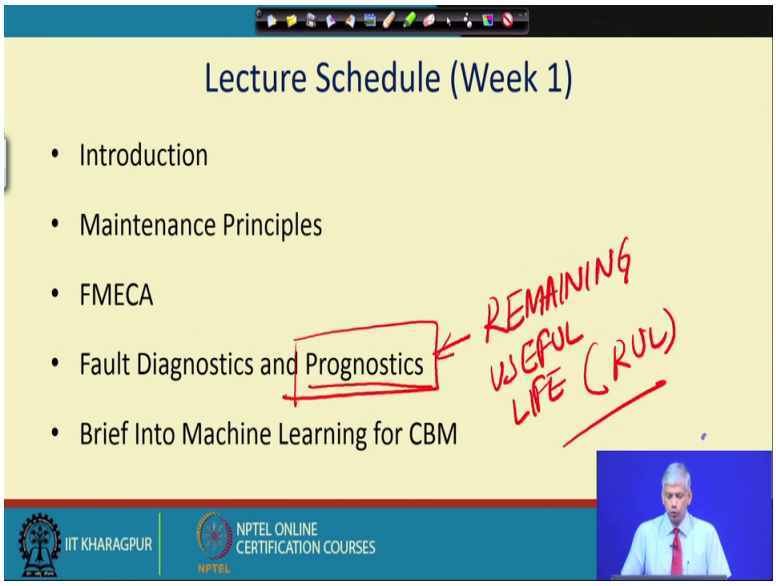

Basically once we are maintaining a machine, everybody in the industry would like to know how long this machine at its present condition is going to last and that is what is covered by; what is known as Prognostics. So, Prognostics is an important area where we find out the remaining useful life, original and RUL of machinery or a component.

And this is what we will be explaining into how Prognostics is done; certain mathematical modeling is used to do Prognostics. Though in this course we will be not dwelling much on the Prognostics, but for just to introduce you to briefly to machine learning for condition based maintenance, how can machine learning help you make a full proof system as to; how or the fault can be detected, diagnosed and even the RUL projector.

And there are lot of techniques available today in the market which do such a machine data analytics and for being the fault diagnostics and then the Prognostics. So, this gives you an overview in the week 1; will give you an overview of what maintenance is and then how we can use FMECA to do which kind of maintenance. And then we will see what diagnostics means in terms of the definition and what is Prognostics and briefly how machine learning can be used for CBM. Now we will move over the next slide.

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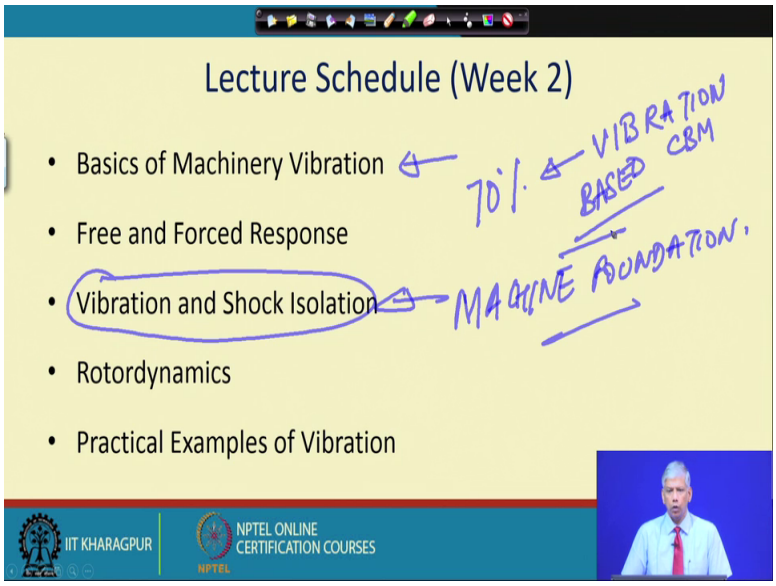

So, in the week 2 we will be talking about machinery vibration; this becomes a prerequisite because as you will see machines when they undergo, it effects they will vibrate, they will manifest themselves with vibrations.

So, in understanding of the basic concept of vibration would help us understand; because 70 percent of the maintenance done throughout the world is basically vibration based and that is what the survey and statistics indicate. So, we are going to talk about vibration; by the way the prerequisite for this course is any undergraduate in the senior year to postgraduates and many of them in the engineering colleges; maybe already have a course on vibration. So, this is going to help you and there are many standard text books on machinery vibration.

So, if you browse through some of the popular books on machinery vibration and studied at least the first order system or the second order system, you will be pretty comfortable in this course. And then we will talk about free and forced response of systems and briefly about vibration and shock isolation. Because this deals with the machine foundation could design because you would see many machines in the industry how to be grouted to the ground through a proper foundation.

And otherwise if the foundation is not proper either there could be exciting through the structural energy being generated in them to a neighboring machine or a neighboring machine could be affecting the performance of such a machine.

I will give an example for example, we have a tool room where we are doing precision measurements and then we have a forging shop next to this tool room. So, you can imagine in each time the forging hammer comes down, the vibration waves underground is going to come and influence the measurements being done in the coordinate measuring machines. So a proper vibration isolation is the required and that is taken care by having good foundation.

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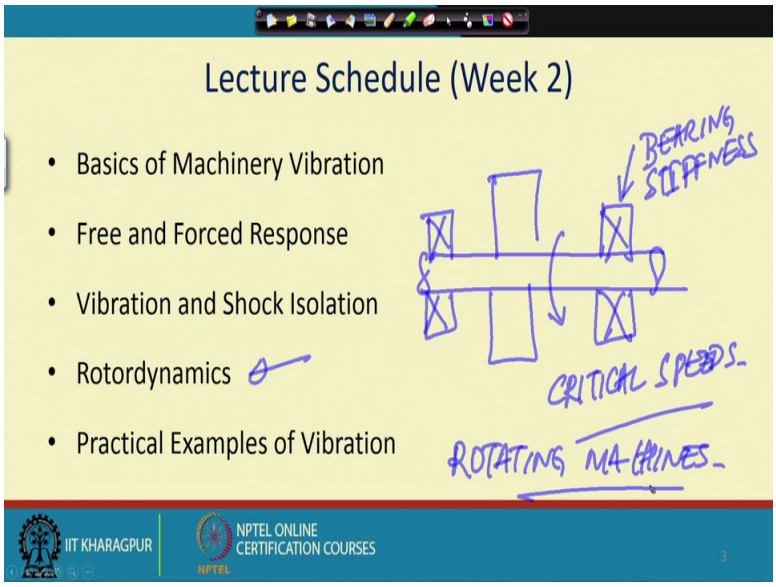

Another area which we need to cover is Rotordynamics because every machine if you think of will have actually a rotating shaft supported on bearings. And then this could be carrying a rotor which could be rotating.

So, the influence of the bearing stiffness, the influence of the lowered or because of this pully gear etcetera on this rotating shaft; we will have an influence and what is the critical speed of the shaft. So, these are issues one needs to know beforehand because we must not have the condition of resonance, the effect of a bearing stiffness; so, all these are accounts one has to take care of. And this we will be covering in the areas of rotordynamics which is a very critical part particularly in the rotating machines. And you will see mostly all the machines where CBM is done, have rotating machines in them.

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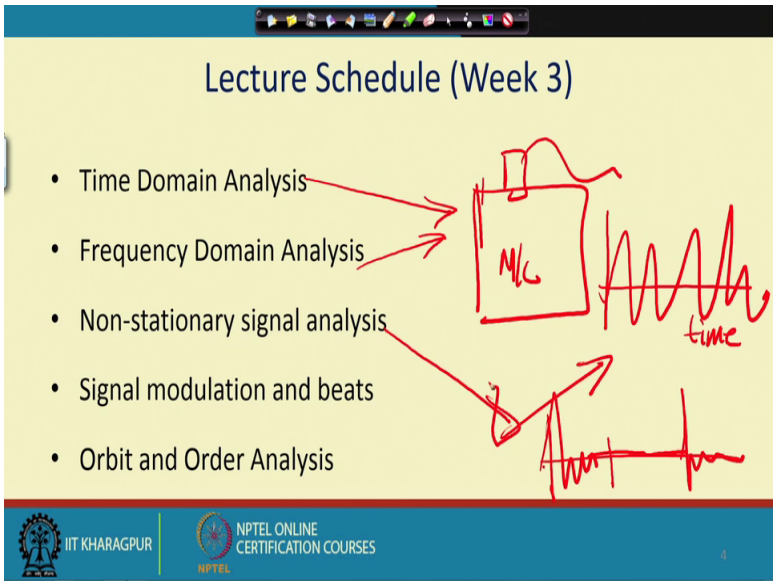

And towards the end of this second week we will be covering about the some practical examples of a vibration particularly relating to CBM. A machine once it is under operation and there are some defects in them, it is going to vibrate. So, this machine is going to give out the signal for the machine and if I put a transducer, I am going to get some signal and the signal in the time domain will look like this; something some signal is. So, we need to analyze the signal both in the time domain and also in the frequency domain.

And sometimes the nature of this signal is not definite for example, our transient could happen and then there is a lull and then the transient is happen. So, this will be a type of non stationary signal which needs to be analyzed. And there are different manifestations of the signals whether signals are getting modulated, signals are beating if two frequencies of machines are very close by; they will have a beating. And something related to the rotations; orbit and order analysis the basics of signal processing will be covered in week 3.

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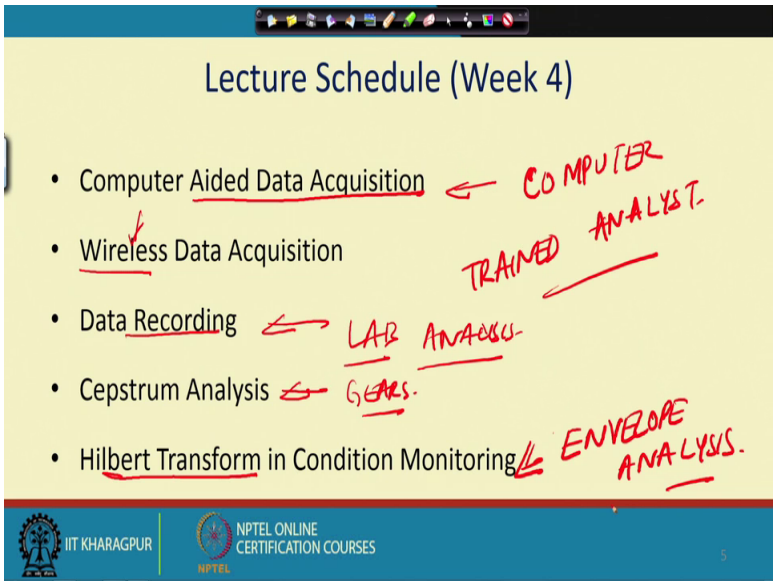

But as I was telling you who does this analysis? It is either this computer or trained analyst. So, this kind of data needs to be taken into the computer by what is known as the data acquisition and is very important aspect which will be covered, what are the ill effects of data acquisition? What are the limits of data acquisition? What are the errors which can keep in your data acquisition system will be covered here.

And then of course, nowadays people are talking about wireless data acquisition in the sense; it is always very difficult to have cables running all the way from the machine to your control room. Like say for example, in a mining plant in a windmill; so there are candidates where we can do wireless data acquisition.

Sometimes it may not be possible for us to do any analysis at sight, so we need to analyze the signal after recording it in a media so that we can bring it back to the lab analysis. And certain areas of special techniques of Cepstrum analysis; particularly used in gears which means to remove the side bands. And then particular a purchase of Hilbert transform; which are used in envelope analysis will be covered in this lectures.

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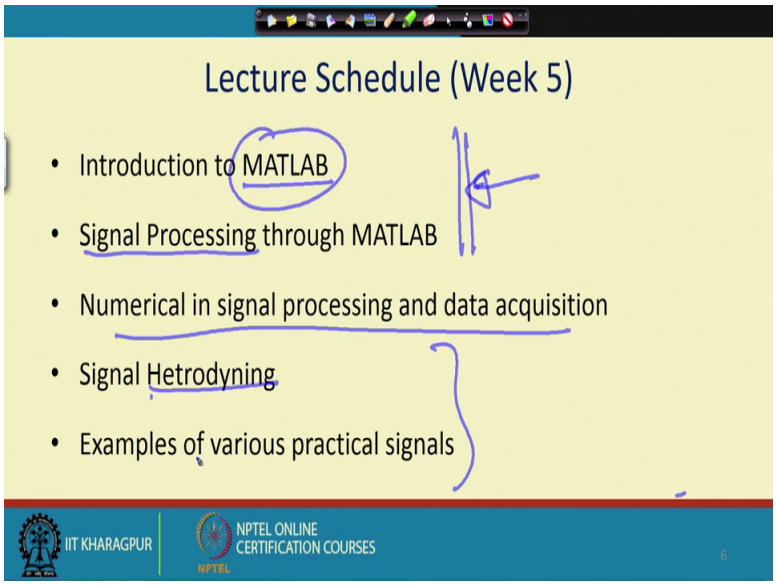

And then next hours, week 5 we will be covering aspects of a MATLAB. MATLAB is a very popular tool which is a software; which is used by many students and those of you who are from engineering schools and colleges, I am sure are familiar with MATLAB.

So, we will be introducing you to a programming language called MATLAB; which will be extensively using for processing the signals which we obtain on machines and of course, I will talk about certain programs and how to do it. And then we will have some numerical on signal processing, which would have covered in week 4 and 5.

And then few examples of how through signal Hetrodyning, we can find out the; for the case of high frequency signals where signal acquisition by a data acquisition system is not convenient; however, a signal heterodyning; we can find out the frequency of unknown signals.

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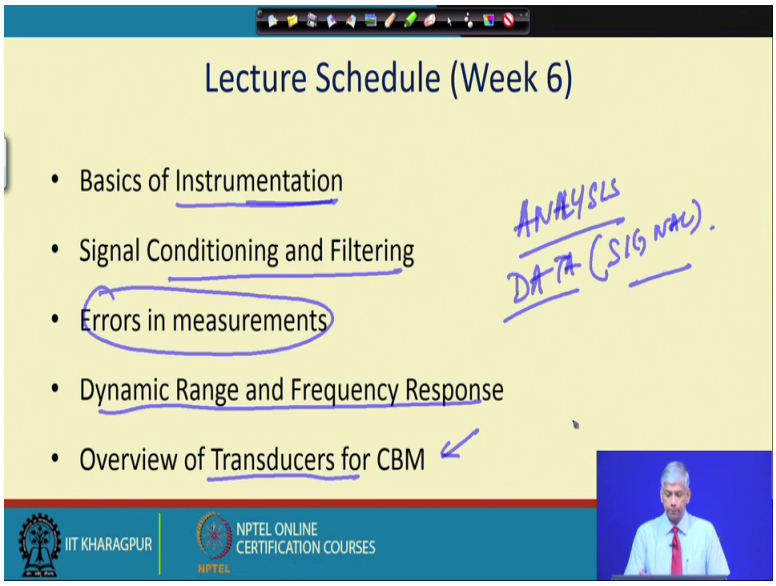

And then show you some practical signals from machines; where we need to do CBM. And towards the middle of the course, we will be having an idea on instrumentation; we will give you an overview of instrumentation. And then how this signal conditioning and filtering is done, errors in measurement is very important because all my analysis regarding the machines health, depends on the data.

If my data or signal is wrongly acquired and so my interpretation is very wrong and that is what we need to avoid and that is what I will tell you, how certain obvious errors can be reduced. Then we will talk about the dynamic range and frequency response of transducers and then give you a list of transducers for different techniques of CBM which are used in a machinery health monitoring.

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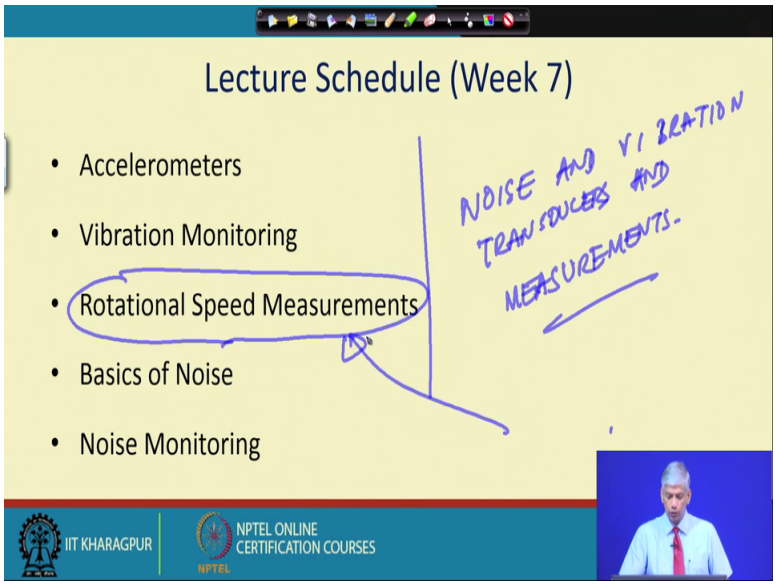

And on week 7; we will be particularly talking about basically this is nothing, but essentially noise and vibration measure transducers and measurements. As I was telling you right in the beginning, 70 percent of the CBM is done through vibration and monitoring.

So, we will be focusing on this and a very important aspect in machinery condition monitoring is the CBM or is the rotational speed. So, how do I measure the rotational speed from CBM is what we will focus on this class.

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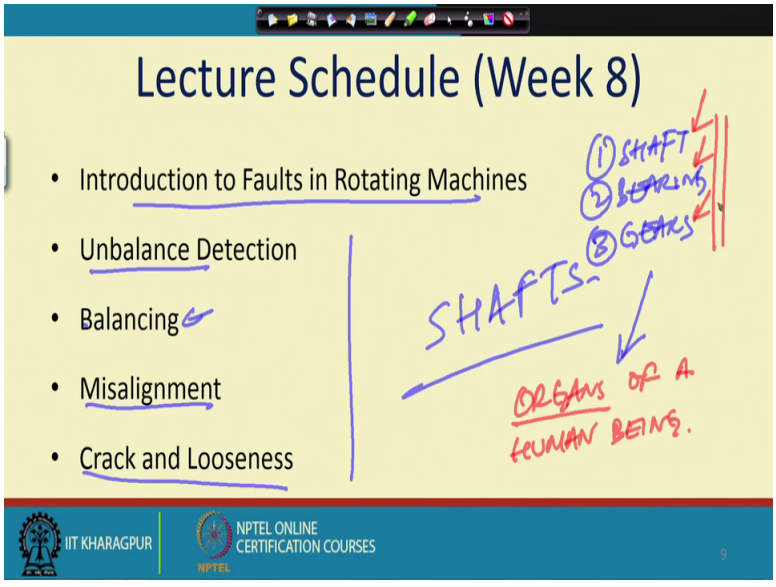

And then week 8, will be mostly focused on the faults in rotating machines. And then we will talk about a certain obvious faults like unbalanced and then of course, how do you do balancing? Misalignment, crack and looseness; which basically happen in all rotating shafts and shafts are an integral part of machine. By the way, I must tell you when you think of a machine; there are many common elements like a shaft, like bearing, like maybe gears etcetera.

So, they are similar to organs of human being; so like a medical doctor diagnosis, faults or defects of the illness in a particular organ of a human being, we will also be finding out techniques to find out faults in the so called organs of or elements of the machines like shafts, bearing, gears, pullies and so on. And this is what is going to be focusing on week 8 of our lecture; I am sorry, so in week 9; I will be focusing on few more machine components.

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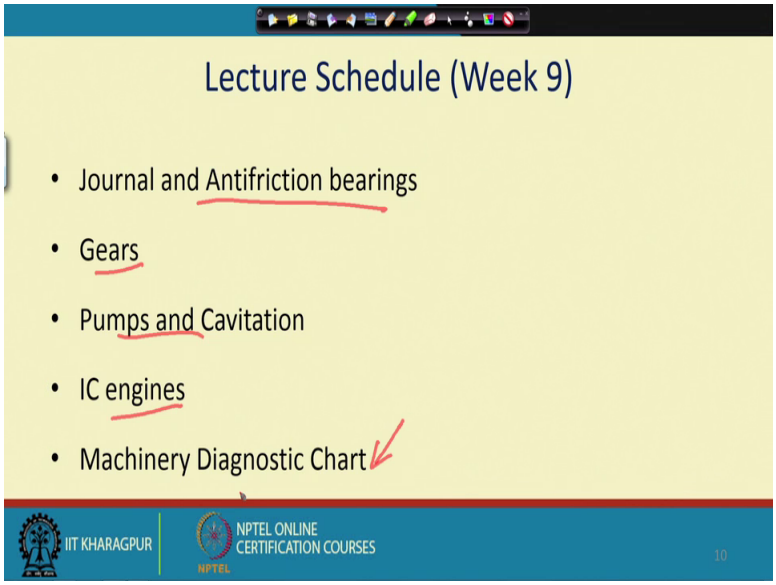

And that is bearings; both journal bearings, gears, pumps and engines and then we will conclude with the machinery diagnostic chart wherein every characteristics of the faults in the frequency analysis will be related to the faults and this diagnostic chart is going to help you diagnose the fault.

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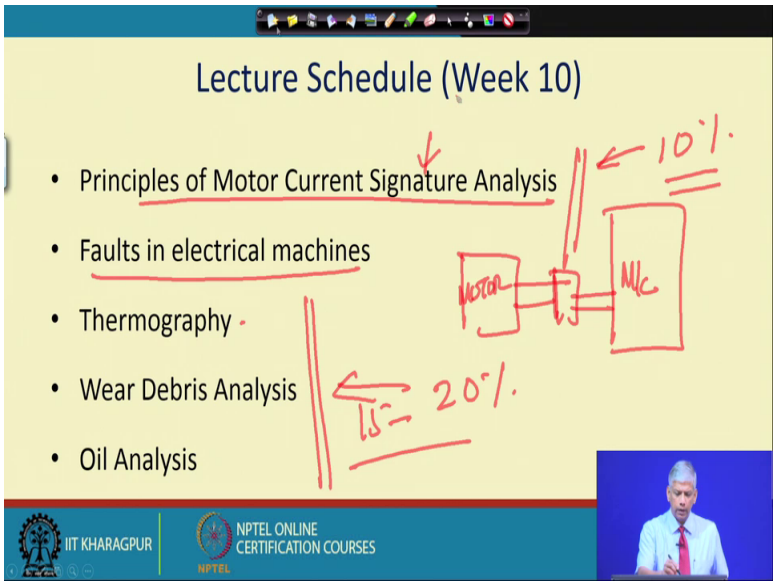

Now, I will move to the next week that is a week 10; there is another new technique principles of motor current signature analysis. In fact, we at IIT Kharagpur have been a pioneer in using this technique of motor current signature analysis, to find out faults in machines being driven by electrical motors.

So, there is a mechanical machine like a pump, like a blower, like a gearbox which is run by an electrical motor. We can indirectly measure the quality of this motor current and then find out what is the fault in the mechanical machine being driven. And this is a very powerful technique and in fact, we have a patent in this technique as well. For that matter that for any rotating machine, we can find out the fault in that machine if I put a tachogenerator and understand the ripple voltage is generated in the tachogenerator, we can find out the fault. And then we will talk about different faults in electrical machines; be it motors, be it transformers and so on.

Actually today; about 10 percent of the industry use MCSA, which was almost insignificant about a couple of decades ago. And then we have the other techniques of thermography, wear debris analysis, oil analysis which we will be covering. And usually this also constitute the remaining 15 to 20 percent and through thermal imaging.

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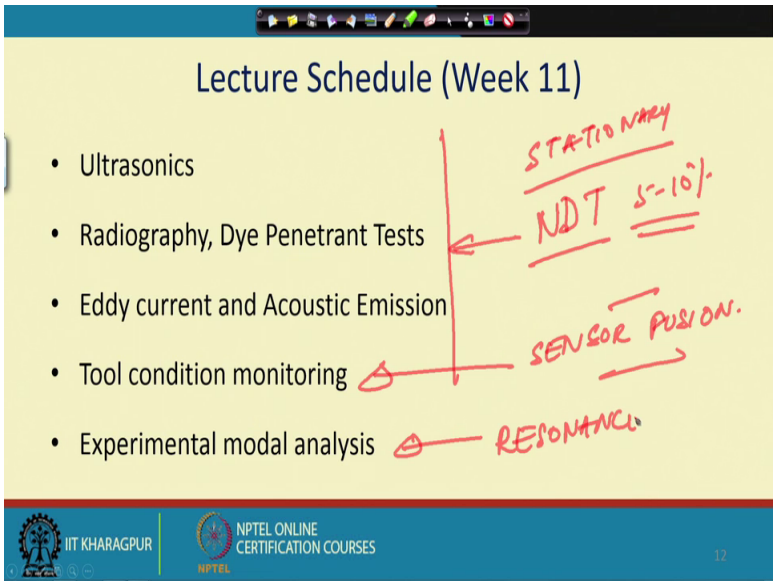

And in the last week, in week 11; we are going to talk about some of the techniques which are other techniques, like which are popularly known as the NDT techniques; non destructive test techniques. And today in many of the quality control aspects of a product are checked through these and particularly like a weld defect; how good is your welding done? How good is your machining done?

Whether there is a corrosion? Whether there is some phenomena; particularly if things are stationary, these things are very helpful. When I talked about vibration monitoring, when I talked about motor current signature analysis; we always had an idea that the machine was running. But in some of these techniques like ultrasonic radiography, eddy current etcetera; the machine can be stationary; and usually again 5 to 10 percent of the industry use NDT as a means to find out defects. And then I will give you an example of TCM; Tool Condition Monitoring where we have used a concept of sensor fusion through a project which we have done about a couple of decades ago.

And then another technique; I will tell you about EMA; where in we find out the resonance of any machine because when a machine is operating, we would not like to have a condition of resonance occurring so that the machine will undergo defect. Because at resonance; the amplitudes increase and then repeated machine will undergo fatigue and there will be a premature failure. So, this needs to avoided we can estimate the resonant frequency.

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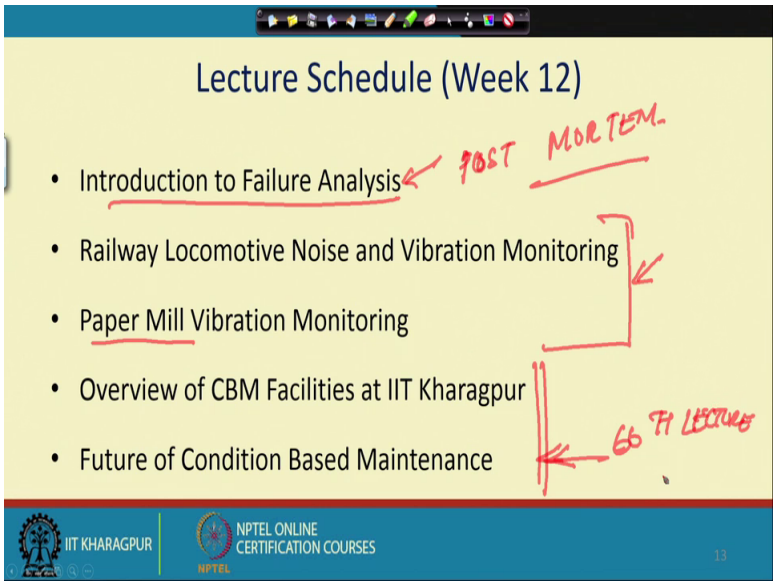

The last week, we will be covering on failure analysis because no matter how best we do CBM; failures do occur and failure analysis something like a post mortem. So, we can find out the cause of the failure and this helps us in better design, better selection of materials. And then I will give you an overview of some; through a case studies on northern vibration monitoring of a railway locomotive, which will did at IIT Kharagpur.

And then case studies from a paper mill vibration monitoring and towards the end to give you an overview of the condition based maintenance facilities, we have at IIT Kharagpur in our acoustics and condition monitoring laboratory. And then of course, what is the future of condition based maintenance will be discussed in this last class that will be my sixtieth half hour lecture.

Now this 12 week course, there will be about a 10 assignments; I think every week there will be an assignment, the modalities will be let known to you through the web. And we will have an end of the semester examination and of course, I am available in terms of a any input you need.

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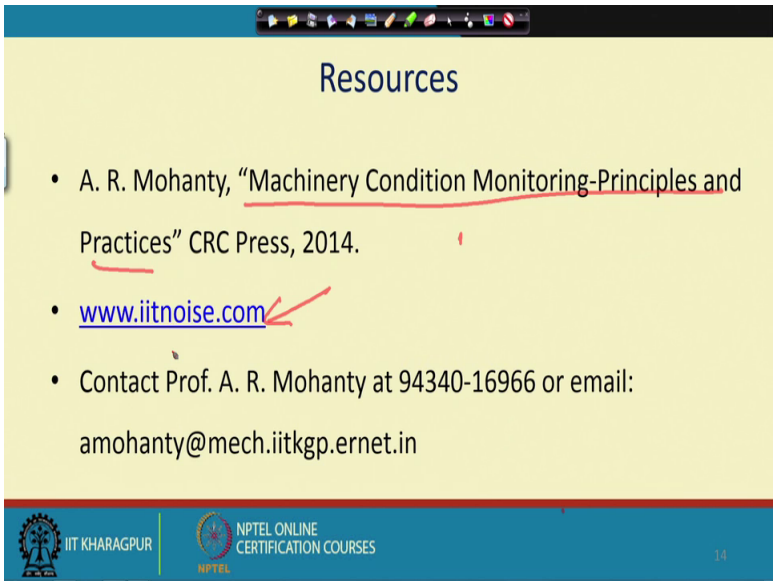

And of course, the details are; I have a book on machinery condition monitoring which is available on Amazon or any other sites through CRC press. And we will be following in this book for the course and many information regarding the activities, we will find at this website IIT noise dot com. And I will be periodically putting up a lot of information at this site in terms of a papers, help notes or programs so that you can access that for your learning.

And of course, you are always welcome to contact me either by phone or email for any queries you may have. So, we will look forward to having interacting with you and you have a fruitful study on this course on Machinery Fault Diagnosis and Signal Processing. So, in subsequent classes I will go into the details of what the different techniques are.

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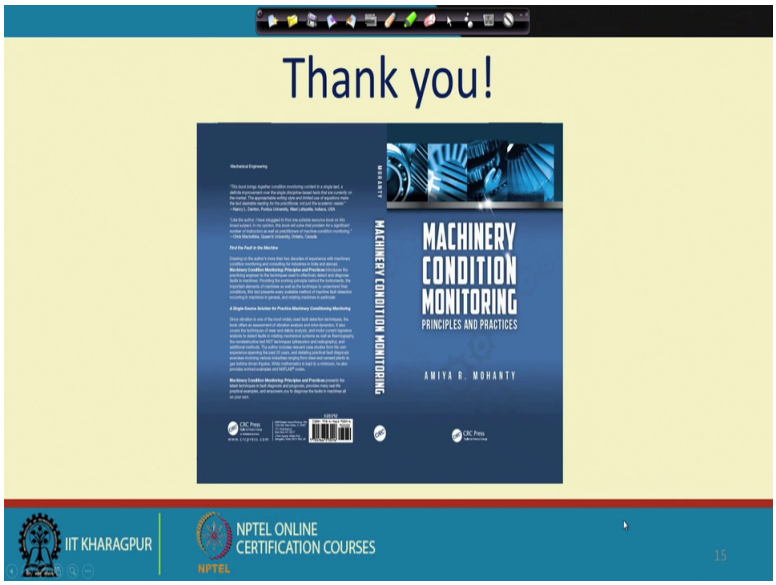

Well, thank you and this is the cover page of my book on machinery condition monitoring, which we will be using as a text in this course.

Thank you.