Machinery Fault Diagnosis and Signal Processing
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Lecture 01
Introduction

Well, this is the first class on Machinery for diagnostics and signal processing. In this introduction class, I will be basically telling you about the course content and what we are going to learn in this course and how the course will be delivered. And what will be the basic content of the 40 lectures which will follow.

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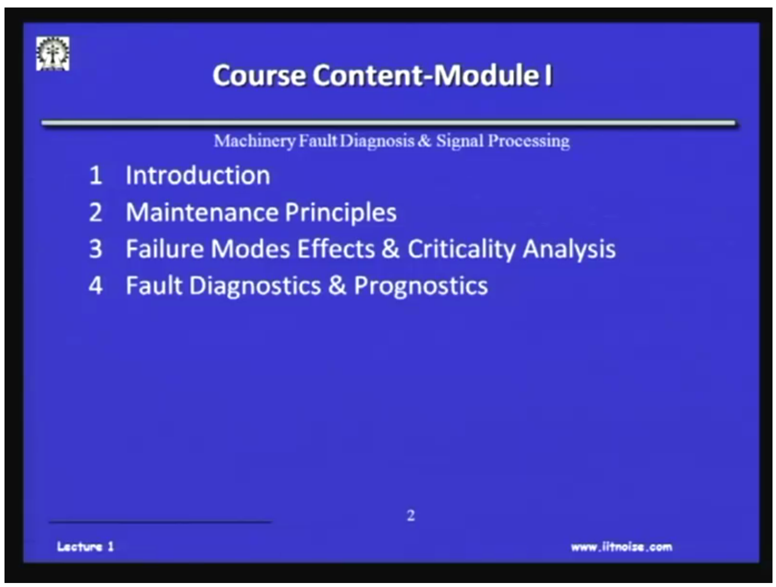

Well, this course will be actually in five modules, okay.

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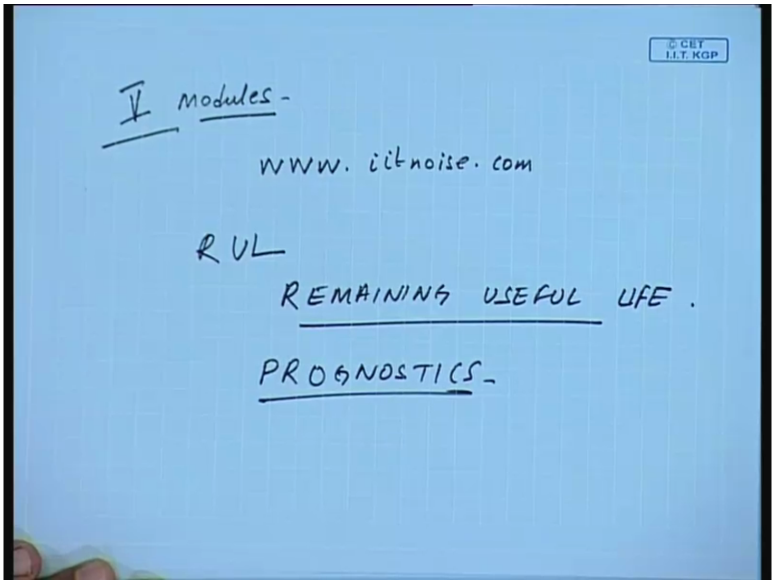

And before that let me tell you if you want to know anything more about this course, you can always go to this website, which will be periodically updated with, you know, handouts on your question papers, tutorials, quizzes, etcetera. So, I will be letting you know when to go and see that website. But, as coming back to these five modules, the very first module is on the Maintenance principles.

And question is in a machine, the idea is, you know, what is maintenance and what kinds of maintenance are available to us. And then, the question comes to know can I just use and throw a machine; or do I need to invest to keep it running. But, these are serious issues. I am going to think of a steel plant, I mean, obviously, I cannot afford to lose a blast furnace; I cannot afford to lose a rolling mill, yeah. But certainly, I can afford to lose, you know, a few motors and pumps, here and there, okay.

So, you all can realize and it depends on the cost of the capital equipment involved; it depends on the criticality of the equipment involved. So, our maintenance efforts will be proportional to the criticality of that equipment to the strategic importance of that machinery, etcetera. So, there are techniques which will let us know like, which kind of maintenance, of course, we do not know what are the available maintenance to us. But we will once we know in the second lecture, what are the maintenance principles available to us.

Knowing that in the third lecture, we will try to know by a method, which is predominantly used by a lot of my industrial engineering, engineers, is this failure modes effects and criticality analysis or which is known as FMECA, how by FMECA decide, as to what kinds of maintenance is to be done; where in a large plant ok, is it always a breakdown maintenance? Is it always a predictive maintenance, is it always a periodic maintenance.

So, these are issues which we will understand and of course, you know, always people ask this question: Well, when is my machine going to fail? I have maintained my machine; it is running nice. But, then, I would like to know how long is it going to live? So, once we have diagnosed the faults in the machine people always are interested in, to know, the remaining useful life of the machine.

They would like to know the remaining useful life of the machine; and then, how do we estimate that? And this is known as the prognostics of the machine. So, we will discuss regarding certain case studies on the machine prognostics. And then, the ones, we know about the diagnostics. So, this will be, these four lectures will be in the module one.

That is the introduction followed by the maintenance principles then, failure modes, efforts and criticality analysis; then, followed by fault diagnostics and prognostics. Now, let me tell you briefly something about this maintenance.

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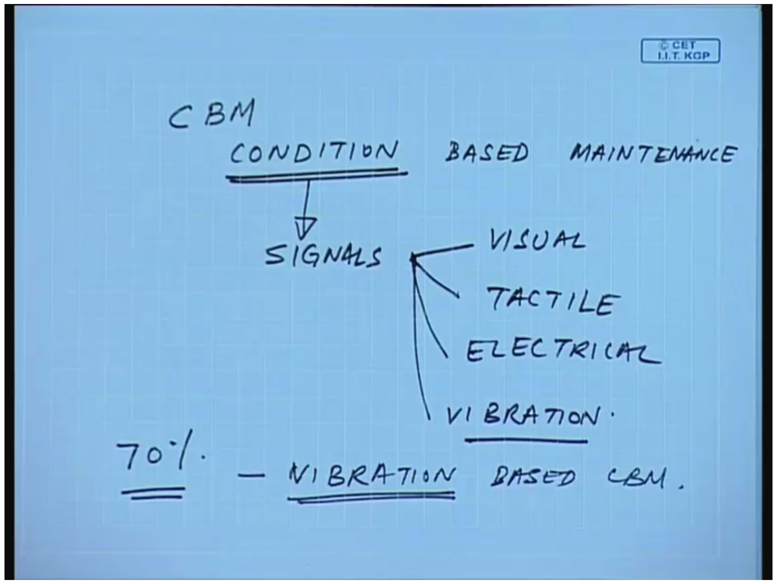

The focus of this course will be something towards what is known as CBM, which is condition based maintenance. That means I have to know the present condition of the machine. Well, question is, my machine is running; how do I know its present condition? Well, when the machine is running, it gives us certain signals. We hear a sound coming out of it. We feel its vibration; we feel its temperature going up. So, these are the tell-tale signs or the signals which convey what kind of condition the machine is presently in.

So, we have to acquire this condition out of the machine by certain signals. Now, the signals could be visual, could be in a tactile, could be electrical, could be vibration, and so on. But again worldwide, about 70% of the cases in the industry are through vibration based CBM. So, this vibration is a very, very important signal parameter which is to be nicely understood.

And the vibration from this machine has to be analyzed so that we know the machines present condition. We are able to diagnose the machines present condition. It is very similar to like I was telling you, in the last meeting, that we will become human doctors. Like when a patient goes to a doctor, a doctor measures the ECG, doctor may take the temperature and measures the blood pressure and these are the parameters or the indicator of the person's health.

Similarly, in machinery, a vibration is a very, very strong indicator of the machine’s present condition. So, we have to understand the basics of vibration.

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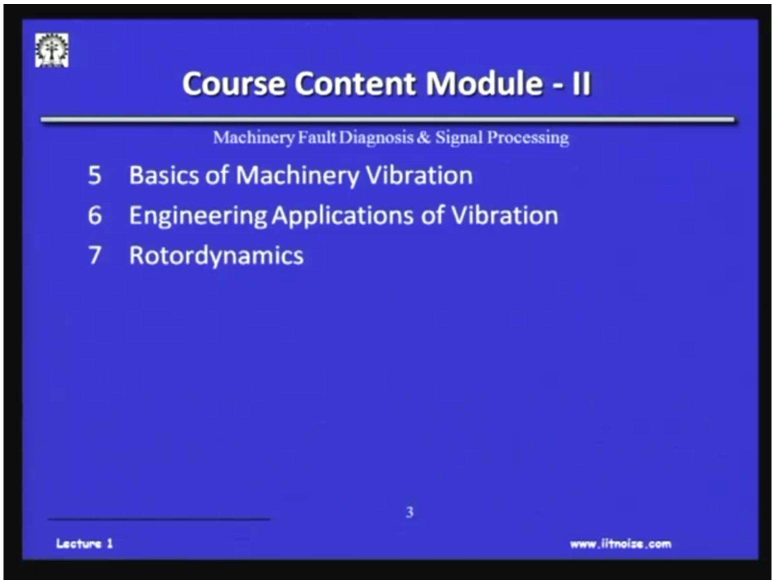

And in fact, the next model of this course is towards that, that we need to have a thorough understanding of the machinery vibration; because this vibration is going to convey to us the machines condition. And there are many applications of machinery vibration. We will use those applications which are useful or beneficial to us in finding out the condition of a machine.

For example, the response of a single degree freedom system or 2 degree freedom system and then effect of the, you know, the basically every machine if you look at it.

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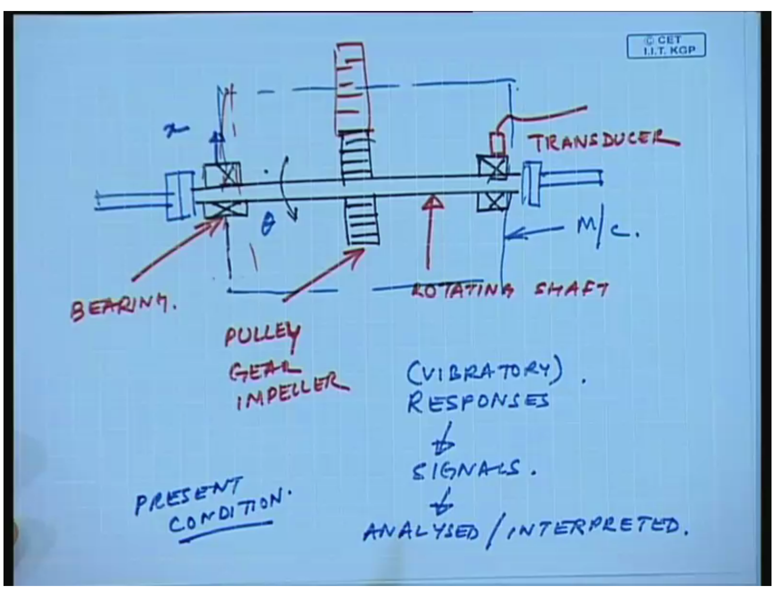

It is nothing but a shaft, okay which is mounted or held on couple of bearings and this shaft could be carrying a gear, could be carrying a pulley, and so on. So, everything on a machine and then we could be capturing the signal from this bearing location by a transducer and this could be our rotating shaft. And this could be a pulley or gear or impeller. There could be one or many and they could be meshing with few more and so on, okay. And everything could be complicated and then the most important thing here is we have bearing.

So, the dynamics and this could be in a casing. And then, we have our very basic machine, okay. Now, this machine could be coupled with another machine and so on, with a coupling, okay. Now, the dynamics of this machine is going to give rise to certain response at these bearing locations. This response could be a linear vibration, in terms of a displacement, it could be a rotation; theta.

So, these responses which are maybe vibratory in nature are actually are the signals which has to be analyzed by us. Analyzed or interpreted so that we can find out the machines present condition, okay. So, you all can appreciate that the understanding of vibration is utmost important to understanding or conducting CBM in a machinery.

So, we will be focusing few lectures on the basics of machinery vibration. Then, particular engineering applications of a person, in terms of the unbalance response, in terms of the vibration isolation, in terms of how do you measure the base excitation, because of a motion at the base of the machine, how do you measure them? So, these are some of the engineering applications of vibration which you will be studying, which are used in machinery maintenance.

And then, we will talk about Rotodynamics in which a shaft is rotating, what about its natural frequency, what is critical speeds, what are the welding of shaft and so on; because as I was telling, every machine has these few elements in common. And if I was to list down any machinery, any plant.

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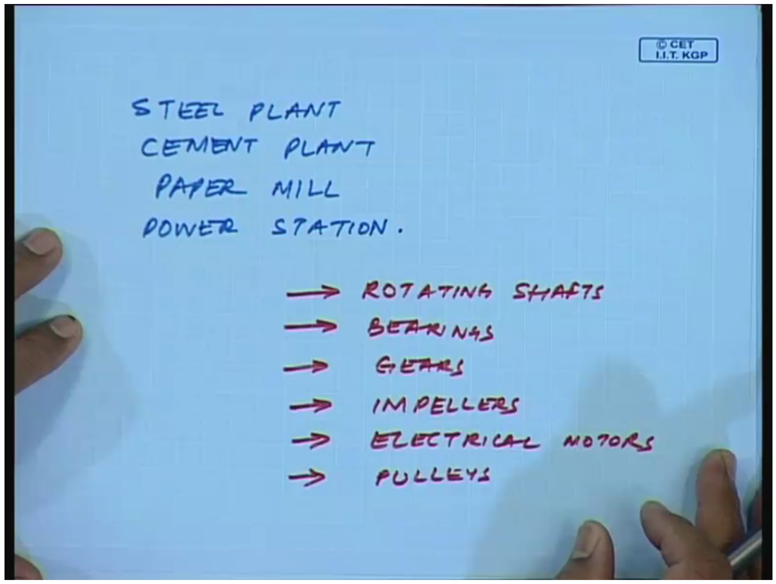

Let us talk about, say, you know, familiar steel plant, cement plant, maybe a paper mill, maybe a power station. If you just think about, you know, very widely about the contents of the machines in these plants. I am sure all of you will agree with me that the common elements in these plants are rotating shafts, okay. There will be bearings, there will be gears. I mean, this comes without any thinking. In fact, there will be fans and impellers.

There will be electrical motors; of course, motors themselves have rotors and bearings. There could be, you know, pulleys, chains, belts, and etcetera. So, you talk of any plant, these are the very common basic machine elements which are present in those machineries, okay. It is very similar to you talk of 10 different human beings. But they all have a heart, they have all have a lung, they all have a liver.

So, these are in fact, the organs of the human being. So, they are the organs of the machines, okay. We are going to eventually become machine doctors, right. So, now, we have to see how the vibration from these machines manifest in themselves certain characteristic features of these components?

So, when I, measure the vibration from these machines, I would like to know what kind of inherent characteristics this vibration signals have, which pertain to the machine, common machine element. Is it bearing, is it a pulley, is it a gear, is it a shaft which is misaligned, shaft which is cracked, shaft which has loose components.

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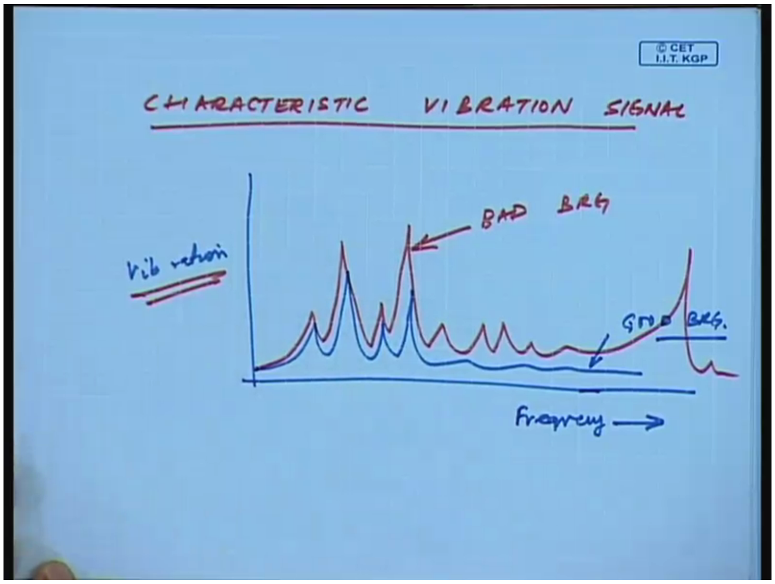

They all have characteristic vibration signal, all these common machine elements. So, this helps us do a fault diagnosis in that machine. For example just for the sake of an example I will give you, say for example, which we have not studied here. But then, I will briefly introduce you to what is known as a vibration frequency spectrum, certain vibration.

Suppose a good bearing has certain response and this is for a good bearing. But if the bearing was bad, maybe, you know, I would get this response at certain high frequency. So, this is the response of a bad bearing; the vibration response. So, just by having a understanding of this two spectra, from a good bearing and a bad bearing.

By looking at the spectra itself or finding out the features of this spectra maybe the RMS amplitude at high frequency is high for a bad bearing which is not there for a good bearing. I can say, if the bearing is unknown to me, whether the bearing is good or bad. So, this is the power of vibration signature analysis.

I will go into the specifics as to what these values are depending on the design, depending on the parameters of the machine components, okay. That we will discuss later on. But just a little briefly the power of vibration based signature analysis or this is in fact a signature of a building good bearing and a bad bearing.

So, by doing a vibration based signature analysis, I can, find out whether the machine is bad or good, okay. Now, I was telling you about that 70% of the cases in the world are vibration based. Well, then, obviously the next question you all would wondering what do you do the next 30%?

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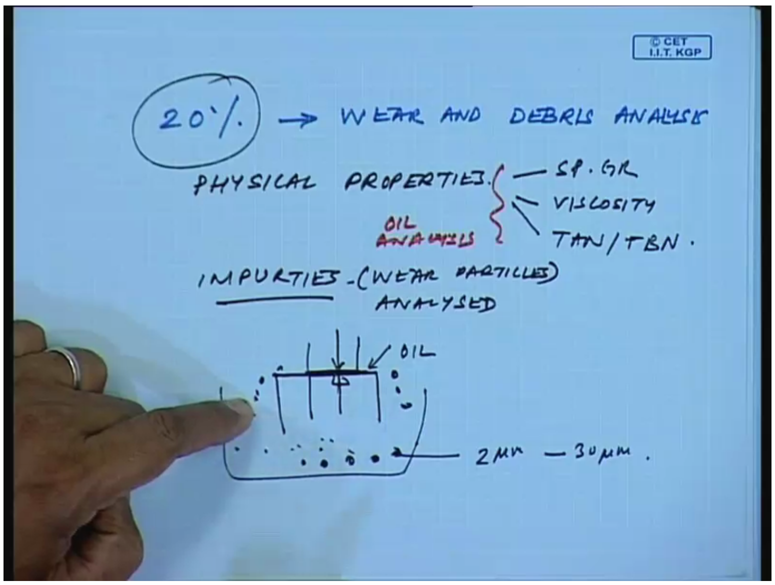

The remaining 20% is actually what is known as by a technique known as Wear and Debris analysis. And this technique what we do is from a gearbox. So, for example, there is lubricating oil in the gears, bar on gearbox which time, what happens, this meeting components wear out, okay. Once these components wear out, these particles get deposited in this lubricating oil.

So in the process what happens the lubricating oil loses some of its physical properties, okay because the lubricating oil has got contaminated. Its specific gravity may change, its viscosity may change, its certain acid number, base number may change, okay. And then, it may also undergo certain impurities. And in fact this is what is known as the oil analysis.

And the next is these impurities themselves could be analyzed. Impurities, I mean, the wear particles. The size the shape of the wear particles give us a clue as to what kind of wearing mechanism occur; is this because wear is going to happen; because when two components have a relative motion between themselves there will be wear.

And then, of course we try to reduce it by putting a layer of oil in between them, okay. So, these particles, which get removed from this varying particle, varying components because of friction will get deposited in the oil. So, these wear particles could be analyzed. Then I can get to clue as to what kind of forces created this wearing.

So, wear debris analysis is an indirect method of finding out if there are abnormal forcing conditions in the machine, okay. Normal wear happens but suddenly you see the composition or the percentage of wear particles has increased drastically, you can understand that you know something is really wrong with it.

And then, that is why we have to take care of how to reduce these excessive forces. Another is because this lubricating oil has been subjected to such impurities, is it going to lose its properties? So, we can do the property measurement of this lubricating oil and let to get some clue as to what is wrong with this machine.

And this is usually done in the nearly about 20 % of the cases do wear and debris analysis. But the problem with wear and debris analysis is that we cannot do this, right at the gearbox, right at the place where we have picked up the oil because the wear particles themselves could be of the size of 2 micron to about to 30 micron, okay.

And imagine our say for example a coal, coal mill or a cement plant and if you have been to such plants they are very dusty the amount of particles in the air which are suspended are more than 2 micron and 10 micron. So, we are going to contaminate once we do such an analysis, right there in the plant. We are going to contaminate the oil ourselves and that is going to give us a wrong reading.

So, there is a, there are procedures as to how we need to sample the soil, what is the procedure also that we do not contaminate it during the sampling. And once we have sampled it we take it back to a specialized lab wherein we try to do the analysis find out the properties of the soil, sorry properties of the lubricating properties of the contaminants and so on.

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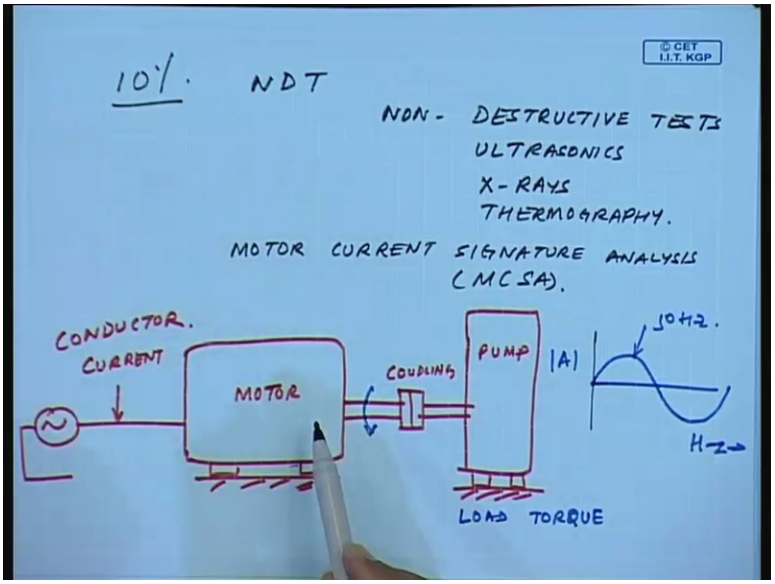

And the remaining 10% of the cases of CBM are what is known as the NDT non-destructive tests. Like in ultrasonic's, could be x-rays or radiography, could be thermography, thermal imaging, okay. Another very important upcoming area is what is known as this motor current signature analysis. MCSA, this means, for example, if you think of any electrical motor or an image mechanical unit and there is a coupling and it is said driving a blower on a foundation.

I have this motor, maybe this is a pump, I have a coupling and I have electrical source, a very interesting thing happens is, you know, all of you would have realized, for example, if I talk of a motor the supply current to this motor is usual here; this is easily a 50 Hertz sign wave, okay. Now, what happens? Once in such a system, if these pump, there is a fault what it is going to give? It is going to give a load torque on this system because of the defect, okay it will be loading.

So, there will be a torquisional load on this electrical motor, okay and this torquisional load has a frequency which is characteristic of the defect frequency of this mechanical unit which is the pump. Now because of this torquisional load, what happens, this motor is subjected to a torquisional loading and the rotor of the motor undergoes a torquisional oscillation.

And because of this torquisional oscillation, the flux or the current drawn by this gets an additional torquisional oscillation. So, the current no longer becomes sinusoidal.

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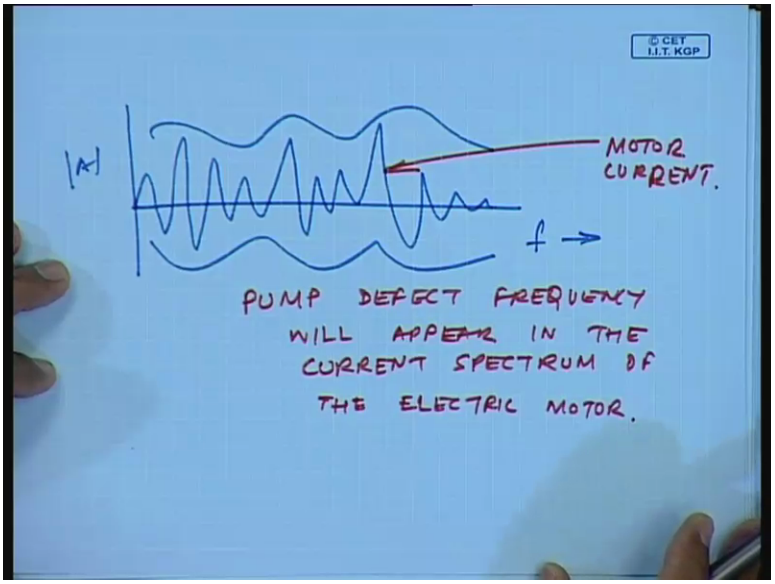

But it gets what is known as modulated. If you look at the envelope, we will discuss this in detail. But just to tell you about this, so, this will, the motor current changes from being a perfect sinusoidal to a amplitude modulated wave, okay. It becomes something like this. So, this has many frequencies. And this if I analyze this motor current I will see the frequency of the pump defect, frequency will appear in the current spectrum of the electric motor.

This is a very strong and a very powerful statement with lot of engineering implications. In the sense, imagine, I am having a pump, okay. Say, for example a submersible pump which is underground. I have no access to the pump, okay. But sitting somewhere in the control room, I would like to know the condition of the pump. Obviously I cannot go down under the ground and put an instrumentation to measure the vibration of this pump. So, how do I measure or monitor the health of such a pump?

So, in a, in the control room, if I was able to measure the current drawn by the electrical motor and if I do such an analysis, I will obviously get a chance, got a clue as to maybe the pumps defect frequency will show up in the spectrum. And this is very, very powerful technique. In fact, in IIT, we have been working in this area about the last decade and we have been very successful with gearboxes.

In fact, now, we have a patent that with any rotating machines, you can find out the, from the current spectrum, default in that rotating machines. You can imagine submersible pump, you can imagine the system inside a nuclear reactor, wherein a person cannot go in, but then, how do I find out the defect in such a system, okay where it is not accessible.

And you know, compared to vibration measurements, the measurements of current is really very easy. And then, we can very easily remotely do it and has it. In fact, this I still want to put it in an upcoming area of CBM. And just to let you know, I was talking about the signals, okay. Now, for signals from the machinery to the place where we are doing an analysis the signals have to be drawn by a cable.

But, nowadays, the technology is such that we need not even have cables. It could be all through wireless, okay. I could be sitting here, maybe with an iPad or an iPod. And then, hold a mobile and then try to remotely find out what's happening to my gas turbine in Alaska, okay. It is not a science fiction, it is possible, okay.

We can know what is wrong with the gas turbine which is running in Alaska. Perhaps, okay. So, through wireless communication, through the internet, okay you have certain transmitters, carry the signal over the wireless, download it here at Kharagpur and then try to analyze it on your laptop, okay. This is possible and we will do it, okay.

So, as I was telling you, this is what is the, how this 100% of the, remaining 10% the condition mounting is done. But by now, so, vibration is a very, very important subject which is to be well understood and which is to which will be used predominantly in this course towards condition based monitoring, maintenance.

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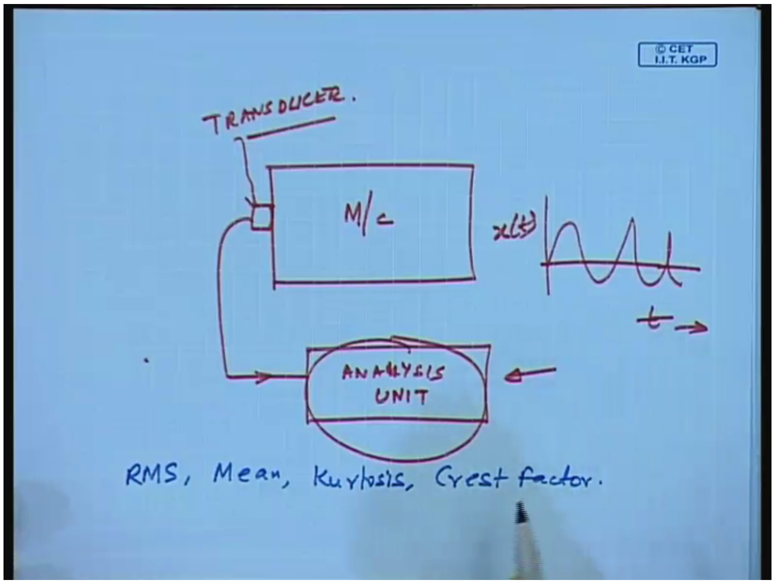

And as I was telling you, in CBM, I have a machine I have to put our transducer to capture some signal and I have an analysis unit. This could be a transducer, okay. And then, this analysis unit is in different types.

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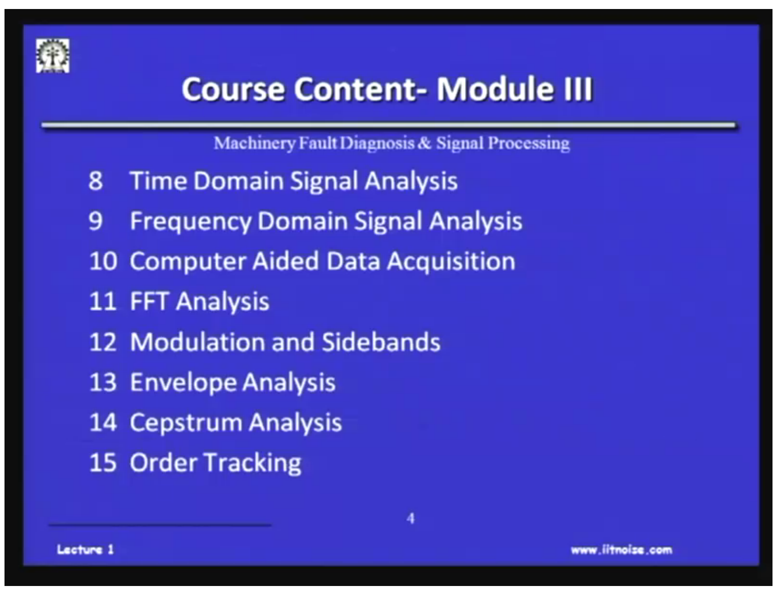

So, if you look at the lecture number eight that is on time dimensional analysis, the basic signal which comes out of the transducer, as you see, in an oscilloscope. I am sure all of you would have used Oscilloscope, excuse me, in your undergraduate. So, by doing a time domain analysis of such signals, we can find out the features of the signal in terms of its certain time demand features like its RMS values, mean value, kurtosis, and crest factor etcetera.

I am sure, in your first year electrical circuits, you would have studied. Sin wave and cosine wave and you must have done the integration to find out the RMS value, mean value, max value, crest factor, etcetera. And these are actually the indicators of the signal. And such analysis helps us, for example, a machine is bad its RMS value of the signal is going to go up. Its bearing as bad, its kurtosis is very, is going to go up.

So, by simple time domain analysis we can find out certain features of the signal which will be telling us the condition of this machine.

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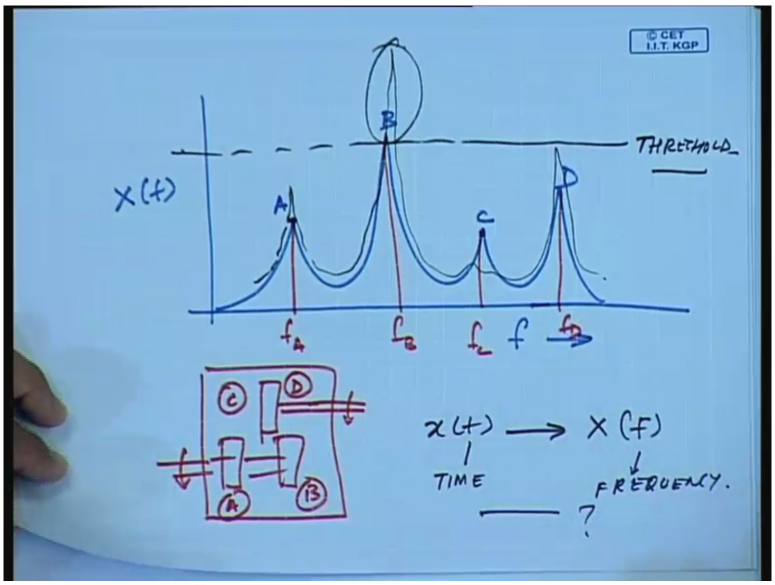

The next lecture is on the frequency domain signal analysis. For example, the same signal in the frequency domain, say, maybe, some vibration signals. This could be component A, component B, component C, component D. Every component in a machinery, for example, I have a machine whatever is the internal, maybe, I will not be specific. But, something, some components are there. Say, this is component A, component B, component C, component D. Anything a generic machine.

So, every component and they are rotating; has a characteristic frequency. It is like the signature of the machine, okay. So, this signature is going to change if the machines condition changes, okay. So, this is what is going to happen. I mean, the signature could change in the form. Maybe one component could be increasing with the time, okay. So, these are, if I put certain base level, I will get alarmed.

Well, something is wrong with this machine. Component B in this machine is having a problem because its level has gone up beyond the threshold level of which I have kept. Who decides the threshold level is something we are going to find out and how. But if this level has gone beyond the threshold level, I will tell because, it is component B something wrong with component B, okay. And that is very important in frequency domain signal analysis.

There are many more methods of frequency. Question is, you know, how do I convert a signal from the time domain to frequency domain? I am writing this as time and this as F. This is in time and this is then frequency, because the power of frequency domain analysis is such that, any signal which you see in the time domain, like you see in an Oscilloscope can be broken up into the frequency domain. And in this frequency domain, you can see these components showing up. And how do you do that is something we find out.

Excuse me, and to do this conversion, we need to convert the signal from the time domain into the frequency domain. We need to take the help of a computer. Certain algorithms have to be implemented in a computer so that this conversion from the time to the frequency domain is possible. But question is, how do, I take my signals which are analog in nature, which I see in an oscilloscope, which I have been just measured with the transducer mounted on the machine.

How do I take it into the computer and that is what we are going to study in the lecture number 10: That is on the Computer aided data activation. What are the issues of sampling frequencies? Why is there a 12 bit machine inferior to a 24 bit machine and so on? What is the need of amplitude resolution and how small a signal, can we detect? How fast a signal can be sampled or stored have?

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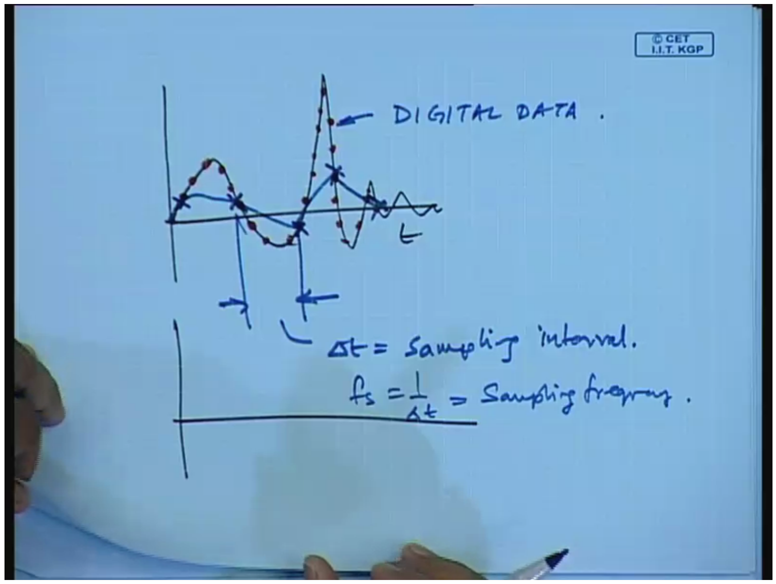

Because see, for example, in a real valves machine, if I have a real valve signal, in the time domain, okay. Something like this, if I take this signal into the computer, I should be also getting it like the same values; because computer only stores numbers in forms of data points, okay. Only the question is, if the data points are close enough, I will get a true representation of the original signal, which is in black;

Rather if I pick up signals one here and one here and then one here and one here and one here and ask my computer, what is the signal? It is going to understand, it is going to draw like this, okay. So you can realize you know, this is what is known as the delta t or which is known as the sampling interval. The power of this sampling interval is very much in the sense unless or the inverse of it is nothing but the sampling frequency.

To retain the features of the signal, I have to always sample at a much, much higher rate. And there are certain theorems and algorithms for that which I will tell later on. So, computer aided detection is very, is a process by which I should not lose my real-world signals because of some interpretation my computer has done. Then, other, all my interpretation will be wrong. So, computer is a fool. I mean, whatever you give it that is what it is going to interpret.

So, if I give him something wrong of my algorithm is such that it interprets it the way it understands, and not the way I understood, then there is a problem, okay. So, we have to ensure that the computer faithfully reproduces the original analog signal which is there, out of this machine. And then, computer, of course, store this data in digital form; digital data, okay.

Now, once this signal is inside the computer I can use many mathematical algorithms to analyze the signal. In fact, the subsequent lectures on FFT analysis, modulation sidebands, envelope analysis, cepstrum analysis, order tracking, etcetera. They are all signal processing parameters which will be used by the computer to understand or find out the features from the signal in a much, much better way.

In a very convenient and easy method so that we can interpret the fault in that machine, okay. Modulation to the inside ones are just telling you about the case of the pump which is driven by a motor, the motor current is no longer a sinusoidal wave; It is no longer pure tone. But, it becomes an amplitude modulated. And if I do an analysis on FFT analysis of such modulated signals, I will get certain sidebands.

And this is very powerful way of understanding the signal. And envelope analysis is trying to find out the low frequency modulated waves, which is carried by this high frequency modulated signals. Cepstrum Analysis is very, very powerful in the form of finding out the families of sidebands and gearboxes. Right now, I just wanted you to know about this term. So, we will be discussing about them in detail.

But being an introductory class, I will just telling you certain terminologies which we are going to study in this class, in the subsequent classes. An order tracking is very powerful. When the machine speed change, the phenomena, if you are doing a frequency analysis, the frequency is going to change. So, if I am doing any signal averaging, but if I am NOT doing order tracking, I will lose the identity of the machine.

So, Order tracking is useful to find out certain important critical frequencies in a condition where the machines are changing having a speed, speed change. So, these lectures 8 to 15 will be covered mostly in the module 2. And that will be mostly towards signal processing. And when we do this signal processing, I will be using a like I was telling you, certain I will be using taking the help of excel to draw certain curves. And then, I will be taking the use of using a MATLAB or to large extent in this course on signal processing.

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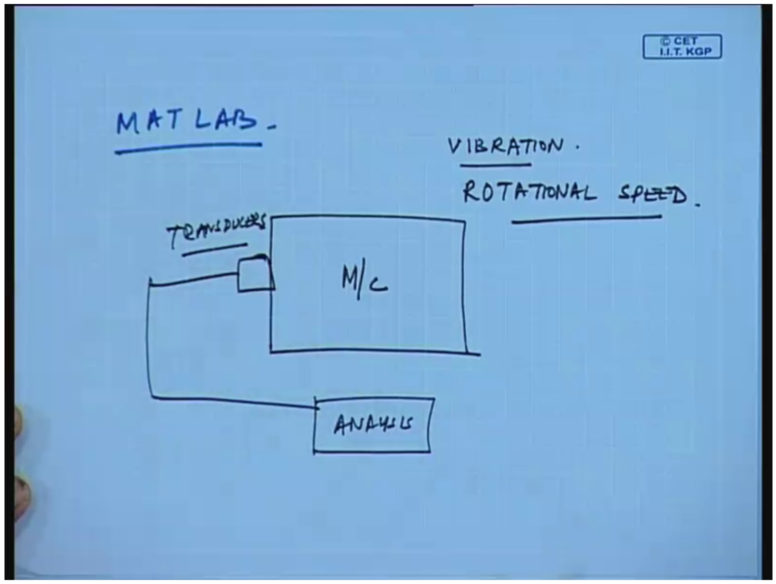

And I understand in our campus, we have licenses for MATLAB. So, you all can install them in your laptop and then use them and wherever possible I will try to give a small examples on MATLAB to do such analysis.

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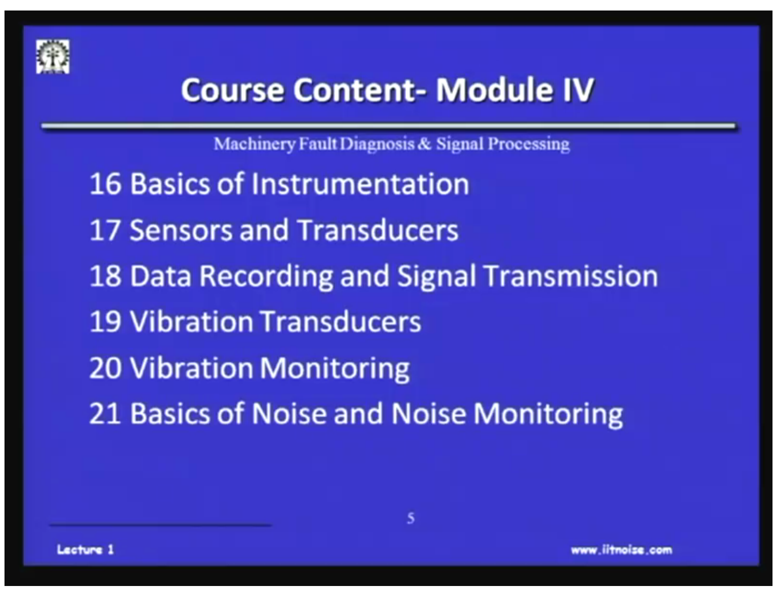

Now, of course, we have talked about signal analysis in the previous module, but module 4 tells us about how do I capture the signals? It is basically nothing but mostly regarding the equipment and how to install this equipment, how to instrument the machine? Because CBM always requires an extra investment, on this transducers, we have talked about vibration, excuse me, vibration monitoring. So, vibration monitoring how do you, how do I measure the vibration out of a machine? What kind of sensors have you put on the machine?

Where they have to be put on the machine? What kind of other sensors and transducers are available to do vibration? And in CBM, a very, very important parameter is also the rotational speed. How do I measure the rotational speed of a machine, okay? And then, of course, many a times this analysis is not done in real time. Sometimes, the technician or the engineer will go around the shop, instrument and record it.

And then, later on, in your lab or in your analysis unit, you can always pull up data from the recorded unit and do the analysis. So, how they recorded once I recorded am I able to store the data in the exact form it was, while it came out of the machine? I am sure all of you must have recorded your voice signals and you hear it out; and then, it sometimes, it sounds different; because the frequency bandwidth, okay some time a CD sounds better than a on cassette tape. It is only because of the frequency bandwidth.

So, there are issues of the media the frequency bandwidth of recording, okay, the resolution of the recording, etcetera. So, these are issues which have to be understood. And I was just telling you about the remote monitoring. Suppose, I need to transfer the data from place A to place B, I can always carry the data in a CD, okay. Or I can always transmit the data over the Internet. And there are limitations of speed at what rates I can send the data, okay.

And that will affect my machine. Suppose, my machine is a very fast moving signal, produces a very high speed signal; so for example a gas turbine rotating at 30,000 rpm, I mean, one second is a lot of data which has to be put. Obviously my internet, you know, maybe I have only 2 GB gigabits per second. It is the maximum rate I have over the Internet. Can I, so what is the size of data which I can send in a packet?

The there are limitations highly reduced you have 2 Mbps lines, okay about five years back, okay. Now, we have 2 gigabyte per second transfer rates. So, there is always a challenge as to the rate at which I can transmit a data and the present-day infrastructure available to transmit such high speed data in real time. Or, of course, I can always you know record the data. But then, recording the data means do I have enough bandwidth to store the data?

What kind of media do I need? And if the data sizes increase, the sooner we move from a CD to a DVD to a blue-ray player, blue-ray discs; all because of the data size. Because we need to store a lot of data, okay. Lot of data means lot of time. So, we have to be very careful into, into what kind of format has to be used and what kind of transmission architecture has to be used, for doing CBM.

And then, of course, we will be talking about vibration transducers, accelerometer, seismic transducers, LVDT etcetera, ED current probes. And then, how do I do vibration monitoring? In fact, what does the, what are the minimum equipment required to do vibration monitoring machine. It could be a pump, it could be a generator, it could be a turbine. So, what does it require?

Equipment required, how do, I install, where, can they be subjected to harsh environment can they subjected to high temperatures, nuclear radiations. And there are issues; and then, of course, I will talk about in Module 4, about basics of noise and noise monitoring because you know, predominantly again, in CBM, noise is not used as a monitoring parameter because of the fact that noise from machine A gets easily contaminated by noise from machine B.

But noise only gives the operator indicating that something is gone wrong with the machine. A loud noise, suddenly, a machine makes a strong impact noise that means something is wrong with the machine. A Rattle noise, a tic-tac noise, a big bang noise; so, these are parameters which give us a warning as to something is wrong with this machine.

And once we have such an indicator as to an alarm indicator, as to what is wrong with the machine, we can always go back to the machine, instrument it with a vibration transducer and record it, analyze it; and try to know more about the machine, okay.

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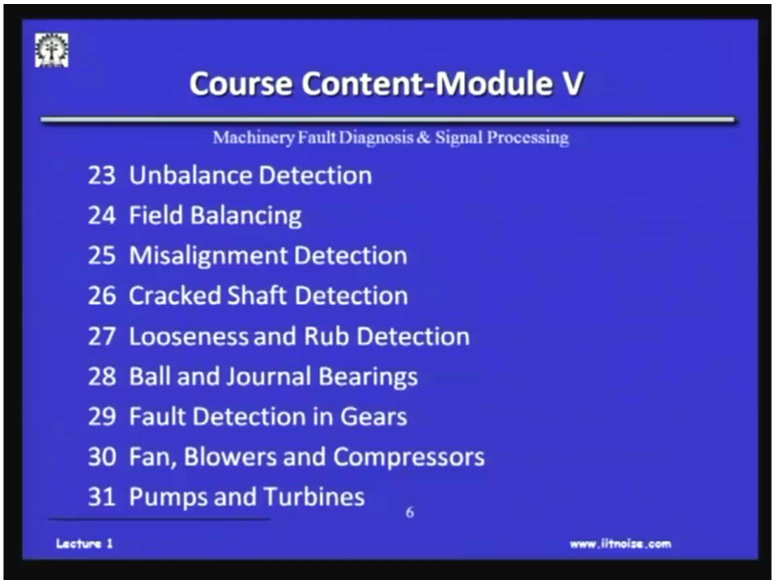

Now, at the conclusion of module 4, by then you would have in fact the half the semester would be towards a module 4. I mean, we should have covered about 22 or about half the lectures by module 4. And that would be toward the mid semester of this course, okay. And then comes actually the application of this; all the signal processing techniques the instrumental technique which you have studied in this course.

Using it for practical analysis of particular defect like defect in a heart, defect in a lung, defect in the liver, similarly unbalanced once we have detected an unbalance in a rotating shaft how do I do a fill balancing Institute.

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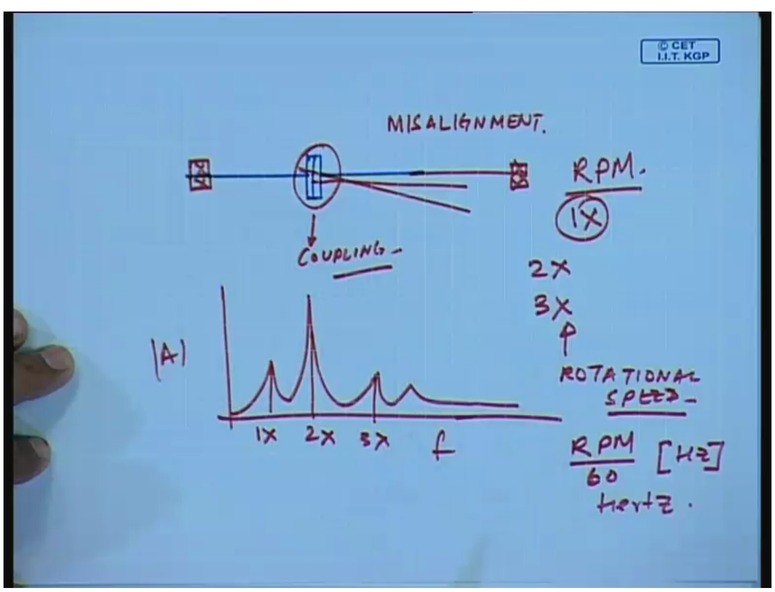

Suppose there are two shafts, which are supposed to be perfectly aligned by a coupling but they will not be aligned and one of them there will be small angular or a small offset misalignment. And of course, you know, they will be also supported on bearings, okay. So, if there is a misalignment which is there, in fact, in all machines. What are the characteristic of such misalignment vibrations? How do I reduce them?

And by now, by, okay what are their characteristics in the vibration signal? Suppose I have a vibration spectrum, how can I just say? If I know the running rpm, by the one thing, I should tell you, when I write 1X that means it is at the rotational speed. 2X means twice the rotational speed, 3X means thrice the rotational speed, X is the rotational speed. Rotational speed is rpm. So, rpm by 60 will be in Hertz.

So, when I say, 1X component that means a rotational speed, 2X means twice the rotational speed, 3X and so on. And they are all harmonics. So, X means the rotational speed. Now, subsequently, we are going to use this terminology in the class. I thought I should tell you right now, ok. So, misalignment does occur in plants and we have to know how to identify misalignment between meeting shafts.

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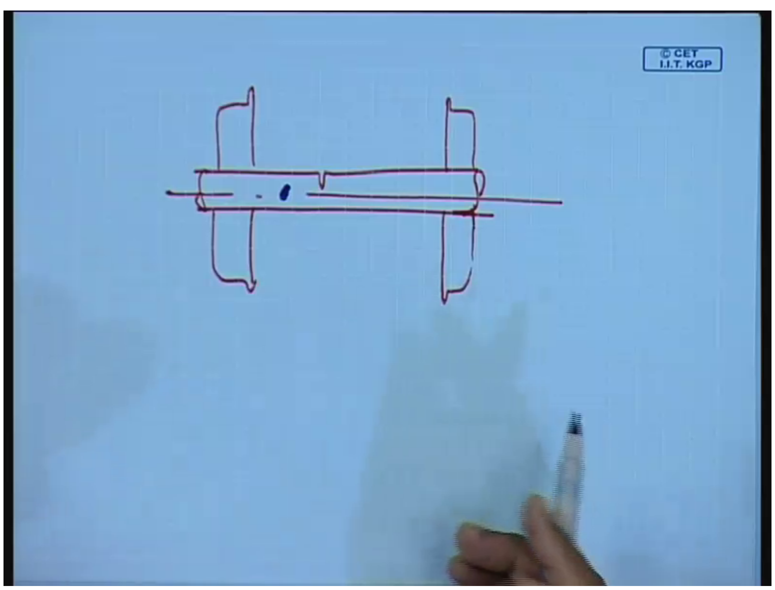

Next is, you know, there are lot of applications wherein cracks develop in shaft, okay. So, how do I detect the crack in a shaft? Can you imagine? I mean, here, you are having a, so let us give an example. Looking at this drawing, you all can understand what I am coming at, okay. So, this is a railway axle. Suppose, there is a crack, and this axle which goes unnoticed. And the train is running, you know, the consequence, know, okay.

Now, this is one way of looking at it. Suppose, this crack is inside this axle, the crack is developing, okay. What could go wrong with it, okay? How do you detect it? First is, how do you detect it, so crack is not visible to the outside. Crack is another case; crack is there on the shaft. So how do you detect such cracks? And by vibrational analyst, analysis and another is by ultrasonic's.

How do we use ultrasonic's to detect cracks which occur inside the shaft? In many a times, next is lot of components on a shaft. Where there are pulleys, gears, there are cases wherein things will be loose, okay. Once things become loose, how do, do that, how do I detect looseness in the system? Suppose, a pulley is loose on a shaft, how do I make sure that the thin components are not loose, okay?

And then, looking at the different other components like ball and journal bearings, know, as I was telling you about every component, there is a ball bearing or an anti friction bearing. How do I detect, the defect and such ball bearings defects and gears, compressors, pumps and turbines. So, these are cases which we will be seeing subsequently in module 5. And then, the module 6, I am until module 5, module 5 predominantly, all the topics will be through vibration monitoring.

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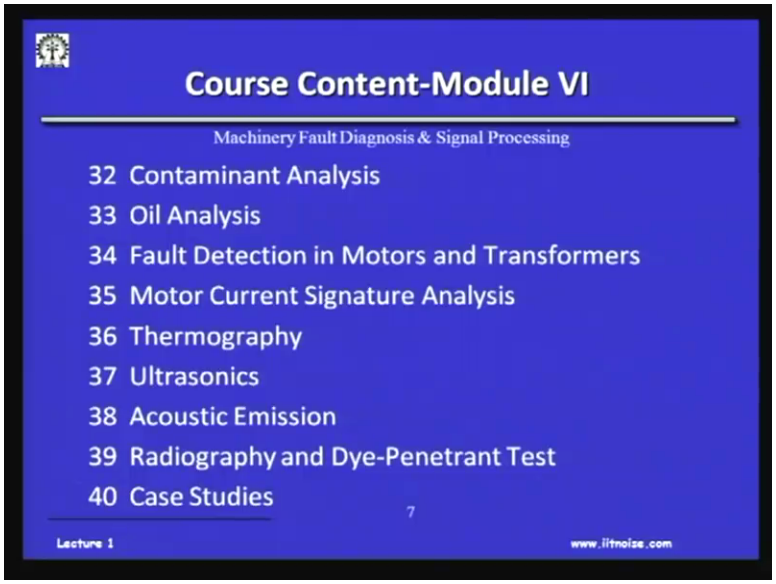

And the module 6, is the remaining 30% of this CBM which I was telling you about wear debris analysis, NDT ultrasonic, motor current analysis and this is what we are going to study about. In fact, the actual number 32 and 33 is on contaminant analysis and oil analysis, ok. So, we will be studying what is known as the wear debris analysis in Chapter lecture 32 and 33. And then, 34 and 35 is towards fault detection itself in electrical motors, transformers.

And how do I use motor current signature analysis for fault detection in mechanical systems. As I was just telling you, the case of a submersible pump and the lecture on 36 is on thermography because as you know, if there is loose contact between conductors, there will be arcing and there will be heat generation. If there is a misalignment because of friction, there will be heat generation.

So, by detecting the heat generated at a bearing location, at a coupling location, at a contact point of an electrical switchgear, I can tell what is wrong with that machine. So, thermography is a very, very powerful non contacting method of finding out fault in a mechanical system. Ultrasonic's again, as I was just telling the example of this shaft, which has a crack in the inside, which is not visible from the outside, how by using an ultrasonic probe, we can detect the crack.

And say for the case of a railway axle, we have a railway workshop, next door in Kharagpur wherein every train axle comes for a periodic ultrasonic inspection. They have a particular schedule at which every train, every each and every train axle will be axle, is tested for ultrasonic floor detection or crack detection menu. In fact I know in Sweden there are places wherein they have camera installed in the platform itself, below the platform, so that they will take the image of the bearing, thermal image of the bearing.

And then transmit to a central database to tell you the condition of the bearing. I am sure you all would have noticed even in the railway stations, nowadays, you know, you will see that colossi going with an infrared temperature detector. Sometimes they used to have a rod, they used to feel if the bearings are hot or not; I know, you have seen that. But you will see that in Kharagpur station, many wait for the trends there will be a guy who will be coming and checking all the temperature of the bearings by an infrared thermometer, okay.

And that is the lot of practical applications are there in thermography. And then, we will talk about ultrasonic's, acoustic emissions, radiography. And I will conclude this course with few case studies from the industry from steel plants, paper mills, ships, etcetera, okay. And with this, I would close this introductory lecture on machinery for diagnostics and signal processing. Thank you, okay.