Machinery Fault Diagnosis and Signal Processing
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Lecture 02
Principles of Maintenance

In the last class, we talked about the introduction to this course. In this class, we will be talking about the principles of maintenance. A question is, you know, what are the techniques of maintenance available to us? And what kind of techniques and tools we need to be known before we can apply maintenance to different plants and which kind of maintenance is beneficial where and how and so on.

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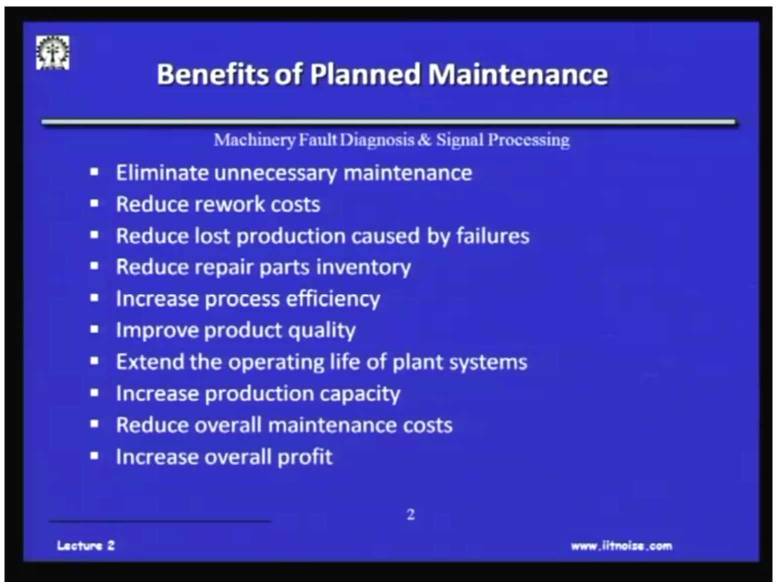

The question is, you know, why do we need to have a Planned Maintenance? Obviously, you know, we are aware this we would not like to do overdue on maintenance; because maintenance also involves cost, okay. I would not like to maintain a re-maintain and maintain and so on, because it is for the sake of maintenance machine may be up and running and doing good.

But, then, I unnecessarily do maintenance, okay. But sometimes, you know, as you all know, for strategy strategic reasons, sometimes we have to maintain it, even if the things may be okay. And I would lot not like my figure to jam in front of an enemy, okay. I would not like my missile not to fire when I wanted to fire, okay. These are cases which we cannot take for granted. But, of course and which we do always you know, the OEM manufacturer of your car would have told, you know, every five thousand kilometre go to the service station, to get your oil change.

Sometimes we do it; sometimes we do not do it. Nothing goes wrong with it, okay. Sometimes we would have gone after 15,000 kilometres. Only thing that the service manager there would have tell you, Sir, you know, you should have come earlier and blah blah blah. But still nothing goes wrong with the machine, okay. So, the idea behind maintenance is that would not like to do a lot of maintenance.

We like to maintenance only when it is necessary because if a perfectly maintained machine is available, it will do its function it was designed for, okay. I would not like to do, have any loss of production caused by failures, right. Suppose, imagine if my maintenance, my machine was never maintained throughout the year and I have a deadline of March 31st. But I have to meet the annual production targets.

And suddenly in the month of March, my machine goes down and I require serious maintenance. You can imagine this is going to affect my balance sheet. But, because for this financial year ending March 31st, I could not reach my achieved target because my machine had to undergo and maintenance. So, these are plans, these are things which we should never do; because you know everything leads to loss of finance. And I mean why am I doing maintenance?

I need to have high revenues, high productivity at low cost, okay. I would not like to lose orders when there are market demand is high because my machines cannot produce, ok. Well maintained, planned maintenance or a plant engineer or plant manager would have planned for its machine's maintenance during the lean market time. For example you can imagine Diwali firecracker manufacturer cannot have his machines down months before Diwali, ok.

It is going to hit the market; it is going to affect the market. So, people always do a plan. I will just tell you an example of this auto companies, particularly, auto companies in our country, sometimes in the month of July, and they do a planned maintenance schedule, ok. And not go at the end of December or not go at the end of obviously not go at the end of the financial year. So everybody knowing on this strategy of the requirement of their products, they find out a time when they do they will do a shut down planned maintenance.

But that does not mean that you will not do your day to day maintenance; you will not do your weekly maintenance or so on, ok. Sometimes it so happens, you know, if I know that only in the month of July I am going to overhaul my machine, I do not store my spares throughout the year. I did not store it from August to the subsequent July unnecessarily, because I know from August to the next July I will not be requiring these pairs, okay because storing spares is inventory cost.

I have to store them, have to keep them, I have to keep a stock, keep a book-keeping on them. Maybe if I require this spares in the month of July I may utmost have them by the month of June. So, my inventory reduces, okay. These are, I mean, this may sound very trivial, but you know, if you think of a large plant sometimes the inventory is as high as the certain critical spares. But at the same time does not mean you know if you are going on the high seas and you have a bearing for your propeller.

And you do not have a spare bearing; you will be in deep trouble, okay. So, depending on the situation, you are in, you are the best judge what kind of critical spares to carry, what kind of spares not to carry, what kind of spares when to carry and so on, okay. And then, of course, you know once we have maintenance properly. You know, if I have a good maintenance schedule in my plant I will always have process which is very efficient.

Which will be producing quality as to having the best surface finish, for example, if I am a machine shop, where I produced fine machined surfaces, suppose, my, I have taken no care on the tool wear conditions, I may be having the work piece surface very rough.

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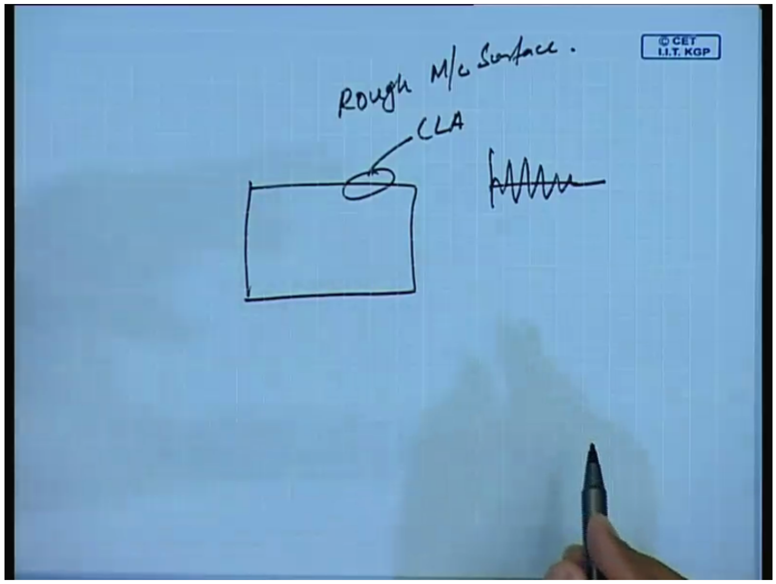

I would not like to have, say, rough machine surface because my turning machine cannot run at high speeds so I cannot have a smooth finish, okay. There has been an intermitted speed fluctuation in the machine, so, these marks are going to stay up in your machining process. So even a simple, a lathe machine has to be taken care of.

Otherwise, if you are doing a machining operation on that lathe, its quality is going to, the machines quality is going to reflect on the work piece, okay. We take it for granted that you know, you have a nice machine. Somebody say this machine has a bad gearbox; somebody may say, well what does the gearbox got to do with your tool? You have a new tool.

So, you should be having nice machine surfaces. But people do not understand that if you have a bad gearbox there will be backlash and there will be a speed fluctuation and that is going to affect the cutting process. Now, they are all interrelated. As engineers, I am sure that you will appreciate it much better than all this dynamics of the machine are interrelated and they will eventually reflect in the final product which you are producing from your plant.

And of course, you know, I would like to have the plant once up run till its maximum useful life. And of course, if all my machines are running at their best, OEM specs, I will have the production capacity increased, okay. I would have; I have seen many plants, they never run to full capacity because they are machines; they would not like to overload them. They are not sure about the design capacity of the machine.

They would have bought a new machine, you know, it can it can be loaded up to, you know, maybe you know 100 horsepower. But they will not load the machine till 80 horsepower, okay. They would say, Oh! I would not like to reach the high levels because it may damage my machine. So, these are uncertainties, okay. They will say that the machine has not been maintained.

So, I would not like to load the machine and create excessive wear and tear to the machine, okay. So, again, if this maintenance is planned like I was saying, the plan downtime, plan inventory, it is going to reduce the maintenance cost. Reduction in maintenance cost means increasing the overall profit and the guys in the finance will always be happy if the cost for manufacturing a component comes down; because that brings about the overall production increase and revenue to the company.

And that is what everybody strives for. I mean, why are we doing maintenance? Because I would like to have high productivity at low production cost or low maintenance cost.

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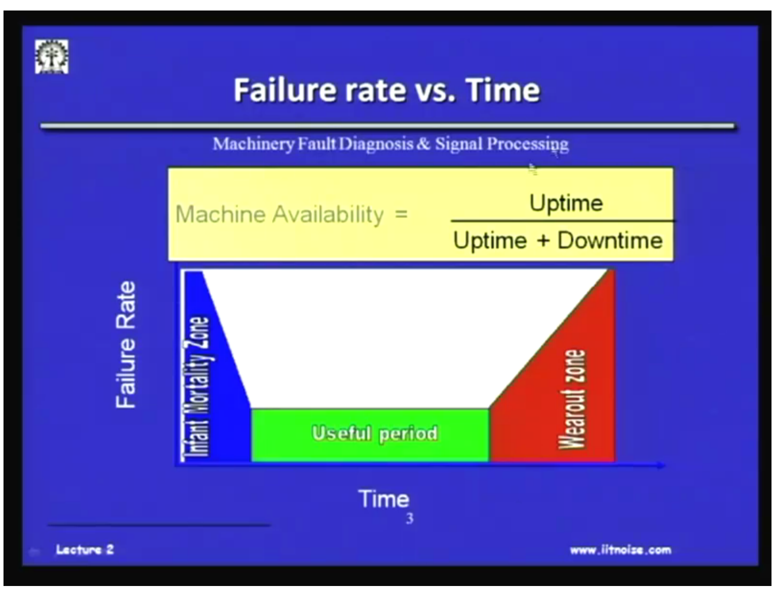

So, this is a very familiar machine availability curve. And sometimes this is known as the bathtub curve. If you look at this curve, there are two axis's: Here, one is the x-axis at the time. And then, you have the failure rate. There are three zones given by this blue green and the wear out zone. When a machine is initially commissioned, the failure rates are pretty high, okay.

This could be because of wrong OEM specs. Wrong integration, installation defects, not trying to, not being able to understand the machine, not able to understand the performance of the machine, operators are not properly trained. So, these are issues and by which we have always be, you all must have faced. May be in a nice example, I always give to all my classes, once you have bought a new computer or a laptop, okay.

I mean laptops are pretty robust and pretty user-friendly nowadays, you know. I am talking about them at ten years ago when people used to buy PCs, you know, first few weeks, there is to be tinkle with the operating system, this audio driver is not working, that hard disk is not being properly read; I am sure all of you would have experienced this, okay. But once you are comfortable with your laptop with the operating system, with the kind of software's.

It undergoes a smooth life, okay. And this initial defects or down times due to your laptop, due to equipment, is what is known as the Infant mortality zone. The reasons could be many: not trained staff, not trained engineers for installation, installation specifications and the requirements are not matching and so on. And then, once these teething troubles are taken care of equipment, founders and problems could be another, foundation troubles problems could be another.

We have this green period and which is known of the useful period in machine. And again, despite our best maintenance efforts, at some point in the time, you will see that the failures happening quite often in the machine. And a point will come, you will find, that it is more expensive to maintain a machine than to buy a new machine, ok. Or the cost because of this frequent shutdowns or breakdowns of the machine is not wise, not financially beneficial for you. And that is where we call a short and then we discard the machine, ok.

So, the machines availability is given by this. Function uptime and downtime is given for the useful period and the denominator of 10 plus downtime is nothing but the total time of the Machine, ok. So, we as maintenance engineers, have to strive for having high uptime, high availability of the machine, ok.

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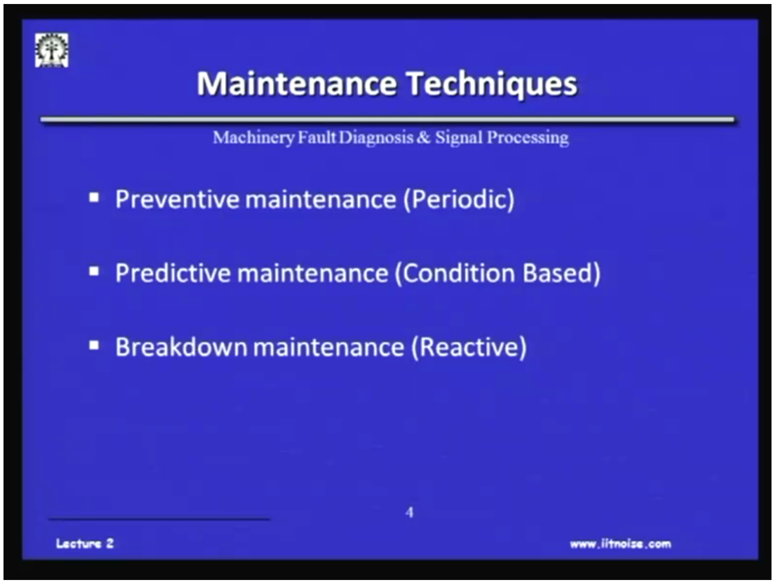

There are three very important types of machine maintenance. And one is, the very first one is, the preventive maintenance or what is known as the periodic maintenance. And followed by the predictive maintenance or the condition based maintenance. And the last one is actually no maintenance which is known as breakdown maintenance or the reactive maintenance.

And in this course, we are actually going to focus on the second one that is the condition based maintenance. In fact, I had told you in the first class that we are gearing towards all this instrumentation, signal acquisition, retaliation, analysis. All because of this CBM I need to know the machines condition by monitoring its vibration, by monitoring its temperature, by its monitoring its pressure, etcetera.

So, we need to the flow conditions. So, we will be focusing on condition based maintenance in this course. But I thought I should tell you about what this preventive maintenance or periodic maintenance is. Periodic maintenance means that I will regularly follow a schedule of maintenance. There will be a time interval fixed.

No matter if the machine is bad or good. I do not care. I will just go on and religiously maintain, replace the spares and then, my machine will be on is up and running. Particularly, in the defence, they do this kind of periodic maintenance because they have to, because of strategy reasons. But that does not mean that they do not do condition based maintenance.

Condition based maintenance is the technique wherein we always, we are I underlined the word, we always know the condition of our machine because certain extra capital investment has to be done, has been done on the machine by instrumenting it with additional instrumentation in terms of transducers and sensors. And then, we have an analysis unit so that every time the machine is running I know its present condition.

I also have its past history in my database. So, by certain algorithms I can say, whether my machine is going to behave the present way or its condition is going to be okay or it is going to be worse. I can find out from the database of my data store, in my database from the previous conditions of the machine.

So, periodic mint sorry, predictive maintenance or condition based maintenance always depends on the present condition sometimes on the past conditions of the machine. But, the machine's conditions need to be known to do maintenance. Another thing, I will tell you, in fact, I was telling you earlier, in our meeting that like a doctor is no good to a dead man or a dead person;

Similarly a maintenance engineer cannot maintain a machine which is already dead, which is not running, okay. I cannot most repair it but I cannot maintain it, okay. A machine has to be running so that once it runs it is going to give us the signals. If a machine is not running, there will be no vibration. There will be no noise; there will be no heat generation. So, I cannot possibly do CBM on that machine.

Utmost I may look into the manuals, look into the design and do a repair of it. But to implement CBM, a machine has to run, okay so that it gives the required signals. And I have the instrumentation to capture those required signals. So, I am stressing on the word, signals, instrumentation, in the case of condition based maintenance because of the fact that to implement condition based maintenance I need to have extra investment done on the,

Even a machine could be as new as I have just bought a new machine today, to do implement CBM on it; I have to do an external investment, right today itself from day one so that I have the investment to take care of the instrumentation; investment to take care of the analysis unit. I have skilled manpower to analyze the signals acquired from the machine, okay.

As opposed to the last one the breakdown maintenance or the reactive maintenance, this is actually no maintenance. I do not do any maintenance on this machine I can afford to lose the machine, if the machine goes down. Like I was telling you in the case of a steel plant, I mean I have a blast furnace. I cannot afford to lose the blast furnace but, of course, I can afford to lose couple of water coolers in my canteen, okay.

So, I mean, if the water cooler in a canteen in the, in the steel plant goes out, okay I can always buy a new water cooler, okay. And you imagine the criticality of that equipment. But, of course, you know if my glass furnace is damaged and down I cannot afford to lose that. So this, these are issues which we will understand in the lecture on FEMICA and that is failure modes effect and criticality analysis. From the failure modes, which, which will affect or function, I can know, what kind of maintenance effort has to be put in which machine.

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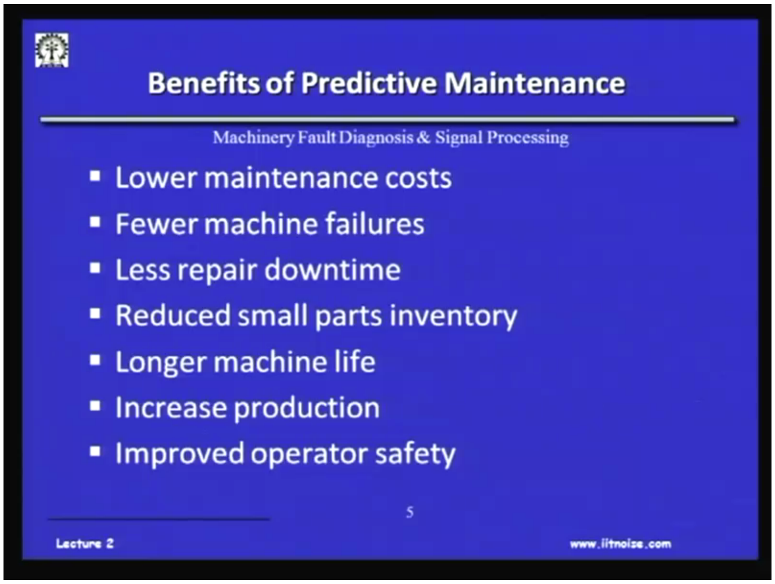

So, I will be focusing this class on predictive maintenance because in predictive maintenance you will see in an example which I will show you subsequently, that the maintenance cost will come down with time because of the fact, every instance, I know the machines condition, okay. I can always know whether my machine is going to undergo a failure, is going to have an abnormal behaviour or not and so on.

So, because of that I will have few machine failures. I will have less repair downtime because, because of the fact that I know the machines present condition, I can always, but by then, with time.

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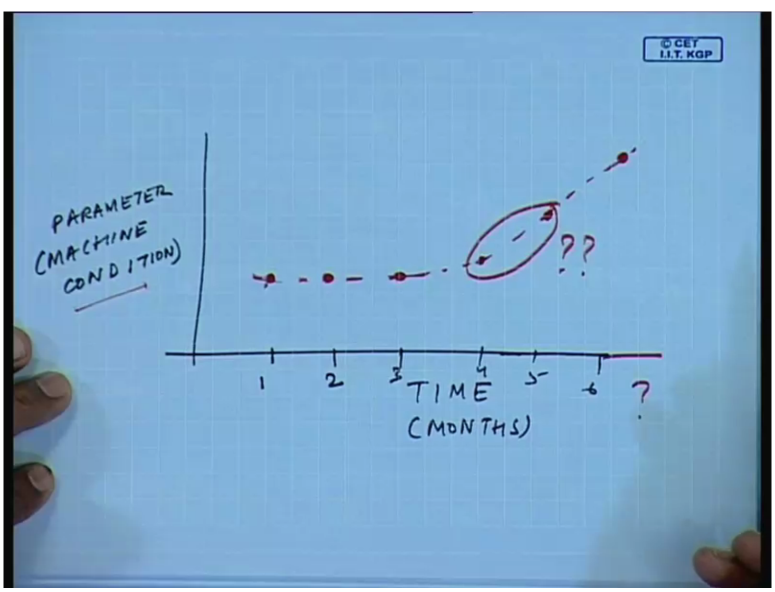

Say, I have a parameter, which tells the machines condition. For example, of time now, this could be an interval, as often one month, two month, three month, etcetera. So, this is in time in months. I have measured, so, here this is the parameter; second month and slowly I see this is happening, okay. Say, if I was trying to do a trending of the machine's condition towards 4th or 5th month at the end of the 5th month, as a maintenance engineer I will be getting worried;

Well something is behaving abnormal of the machine and why this parameter coming down. So, I know well by 6th or 7th month I need to have a major repair or studied into the problem in this machine so that I may be having certain critical spares already available to me by the 6th or the 7th month and so that from the month one I did not stir this critical spares.

If I know it takes you know only one month to get these critical spares I can plan by the end of 5th month to get this critical spares. That is one way of looking at it, okay. And then, I can be prepared that you know, my machine is going to have a downtime, so I can, for example, I will give you an example here. Suppose, you know, we have a festival of Bhasera wherein we give holidays to the workers, okay.

Imagine at the peak of the Bhasera, my machine which is to be producing and there is a demand that it has to take a serious split down, so I have to pull out my workers or engineers from there. The Bhasera occasions or holidays I have to pay the workers over time because I have to pull them out from a scheduled holiday, I have to have the spares ready; so this all add to cost.

But had I planned it earlier and because I know the machine's condition well at the end of 4th month, I know, I will have a high production demand towards the end of 7th months. This is the time wherein I can take a repair, ok. So, these are the cases wherein I can do the, reduce my inventory. And then, of course, I know, if I do a proper downtime, I can reduce the machines availability and increase production.

And if I know this machine is going to have an abnormal behaviour I would not like my operator to be very close to the machine, okay. I have had a case wherein, we have, we have a plant in very close to Kharagpur, Haldia of a large FMCG manufacturer, one night the plant engineer gets a phone call that the gearbox, in fact, blew apart, okay.

And this is a plant which they produce detergent, ok you know, a detergent production is very similar to cement manufacturing; they have a mixing; they have a rotary kill and that rotates at a very low rpm and then, heated at one end. So, if you have a motor running at 1500 rpm and the kill is rotating at 2 to 3 rpm, you can imagine, the amount of reduction being brought about in this gearbox.

And this gearbox was very critical to that detergent plant. And this gearbox because of reasons we will find out later on, in fact, that is the case study, I will discuss towards the end of this course. That this gearbox blew up, okay. Imagine if the operator was standing next to it unfortunately it was in the late night shift and nobody was there, okay.

Imagine if an operator was standing next to it would have been dangerous. So, if we know the machines condition, we know when it is safe to go closer to the machine while it is operating and so on, okay. So, all these are the benefits of predictive maintenance. And in this course, as I was telling, we will be focusing more towards the condition based maintenance.

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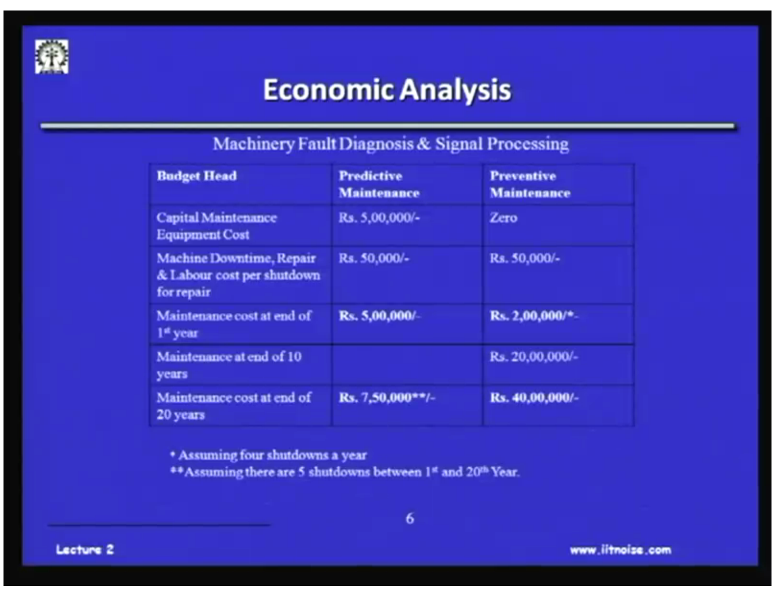

Budget Head	Predictive Maintenance	Preventive Maintenance
Capital Maintenance Equipment Cost	Rs. 5,00,000/-	Zero
Machine Downtime, Repair & Labour cost per shutdown for repair	Rs. 50,000/-	Rs. 50,000/-
Maintenance cost at end of 1st year	**Rs. 5,00,000/-**	**Rs. 2,00,000/*-**
Maintenance at end of 10 years		Rs. 20,00,000/-
Maintenance cost at end of 20 years	**Rs. 7,50,000**/-**	**Rs. 40,00,000/-**

Now, I always give this example to all my classes on the Economic Analysis. As to I am doing a comparison on the predictive maintenance and the preventive maintenance. The question is, you know, which one is good and which one is not good, in the long run. These are few budget heads in the first one and as you can see this. The capital maintenance equipment cost. Day one, I would require and though both my machines are new, I am just doing a comparison.

Both my machines are new, day one. I would require an additional expenditure towards the signal acquisition, the transducer the analysis unit. I need to have that in place. But for a preventive maintenance or a periodic maintenance, I require no investment, okay. Now, let us look at the case of the preventive maintenance, assuming there are four shutdowns a year. By four shutdowns I mean four scheduled maintenance in a year.

And the total cost of this maintenance which includes the machine downtime, the repair, labour cost per shut down, for repair is fifty thousand rupees. For four such repairs in the preventive maintenance cost at the end of first year I would have spent Rs.2 lakh rupees, right. At the end of ten years, if I was religiously doing this preventive maintenance I would have spent 20 lakhs. At the end of 20 years, I would have spent 40 lakhs, okay.

And then, if you look at the; because I am doing predictive maintenance, I am not doing maintenance on a regular schedule. I am only doing a maintenance, as and when the signal indicators let me know that these machines require some maintenance. And usually, this is a figure that, at the end of 20 years if there are only five shutdowns, because of maintenance. Since we are doing predictive maintenance the number of shutdowns will be less and this happens to be five. And this is not a data which I have cooked up, okay.

This is a data which is there from the server report given by industries in many journals. And this is a compilation of such. In the span of 20 years, there are only five shutdowns. So, the five lakhs is my initial investment. And then, I would have spent an addition of two and half lakhs. So, the end of twenty years are all spent only seven point five lakhs if I was doing predictive maintenance whereas I would have spent 40 lakhs in the case of preventive maintenance.

We do not realize that. But this is the statistics obtained from industry, who are doing this as benchmark studies and have reported them in journals. But always we have a problem with the engineers, maintenance engineers asking the management for more investment, right. Day one, because the management will obviously say, well we have just bought a new machine, why do you require an additional expenditure of five lakhs for maintenance?

Because I from day one I need to do a predictive maintenance so that I have the right equipment and infrastructure to acquire the signal and know the machines condition. So, that is why, this five lakhs to be spent there in the day one. But in the long run, we spend about, we save about more than 22 more than or 32 lakhs in 20 years.

If you do such an accounting, and in fact, nowadays, you know, I am talking, telling you the scenario of the Indian industry. In fact, there are many plants, you know, I am just give you the examples in the last two decades, okay. About two decades ago, okay people hardly knew about vibrations, okay. People, I mean, vibrations was always there even in any engineering curriculum.

We are hardly being taught machinery vibration as a full fledged course, okay. And in the industry we used to have some meteors, you know, yes, to just give you, just one number. And there are certain ISO standards as to certain horsepower. This has to be the overall valuation level and there is to be a just a few people in a maintenance cell.

Workers and technicians they used to go to the machine measure its vibration and forget about it, okay. If there was a breakdown, people will blame each other, you have not recorded the vibration; they used to go back to their old logbooks and logbooks torn, pages flying here and there. And this was actually the scenario twenty years ago when people used to call me to the industries to fix their problems.

I used to ask them do you have any pipes and data. They would show me old logbooks on a written sometimes their pen, sometimes their pencil, sometimes by but they did not know by what, in what units, they have recorded the data. Sometimes they do not know I have seen they have not put the transducer in the wrong place; they do not know if there was a proper battery in the meter.

This is some display they write it down; there was no calibration of the meters and this is, this was actually the scenario twenty years ago in our Indian industry, okay. But, today the scenario is altogether different, okay. If you, if you go to any industry, they have smart screens everywhere with touch screens next to the machine; they have instrumentation, transducers mounted on the machine;

Data's will be automatically logged into the data logger; Engineer just goes touches the touch screen; sees the data log, sees the trending chart. And there are subroutines, algorithms that will tell you when the machine is going to have a down time. And this is the state of the art in the, e industry, nowadays, okay. And now you will see wireless coming a big way into the industry. There are no more long cables laying here and there others telling you, monitoring machine sitting in Kharagpur, monitoring machine in Alaska is not a science fiction, anymore.

It is possible because of the advantages and the advancements done in electronic instrumentation and computers in miniaturization of the transducers. Transducers are smart enough; they are fault tolerant; they can be such calibrated by techniques, okay because, you know, these are the advantages of predictive maintenance. And engineers are smart as you are, nowadays, okay; everybody understands instrumentation; everybody understands computers and electronics.

Everybody understands computer languages; everybody understands the vibration, okay. So, there has been a paradigm shift in maintenance engineering in the industry both in the academia and in industry, okay. In fact, nowadays, the, you know, we are talking about predictive maintenance, you know, nowadays, the focus has been to.

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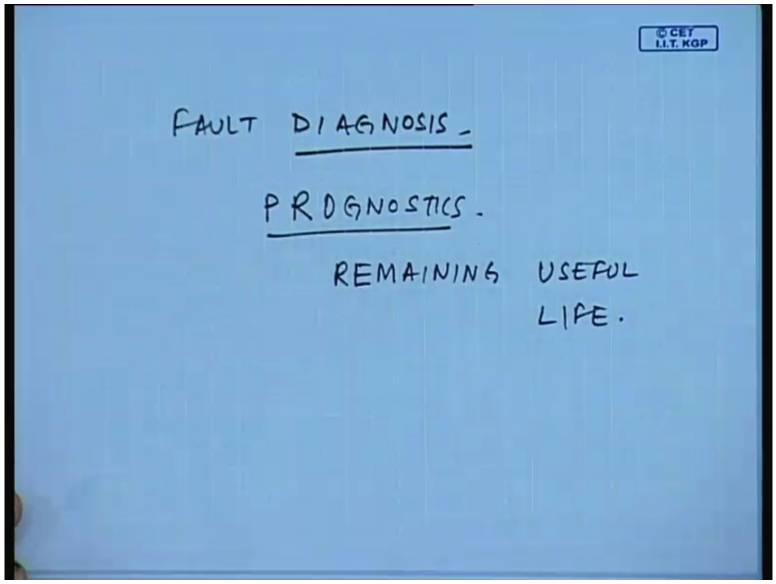

If there is a problem in the machine they would like to know what is creating the fault in the machine. And the next is there are mathematical algorithms as to find out a remaining useful life of a machine and that is very important. I mean, obviously to an engineer, then, very next question is well my machine is running fine, when is going to, when is it going to go down. Now that is the question everybody asks.

Your management would ask you. I mean, can my machine survive for next ten years, okay. And how would you answer that? You have no clue. All you know is; you have data till present from the past ten years. You cannot, you know. So, there are lots of mathematical tools available, models available, which will let you know whether my machine is going to last, survive, for the next ten years or next fifteen years; Or when it is going to have a condition wherein the machine will be totally unacceptable, okay.

So, you all can understand the benefits of predictive maintenance by this small example which I showed you. Now, what are the techniques available for vibration sorry for a predictive maintenance? As I was telling you, we had some idea about the techniques available for operative maintenance in the last class. I told you about that 70% of the cases of predictive maintenance is by vibration monitoring followed by wear debris and the oil analysis which is the remaining 20%.

And then, next, comes the motor current signature analysis, the thermography and the NDT techniques which is the remaining 10%.

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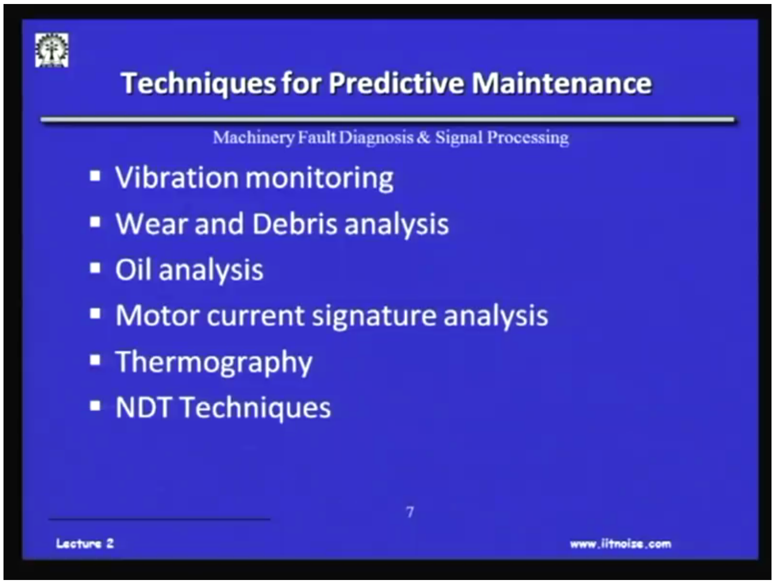

I will just to give an example on thermography.

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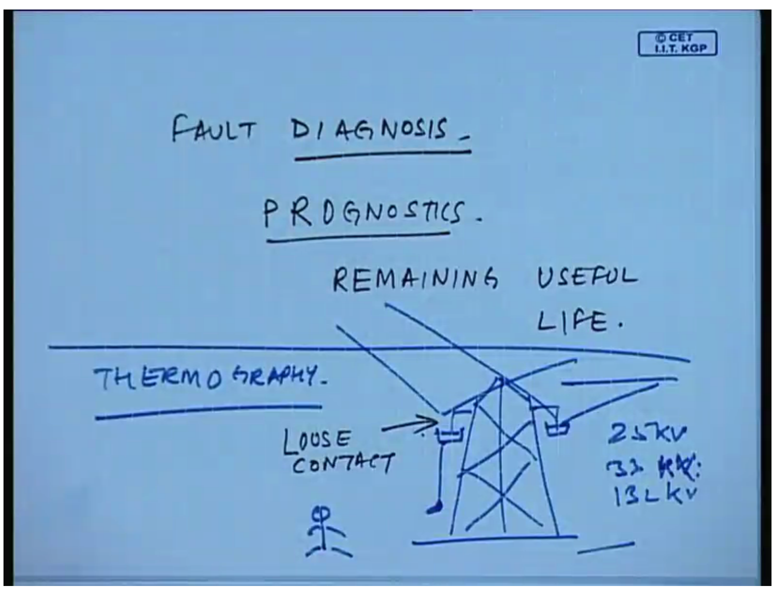

I will just tell you an example with the industry nowadays is using to save power lost during power transmission, you know. This is high-voltage transmission towers, okay where in the, have a certain switch gears, you know, they will be operating a switch gear. And suppose, you know, from one transmission tower in a line, line goes to another grid, they will be having switch gears, okay. And this switch gears have to make contact, okay.

And this is high from the ground, you know, from the ground. And then, you are standing somewhere here. Obviously, this is you know 25 kV or 33 kV lines, 132 kV lines, okay. And they are transmitting electrical power, okay. Now, imagine, in this switch gear, if there was a, loose contact, okay; there will be, because of loose contact, they will be arcing and they will be heat generation.

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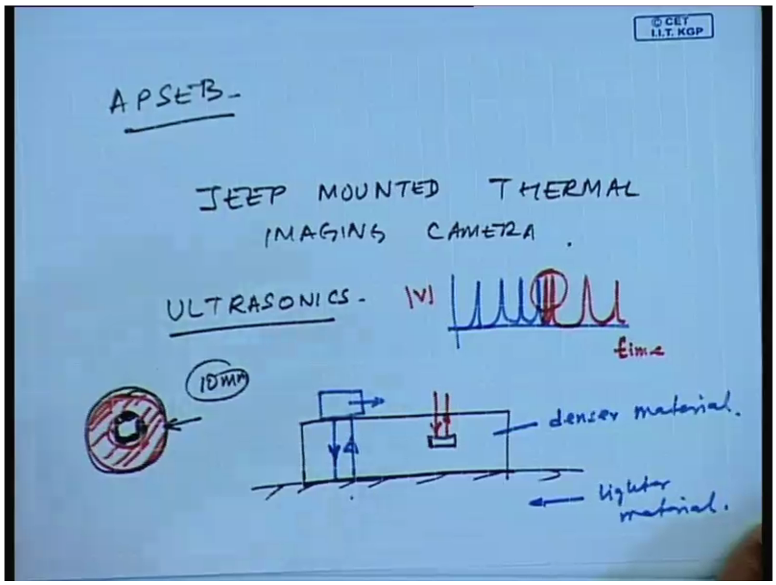

And there will be loss in power transmission. In fact, this is a case study, repress, reported by Andhra Pradesh State Electricity Board. I was there in one of the 50 meetings and they were mentioning that they have done a substantial amount of power savings in the power distribution by ensuring that there is no loose contact in the switch gears while at such high voltages.

And how did they find out that switch gear loose contact? Obviously, because of the high-voltage power generation, I cannot physically climb up the tower and check with a measurement. What they did was, they had Jeep mounted thermal-imaging camera to shoot at the switchgear and find out the hot spots, okay. And they did lot of, because of the, you know, the electricity board reports through the figgie that there is lot of power loss in the transmission itself.

Not in the generation but in the transmission. And switchgear loose switch gear was a very, very large component. And that they could reduce by doing thermography, ok. Thermography, we use when detecting faults. We may not be able to diagnose for example a coupling between a pump and a motor. If there is a misalignment, I can put a vibration transducer measure the vibration, do an analysis and tell well there is a misalignment.

But, often, just to know whether there is a coupling misalignment I will just shoot the camera on the coupling. If the coupling is hot, I know something is wrong. So I did not take I can identify hot couplings; I can identify hot bearings in the case of the rail axle; I can identify hot conductors between, behind a panel. For example, you are talking about the ship which comes to the port for few days for an overhauling.

I obviously cannot remove all the claddings and the panels and to see all the conductors whether anything is hot. You can just do a thermal imaging scanning and find out the hot connectors and then take corrective measures, okay. So, thermography is a very, very quick and easy way to detect abnormal heat changes. And this abnormal heat changes could be because of misalignment, could be because of loose contact, and could be because of high current being flowing in the conductor etcetera, okay.

And this NDT technique is another technique wherein we have the techniques of ultrasonic's, the techniques of acoustic emission, pornography; how do you detect crack in a shaft from the outside? For example you would have done a fine casting of a cylinder block, okay. You know, the engine, they do a casting of the cylinder block and the some of this surface or machine and components are fit into that machine, the cylinder block.

But if there is a thin hairline crack in that casting and because everything will be under high pressure, during the operation of the engine the boil or the flue gas or the combustion gas etcetera are going to leak out, okay. And then, you will lose compression in the engine and this engine is going to be no good. So, how do you detect such hairline crack on the surface? A surface you possibly cannot see through your naked eyes.

Everything will be nice machine but there will be thin cracks. So, this is what is known as the dye penetrant test. You can put a layer of dye and then under special camera you can see this dye will glow and you can know whether the crack is visible, crack is present or not. So, certain entity techniques are used for finding out defects in the machine. Ultrasonic is very popular in the sense, I will just give you an example of ultrasonic's.

Say, for example, I have a metal piece and there is a crack here void. So, if I have an ultrasonic transducer, this ultrasonic transducer, what happens is it gives a wave, okay incident wave. And this is a denser material. This is of another material. So, there is a density difference at this interface, so because of this density difference there will be a reflected wave.

So, in this trans receiver, you will see a pulse and if you row this transducer, every instance, you will see a pulse intensity equally spaced but when the scenario, when it comes here, just right above the pocket of the void, because of the density difference, this is going to bounce back. So, you will see suddenly a very close phasing.

And then, again this is, say time some voltage level. So, this means because the time taken will be less because the distance travel is less, okay. So, this means that there it came across an obstacle which was of a different density then this common homogeneous material, okay. And that is the principle behind ultrasonic waves are as you know, high frequency they are very directional; because high frequency waves are directional like you would have heard of a siren.

If there is a siren at high frequency, you always turn your heads towards the siren, because high frequency sound or noises are directional. Same is true with ultrasonic's, okay. So, if I have an ultrasonic scanning of this I can do that in fact the ultrasonic thickness gauge is based on this principle okay. If I know the speed of the ultrasonic wave, in this medium, I can calculate the, from the time taken I get calculated the distance or the thickness of the specimen.

In fact ultrasonic's are used another way is to find out the, in lot of this tubes, lot of the large tubes you know of certain cross section whenever they carry a lot of chemicals, know either some things get deposited, clogged; because of this clogging, what happens the thickness as measured here. Suppose, originally this was a 10 mm thickness because of its time, because of this depositions of the solid particles, there will be variation to this 10 mm.

And if you row an ultrasonic transducer, all around the circumference of this tube, you will know whether in the internal, which is not visible, I mean, possibly vibration monitoring cannot measure it. But if I, if I can row a transducer all around the circumference of this tube I can know what is wrong in this. If there is any formation and it deposits in the inner wall of the tube okay. People of course, use, you know, radiography also x-rays; another way so there are many ways to do such NDT techniques that can rustle necks, acoustic emission, radiographic, etcetera.

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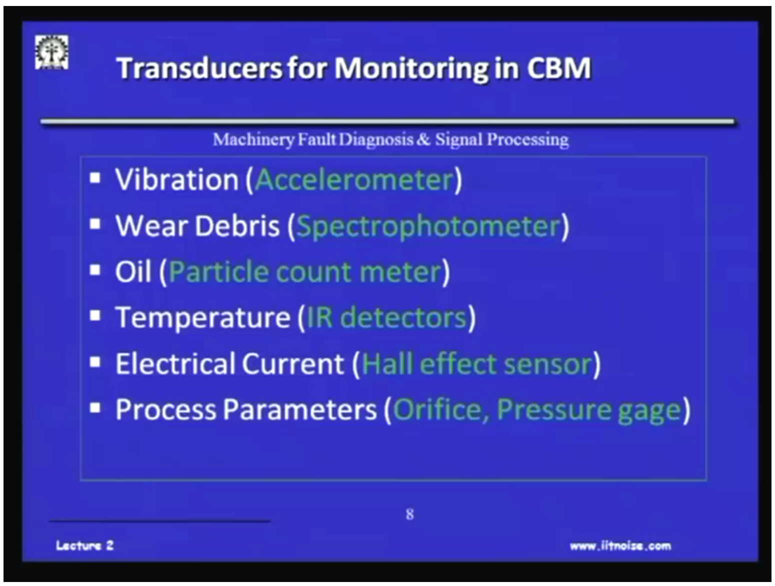

Now, to implement all this CBM or condition based, these parameters vibration, wear debris, oil, temperature, current, process parameters. These items written in green are actually the transducers required to sense these mechanical parameters. And these transducers could be for vibration, it is accelerometer and for this wear debris it is the spectrophotometer. Because I was telling in this wear debris, the wear debris, fall off apparent material by knowing the wear debris chemical composition,

I can know, comparing the, knowing the chemical composition of the parent material, I can very well know where this or which component has worn out and because of which this particle has got deposited in the lubricating oil. So, that is done with specialized equipment known as a spectrophotometer. And spectrophotometers are very expensive equipment. They require specialized facilities to operate.

So, obviously I cannot be doing putting a spectrophotometer next to a gearbox in a cement plant, okay. Spectrometer, photometers are, are in dedicated central research facilities in IIT, Kharagpur, we have several of them in many departments. And wherein, all we do is, we bring in the oil sample. We can through spectrophotometer, we can know, its chemical constituents. We can, we can know, the composition of this where debris particles as to what percentage of iron is present, what percentage of zinc is present, copper is present, etcetera.

And then, of course, always compared with the chemical composition of the parent material and see if zinc is in that component and I have a strong amount of zinc in the wear, I know that parent component has or not oil. There are many ways to measure the parameters in the oil but one very handy way is to known as the particle current meter; As to what is the size of particles available in the particle and whatever what is their concentration in parts per million.

How many such particles are there? Temperature in infra infrared detectors RTD's, thermistors etcetera can be used to detect temperatures. Electrical current, no, you can use the simple ammeter; But Hall Effect sensor is a technique which has a very, very high frequency response; because I was telling you, in the motor current signature analysis, it is just not the amplitude of the current but it is the nature of the current, in terms of its frequency content.

It is just not 50 Hertz but it could be 50 Hertz and also frequencies around the mechanical defect frequencies which is being driven by this of the mechanical unit; which is being driven by this electrical motor. So, on Hall Effect sensor is a transducer which is used to monitor electric current. And then, next comes the process parameters as to the finding out the flow rates of the processes, particularly, chemical process plants, in fertilizer plants, etcetera.

People who would like to monitor the flow rate with orifice or a venture meter or a turbine flow meter. There are lots of pressure gauges to measure the pressure in the chemical process and so on. So, these process parameters indirectly will give a clue as to what is wrong with the machine surrounding that chemical process.

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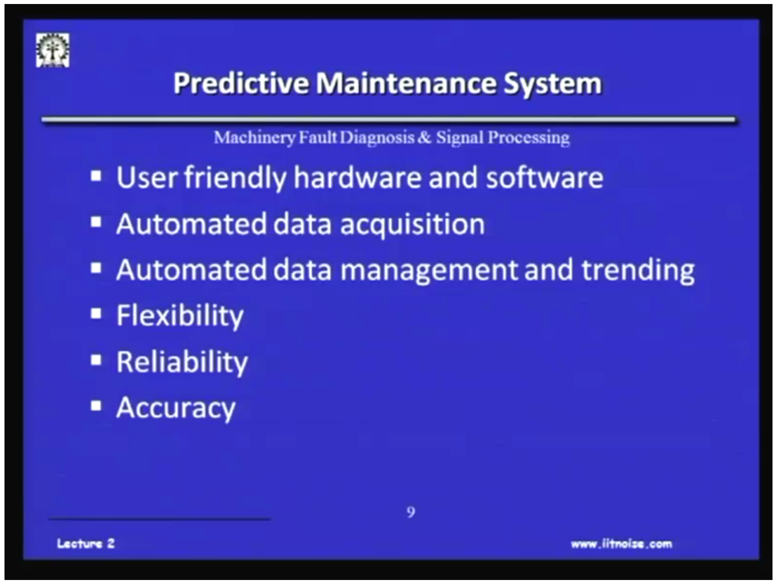

Ah, you have a fairly a good working idea about the components in the predictive maintenance system. We, of course, need to have the machine, we need to have the transducers, we need to have the data acquisition unit, we need to have the computers or the data has to be stored in a database, we need to have a skilled manpower and analysts who will analyze this data.

And so a very generic predictive maintenance system will have the user-friendly hardware and software. Hardware could be the transducers for weathering vibration transducers, for measuring the pressure process parameters, temperature transducers, or measuring the temperature the transducers for measuring the current, etcetera.

And on software which will tell, when to acquire the data, how much of data to acquire, how long to acquire and so on, what are the related data's to be acquired simultaneously. So, once this software drives this whole thing this data has to bestowed, acquired by a computer related data acquisition. It need not be just one data at a time; it could be multiple sensors at all times.

I could collect data from all 16 sensors around my machines at one given instance; because there will be a lot of statistical processes signal processes, wherein we will find out relationship between two signals, whether they are related or not. Otherwise, we cannot, if they are, if I, if I do not acquire them at the same time it is very difficult for me to tell them that they are related. Because once they have to be correlated, they have to be acquired at the same time.

And then, we need to have a data management system which will be responsible for storing the data and doing the training; because if this, if this has to be automated. Imagine if I, if my plant, if a steel plant, I have hundreds of gear boxes and pumps, obviously, everybody cannot be going run into each machine and doing a data logging or data taking by hand. So, this has to be automated.

This has to be through a computer driven system, it may have cable, it may not have cable, it could be Wireless. But all this data bases with the proper nomenclature and identity of the machine has to be taken in. And then, today I have a system for a steel plant; the same system perhaps could be used in a cement plant; the vibration transducers are the same, the principles are the same.

Only thing is that I have to mount instead of a gear, the steel plant I have to mount in a cement plant. So system has to be very automated it has to be flexible and of course it has to be reliable. I mean garbage in, is garbage out. if I give a junk data to my computer it is going to give this give me a junk out that should not happen, okay. And then the reliability it has to be accurate. The transducers have to be calibrated and then it should not give any false trending and so on, okay.

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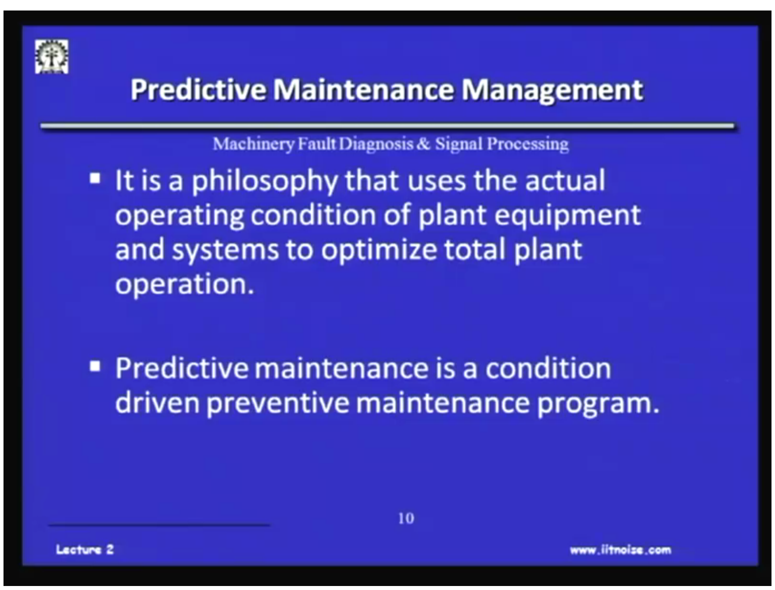

So, while coming to a close I would say, the predictive maintenance is a philosophy that uses the actual operating condition of a plant equipment and systems to optimize the total plant operation okay. It uses the actual plant operating condition; it cannot be of a dead plant. And then, it is a condition given prevent, it is a condition driven preventive maintenance program.

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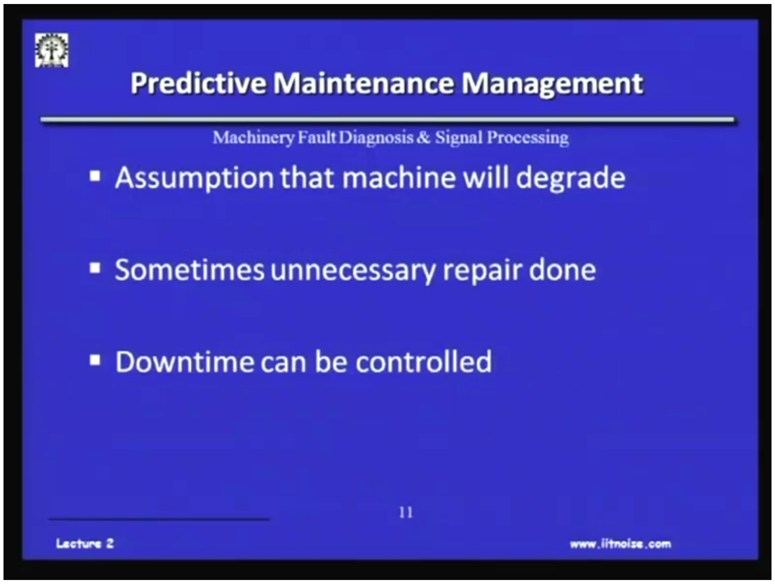

Wherein in predictive maintenance we assume that the machine will degrade sometimes or no because of some slips; unnecessary repair may be done; of course but downtime can be controlled.

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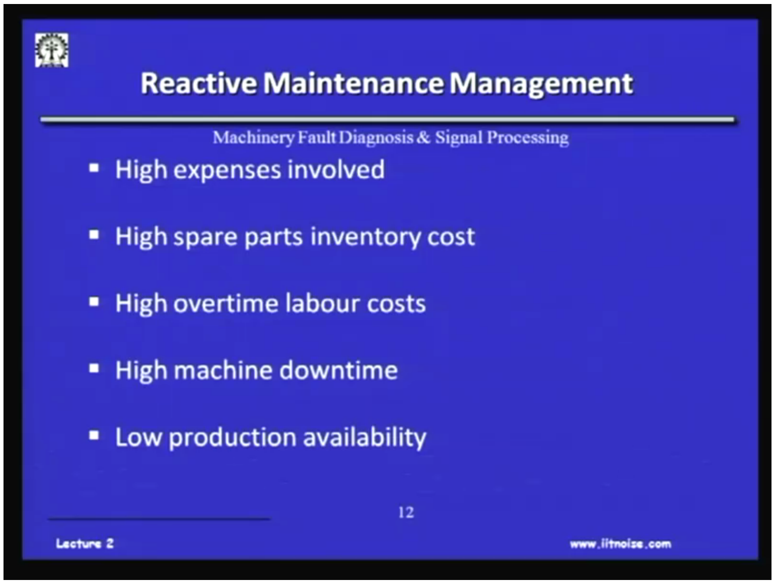

Whereas in reactive maintenance because I have done no maintenance, suddenly I have to have high expenses involved; high spare parts, high overtime because on a rush day I have to repair this machine spares not available because machine has suddenly undertaken a breakdown or to import it. So, these are the advantages, disadvantages of the reactive maintenance.

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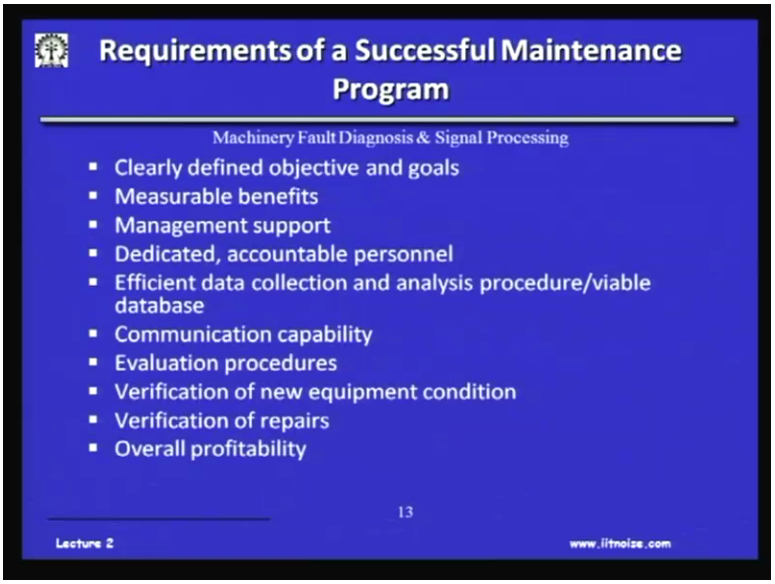

So to have a successful maintenance program, I need to have these conditions. They are dedicated manpower who understands the entire process. And there has to be good communication between the place where I am taking the data and where I am doing the analysis. I sample oil from one machine and the technician to the other end is thinking it has machine B where I am new to the data from machining. Labelling and data communication between the labs is very, very essential, okay.

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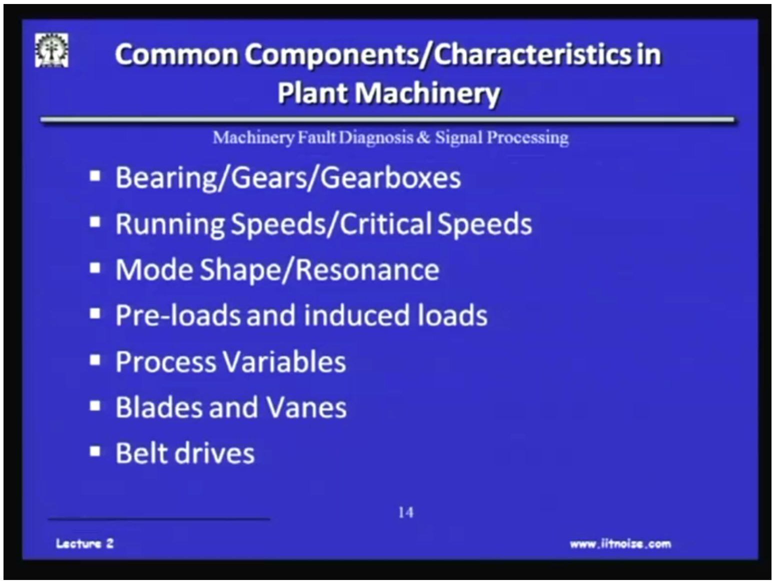

So, some of the plants, you all know this by now, that these are the common elements in their plants and machineries which we will be talking about in this course.

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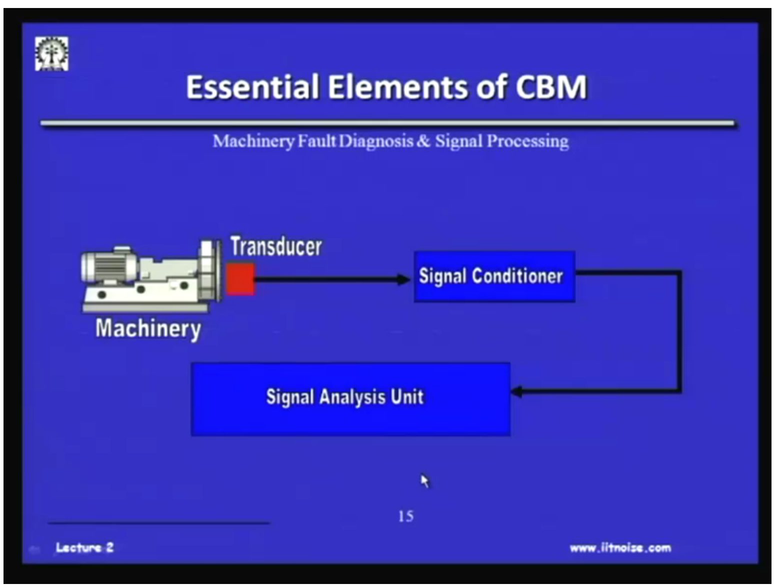

And this is the generic arrangement of CBM, the transducer, signal conditioner and the signal analysis unit, okay.

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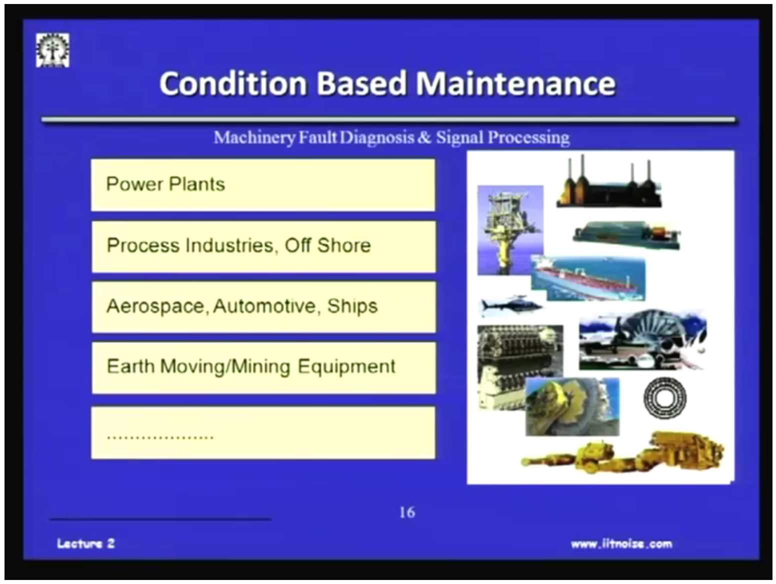

And you will see CBM is almost used everywhere. And in the subsequent classes, you will see how we use them through different machines. Thank you.