Machinery Fault Diagnosis and Signal Processing
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Lecture - 02
Maintenance Principles

This is the second lecture on Maintenance Principles.

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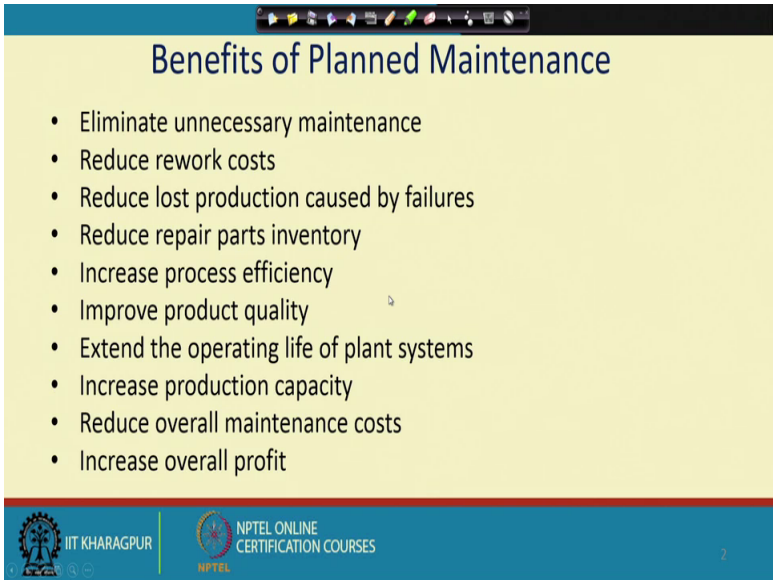

So, I am first going to talk about the different aspects of maintenance and then as you all; obviously, know what is the benefit of maintenance? Because end of the day when an industry has put assets in operation, they would like to know regarding the life of their assets; assets in the sense being machines.

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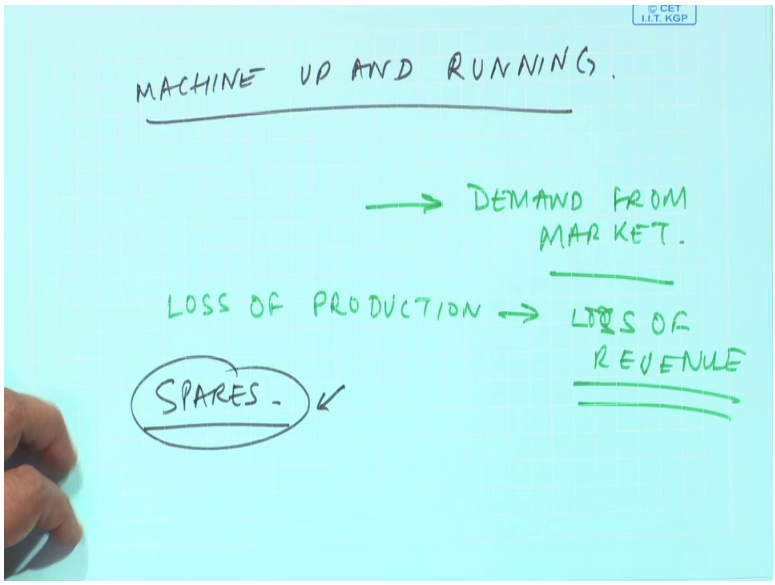

Because the machines have to be up and running at all times and that is the objective of machine maintenance. So, if we have the maintenance planned; obviously, I will not doing unnecessary maintenance or maintenance for the sake of doing maintenance; will be reducing lot of rework cost and lost production caused by failures.

Imagine, if I will give an example where the rush of order and then we need to deliver because there is a strong demand from the market. So, if we sell more; we are going to make more profits, but immediately if your machine was not maintained; what would happen? There is a sudden loss of production. So, loss of production leads to loss of revenue, so we need to be careful that our machines do not have any defect.

Now, if I did not do any machinery maintenance; I would be having lot of space in my store because I would not know which one is going to fail. But imagine if a machinery required a very critical component and which was not there in a inventory because I had not planned and then suddenly there is a catastrophic failure. So, I am going to find out how do I get this critical space? So, this is an issue.

So, if the maintenance is planned and I know which is the most important component which is to be stored in my inventory, I can have a reduced spare parts inventory. I will increase the process efficiency, if my everything is in correctly ordered and of course, this is going to influence the production quality.

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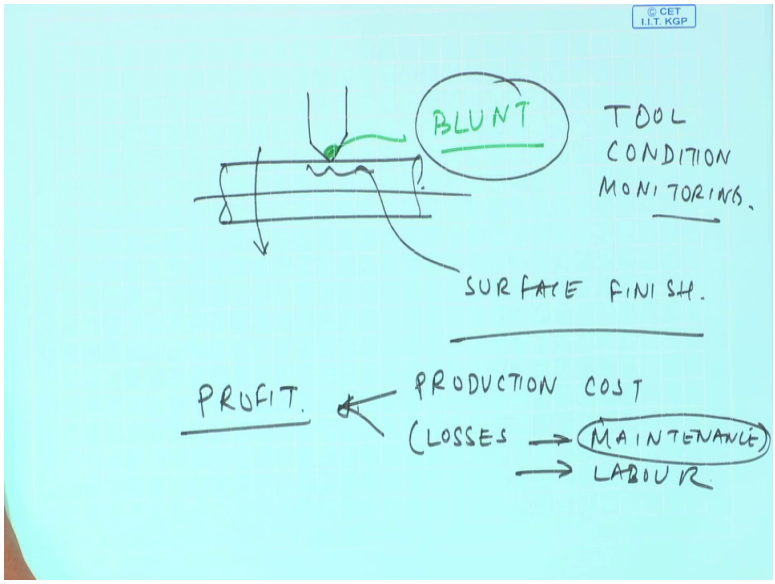

So, my product quality is going to be better; imagine to do a machining operation on a surface, some sort of machining operation has been done. If this tool was blunt because it was never changed, because it was never monitored; so, this is going to affect the surface finish. In fact, people do tool condition monitoring to ensure that such qualities are not affected because of improper cutting tool or the cutting tool was not changed. So, the product quality needs to be improved, if I had a good tool condition monitoring in place.

Of course this would then; obviously, lead to increasing the overall life of plant systems, including production capacity and of course, if the maintenance is planned I am not doing any unnecessary maintenance. It will overall reduce the maintenance cost and overall profit because any company or industry they would like to make profits. So, their production cost should be a minimum and if I losses because of maintenance is the minimum; of course, there are many other things, like labour etcetera, but if this maintenance losses are reduced; I will increase my profit.

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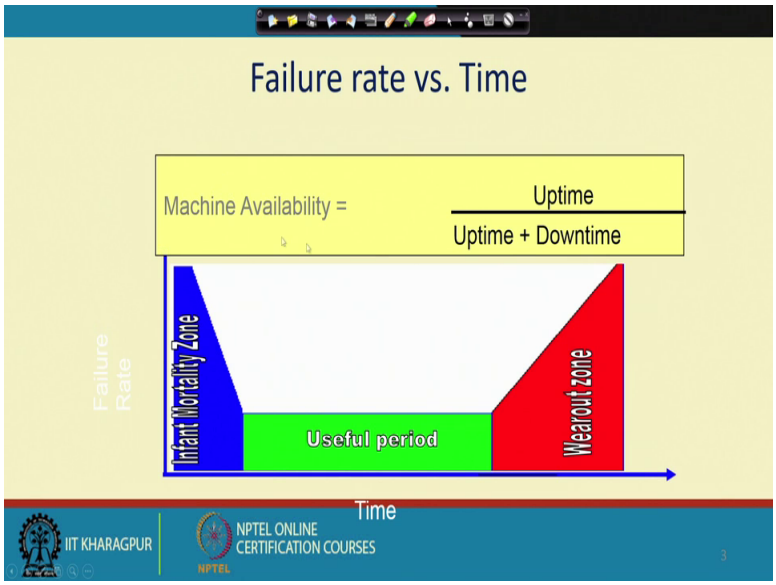

So, this is a typical bathtub curve; where this Y axis is the failure rate and time. So, what happens when a machine is initially put in place, the failure rates are very high and that is what is known as the infant mortality zone. And this could be because of the incorrect operation, incorrect foundation, incorrect understanding of the machines maybe there is some design defect.

So, once these are taken care of the failures reduce and then they come down and this is what is known as the useful period. Again towards the end of the life of the machine, what happens? This where increases and the failures engage with time and time would have come, when it is not wise to do any maintenance and it would be necessary for to almost replace the machine.

So, this machine's availability is defined something as the uptime is the period in this green; divided by the total time which is known as the uptime plus down time.

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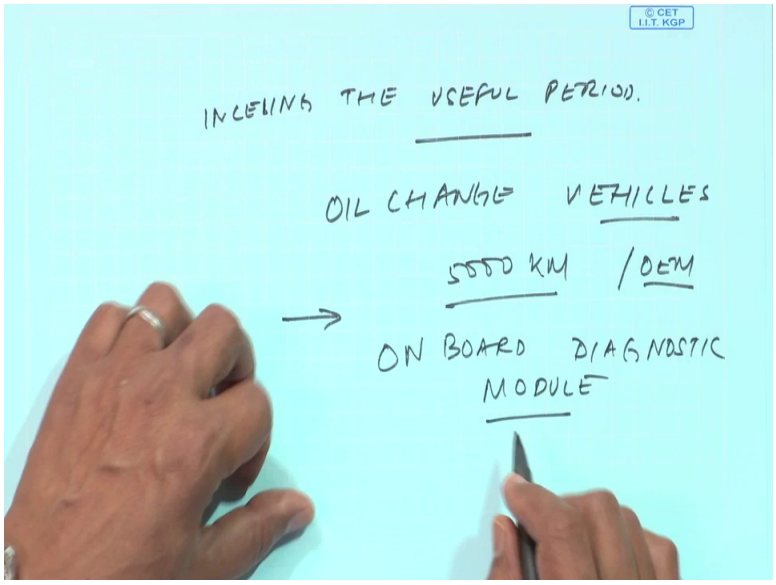

So, in CBM we always make efforts to increase the machines availability and this is only done by increasing the wear out; it should be the increasing the useful period. So, all the efforts which we are going to give to maintenance is only to reduce the machines downtime. And then make increase the machines availability and this is known of the typical bathtub curve.

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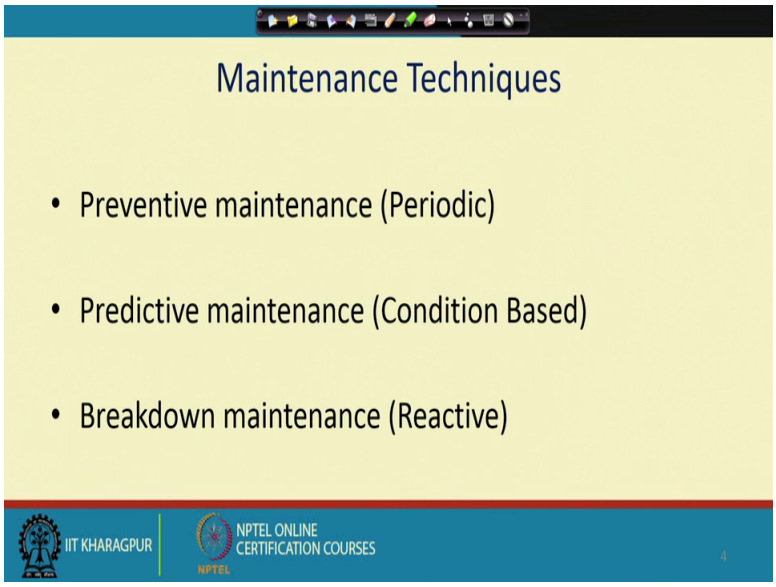

Well there are different techniques of maintenance available to as today; one is the periodic maintenance, another is the condition based maintenance and the reactor

maintenance. So, periodic maintenance is something which is also known as preventive maintenance that religiously without implementing any sensors on the machine, we religiously do a service or maintenance on the machine.

For example, I will give an example is the oil change which we do it in our vehicles; be it a two wheeler or a three wheeler or a four wheeler. We go every 5000 kilometer, if they OEM manufacturer has told that you go and change the oil, we go and change it whether we do not care whether the oil is good or bad.

Of course, we know things today are changing that in many of these automobiles they have; what is known as an onboard diagnostic module. So, we will do maintenance only when the system tells us to do maintenance. Particularly in the defensive applications where periodic maintenance is done, there we know we always ensure that religiously we maintain our system so that they will perform, whenever they are called for form.

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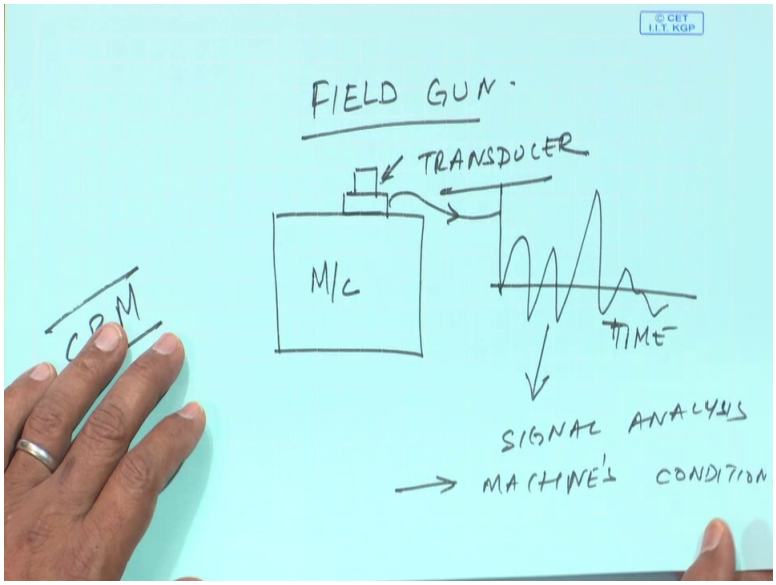

For example a field gun; so, when the commander or gives the instruction to fire the gun, the gun should fire; it should not misfire because it was never maintained and that should not be the case. So, for many of the strategic applications we still do periodic maintenance whether that gun required maintenance or not; is a material because it could be expensive it is not a concern, but the gun should fire always. As opposed to today in the industry, we do what is known as predictive maintenance.

We will understand the machines present health condition. So, this is my machine; so I will put a transducer on this machine and then get some signals in the time domain, some signal. Analyze the signal and then try to find out from a signal analysis, what is the machines conditions? And this is my transducer.

Now, this is what is actually done in CBM or known as condition based maintenance. And in fact, in this course on machinery for diagnostics and signal processing; we will be actually talking about how CBM is done? We will talk about these transducers; what kind of analysis needs to be done? So, this is what needs to be studied in this class.

And then there is the third type of maintenance is what is known as the reactive maintenance. Reactive maintenance is a maintenance; when we do no maintenance at all, we will only maintain it when it has failed.

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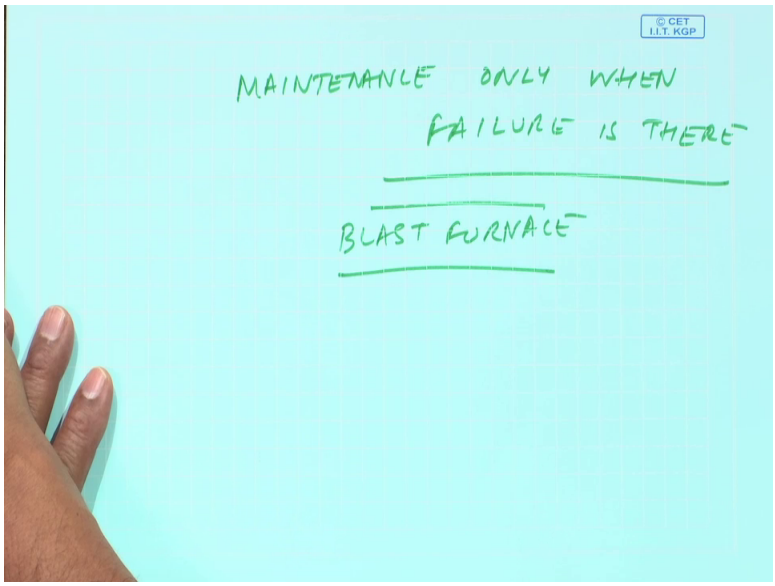

Maintenance only when failure is there, imagine I will give you an example; say we have a; I always give this example in my class. So, we have a large steel plant where the critical component is the blast furnace; I need to maintain that blast furnace with all my resources best resources available, but the same amount of effort which are given to the blast furnace; obviously, I will be never giving that kind of maintenance efforts to the maybe the water cooler in the cafeteria of that steel plant.

I can afford to not maintain the water cooler of course, I have to make sure the water quality is good, but in terms of you know if the water cooler has failed, I did not revive it. I did not replace the compressor; it would not be wise, I can just go ahead go ahead and replace of water cooler and that is an example of a reactive muffler.

I will give another example; we all use a ball pen, some sort of pen. We never try to maintain to find out how much ink is left in the jointer of this pen. If the refill is exhausted, we get a new refill and that is kind of an example of reactive maintenance because the pen is out of the refill, refill is the exhausted; we replace the refill.

So, in the long run reactive maintenance is done only when the criticality is the minimum and then the efforts, the costs are negligible compared to the other two costs.

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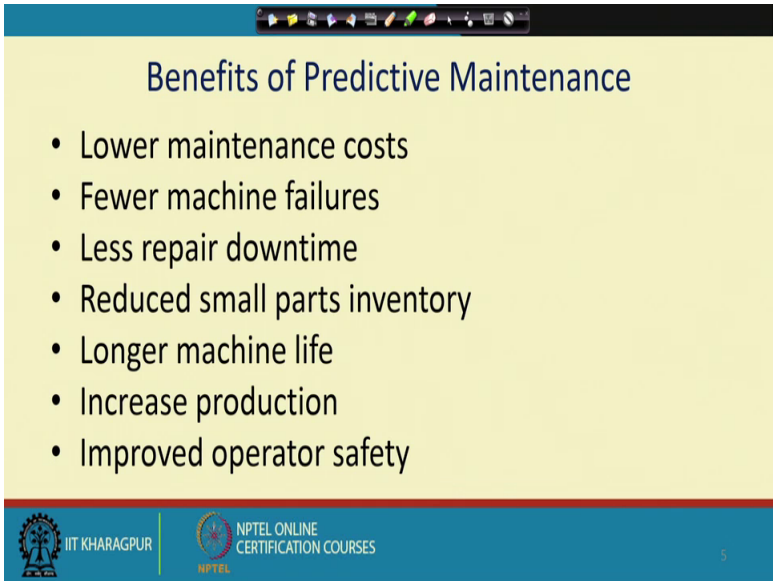

So, as I was telling you in this course; we are going to focus more on predictive maintenance because this predictive maintenance means that every time I am monitoring the health of the machine, it will have lower maintenance cost because I know the condition of the machine, I will know; I will have fewer machine failures because I have always maintained it. And then of course, because the maintenance is been done always; I will have less repair downtime; because I know which component is going to fail and so I could be prepared; I could just store the critical spare parts in my inventory and thus I will have a longer machine life and an increased productivity and improved operator safety.

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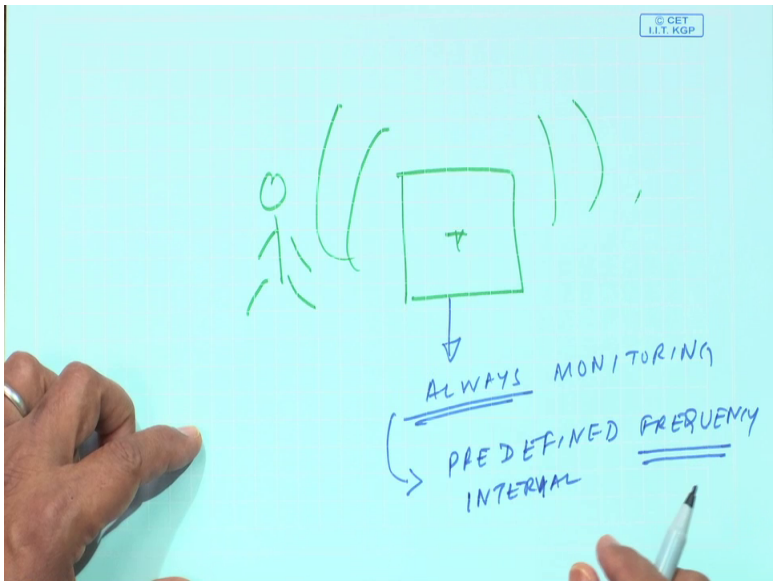

Imagine if the machine was never maintained and then suddenly you send an operator next to the machine and for some reason, the machine blew up. Because it was in a condition so bad that it almost failed and then components flew apart. I know cases where in machines were not maintained, the gearboxes are blown up in the middle of the night and then they have affected the workers.

So, these kinds of effects will be controlled if I am always monitoring the health of the machine; when I say always is it every instance? Or at some frequency some predefined frequency that depends frequency interval and this frequency interval is related to the criticality of the machine.

Some for example, patient in ICU this is always monitored round the clock 24 by 7, but on a patient in a normal bed maybe know doctor visits twice or four times every day. So, you can understand depending on the criticality of the machine, this frequency interval can be changed on which we are doing monitoring health of that machine.

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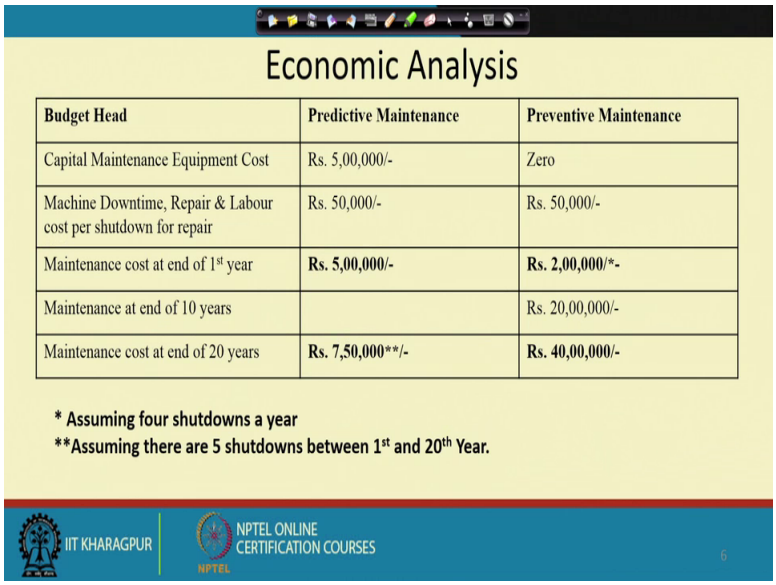

I will give you an example as to why; which one is beneficial in the long run; we are comparing here predictive maintenance and preventive maintenance. As we start in day 1; the predictive maintenance, there is a high involvement of the capital equipment cost; as an example of which I am giving you; initially I have to invest 5 lakhs and this could towards what is known as the additional transducers system sensors, which has to be put as opposed to no transducers put in the preventive maintenance.

So, initially at the beginning of the year; I would have invested nothing in the case of preventive maintenance, but I would already incurred an additional 5 lakhs. Just as an example for each downtime of the machine, the repair and the labor cost per shutdown for repair if it is 50000, it is same for both the cases. So, if I first look at the preventive maintenance; assuming I do regularly four shutdowns a year; every quarter there is a shutdown.

So, in the first year I would have invested; spent about 2 lakhs for doing preventive maintenance, at the end of 10; years I would have spent 10 times 2 lakhs; 20 lakhs, at the end of 20 years; I was spent 40 lakhs; on that same machine if I was being preventive maintenance. But if we look at the predictive maintenance because as I was telling you predictive maintenance will only be done; maintenance will only be done when the signals are analyzed and we have come to a conclusion that a machinery maintenance needs to be done.

And then at the end of 20 years; I would have only spend 7 lakh 50 thousand because there is an assumption that there are only 5 shutdowns between the first and the twentieth year. This is an figure which has been obtained from industrial service, so you see at the end of 20 years; in the long run my predictive maintenance or condition based maintenance, I would have only spent 7 lakh 50 thousand; whereas, my preventive maintenance I would have spent only 40 lakhs.

So, in the long run predictive maintenance pays, it is much cheaper, but initial investment costs are high. We will also required trained manpower to analyze the signal, but nevertheless today the technology is such that the machine learning which we will be talking about later on. Even once we have transducers in place; signals can be acquired, analyzed and the conditions of the machine can be known and corrective measures could be taken and this is why CBM is done.

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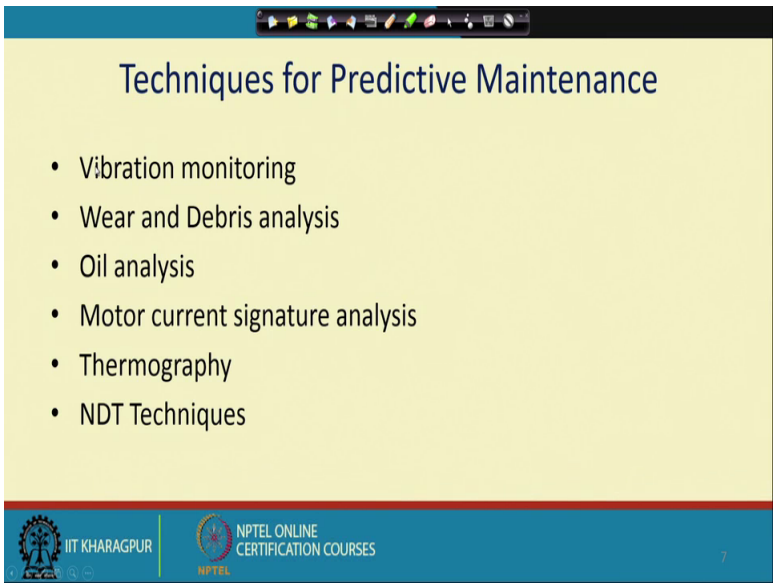

What I was telling right in the first class, what are different techniques of predictive maintenance or condition based maintenance available to us today?

Mostly the predominantly, the predictive maintenance technique available to us today is the vibration monitoring; 72 percent of the industries throughout the world do vibration mounting and in fact, in this class that is why I was telling you and the beginning as a prerequisite, it would be good if I have already had some knowledge on vibrations; machinery vibrations and I am sure those of you who are coming from undergraduate

colleges, we have in your final year as many times as a core or an elective courses on vibration; which will be helpful to understand machinery condition monitoring.

And then we will talk about; these are again two popular techniques of wear and debris analysis and oil analysis. As you will see in machines, there are a lot of beating parts beat; bearing or comprehend sliding against each other and they press onto each other.

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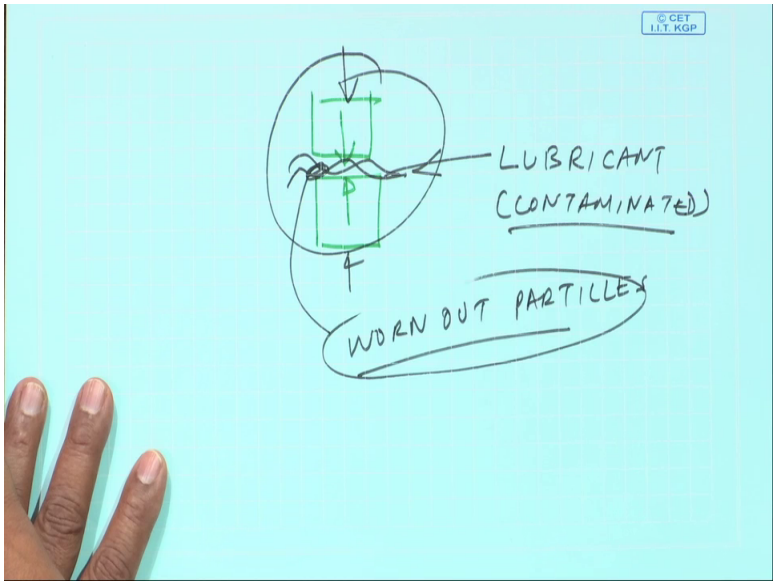

So, we put earlier of lubricant; so because of this forces particles will get worn out and get deposited and the lubricant also gets contaminated. So, the level of contamination of the lubricant and the composition of these worn out particles; gives us some clue as to the condition of the machine. And this is what essentially is done in the wear debris analysis, these are the contaminants which could be analyzed where chemical composition known.

And then we have the oil analysis, their physical property etcetera is going to change and this is what does called in oil analysis. And these wear debris and oil analyses almost twenty percent of the industries use this and the other remaining techniques of the motor current signature analysis, thermography NDT techniques are also around the 10 percent.

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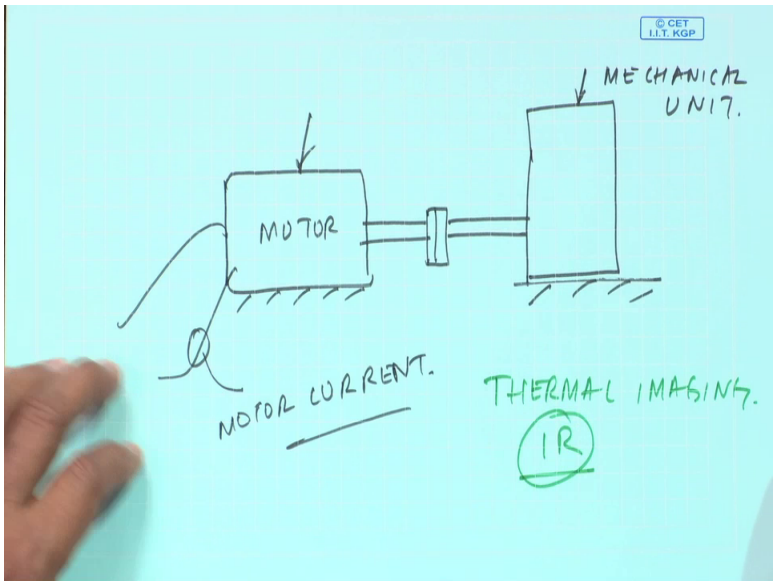

I was just telling you in motor current signature analysis is any electrical motor, which is driving. This is a motor through a coupling which is driving a mechanical unit; so, if a fault occurs in this mechanical unit; I could understand by analyzing the motor current. We can of course, understand the condition of the motor; we can also understand the condition of the mechanical unit. And that is what we will be covering in motor current signature analyzes.

Thermography is another area where in through thermal imaging because everybody radiates IR radiations; Infrared Radiations.

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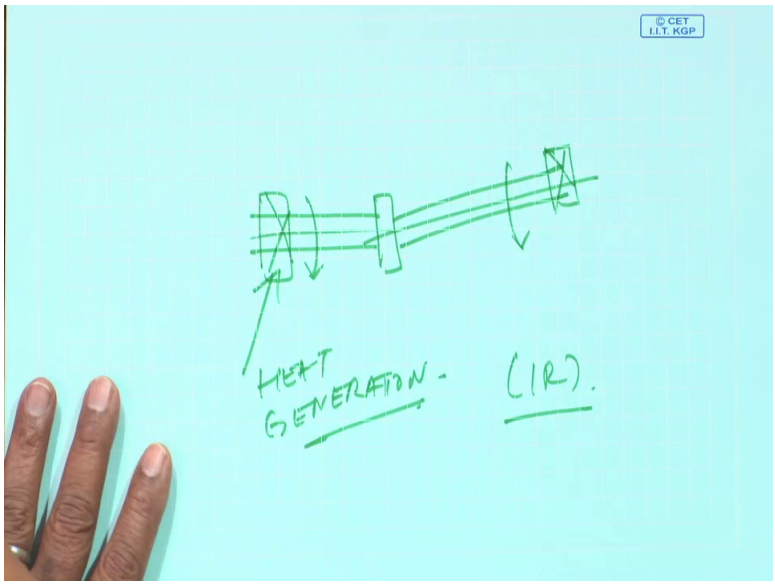

So, by measuring the infrared radiations we can measure the temperature of the surface. If there is a shaft which is misaligned and this is supported on bearings because of this misalignment forces, there will be an friction; Additional normal load on the bearings and because of the friction, there will be lot of heat generation. And this heat generation can be measured through IR radiations. So, this thermo graphic gives us an indirect measure to find out the condition of the machine. And then we have another technique, which I was telling NDT techniques.

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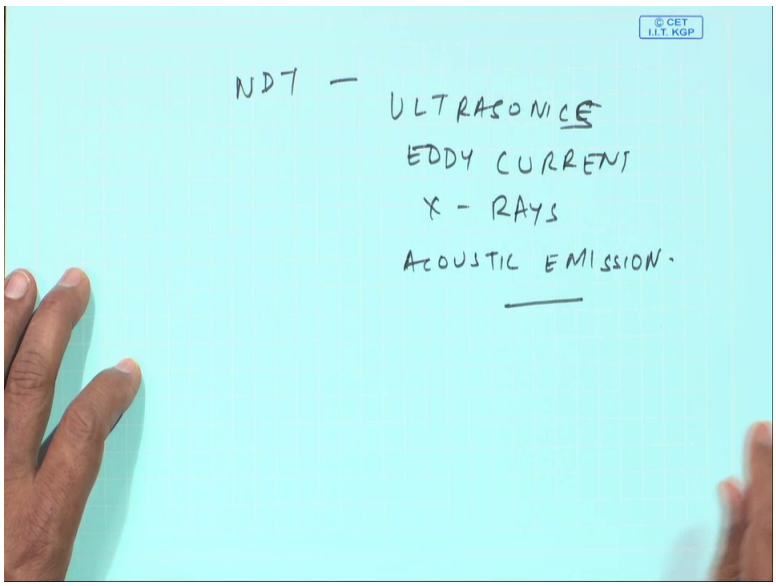

There are different types of NDT techniques like; ultrasonics, eddy current, X-rays, acoustic emission; these are not so much used for online health monitoring or online condition monitoring, but they are actually used for quality checks on the type of welds. Many of the nuclear reactors when the components are welded, they have lot of redundant checks by ultrasonics, by X-rays etcetera, boiler tube conditions, thickness measurements, internal crack detections. So, these are some areas or structures which are done by entity techniques.

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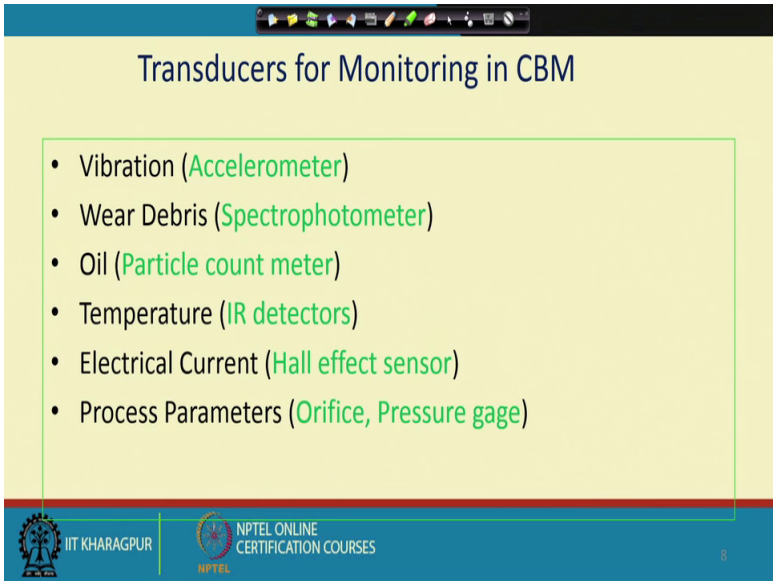

And as I have told you in CBM or condition based maintenance, all these written in black vibration, wear debris, oil, temperature, electric current, process parameters; these are the mechanical parameters which would change with machines condition and we need to put transducers in place to measure the condition of these signals. And then we will be talking about these transducers or equipment later on, when we talk about instrumentation.

So, we need to study these parameters measure first is measure them, analyze them and come to a prediction of the condition of the health of the machine, diagnose its fault and so on.

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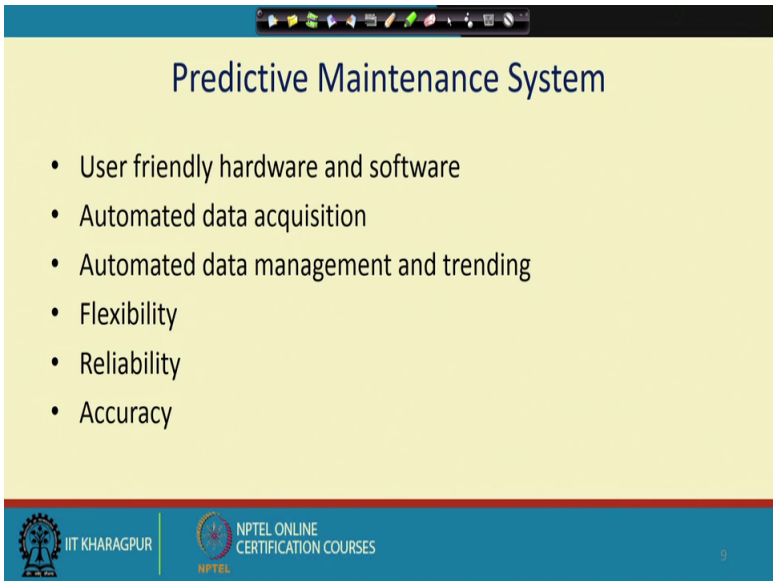

But a predictive maintenance system today; has a lot of hardware in it, hardware are essentially the transducers and then there has to be a automated data acquisition system so that all the sensors, all the signals from the sensors coming to the system and then there has to be a software. The same system today is being in the steel plant, the same one could be used in a paper mill, in a cement plant, in a ship, in an aircraft.

Of course, automated there is a lot of data coming in; there has to be automated data management and trending. And then there will be; it has to be a flexible, reliable and accurate.

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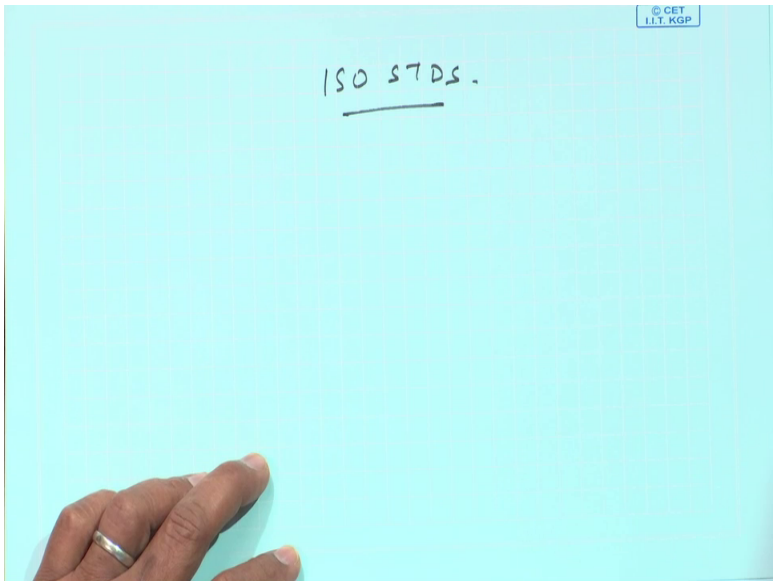

So, such software systems are available and then there are many ISO standards available for such software's. I will come to the standards later on, when I talk about the different software's used for machinery condition based maintenance.

So, in a nutshell you know the different techniques of CBM maintenance in particular the periodic maintenance or the preventive maintenance. The condition based maintenance or the predictive maintenance and then the reactive maintenance or the breakdown maintenance. And then scores on machinery for diagnostics and signal processing will be actually covering what is this predictive maintenance and what are the techniques to measure the signals out of these machines, how to analyze them and how to come up with solutions to diagnose and perhaps also (Refer Time: 26:12).

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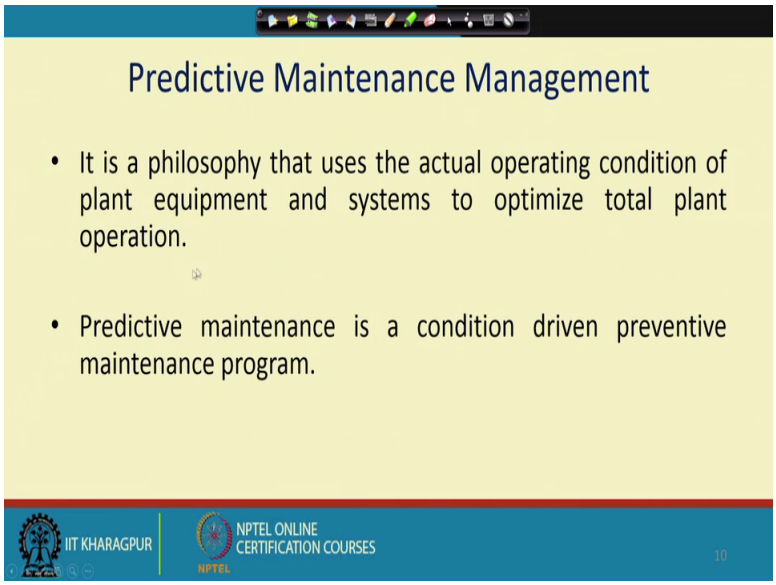

So, a predictive maintenance management is a philosophy that uses actual operating condition of the plant equipment and system to optimize total plant operation and predictive maintenance is a condition based preventive maintenance program.

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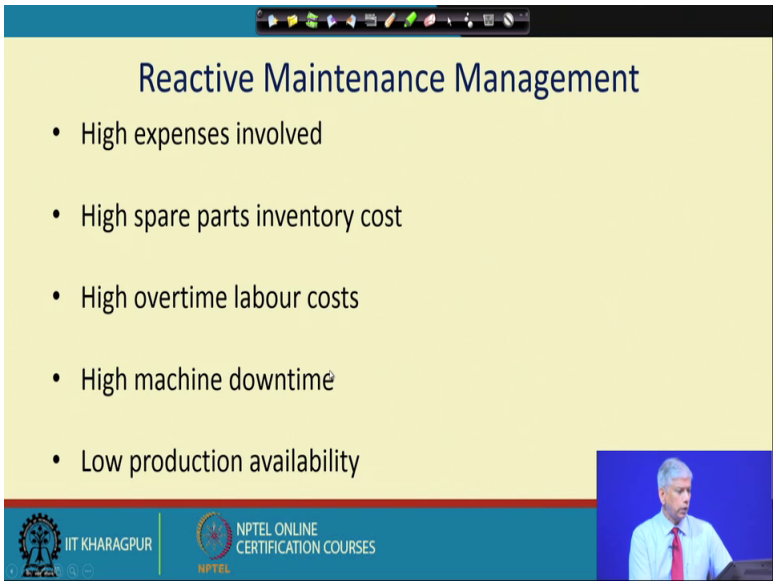

As opposed to reactive maintenance, we will have high expenses involved, high spare parts involved and so on.

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So, requirements of a successful maintenance program will have the all these features.

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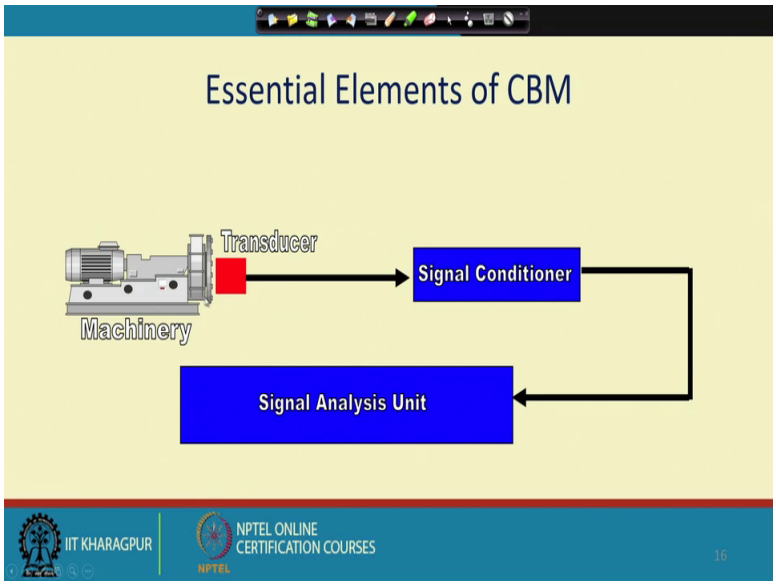

So, in the CBM we have machines, transducers, signal conditioners and the signal analysis unit; so, we will be covering this in details.

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And today CBM is used almost everywhere.

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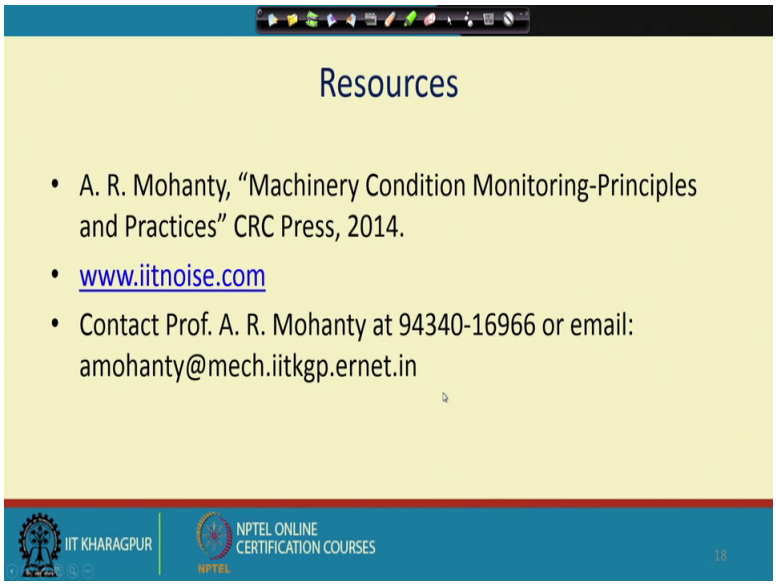

And towards the end of this course, as I was telling you there are resources available for this course in my book and I have a website.

Thank you.