Machinery Fault Diagnosis and Signal Processing
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Lecture - 49
Wear Debris Analysis

Yeah, in this lecture, we want to talk about altogether new area again which is known as the wear debris analysis, you know right in the beginning of this semester or this lecture series, I had told you that usually condition monitoring is done by vibration, then we had a technique called wear debris analysis which is nothing, but the contaminant analysis and 20 percent of the cases in the world, actually, use wear debris analysis.

Wherein, they analyse the lubricating oil and find out the properties of the oil and also the get a clue as to the failure mechanism or the wear and tear mechanism the machine because by studying the composition of the debris which have got deposited in the oil.

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Tribology is nothing, but the study of friction lubrication and wear.

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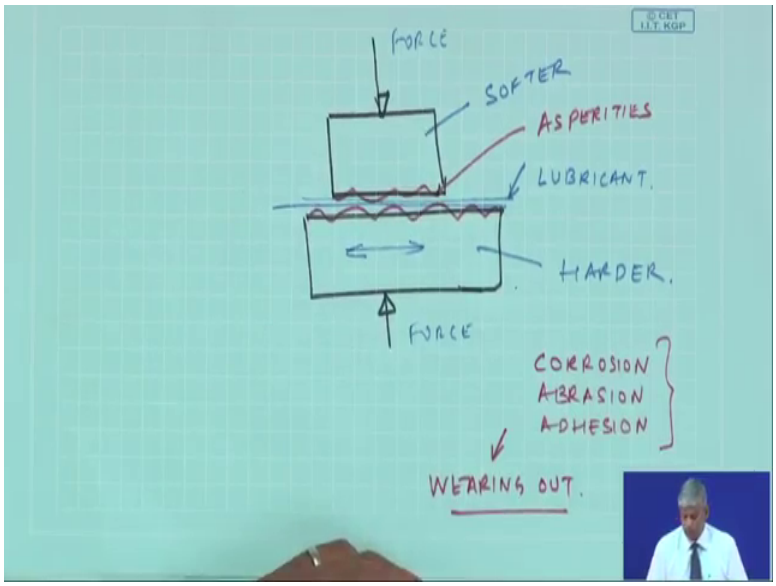

So, what happens you will all realise that where you are talking about machines may be two members are coming in contact with each other, but the surfaces are really not smooth. So, there are source some asperities and to reduce the friction, we put layer of lubricant and because of this force and they could be sliding.

So, mechanism of sliding under the application of pressure may be another thing, one is softer material, one is harder. So, in while you design a machine, you will come across a scenarios. So, what happens because a forces because one being hard one being soft because there is surface roughness's, there is a lubricant, on top of it, there could be corrosion ok, corrosion on the surfaces, there could be abrasion, there could be addition, these will give raise to this surfaces wearing out wear out occurs ok.

So, where do these wear particles go? So, the wear particles will get deposited in the fluid medium.

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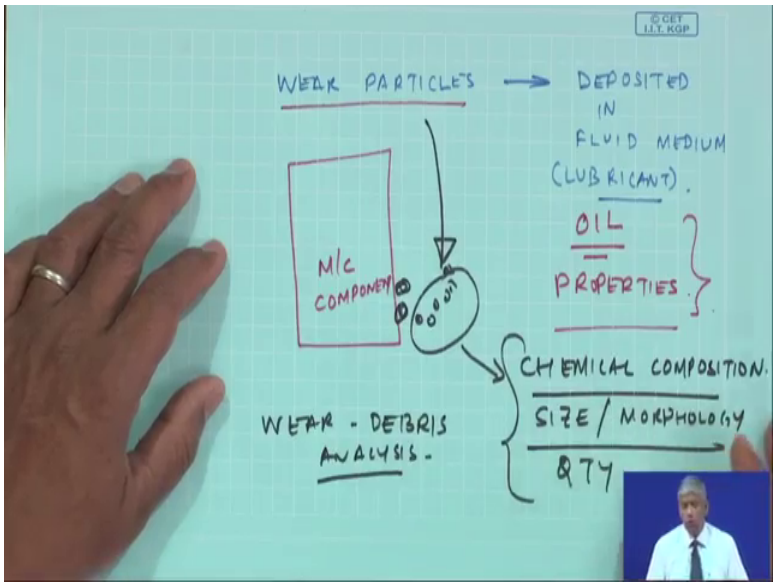

The fluid medium is lubricant. So, in the process, what happens the lubricant also get spoiled ok, lubricant are be can tell, it as oil. So, oil will also get contaminated. So, all something will the oil properties would change ok.

So, we will study about the oil properties in the next lecture that is on oil analysis, but even these wear particles because they have worn out from a parent material because this is my component machine component and this is because of friction and wear and etcetera, these particles are flit out. So, these are the wear particles and they will get deposited in the oil.

So, studying these wear particles, their chemical composition and their size, their morphology, their quantity. So, all of these give us a clue as to what is the condition of this machine, from where this wear particles have come up and this is essentially what we are going to study what is known as wear debris analysis.

So, this need not be done real time, the recently some developments are happening to do a wear debris analysis, real time by focusing on a camera system looking at the images of the wear particles and you can analysis in real time people, also can get an ideas as to wear debris analysis, but for our sake of discussion, we will say that all you need to do.

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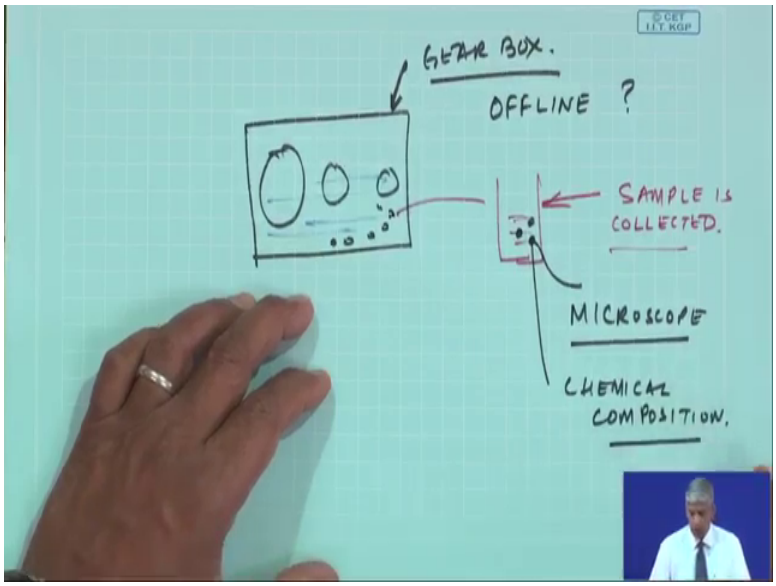

Suppose, I have a large gearbox, is a gearbox in outside and there is lubricant taking oil.

By now we have studied, but by putting a wires and transducer and doing an real-time signal analysis in situ measurements, I can find out faults, but sometimes it. So, happens these gears will wear out and they also these wear particles will get deposited. So, the oil gets spoiled, but looking at this the chemical composition the size. So, the wear particle the shape the quantity we can get a clue as to what is the condition of the gearbox and this is usually done offline.

So, who does this so. In fact, wear debris analysis it all depends on all the address collect a sample is collected and then we can if you are looking for wear debris we will look in to this particles under microscope sometimes the particles are so small, then microscopes are not good enough.

So, we have to look under a little high magnification and then how do we also need to know the chemical composition on this. In fact, you know every compound or sorry every element when heated or ionised ok, they will the electrons will jump from an orbit at their characteristic frequencies.

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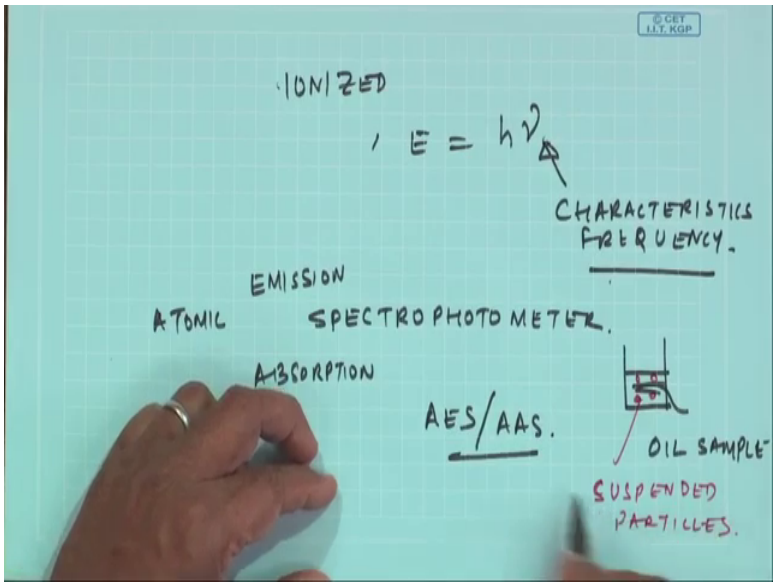

So, if we have a spectrophotometer which can measure the energy of these electromagnetic radiations at that characteristic frequency, I can know what kind of chemical element is there. So, such devices are known as spectrophotometer. So, one is an atomic emission another is absorption.

So, AES and AAS and these are very costly lab type of equipment. So, they cannot be carried to the field and so other way is we have to get that oil sample in which these particles are suspended like a colloidal solution and we can see the chemical compositions characteristics, one is the quantity.

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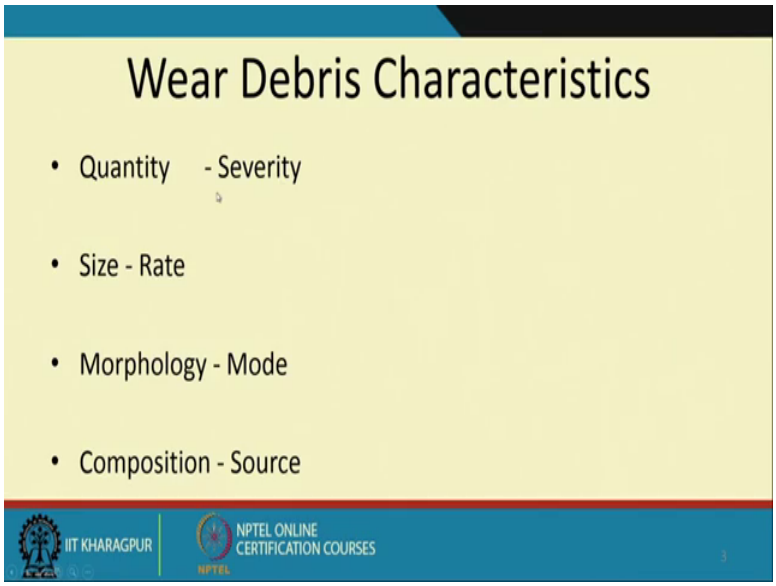

So, how do I know the quantity, there are devices by which you know we can see the particle count in terms of by a laser devices we can measure the particle count through an optical technique.

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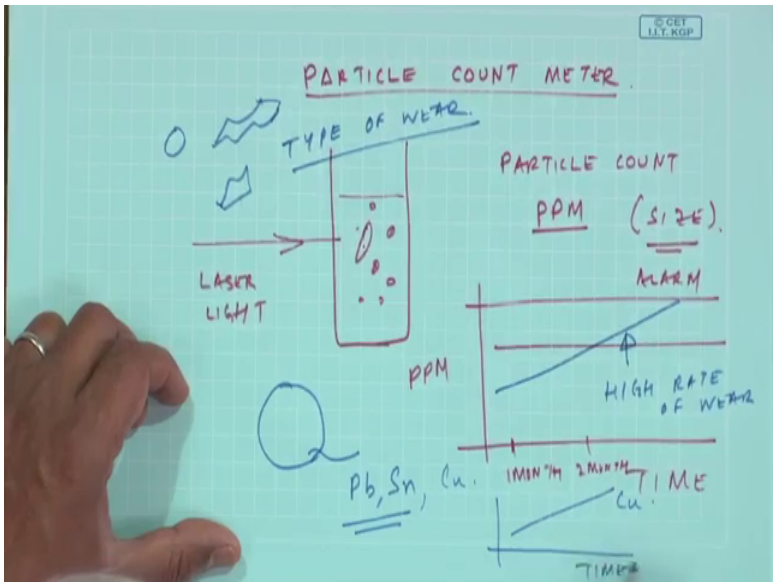

Suppose, I have a particle and then there are particles suspended in the fluid, if I shoot a laser beam and depending on the size of this particles in a given volume the energy will get reflected from this surfaces. So, I can have a clue as to the particle count in a given volume; so, parts per million of a particular size. So, such particle count meters are

available which can give us an idea as to what the; what is the amount of particles of a different different sizes.

So, we can have a filter allow or light of certain diameter to pass through and so, on and light beam and then this quantity changes with time PPM with time. So, this will; obviously, give me an indication that high rate of wear is occurring as opposed to this. So, this is an; we can have an alarm conditions and this is not real-time know maybe this is one month every month or every quarter I am doing this because they are expensive no we cannot.

So, all I do is you know every quarter enough, here I pick up the all sample do this particle count and if I see that this wear high rate of wear is increasing the parts per million is increasing of a particular size I know something is going wrong with this gearbox.

So, this is just to give an example, how wear debris help us get a clue as to the wear rate and as to what is wrong with this machine severity of the defect is that suddenly wearing very fast or if there are in foreign component, for example, dirt has got into the system and of course, the wear particles you know some particles, we will see later on some are circular some are like plate some are sharp edges ok. So, this also gives us the morphology, gives us an idea as to the type of wear and composition, suppose you know, we are talking about the journal bearing there is Babbitt material has may be lead or tin etcetera or copper ok.

So, if I see a high rate of you know maybe copper increasing with time, I know my which it normally should not be I know well my bearing lining is feeling wearing at a high rate. So, this kind of observations can very specifically to a particular element only be done with wear debris analysis because if we think of a journal bearing monitoring at most, I can measure through vibrations that the clear ends has increased or decreased, ok.

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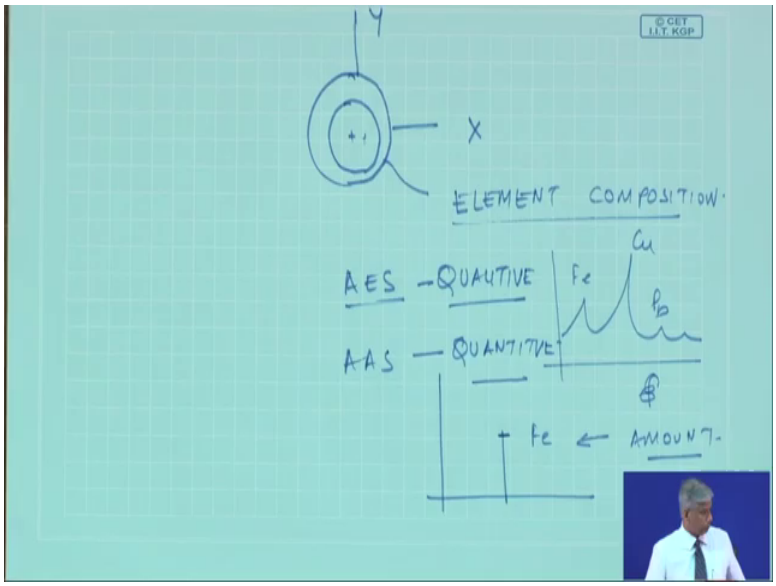

The gap has increased or decreased to an id current probe if this gap has increased, but the composition element composition can only be done through a spectroscopy.

So, coming back to the discussion of atomic absorption spectrophotometer; so, in this, we can measure the all the elements which are coming out of this spectrum depending on their element may be copper ok, but the atomic absorption spectrophotometer which can be calibrated to know the actual amount of the particular element.

So, you will get a qualitative assessment of the type of elements present, but in atomic absorption it is calibrated I can get a quantitative estimate of the type of element present in the wear debris samples.

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So, by now you get a feel that in machines when there are mating pairs and this kind of wearing mechanisms can occur.

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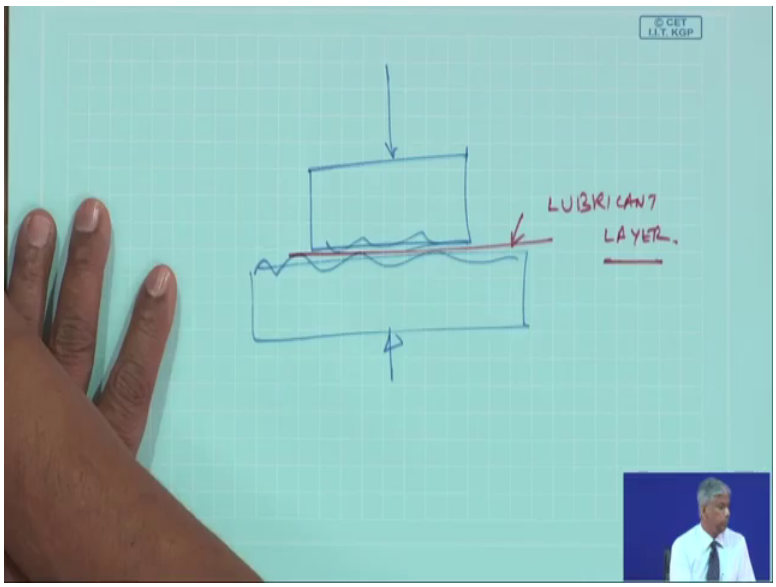

This is my lubricant layer. So, there could be addition there could be abrasive or cutting wear delamination fatigue after delamination occurs in composite materials fatigues corrosion or oxidation wear and electrical attack acid attack ok.

So, all these will lead to particles getting deposited in the wear. So, we will looking at the particles get a clue size shape quantity and of course, the composition will give us an idea as to what is wrong with this machine and this can be done in a very timely manner.

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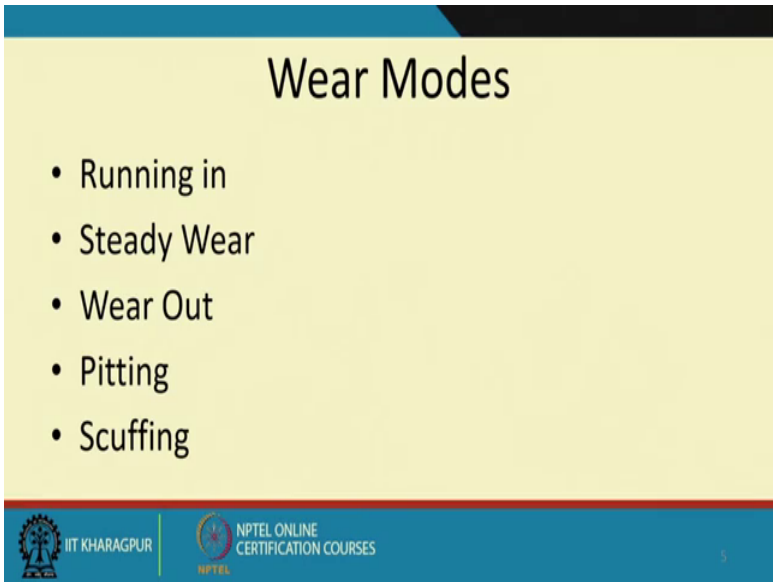

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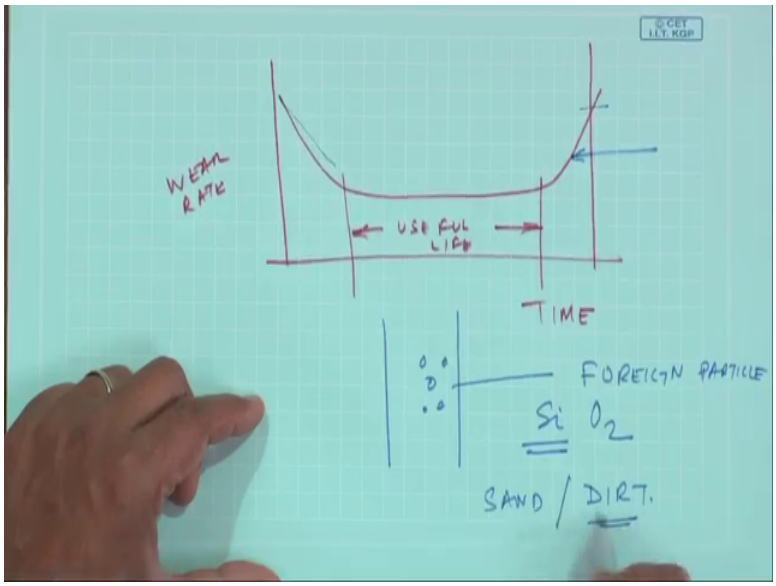

So, some of wearing modes you know you recall the bath tub occur with time wear rate and which we are defined this as the useful life period. So, the initial run in where we have an high wear rate and towards the last time the end of the life of the machine we have a high wear rate ok.

And you will see the surfaces there could be pits develop there could be coughing and sometimes also there could be foreign particles usually silicon because you know the silicon dioxide sand dirt ok, they can get trapped in the lubricating oil because of very bad environmental conditions and dust environment.

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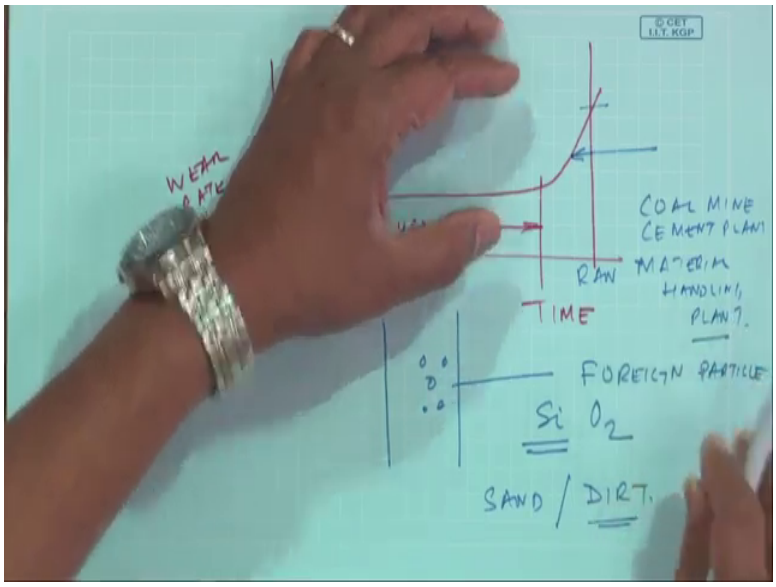

So, for example, in coal mine cement plant in a material handling plant raw material handling plant by the way in all these plants the bearings are actually seals ok.

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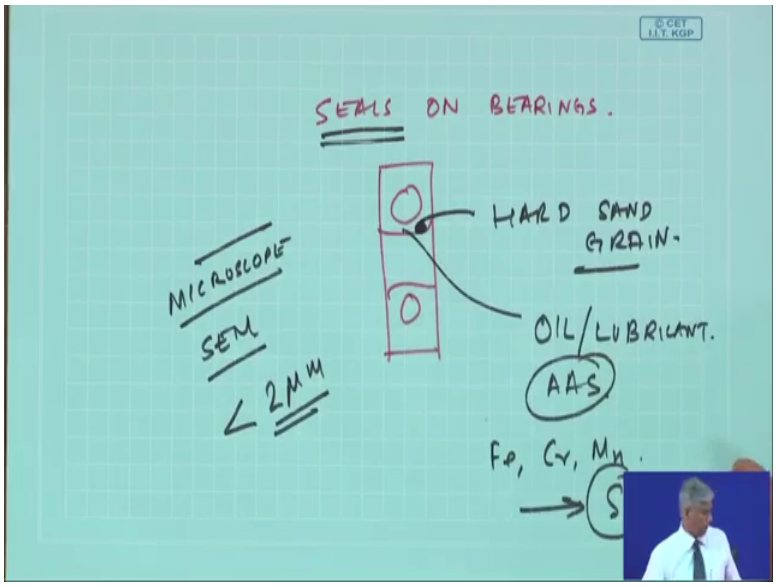

So, seals form on bearings because imagine, I have a bearing and one foreign particle gets trapped hard sand grain. So, this is going to score the races and it will form lot of pits. So, this has to be avoided.

So, if I somehow this silicon has entered if I take the oil or the lubricant and do AAS of that I can find out what whether silicon represent. So, I know in a metallic compound had iron may be some alloying element, but you know, I will be wondering where from the silicon came because to begin with the parent machine did not have silicon's already come. So, this is where AAS or spectrophotometric helps us finding out this chemical elements.

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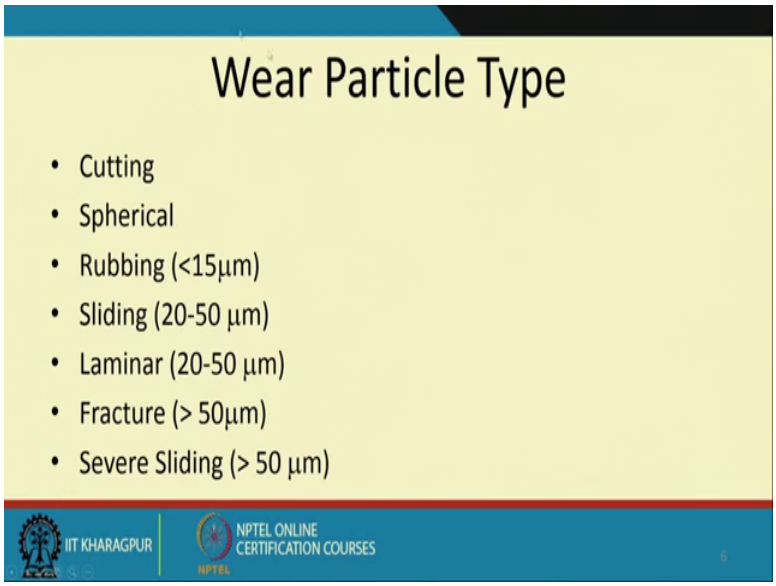

So, depending on the wear particle type there will be different sizes of this some the cuttings spherical or rubbing wear you know typically the sizes are very very less, may be 2 hour you know if you if you rub in your hand, the oil you will find that it is feeling rough of. So, this roughness is because of this wear particles are getting in the oil.

So, to measure them, we have to look under microscope sometimes high magnification is required because you know, I am I do not recommend scaling electromagnetic scope, but is the sizes are less than two micron may be SEM can be used.

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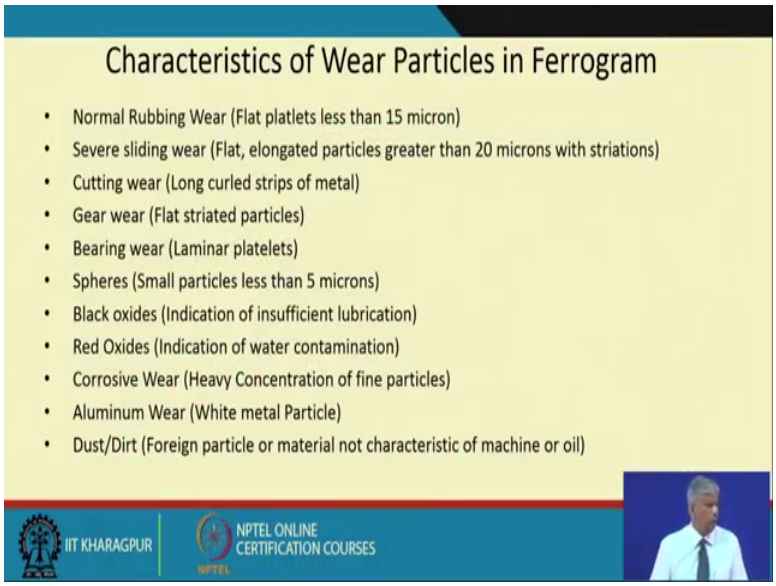

Now, depending on the type of the particles for less than two microns we can do spectrophotometric.

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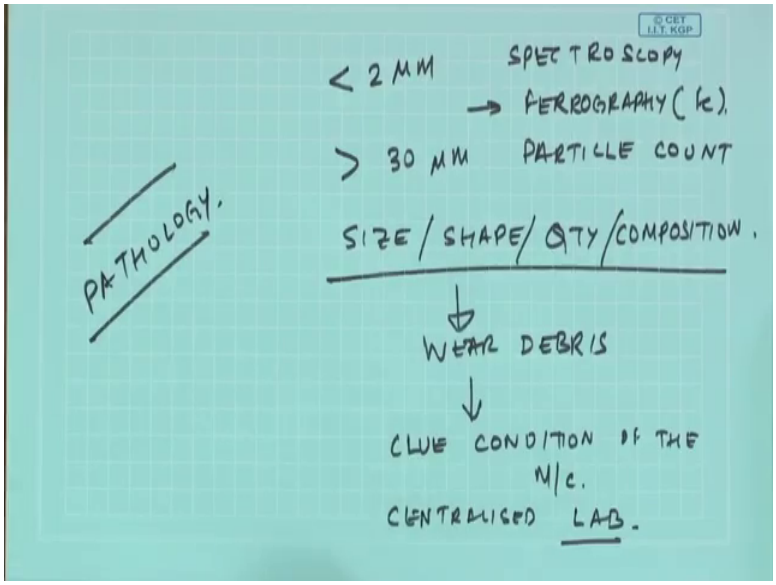

And more than 30 microns we can do just particle count sometimes inside is known as the ferrogram, but this is only good for ferritic or iron surfaces.

So, normal rubbing wear will be having flat plate less than 50 micron severe sliding wear flat elongated particles greater than 20 microns with striations cutting wear long curled strips of metal gear wear flat striated particles and so on bearing wear laminar platelets

spheres small particles less than five microns black oxides indicate insufficient lubricant red oxides indicate water contamination corrosive wear heavy concentration of fine particles aluminium wear white metal particle dust or dirt foreign particle or material not characteristic of machine or oil.

So, these as I was telling you very important words size shape quantity composition help us study wear debris and this gives to clue as to condition of the machine see unlike the vibration monitoring where you required a very train signal processing person or a software here in wear debris analysis, all we do is just collect the oil sample give it to a centralised lab and they will do the all the tests.

So, this is like a human pathology lab pathology of the machine ok, like you give your urine and blood sample for analysis, similarly, here we give the oil sample where we look into the wear particles.

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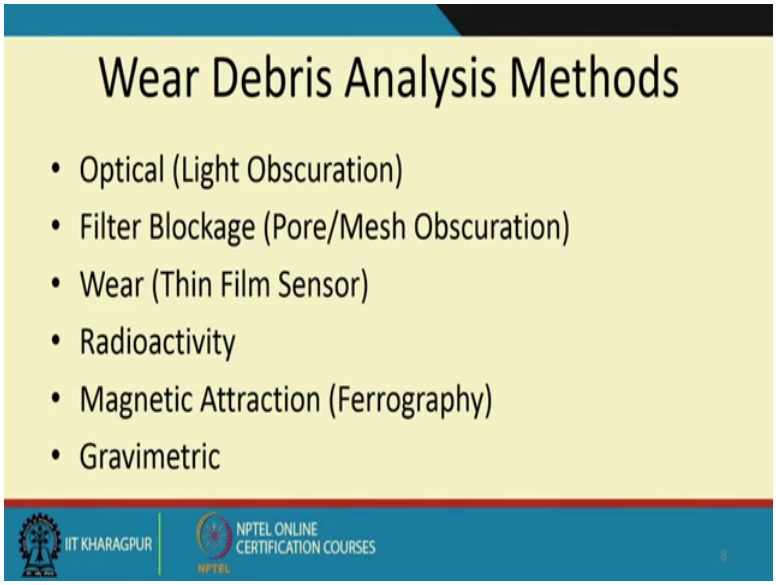

So, some of the wear debris analysis methods optical or the filter blockage, so, you know of course, there are also thin film sensors used to monitor the wear radioactivitys also been used and magnetic attraction because it is a ferrography ok.

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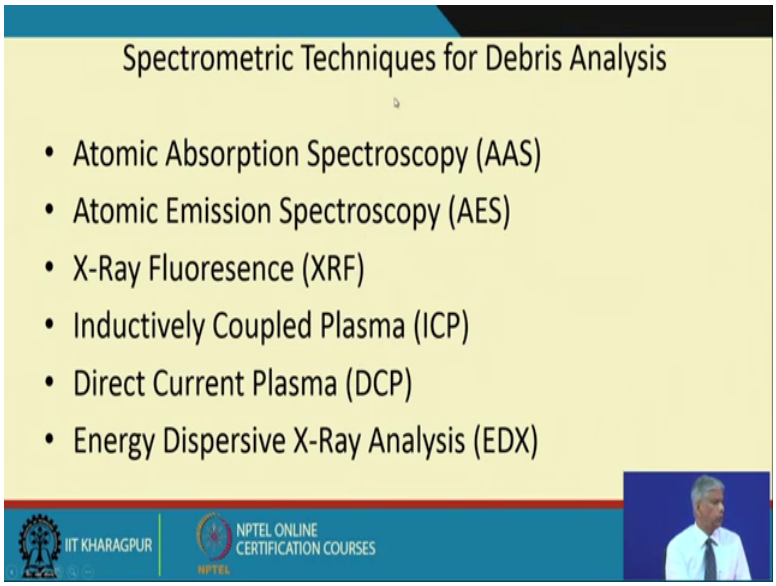

Some of the spectrometric technique used for debris analysis I just mentioned you atomic absorption spectroscopy or atomic emission spectroscopy XRF, SRD, ICP, DCP, EDX. So, these are some of the machines spectroscopic machines which are used for doing the analysis, but mind you they are very very costly couple of them could run to few crores or few less than crore.

So, these are very costly equipment and every plant need not have such machine. So, all you need to do is sampled the all and send it across.

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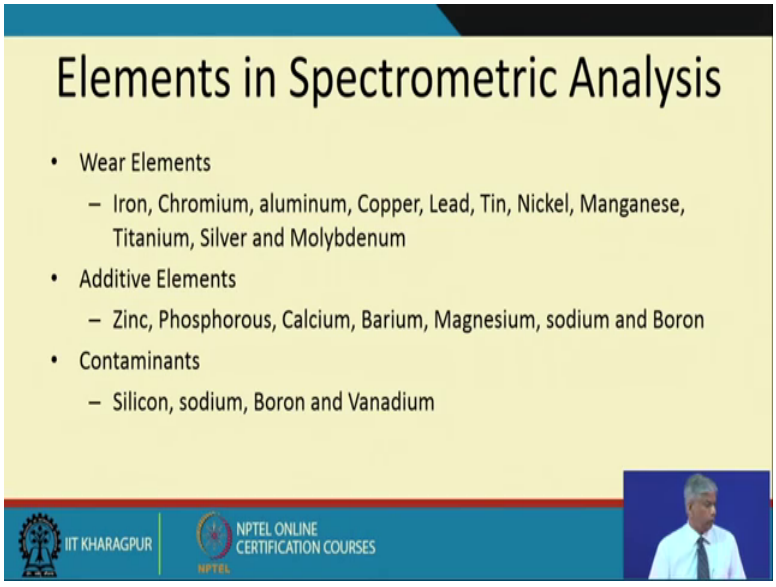

So, some of the elements in spectroscopy analysis we must know beforehand that these are the typical wear elements which we will find in any oil sample and some of this additive elements are used because of the composition and then the contaminants silicon is the most sodium and so on.

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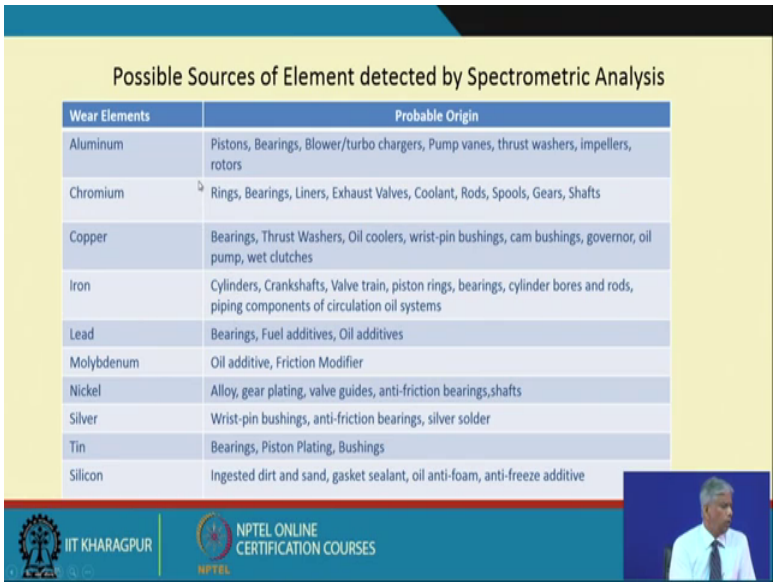

So, we need to have an idea from a materials point of few that every machine component or the what is parent machine component what is the material composition.

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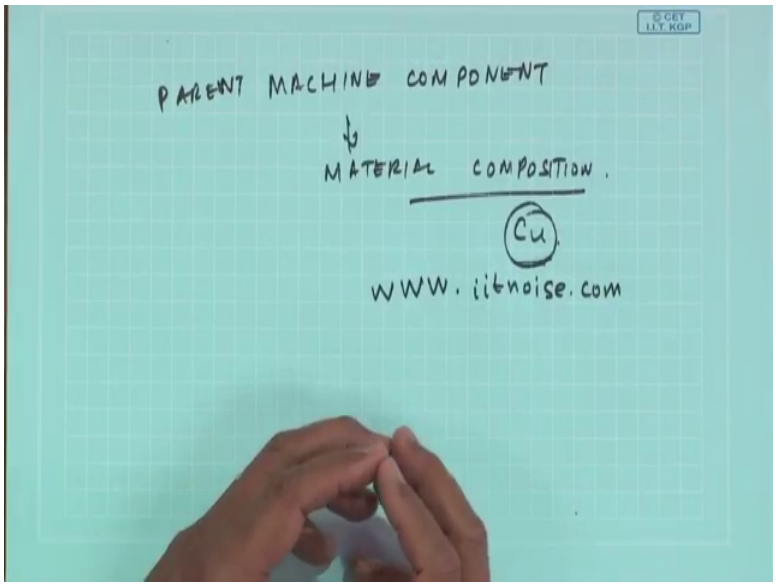

So, this will give us to a guide that if I see may be copper I know in a machine in a gearbox, I see copper will all be wondering you know in me in my first case perhaps there is no copper. So, where this copper come from maybe the general bearing in some bearing has copper because of the lining and then this copper came above.

So, typically wear elements and they are found in pistons aluminium and some pistons chromium in lot of this valves, etcetera, copper and bearings pin bushings iron, of course, every mechanical machine components as good amount of iron lead is use as an additive and bearings molybdenum was an oil additive nickel for hardening the surfaces valve guides anti friction bearing solders tins and bearings silicon ingested dirt and sand gasket sealant oil anti foam and anti freeze additive.

So, we can come down to the elemental level by spectroscopic methods and so, all we have to do is the amount of this element present in the lubricant or present in the oil because of the wear debris particles and how it came across into the system is what we need to study.

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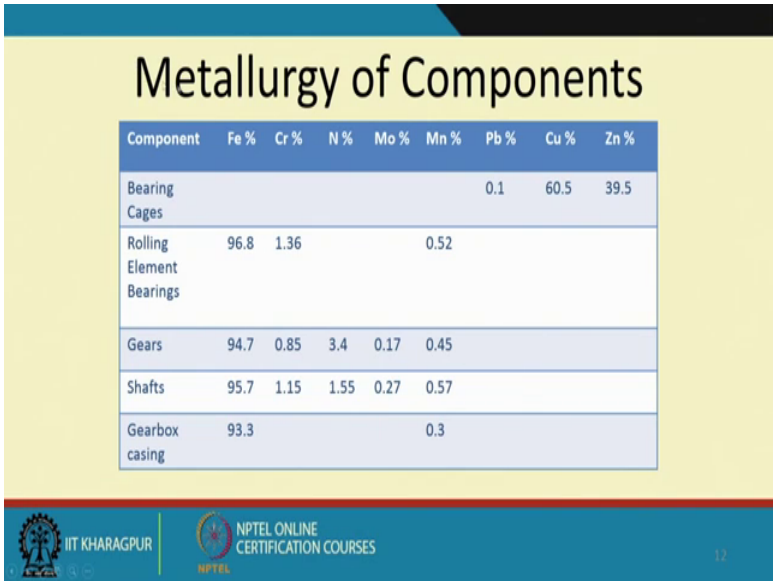

So, if you see the typical metallurgy you know rest all the iron here bearing cages usually copper and zinc rolling element bearing there is some amount of chromium and manganese gears typically iron shafts iron gearbox casing iron, but these trace elements for example, I see in a gearbox, I see traces of molybdenum or I will see traces of you know nickel or nitrogen.

So, I will know that some components has failed and if you if you go to my book, Machinery Condition Monitoring Principles and Practices, you will see the details in this website, few case studies wherein through chemical analysis, we have found out the composition and we can indicate whether the material to begin with was inferior a particular amount which should not be there was present and this also helps us.

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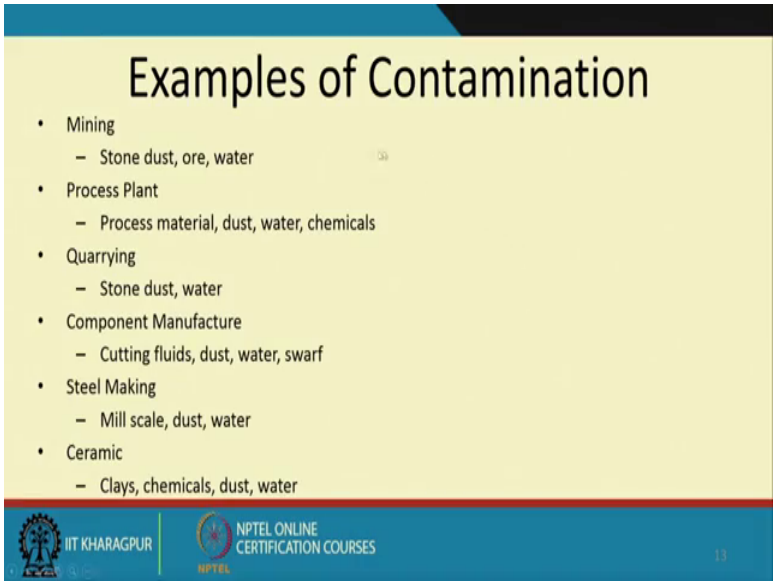

So, some of the examples of contamination are mining process plant query I was talking about you know querying stone dust water mill scale dust water. So, all these components will get deposited in the lubricating oil and then later on.

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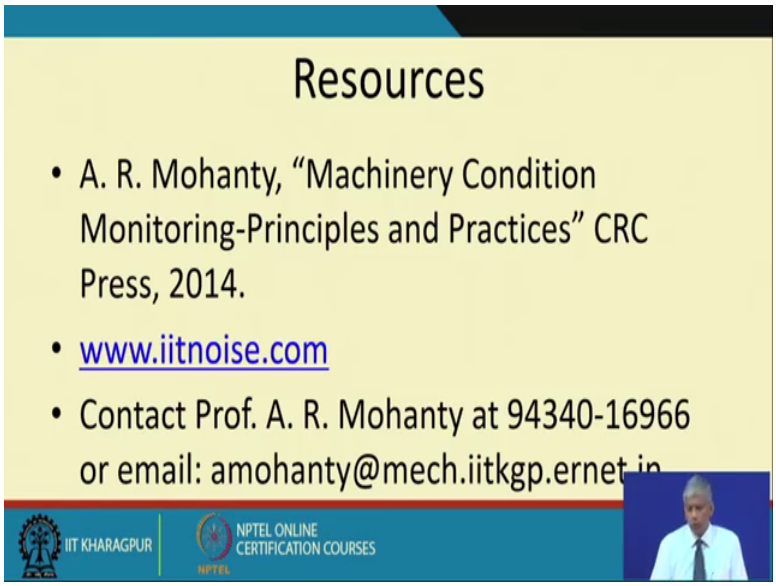

We will see how we can select this lubricating oil so that these contaminants do not get picked up and then we do not get a wrong indication of all like a false positive that something has gone wrong ok.

Thank you.