

Machinery fault diagnosis and signal processing
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Module No # 07
Lecture No # 32
Contaminant Analysis

So far we have discussed about machinery condition monitoring in the sense signal processing and then how through vibration monitoring we can able to find out faults in mechanical systems. Now we will begin the module 4 of this course where in we will be discussing the other techniques of machinery condition monitoring that is normally the where W analysis is known as and then we have the other condition monitoring technique like the motor current signature analysis.

And how non-destructive test NDT technique you know ultrasonic, the radiography acoustic machine also thermography are also used to find out faults in machine. Usually you know about 70% of cases are in condition monitoring are through vibration analysis and universally through out surveys in the industry it has been found that usually the that 20 % actually belongs to this category which will be discussing on today's lecture on contaminant analysis.

And then the subsequent lecture on oil analysis how basically we analysis the oil the lubricating oil. And the debris which are deposited in them by examining in them we can find out whether the machine detracting fast or slow and so on. So I will be discussing on contaminant analysis;
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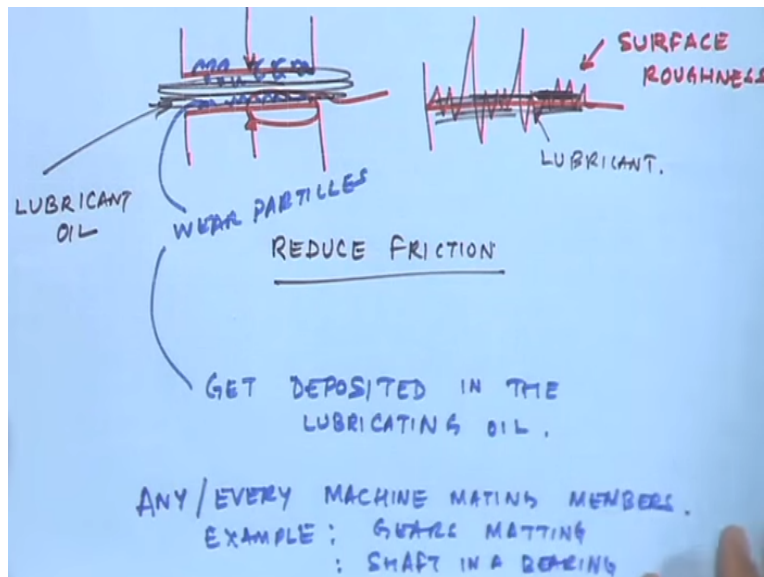
Tribology

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- Friction
- Lubrication
- Wear

As you know the tribology is study of friction lubrication and wear in mechanism or machines.

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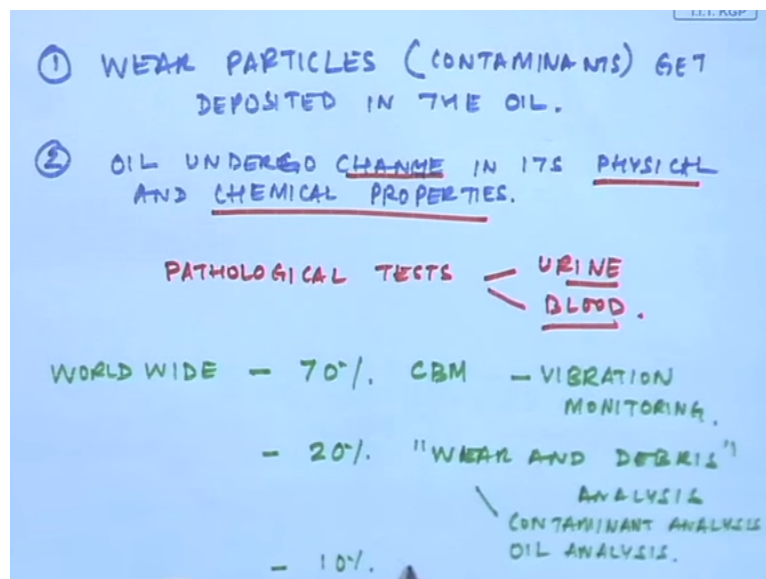
For example when we have two machine members attracting with each other there is on normal force on to them and this surfaces may not be smooth as I showed you in the case of the bearings they may have a surface roughness. And usually to and once this two components rub against each other because of an load we actually put a layer of lubricant okay. So the purpose of the lubricant is to reduce the friction because reducing of friction between two meeting machine members.

Means that the forces of the power to consume to move them will reduce because of the friction. Friction can be reduced by closing this asperities in these surfaces by having this lubricants here okay. But in the process what happens these particles here also were out okay because of loading because of ampersand so on. And these particles were particles get deposited in the lubricating oil.

So two very important things happens because of this process in machine so this happens in any or every machine matting members. Example gears matting shaft in a bearing could be bosch could be journal could be antifriction okay. So when two materials meet against each they rub against each other there will be lot of heat generation and one may be softer than harder the other so it is going to wear out.

Like when you have a eraser rubbing on a piece of writing you know this rubber flicks peel of the eraser okay.

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So what happens is two important happen number 1 because of such an process the wear particles or which we call them as the contaminants get deposited in the oil okay. So the concentration of the wear particles the nature of the wear particle the rate which they have been deposited in the oil gives us some clue as to what is wrong to the parent material from which they have worn out because of may be excessive load because of less lubrication because of temperature defects.

So these are factors which are responsible for the wearing out of these particles from the mating members. Now understanding where the wear particles came off from which can know whether parent material poorly designed was up the softer material I did not have proper treatment was not lubricated was not subjected to higher temperature. So these are the same scenarios which we need to investigate.

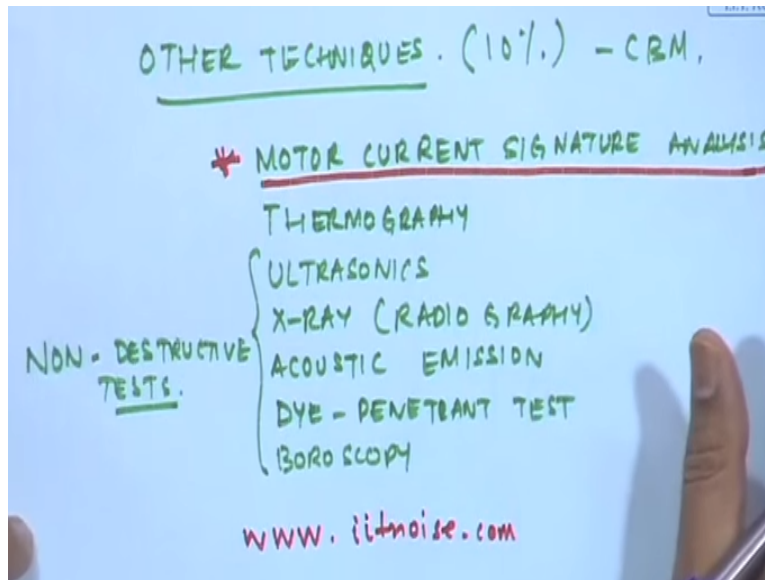
And then also knowing from the chemical composition of the wear particles if it is as for example if it is as just come out of a journal if you see lot of zinc or tin or lead we know the bearing is wearing out faster than shuffle supposed to be so these gives us indication as to oil why and how or how quickly then the machine is detracting. The next of course happens is one this wear particles get deposited in the oil the oil will undergo a change in its physical and chemical properties.

Because the virgin oil you know I mean virgin oil I mean the oil which was you know a new and which has not been used in machine it has certain physical properties like its density, like its viscosity like its oxidation vapor etc. So once these contaminants gets deposited in the oil it will its properties is going to change okay. If properties monitor this properties we will know that something has gone wrong with the machine.

It is very similar so this contaminant analysis which we are going to discuss in today's lecture and I the oil analysis in subsequent lecture basically they are like pathological test which we do when we go to the doctor okay like we do in urine analysis or blood sample analysis okay. Similarly for the machines we also need to look into this wear particles and all analysis okay. Now throughout the world worldwide we should tell that again 70 CBM condition based maintenance is done through vibration monitoring.

And these are from statistical information which is available in the literature and usually 20% is what is known as the wear and debris analysis which is essentially nothing but the contaminant analysis and all analysis okay.

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And then remaining 10% is other techniques (()) (10:21) so in this other techniques I have what is known as the motor current signature analysis then we have what is known as the thermography then we have the ultrasonic some of them are the non-destructive techniques like x-ray or radiography, acoustic emission then we have dye penetrant test then we have baroscopic etc.

This are the NDT so this form of 10% of the CBM throughout the world recently what happen this motor current signature analysis has become a leading technique in finding out CBM and we in IIT Kharaghpur have done some pioneering research in motor current signature analysis to basically find out faults in mechanical systems using the current drawn by the electrical motor which is driving at the gear box or the mechanical driven unit.

And details about this research can be found in my website and in fact the subsequent classes we will be referring into the some experiments and the literature which we are blast in this areas. So today I was telling you we will more into this contaminant analysis in this class. So this kind of a preview let us see what is this contaminant analysis we are going to talk about.

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Wear Debris Characteristics

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- Quantity - Severity
- Size - Rate
- Morphology - Mode
- Composition - Source



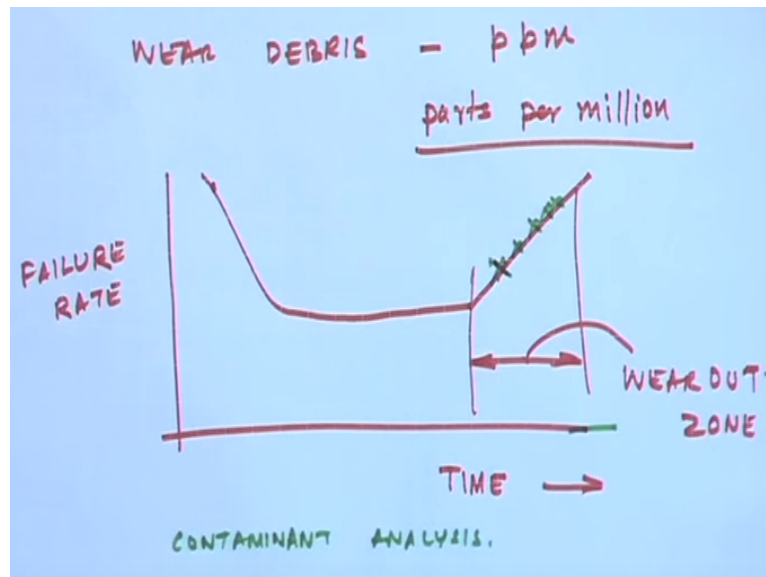
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So as you will see here the contaminant or the wear debris as certain characteristics one is the quantity of course if the quantity is high in a given composition usually they are measured in parts per million.

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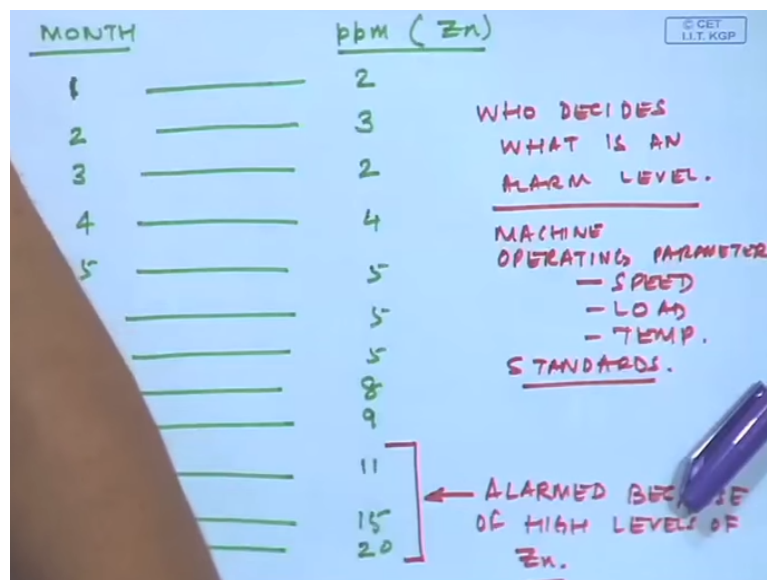


See this wear debris are measured in PPM parts per million okay and if will know if you go back to the familiar bath tub curve what is going to happen is we have the infant mortality zone and then the uniform failure rate and then two of this and you have this wear out zone okay and what happens suddenly at a given time if you see that the wear debris parts have increased that increasing with time you know that the defects severity have used okay.

So in the laboratory where you do the contaminant analysis by the way this contaminant analysis etc cannot be done that means next to the machine like when you have vibration monitoring we just put a vibration transducer next to the machine and record this in do an analysis and tell where the fault is and contaminant analysis are all analysis it cannot do that all is you have to collect recollect the bladder urine sample and send it to a pathological lab.

Similarly in this machines also we have to collect the oil and the contaminants are there give the entire sample to a lab. Wherein they will be doing contaminant analysis there in where they will check this severity by calculating the quantity of the particles present.

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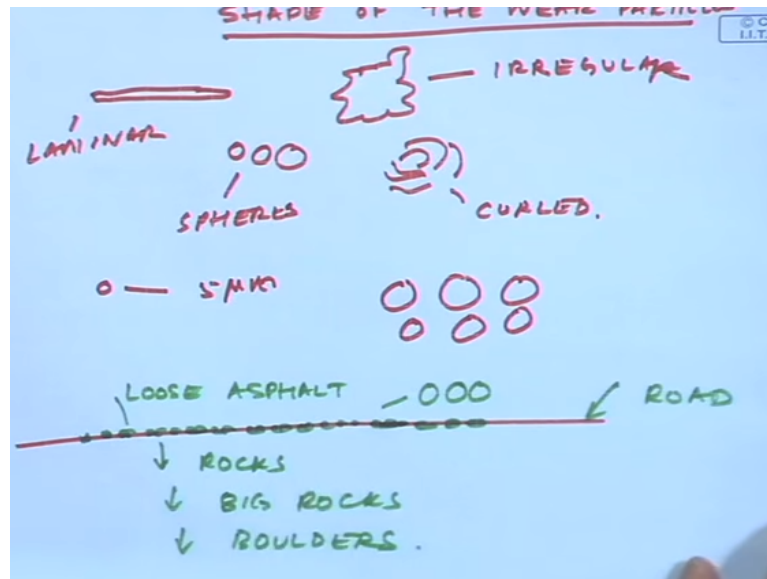


For example in every month okay you see the PPM of may be zinc in a machine components. So in first month end of the first month, second month, third month, four month, five month okay after every month you will be collecting the oil sample and giving it to a lab okay and suddenly to being with you know this is about 2 parts, 3 parts to being 2 parts this could happen because of measurement around once it is 3 then again its coming down.

But you know 4 constantly 5 and then you see suddenly okay and you see towards the end this is where you need to be alarmed. Because of levels of zinc well but then you might be wondering who decides what is an alarm level well this depends on many things this depends on the machine of course this depends on the operating parameters like speed, load, temperature okay in the machine would blower, gear box etc.

So far these there are standards of industries have their own standard based on their experience they say if I get more than 50 PPM of zinc I should be alarmed at the machine had under gone a severe failure okay. So this severity is actually the severity level of the alarm level is actually decided by user himself. Now what happens the next point is size of the particle you know we are getting size of the particles in the wear debris are they come in many forms.

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One could be laminar strips one could be irregular strip particle spheres some could core strips. Because some could be lead to the (()) (19:30) were wear particles but the rate is very important because what happen we have a some having 5 microns by suddenly the surface has were not so much I am getting large bolt outs large spears good example of this we have a fresh road okay nicely metal road okay.

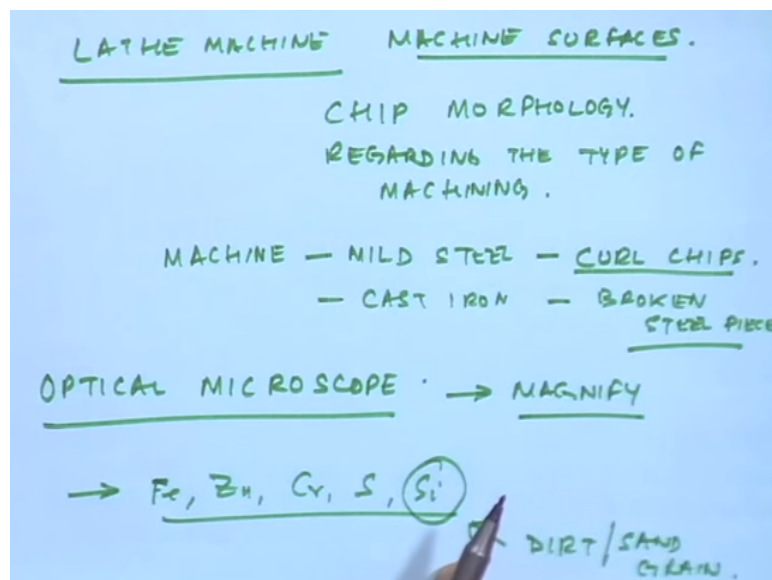
And then initially we have lot of loose asphalt okay and with time you will see suddenly you will get now big chunk spheres big rocks will looser faults small rocks then you have big rocks then you have you know boulders coming out. If you do not treat this road no treatment is done which time because of whether in running conditions initially asphalt coming out and the gravels and then the rocks and the bid rocks followed by boulders okay.

Similarly same this happens this machines as well we will have you know small strips coming out as small spheres coming out but if you go we will have big components coming out big

spheres coming out and so on. So the size will decide on the rate of a severity on this wear debris okay so with time you will see that the particle size may be 5 microns to being with an and then it become 20 or 10 microns and so on.

Next is the morphology and move on is the whether where it the shape is laminar like strips whether it is curled whether it is spheres whether it is irregular. You must have noticed that while you do machine and the laboratory even the workshop in usually machine.

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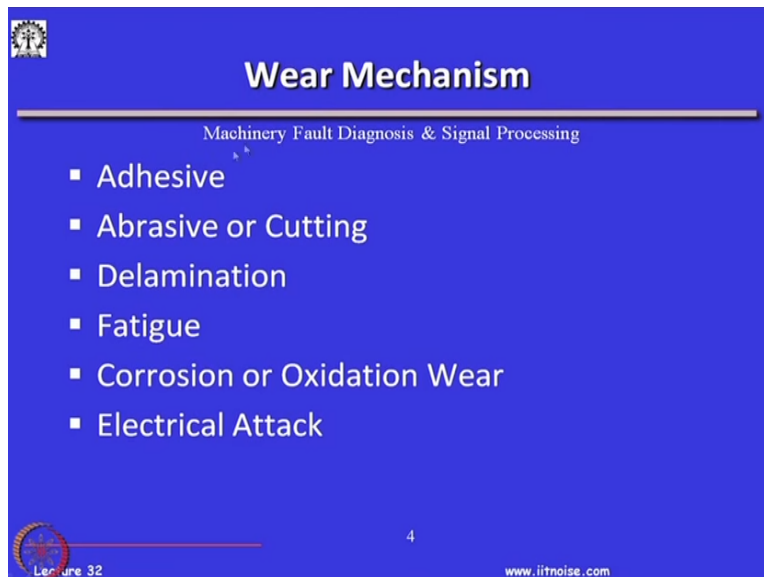
To machine sources okay they chip morphology tells us regarding the type of machining. Am sure must have all seen you while machine from MILD steel you will get curled chip okay. When you have CAST RM we will get broken steel pieces there is now continuous strip here but here you will get broken strip. So this tells us about the operations of course here we are making it happen but in machines because of were in here we will get this particles coming out.

So some particle could be like a sphere some particle could be like a strip some particle could be sphere some particle look could be curled some particle may be lot of force on them and so on. So depending on the morphology of this over all particles you know of course we cannot see them in our naked eyes. So we need to use optical microscope to being with and then we have to magnify them to see them okay.

And then the most important part is the composition wear debris particles the composition one of the wear debris particle is will tell us what is the parenting material in terms of the composition whether it is a in a lot of wear in lot of zinc lot of chromium lot of sulfur lot of silicon okay. We know for example the good example is silicon okay the sand grains or the dirt actually have silicon silica.

Suddenly in the contaminant I find lot of silicon or sand grain coming up I will know that means lot of foreign dirt has gone into their machines okay. So these are details if I know the parent composition of the material and I know that in my work particles are certain elements composition is increasing I know when a given machine from where they particle has come out and which component in this machine is detonated that knowledge will be known to me.

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The slide is titled "Wear Mechanism" and is part of a presentation on "Machinery Fault Diagnosis & Signal Processing". It lists six types of wear mechanisms:

- Adhesive
- Abrasive or Cutting
- Delamination
- Fatigue
- Corrosion or Oxidation Wear
- Electrical Attack

The slide also includes a small logo in the top left corner, a page number "4" in the bottom center, and the text "Lecture 32" and "www.iitnoise.com" in the bottom left and right corners respectively.

So this wear mechanisms are many for example when the particles are matting one may adhere to another because of temperature fluid. And then because of rubbing they may try to bring out pull out surface of this material there could be lot of abrasion one is hard other is soft it could be using as an abrasive okay and this abrasive happens in normal machines not that this is bad.

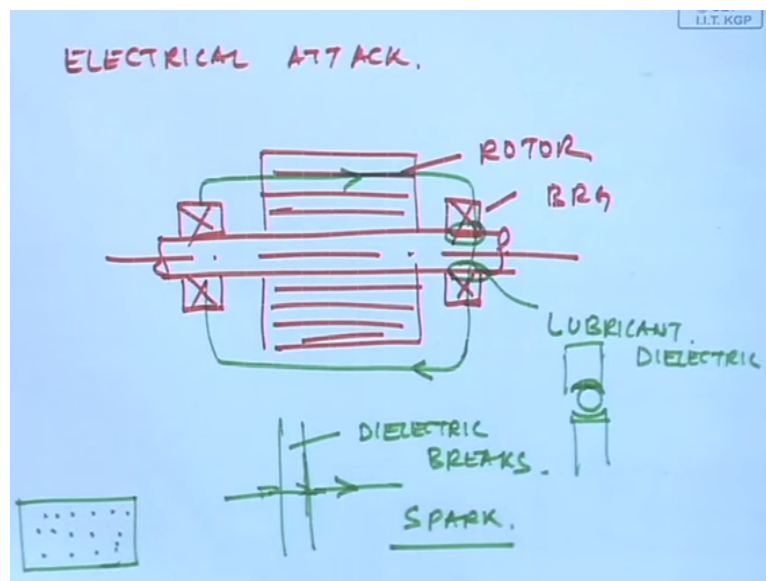
This happens only thing is that whether the rate at which it is happening is more whether I could do something to arrest them. For example if you think of a journal bearing if you are abrasive is so because we use of bearing generally bearing the inner liner must be softer than the shaft material. So in process in the shaft being a hard surface is going to wear out the inner bearing surface now

imagine if this inner bearings surface is wearing out process the bearings clearance is going to increase.

Now this clearance increases you know the level by P is going to change and then from the (26:53) equation we will see that the load carrying capacity of the bearing is going to reduce. So some machines are designed of course one machine one component will be hard and another will not be hard but that has not been that vibration does not take place in normal terms vibration where will take place everything is that we should do worried that the relative vibration is not excessive so that it creates certain condition where in my bearings clearance increased and this bearing is not able to sustain the load which is given to here okay.

And of course in other delamination occurs in fatigue because of you know the load reversal the road cycle fatigue kind of load and another important thing is the corrosion or oxidation wear because of an environment this corrosive things could have happen and electrical attack happen this particularly when there is a electrical loop or a ground voltage going through a machine and because of was lubricating oil.

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This electrical attack actually happens particularly think of the case of an electrical motor okay and there is rotor this carry the rotor okay I am not drawing this rotor here. What happens because of the there is always a small amount of voltage what is going on okay. Now at this

interface there is a lubricant either if it is a general bearing or ball bearing there is thin layer of lubricant between the inner races outer races etc., okay.

And this actually dielectric even I am bring in of voltage across a capacitor okay and this dielectric brakes this voltage is going to get a pass through okay. So this intermediate passing of this EMF will create a spark because there is potential. So this sparking comes with high energy of heat so this going to produce lot of pitting on the surface pitting on the bearing surface I have I will show you in the next class some pictures of what happen when this bearings pit.

So lot of pitting marks will come on the walls of the inner race of the outer race because of an electrical discharge are going through this circuit okay the usual way to avoid it is to have a good grounding if you ground it this should not happen I will say some. But then these are responsible for initiation of the pitting and if these goes once this surface as pitted because of load and temperature they are weaken and then with time this false pitting will be bringing will become large scoules in the locker and then lot of large chunks of material is eroded.

So surface are going to note again one has to be very careful when designing electrical motors of particularly when we have high voltage electrical in you machineries where in there are parts when with there are lubricants and then when there is dis-contact. We may not get an voltage as we measure but when they are going at high speed because of this EMF with grounding is not proper we will get this spark and this spark are responsible for actually like an erosion like an EDM like an electrical discharge occurring.

You know in fact people use this high voltage powers in electrical discharge machining to machine surfaces. But here this same heat is DMC may be harmful to our machines.

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Wear Modes

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- Running in
- Steady Wear
- Wear Out
- Pitting
- Scuffing



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But in this wear modes when we have an initial the infant mortalities in zone of the spark occur in that usually running in wear modes because of the may be it was not properly aligned may be the surfaces where having lot of bad surface finished to agree lot of the machined surfaces are not clean okay and this debris were there which is then followed by a steady wear.

And then we have the wear out towards the fag end of the life of the machine will have a severing out followed by pitting and then this pitting goes unnoticed will have large materials coming out which is known as scuffing.

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Wear Particle Type

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- Cutting
- Spherical
- Rubbing ($<15\mu\text{m}$)
- Sliding ($20\text{--}50\mu\text{m}$)
- Laminar ($20\text{--}50\mu\text{m}$)
- Fracture ($>50\mu\text{m}$)
- Severe Sliding ($>50\mu\text{m}$)



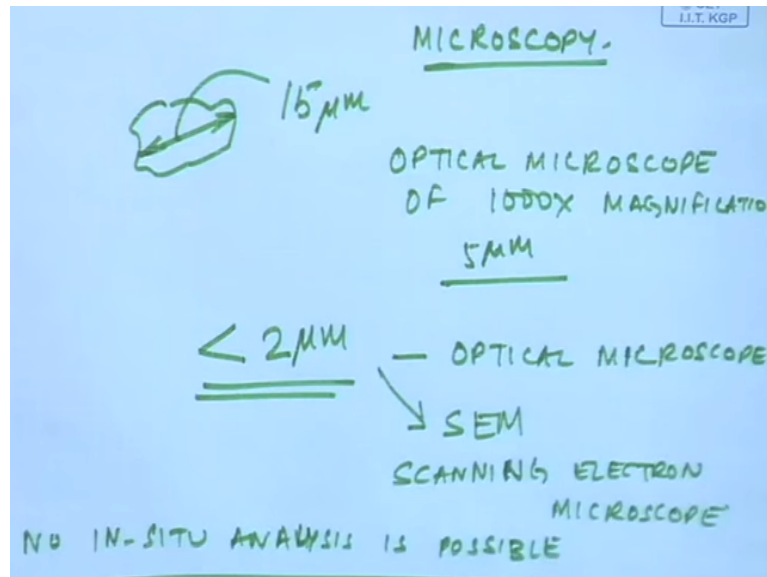
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And usually this wear particle types you had drawn few of them like the laminar and the regular shape of the curled shape the typical size of this wear particle you know it could be cutting it could be spherical if it is rubbing it is usually less than 15 micron by this size.

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I mean if you see under the microscope one of the dimension this happens to be 15 microns this has to be seen through only microscopes when normally usually we use an optical microscope of about 1000 magnification. So with that we can see either of about you know maximum of 5 micron okay. But unusually with wear particle is are of bigger sizes and then we will see sliding is 20 to 50 microns, laminar 20 to 50 microns fracture is big severe sliding is big 50 micron etc.,

You can see it in an optical microscope with 200 and 500 zoom magnification but the wear debris particles to understand the chemical comb user we require the wear particles will be of the order of less than 2 microns and this is not possible by optical microscope this has to be seen through an SEM scanning electron microscope. Obviously as I was telling you no in-situ analysis is possible okay.

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Characteristics of Wear Particles in Ferrogram

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- Normal Rubbing Wear (Flat platelets less than 15 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)
- Bearing wear (Laminar platelets)
- Spheres (Small particles less than 5 microns)
- Black oxides (Indication of insufficient lubrication)
- Red Oxides (Indication of water contamination)
- Corrosive Wear (Heavy Concentration of fine particles)
- Aluminum Wear (White metal Particle)
- Dust/Dirt (Foreign particle or material not characteristic of machine or oil)

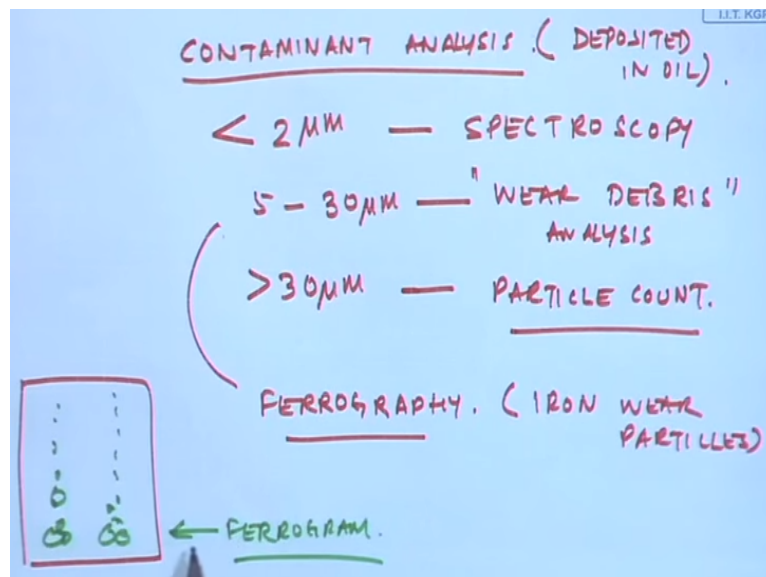


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In case of this wear particles okay so what we do basically there is technique you know if you look at this contaminant analysis depending on the size of the particles which an difference modes of investigation which the particles has less than 2 microns I will use what is known as spectroscopy if it is between you know 5 to 20 microns I can use what is known the wear debris analysis.

And if it greater than 30 microns I can use what is known as the particle count okay and usually there is a method is known as ferrography. Wherein we have iron wear particles so actually all

this contaminant are actually deposited in oil basically the lubricating oil which is there in between the two mating members actually uses.

We use that oil to understand this contaminants the oil it can be taken dried in the piece of iron put on a piece of paper and then with an magnetic field or a gravity field it can be laid in such a manner such that heavier particles are going to deposited in the bottom and the top particles on the top. So you will see of ferrogram like this surface like this this could be large particles and then towards the end it could be small particles ferrogram.

And ferrogram you can measure you can see it on microscope and see the nature of the nature and size also and then try to understand how severe you are getting mechanism is okay. So if you look at the characteristics of wear particles in a ferrogram usually normal rubbing wear means you know which occurs like flat platelets like less than 15 microns if the wear become severe sliding we have flat elongated particle greater than 20 microns with striations then there will lot of marks.

Cutting wear long curled strips of metals which you must have seen in workshop gear wear flat striated particles bearing wear lamellar platelets spheres small particles less than 5 microns. Black oxides indicates insufficient lubrication red oxides indicates of water contamination corrosive wear because of heavy concentration of fine particles aluminum wear white metal particles when there is dust or dirt foreign particle or material not characteristic of machine or oil.

So what happens these are the particles which see from a macroscopic level under and optical microscope and just only looking at this size and the shape we can have some clue has to what kind of wear to place what kind of contamination to place. Is it contamination with dirt or understanding machine this can be done but this analysis never tell us about the chemical composition of wear particles where it is made on iron whether how much of parts of copper is there how much parts of zinc is there.

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Wear Debris Analysis Methods

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- Optical (Light Obscuration)
- Filter Blockage (Pore/Mesh Obscuration)
- Wear (Thin Film Sensor)
- Radioactivity
- Magnetic Attraction (Ferrography)
- Gravimetric



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For that we have to do what is known as spectroscopy okay before I go into spectroscopy I will tell you some of the wear debris analysis method basically wear debris are done for particles which are above 5 microns and beyond. So I could see under an optical method I can have a light beam passed to a oil through an wear particles and because of the density of the wear particles increasing this light is going to get reflected.

And this can be detected by a photo detector so the intensity of the light reflected back gives me a clue as to how much percentage of that opex surface wear particles are there in the oil. SO in a given milliliter or oil I can have an estimate as to how many parch per million of solid substances are there filter blockage can have a pore or mesh and then like a normal seve I can say not 5 microns stayed back then I can this is the pach per million of 5 microns.

And if I increase this size may be 10 microns, 20 microns and so on I can do wear particles can also be measured radioactivity through thin film sensor like magnetic attraction is by ferrography or the gravimetric which I just discussed in the last slide.

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Spectrometric Techniques for Debris Analysis

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- Atomic Absorption Spectroscopy (AAS)
- Atomic Emission Spectroscopy (AES)
- X-Ray Fluorescence (XRF)
- Inductively Coupled Plasma (ICP)
- Direct Current Plasma (DCP)
- Energy Dispersive X-Ray Analysis (EDX)



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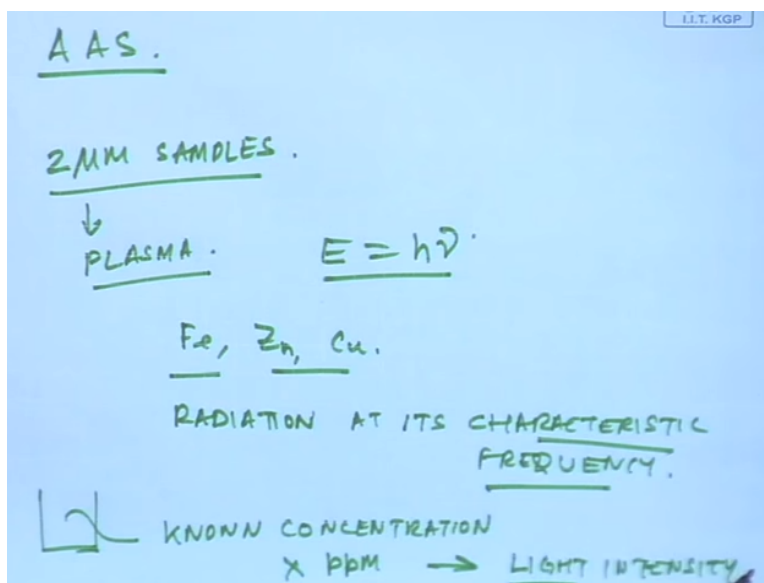
But to know the chemical composition of the wear particles we have to do what is known as spectroscopic technique for debris analysis they have to sizes less than about 2 microns which are not possible to see obviously in an naked eye even with high power magnification may be 100, 1000 magnification you may at most see about 5 microns beyond that we have to use what is known as the this fine particles we have to use we need not count there number of masch per million.

But rather find out the chemical content on this particles and that is done through all this techniques and these are all specialized equipment like the atomic absorption spectroscopy known as AAS, atomic emission spectroscopy AES, XRF, Inductive coupled plasma ICP, DCP, EDX etc., okay. These are very sophisticated equipment each of these equipment could be causing anywhere from 50 lakhs to crores each of this equipment's.

So obviously when I have a plan what is the gear box only 50,000 rupees or 1 lakh rupees it will be not economical for me to have having my plant all these by machines okay in fact none of the engineering industries have these where they do planned operation. But to analysis or to know the condition of the machine this oil which have been collected from their gear boxes or you know pumps etc.

Has to be collected and sent to a centralized laboratory I were in these laboratory people can do analysis within the sophisticated equipment.

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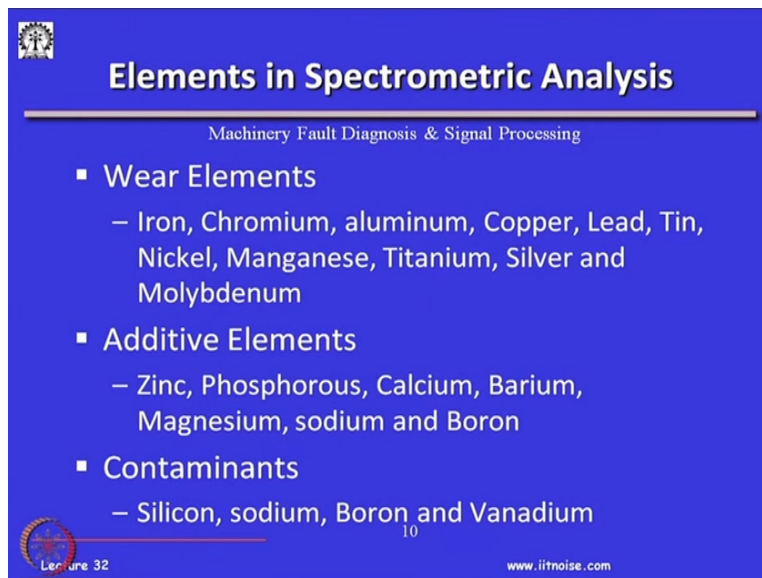
And I will tell you briefly about one of them they are atomic or sends the photometer what happens you know this 2 microns samples which are there they are heated to a such a high surface that we have a plasma coming on high. Then you know $E = h\nu$ okay the plant full of radiation and energy which is emitted is at the frequency of the radiations of the chemical elements present in this in this wear particles for example suppose it has iron, suppose it is zinc copper etc.

So the radiation of these atoms electrons in an higher end if it goes its plate it goes at a particular frequency same is through for zinc and the for copper radiation at its characteristic frequency. So all I have to do is at that characteristic frequency I have to measure the intensity of the radiation and that is what is done through an atomic other absorption or a machine spectrum. So basically I have a sample which is heated and then radiation will be there I will have another source wherein I will be giving the from a concerned radiation from a known concentration.

Some XPPM I know them out of light intensity so I will see the unknown intensity which I will which have been radiated out of the elements and then from unitary method and find out what is PPM. So I have to know for the particular element I am trying to identify I will need to know it electromagnetic radiation frequency okay.

So there are all stand at which are used standard lights are used are used to identify the chemical elements okay.

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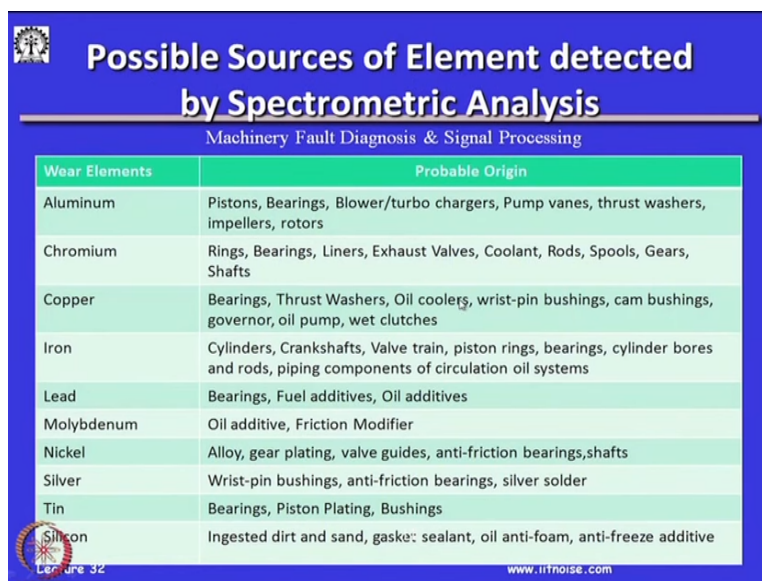
Elements in Spectrometric Analysis
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- **Wear Elements**
 - Iron, Chromium, aluminum, Copper, Lead, Tin, Nickel, Manganese, Titanium, Silver and Molybdenum
- **Additive Elements**
 - Zinc, Phosphorous, Calcium, Barium, Magnesium, sodium and Boron
- **Contaminants**
 - Silicon, sodium, Boron and Vanadium

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So typical the elements in the spectrometric analysis where elements are this are usually iron and chromium aluminum, copper. Lead these are the wear elements which happens. And sometimes we give some additive elements and then these are usually contaminants silicon, sodium, boron and vanadium okay.

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Possible Sources of Element detected by Spectrometric Analysis
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Wear Elements	Probable Origin
Aluminum	Pistons, Bearings, Blower/turbo chargers, Pump vanes, thrust washers, impellers, rotors
Chromium	Rings, Bearings, Liners, Exhaust Valves, Coolant, Rods, Spools, Gears, Shafts
Copper	Bearings, Thrust Washers, Oil coolers, wrist-pin bushings, cam bushings, governor, oil pump, wet clutches
Iron	Cylinders, Crankshafts, Valve train, piston rings, bearings, cylinder bores and rods, piping components of circulation oil systems
Lead	Bearings, Fuel additives, Oil additives
Molybdenum	Oil additive, Friction Modifier
Nickel	Alloy, gear plating, valve guides, anti-friction bearings, shafts
Silver	Wrist-pin bushings, anti-friction bearings, silver solder
Tin	Bearings, Piston Plating, Bushings
Silicon	Ingested dirt and sand, gaskets: sealant, oil anti-foam, anti-freeze additive

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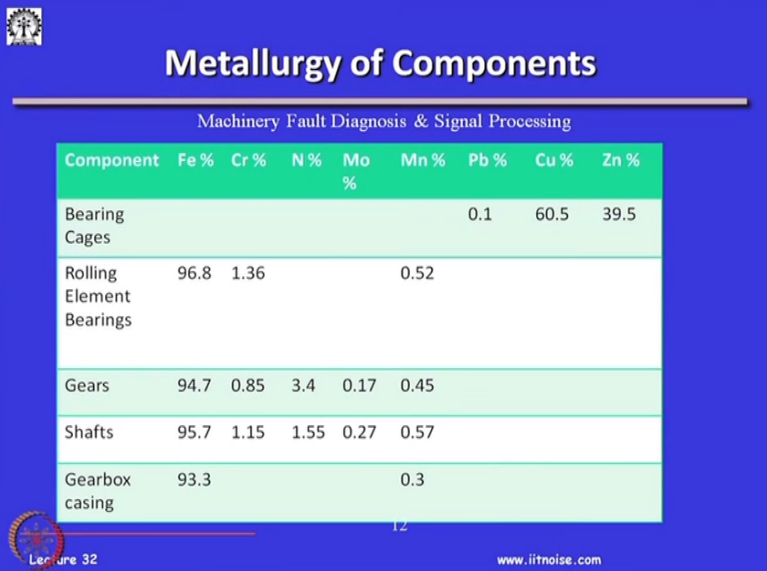
And one of course we need to know in the engineering applications of the machines what are the typical wear elements it is from aluminum to silicon and what is the probable origin. So example

if I see lot of aluminum I know these are the possible sources wherein aluminum is there suppose I see chromium these are the possible sources to the exhaust valves etc., or else shaft.

And when I see silicon I know it is just dirt sand sometime gasket, sealant oil and foam anti-freeze additive. So these will be known to us from the original designer to know from the materials of the element and then look out for this. Sometime many machines which are just available to us its material combustion is not known to us sometime it is difficult thing what is the experience if you will see that you know usually in particular components in coming out.

We can do diagnostic measures to find out where what is the source of the material so this is only possible by spectrometric analysis wherein we have a copper is usually coming out of bearings lead is also coming out of bearings and everything of course in a industries made out of iron and silver particularly in wrist pin bushings, anti-friction silver sold etc. So these gives us a clue as to what is the possible source of the elements where we by auto metric analysis.

(Refer Slide Time: 48:03)

The slide is titled "Metallurgy of Components" and has a subtitle "Machinery Fault Diagnosis & Signal Processing". It contains a table with 8 columns: Component, Fe %, Cr %, N %, Mo %, Mn %, Pb %, Cu %, and Zn %. The table lists the elemental composition for five different machinery components. The slide also includes a small logo in the top left, a circular logo in the bottom left, and the text "Lecture 32" and "www.iitnoise.com" at the bottom.

Component	Fe %	Cr %	N %	Mo %	Mn %	Pb %	Cu %	Zn %
Bearing Cages						0.1	60.5	39.5
Rolling Element Bearings	96.8	1.36			0.52			
Gears	94.7	0.85	3.4	0.17	0.45			
Shafts	95.7	1.15	1.55	0.27	0.57			
Gearbox casing	93.3				0.3			

And usually this is the composition of the components which are there in the machinery one is RM, chromium, nitrogen, manganese, lead, copper, zinc usually in bearing cages it is which has high copper and zinc as you can see if you have rolling elements bearings it is high iron gears very much iron shafts are in gear box casings. So sometimes you will see this magnitude etc and these kind of metallurgies only available by doing an spectroscopy.

For example you give me a piece of iron it is not 100% iron it is may be iron coming out of gears may be only there is chromium there is nitrogen there is nitrogen highnet because of the case carbon with all nit riding the gear surfaces are hard because of the radiation of high level of hydrogen are there so suddenly in your contaminants if you see high level of nitrogen you will not well my gear is bearing out fast of that should be.

If I see high amount of zinc this bearings are varying out faster so these kind of clues as give us indication upto wear from this materials have come out of okay. So to summarize in this class on contaminant analysis we have seen what are the different types of contaminant available. Contaminants can be distinguish in terms of their size something less than 2 microns we cannot see them through a very high power magnification of 1000X.

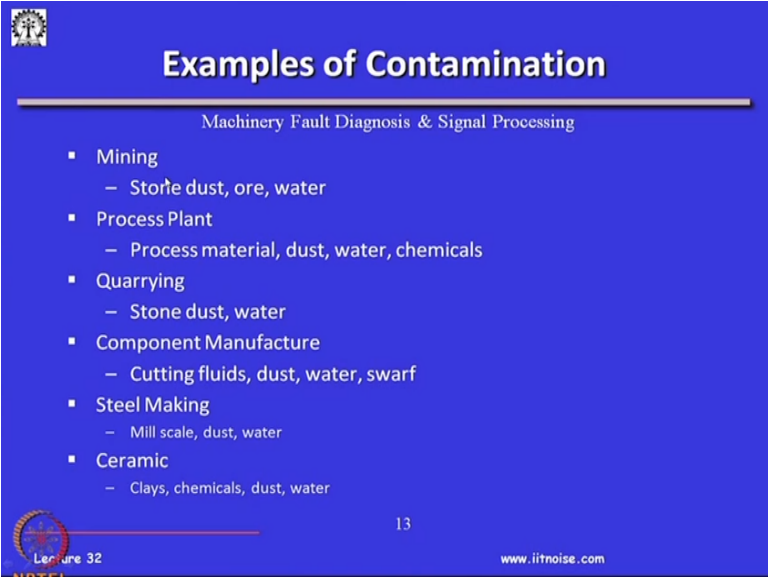
We have to do spectral analysis this spectrometric analysis is done through atomic absorption spectrum through photometer or in spectrometer emission spectrophotometer, XRF, ICP etc. Wherein we get to know the chemical constraint of over naught particles has to how much percent of iron is there copper is there zinc is there lead is there nitrogen is there and all we have do is regularly in frequent interval we have to see the chemical composition of wear particles.

Am not asking you to rub of scrap of a material from a machine but what is already deposited in the oil which is there as an lubricant okay. So then from this contaminants we can try to get those two what is the parent source and why this vary next comes the size the bigger sizes about 5 microns are greater we can done look into the through microscope we can see the size shapes is that their laminar whether they spherical where they are curled whether they have irregular shape cut shape.

So this gives as an indication as to the where mode whether it is addition abrasion there it is corrosion there it is because of an electrical interference etc. So these understanding of the wear modes and next comes where the size are large and then their ferratic we can develop ferrography and then to ferrograms. But if the size is more than may be 30, 40 or 50 microns we can just use and opticals source and just do a particle count is to given liquid what is the parts per million of the wear particles.

Nothing to do about the contaminant of the composition of their particle but whether it is 50 PPM in a given ML of the liquid is that concentration of wear particle increasing its time if it is increasing we need to cut alarm. So this is how the contaminant analysis helps us in identifying the severity of defects or the wear mechanism in a machine and of course the other system measurement technique of course is the oil analysis which I will discuss in the next class okay.

(Refer Slide Time: 52:18)



The slide is titled "Examples of Contamination" and is part of a presentation on "Machinery Fault Diagnosis & Signal Processing". It lists several industrial processes and the contaminants they typically produce:

- Mining
 - Stone dust, ore, water
- Process Plant
 - Process material, dust, water, chemicals
- Quarrying
 - Stone dust, water
- Component Manufacture
 - Cutting fluids, dust, water, swarf
- Steel Making
 - Mill scale, dust, water
- Ceramic
 - Clays, chemicals, dust, water

The slide includes a small logo in the top left corner, a red progress bar, and footer information: "Lecture 32", "13", and "www.iitnoise.com".

And examples of contaminants as a closer we will have a the mining usually if you go to mining is stone, dust, ore or water. Process plant is process materials, dust, water lot of water comes in this mining process plant and quarrying component manufacture ceramic lot of clays and chemicals so this also gives us to clue as to what happens okay thank you.