Machinery Fault Diagnosis and Signal Processing
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Lecture – 45
Machinery Diagnostic Chart

Yeah end of this 9th week I believe yeah we will talk about infact an overview of whatever you have studied so, far to find out defects and mechanical systems, and this I will actually discuss with you with what is not the missionary diagnostic chart ok. So, just give you an overview of whatever you are discussed in the last may be ten classes on starting from faults, and motors gears bearings shaft systems and so on.

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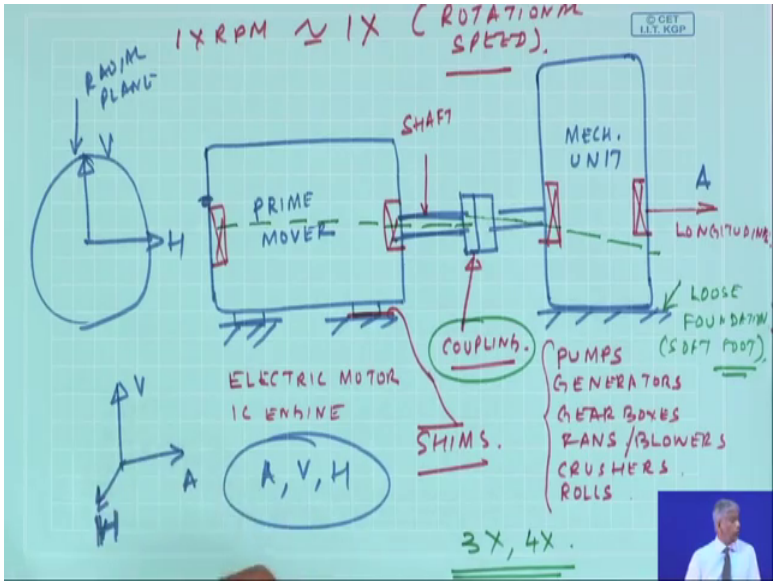

Just to recap what is everything about. So, by now you all know that, in general this is the configuration of all machines which will come across all out not saw all, but almost all ok.

So, again just to recap what are the common elements; common elements, my prime mover mechanical unit what is the prime mover usually an electric motor, or an IC engine mechanical unit could be many Pumps, Generators, Gearboxes, Fans, Blowers, Crushes, Rolling mills, Rolls etcetera, and then they are this is my bearings, and these are the Shafts, and I have the coupling, this is this scenario of any machine for that matter.

So, we know bearings there can be faults, in gear boxes gear could have faults and so on, impellers could have faults and so on. So, we will just try to and then of course, they could the structural cracks foundation being soft loose soft footents on.

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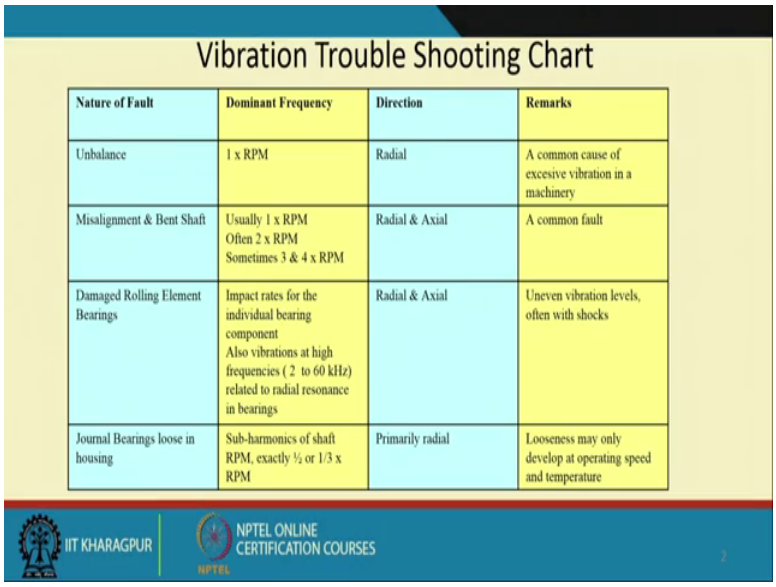

So, we will look into one by one just to give you an overview of what is natural fault what is the dominant frequency in the spectrum vibration spectrum, and what is the typical direction, and sub remarks. So, an unbalance can occur where can an unbalance occur, unbalance can occur in the rooter of the prime mover can occur in the rooter of the driven unit, which could be carrying fan you all know, something get deposited in the fan blade ok, there could be a fault, and this is one times RPM means, which I had earlier told about 1 X this is nothing, but the rotational speed rotational speed of the unit of the mechanical unit.

So, if it is unbalance you all know that this will be AMY omega square r, where omega is rotational speed, and predominantly you all again now know that this is the longitudinal axis, and of course this is the radial plane. So, I will have a horizontal in this axial.

So, A axial vertical horizontal as you know just again to recap vibration at any point can be measured, in this 3 directions A, horizontal and vertical of course, I am not talking about the rotation, there could be subords this axis as. So, predominantly anywhere you see high vibration in the radial direction, and if you of the luxury of changing the rotational speed, you know this unbalance force is nothing but.

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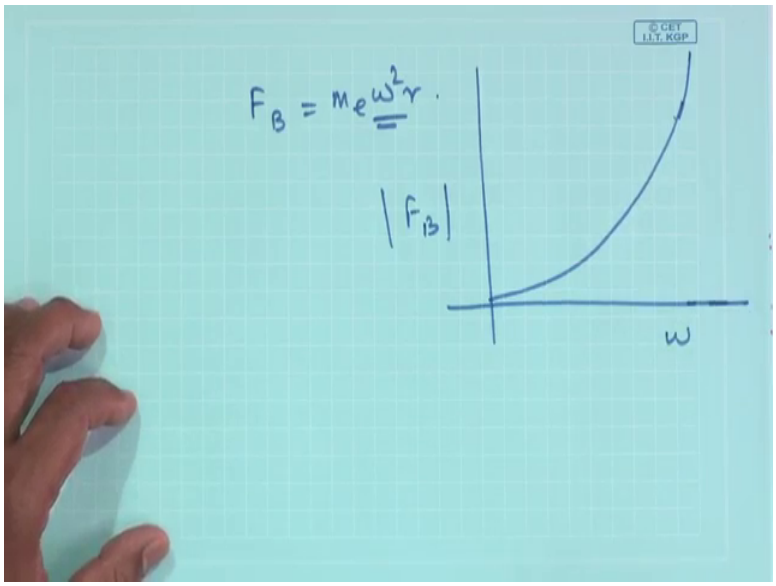

So, if this omega if you if you had the provision of changing omega you will see that this force would increase like an parabola so on. And there could be second case misalignment, and bent. So, these shafts could be misalign ok, and you know again we are discussed how alignments can be done, and this columns occur because of loose foundation of (Refer Time: 07:01) soft foot this can happens.

So, when a people give shims feeding instauration to align it; however, despite the best efforts of doing this alignment, because in sometimes it is couplings are chosen. So, that the net unbalance effects are reduce, because some of the couplings can take certain angular deviations

Now, they will as if there is a misalignment, usually there is a axial vibrations also, and you will see three to four times x also occurring in the case of unbalance 3 and misalignment, this also occurs in the case of misalignment, and if things are bent if shafts are bent.

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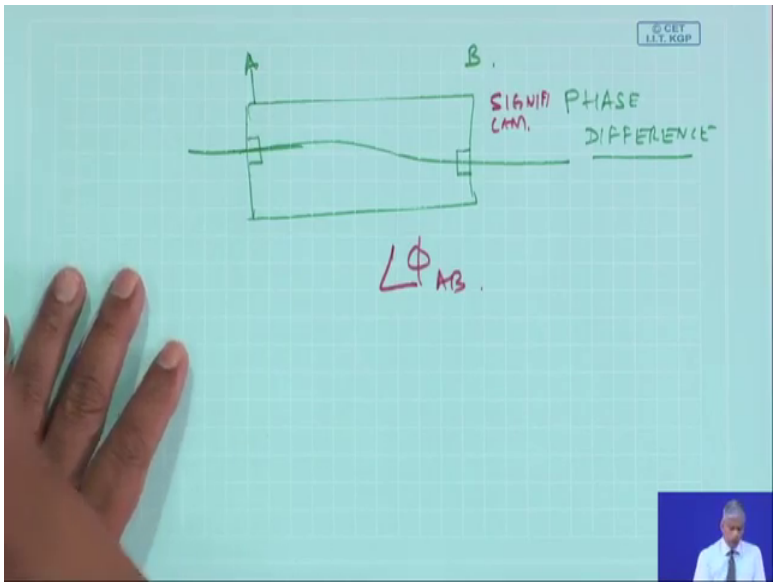

This is heavy spot. So, sometimes between the 2 points A and B there could be significant phase difference ligand just to recap, you know this classes mostly a recap of what you have discussed earlier.

So, to find out the phase difference between 2 signals all have to do is take the cross phase between A and B. So, if an dual channel fifty analyzer at phi naught the phase between A and B as nothing, but this is very easily possible ok, there will be significant unlike unbalance there will be significant phase difference, if there is an unbalance the phase difference would be almost same ok, because same time both of them would be almost 0 right.

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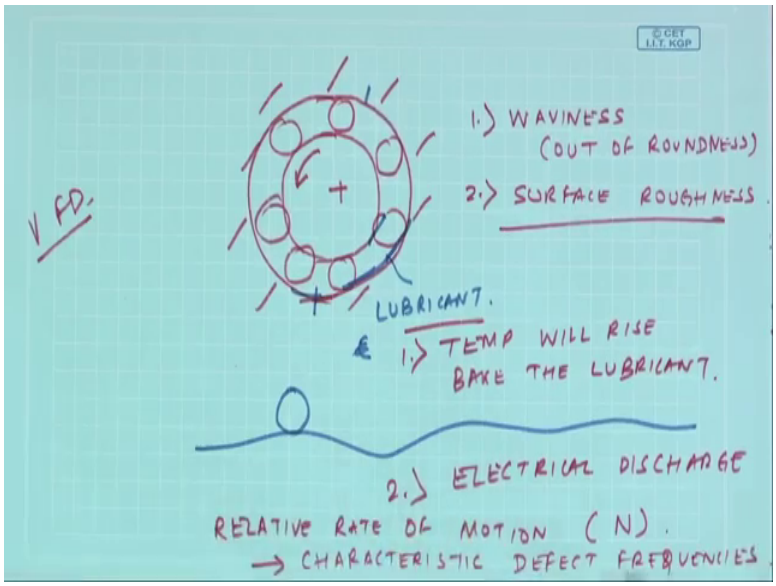

Now let us come to the next very very important case of defect, and that is the case of a rolling element bearing. So, for rolling element bearing there are 2 reasons while the vibrations occur one is waviness, which is out of roundness, because we are supposed to manufacturer perfect ring, but then if I leave the ring there is there is lot of un relations ok, if I if I open up this.

So, this on top of it I have a rolling element so, if a rolling element is going over wavy surface, there will be vibrations, and another is the surface roughness. So, new bearings also have vibrations. So, it is only because of waviness and surface roughness, as a manufacturer they reduce this vibrations by putting a layer of lubricant, and bearings are actually seal for life ok, but in the process of application or not in process of operation unknowingly sometimes, because of excessive load, or subject to a high temperature the temperature will rise, and bake the lubricant is one reason another reason sometime because electrical discharge particularly, and motors where the speed control is through VFD drive.

So, there is a lot of high frequency transient switch occur. So, high frequencies sparkings occur. So, they erode the surface, and make it steal worse. So, these are reasons why bearings vibrate, beat a new bearing or be a used bearing her a bearing and operations. Now so this bearing is a very excellent candidate ah for actually condition monitoring, and from academic point of you because the couple of things which can happen.

If you see all this rolling elements, they all will operate because of the inner race is rotating, and the outer race is fixed there are applications of the vice versa happens. So, all of them we will have a relative rate of motion, related to this a rotational speed n, and these are known as the bearing characteristic defect frequencies, and are discussed thisearlier also.

So the bearing what happens or will have any damage rolling element radial, and axial vibrations uneven vibrations levels often which shocks (Refer Time: 13:35) shocks what will little later, impacted for the individual bearing components of these characteristic defect frequencies, and their harmonics will show up in the bearing spectrum, but the most important thing is also vibrations at high frequencies 62 kilo hertz related to radial resonance and bearings, and why again that happens you know now.

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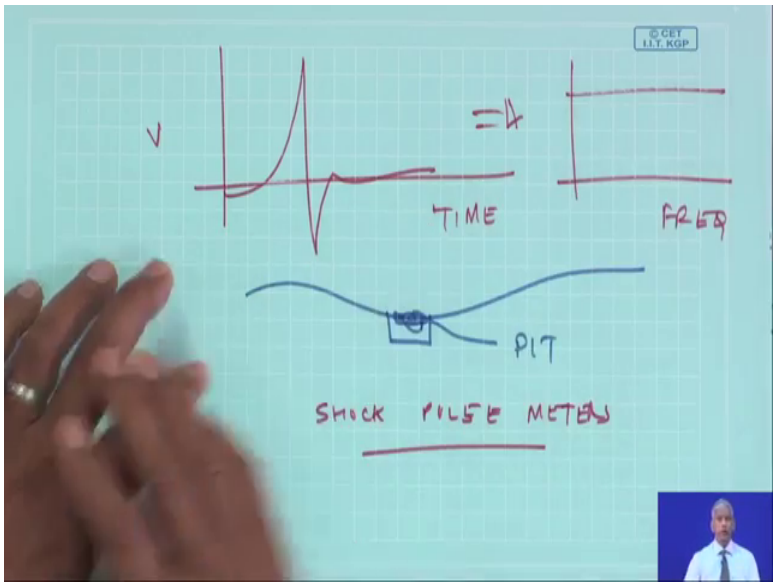

If the impurities have come to a suttle such level that there is a large pot hole, because of if pit has occurred. So, this will give rise to lot of high frequency impacts in the time domain, and you all know by now this in the frequency domain is nothing, but a high frequency vibrations.

And that is the principle behind the commercialism shocks pulse meters are available to monitor them this vibrations, and this occur and this will excite the bearings resonance, and are designer always ensures that the bearings natural frequency is nowhere close to the operating speed of the machine, but we if you are to measure the high frequency

radial resonance of the bearings, we can say for sure that a bearing defect has occur. and that is a of the rolling element bearing.

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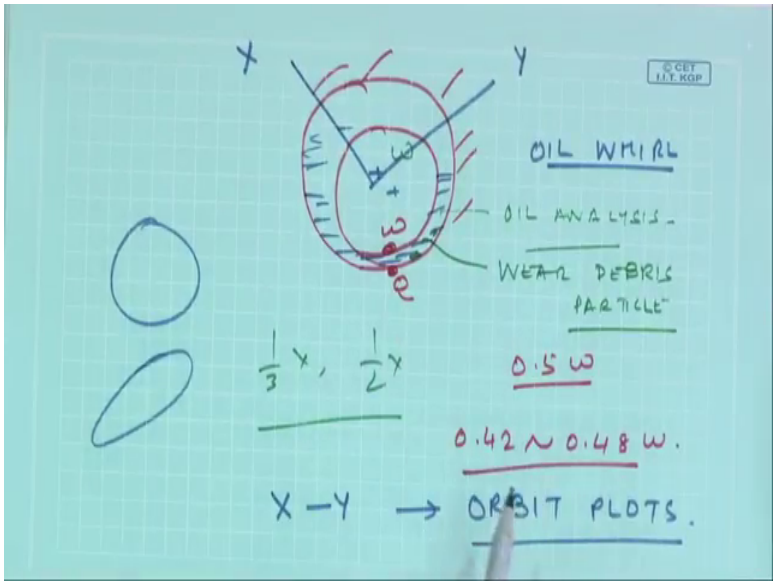

Now, of course another class of bearing is this journal bearings of course, is a fluid film bearings fluid is there, and of course because of the eccentricity there will be a pressure build up, and what happens many times you see the phenomenon of oil whirl will occur, this oil in whirl in frequencies, we will see that will discuss in the next slide.

But many a times if the bearing housing is loose in housing, I will see sub harmonics of half or 1 by 3 x RPM and being radial this you see primary they are radial vibrations ok, and looseness will defect of course, another important thing of course, not related to vibration which will discuss later on is this Wear particle, Wear debris particle is something which we are going to see, then we talk about this journal bearing, when talk wear debris analysis lot of deposits will occur in this oil, and through an oil analysis we can understand the condition of bearing.

But from a vibration mode of view you will see lot of sub harmonics, sub harmonics means the fractional harmonics, other 1 by 3 X 1 by 2 X etcetera, which will see the vibration spectrum.

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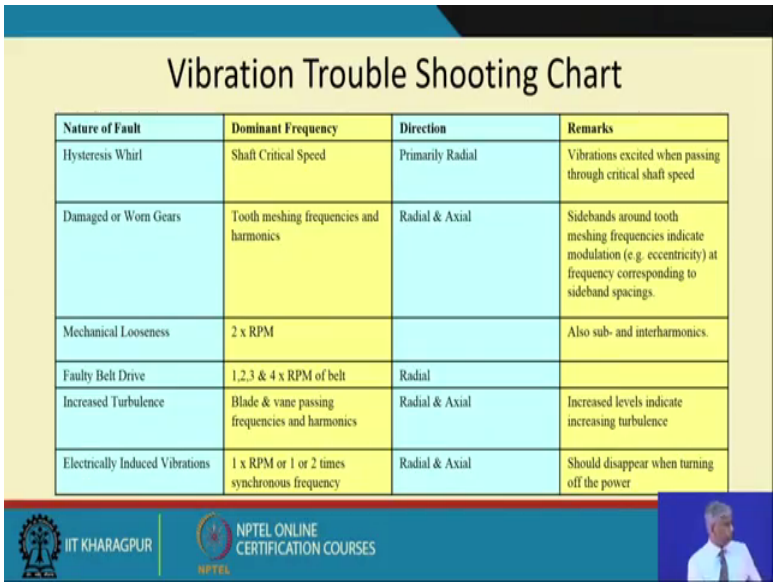

Nature of Fault	Dominant Frequency	Direction	Remarks
Hysteresis Whirl	Shaft Critical Speed	Primarily Radial	Vibrations excited when passing through critical shaft speed
Damaged or Worn Gears	Tooth meshing frequencies and harmonics	Radial & Axial	Sidebands around tooth meshing frequencies indicate modulation (e.g. eccentricity) at frequency corresponding to sideband spacings.
Mechanical Looseness	2 x RPM		Also sub- and interharmonics.
Faulty Belt Drive	1,2,3 & 4 x RPM of belt	Radial	
Increased Turbulence	Blade & vane passing frequencies and harmonics	Radial & Axial	Increased levels indicate increasing turbulence
Electrically Induced Vibrations	1 x RPM or 1 or 2 times synchronous frequency	Radial & Axial	Should disappear when turning off the power

And of course, you will see the oil whirl occurs, because the reason that if the shaft is rotating at speed omega, you see this point which is rotating this has an om speed omega, and this has a speed 0 which is a trust. So, the average speed is somewhere around you know I 0.5 omega, but actually the oil will frequencies 0.42 to 0.48 omega.

So, you will see the oil whirl frequencies even in a good journal bearing, but if you are monitoring the oil whirling frequencies, you can see what is the condition of the bearing as opposed to amplitude oil whirl, but for bearings to maintain that the section (Refer Time: 17:56) is the same we can do what is known as the relative vibration displacements through, X and Y we can do what is known as the orbit plots.

We are discuss them during orbit plots. So, if t he orbit plots change the shape you know that X and Y are not of the same magnitude, and this also gives us an clue as to something is wrong through the journal bearing.

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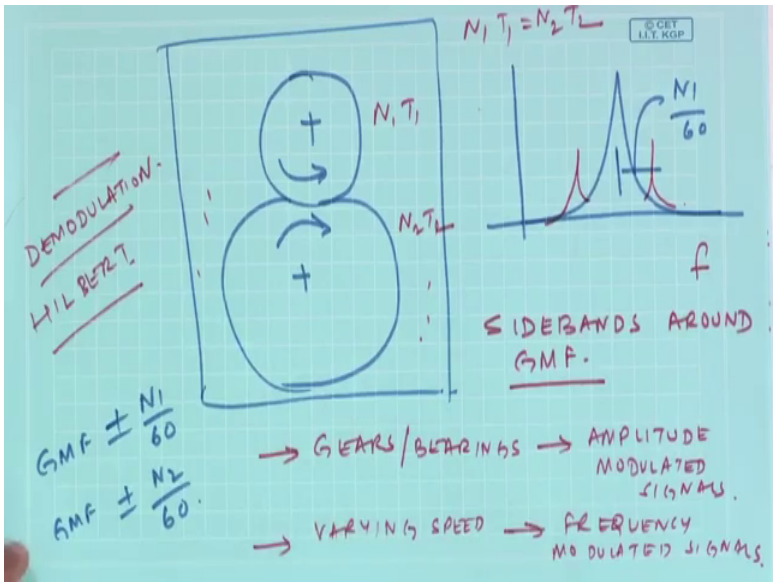

Now we will come across many Gears, they will teeth's am not wrong. So, one is because of a gearbox of course, there are bearings so on there are lubricant etcetera, I will see very importantly is this gear machine frequency and the frequency domain, and then Side bands, Side bands around GMF it is a telltale science of course, we have to one has to monitor them, and usually radiant's. So, sidebands around tooth meshing frequencies indicate modulation eccentricity at frequency corresponding to sidebands spacing's ok.

So, when gears are subjected to varying load Gears or Bearings subjected to varying load, I will have amplitude modulated signals, and when they are as it varying speed I will frequency modulated signals, so why proper demodulation, and Hilbert transform is one technique of doing demodulation.

In fact, this class is a good review of a whatever faults conditions, we have discussed so far, and this is the good idea to understand this class, and recap what you have done. So, sidebands around tooth meshing frequencies indicate modulation eccentricity at frequency corresponding to sideband spacings, and you all know if this gear add N 1 T 1 teeth N 2 T 2 teeth. So, N 1 times T 1 is equal to N 2 times T 2, and this distance in hertz will be N 1 60. So, you will have what is known as GMF plus minus 1 by 60 and GMF plus minus N 2 by 60 and so on.

And for different gear boxes you can calculate the gear machine frequencies, and particularly for planetary gear boxes.

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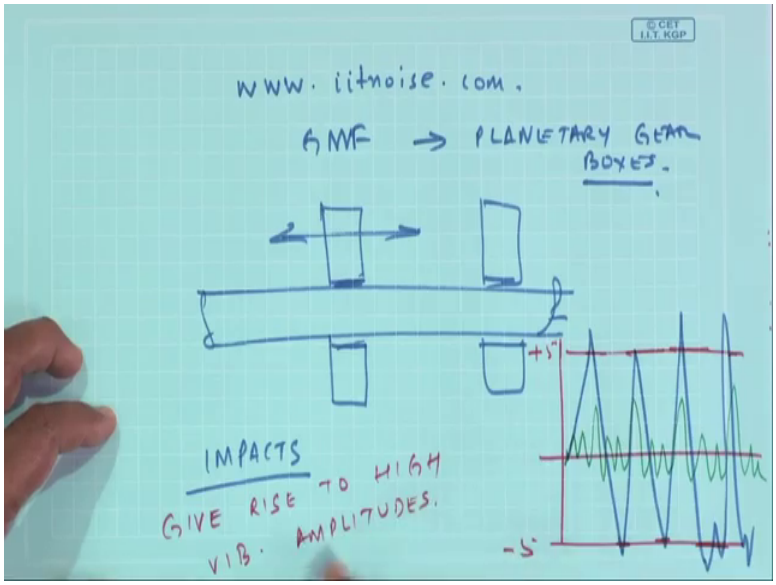

You can referred to my book details of which you can find out at IIT noise dot com, where I have given to find out GMF of planetary gear boxes ok. Now another very important machinery fault is mechanical looseness, we talked about so many elements here shaft carrying as an component, they are loose they are they can slide around ok, they can hit against something else so, lot of this impacts will occur.

So, when impacts occur the vibration signal actually for a nice periodic signal, but if impacts occur what happens lot of high values occur, but then because this is limit of my data acquisition system lot of clipping occurs clipping of the waveforms occur, impacts give rise to high vibrations amplitude.

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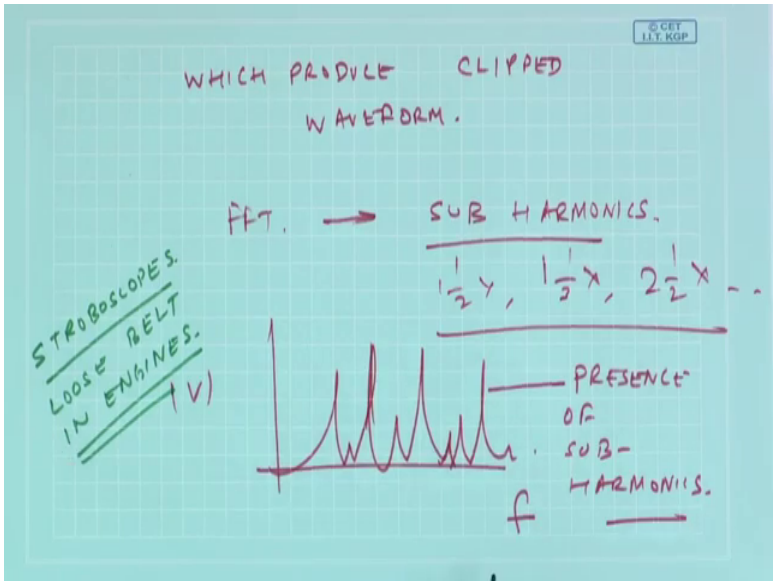

Which produce which produce clipped waveform, so if you do an FFT of clipped waveform, we will actually see lot of Sub Hormones so, 1 1 and half X 1 3 X etcetera 2. So, these are the telltale sciences. So, lot of lot of internals sub hormonics (Refer Time: 24:17), and these are the telltale science of signals, where there is lot of looseness in the system.

You will come across machines where there are lot belt drives of course, when I told you to detect looseness, we can use what is known as stroboscopes like finding out Loose Belt in Engines. So, this can be found out in search systems ok.

So, in a faulty belt drive the RPM the belt, and particularly in the radial directions. Now in a fluid handling device beat water air, I am talk about turbines I am talk about pumps, talk about compressors. So, if the turbulence has increased because of a defect, they will be dominant blade and vane passing frequencies and harmonics, and they will be in radial, and axial directions, and then the levels would increase indicating that there is an increase in the turbulence, but many of these scenarios.

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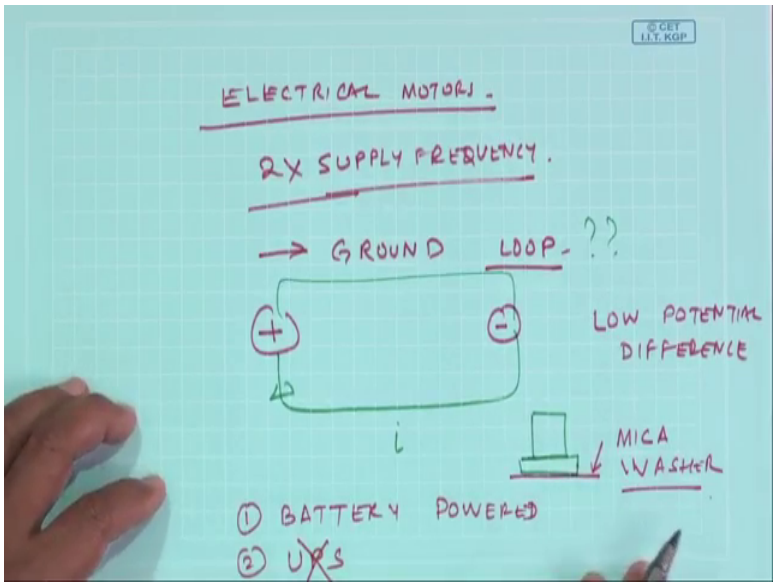

You will come across that many systems are actually driven by electrical motors, many a times the supply frequency related issues do come up, or twice the supply frequency will come up in the spectrum, and sometimes because of the grounding in proper grounding there is a ground loop, which occurs and this if it is not avoided between your instrumentation, if any 2 devices are kept at very low potential very low potential difference, and if there is a conducting path, they will there will be a flow of current.

So, those of you who are doing instrumentation for CBM ground loop prison problem which occurs in all concerned measurements. So, sometimes when you mount an accelerometer, it is good practice to put Mica Washer it is 1 minute and some of these instrumentation, you can have them Battery Powered, even if you run them on UPS is not good, because they still use an AC signal, and they will be ground problem so, this problem. So this problems can be taken care of and of course, you will know for sure that whether a particular vibration is because of the electrical signal is want to switch off the electrical supply.

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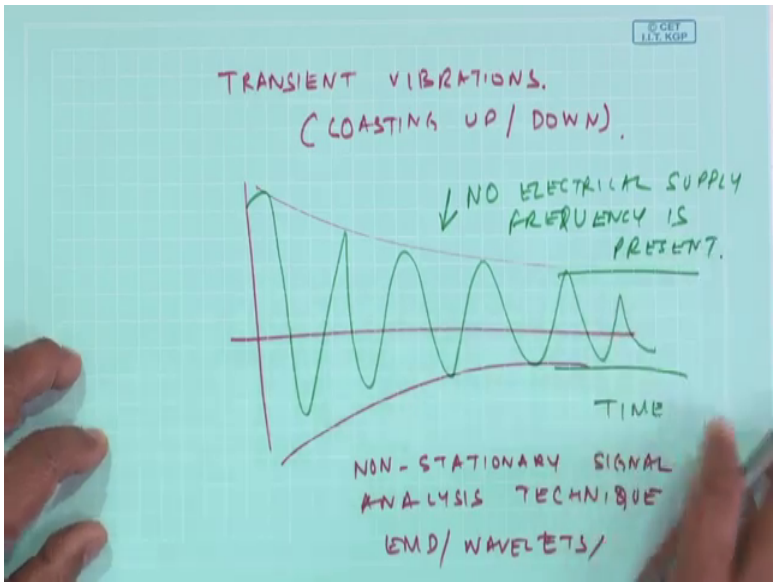

And there will be many case cases, and particularly for transient vibrations which is known as you know coasting up a machine down.

So, what will happen so machine that given examples earlier, So, machine is a switched off vibration would reduce, and if there is no power; obviously, there is machine come down rest. So, such and then of course, these are transient signals. So, we have to use non stationary signal analysis technique to deal such signals like EMD or wavelets, but the best part about it is know electrical supply frequency is present, but however, in many of the electrical systems.

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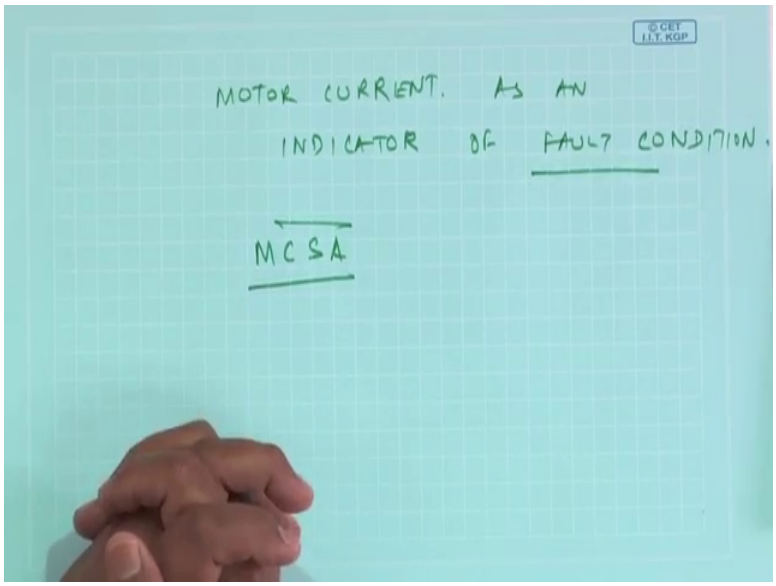

We take the motor current as an indicator of fault condition, and this is something I would I am going to discuss next week when it talk about MCSA the theory behind it in the practical applications. So, sometimes it is not good to eliminate vibrations, I am into it is a good idea to eliminate vibrations by switching off the electrical parts of apply frequencies. So, this will disappear when we turn off the power, because anything related to the electrical signal will get switched off ok.

So, this can be taken care. So this class give you an overview of whatever we had studied so, far in terms of finding out faults in mechanical systems. So, basically mechanical systems consists of a motor, or a prime mover driving mechanical unit, and the different common machine elements which one will or machine components one would come across or rotating shaft, which could be unbalance, which could have a crack, which could be misalign and of course, it could carrying bear gear supported on bearings, put in a housing which could have cracks which could have a (Refer Time: 32:02) problem and so on.

And then the bearing themselves could be general bearings or under friction bearings. So, all these things will manifest as vibrations signals, and as you will see you know the signal which comes out when never says that I am from bearing or I am from gear, everything will be composite signals. So, you have to use our signal processing techniques in a very efficient manner in CBM to identify the characteristic frequencies as

per the charts, I had just discussed. And if you follow this chart you will be able to practically find out many faults in systems, but let me tell you this is not an exhaustive list.

And again from experience sometimes, I have seen that systems always do not follow this charts, in my book, in an a pendex, I have given another chart which is out of my practical experience, and dealing with the (Refer Time: 33:07) of different industries a doing machinery condition monitoring. So, you can refer to my book to see this chart, and see some practical case study wherein, we can find out fault in systems.

Thank you.