Machinery Fault Diagnosis and Signal Processing
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Lecture – 43
Pumps and Cavitation

So far, we had discussed about the faults in bearings and gears well because they are the most common machine elements apart from the of course, the rotating shaft and today, we will focused mostly on the machines like pumps compressors turbines and so on and of course, with pumps there is a phenomenon associated which is cavitation and how actually all these help us in monitoring the condition of a fluid machine, be it a pump and so on by actually monitoring the vibration due to cavitation and we will understand what this cavitation is and so on.

Before I go into pumps and cavitation of course, these fluid machines, we are talking about they will handle either air or a gas.

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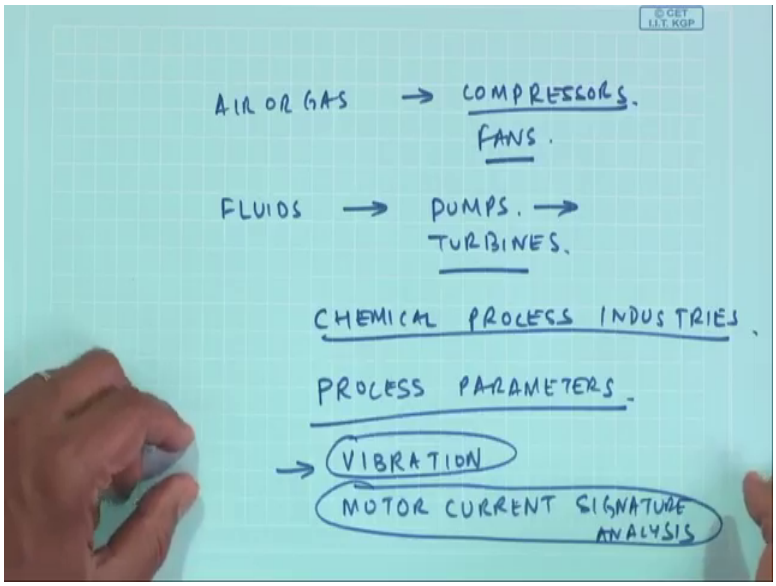

And they are the compressible fluids which are handed mostly by compressors or fans and then we will talk about fluids will the pumps because we will have turbines as well. So, depending on the application, when we give in a mechanical energy and then you get an hydraulic pressure jump or pressure increase the flow rate and so on and we will have the pumps or vice versa. We can use the fluid to generate a mechanical power as in

turbines. So, depending on the applications, we will see in industry pumps turbines compressors fan either with the working fluid being air some sort of gas and or in fluids and liquids fuel etcetera.

So, all in the chemical process industries one will come across all these machine elements or machine types which are pumps turbines compressors and fans and of course, you know they can be classified depending on the kind of flow other kind of direction of the flow kind of energy which is transmitted and so on, but in a chemical process industries lot of the process parameters do get affected and sometimes the process parameters know; what are the process parameters like in flow rate like in velocity like in the pressure like in the temperature.

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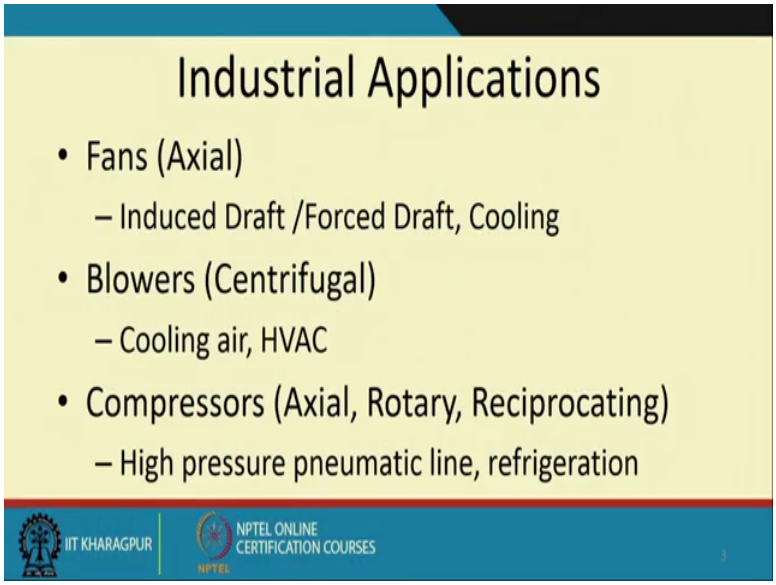

These are some of the process parameters which the condition monitoring or the plant maintenance engineers always watches to see, how efficiently the machines are operating.

However there are also instances wherein, we will see in this class, how through vibration and another topic which we are going to discuss in detail next week that is motor current signature analysis. I will just briefly introduce you to motor current signature analysis and how they can be used to also find out the condition of the mechanical unit being driven by an electrical motor and this electric motor unit this mechanical unit could be a pump and so on.

So, if you look at some of the industrial applications of this fans; the axial fans, we have the induced draft fan fd fan an of course, certain cooling fans particularly in power plants, you will see this kind of fans which will blow in air sucking air to the boiler and then exhaust out the flue gases And the air feed to boiler etcetera.

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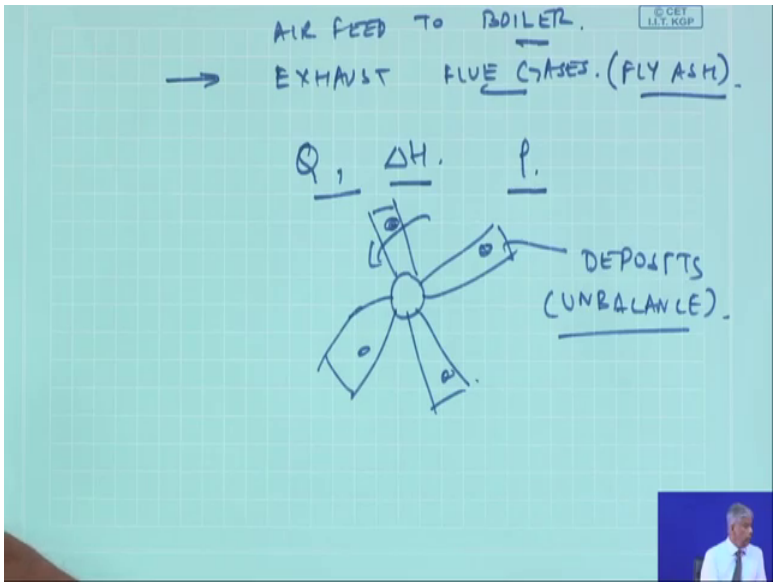

So, you require fans of a particular flow rate particular pressure head of course, handling a particular density of the fluid and I had given you an example just to recollect particularly, when flue gases come out of the boilers, they have lot of fly ash particularly, in a thermal power plant and this fly ash could get deposited in the veins or blades of the fans. So, there could be deposits and the deposits could lead to unbalance, we have discussed how unbalance can be detected can be rectified and so on, but such scenarios happens in industry where we have flue gases delivering and getting having fly ash and who get deposited in the blades which will create an unbalance.

Similarly, we have lot of blowers like in the cooling air or in the hvac systems of course, it depends on the speed and flow rate, etcetera and then we have compressors again axial rotary reciprocation like high pressure pneumatic line refrigeration and so, on. So, in the industry you will see all these things happening and particularly they are very noisy of course, the design of the silencers is a different issue, but how do you understand that something has gone wrong with these devices a very important parameter that is similar

to gear machine frequency is what is known as this vane pass frequency which is nothing, but number of veins times the rotational speed.

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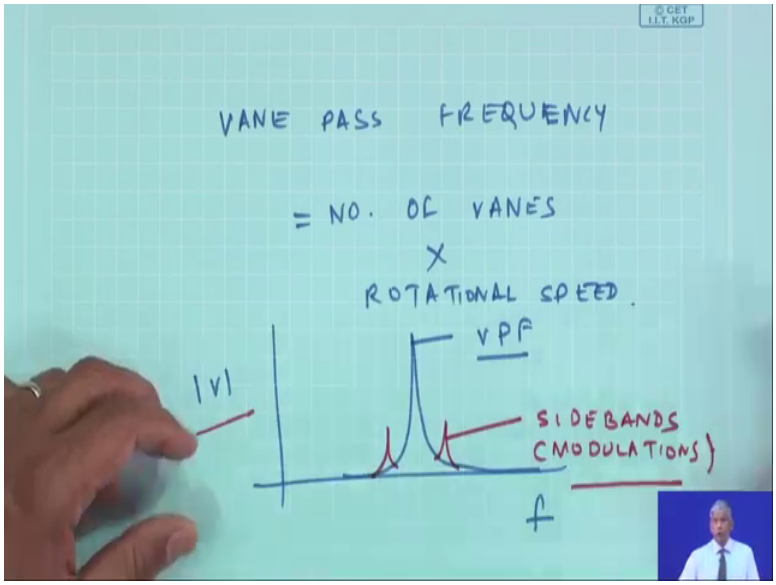

Sometimes, again you will see there is a in the vibration spectrum you will get the peaks at the vibration have vane pass frequency, but you may sometimes also get side bands and you know side bands are only because of more relations. So, one could monitor the vibration and look out for the amplitude of the side bands of course, you know sometimes, again, let me tell you the practical problem of monitoring these things is whenever we have a machinery now by now, you must be getting an idea that any machine I am talking about.

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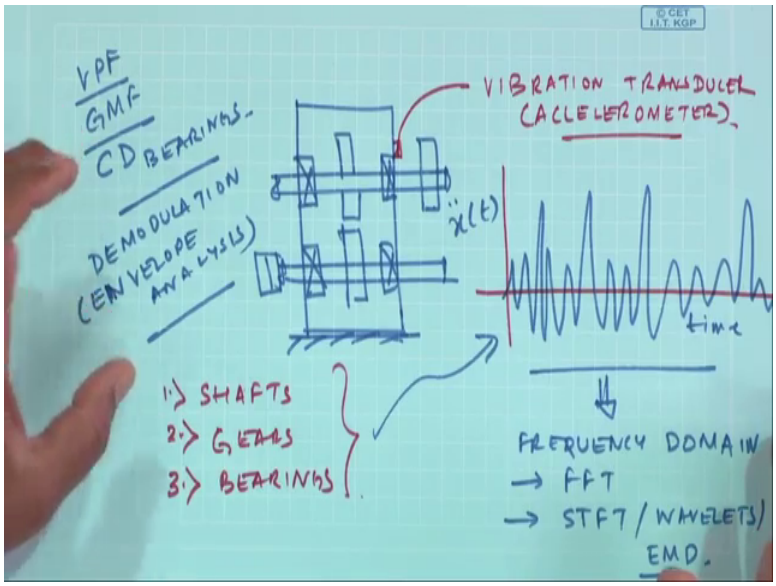

there are shafts which are supported on bearings they could be carrying pulley they could be carrying gear whatever there could be a pulley and so on and they are on my foundation and they have been driven by a some unit and if I put one transducer or vibration transducer and you know that accelerometer. In fact, the piezoelectric accelerometer is one type of accelerometer which is predominantly used.

So, when a fault is occurring in all of these for example, shafts bearings gears if I will list them let them down soft could be having misalignment cracks and then of course, there could be unbalanced, we have gears we have bearings and by now, we know how the defects in these individual system would look like, but when I am picking up a signal by an accelerometer in the time domain it will be everything will be there some x double dot t. So, this is because of all the faults.

So, it is actually a carefully transforming either to the frequency domain of course, by now you know how to convert them to frequency domain bleated if it is a stationary signal you can do FFT or you can do STFT or wavelets or even EMD if it is a non stationary signals.

So, once I characterize the time domain signal into a frequency domain I can get all this telltale science of whether vane pass frequency is there, whether gearing mass frequency is there wherein the characteristic defect frequencies or the bearings are present. So, all these can be individually identified on top of it sometimes because of modulation I have

to do what is known as demodulation or trade name in some industries envelop analysis we have covered this all this beforehand.

So, I am giving you an example if you go to an industry to monitor the vibrations of any machinery you will get a signature like this. So, you have to use your techniques of signal processing bit FFT or STFT or EMD or wavelets find out the appropriate characteristic frequencies and then only monitor the amplitude had these characteristic frequencies and to find out what they fault is.

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So, just for the sake of completion classification of compressors you will have positive displacement or the rotary compressors like the 1 rotor or 2 rotors and the turbo compressors like the axial flow or the centrifugal flow. So, you will see in industry many of these compressors you will come across.

So, the somebody asks you find out the fault in a particular compressors, how do you do it, well, thumb rule is measure the vibrations as close to the dynamics of the system and that could be very close to a bearing and again find out these wind pass frequencies see if sidebands are there sometimes just a plain fast Fourier transform you may not be able to distinguish the sidebands from the noise floor and be careful you know when I am talking about noise floor this lot of lot of practical experience I am talking here.

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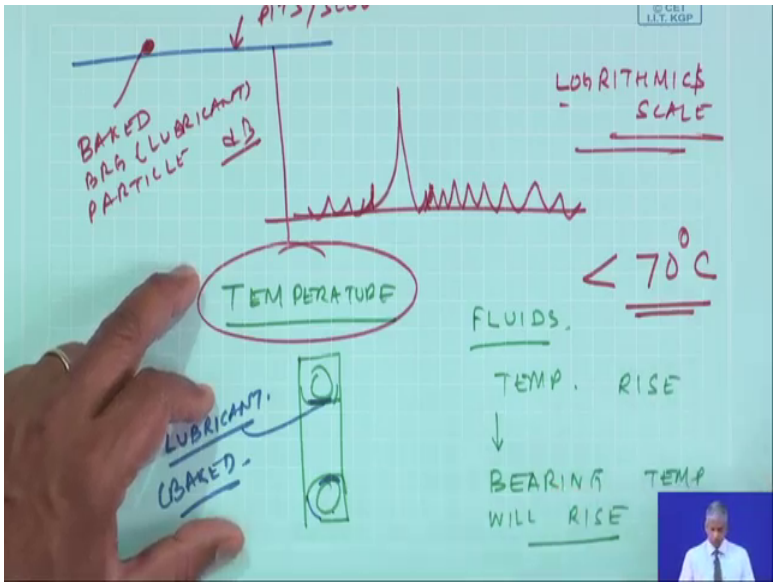

Sometimes the noise floor is so, low that these sideburns are buried. So, we have to use some techniques like I told you know sometimes in a logarithmic scale well scale will help you ok. So, you see this in a dB scale.

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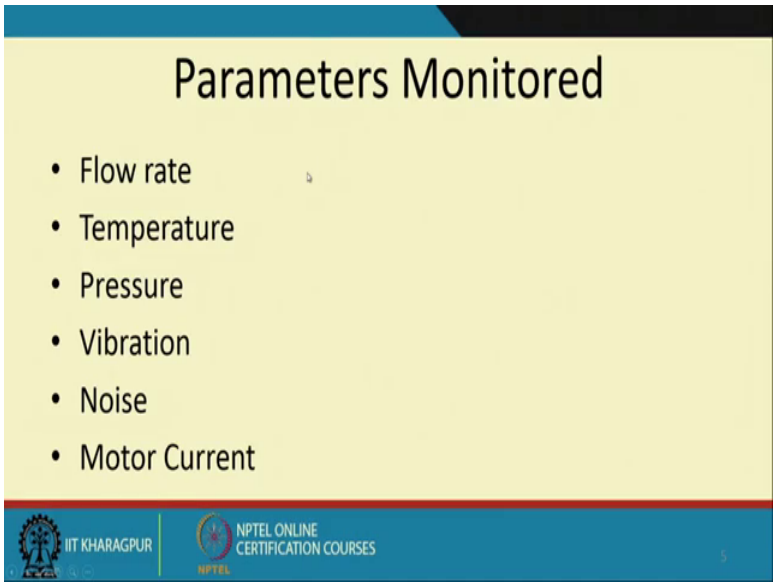

So, that the small changes would be amplified and so on; Now what are the process parameters to be monitored in such fluid handling machines flow rate temperature pressure position noise motor current, again, just to recollect temperatures and told you

that many of these fluid handling devices compress fluids. So, when you compress the fluid that temperature would rise.

So, what happens the temperature rise the bearings will also become bearing temperature will rise now if bearing temperature rise what happens, I had told you that this bearings, there are certain races on which there are rolling elements and then there is a layer of lubricant. So, the lubricant will get baked and then it will form a hard carbon residue which will become unlike an impurity if you open the race of the bearing there will be like an impurity because of a baked bearing particle or bearing on lubricant particle. So, on top of it, if this becomes a very hard surface it will create pits and score the race and then it will lead to more vibrations.

So, always when you are monitoring process parameters a temperature becomes a very important parameter in many industries, they never allow temperature of the bearings to go below 70 degree Celsius and same as to for vibrations you know, I had referred you to the vibration standard the ISO vibration limit standard.

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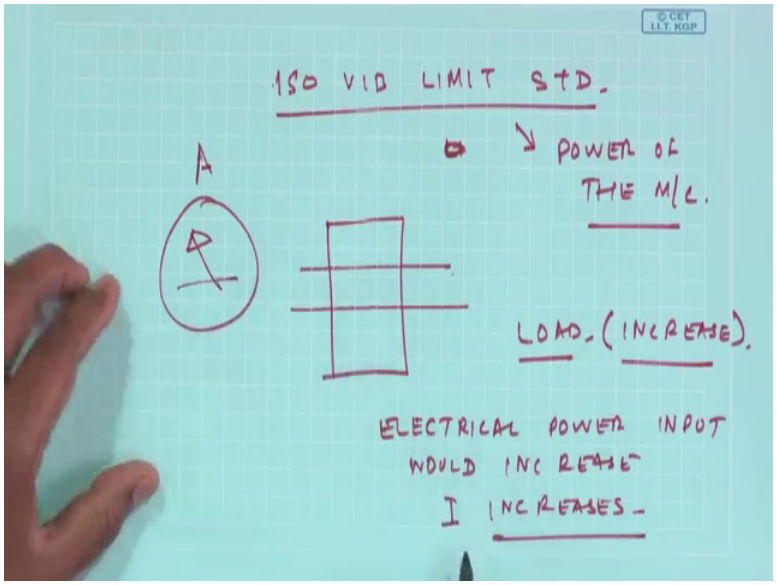

So, make sure the absolute level of the rms of the rms level of the vibration is within the limits of depending on the which is related to the power of the machine ok, even if that is done you can do it and another very important thing is because of some obstruction and the fluid handling device ok. If there is an obstruction either in the delivery side or in the intake side there will be a load on the system. So, because of the load would increase,

what would happen your prime mover draw more power more electrical power input could increase. So, just so, for the same voltage the current I increases.

So, even just monitoring the current by a simple ammeter you will give you an indication that it has become excessive and then there is something wrong. So, I must tell you that though I told you that seventy percent of the cases in machinery condition monitoring is by vibration monitoring, but then there are some easy signals which are being given out by process machines, it could be motor current, the current on by the motor, it could be the bearing temperature, it could be the flow rate, it could be the speed at which the fluid is flowing etcetera apart from the vibration and the noise are which are also good parameters.

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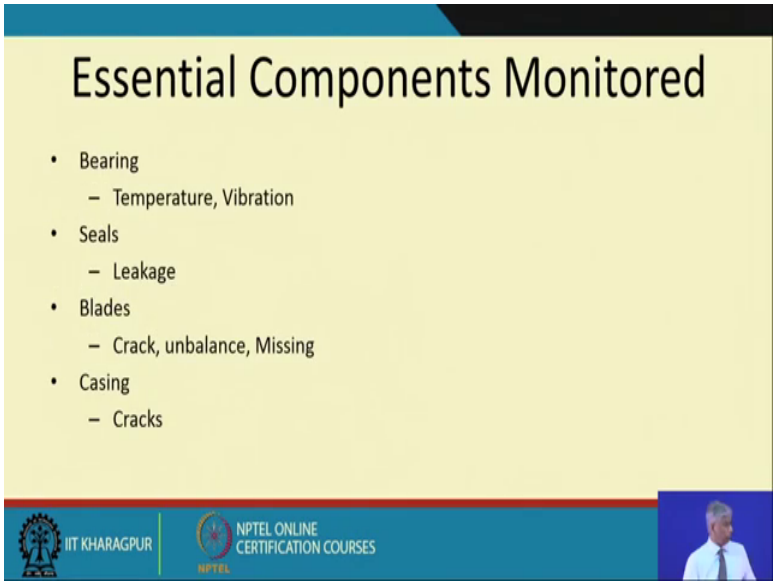

So, in fluid machines what are the essential components which are monitored the bearing temperature vibrations seals there will be lot of leakage in the seals. So, seal leakage could be measured either through an infrared thermography or a thermal imaging and blades cracks unbalanced missing you we all know and casing cracks this all can be monitored by vibration. So, some of these cases situations can be monitored either through vibration either through thermal imaging.

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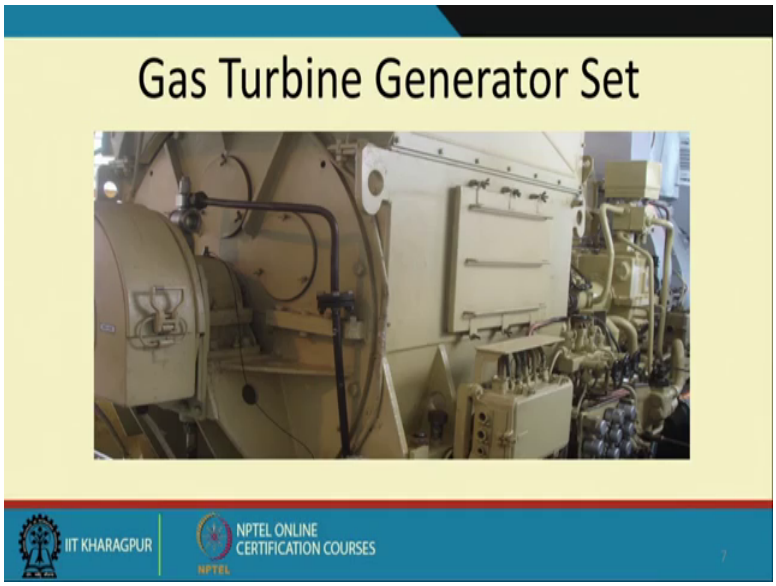

So, we will discuss about motor kind of signature analysis and thermal imaging next week, when I talk about other techniques of doing condition monitoring and another thing, when I am talking about motor current analysis, you see in a lot of the applications there are gas turbines beat in your ships your aircrafts which power the system, but then this gas turbines also drive a generator gas turbines would drive a generator ok.

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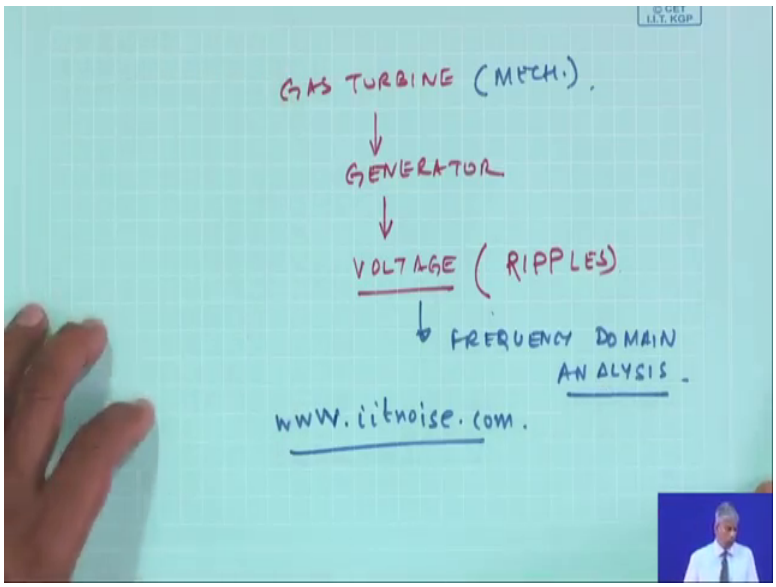

So, generator would generate a voltage, so in fact, if you look at the ripples or do a frequency domain analysis v frequency domain analysis you can find out the mechanical

defect in such gas turbines and I have a patent on this and for the more details of this patent you can go to my website and anybody who wants to obtain the license of this patent from me can get in touch with me. So, for that matter any mechanical device which is being coupled with the generator and if somebody does an analysis of the voltage in generated by this generator, we can find out the different frequencies or the mechanical unit and this is what we did for the case of a gas turbine ok.

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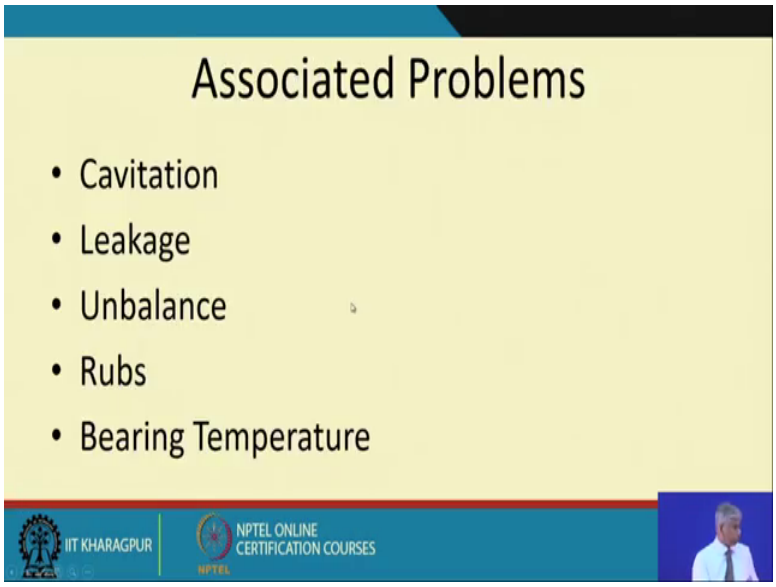

But some of the associated problems in fluid handling devices are what is known as a cavitation and cavitation in a fluid handling device occurs when the fluid is going at a very high flow rate that the fluid pressure becomes less than its vapor pressure ok.

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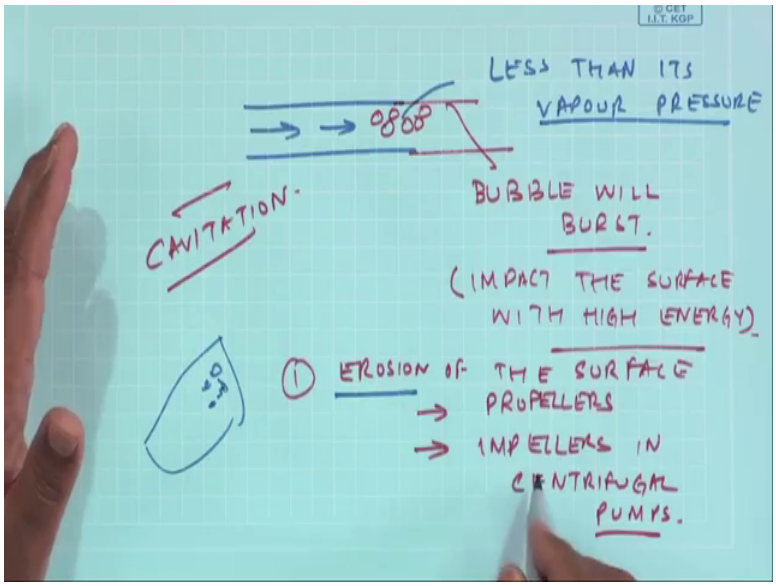

So, if you increase the flow rate and or if you change the pressure upstream and downstream you will get its vapor pressure. So, once what happens there were a lot of bubbles suddenly which will form and further downstream and the pressure equalizes to the atmospheric pressure where you are discharging ok; what will happen this bubbles will burst bubbles will burst.

So, bubble bursting what happens they impact the surface with high energy ok. So, this happens in the. So, what happens they will create erosion of the surface is the net effect and this is determined in propellers in ships even in a impellers in centrifugal pumps. So, if cavitation is not checked, it will lead to weakening of the structure and then eventually failure. So, there will be lot of you know on the blade there will be lot of pitting marks and of course, you know if things have eroded and if they are not uniform they will give rise to unbalance they will give rise to things may crack and break and so on.

So, cavitation is not it is a physical phenomena; we cannot avoid it because if our process parameters are not under control. So, the way to reduce cavitation is operating at low speeds ok, but how do you detect cavitation is what we need to know from a monitoring point of view how to detect cavitation see because of this sudden explosion of bubbles where implosion is actually a better word of bubbles.

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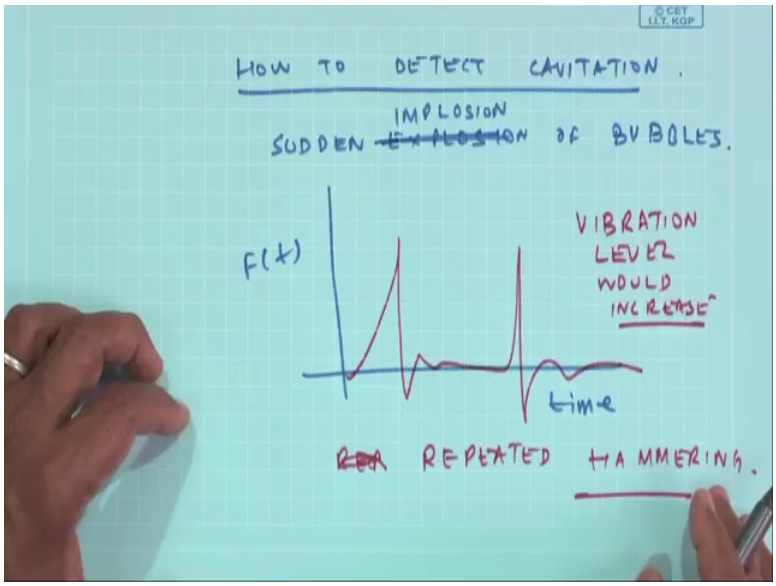

They will give rise to in the time domain something very very similar to physically, you can see as if something is getting hammering repeated hammering is what you can repeated hammering is what happens.

So; that means, as if somebody is hitting. So, of course, the vibration level would increase, but what can you say about the characteristic of the vibration level in terms of the frequency and you are know from your experience with frequency and time signals.

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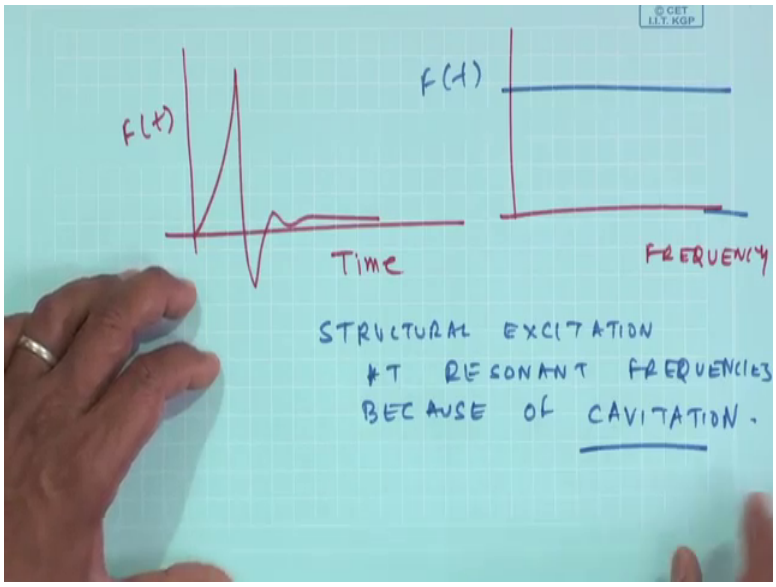

So, impulse in the time domain because of one hammer will actually excite all frequency so; that means, again similar to very similar to the phenomena which I discussed during impacts in the races of the bearings. So, what happens this is also going to excite the structure. So, there will be structural excitation at resonant frequencies because of cavitation ok.

So, just by of course, you know one has to again be very careful about the transducers you know many times we try to measure High frequency vibrations by whatever accelerometer, we have in the lab or with us ok.

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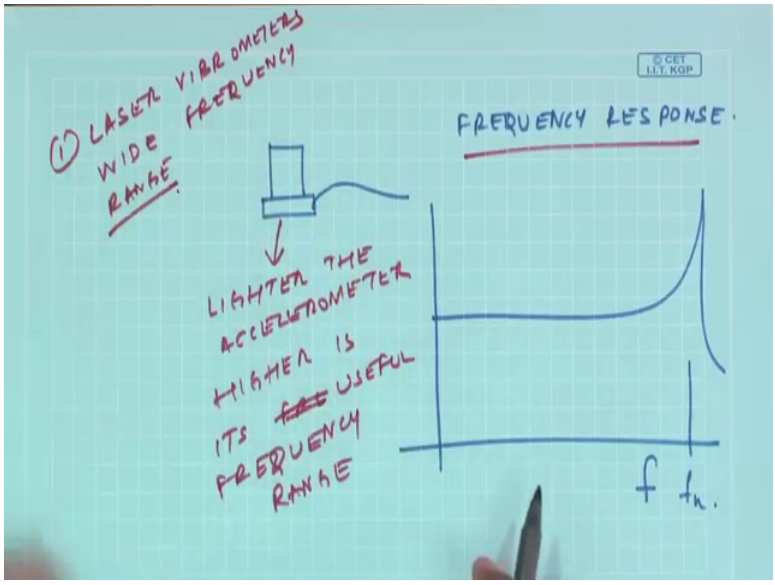

Be careful regarding the frequency response of the accelerometer if you will recall in the accelerometer chapter, I had discussed about the frequency response of accelerometers, the lighter the accelerometer higher is it is useful frequency range. So, make sure that you have the right kind of vibration based accelerometers to measure cavitation because it is a very high frequency vibrations because when a machine is running you; obviously, when you put the vibrations you will also see the rotational shaft speed one x or its multiples or the vane pass frequencies and so on.

But cavitation we will create a high frequency vibratins and this will be monitored only with an accelerometer which is which can measure at high frequencies otherwise another method is you can use laser vibro meters because laser vibro meters have a wide

frequency range ok, its can be done of course, another problem which we which occurs in all these fluid devices is the leakage at the seals.

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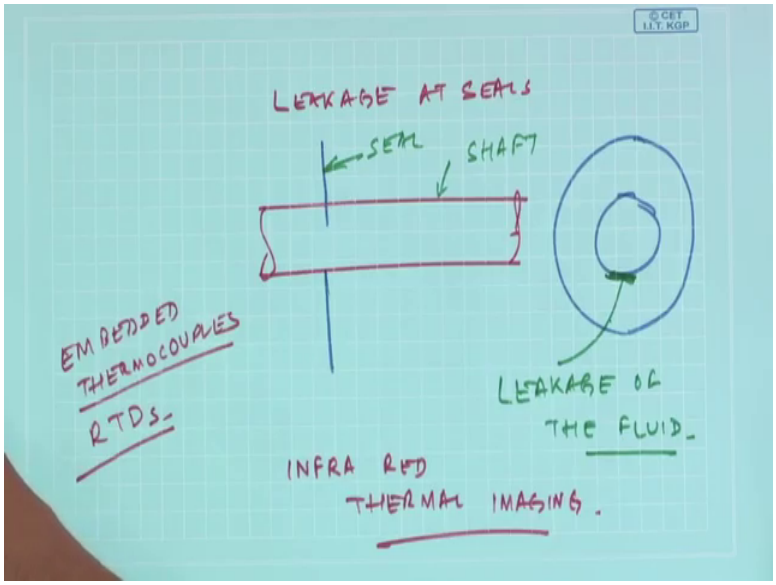

So, where shaft is running and all around it there is a seal and there is a leakage pass the seals some leakage is a of the fluid usually in such turbomachinery in this fluid is actually at a different temperature compared to the seal or the shaft

So, through a technique called infra-red thermal imaging which I am going to discuss next week, you can see that such leaks in the system can be detected because we know about unbalance rubs and of course, bearing temperature again either you can use infrared thermal imaging or you can embed embedded thermocouples couples RTDs, etcetera, it could be used.

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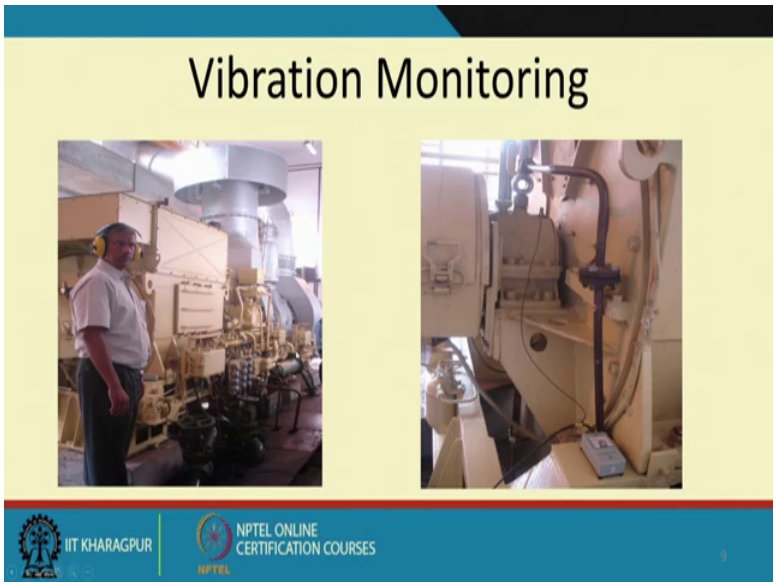

So, this is a case on the same gas turbine, you know where we are monitoring the motor current perhaps in the next slide you will see and we are also measuring the vibration within any acceleration transducer.

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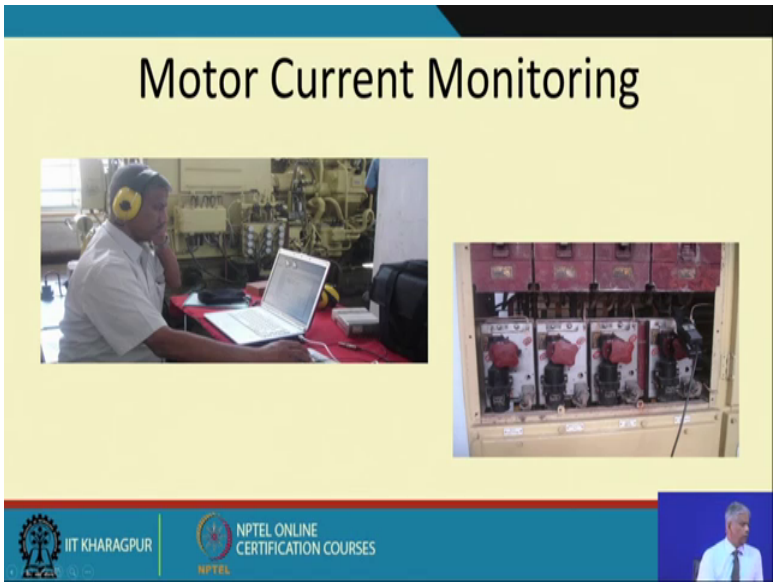

And the same thing could be then measured by a motor current this for some Indian Navy preparation we are doing it.

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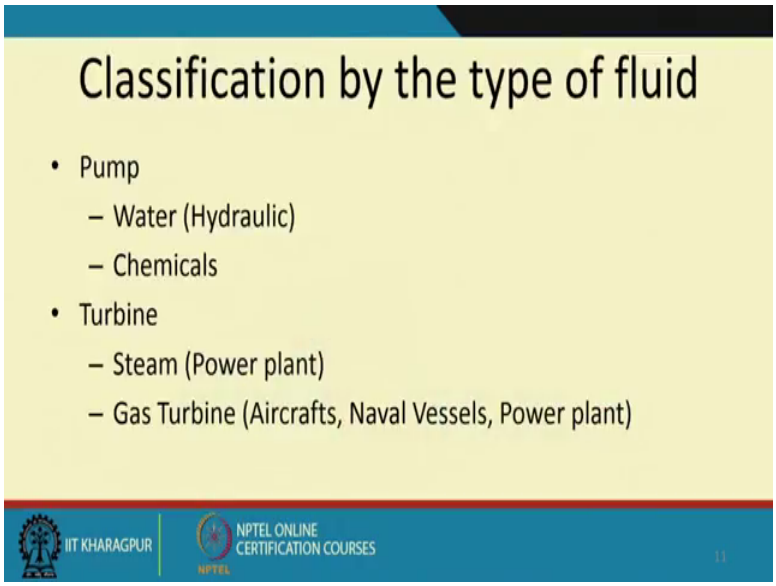

So, again you when you go about pumps and there will be water hardly pumps or chemical process plants and then turbines and steam power plants gas turbines and aircrafts naval vessels power plants.

So, all these can be monitored by the technique which we know by now and I believe by now all of you must be getting a feel that you should be able to monitor the health of any machine beet a motor beet a gearbox beat a pump beat a turbine and so on and then I will in the next class, I will talk about a case study in the case of an IC engine, how do you monitor the fault and then I will wrap up this week with an overview of how do you classify the faults in all such rotating systems.

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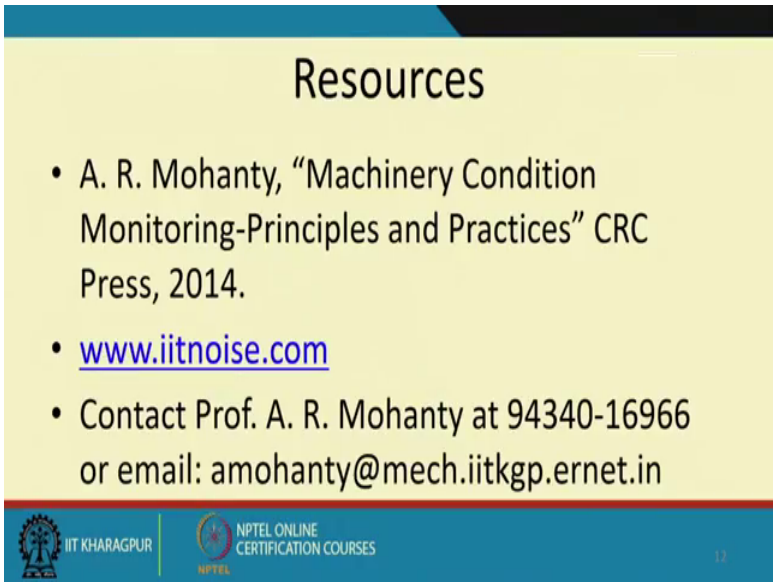

Thank you.