Machinery Fault Diagnosis and Signal Processing
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Lecture - 39
Misalignment

We will continue our discussion on the defects in rotating machines, in the previous classes we talked about balancing and sorry in balancing how we can remove imbalance or unbalance by in balancing the rotor shafts and then another very important fault or very commonly occurring fault is misalignment you know sometimes, in real world it becomes very difficult to distinguish between misalignment and unbalance also, but never the less misalignment there are many reason why misalignment occur and I will come to that.

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I will just a little bit and as I was telling you in the laboratory, we have this rig wherein we created artificial misalignment by introducing shims on the base ok.

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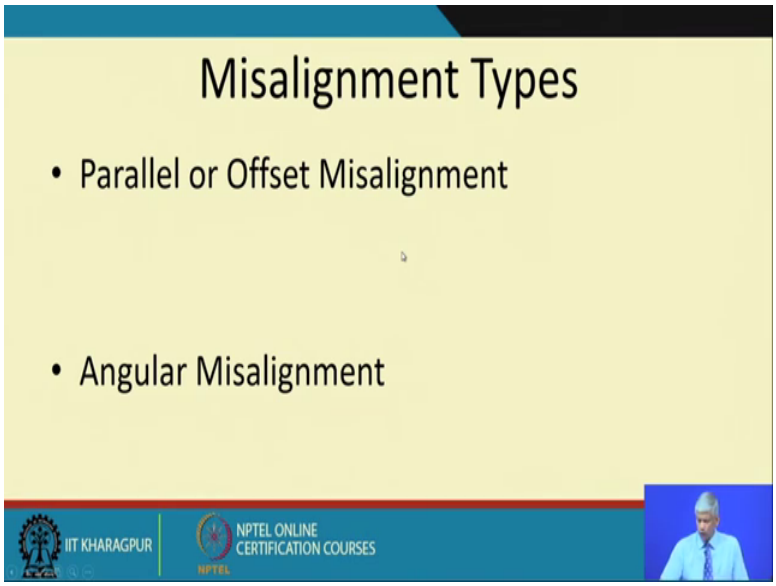

So, what is this misalignment and soon see ideally as I was telling you before in all this machines which we are talking about there is a prime mover.

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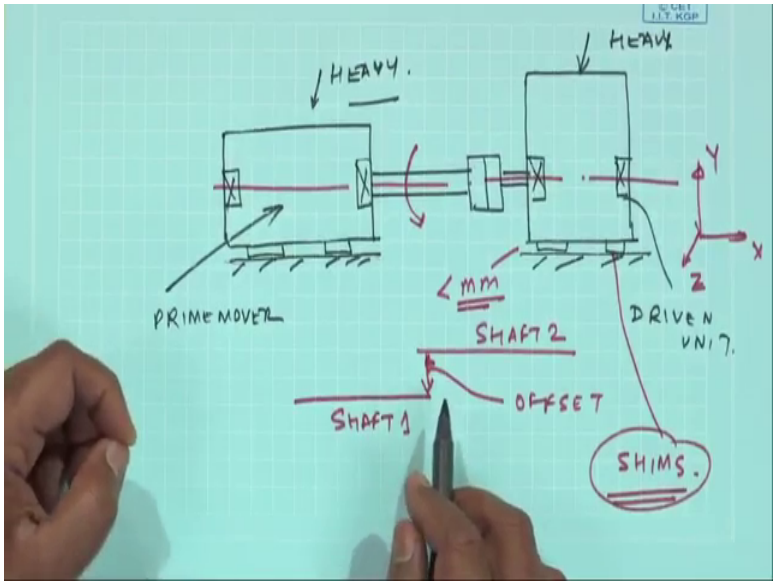

Which is driving a mechanical unit and this prime over is actually on a foundation and similarly the driven unit this is also on a foundation and mind you these machines can be very large; I just give an example of the cement plant this could be a large cement clin driven unit. So, they ideally if a shaft the both the shaft I am just drawing the central line as a shaft, they have to be you know single straight line see if we rotate there are no

forces, because of either what is known as the parallel misalignment. So, this is what is known as offset. So, shaft 1 shaft 2 so this is what I mean by a parallel or misalignment why did this happen may be this was at a different position along this direction, so along y direction perhaps, so as shifted or along z direction and so on.

So, this happens misalignment happens because, when you are installing large machines this foundations I have to be almost very straight line smooth, because of little defect in the construction and this tolerances could be order of few mea millimeters less than a millimeter. So, that again brings about these are all rigid machines and we are bearings here they are all very rigid bearings supporting this systems. So, this kind of problem may occur and then they could be very heavy machines.

So, we have to physically ensure by putting some caring for the high difference by what is known as putting shims, shims are nothing but very harden steel plates which can take big amount of load and they can make up for this gaps, if this has gone up I can put shims at the foot of this machine and raise this shafts.

So, that they are aligned now how much to put where to put is something which we will physically do it and this problems occur because of many things usually once you are installing heavy machines it is defects or during installation.

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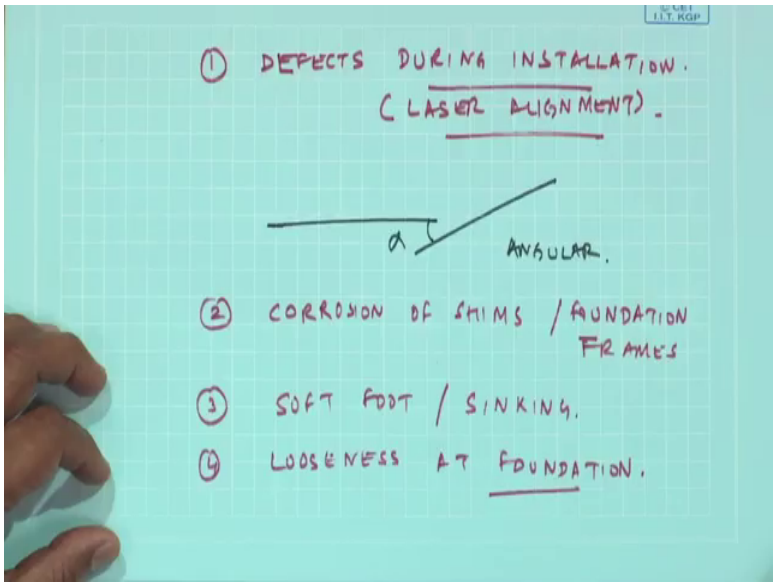

Now a days you know people use laser for alignment there again commercial companies we will align a systems and I am sure those are few who have taken your automobile to the car servicing stations, they will do a wheel balancing they will do an tire alignment or wheel alignment when it ensure that there is a uniform varieties in the tires and then another misalignment is this angular misalignment there at an sum angle.

So, continuing our discusses another could be this corrosion of shims or foundation frames, another could be soft foot sinking looseness at foundation; well I am not going to teach you about foundation design, but you know how good foundation design has to be done and then how vibration acceleration has to be done and so on. So, these are all possible reasons why misalignment can occur and I know of a case where in very close to the sea.

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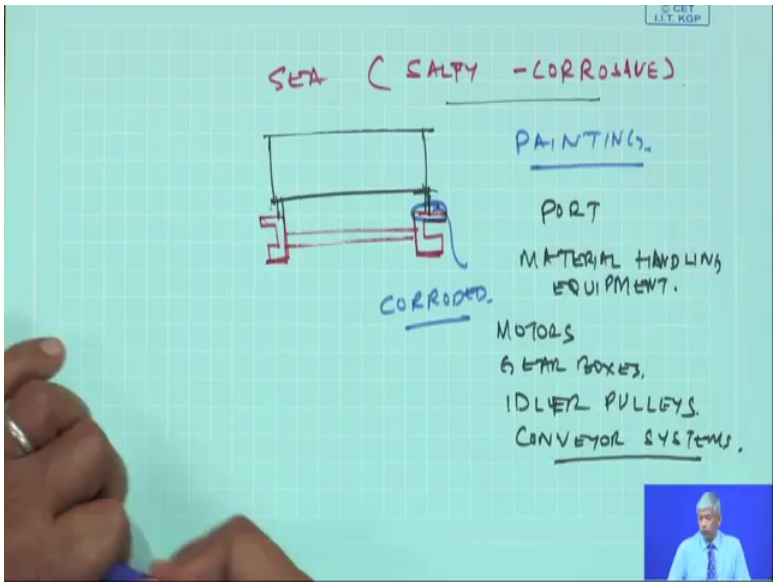

The atmosphere is salty, corrosive and you know this channels are available frames made out of channels and on to this the machines are put with proper foundation bolts and so on, imagine and then they are resting etc. I have I know of a case where an equipment where bought to the shore because, there was a port where there were lot of material handling equipment in terms of motors gear boxes, driven you know idler pulleys for the conveyor systems.

It was a new plant, but as soon as the conveyor system started operating they made excessive vibrations, on close examinations we measured the vibrations on closed

examinations we observed that these shims or these foundations had corroded and during installation whatever shims we are put, they corroded with time and so usually painting is done anti corrosive paintings are done to avoid such excessive variant here and so on.

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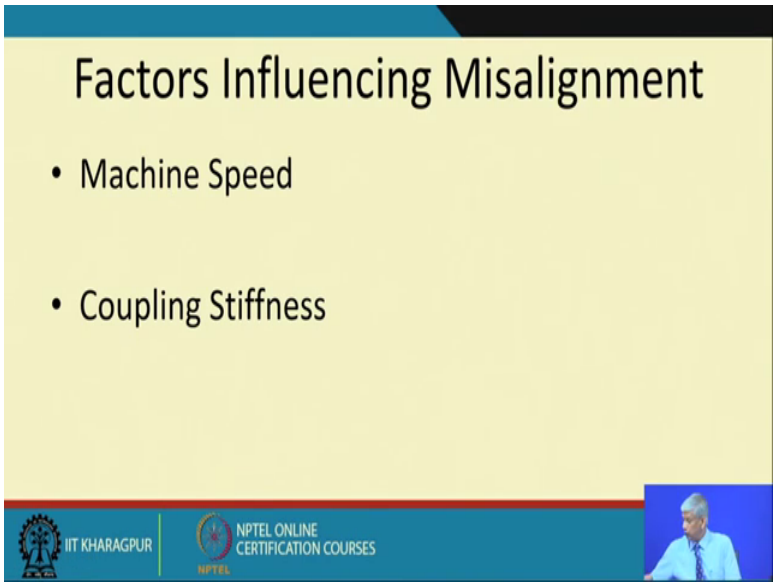

So, what are the factors affecting misalignment this misalignment can get increasingly high if the machine speed is increased, the coupling which is supposed to take away all the misalignments, here there is a small amount of misalignments this coupling can take them away for example, you would have heard of I will come to the coupling in little bit.

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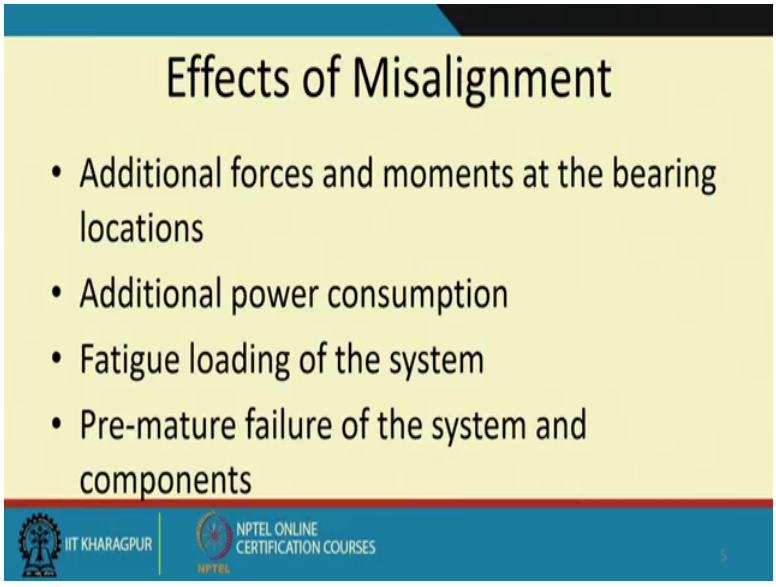

So, what happen the effects of misalignment is additional forces on moments at the bearing locations additional; obviously, if there are additional forces and moments they will be additional power consumption, because the frictional normal forces have increased. So, the frictional force would have increased and additional power consumptions to overcome this frictional forces; obviously, fatigue load of the system and premature failure of the system and components.

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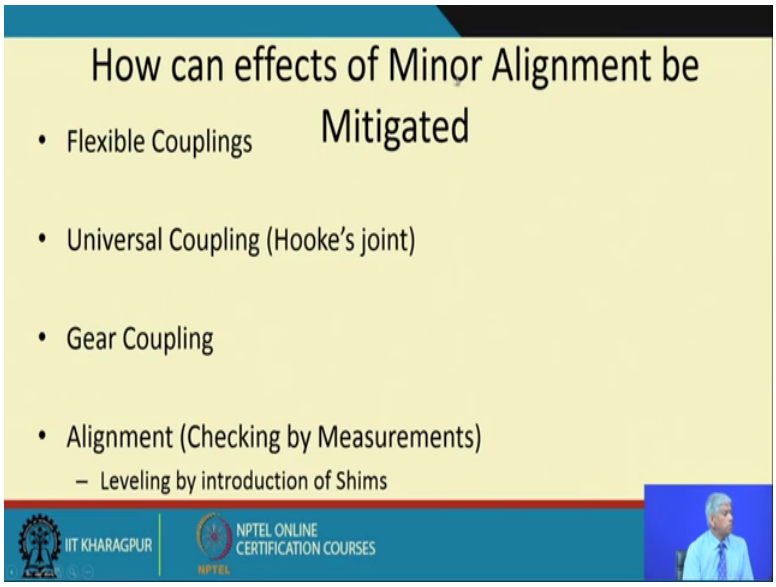

So how can minor misalignment be mitigated 1 is to have flexible couplings and you would have seen in all these machines which are driven by motors there are flexible couplings.

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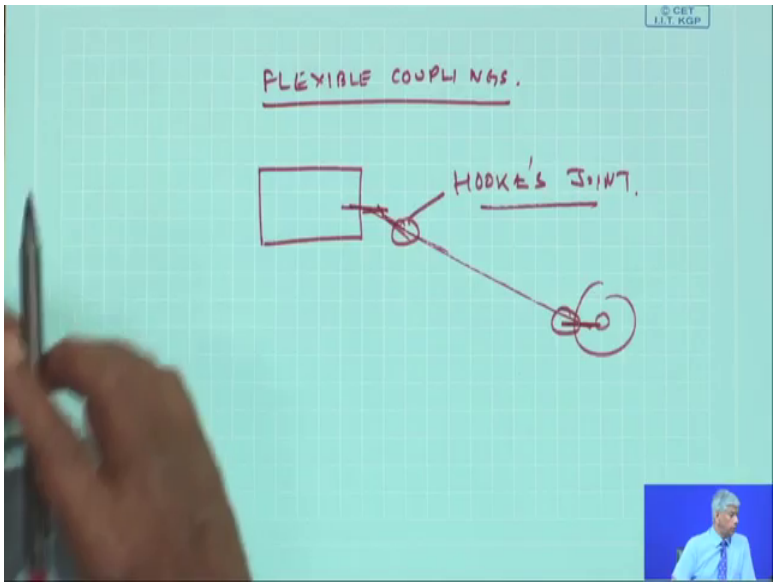

The helical couplings and so on gear couplings etc, but another in automobile we have a shaft or a engine here and differential here. So, there is a large angular deflection, so they put what is known as the hooks joint because, the angular defluxions or the angle of these 2 shafts are very high; but I am not talking about these kind of couplings, but small flexible coupling can be used, but despite having the couplings there is strong presence of misalignment. So, alignment is checked by measurements and leveling is done by introducing shims and shims can have their own problem.

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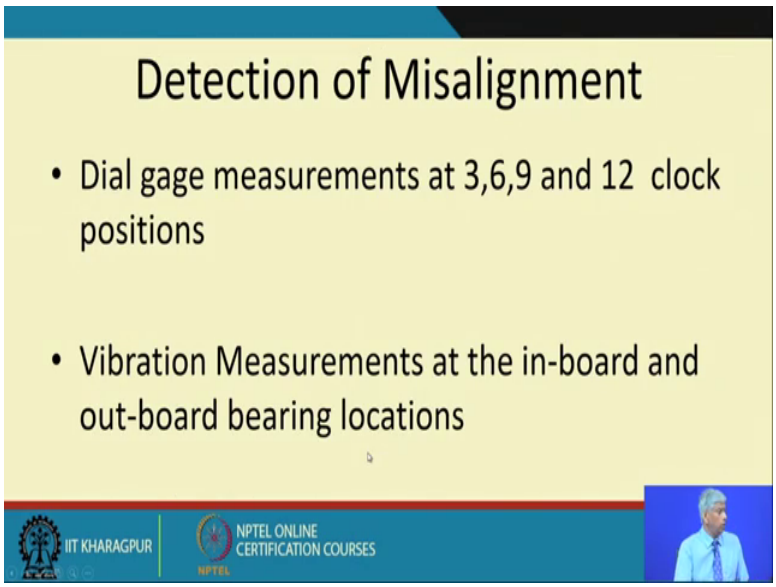

So, during installations for large machines you can always you know.

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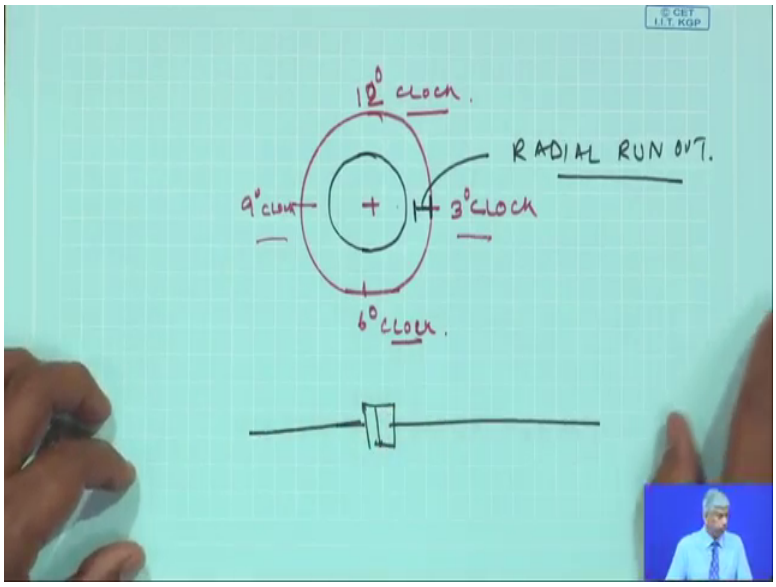

What is going to happen because of misalignment is 3 o clock 6 o clock and then the 9 o clock and this is 12 o clock this nomenclature is followed in the military and we also follow it here 3 o clock means looking at the watch 3 o clock means this position and so on.

So, if the shaft is rotating in the circle, the distance which it moves is the radial run out. So, radial run out if it is same in all the 3 directions or all the 4 directions; that means, the shaft is concentric with the housing. So, if shafts have both the ends are checked for the radial run out and if they are the same you can say for certainty that this shafts are aligned, otherwise you know you have to move shims on either of the locations so that they are aligned and vibration measurements are in board and out board bearing locations you can measure the vibrations and then you can find out.

So, but then from a vibration monitoring point of view how do you detect misalignment and that is very important as you would have seen in a shaft system.

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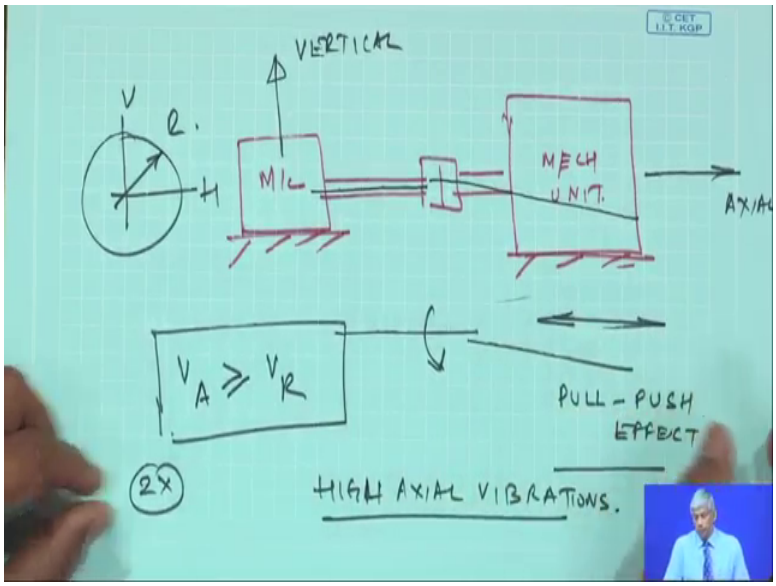

Is this shafts are misaligned there will be you know when they are rotating they will be a strong axial pull push effect, intuitively you can think softer rotating like a cone you know pulling pushing. So, this give rise to high axial vibrations, in one of the earlier classes I had mentioned you that this is the axial direction or the longitudinal direction and these are the radial direction; this my horizontal vertical this is my radial plane and then actual.

So, usually the actual vibrations V axial is higher than V radial and this is a sure case of letting you know that I am misalignment has occurred and usually if you look at the rotational speed being 1 x usually high vibration occurs at 2 x. So, 2 x vibration with a strong axial vibration compared to the radial plane is sure indicator of misalignment and the systems, but out of my practical experience I must tell you that whenever we have a machinery with misalignment.

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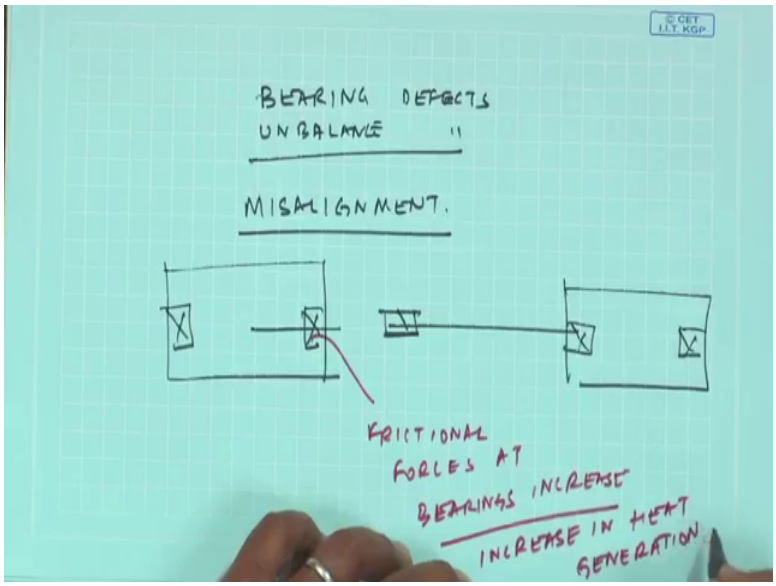

It will lead then this was neglected this is becomes difficult to sometimes identify because of bearing defects, because of unbalance etc and so on. So, 1 has to keep in mind.

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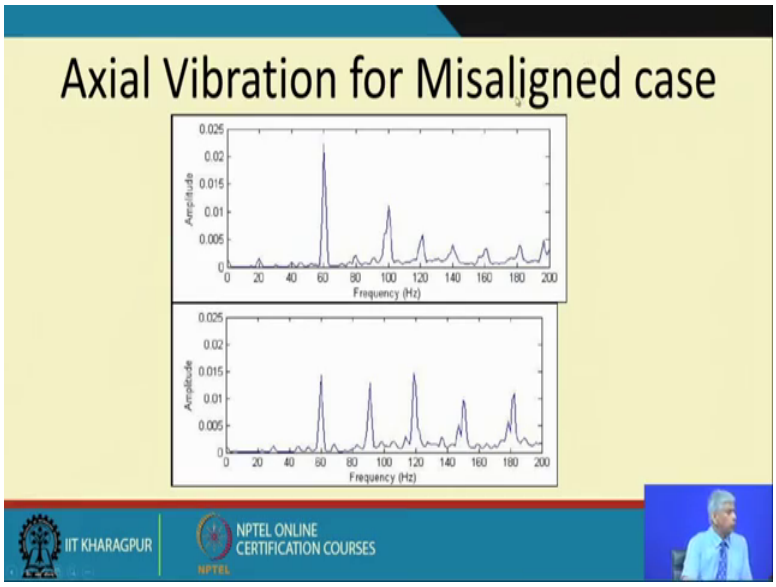

So, the best way is to look into the k vibration for the case of a misalignment, this was a shaft which was rotor rotating and then I can see very strong 2 x component here and this is 1 axial variation for misalignment case.

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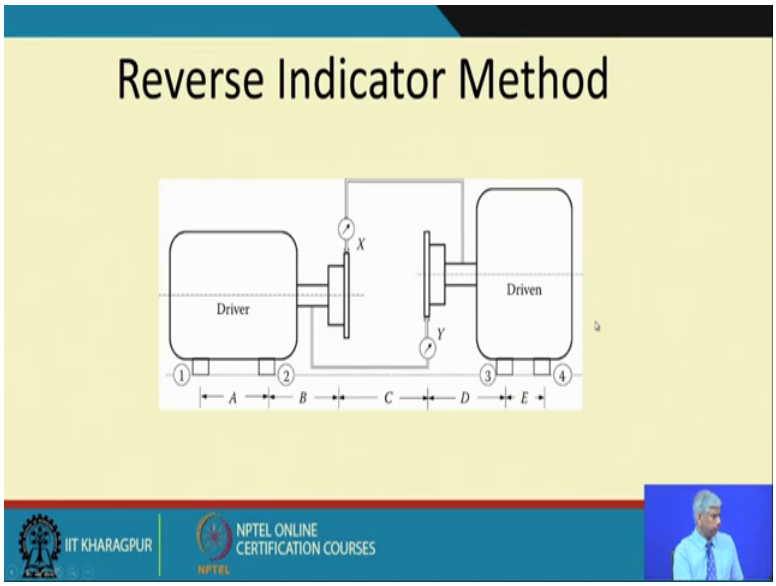

But question is you know I very crudely told you that we can measure the method by measuring the vibrations at 12 o clock positions 3 o clock positions 6 o clock and 9 o clock and by measuring the vibrations, we can see whether there is a strong axial component. I would be confirming that there is a case of misalignment, but later on we will see when we talk about misalignment; there will be forces coming additional forces coming to the coupling and this will also give some forces to the bearings, the forces to the bearings increase this frictional forces at bearings increase.

So, this leads to increase in heat generation at the bearings, so later on when we discuss a technique called thermal imaging by what is known as infrared waves, which is known as the thermograph.

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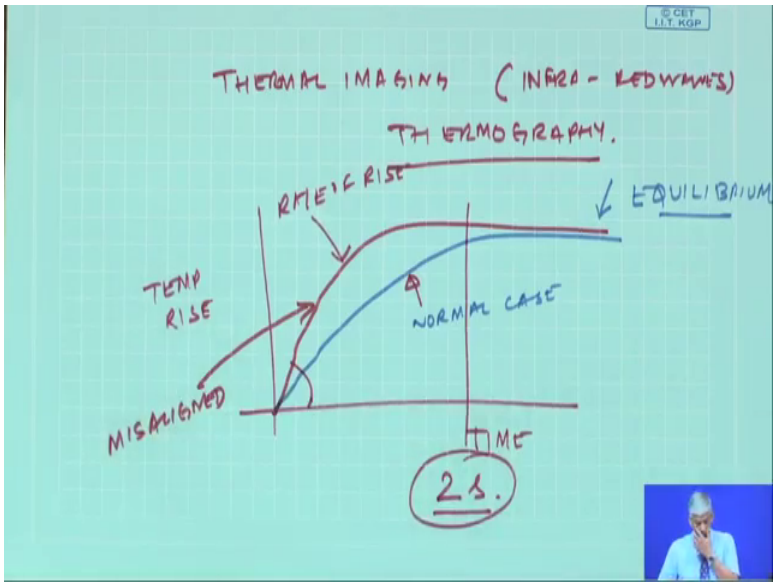

In fact, our search group had found out that if you with time, if there is a misalignment the temperature raise at the bearings; if it is a misalignment case there arises more compared the rate of rise more and this is my equilibrium. So, this is the rate of rise the slope here is much higher than this so therefore the normal case and this for the misaligned queues and this happens within the order first order time cost in the system and this could be as for typical cases within the time constant of the system the temperature rise, so you will see later on by monitoring.

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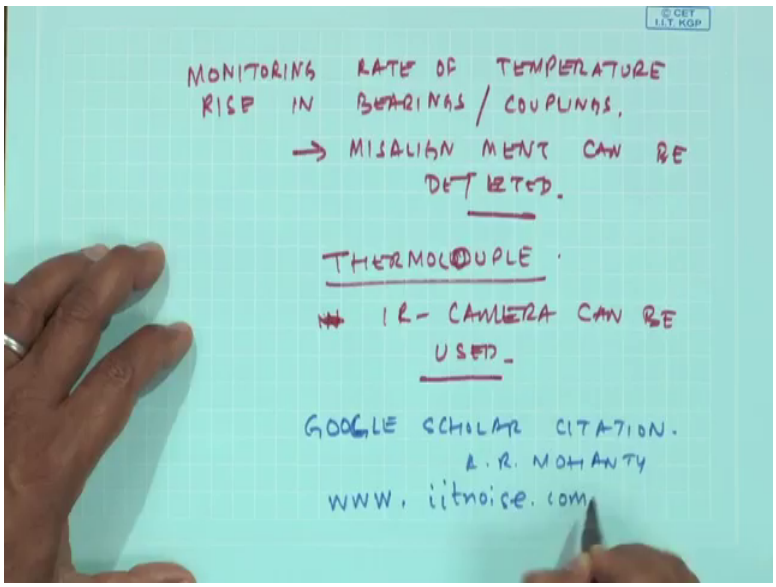

Rate of temperature rise in bearings sometimes in couplings misalignment can be detected. Now obviously because they are rotating systems I cannot use the conventional measuring devices like you know a thermo couple. So, non contactic temperature measurement device like IR camera can be used and this example by the way we have reference our research work on this is available and you can.

Find me in my Google scholar citation you can find this paper or you can go to my website www IIT noise dot com to see the details about this in a journal paper on a I may key journal paper, where our group was a first to detect the presence of misalignment in a rotating shaft system by measuring the rate of temperature rise through an infrared camera and this has lot of significances now imagine the challenge which we have today is I am mentioning about wind turbine. You know wind turbines are being put to use to use energy as alternate source of energy to and then there has been lot of use of this wind turbines, but you see this wind turbines.

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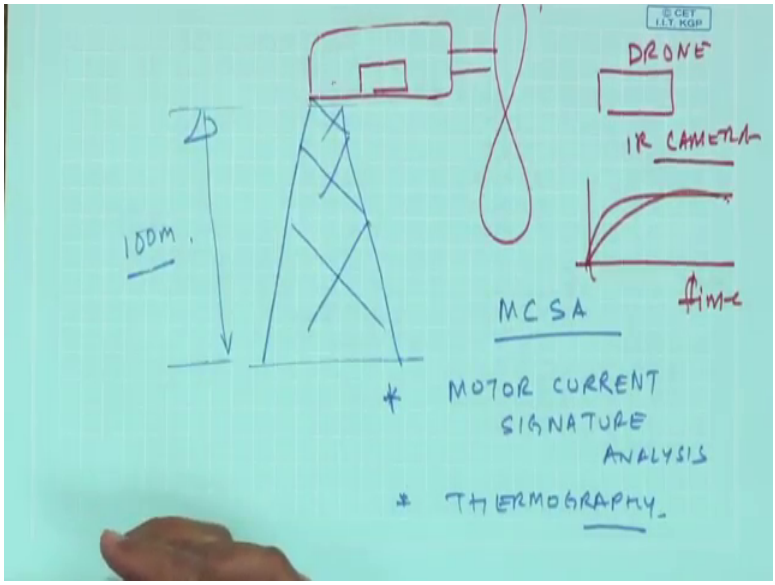

Are put on ultrasounds very high from the ground and this could be as high as 100 meters and then we have this turbine large fan and this that is the gear box and then all those devices here there and then we have a generator etc and physically to measure any defects in this gear box or the generator, of course you will see another new technique which am going to discuss later on is MCSA.

I am just giving you some new topics to browse and get excited about and which we are going to discuss about later on, another is thermograph with eventually we will see by now. But we are using lot of vibration monitoring techniques for detection of faults in system like in balance or misalignment, but now with research being continued or carried out throughout the world lot of new technologies have come up, one being motor current signature analysis other being thermograph.

Now imagine if you have a drone with an IR camera and this drone goes up with infrared camera, you can measure the temperature of this bearings and acquire it quickly and then see this rate of rise and that will be a very easy way to detect infra detector misalignment and large place where conjunctional vibration monitoring would be difficult for example, one is the site and if you go to the north sea there all anchored to the ocean bed.

So, this are challenges to us to find out misalignment in rotating systems and you know the consequences of having misaligned axial in railway coaches or locomotives you know it can lead to derailment etc. So, misalignment will lead to bearing heating coupling heating if you have better techniques of detecting bearing heating or coupling heating we can find out misalignment and such systems ok.

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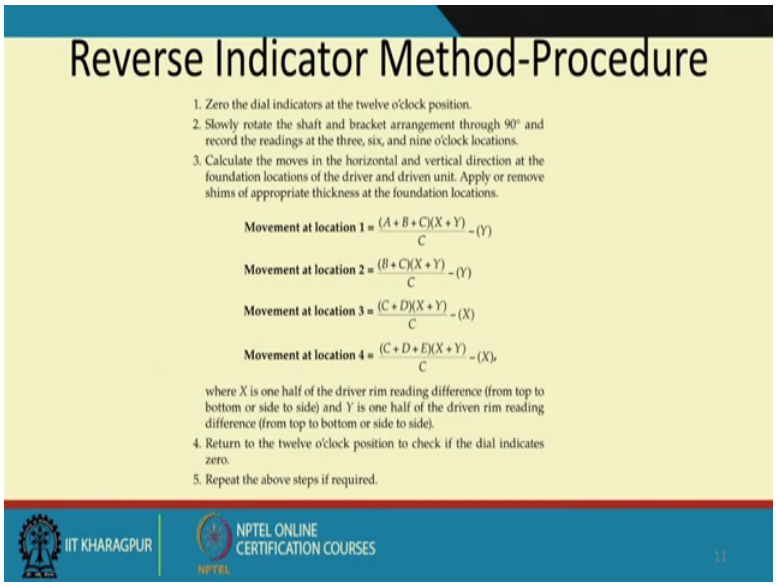

So, reverse indicator method if you notice this we have dial gauges just to measure x and y on the rim of these machines and these are dimensions A B C D E. So, all you have to measure you say dimensions A B C D E. So, we will they will reverse indicator method

procedure is like this 0 the dial indicators of the 12 o clock position, slowly rotate the shaft and bracket arrangement through 90 degree and record the reading at 3 6 and 9 o clock locations. Calculate the movements in the horizontal and vertical directions at the foundation locations of the driver and driven unit apply or remove shims of appropriate thickness at the foundation locations.

So, we can measure the movement at location y 1 2 3 4 where x is one-half of the driver rim reading difference from top to bottom or side to side and y is one half of the driven rim reading difference from top to bottom or side to side, return to the 12 clock and check 12 clock position to check the dial indicates if 0 repeat the above steps if required.

So, this process people do to do the removal of misalignment when they are installing machines and this could be measured by dial gauge, but only thing is that if these are large systems if they are rotated slowly by hand. So, usually any misalignments are actually today of course we have laser based systems.

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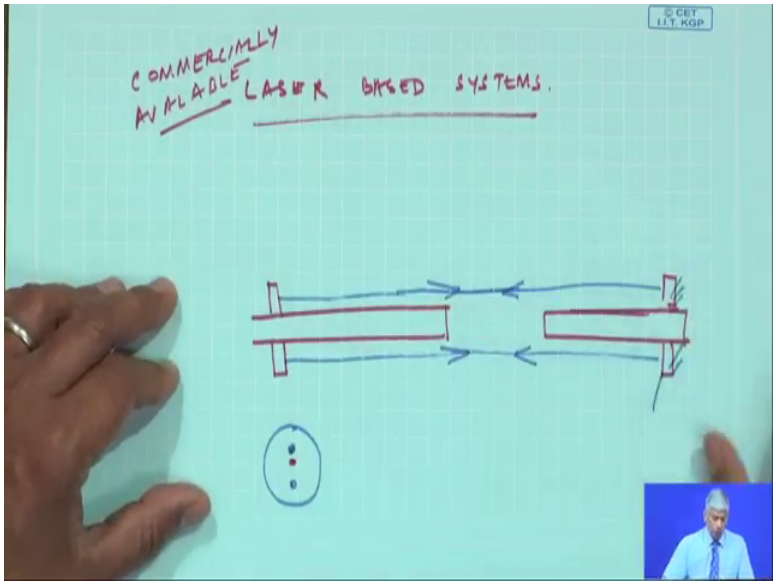

Suppose this is a shaft and this another shaft, if I am shooting a laser beam; if the laser beam goes out if they are misaligned they are aligned the laser beam goes out like these it will come out this way laser beam goes out like this and come out this way and then what happens is if you look at the mirror here there will be 2 dots, one going like this and one and there I have put reflective mirror. But if their misalignment there is reflection of the laser beam would come at a different spot. So, such laser based systems are

commercially available to do the alignments in such systems and this is again out of my book, so you can get the details in this book.

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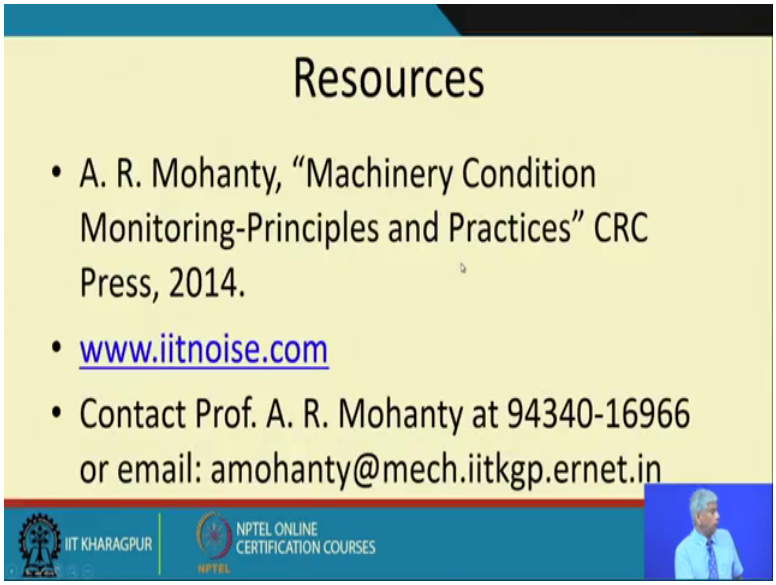

Thank you.