Machinery Fault Diagnosis and Signal Processing
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Lecture – 38
Field Balancing

In the last lecture I had discussed about balancing and then we saw that you know how balancing can be detected beat in a sign in a plane, which is within the 2 bearings or in a plane which is over hang out of a bearing in a shafts system.

But as you will see in industry many of the problems occur because, of an unbalance inner rotating system and we must also know what are the methods available to us for doing a field balancing of the matter doing the balancing and then specifically we will see how field balancing can be done and then today in this lecture, we will discuss about couple of ways, how field balancing can be done on a rotor system having a single plane unbalanced.

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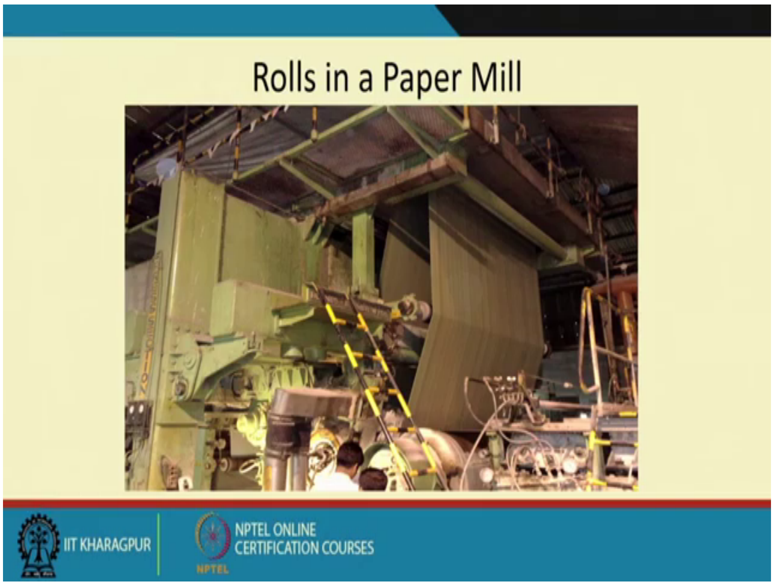

Well you all know the need for.

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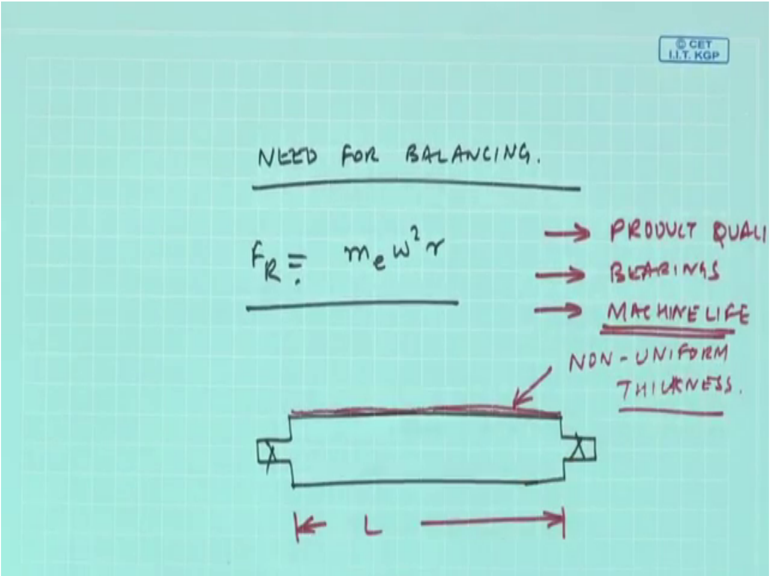

Balancing because, it gives rise to an radial unbalance force and which could load the bearings which could create un uniform deformation in rolls. This a role and if there is an unbalance if it is a long roll some length like in the case of a paper mill, the number of rolls if there is an unbalance the thin layer of paper which is there can have an non uniform thickness..

So, in effect this is going to affect the product, quality, effect the bearings and if things fail it will affect the machine life and that is more important for us to have a longer machine life, because of ensuring that there is no unbalance. Now how can this be done. So, we can always remove the rotor and bring it back to a dedicated balancing machine.

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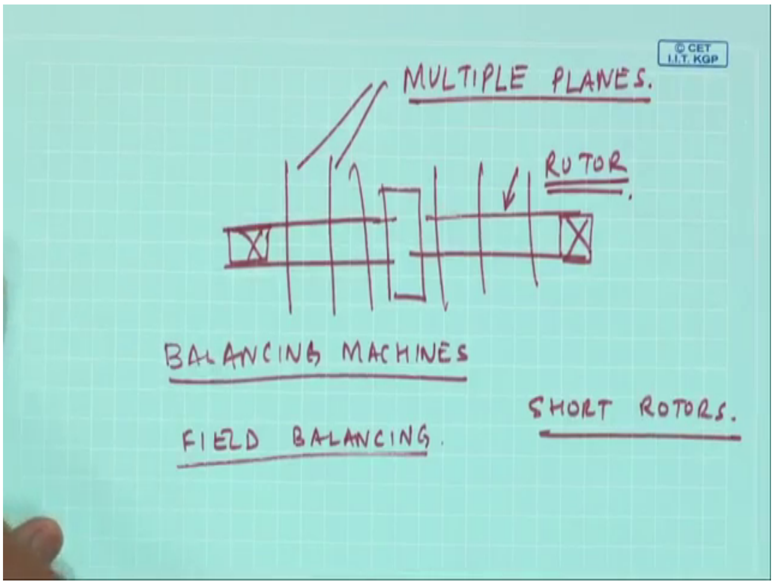

There are commercially available balancing machines , but many a times it is just not possible to do or to have balancing machine, which will where we can bring the rotor in to this system ok. So, how do we ensure that this system is balanced ?

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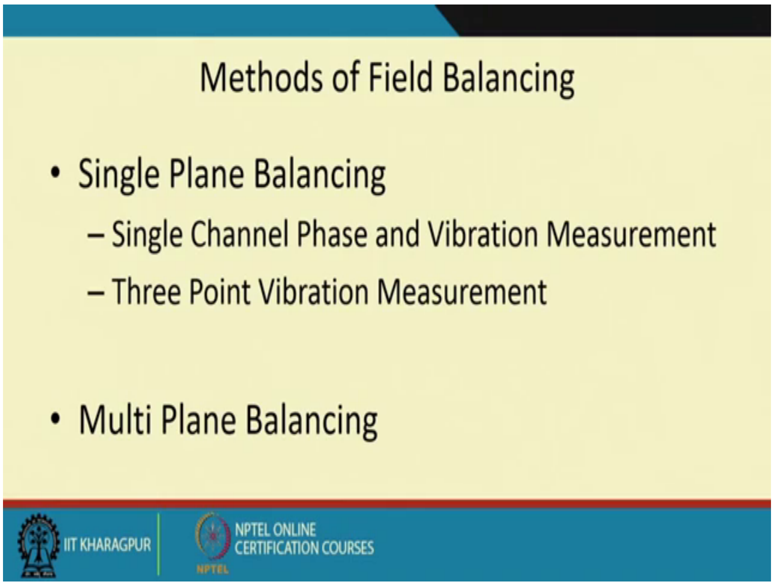

So, there are what we do we have to do in that case what is known as do a field balancing. So, without removing the disc from rotor we will balance it and there are balancing can be done in either in single plane or multi plane, if it is a long rotor this could be doing in balancing could be done in multiple planes or we can do it in single plane; particularly for short rotors we can do it in single plane balancing. Now will discuss how this single plane balancing is done by the this 2 methods 1 is single channel phase and vibration measurement 1 another is 3 point vibration measurement. So, if I look at the disc.

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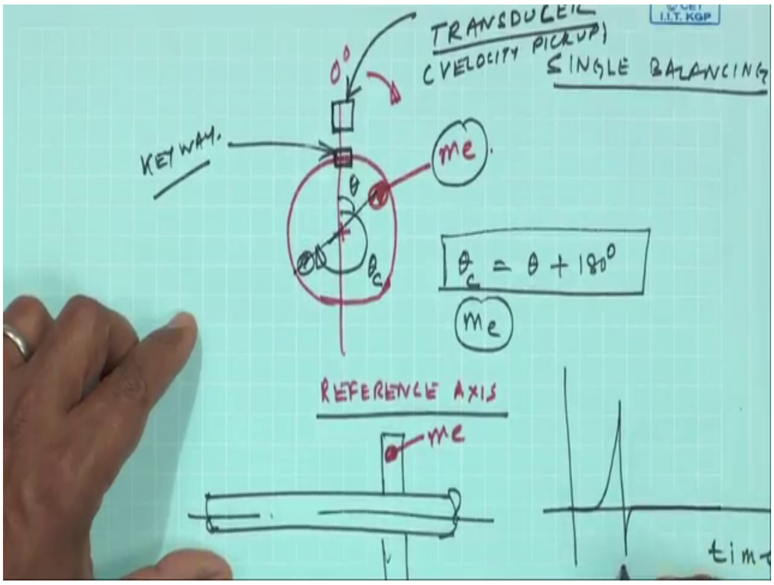

How do I create or unbalance, suppose there is an unbalance mass me, so with some reference suppose this is my 0 degree with some reference axis , I need to know what this angle theta is and then what is done unbalance amount.

So, once I have that my theta correction would be this angle , so theta correction is nothing but theta plus 180 degree and then the amount unbalance must me and this is done or this is known as single balancing. So, the first and foremost is to know this reference axis. So, whenever I have 1 and I mean by this disc I mean on the shaft I have a disc, so that was just a side view of this shaft ok.

So, in the from the side view I can see suppose this is my unbalance mass me I need to rotate it and usually to measure this reference axis we have some probe here, which will be measuring which could be the transducer to measure and this is usually the velocity pick up location or wherever there is a key way on the shaft ok, so this could be my key way. So, physically on the disc I can have some marker, so with reference to that marker how do I know it is 0 degree.

So, whenever in my velocity pick up in the time domain I get a pulse this means this is at 0 degrees, because whenever this key waves right below the velocity pick up I will get this pulse.

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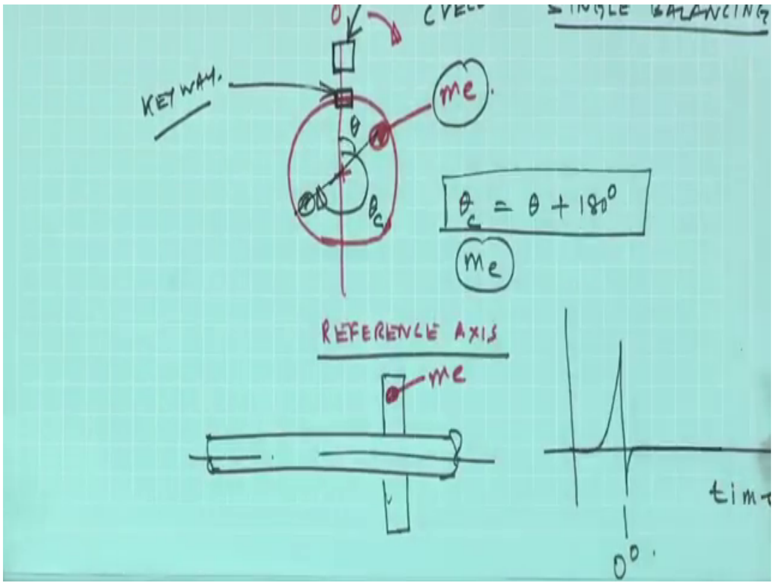

So, this signal must be 0 degree and then from there I can. So, always whenever I have theta correction I will measure my theta plus 180 degree from this point. So, this is very important and at the first step.

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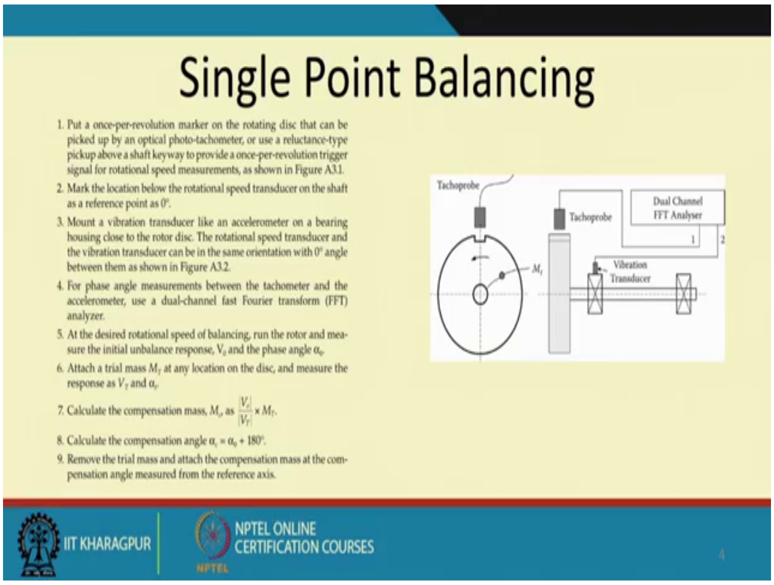

So, let me tell you the procedure here in the single plane point balancing is what I have shown here this is some mass. So, put a once per revolution marker on the rotating disc, that can be picked up by any optical photo tachometer or use a reluctance type pick up above a shaft key way to provide a once per revolution trigger signal for rotational measurements as shown in this figure ok. By the way this figure is from my book machinery condition monitoring principles and practices, so you all can refer to that book for detail.

So, this is my shaft and here I have put the vibrations transducer because, the vibration transducer can only be put on a bearing housing, and this is my tachoprobe which is just below the key way. So, if you see in single plane balancing, I need to know the relative phase angle between the vibration measurements and the tacho probe. So, for that I can have a dual channel FFT analyzer. Of course you know dedicated, because I need to know this phase angle between them to find out the phase angle, there used to be dedicated phase meters or you can have dual channel FFT analyzer.

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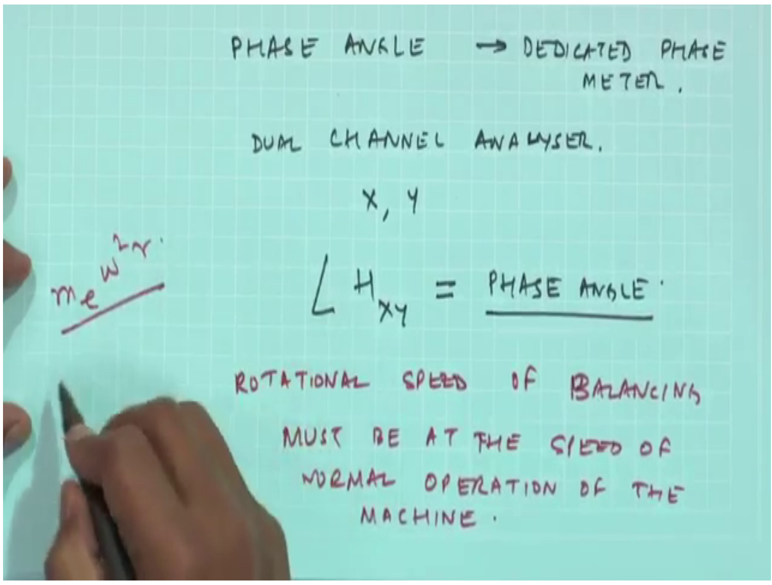

So, if I have 2 signals x and y, I can find out the angle between h x y and that is the phase angle and in the last class I had told you how we can calculate that and for us the dual channel FFT analyzer calculates phase. So, the first point is mark the location below the rotational speed measurements on the shaft as a reference point as 0 degree. So, this becomes a 0 degree. Now next is mount a vibration transducer like an accelerometer on a bearing housing close to the rotating disc.

So, the cell be closed it cannot be too long otherwise there will be couples coming in, so this will behave as if they were in phase the rotational speed transducer and vibration can be made in a same angle with same orientation is 0 degree angle between them as shown in this figure here and so fore for phase angle measurements between the tachometer and the accelerometer I can use the dual channel FFT analyzer, which will do this kind of calculations..

Now at the desired rotational speed of balancing, run the rotor and measure the initial response V naught and the phase angle alpha theta ok. So, just measure at the rotational speed because I will tell you we need to also measure at the same rotational speed rotational speed, of balancing ; must be at the speed of normal operation of the in because of the fact let me tell you one reason.

I have a machine running at 30000 RPM at the normal operating speed, now at 30,000 ampliance there is some residual of unbalanced mass and suppose a balanced heat at only 3000 rpm, if there is a little residual unbalance this run unbalance is going to blow up to a large force at high speeds of 30000 rpm. So, balancing was done at 3000 RPM and operating is operation is being done on the machine is operating at 30000 RPM so 10 times..

So, this unbalance mass will blow up by a factor of 100, so this is something one has to keep in mind and I have seen many case studies despite the balancing machines fail because, a vendor was supposed to do the balancing at normal operating speed, then usually do not have machines to balance at the operating speeds do it they do it at lower speed, and the residual un balance blows up at the high operating speeds; this something your keep in mind. Coming back to point number 5 here, so at the desired rotational speed of balancing run the rotor and measure the unbalanced response V naught and the phase angle alpha naught.

So, then we will attach a trial mass at any location on the disc and then we will measure the vibration and the phase angle because of that trial mass V T and alpha T. So, the compensation mass is then calculated by this expression V naught by sorry V naught by V T times M T. So, this is my compensation mass and then I will get the compensation angle as alpha V as alpha naught plus 180 degrees. So, will remove the trial mass and attach the compensation mass as the compensation angle measured from the reference axis.

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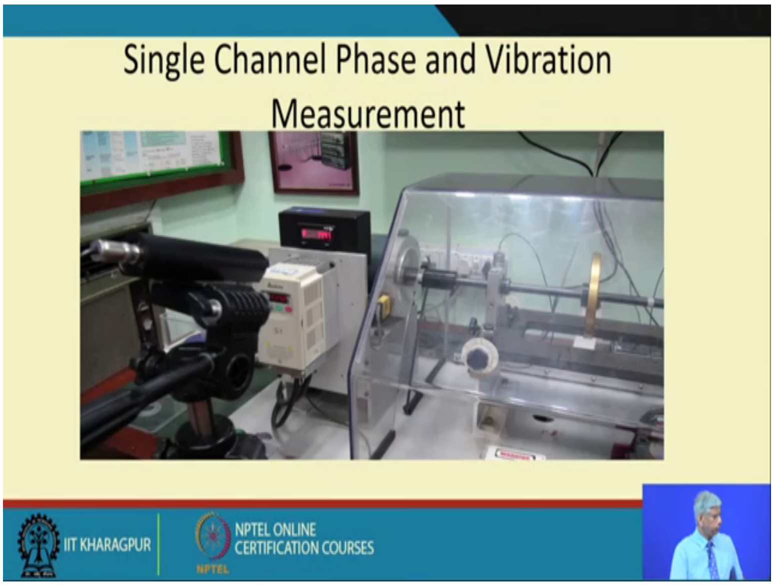

So, this is how this signal channel phase and vibration measurement is done in the laboratory. So, I will have a rotating shaft which at disc, wherein I can put in a known unbalance mass just for the sake of discussions here and this is the accelerometer which is kept on the bearing housing, this is a tachometer a tacho probe to measure the reference axis on the rotational speed.

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So, initial unbalance at 0 degree at some 0 degree because, this reflect tape 0 degree mark.

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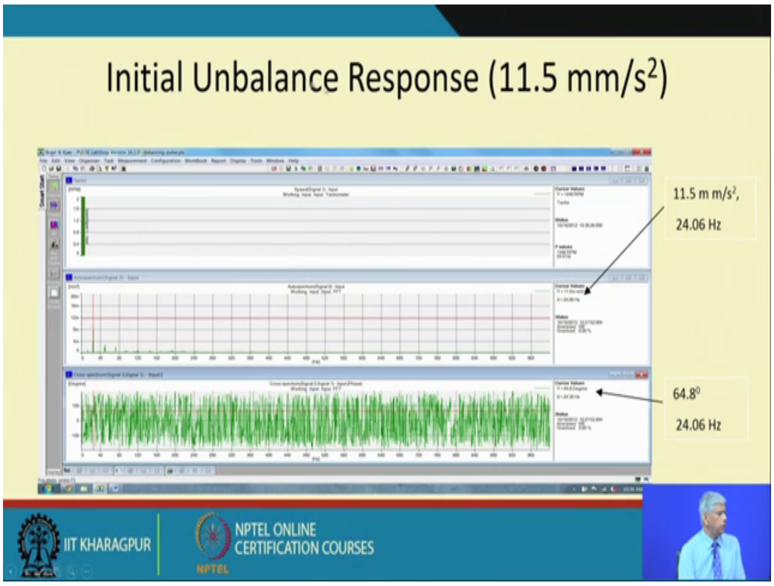

Then we measure the initial un balance response by taking the transfer function.

So, at this same rotational speed the unbalance response is 11.5 millimeters per seconds square and the phase angle is 64.8 degrees ok.

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Then we will put a trial mass of 6.14 grams to the system the trial mass has been attached.

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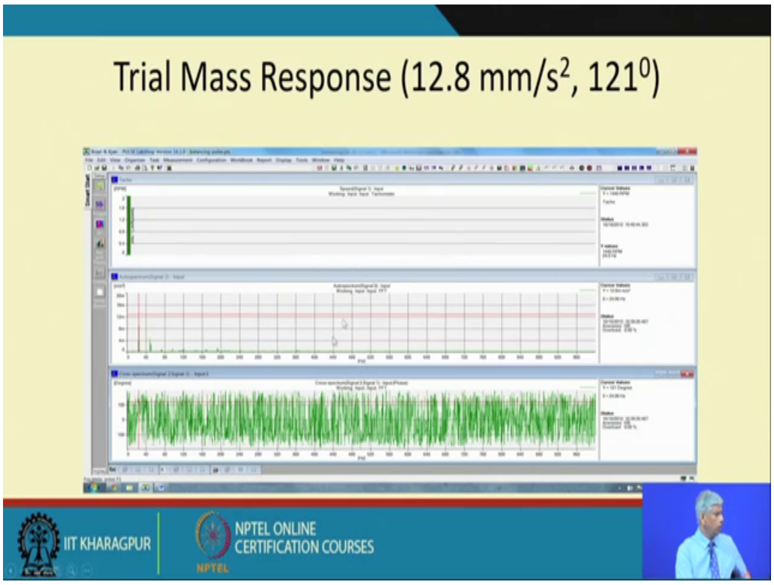

Will measure the trial mass response as 12.8 millimeters per second square and 121 degrees and then we will calculate the compensation mass as V naught by V T times M T and the compensation mass measured from the trial mass axis is given by from the trial masses ok.

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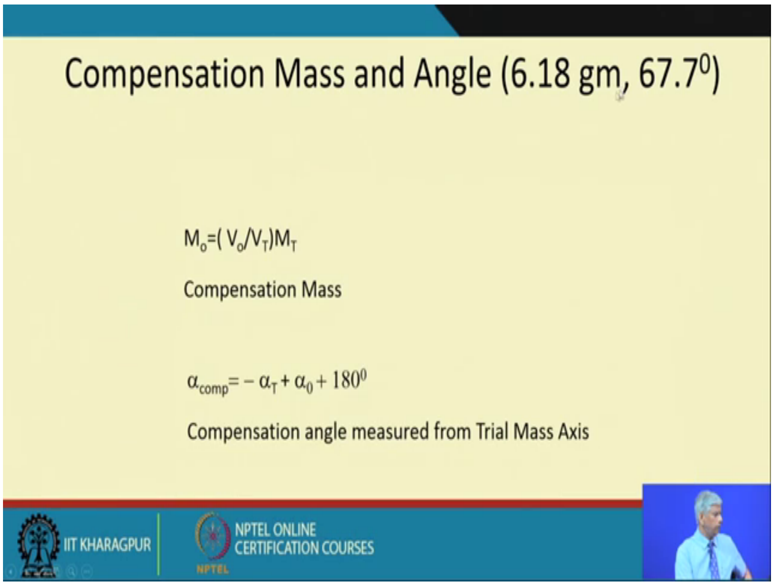

So, if you denote as a travel axis they should have been not there ok, it could have taken from the reference axis we can do it either way and then balance it. So, this is one way of balancing a shaft, just by having one measurement without stopping the machine and you know at once and put a trial mass and measure 2 responses and then measure the phase angle, but only thing is that I need to measure the phase angle and sometimes that could be a challenge in insitive Measurements and of course in this experiment.

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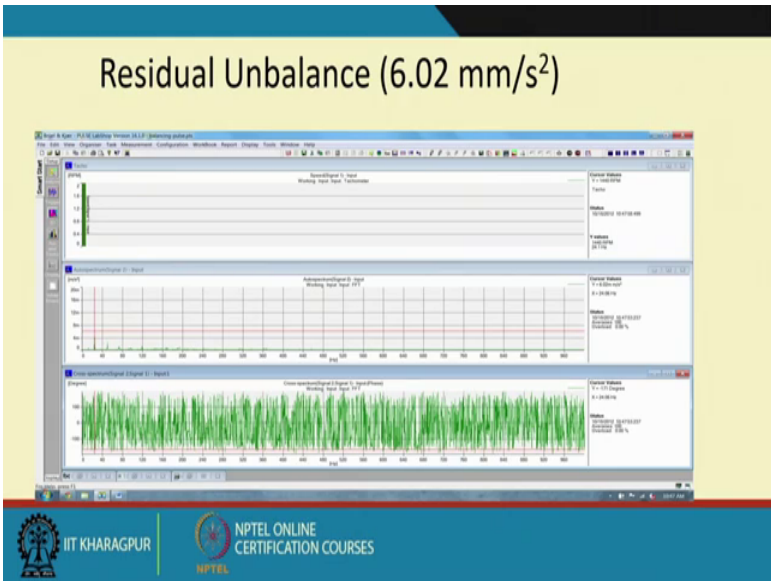

The residual unbalance then came down to about 6.02 millimeter per second square and it all depends on how good your travel mass is how sensitive you are to the initial mass and so on and this one of the very popular ways of balancing single plane balancing in systems. And the another method of balancing is known as the 3 point balancing.

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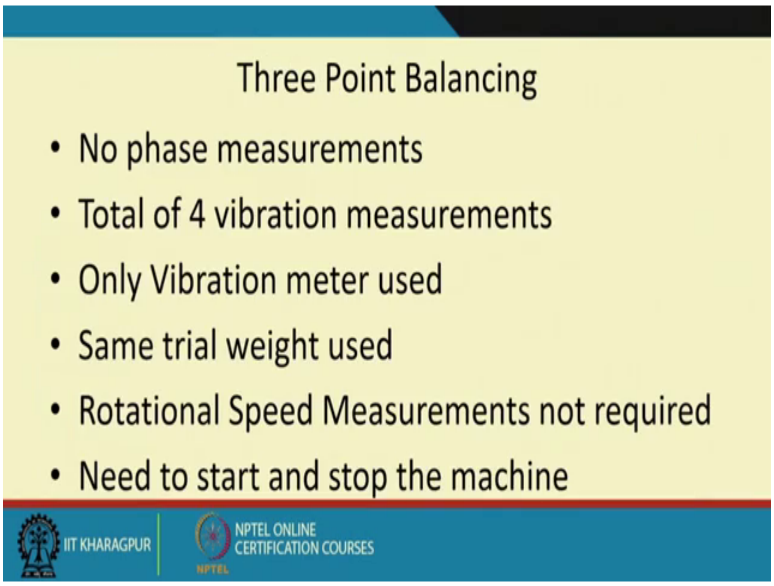

Here you see there are no phase measurements that is the advantage of this, I do not require any sophisticated dual channels FFT analyzer to do the phase measurements, only thing is that I have to measure 4 vibration measurements and then only one vibrations of the same vibration meter is used same trial is used rotational speed measurements is not required; however, we need to start and stop the machine each time to put the vibration weights or the trial weights.

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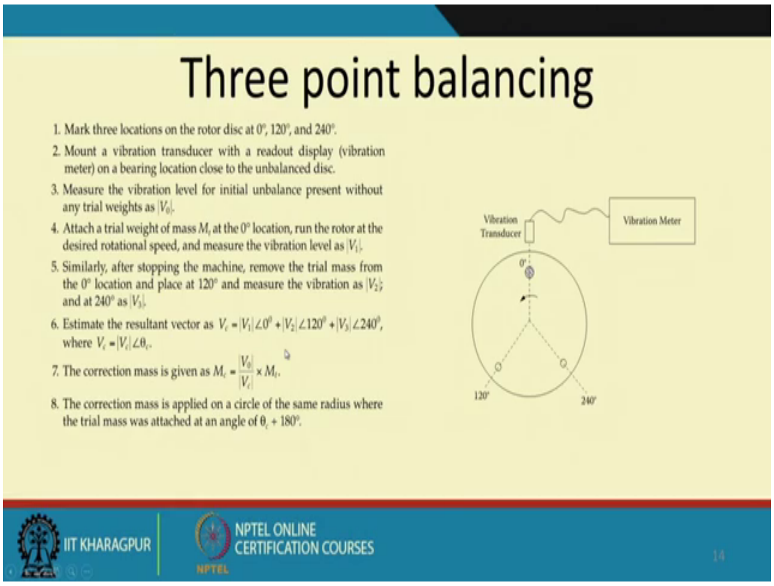

So, the procedure goes like this I have a disk, wherein I have put the reference axis I have sum 0 degree. So, mark 3 locations at 0 degree 120 degree and 240 degree mount a vibration transducer with a readout right; here measure the initial unbalance present as V naught put a trial not mass M T, measure the vector as V 1 at 0 degree similarly put another trial mass. I mean remove the trial mass from 0 degree put it as 120 degree measure the response V 2 similarly remove then third run or the fourth run remove the trial mass and put it at 240 degree and then I will get this vector V 1 at 0 degrees V 2 and 120 degrees V 3 at 240 degree, then I will get the V correction mass as just..

But mind it these are all vector additions and then we have the correction mass given by the sum resultant of this vector V C, which is nothing but vc magnitude and it comes with the phase angle theta C and the correction mass M c is given by v not by vc times mt and the correction mass is applied on a circle of the same radius by the way. It has to be all of the same radius and the correction mass is theta V plus 180 degree and am sure in many of the PG labs on vibrations or condition monitoring these are done.

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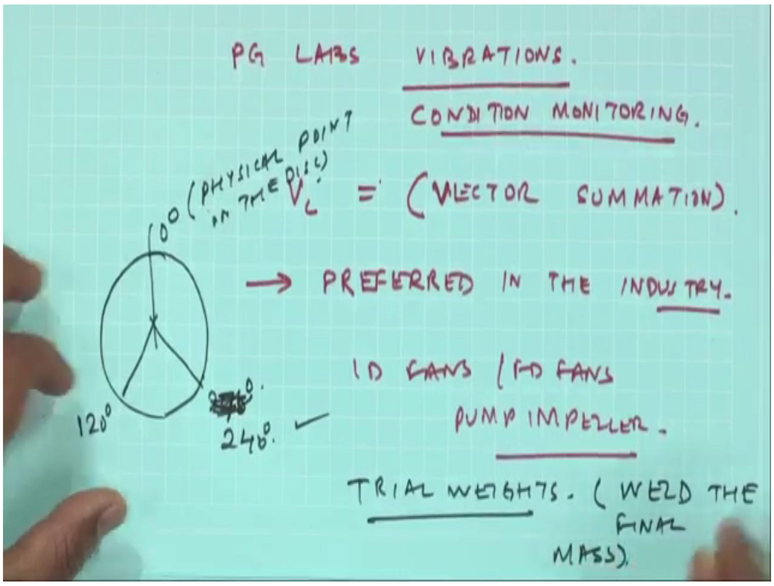

So and you can see only thing that you have to have this Vc as a vector summation and this is very much preferred in the industry it is very simple and no phase measurements all you have is 3 measurements and then you have to have a 0 degree and so on. And in as you will I must tell you those of you who are attending the course on align life and registered for this course and there are many small consulting houses you know day in and day out you know just carry this equipment with them just a vibration meter and trial mass and do a vector summation and do field balancing of ID fans, FD fans, pump impeller and make a living out of balancing rotating machines ok..

But only thing that you have to be very careful as I was telling you in the last class, I will in little while ago that the balancing must be done at the same operating speeds..

Otherwise if you do it at a lesser speed, this unbalance mass is going to blow up and then we will have problems with this. So, I will give you a practical examples 3 point balancing which we have done in laboratory.

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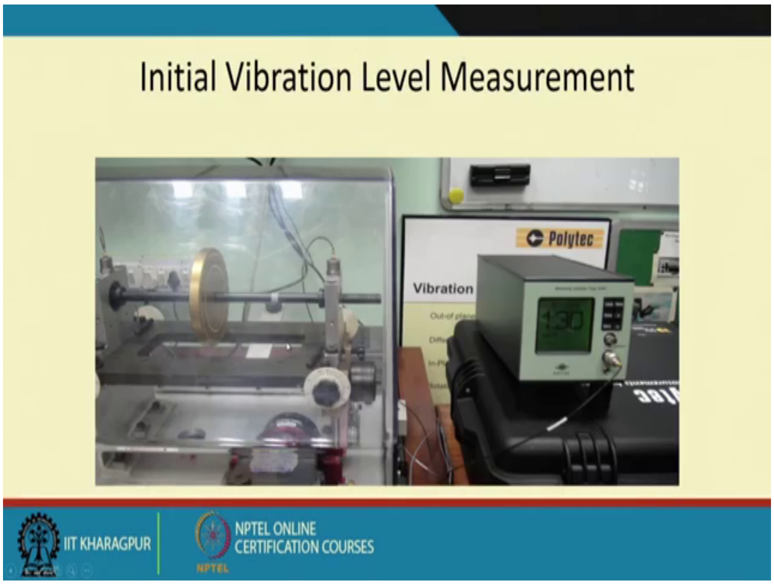

The same kit this is machinery fault simulator which we can have by the way this machinery fault, simulator is almost very popular in every universities and so on; where in we can simulate many experiments and many of the results which am going to share with you in this lecture series or in this course are out of experiments done on this rig..

So, we have an uniaxial accelerometer put on the bearing which is supporting this unbalanced disc this yellow colour disc or the golden colour disc. So, we measure the initial unbalanced sum units of 133 ah millimeter per seconds square, if you can see in the vibration meter it is immaterial, but I just want to show you how simple this is ok, we run it only thing is that we have to know the reference phase which 1 is a 0 degree.

So, physically your 0 degree should correspond to a point sorry to a point physically on the system on the disc. So, you can put the marking tape put a paint etc and something about this trial weights , I have seen in many places the weld the final mass even today if you see automobile tire rims.

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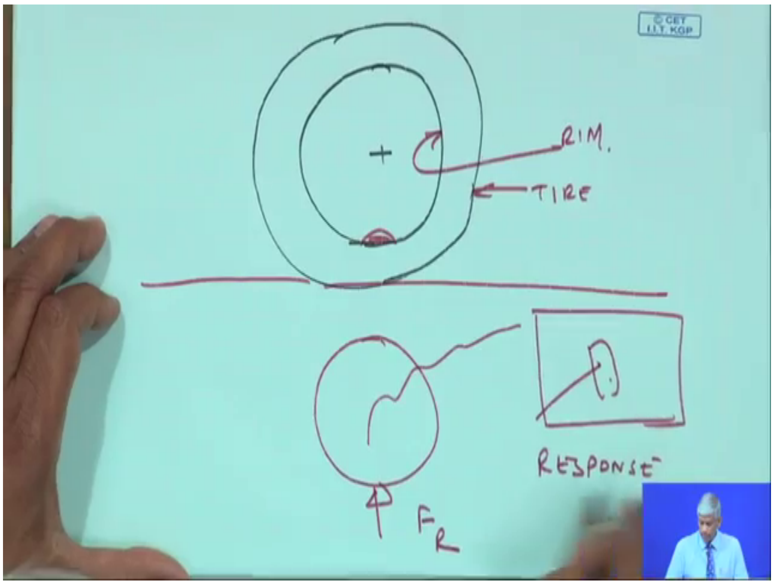

Am not drawing the well let me draw the tire excuse my drawing it is not a perfect circle is a. So, imagine if this was an every bit of unbalance in the tire and the vehicle was going on a road. So, every time the vehicle is going to get subjected to a force and this force going to transmit and then it will excite the response in the body ok. So, this response may not be desirable, so in people in NVH that is noise vibration and harshness.

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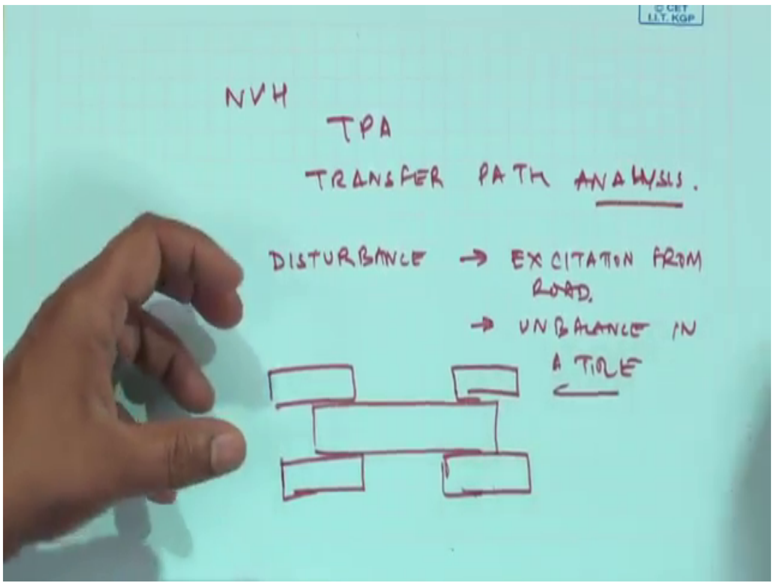

They do what this is known as TPA transfer path analysis, to find out the effects of an disturbance could be excitation from road or unbalance in a tire. So, imagine if you are driving a very high speed the vehicle which is running at you know very high speeds on the highways and then if your tires were unbalanced, so you will be subjected to forces 4 tires we can say.

So, they will you will there will be a if the force forces are brought in phase; that means, all 4 are not at the same time at the same direction use your vehicle could have a twisting moment could have torsions. So, this is going to affect the response of you I mean the feel of the vehicle when you are driving at a high speed. So, now a days you know if you if you go to change the tire of your vehicle people do balancing of rims and there are dedicated balancing machines which do all these balancing for you all and 1 has to know the importance and the effect of unbalance you know high speed machines and the challenges today are when you are talking about high speed engines.

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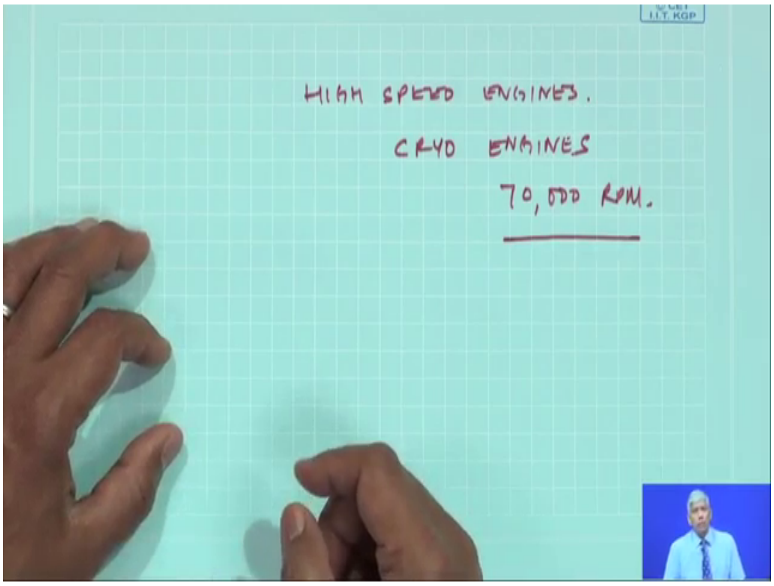

So, example you know we talk about rocket engines the cryo engines running at 70,000 RPM. So, you can understand if a little bit of residual unbalance is there how much of problem it creates ok..

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So, continuing with this we measure the vibration at 0 degrees we get a value 1.56 meter millimeters per second square.

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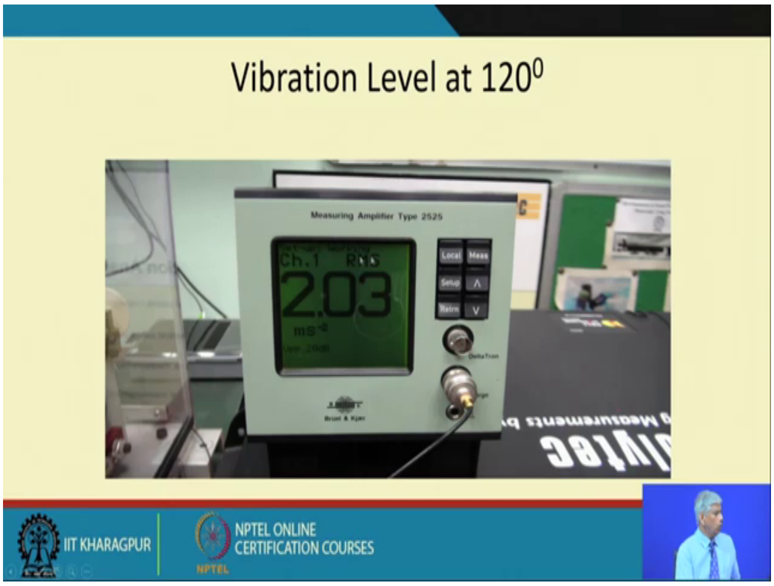

We measure the vibration level at 120 degree as 2.03 millimeters per second square.

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And we measure the vibrations at 240 degrees at 7 and 35 millimeters per second square.

So, once you have this vector you will do the vector summation and get the compensation mass by the way this is all vectors summation and then you have compensation mass.

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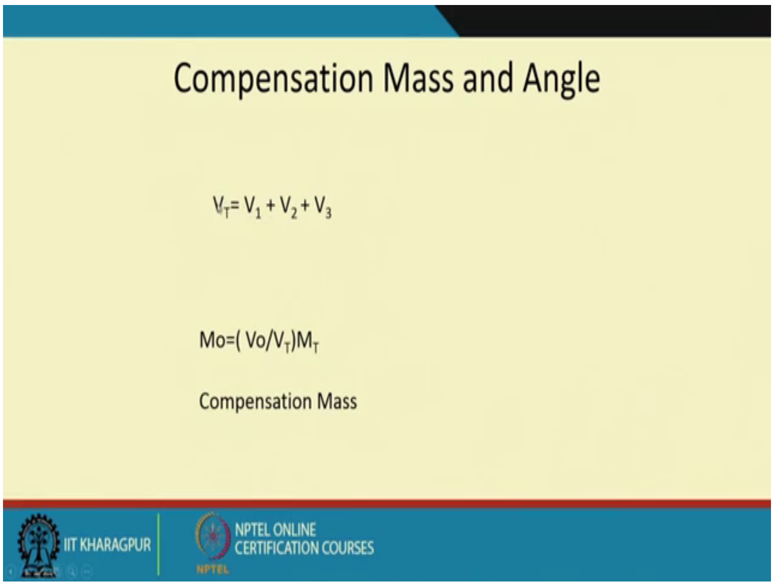

And then we will put it at the correction plane of alpha c plus 180 degree ok.

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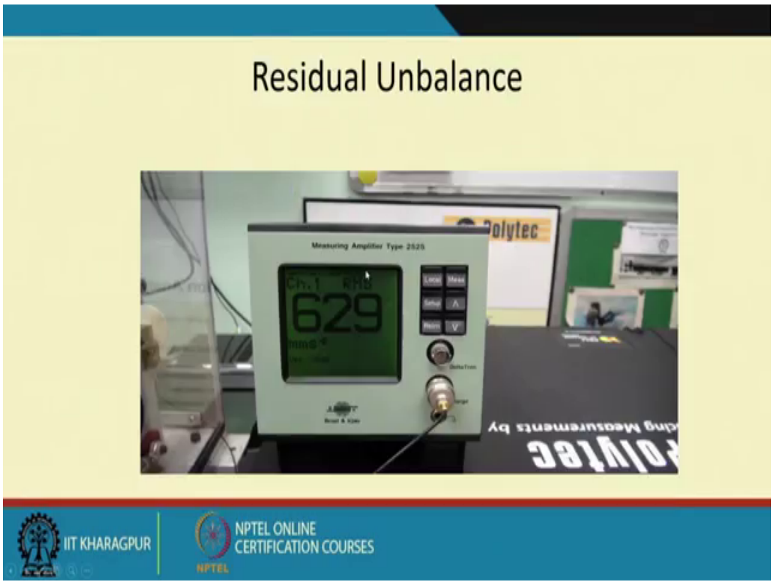

And thus the residual unbalance in the system can be done, so this. So, today we discussed about 2 examples wherein we can do intuitive balancing, now why do we do intuitive balancing or field balancing it is because for the fact that this machine or the this shaft cannot be easily dis mattered and brought over to the shop where we have a dedicated balancing machine, rather we do it intuitive in intuitive we can do it single plane balancing just by measuring a vibration and phase or we can do what is known as the 3 point vibration measurements ok.

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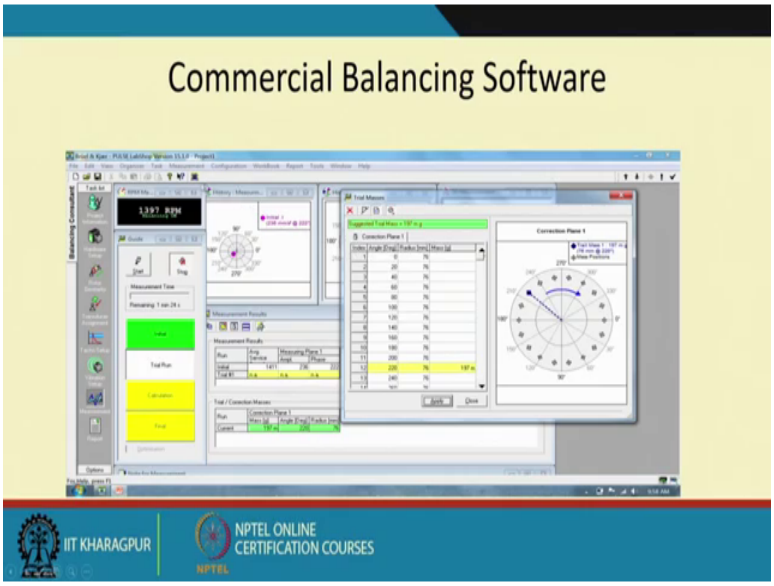

And of course, there are many commercial balancing software available, if you look into the internet there are many companies who make a living out of balancing rotating machines throughout the world and in this software's are there to help you, but there is no rocket science in the software. I this is nothing but a vector summation of the vectors which has been created because, of the unbalance mass and the trial mass and all we have to do is close that vector triangles, so that do we have static equilibrium.

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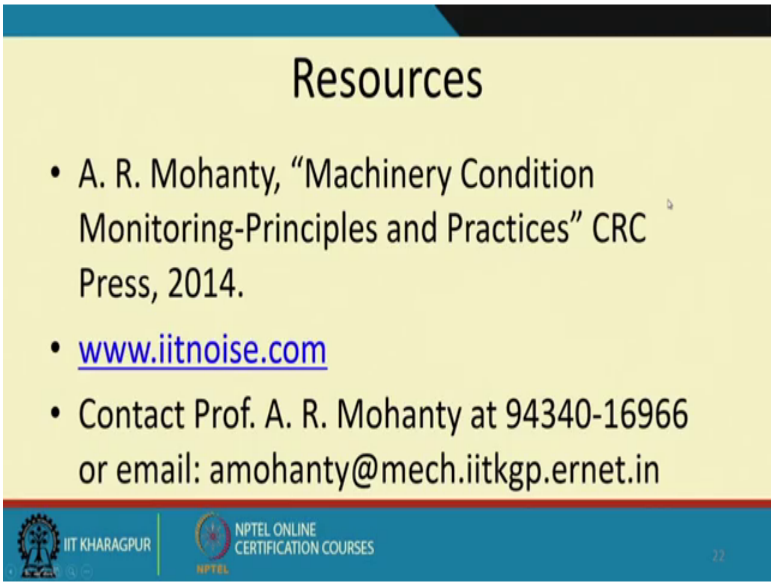

By the way these 2 examples which I gave you are there in the appendix of my book. So, those of you want to know about more it about it in details can look into my book.

Thank you.