Machinery Fault Diagnosis and Signal Processing
Prof. A. R. Mohanty
Department of Mechanical Engineering
Indian Institute of Technology, Kharagpur

Lecture - 58
Paper Mill Vibration Monitoring

Well, by now all of us must have got some feel on how CBM has done on machineries. In the last class I discussed about how noise and vibration are monitored in a railway locomotive visa v the track condition the vehicle speed and so on. Now, I will today I will introduce you to another such interesting topic from the real world on paper mills you.

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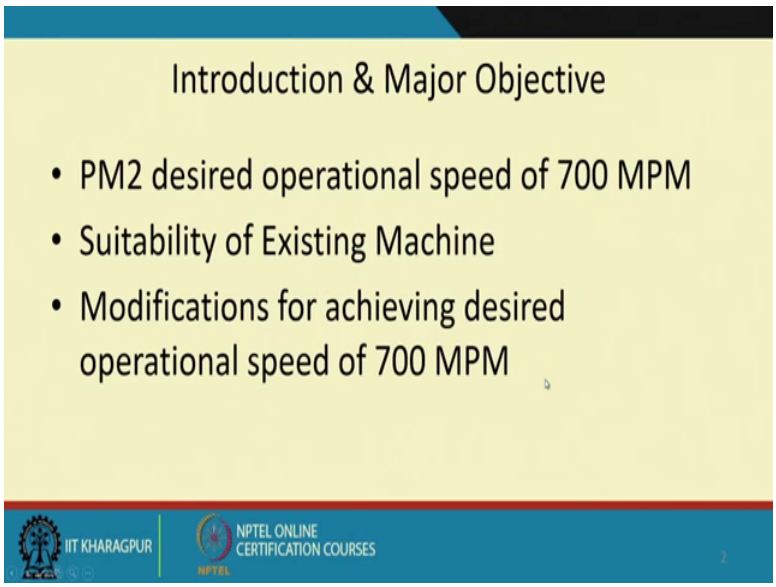

So, paper mill vibration monitoring, before I get into the paper mill I will briefly tell you what we intend to do and what was desired to do.

So, you know in paper mill the plant speed is actually given in the linear speed in meters per minute. So, if I need to increase the speed the productivity of the plant would increase and every owner of a plant or like the productivity to increase ok. So, the objectives of this study which we did at IIT, Kharagpur for a plant in India, that we wanted to check it off first of all whether the plant existing plant is strong enough to endure these stressors and vibrations because of running at 700 meters per minute.

And if some modifications are done to achieve this what has to be done in terms of not damaging the plant, in terms of structurally, in terms of damaging the bearings and so on. So, before I get into the details of how it is done I will briefly explain you how paper is actually producing such paper mills.

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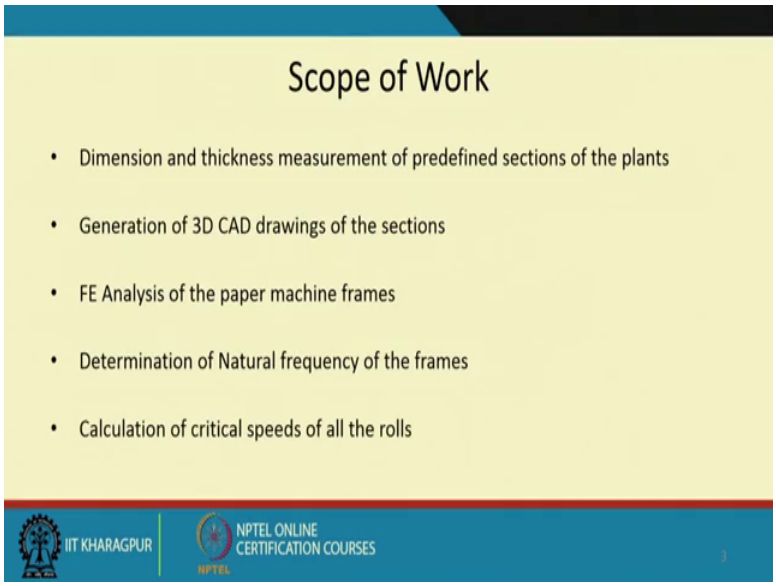

So, well just briefly to come back to these scope of this work was or let me come back to how a paper mill works ok.

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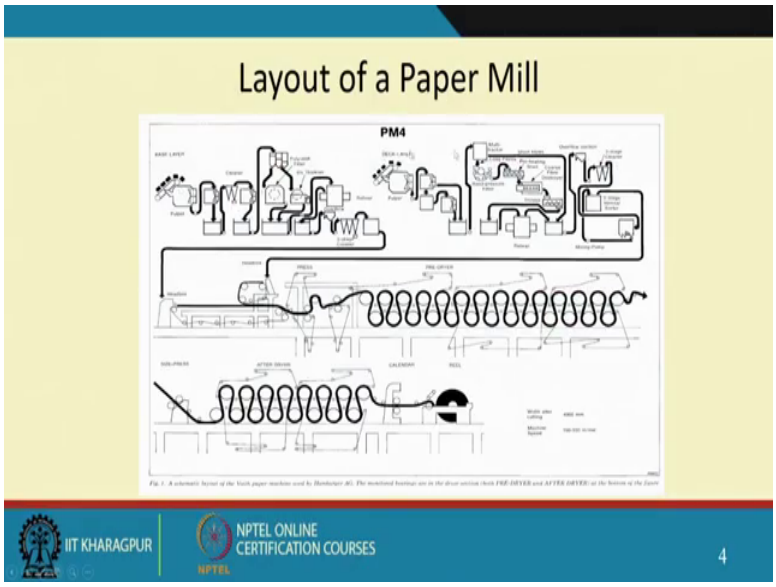

Now if you see here there are you will see lot of these are rolls and this black line is actually what is being fed to the paper mill.

So, basically it is a slush of waste paper would bark with water clean with caustic soda etcetera after all this has been chemically treated washed cleaned this pulp is actually fed on a wire rope basically there is a wire. So, this is full of ash loss full of a lot of liquid in it and then there is a pressing section here. So, this is roll here which press onto this and after the initial pressing ok. You will see the water is squeezed out of this lust which forms the bulk of the paper and these are all basically chemical treating treatment areas wherein you can have the waste paper.

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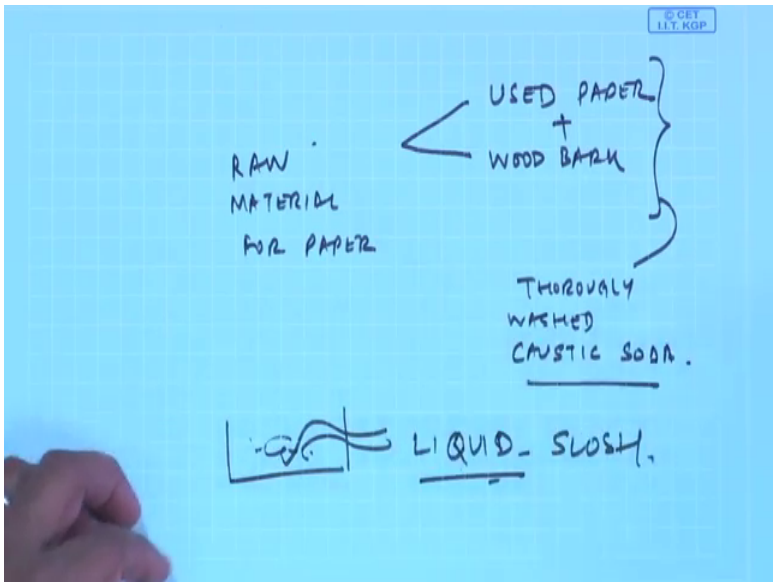

So, when we the raw material for the paper is actually either used paper or wood bark or a combination of them and they are thoroughly washed with caustic soda ok, and this forms a very liquid slosh is there. So, when such slosh is fed onto the wires I will show the pictures in a little bit and then basically if they are pressed the initial pressing is the water the squeezed out and this will be a wet damp layer of paper which would come out.

Eventually what happens? So, this paper has to be slowly pressed and then again it has to be dried. So, these rolls are big rolls wherein we put dry steam. So, the extreme dried and each of these rolls could be about the close to a meter in diameter and the width could be as long as four meters ok. So, you can have a 4 meter by rolls of our sheets of paper

coming out through a number of these dryer rolls and then finally, there is a sizing press and again after the drafts there again dried after dryers.

So, here it is actually the white paper actually starts to come out and then the end we have what is known as the calendaring wherein we press calendar is nothing, but like ironing your textile or shirts or garments similarly iron the paper and of course, finally, the pop real worthy everything is taken off. So, if the plants output is you know 80 tons per day, somebody wants to make it 100 tons per day or per hour per hour; obviously, the speed at which the paper is being fed through this rolls has to increase.

So, the problem becomes twofold, one is then I need to increase the linear speed of all these I mean the linear speed; that means, I need to increase the rotational speed. So, what would happen because these are all rolls some of these rolls may undergo critical speed they would be under the condition of resonance.

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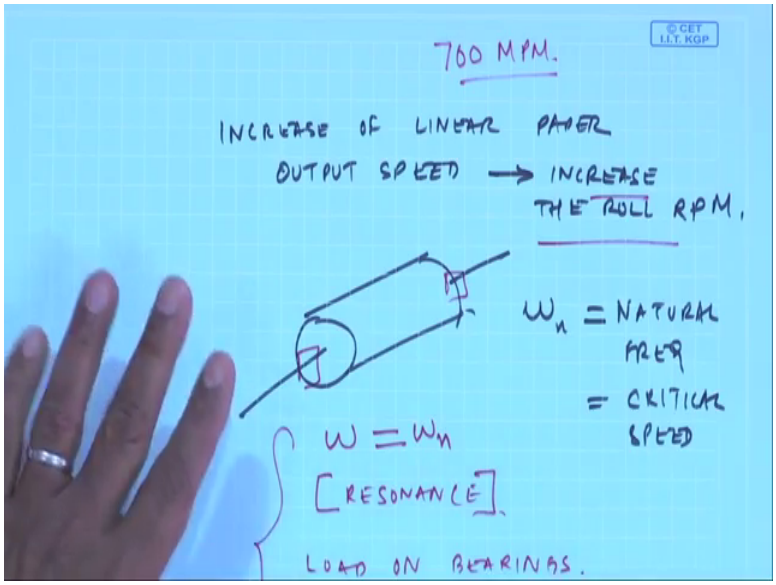

So, increase of speed, increase of linear paper output speed would mean increase the roll RPM. But you know by now when I have a roll or a shaft it has certain rotational natural frequency or what is known as its critical speed. So, by increasing the speed I may so happen this increased speed may become equal to omega n. So, I will have the condition of resonance. So, resonance means large motion. So, this will be long stable and then eventually things may fail or break that is one.

Now, because of this increase in speed the loads would increase if loads increase what happens because you are giving out more paper per hour or ok. So, the loads increase the loads on the bearings which are supporting would increase load on bearings I will show you how the loads on the bearings are calculated and then loads on the structure ok.

So, these are the problems. So, if somebody asks you to check for a linear speed meters per minute whether your plant is safe we need to sway through an analysis whether the plant is safe because of the stresses because of the resonance conditions and so this is briefly how a paper plant works.

Now, let me come back to what we needed to do. Because to calculate any stress on in a structure that reeks of fem are available standard softwares are available to do an FEM stress analysis.

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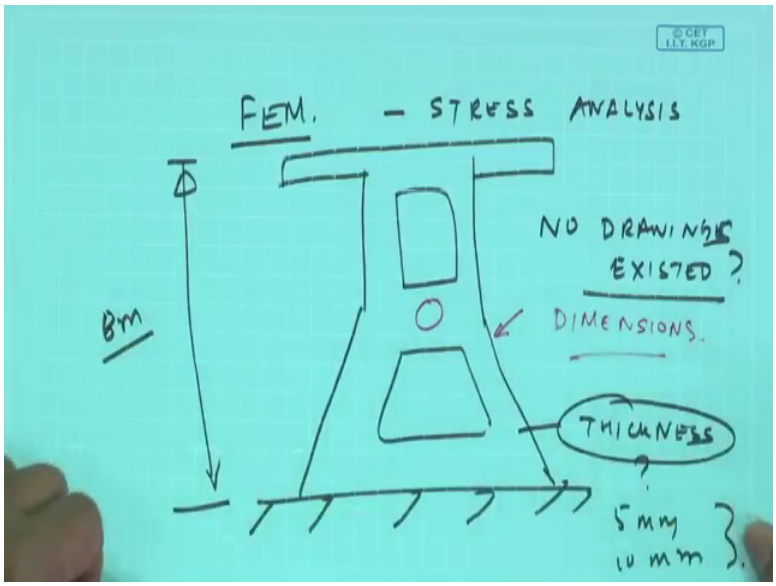

But then if I have a structure like this, some sort of structure which is supporting the rolls they just aside you. So, the dimensions of these are first to be known, but you are given this task to a very old plant where no drawings existed ok. So, this is a challenge to us. So, we had to first find out measured the dimensions.

So, we had to measure the dimensions of the critical sections and you maybe even in a structure the thickness is unknown from the outside what is the thickness is it 5 mm, is it 10 mm how do you know of an existing plant. So, I will just tell you how it is done then

of course, we have to generate the 3D CAD drawings of the sections, and then do the FE analysis of all the frames, determine the natural frequency of the frames to see that they do not coincide with the operating speeds and then calculate the critical speeds of the all the rolls ok.

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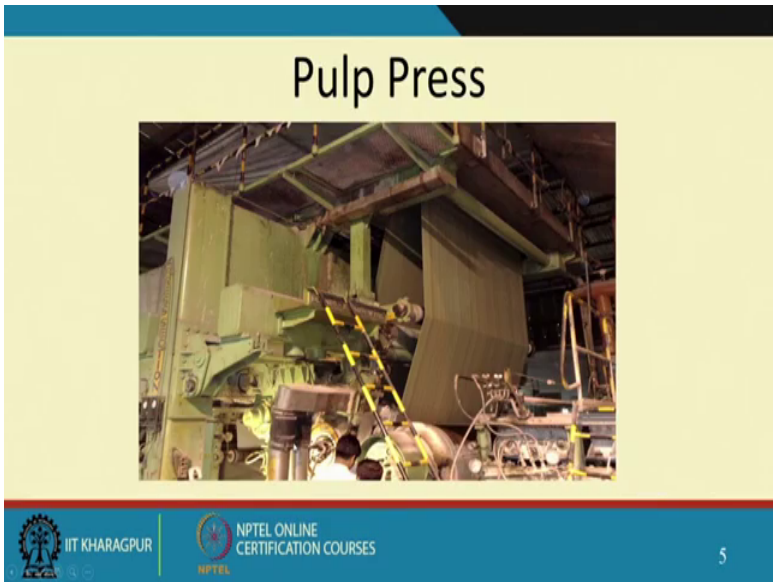

So, this is just a view of the pulp press or the pulp which comes in there a kilo wire and the some of them are about 4 meter long.

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And this is in the pressing sections you can see a big roll here ok. So, they are hydraulically operated ok.

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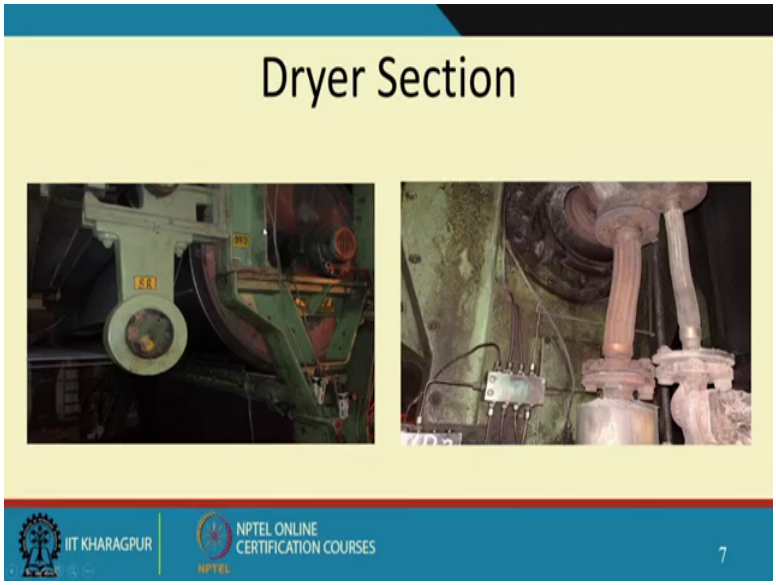

Then this is the view of the dryer ok, you can see a big dryer which are streamed right and this is a big roll driven by an individual motor sometimes, sometimes and then this is the bellows through which hot steam is inserted inside the drum the dryer rolls are actually hollow drums.

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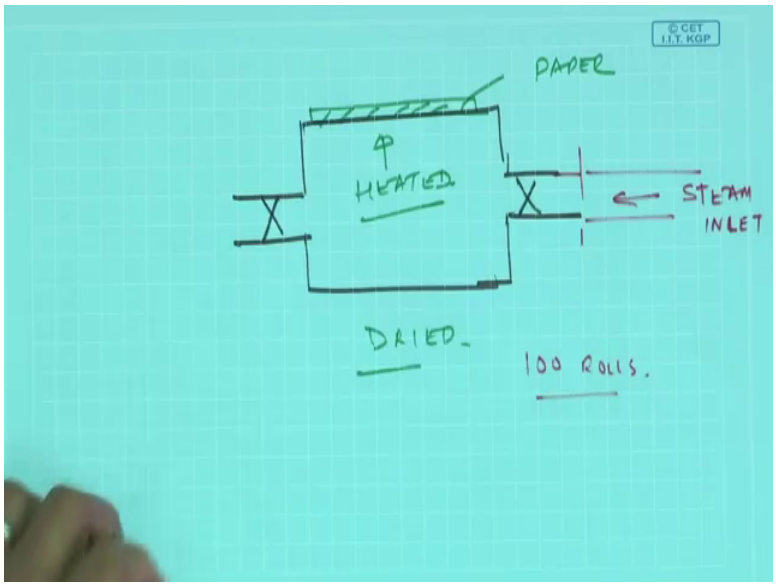

Each of the dryer rolls is supported on bearings, but then they are connected to stream inlet. So, the paper which goes in here is heated and thus it is dried. So, one roll is not sufficient enough to give the amount of heat required. So, they have to be continuously. So, these dry rolls there could be 100 such rolls in standard paper mill ok.

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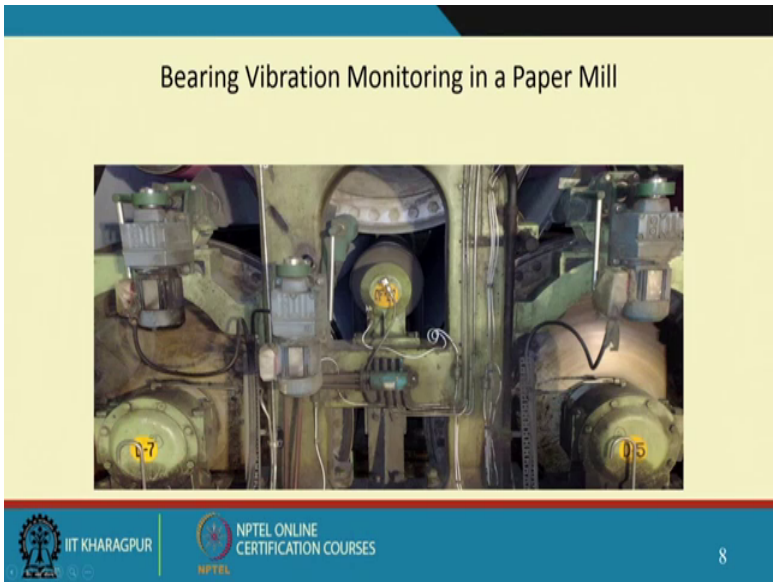

Now, as you will see each of these dryers are supported on bearings and you will see accelerometers have been mounted permanently installed and you will see this steel cabling they are nothing but signals coming out of every bearing of the rolls and which go to the central server. And then of course, we have the number of the bearing then we can find out what if there is a problem and you all know now by looking at the FFT analysis or doing the spectrum analysis of the vibration signal you can tell for sure whether there is a fault in the bearing and so on so forth.

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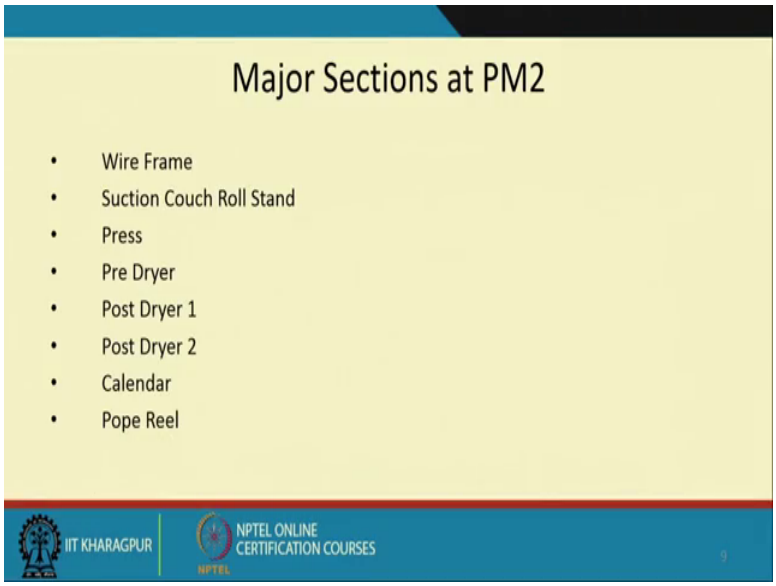

So, major sections wireframe the cultural stand the press dryer pressing is there and then few of the dryers the pre dryer and the pose dryer and then the calendar and there finally, is the pope reel.

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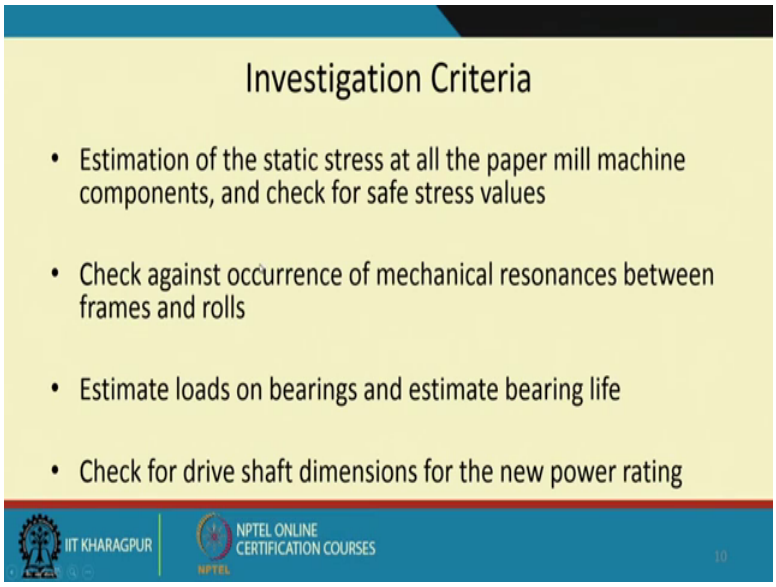

So, our investigation criteria was estimation of the static stress at all the paper mill machine components and check for safe stress values if they were not safe we need to reinforce structurally. But mostly is important is check against occurrence of mechanical resonances between frames and rolls because the frame has a natural frequency the roll

natural frequency or the roll operating frequency must not coincide with the frames resonance. And of course, we can estimate the loads on the bearings and estimate the life and check for the driveshaft dimensions for the new power rating right whether they are safe or not.

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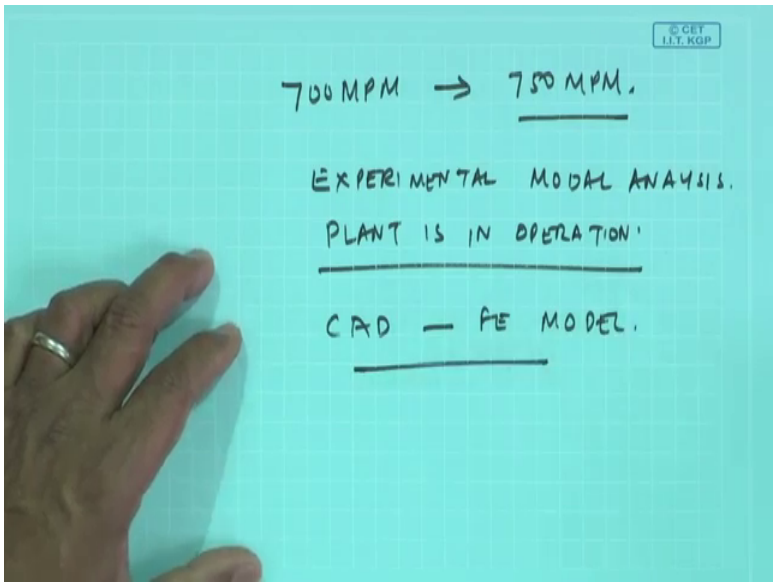

Because the problem happens if you increase from 700 MPM to maybe even 750 MPM you can understand all the speeds would increase I may have under going into the residence there could be high stressors things would fail and thus this has happened.

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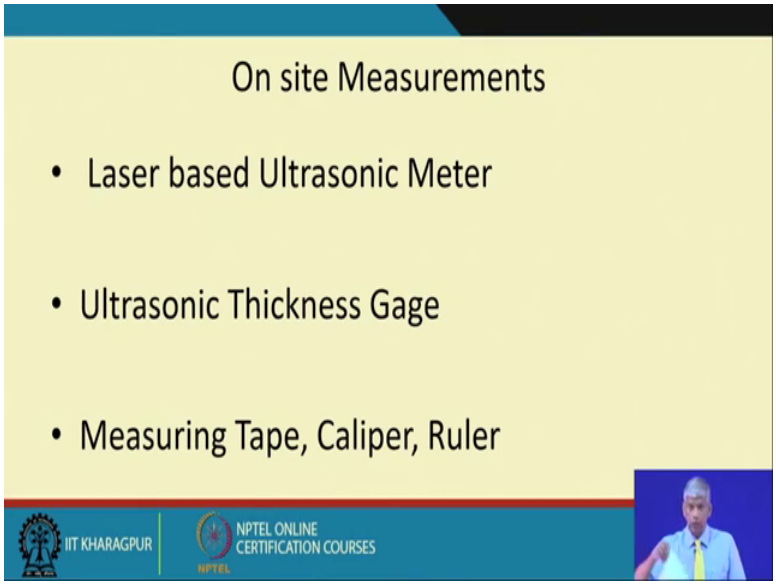

There were no dimensions available ok. So, we you know to measure from long distances we measure used a laser based electronic meter to measure the diamensions and some of this height could be another somewhere about 8 meters to 6 meters to get the exact height we used to shoot a laser beam and get the. So, such a laser based distance electronic meters are available.

Ultrasonic thickness is the thickness as you had seen earlier ultrasonics can be used to measure the thickness of an unknown and of course, wherever necessary we also used a measuring tape caliper and ruler. So, one such dimensions were measured.

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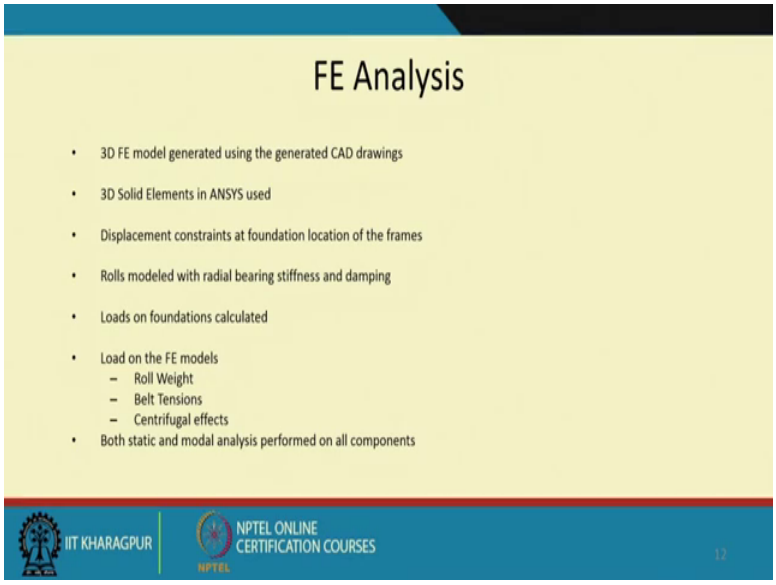

We constructed the CAD model and we use a commercial software ANSYS and then of course, model them by giving a displacement constraint giving appropriate stiffness and damping of the rolls because of the bearings. And then the loads on the foundations were calculated, loads from the on the ephemeris with the roll weight because this rolls are pretty heavy and then the tensions and the centrifugal effects and then of course, the modal analysis was performed because in such a large plant it becomes humanly impossible to do experimental analysis.

And by the way let me tell you all these measurements of the dimensions were done while the plant was in operation. Plant is an operation because no owner or management would like to shut down because in a shutdown costs money and because you know plant is in operation dimensions have to be measured. So, we need to have the right kind of

instrumentation to measure them and then of course, you make a cad model or of them you make your FE model and do the analysis. So, I am going to go through some of the FE models and the conclusions and so on.

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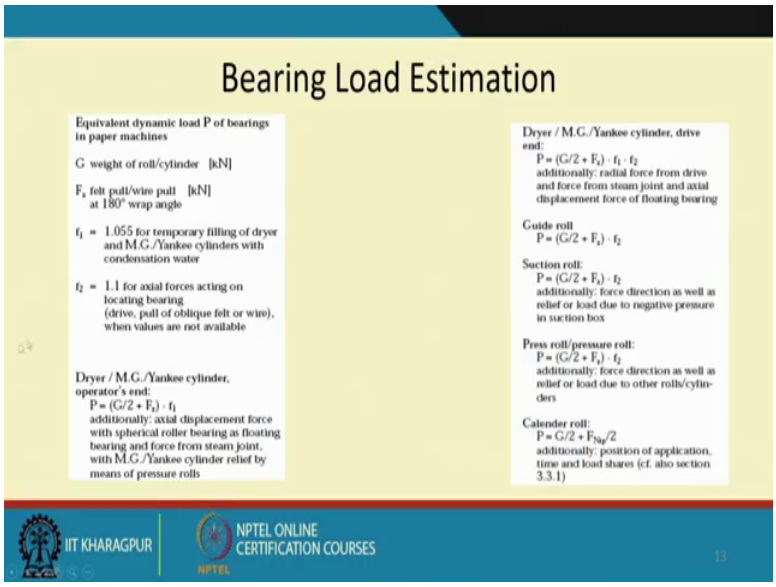

So, by the way to estimate the bearing load estimations this is the weight of the roll of the cylinder and then the angle of wrap needs to be known. So, you can calculate the dryer or the M G roll, these are the rolls you can calculate the loads similarly for the dryer summer for the guide roll, suction roll, press roll, calendar roll. So, all these expressions are known to estimate the loads.

So, these loads would be applied on the modals and they would all change with the belt pulley because if you are going to transfer more material at a higher speeds these values would change ok.

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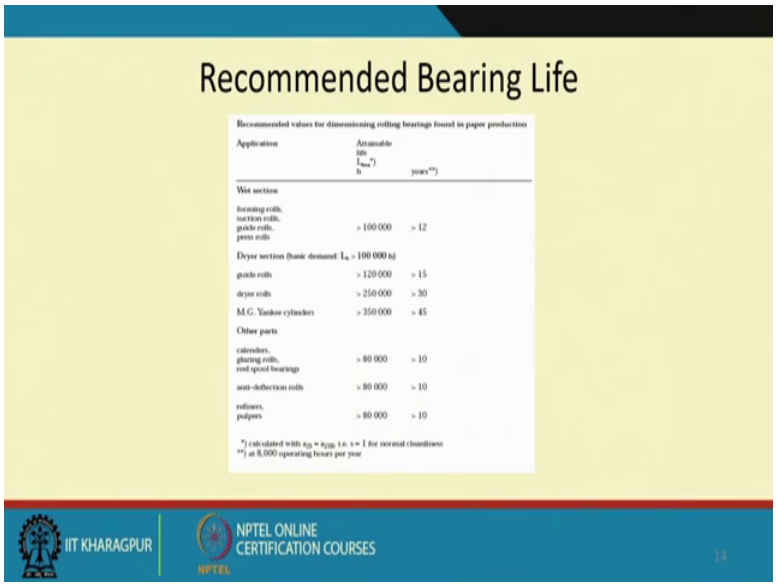

And of course, there are recommended bearing lives in terms of years of service. So, we have to calculate the bearing life and this is mostly a design problem those of you who know the design calculations for estimating the bearing life we need to have the right estimate of the loads be it radial and axial or a combination and the direction you want for the bearing or the plant to operate and from that you can find out the bearing dynamic rating capacity and then you can select the bearings.

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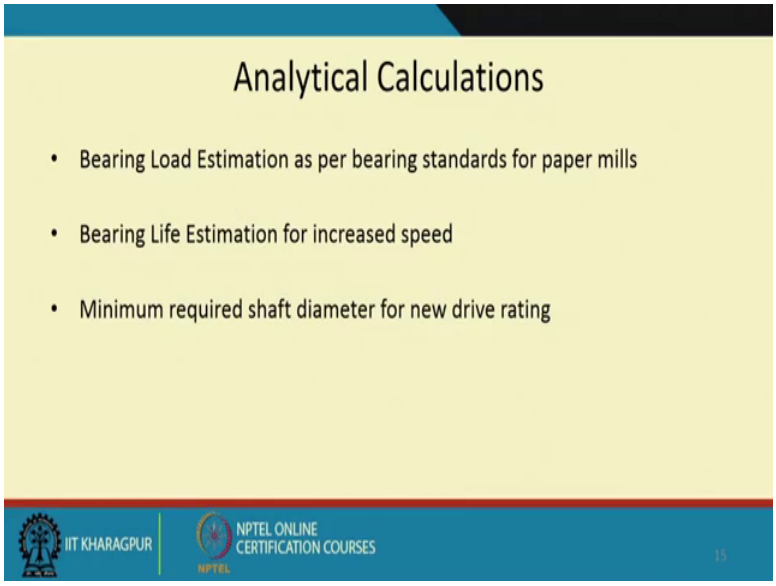

So, and then of course, the analytical calculations was bearing load estimation as for the bearing standards for paper mills, bearing life estimation for increased speed, minimum required shaft diameter for new drive reading. So, this was done.

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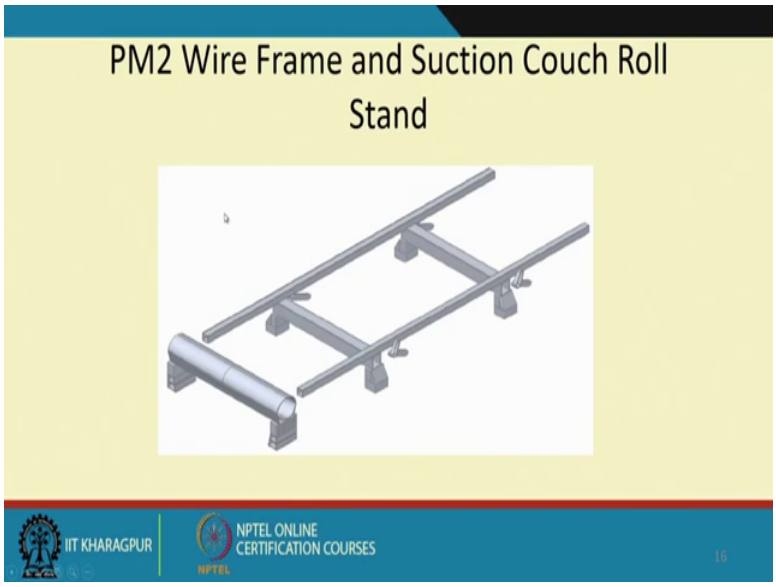

Now, this is an CAD modal of the wireframe and suction cultural stand this is right in the beginning. So, this is the suction coat stand and in the wireframe ok.

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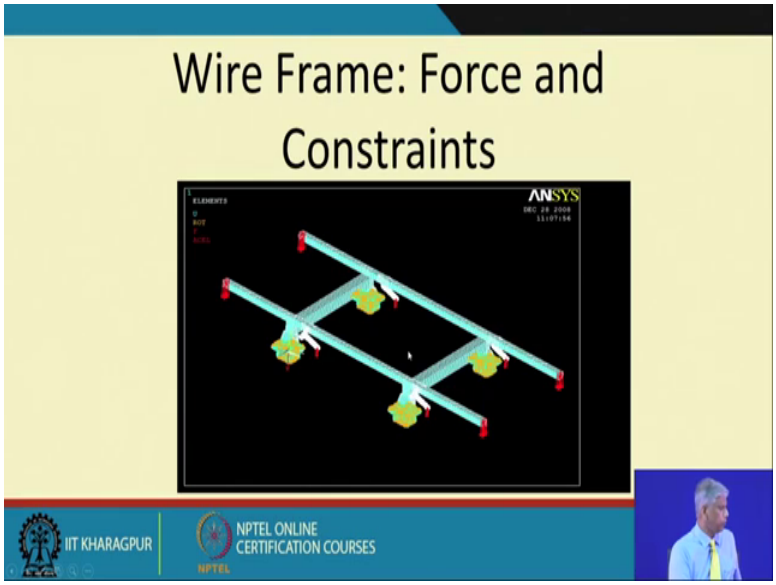

The major components are modeled once the cad was available we needed to have the FEM model showing the locations of the forces and the constraints.

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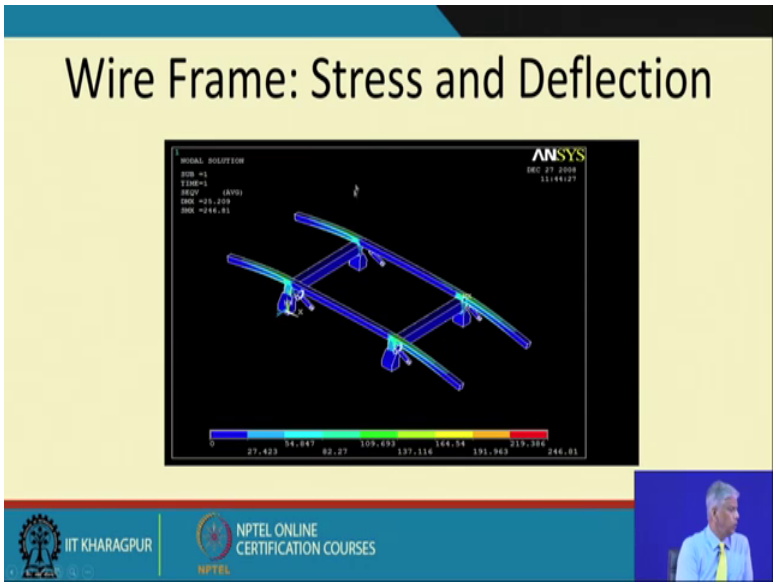

And then of course, we can estimate the stresses and the deflection and then ensure that the stresses and deflections are within the limits.

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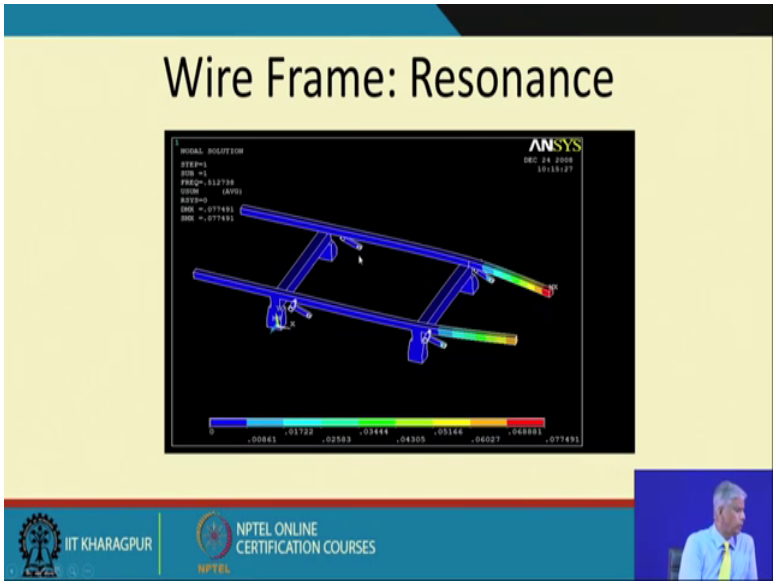

And most important is the wireframe resonance whether any resonance is occurring, you know particularly these frequencies are given here and so on.

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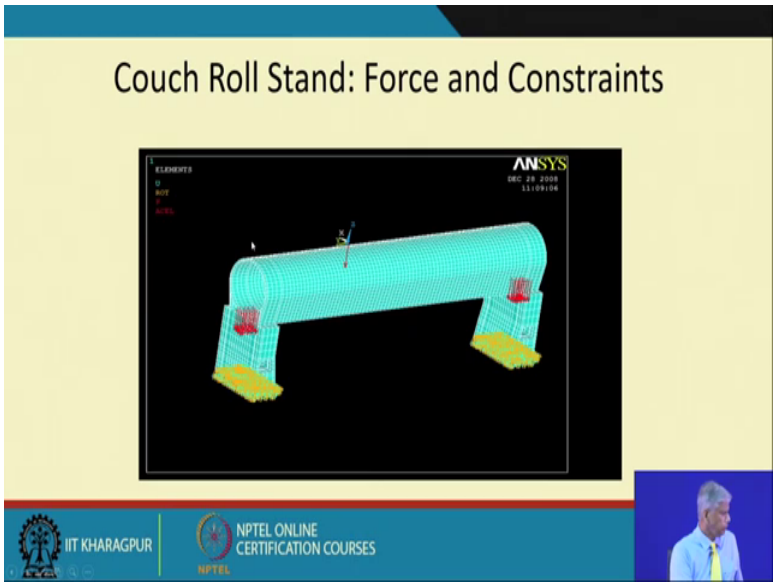

Similarly, for the couch roll force and constraints these are the constraints because they are the bonded the yellow colors and the red one are the forces coming at the bearing locations.

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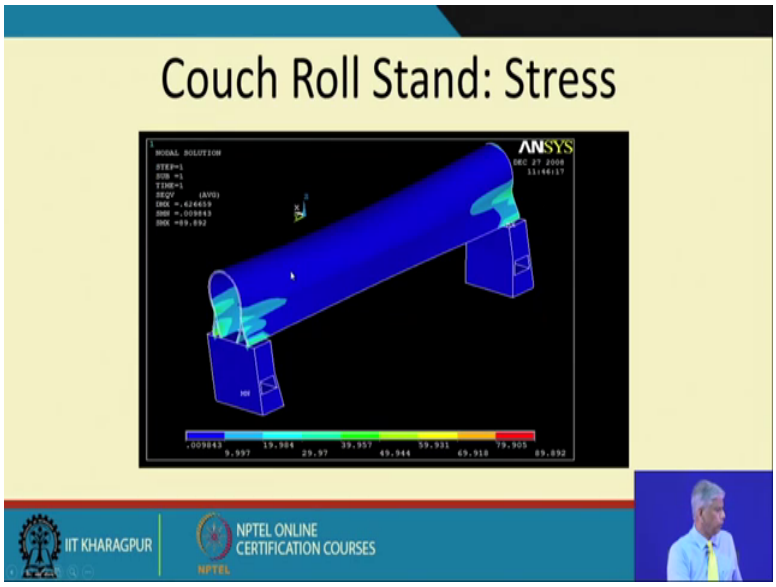

Similarly, you estimate these stresses this just seems to be safe.

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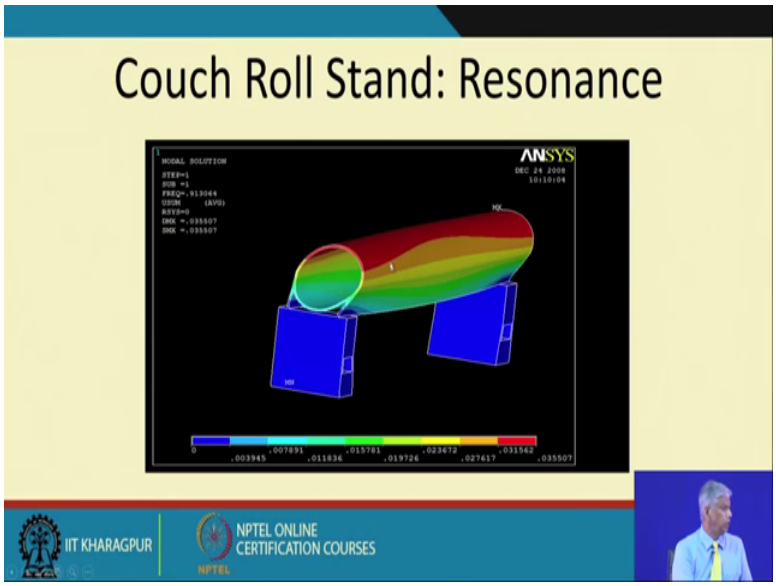

And of course, there is a resonance, so we need to estimate the frequencies.

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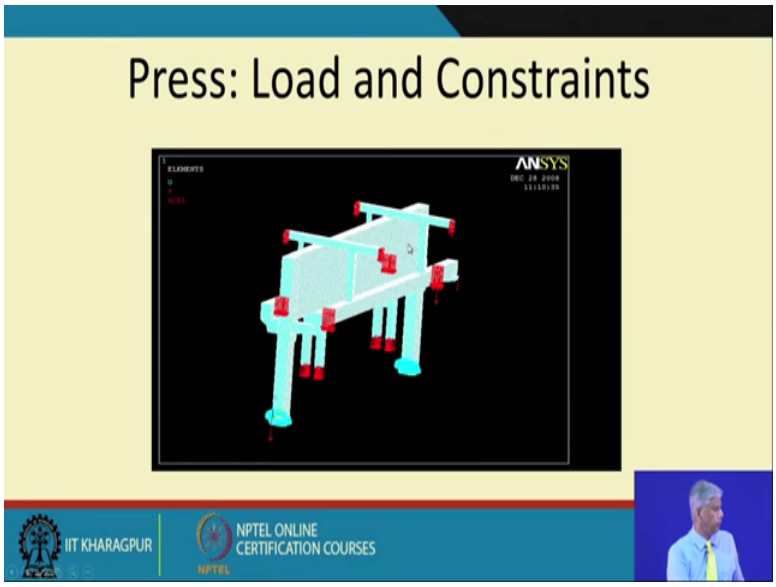

Similarly, for the press, loads and constraints are given the because these are all the frames. So, if these hold the rolls the forces come onto these frames and then we can estimate the loads.

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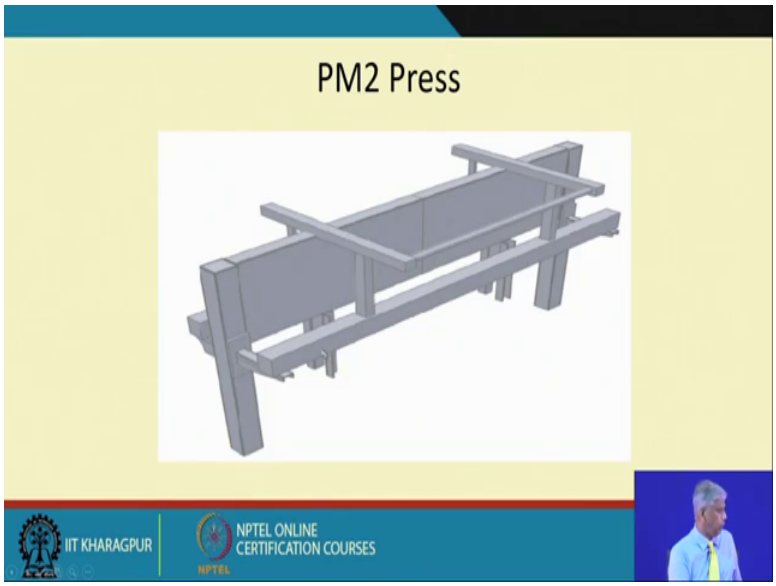

And this is the CAD model of the press.

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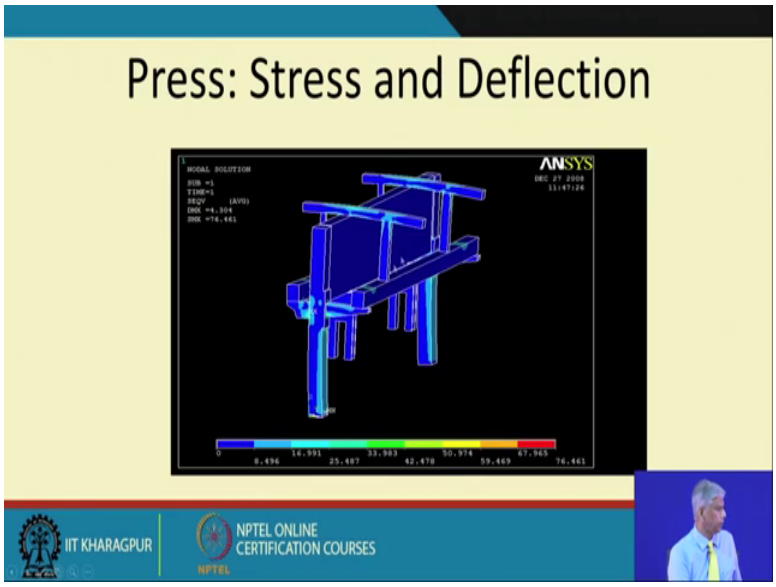

This is the stress and deflection calculated out of the FEM results ok.

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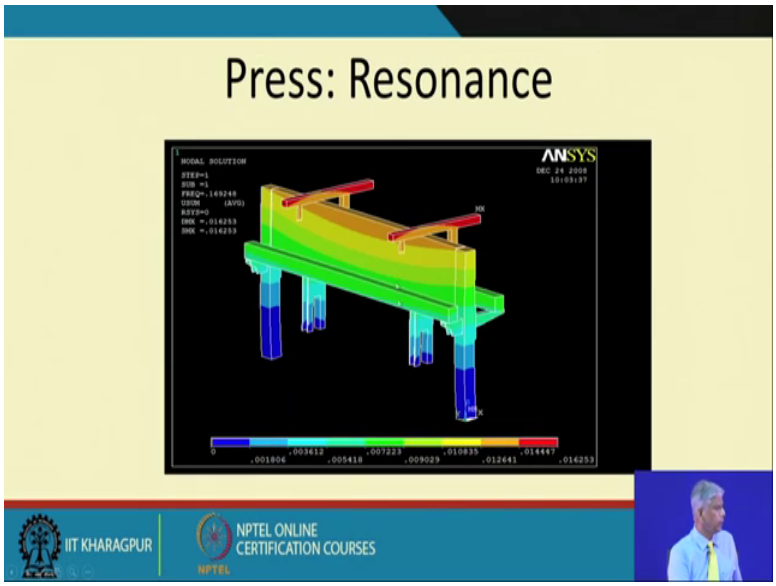

And then of course, you can see the resonance of the plate ok, of the press.

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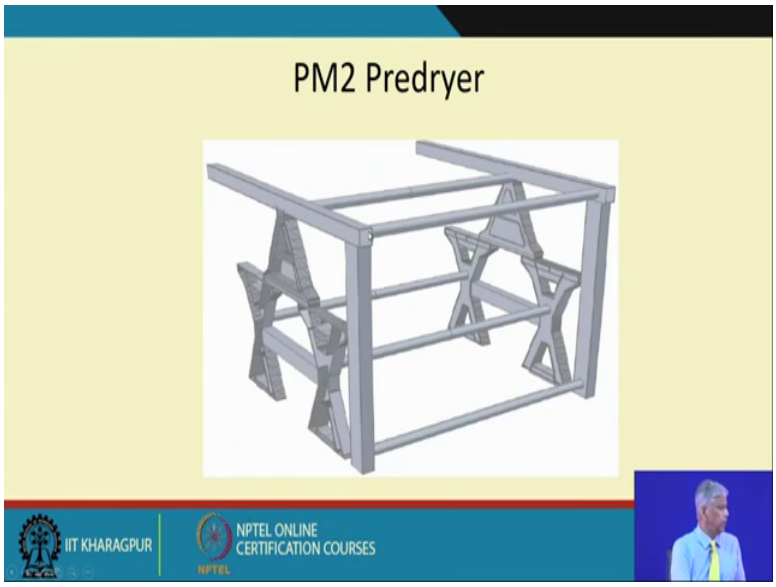

Similarly, for this drives you know these frames each one of them hold many rolls ok. So, we have to see that.

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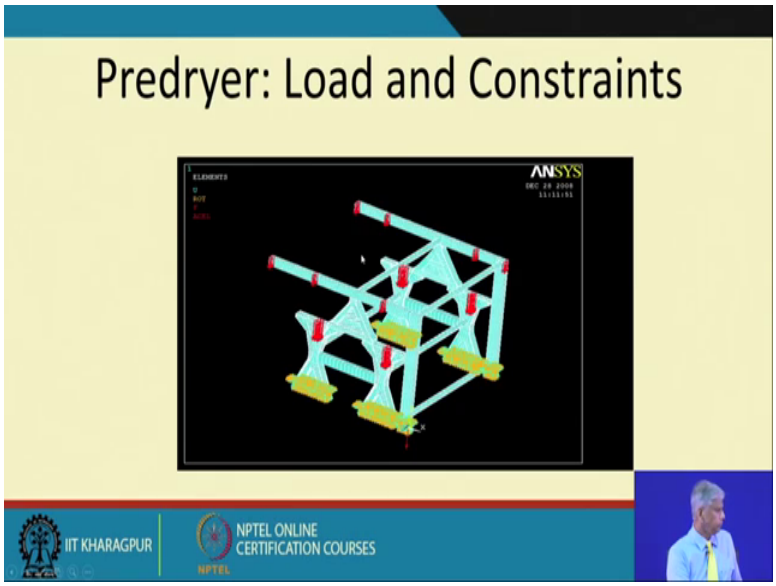

Loads and constraints, there are the loads and the constraints.

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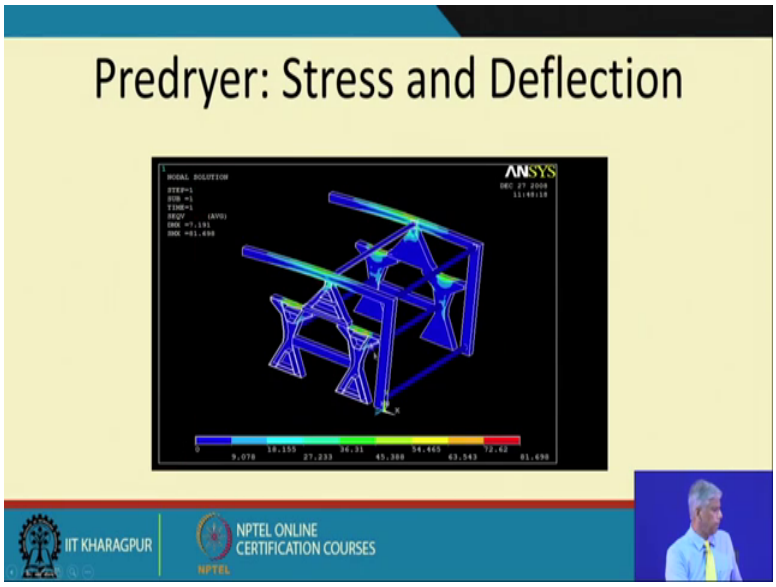

And similarly this stress and deflection for the pre draft were done.

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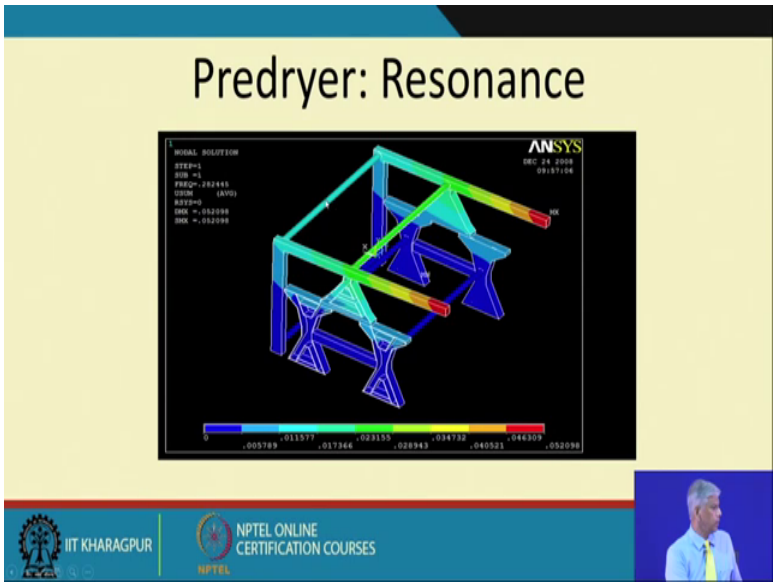

Pre dry resonances.

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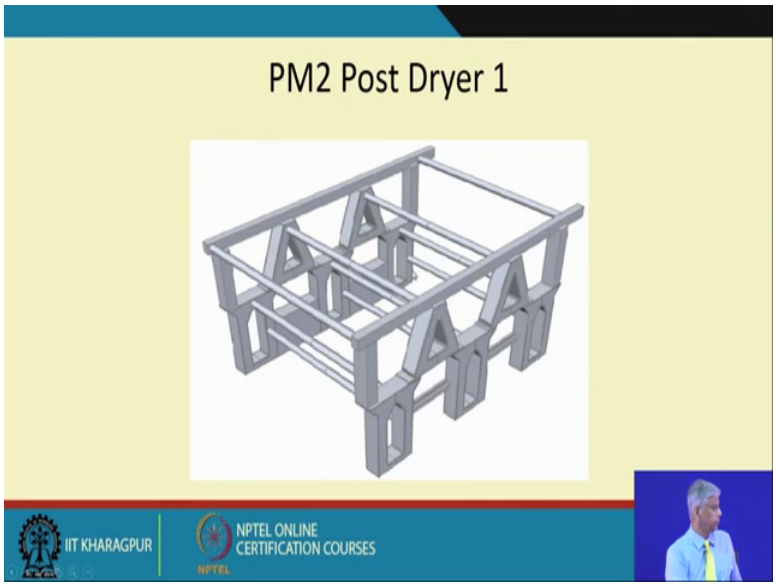

Similarly, for the post dryer. So, you know all these typical dimensions give you a feel of the dimension and this is about 4 meters and this about 8 meters. So, you can imagine such models for the entire plant has to be done for all the sections for the press section for the pre dryer, post dryer, couch suction, couch calendar pope reel, everything else because no component can be under resonance. Because you know as a CBM engineer you would be only perhaps monitoring real time bearing vibration real time.

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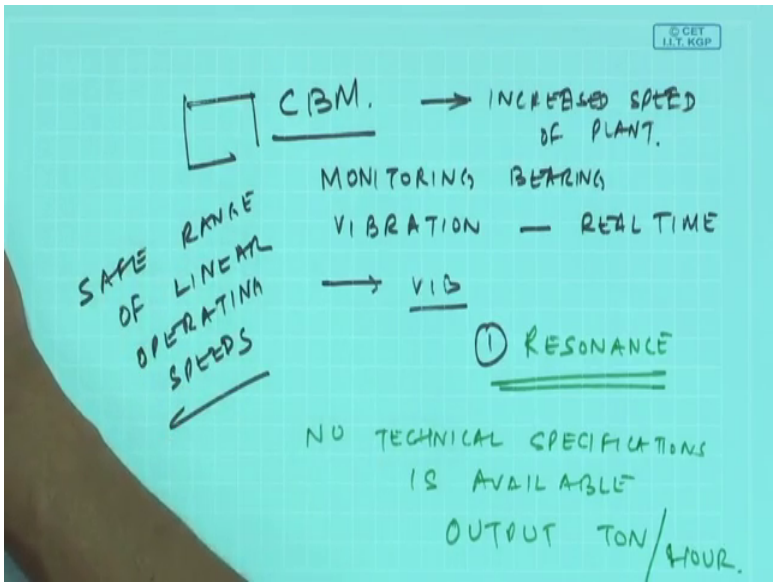

But if then somebody increase the speed of the plant, these vibrations would increase and one has to be safeguard against resonance.

So, to safeguard against resonance one has to do such analysis because this is a plant where no technical specifications is available other than the output in tons per hour ok, because the owner who may not have any engineering idea may say well how do I increase from 80 tons per hour, 200 tons. He would say if we had no engineering science well increase all the speeds. But the problem with increasing speeds is conditions of high stresses resonances. So, we as inner designers, engineers CBM specialists need to do this kind of a study in the background and then recommend to the CBM guys well you know we are having roll resonances. So, avoid operating at a certain speed or tell them the safe range of linear operating speeds and that is most important.

Particularly in machines or in plants where there are many such machines and similarly for the post dryer.

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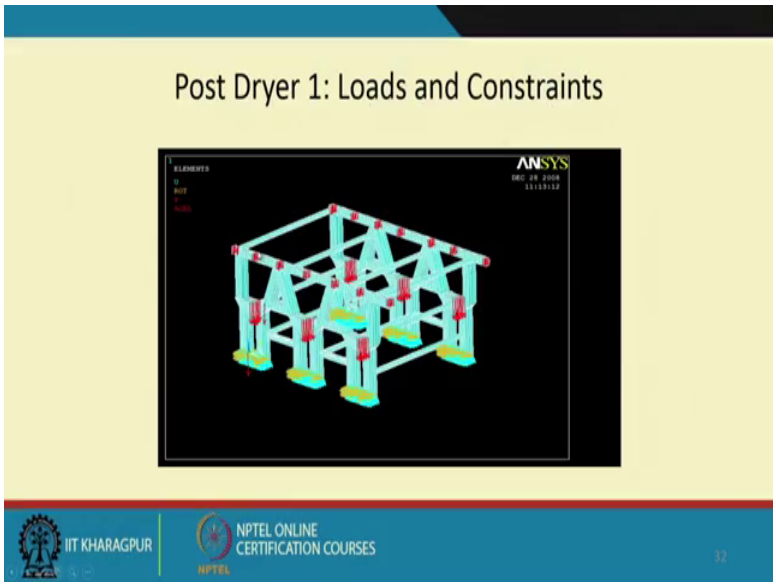
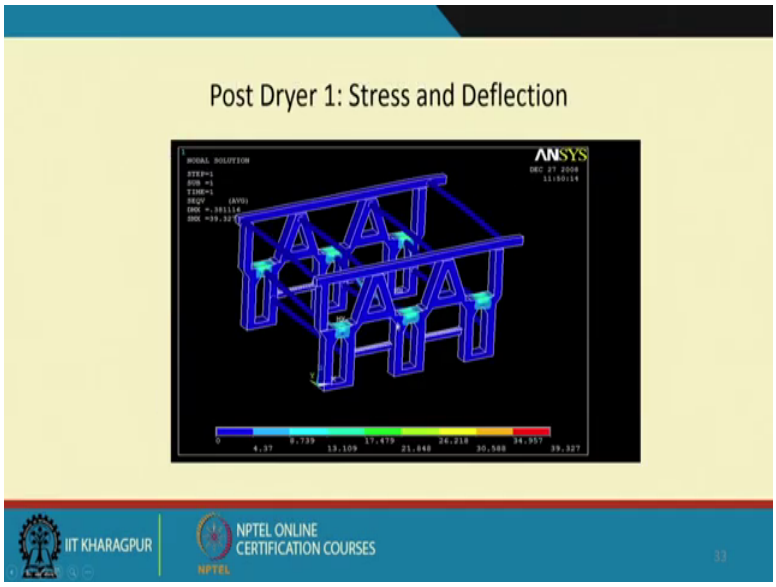


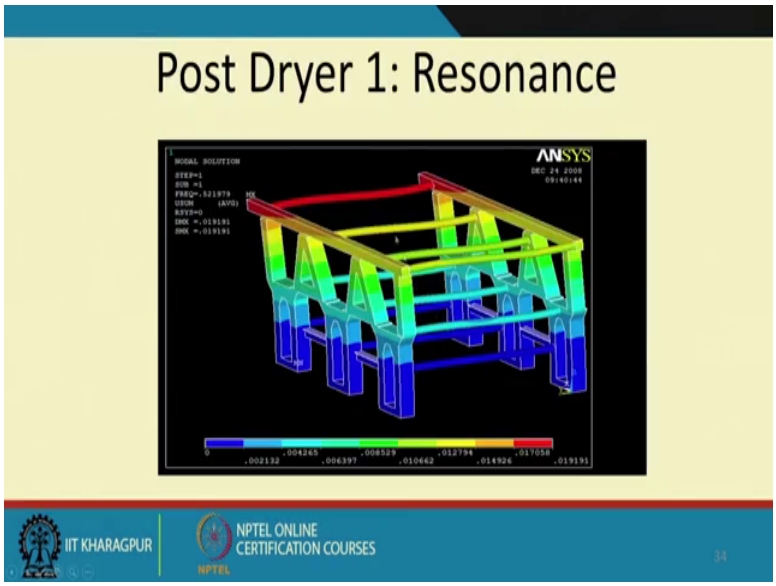
We can see again the loads there are many loads and the stresses.

(Refer Slide Time: 22:52)



Stress and deflection and you can see the resonances.

(Refer Slide Time: 22:55)



So, if there is high resonances maybe we have to stiffen it and then check the model against the new natural frequencies.

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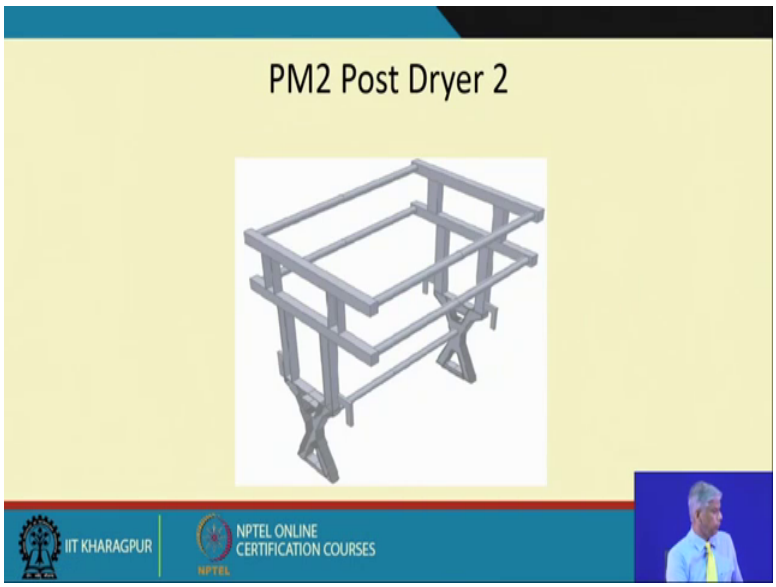
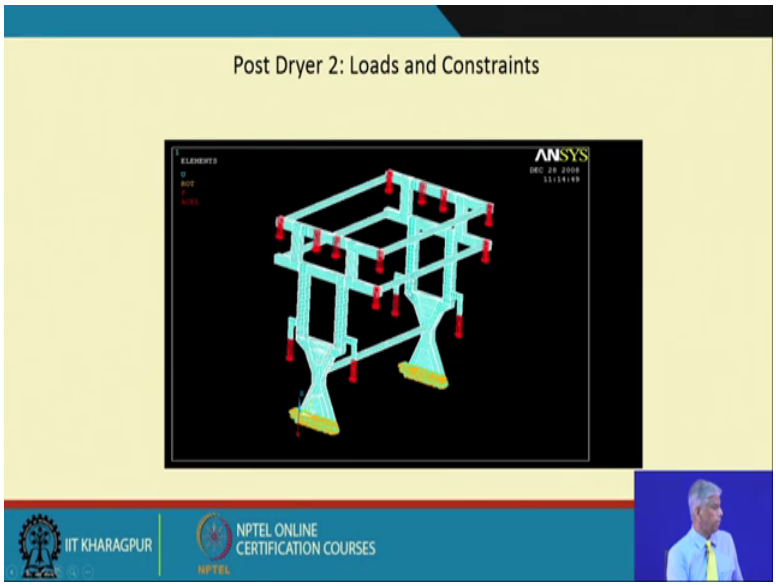


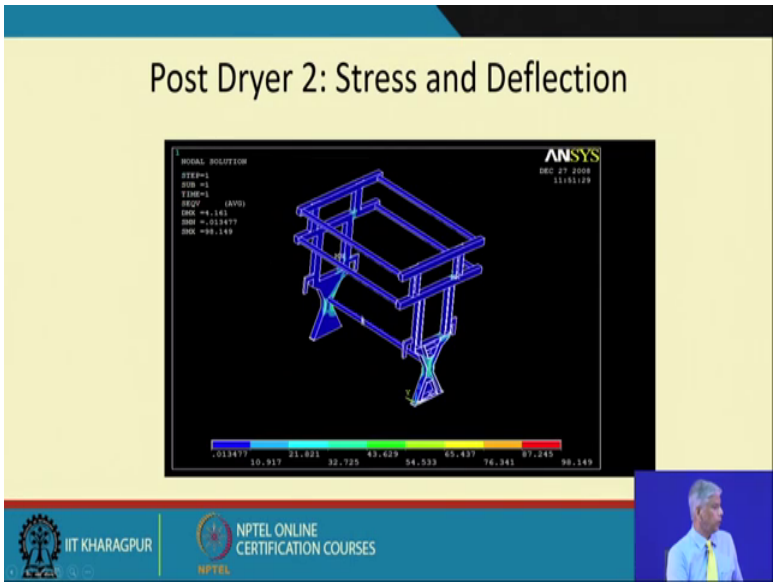
Similarly, for the post dryer.

(Refer Slide Time: 23:08)



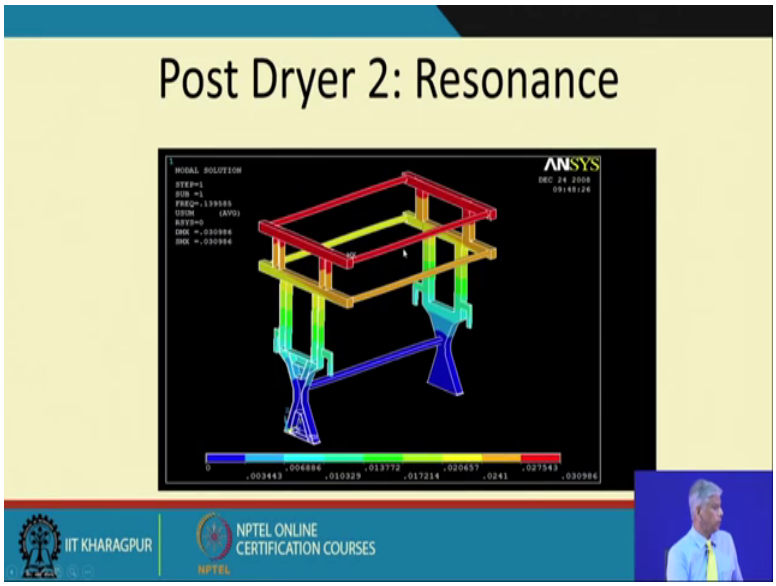
Loads, constraints.

(Refer Slide Time: 23:11)



Stress and deflection, resonances ok.

(Refer Slide Time: 23:12)



And similarly for the calendar.

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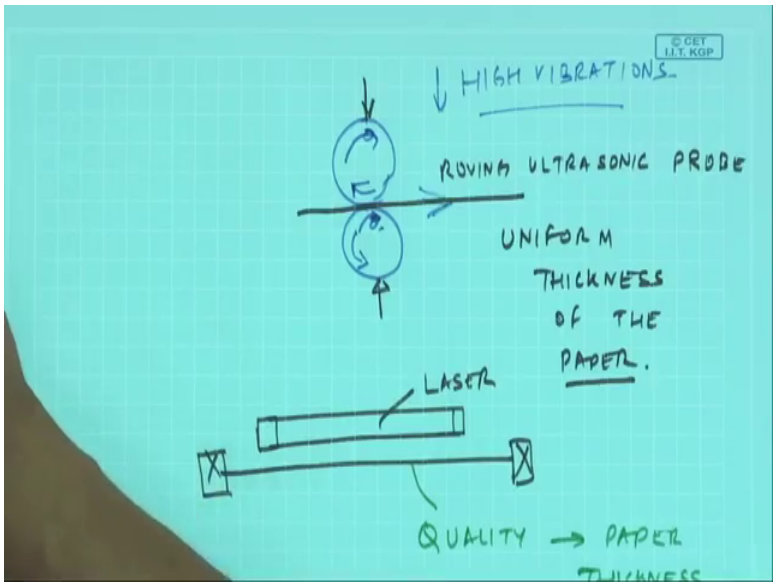
Calendar is a location where finally, between the two rolls.

(Refer Slide Time: 23:26)

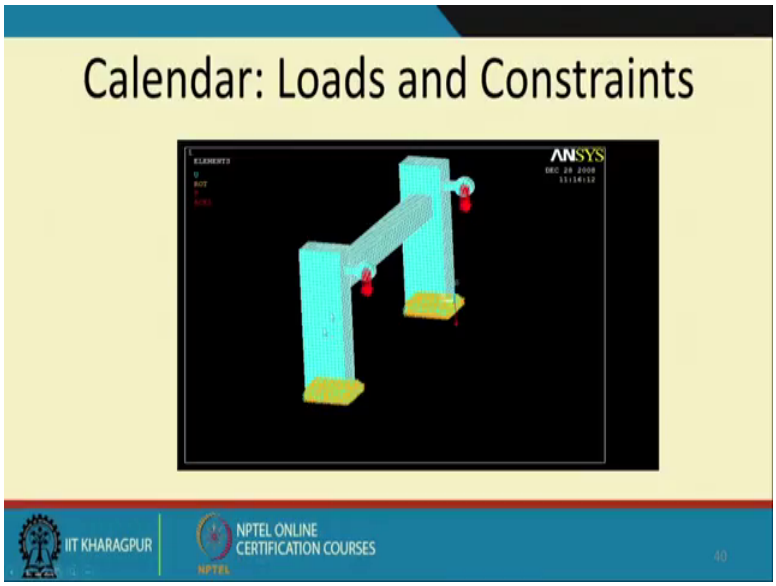


The paper comes out and it is actually pressed. So, we have a uniform thickness of the paper. In fact, to measure the thickness there is a roving ultra sonic probe along the length and breadth. So, this is a paper supported and rolls there is a roving ultrasonic paper and sometimes it is an ultrasonic or a laser beam is used to measure the paper thickness.

Because the paper quality depends on the paper thickness and there should be no shrinkage and if I increase the speed what would happen if I increase the speed of all the rolls both of them are going the same direction sorry ok. So, paper is coming out in this direction.

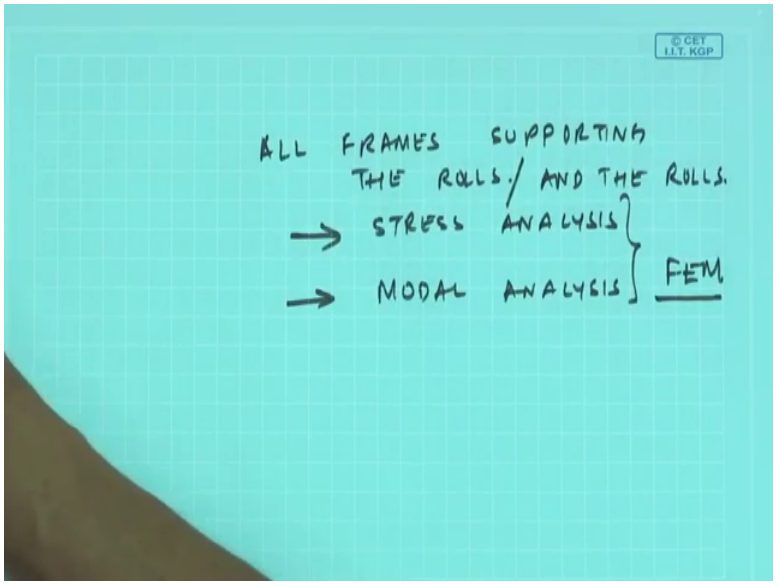
Now, imagine if I increase the speed. So, this would lead to high vibrations and this may lead if they lead to resonances these paper thickness may not be the same.

(Refer Slide Time: 25:28)



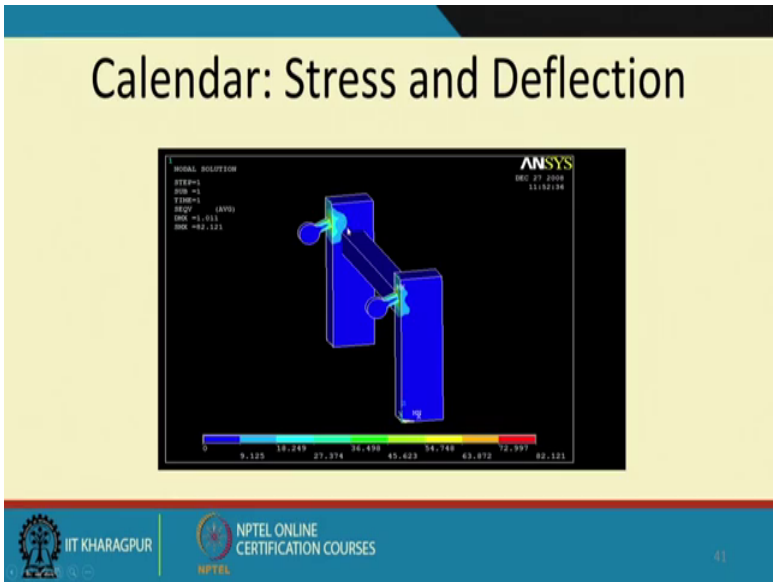
So, all the frames of the paper mill, all frames supporting the rolls stress analysis is to be done and also modal analysis.

(Refer Slide Time: 25:38)



So, putting the rolls and the rolls and this is done by a standard FEM package.

(Refer Slide Time: 26:20)



So, similarly you see the stress and deflection.

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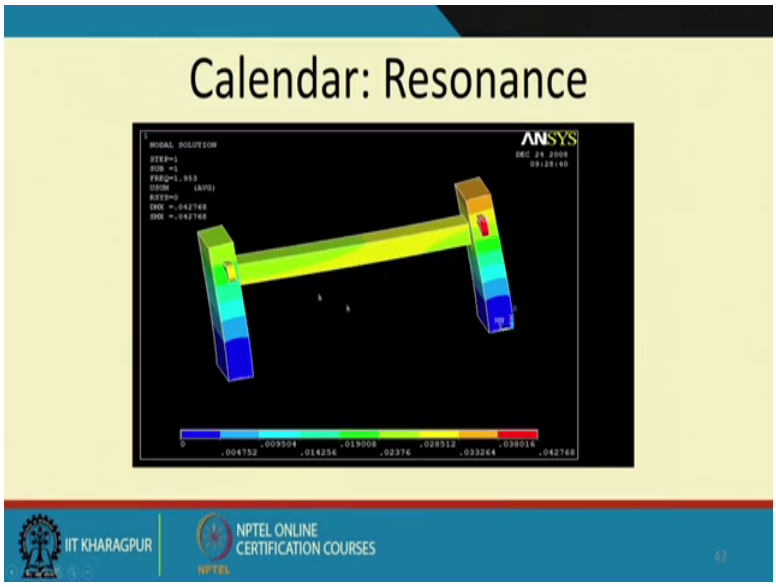

The resonances.

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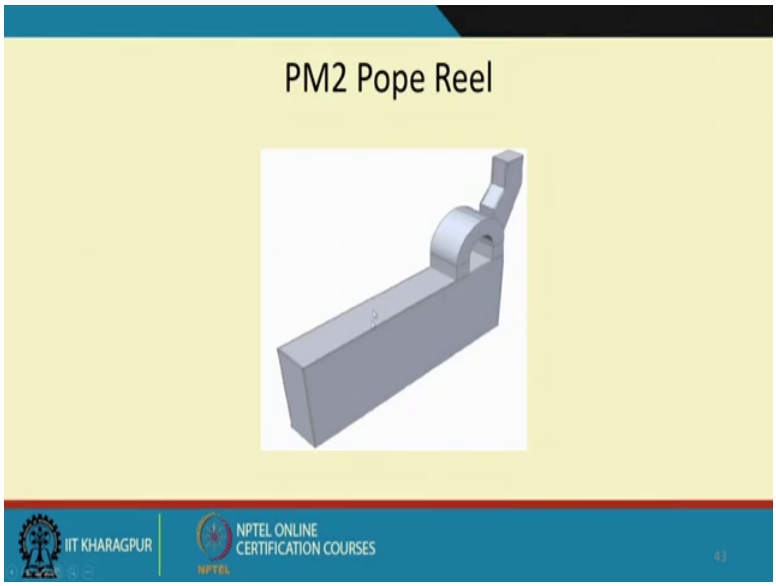

Again for the pope reel the last reel where the paper rolls come out.

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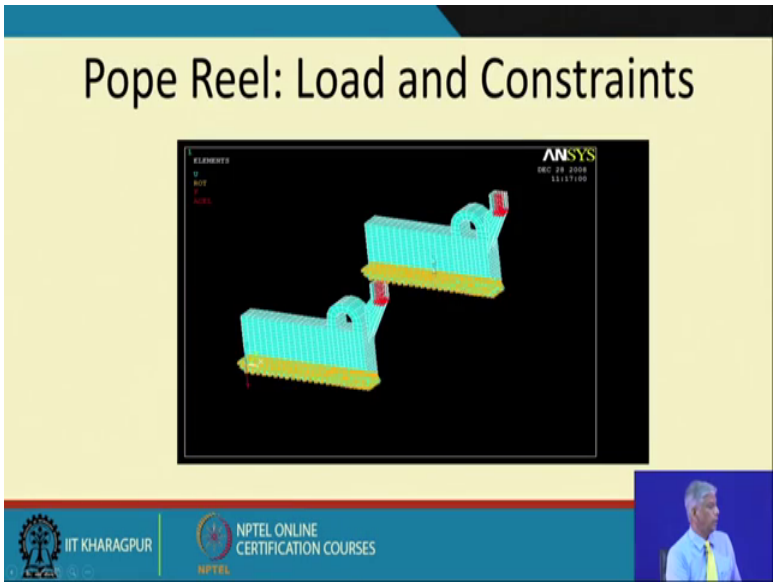

And then they are eventually transported.

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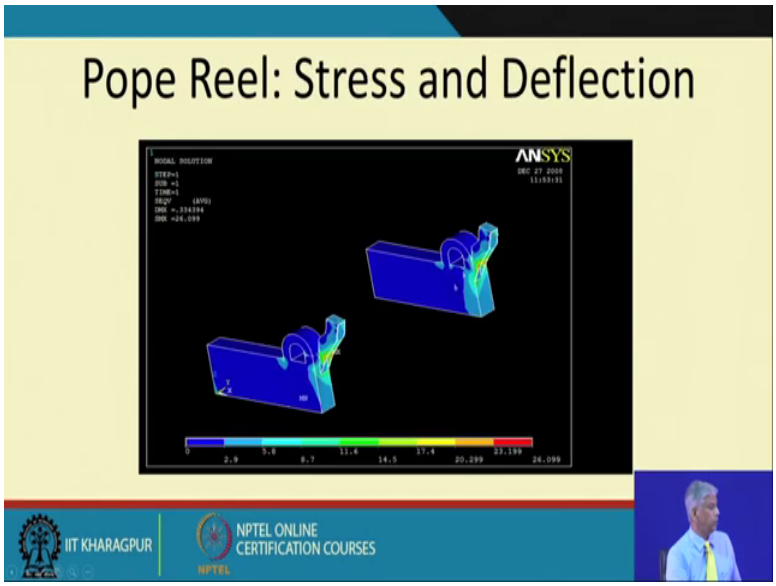

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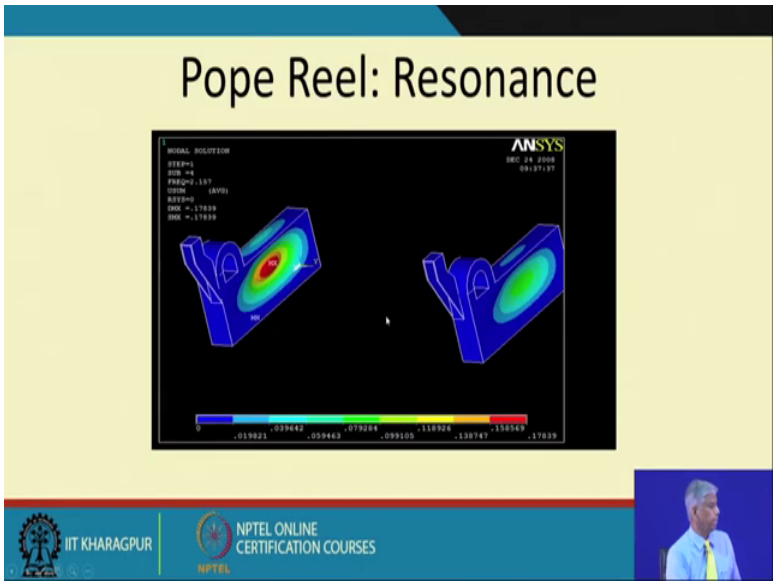

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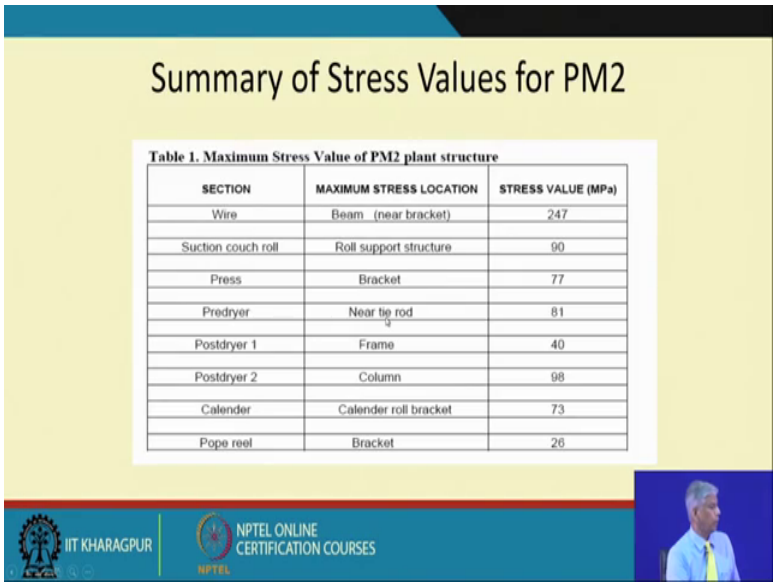

So, we found out the maximum stress by our analysis and they happen to be safe for all the sections through this study.

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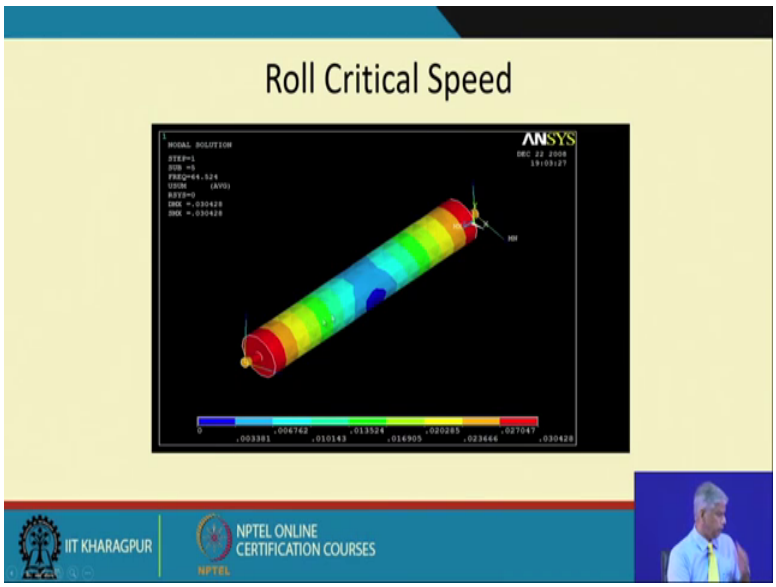

But then we studied the roll critical speed for all the rolls by an FEM analysis.

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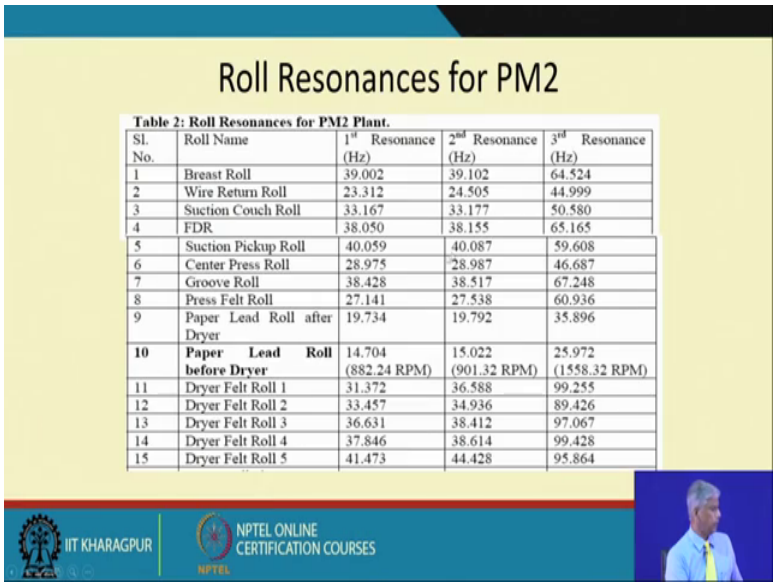

And then we calculated the resonance conditions for all the rolls because there are many dryer felt rolls and dryer rolls.

So, we ensure that these are to be avoided. So, certain RPM there was a problem of the paper lead roll before dryer where the resonances where close to the operating speed. So, he had to vary the speed and do a modifications ok.

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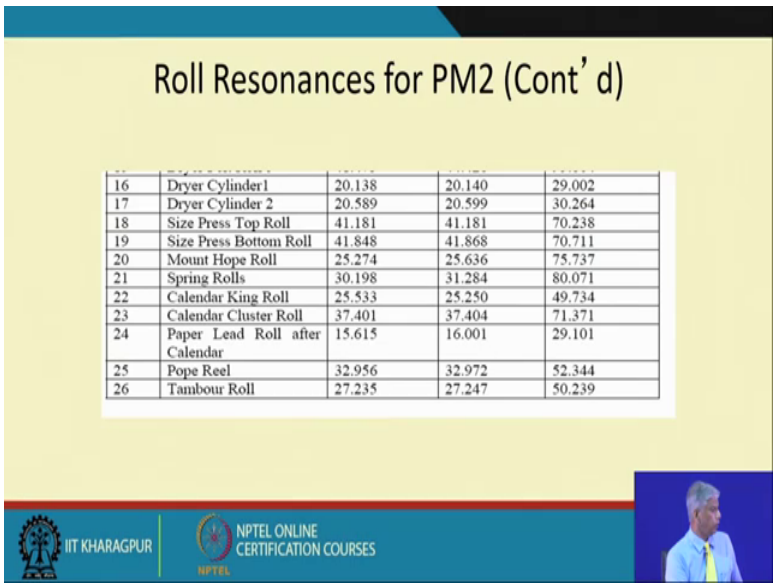

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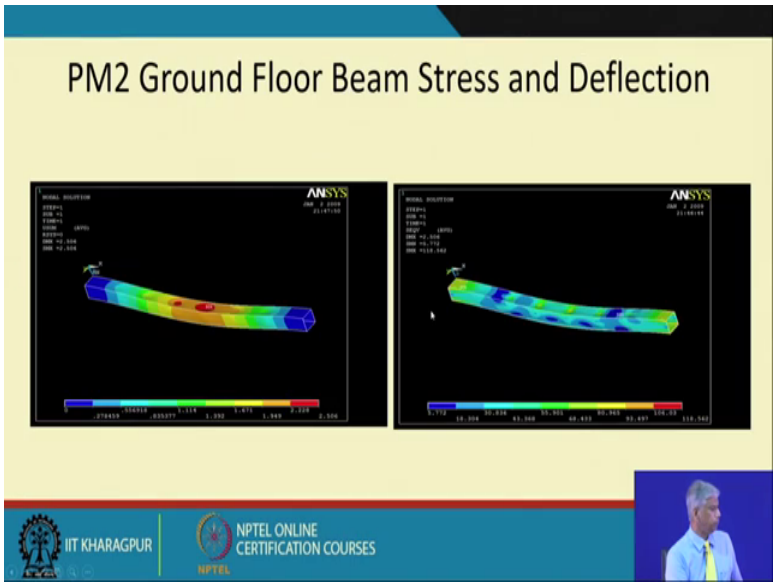

And of course, the supporting beam also needs to be checked for stresses.

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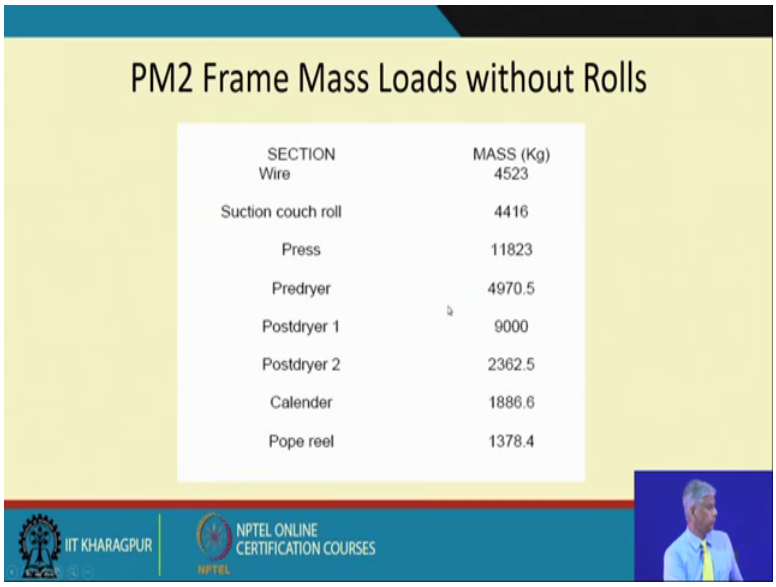

And of course, to do such analysis we had to take the mass of these units, and on this you can come get from the cad models and once you have the density we can get the cad model from the cad models mass can be estimated.

So, this gives you an idea as to for a plant where no technical specification is known. How from the increased operating speed one can be sure that no problem is going to

occur in the bearing or what is the bearings life and whether it is safe to operate the plant at these conditions ok.

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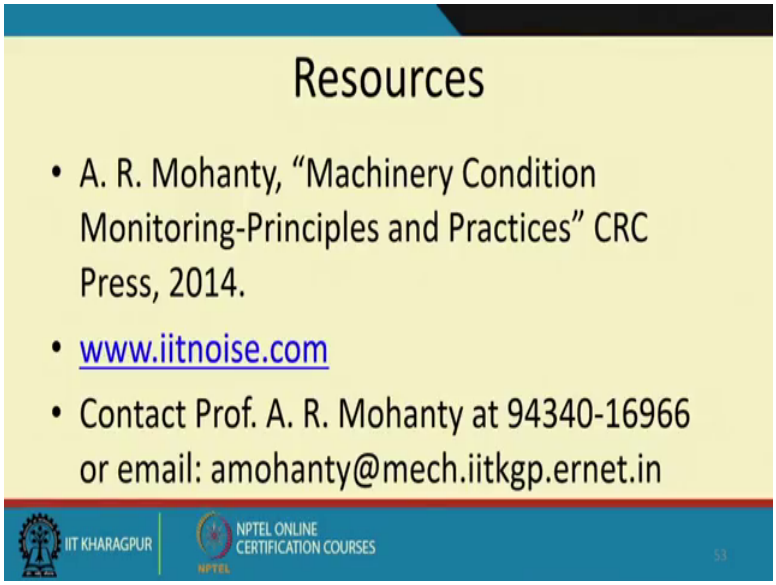

Thank you.