Machinery Fault Diagnosis and Signal Processing
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Lecture - 57
Railway Locomotive Noise and Vibration Monitoring

In this lecture I am going to discuss on the on a practical example of how noise and vibration inside a railway locomotive are measured; both during stationary conditions and while the locomotive is on the tracks and running at or traveling at a certain speed. Well just to recollect when you talk about design of machineries, you know today in the transportation sector we are all concerned about the noise being emitted by vehicles which are plying on the road, railway locomotives, plying on the railway tracks.

So, there are two issues in it, one as the noise level inside the cavity or the passenger compartments on the drivers cabin, visa we the noise outside to the passerby x or to the by standards either along the track side or the railway platform or on the roads. So, we need to see what is the present condition; of the machinery from the noise and vibration measurements.

So, this I am going to talk about on will be locomotive noise and vibration monitoring.

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This is a case yesterday on a work we did for the Indian railways and so, railway.

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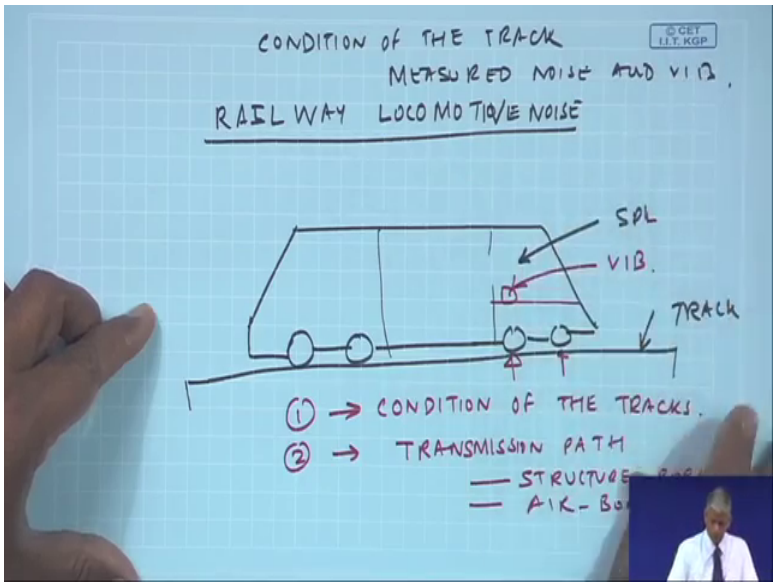

So, when we have a cab, there is a track and somebody is measuring the SPL in the cab and the vibration level.

So, these are influenced by most important is the condition of the tracks and of course, the transmission path by the transmission path I mean, the energy getting transferred from the tracks either directly or that is the structural borne or the airborne ok. The question we are doing this study is can we know the condition of the track a track from the measured noise and vibration.

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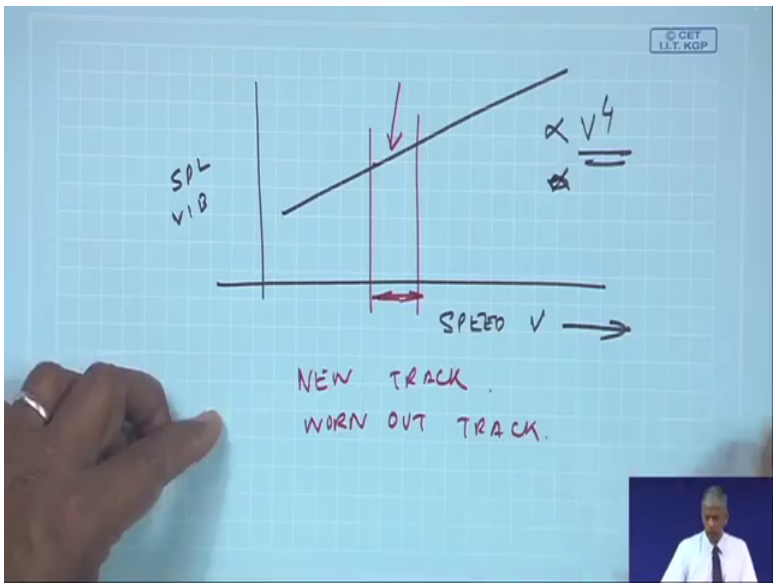

There are many empirical studies being done, where with the speed of the vehicle either the SPL or vibration follow some curve. I would not like to characterize as values, but them says it is d proportional to velocity for some morals proportional to and so on and then few constants are there.

So, but then when we are monitoring at a particular vehicle speed, we need to measure for a new track or an worn out track because energy transfer is because of the wheel real interaction and the surface roughness both on the wheel and the track play an important role.

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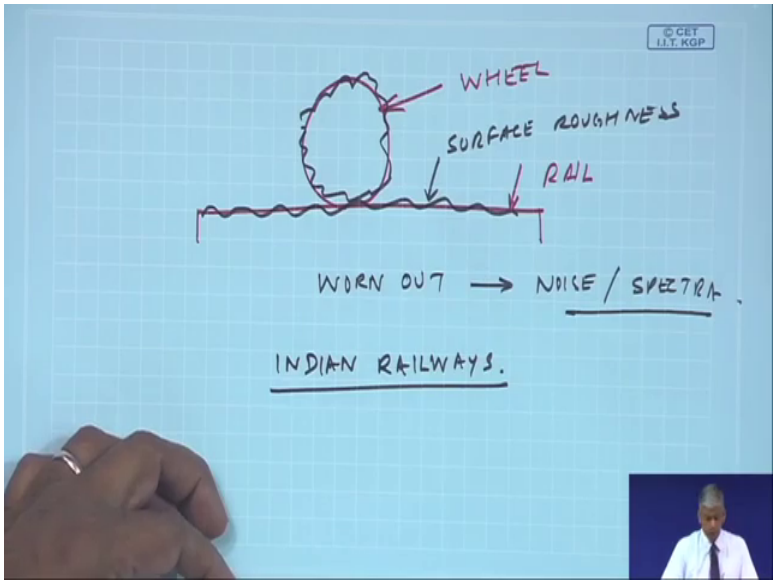

So, if tracks get worn out, they will produce a noise of a different spectrum.

So, this is what needs to be studied we did it for the case of Indian railways for a particular class of locomotive, because this was never been done for the Indian railways and we are at IIT Kharagpur did it for the very first time fortunately we have a big relieve workshop at Kharagpur.

So, the railways were kind enough to give us this locomotive to do a northern vibration measurement trials, well the there are many objectives in this work one was to reduce the interior noise levels of the cabin both there are two cables one at the rear and the front or that known as cab 1 and cab 2, one close to the radiator fan another close to the engine end and these railway locomotives are mounted on two [FL] which hold the under frame

and over the under frame is the cab structure, which has been put and engine sits somewhere in between.

Now, as I was telling you when this is plying on the tracks at a certain speed, there is a certain amount of vibration in the floor of the cab and also the sound pressure level. So, to do this experiment what we did is you know we instrumented the cab with two ends.

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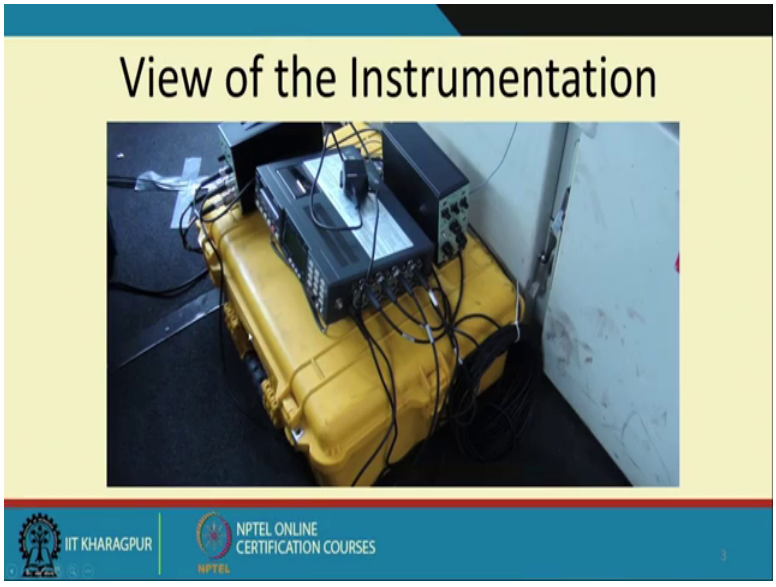

Both in both the cabs; this is a cab because this trend can either go locomotive can go either this way or this way and the driver needs to change its position ok.

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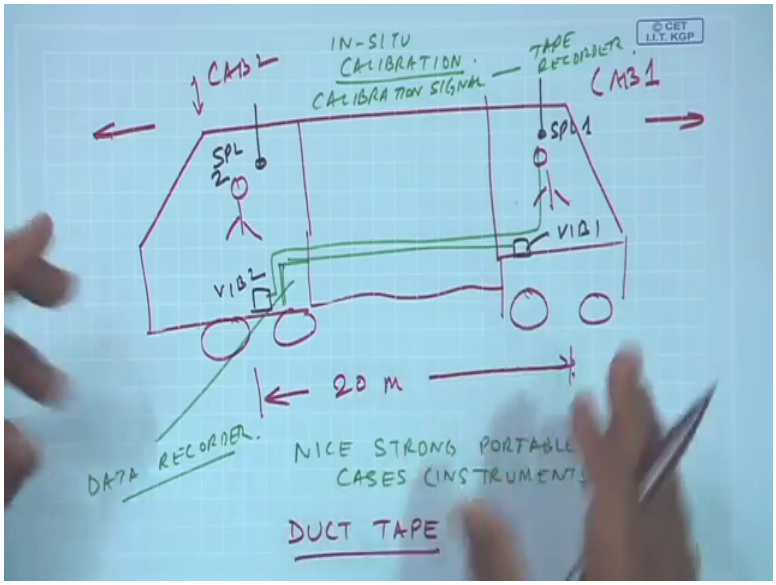

Now, we kept our instrumentation and this is about close to about 20 meter long ok. So, I am telling you the practical scenario of putting such measurement in place. So, we had our data recorder. So, basically we put one microphone here SPL 2 SPL 1 and then vibration 1 and vibration 2. Now, in one location, we put our data recorder and that is this yellow box which you see and those of you who are doing a lot of field measurements, it is good to get rid of some nice strong portable hard cases for your instruments.

Such boxes you know which we call our favorite pelican yellow boxes you can transport a lot of delicate equipment bit transducers, be it your cameras, be it your recorders. So, I usually have you know about 4 or 5 of them in my lab, wherein we take all our equipment because when you talk about a 50 analyzers, we talk about more sensitive microphones accelerometers, charge amplifier as many times as you would see you would have gotten field from this course that though we have demonstrated to you many version issues on signals coming out of a machinery fault simulator.

To understand whether a misalignment has occurred or an unbalance has occurred, many times we have to go to the site be it a port be it a cement plant a mine a steel plant ok. So, how do you an all for this matter a railroad or a railway locomotive. So, how do we transport our equipment? So, it is good that you must have some strong instrumented cases to carry your equipment. Now the most important equipment here is the data recorder ok. The reason we have the data recorder is because you see there are four channels 1 vibration, 2 vibrations and 2 sound pressure levels.

For the cable and the data recorder is fixed at one place and you can see in such film measurements it is good to have the piezoelectric accelerometer cables should not be whipping around. So, it is good to anchor them with duct tape which can peel off, but which is very strong and it holds on to the. So, this is the carpet of the floor of the cab and these are the two charge amplifiers, one for the for the accelerometer and now two for the sorry one for the two accelerometers and two microphones because one thing I must tell you about this data recorder.

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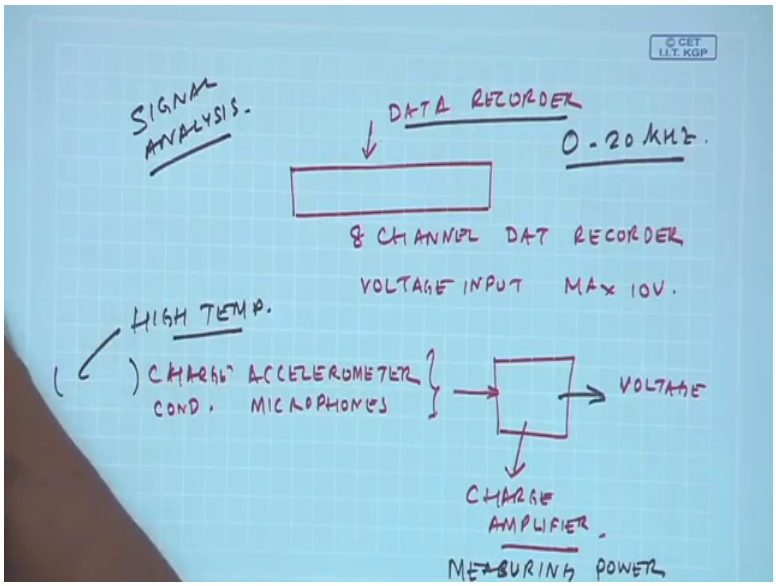

This data recorder is an 8 channel that recorder, which takes only voltage input the max of 10 volts. But when we have the accelerometer or the microphones they will give you a voltage amplifier voltage signal only if they have been conditioned with their corresponding charge amplifier.

And these are all charged at accelerometers and condenser microphones; the reason in real field measurements when the charge accelerometers are used because of the high temperature ok. So, we used high temperature charge accelerometers and similarly condenser microphones which require a polarizing voltage. So, its measuring power supply.

So, the output of this is the voltage signal which goes to the that recorder. So, that recorder we can record all the from 0 to 20 kilo hertz. The reason we do this is because when you are going on the tracks in a train you know particularly Indian trains you can see how much of vibrations it is there. So, it becomes humanly impossible to do any meaningful signal analysis.

So, this is true for the case of a cement land and coal mine right or in situ analysis is very limited. So, it is good to store all your signals in a data recorder like this. So, to summarize in order to carry this equipment or to this site we need to have such cases and particularly in a in CBM, when you are doing lot of industrial monitoring in the field it is good to have such equipment.

So, and then another thing is that when you are talking about this 20 meter long. So, I need to lay the cables all along the locomotives frame to go to the reconnaissance. So, we need to have long cables ok. So, when we have long cables we do not know what is the voltage drop. So, we also need to do what is known as the in situ.

In situ calibration of the signal and it is good to store a calibration file calibration signal in the tape recorder and this I am telling purely from my practical experience doing measurements in the field that it is a very good idea.

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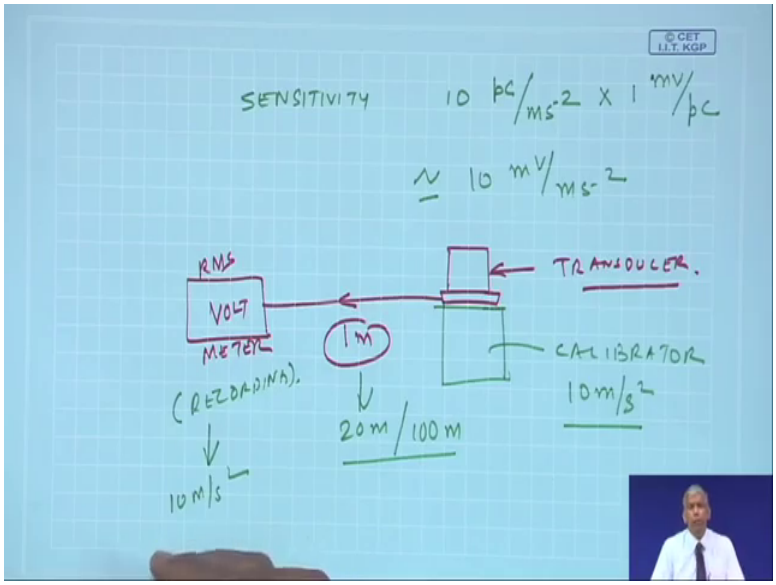

Because see when I look into the sensitivity of a transducer say it is written as you know 10 picocoulomb; per meter per second square ok.

And then times its voltage you know maybe some voltage sensitivity 1 millivolt per picocoulomb. So, then this will boil down to 10 millivolt meter per second square ok. But this is when I have a transducer and then I am measuring it within maybe one meter of cable some voltage measuring source transducer being f is a electric accelerometer.

Now, what if this length becomes long becomes 20 meters or becomes 100 meters in many of the field applications. So, it is always good to give a calibrated signal here calibrator and if you know this calibrator is giving you an mechanical acceleration of 10 meters per second. So, whatever voltage you are getting on the voltmeter or recording, you know that corresponds to ten meters per second square even with a large cable.

So, if there is a voltage drop in this cable it will be a counter further than this calibration signal. So, henceforth when you do a real measurement without the calibrator whatever voltage you get, you can always relate to this. So, always in the field measurements, it is when we are recording data it is good that you have recorded unknown calibration signal.

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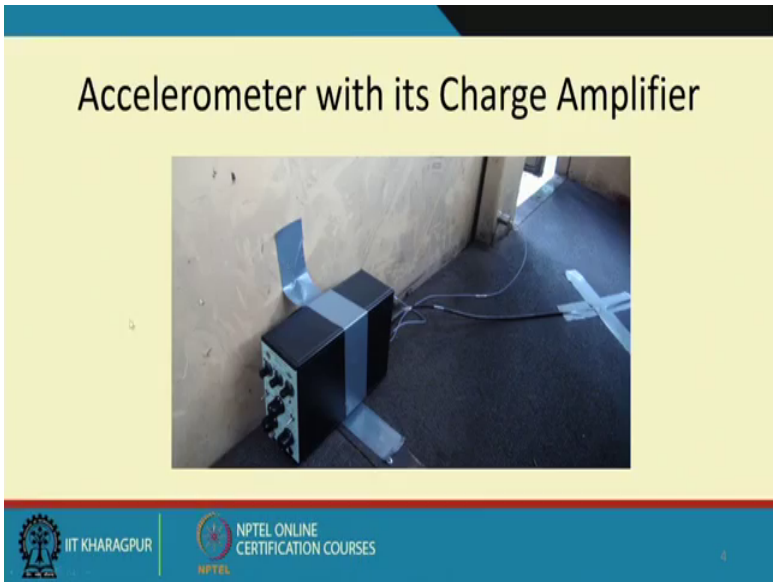

Now, this is a view of the charge amplifier used for the accelerometer and you can see how this duct tapes come handy to anchor it there are temporary anchoring, because I do not want to; obviously, permanently mount these and then you can see the accelerometer mounted in the door column of the cab and these cables are always strapped down.

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So, that they do not move around and same is for the microphone you know microphone is suspended from the ceiling ok.

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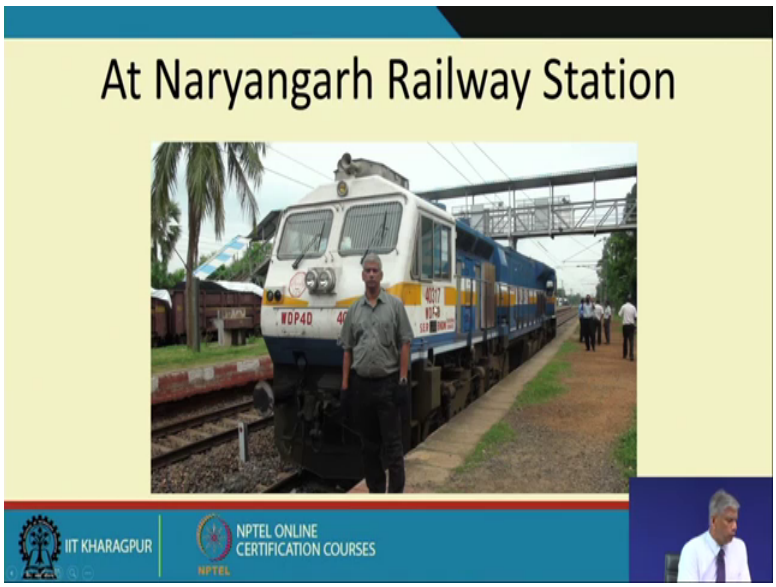

And then all these cables go up to the data recorder this is the same locomotive 40317 which was there in the workshop we ran it from Kharagpur railway station to Naryangarh its closed about, 30 kilometers either way. So, we went up thirty kilometers down the track and then 30 kilometers back to our Kharagpur railway workshop, wherein I had the crew cab the crews to help me ok.

They drove the locomotive, but I was there doing all the recordings incidentally these locomotives.

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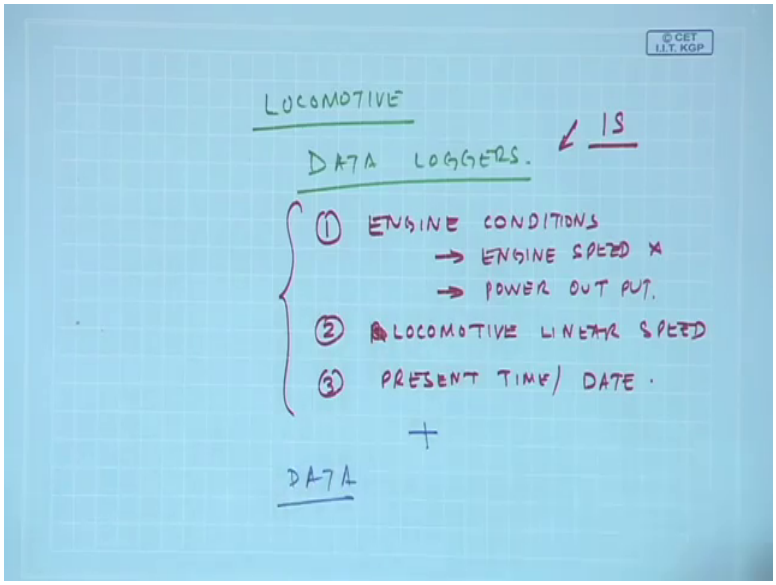

Now, also have data loggers wherein as soon as I start the engine it will keep a log of the engine conditions by mean what is the engine speed and the power output ok. The reason this power output is very easily measured and because these diesel locomotives actually have an electric serious traction motor.

So, they measure the voltage and current and then they can estimate the power, but this engine speed is very important and most important is the vehicle speed or the locomotive linear speed along with the present time and date stamp ok. And they recorded in every 1 second, every once again this information is there in a data logger and once you have done the journey you can hook up to the data logger and pull out all this data and this helps both in monitoring the health of the locomotive doing any accident analysis checking out the drivers profile with the driver ride riding driving it correctly and so on.

So, this helps. So, to this we what we did is we interfaced our data ok.

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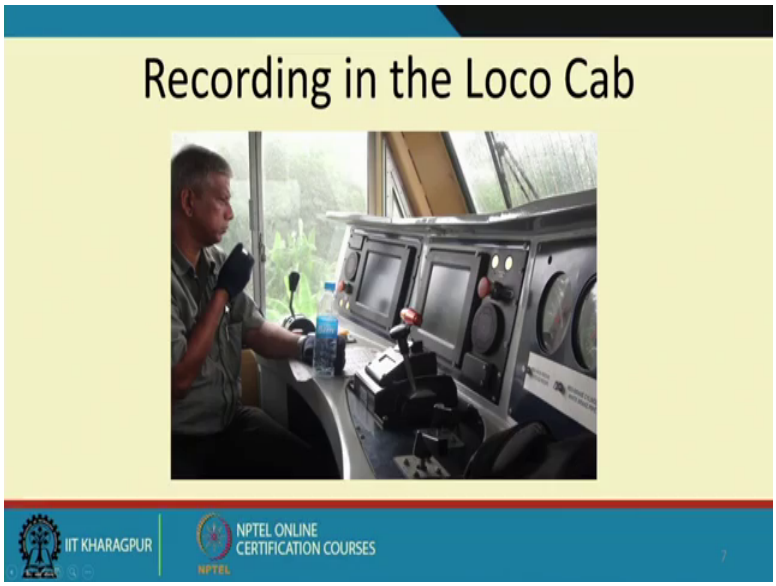

So, this is my cell phone on the drivers loco where in this queue, I give in to the data recording as it looking at the engine speed what is the speed what conditions and that day it was a rainy morning in the July ok.

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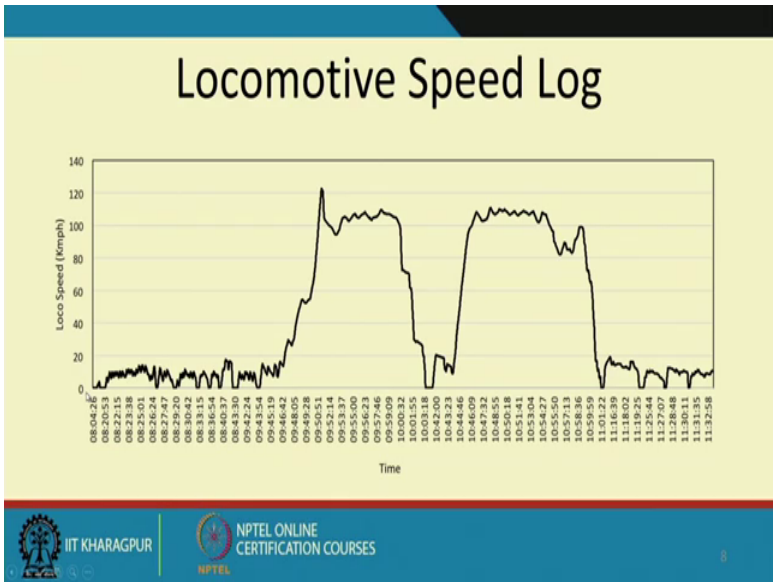

And you see this is the local speed in kilometers per hour and this we pulled out of the data logger and this is the actual time, we started somewhere from Kharagpur around 8 in the morning.

We are shunting till we got to go ahead to go on the tracks and then about 946 to about close to about 10 about you know somewhere around you know 15 to 20 minutes either way ok. And then we stopped for a while if you can see here 10 or 3 and 10 42 we stopped the engine and because we have to turn around in a different cab ok.

Because there is a cab one cab to one while going forward in one direction and we pull it back from the other direction. So, we can see momentarily there was an increase in the vehicle speed because you know the driver sped up and then of course, we reached up to 120 kilometers per hour in the south stretch and then we again came back to Kharagpur.

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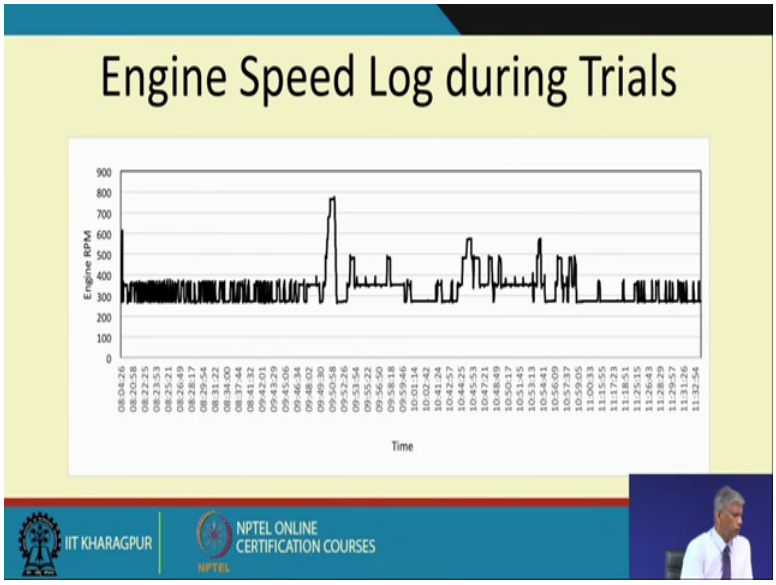

So, this is the real time log and as I was mentioning you this engine has a speed log during the trials again 10 40, 10 41. So, this is the engine rpm.

So, engine was highly no engine can go up till about 800 900 rpm and its the diesel engine. So, we were there was hardly any load ok. So, the engine did not rev up because there is an empty loco and that instance where the speed up suddenly it has gone up a notch and these engines have it nicely we can adjust the notice and it is the engine speed and again there was a lull because we stayed from ten to ten forty one here and then we came back to Kharagpur.

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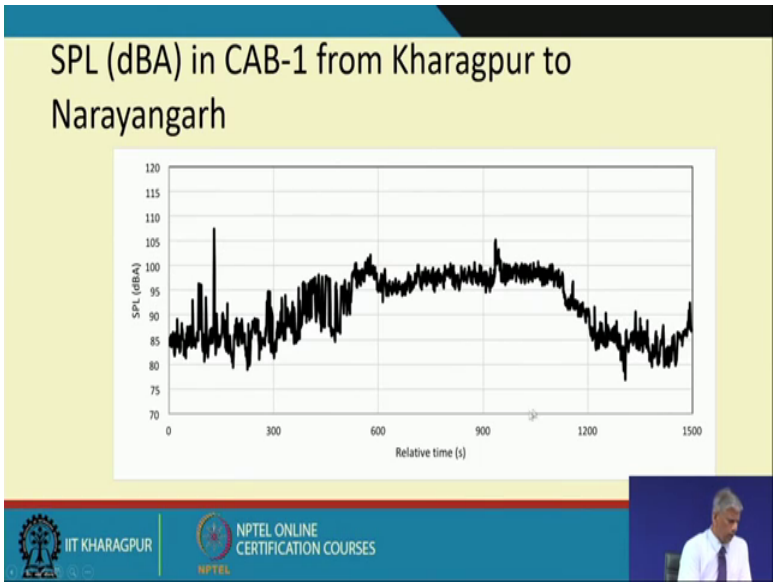

So, engine speed was not much divided from 200 300 rpm and this is the relative time you know about 1500 seconds and that will burn down to how much about 25 minutes or. So, and this is the SPL in cab 1 while going from Kharagpur to Narayangarh the overall s sound pressure level in dBA scale is what we have measured in the cab 1. And you see as soon as you run up these are these are certain high levels because when you leave the character station, there is a lot of track changing which occurs and the locomotive moves from one track to another.

You hit the gaps in the tracks and then once you are in the smooth track this is the overall level about 95 to 100 decibel is the noise level ok. When you are running even at speeds of if you see average speed is about 100 kilometers per hour ok. So, this is the cabinet level of course, you know we need to correlate again to the track roughness and the noise and vibration level.

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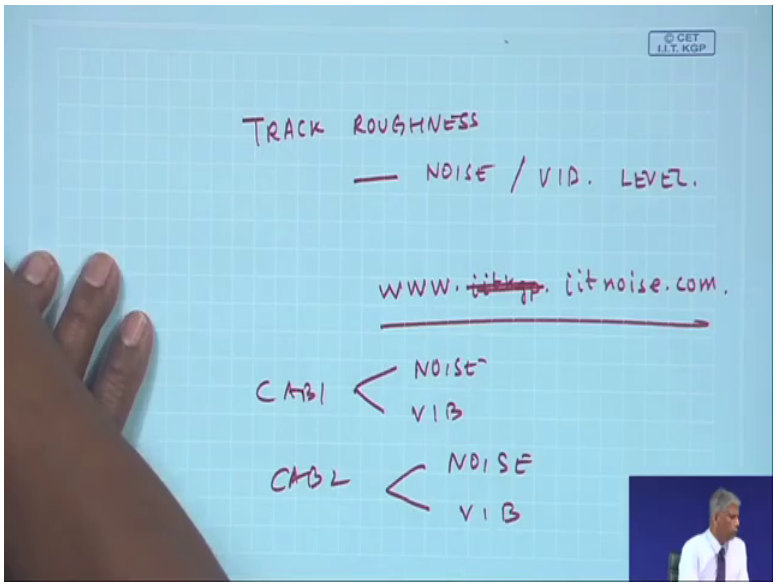

This being a public forum I cannot discuss all the results here, but those who are interested can contact me through my website and then I can be glad to share more information on this.

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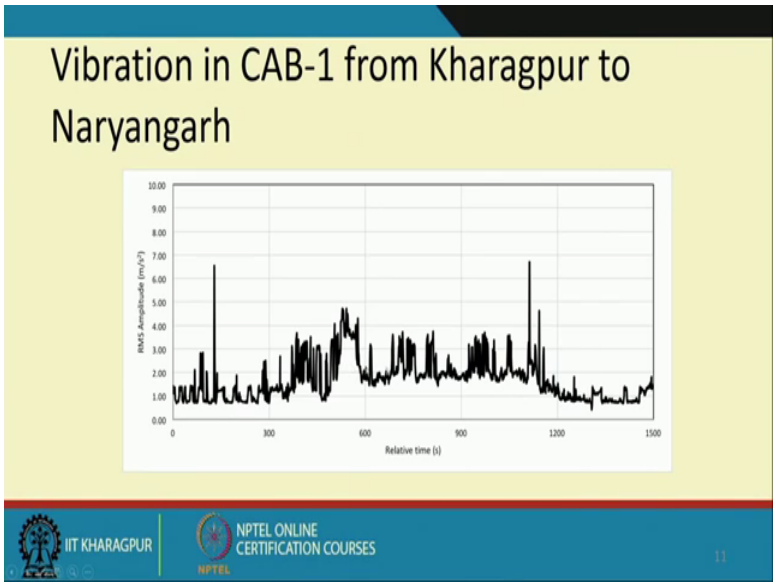

And then if you look at the vibration level from 0 to 10 meters per second square. So, when the you are running comfortably these levels are on the floor of the cab about, 2 to 3 meters per second square ok.

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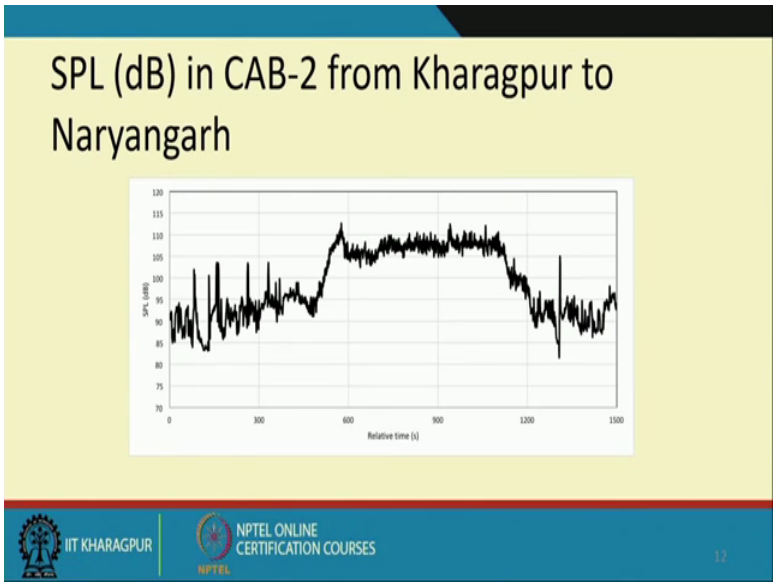

And then a similar thing happened in cab 2 there is another end because we instrumented 4 cab 2 cabs cab 1 and cap 2. So, cab 1 noise and vibration cab 2 noise and vibration. So, in one way so, there is this data again and a similar level this is the SPL from and then the vibration level.

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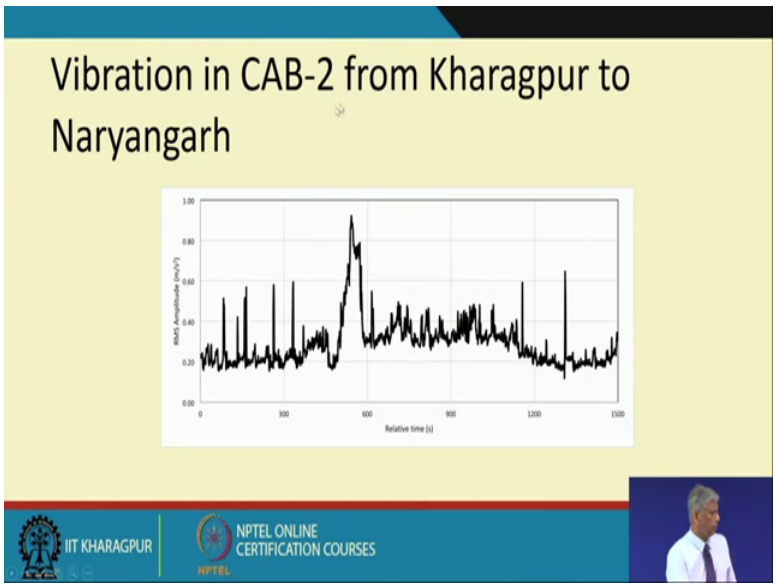

So certain instances occur where it is suddenly gone up.

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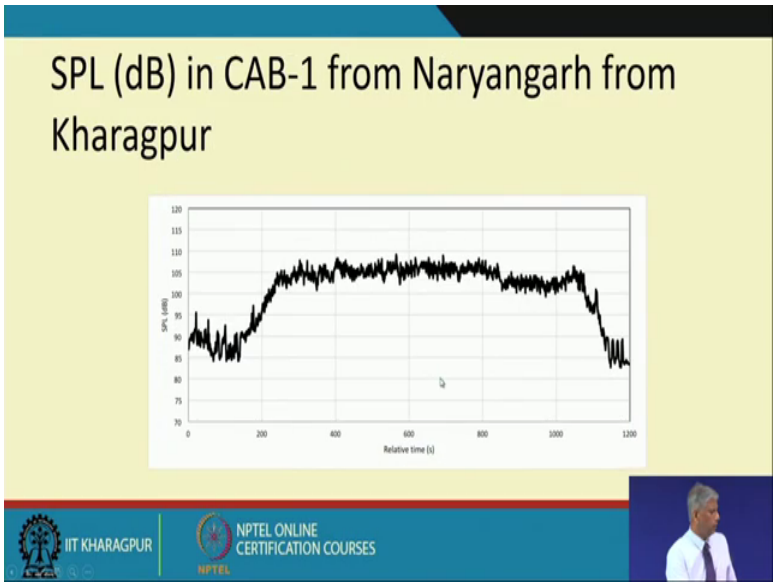

So, you get and then this is the on the return path cab 1 and then the vibration path.

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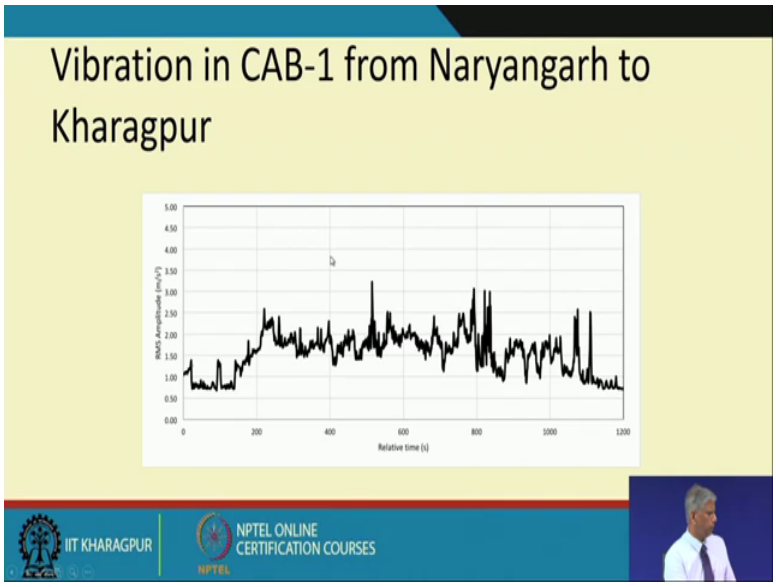

So, what I need to say is some of these data as recorded can be analyzed and then we can interpret many things about the levels as per the ISP standards are the sound levels as per the human comfort of the crew and what improvements needs to do visa v what is the track conditions. So, all this can be done and these can be instrumented permanently also in the locomotive and so on ok.

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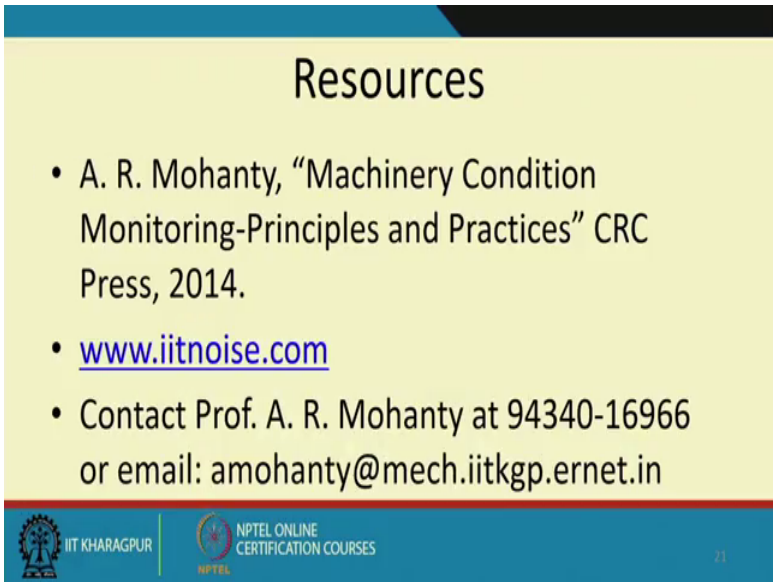

So, just this give you an overview of how in a practical situation you can do noise and noise measurements for monitoring the condition of an equipment ok.

Thank you.