NOISE CONTROL IN MECHANICAL SYSTEMS

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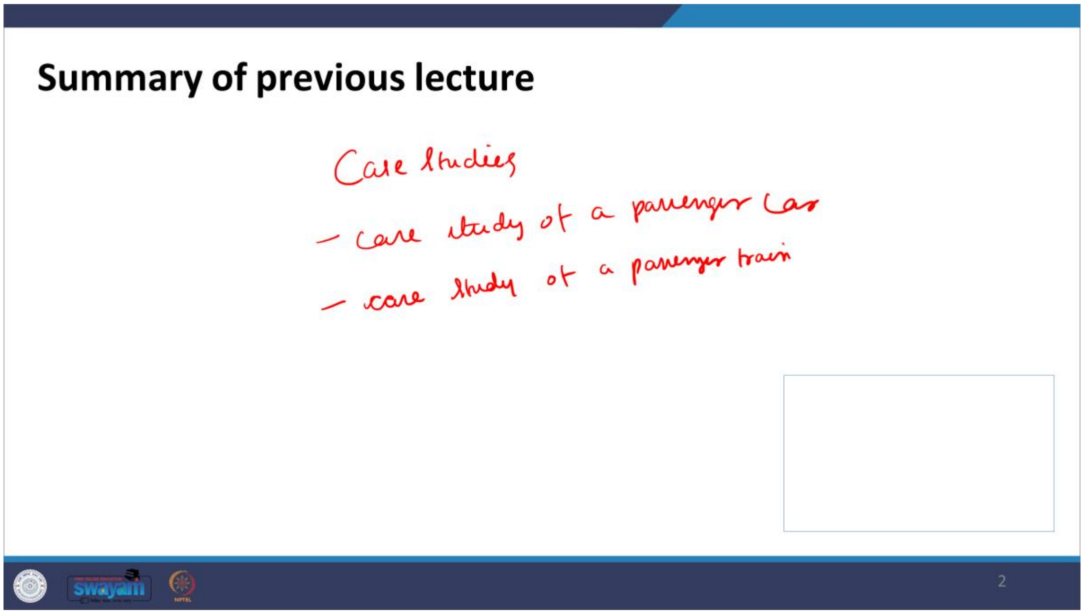
Week: 12

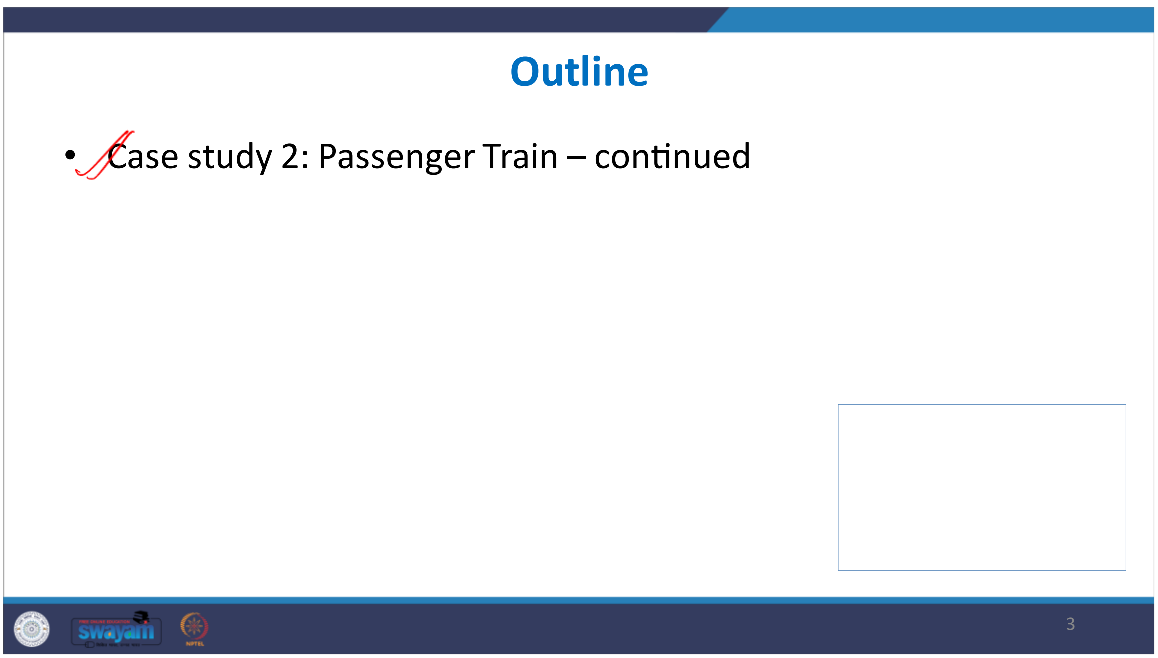
Lecture: 58

Lecture 58: Case Studies of Noise in Mechanical Systems 3

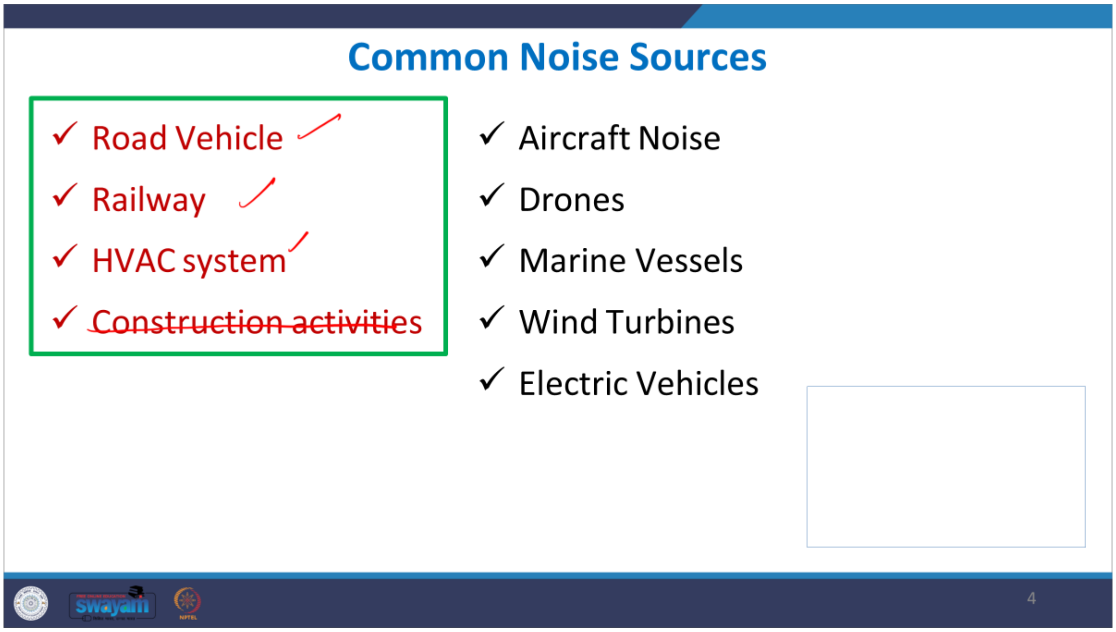
Hello and welcome to this course on noise control in mechanical systems with myself Professor Sneha Singh from IIT Roorkee. So, we have been discussing about some case studies on noise control in mechanical systems which is the last module of this course and we have done the case study of a passenger car and we have begun and discussed done a case study of a passenger train.



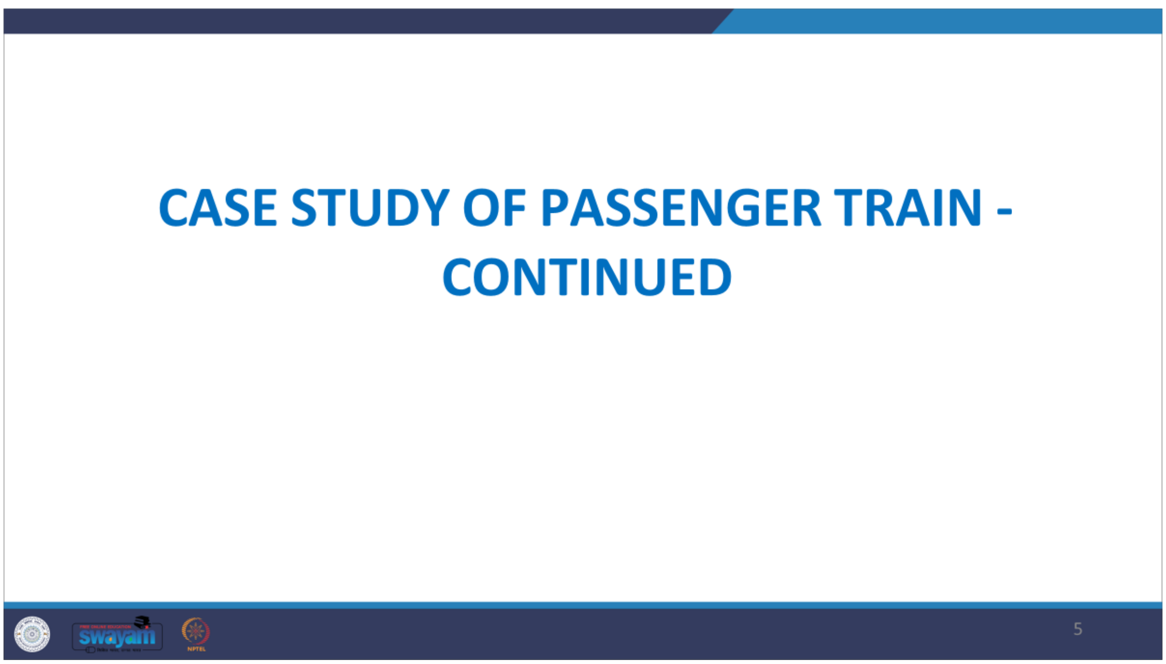
So, we stopped you know midway in the case study of a passenger train and which is what we will continue further in this particular lecture ok.



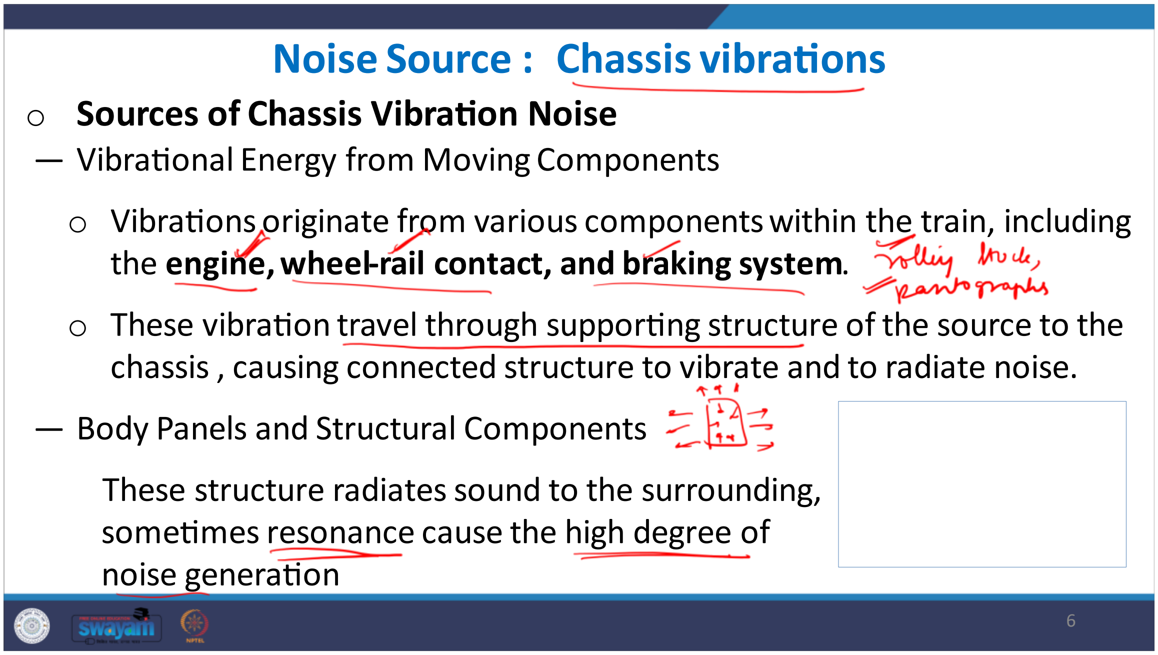
So, common noise sources are these and one by one we will discuss about a road vehicle the railway and the HVAC this is something which we will not discuss.



And so let us, you know, continue the case study of passenger train.



So, we have already seen the various sources of noise in a passenger train. First of all, it is the engine noise. Then we had the aerodynamic noise.

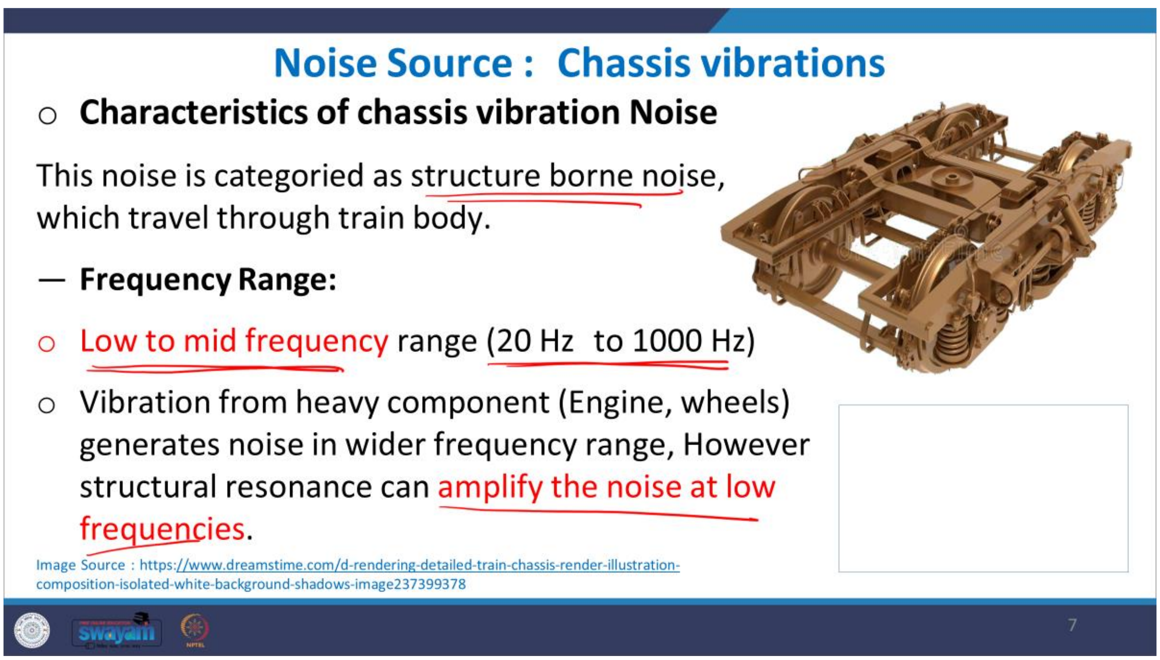


And also now we'll discuss about. So, we had the engine noise, the wheel rail interaction noise is also very important and after the wheel rail interaction noise, we have this aerodynamic noise as well. So, today we will discuss in detail about the noise due to chassis vibrations. So, obviously, the source of the chases vibration noise is the vibration of the chases of the train. Okay. So, this vibrational energy from the various moving components within the train, it could be either from the moving components of the engine, the rolling stock, the wheel rail contact, the braking system and various other components

That is operating during the train run, and because of its operation, the components are vibrating. This vibration then slowly progresses in a structure-borne way and passes into the main frame or the chassis of the train. So, they are mainly structure-borne noises that travel through the supporting structures of the source to the chassis, causing various connected structures to vibrate and radiate noise. Even the body panels and the structural components also start radiating noise. We have seen how, in the machinery, when we have large panels beyond the coincidence frequency, whenever they are excited, the structural vibration will then be converted into longitudinal waves, okay? So, these panels become a major noise source beyond the coincidence frequency, and they start radiating noise into the surrounding air. Then, this noise can reach

Not only the surrounding air—which is, you know, if this is your train—the noise can reach into the outside atmosphere and the nearby people along the railway track. It can also transmit into the cabin and disturb the passengers and the drivers. And, you know, many times when the vibrations due to the engine component or the rolling stock—the vibrations due to the wheel-rail contact, the braking system, or the pantographs—okay, the vibrations of various of these components—if they have a frequency that matches with the frequency of the frame of the train—then the frame will be set into resonance. So, when the vibrations—the frequency of vibrations of these components—match with the frequency of the structure,

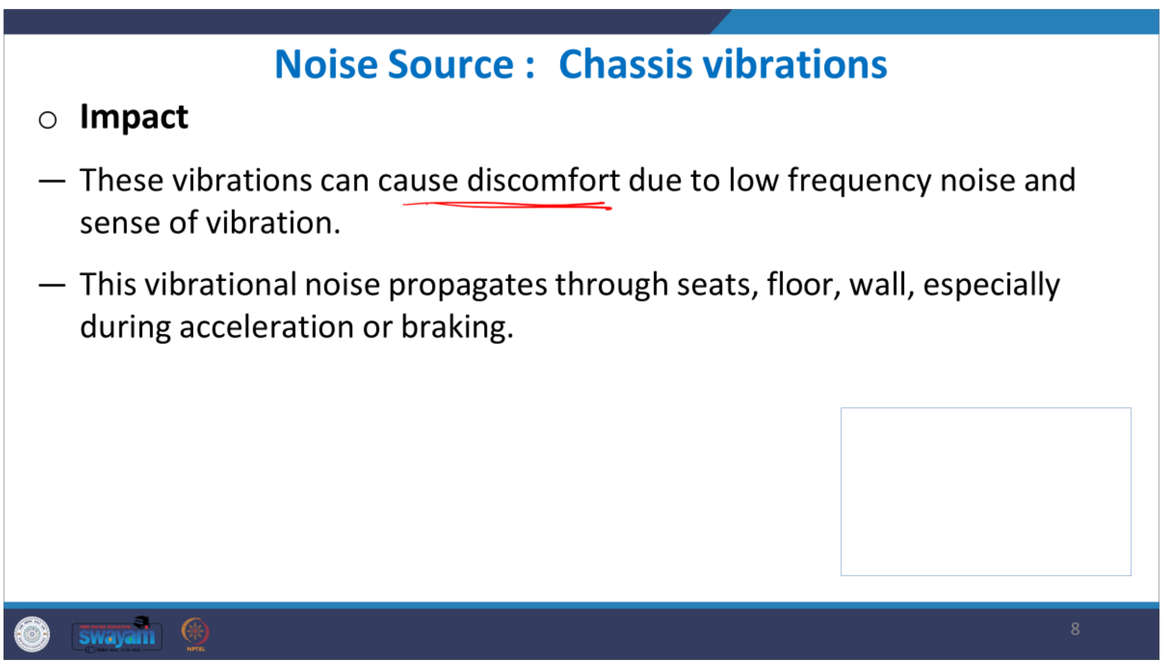
here, the chassis acts as the pathway for vibration transmission. So, when the vibration corresponds to the chassis's natural frequency, then resonance is set, and in that case, the vibrations of the chassis amplify further, hence producing a very large level of noise. What are the characteristics of this chassis vibration noise? The noise is characterized as structure-borne noise, obviously, because it is the noise that is transmitted in the form of vibrations in the chassis. So, here, the chassis itself is not the source.



The source originally was these various components of the engines, all these various components of the train. Then, because they were working, they started vibrating, and this vibration transmits and flows into the entire train by passing through the chassis. So, it is a structure-borne noise. It travels throughout the train body, and as already discussed in the previous module, when we were discussing the differences between air-borne noise and structure-borne noise. Typically, the structure-borne noise has more low-frequency content, whereas air-borne can be low to high—all audible frequency ranges are covered in air-borne noise.

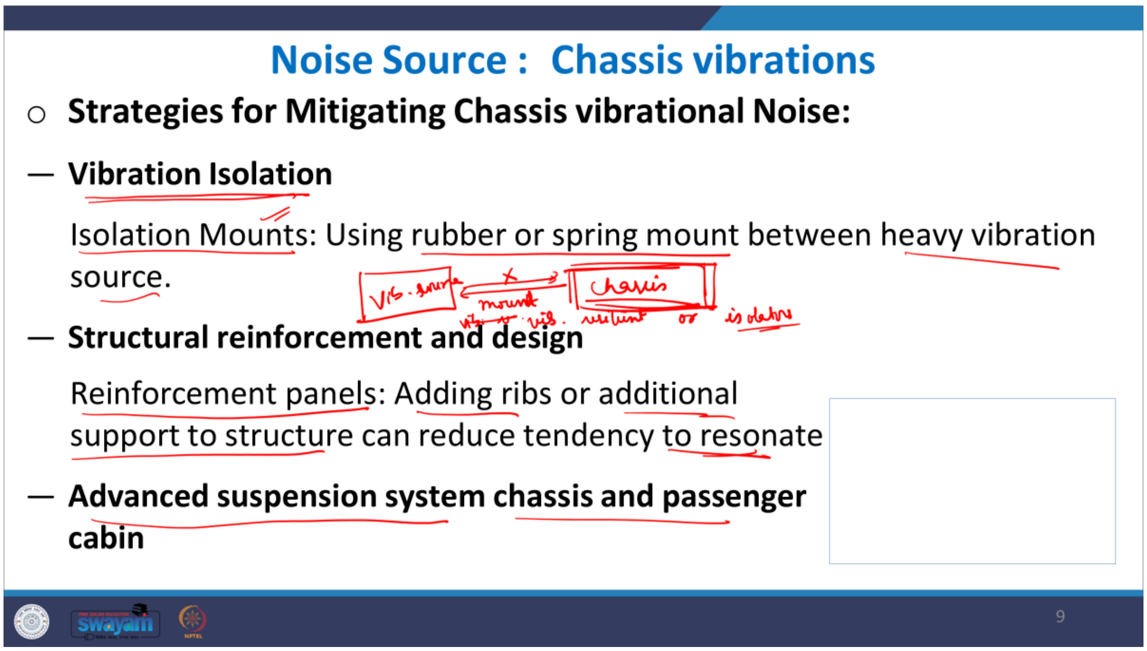
So, because most mechanical structures, due to their dimensions, have natural frequencies always in the lower range. So, whenever sound passes through in the form of vibrations through these structures, the lower frequencies are amplified, and the higher frequencies are not. So, the chassis's vibration, being structure-borne, has low to mid-frequency content within this typical range of 20 to 1000 Hz. The vibration from heavy components, such as the engine, the wheels, etc., generates noise in a very wide frequency range. But because the structural resonance corresponds to lower ranges, the noises at lower frequencies get amplified, so the overall chassis vibration has higher low to mid-frequency content.

What is the impact of this? Obviously, these vibrations—first of all, this noise propagates through the chassis or the frame in the form of vibrations, and whenever the vibrations exceed the coincidence frequency, they radiate into the air. So, here the impact is twofold. Obviously, the vibrations that are there will cause discomfort due to the low-frequency content in that vibration and just the sense of vibrations.



Obviously, if you are sitting in not a very well designed or an old model train and you see you know the vibrate when you touch the chassis or when you touch the just the body of the train while it is moving you can feel the vibrations. So, whenever you touch it you feel the vibrations and it is not a pleasant feeling. The long term exposure to these vibrations in our body can have negative effect. It can cause fatigue. It can cause various kind of sensory-motory disorders as well.

So, it is not a very pleasant effect. It causes discomfort to the passengers the more vibrations there are. And once these vibrations propagate as noise, it causes discomfort through the noise level as well. So, what are the strategies for mitigating these chassis vibrational noise? First of all, obviously, because it is a structure borne noise, which is passing as in the form of vibrations.

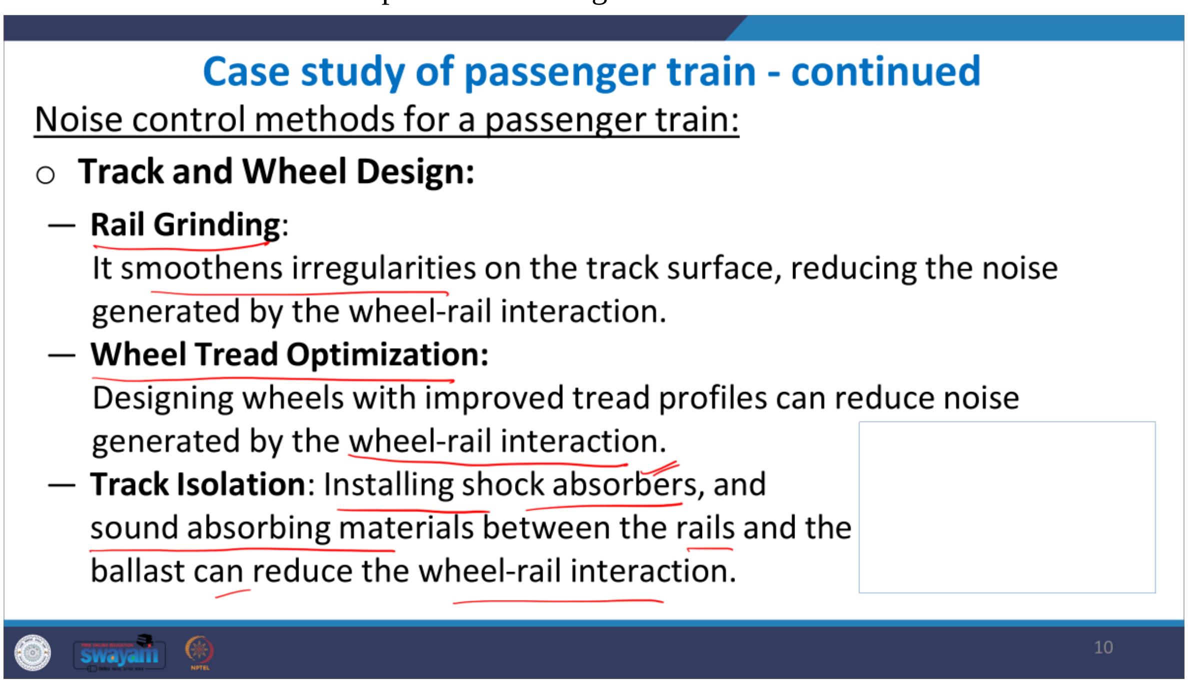


So, you would like to attenuate this. So, you can do it using the standard techniques of vibration isolation. So, isolation mounts could be there, which means that all these sources such as, you know, the rolling stock, the pantograph, the engine, the wheel rail contacting, the braking system, all these original sources, they should be connected to the chassis via some mounting. Okay, so the mounts or the systems are

or the structures that are connecting these sources to the chassis they should be more vibration resilient so that they can stop the vibration to pass into the chassis so isolation mounts such as you know the rubber or the spring mount between the heavy vibration source so whatever is your vibration source be it the engine the rolling stock etc and then this is your chassis system so between them the mounting system that is there, which is used to mount this source to the chassis, it has to be either, you know, vibration resilient. It should be able to stop the vibrations. It should be more like vibration resilient mounting or use of isolators in between in these structures so that the vibration does not pass through from the source to the chassis. Then the structural reinforcement and design can be done for the chassis itself.

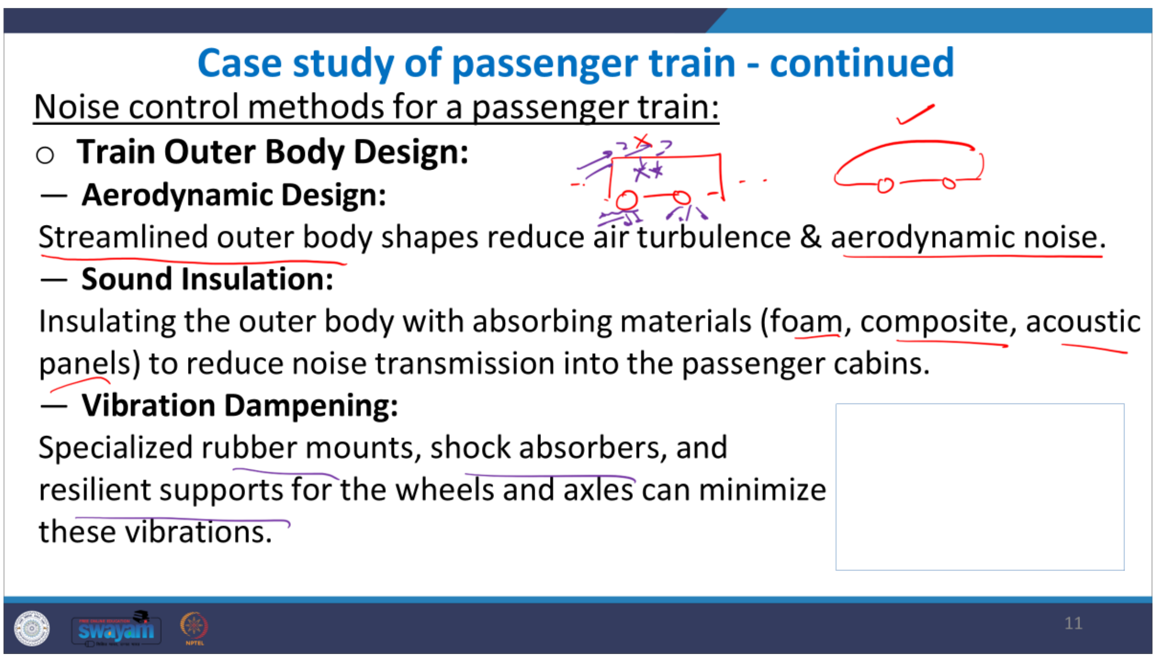
So the chassis could have more better design of the chassis which means that you can have some reinforcement panels such as you know adding the ribs or the additional support to the structure it can reduce the tendency to resonate. So that even if the vibrations are passing, so the first thing is to stop the vibrations from passing from the source to the chassis. You can do it using isolation mounts or using more vibration resilient mounting. And the other could be the chassis itself could be made sturdy enough so that even whatever vibrations that are passing into it, they are not easily set into resonance. Then various kind of advanced suspension systems can be found between the chassis and the passenger cabin.

The noise control methods for a passenger train. So, so far we discussed source by source what are the individual you know noise mitigation strategies that can be used. Now, let us see a summary of the overall passenger train and the noise control methods which are usually implemented in this. So, first of all because at mid or higher speeds the most dominant noise is the wheel rail interaction noise. It could be either through the rolling noise or the road or the rail inputs and rail irregularities and



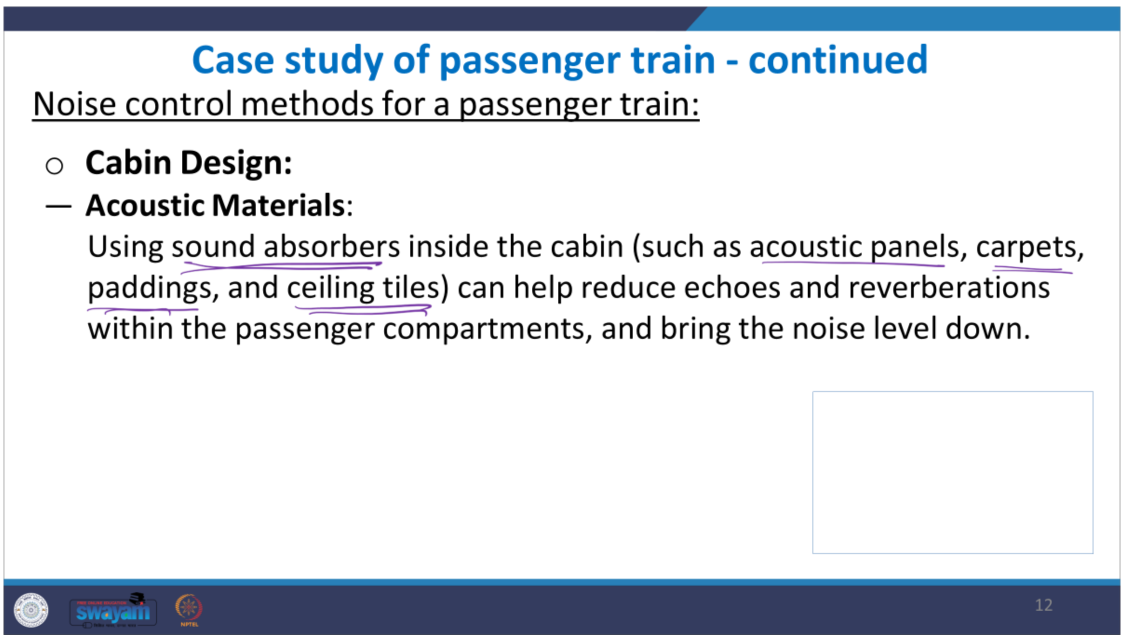
So, whatever is so the track and the wheel needs to be designed properly to control this very dominant noise. So, rail grinding will smoothen out the irregularities on the track surface it will reduce the noise generated by the wheel rail interaction. Then the wheel tread optimization can be done once again in order to reduce the noise due to the wheel rail interaction. So you can have smoother tracks and a smoother wheel tread design so that when the two surfaces they are coming into contact the frictional noise can be reduced the rolling noise can be reduced. then the track isolation can be done which means that wherever you know the two tracks are being joined together they are suddenly in these joints or discontinuities we have a heavy vibration.

So what you can do is install the shock absorbers at these joints or various kind of sound absorbing materials between the rails and the ballast and all of this is going to once again reduce the impact due to the wheel rail interaction. Then to control the aerodynamic noise obviously the train outer body design plays an important role. So, just like track and wheel design is used to reduce the various components of wheel rail interaction noise. If suppose the trains outer body is designed properly first of all the aerodynamic noise can be controlled.



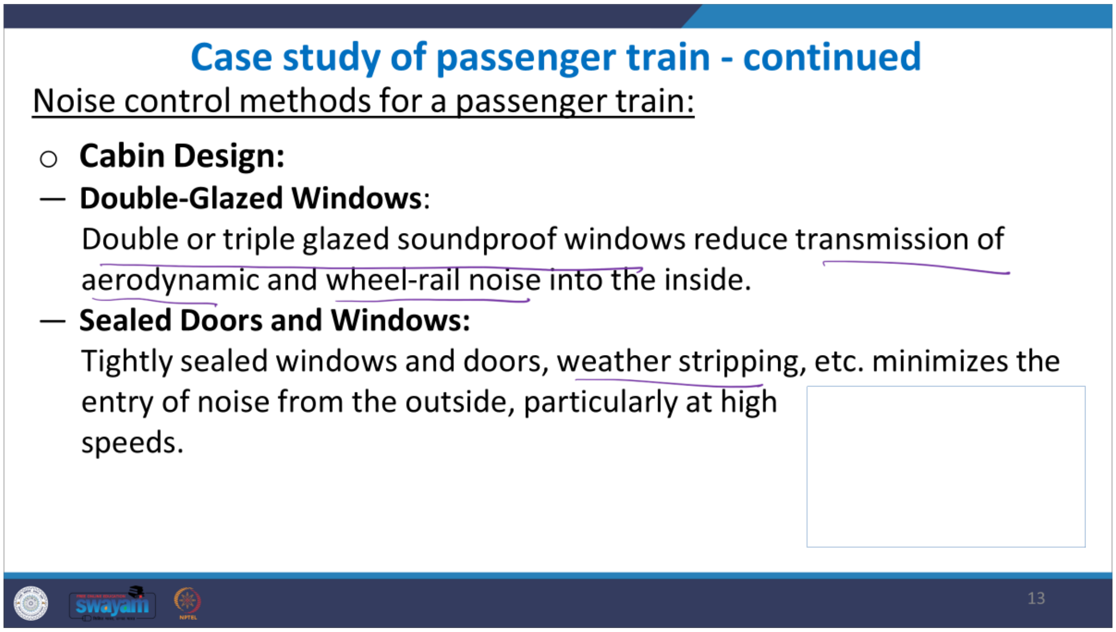
By using more streamlined design, so instead of having a train engine like this, we can have more streamlined design like this, which can, so where the, there is no abrupt change in the airflow over the train's body, okay. It is not offering any abrupt changes to the airflow and turbulence is being reduced and the aerodynamic noise is coming down. Then sound insulation obviously insulating the outer body with absorbing materials such as foam, the composites, the acoustic panels etc. All of this is going to reduce the transmission of the aerodynamic noise and the wheel rail interaction noise inside the passenger cabin. So whatever noise is being generated here, so let us say this is the noise generated by the wheel rail interaction noise.

The noise generated by the aerodynamics should be stopped from going inside the passenger cabin if you install proper sound insulation on the outer body. Then, vibration-dampening specialized rubber mounts could be used—shock absorbers, resilient supports—all of this will minimize the vibrations of the chassis and other components. Then, cabin design—even inside the cabin, in most modern trains, what you find is that there is a lot of carpeting, a lot of padding, and a lot of absorbers being used. So, you have the hard surfaces. So, what we do is, because the train cabin becomes a closed indoor space.



So, it has a reflective or reverberant environment. The acoustic field is reverberant in nature. So, in a reverberant field, the noise gets amplified because of the multiple paths it covers and the reflections that happen because of it. So, we can reduce—we can bring down the noise level in this reverberant space of a cabin by reducing the reflections, and for that, we can have many kinds of sound absorbers present inside the cabin. It could be in the form of acoustic panels, carpeting, various kinds of padded seats, etc.

And the ceiling tiles—all of this—so that the inside reverberant space is such that it has a lot of absorbing surfaces and the reflections are minimized. Then, the cabin design—just like in the cabin design, we can have various kinds of absorptive surfaces inside, we can also have double-glazed windows. So, these double- or triple-glazed soundproofing



windows further prevent the transmission of the outside aerodynamic and wheel-rail noise from entering the cabin. Then, sealed doors and windows—all these, you know, windows and doors should be tightly sealed, and weather stripping could be done so that there is no leakage. Even if you install a lot of insulation, even if you have a good insulating cabin or a lot of absorbing materials, but if there are a lot of air gaps, there would be leakage. Even if you have a very good cabin design, but because of a lot of these leakages. Or the lot of air gaps present, the noise is going to come inside; it is not going to be very effective—the levels will still be very high.

So, proper sealing could be done, and these acoustic leakages could be minimized. Then, there are various advanced technologies that are also emerging. So, as already mentioned, the most dominant noise source is the wheel-rail interaction noise, which could be due to the rolling phenomenon, the friction between the wheel and the rail, and the vibrational inputs from the rail transferring into the wheel and axle system. So, one solution would be to adopt a different technology to propel the train, thereby avoiding wheel-rail interaction noise as much as possible. One such technology could be Maglev, which is emerging.

Case study of passenger train - continued

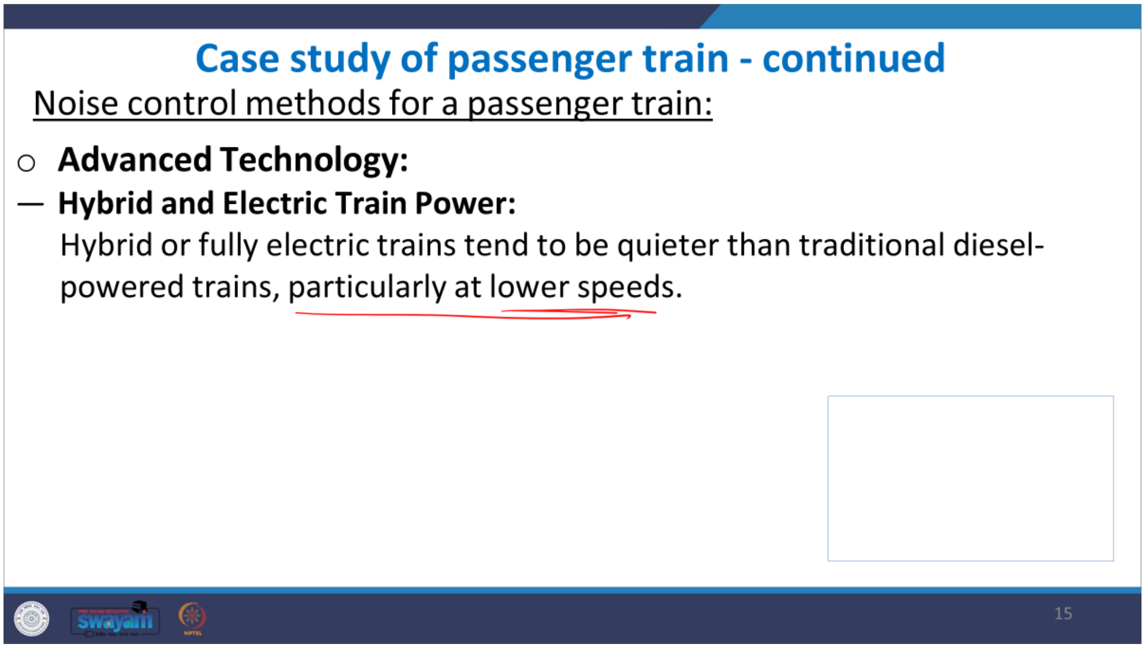
Noise control methods for a passenger train:

- **Advanced Technology:**
  - **Maglev Technology:** In high-speed trains, magnetic levitation (maglev) trains, which float above the tracks, are inherently quieter than conventional trains because they avoid friction between wheels and rails.

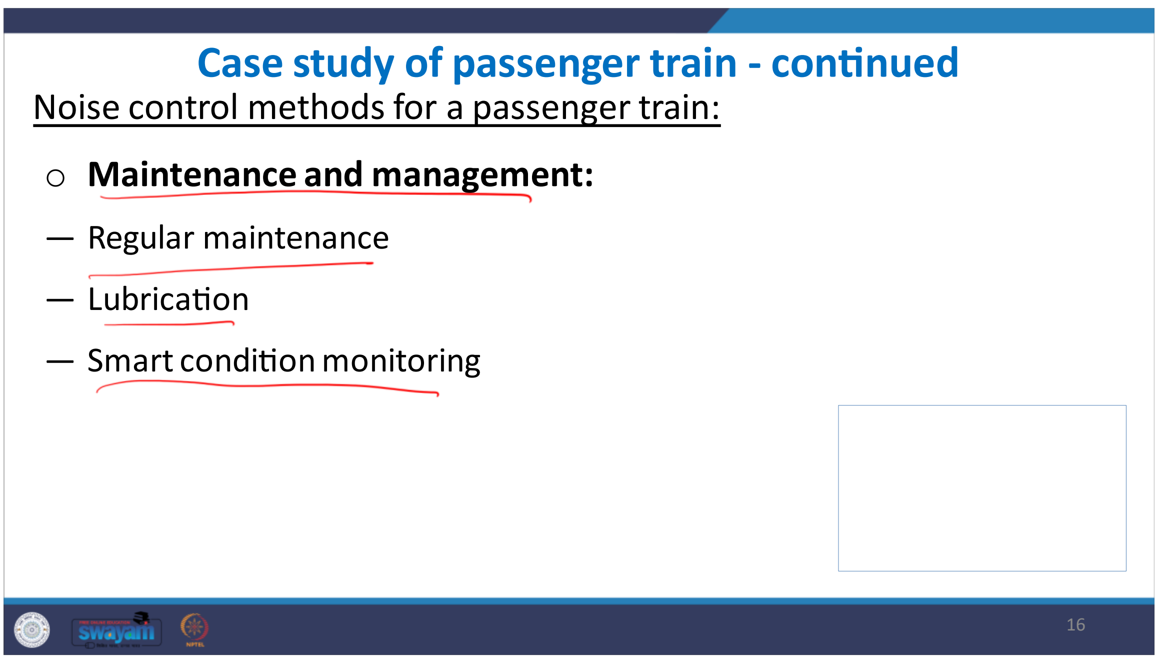
Image source: Google Images

This is a new form of train propulsion technology where the train moves using electromagnetic induction. So, many of the tracks have electromagnets. Due to the attraction and repulsion between the train's electromagnets and the track's electromagnets, the train moves forward. So, what happens here is that the train is never in contact with the track. There are no wheels on the train and no traditional railway tracks.

So, this is a typical schematic where there is no direct contact between the train and the track. The train is slightly suspended or levitating, and because of this, frictional noises and rolling noises can be avoided. Because of the new propulsion technology, other advanced technologies such as hybrid and electric train power would help reduce engine noise, as diesel engines are much noisier in operation. Replacing them with quieter electrically powered trains would significantly lower noise levels, especially at low speeds. At low speeds, engine noise is dominant, but as speed increases, wheel-rail interaction noise becomes dominant.



For all these methods, maintenance and management are very important.



At the end of the day, it is a mechanical system, and the rule of thumb is that when a system—any kind of mechanical system—is operating, if you can reduce the amount of resistance to its smooth functioning, you are going to bring down the noise level. So, basically, the machine should be in proper condition and should be able to function smoothly. The more it is further away from the ideal design and smooth functioning, and the more faults there are in the machine, the higher the noise level will be. So, regular maintenance and management are key for almost every mechanical system.

So even for a passenger train, maintenance and management are very important. Smart condition monitoring can be implemented where you can make use of deep learning techniques or other kinds of artificial intelligence techniques and you can monitor the vibration levels or the electrical signals on board. So, on board, you can have sensors to collect the vibrational data, the electrical data, and the acoustics data while the train is running. Based on the signature profile, you can predict whether a part is working well or has failed, and which component may need replacement. This will not only ensure that the train works smoothly but also that the noise levels remain in check. Regular maintenance and lubrication among the various contacting surfaces are always important.

So, with this, I hope you enjoyed this lecture. Thank you for listening.