NOISE CONTROL IN MECHANICAL SYSTEMS

Prof. Sneha Singh

Department of Mechanical and Industrial Engineering

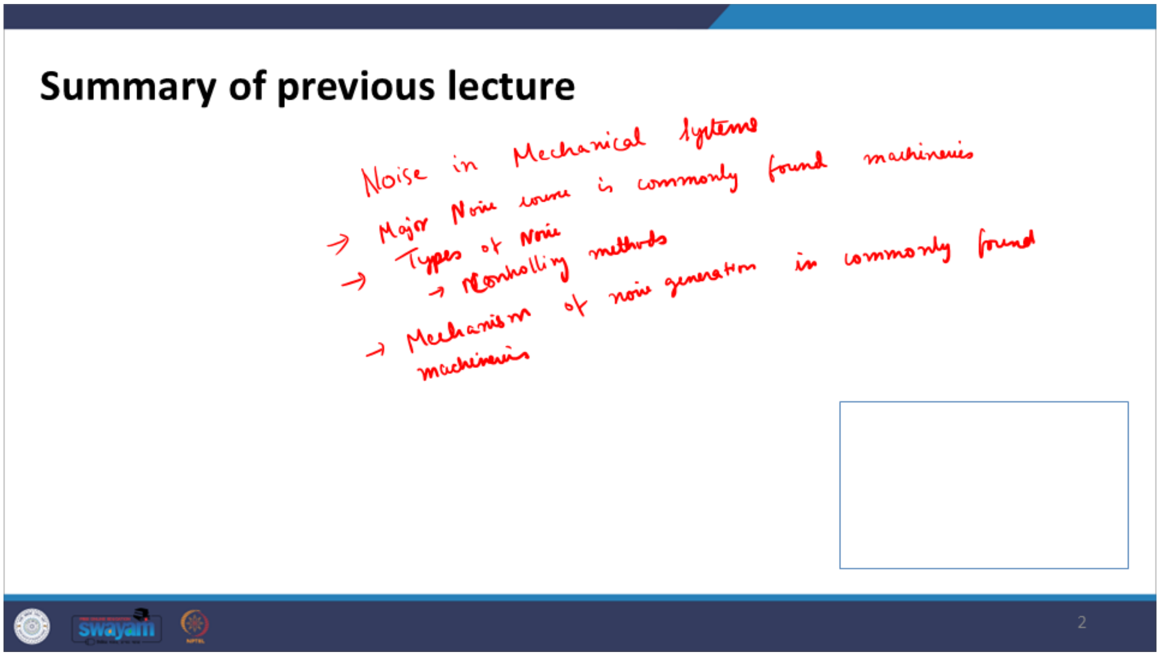
IIT Roorkee

Week:12

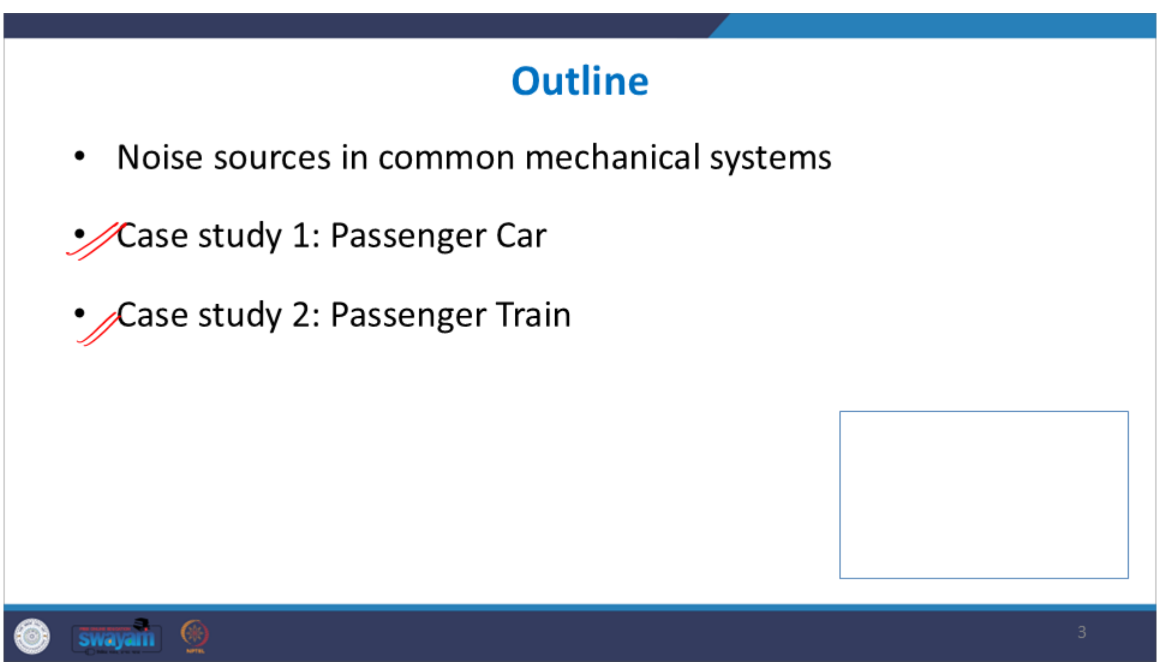
Lecture:056

Lecture 056: Case Studies of Noise in Mechanical Systems 1

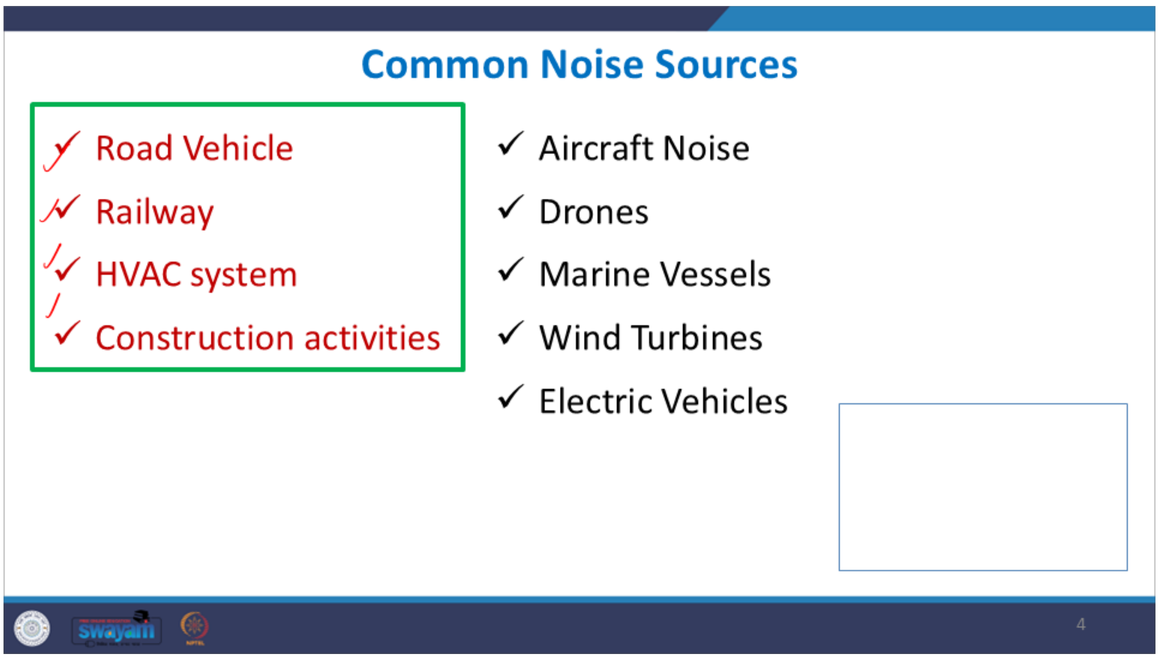
Hello and welcome back to this lecture course on noise control in mechanical systems with myself, Professor Sneha Singh from IIT Roorkee. We just covered a module on noise in mechanical systems. We covered the major noise sources in the different types of common industrial machinery. Sources in some commonly found machinery. And then the types of noise typically present, like the structure-borne or the airborne noise, and what are the different means of controlling these types of noise—controlling methods that are typically applied in mechanical systems. And also, the mechanism through which the noise is typically generated in common machinery.



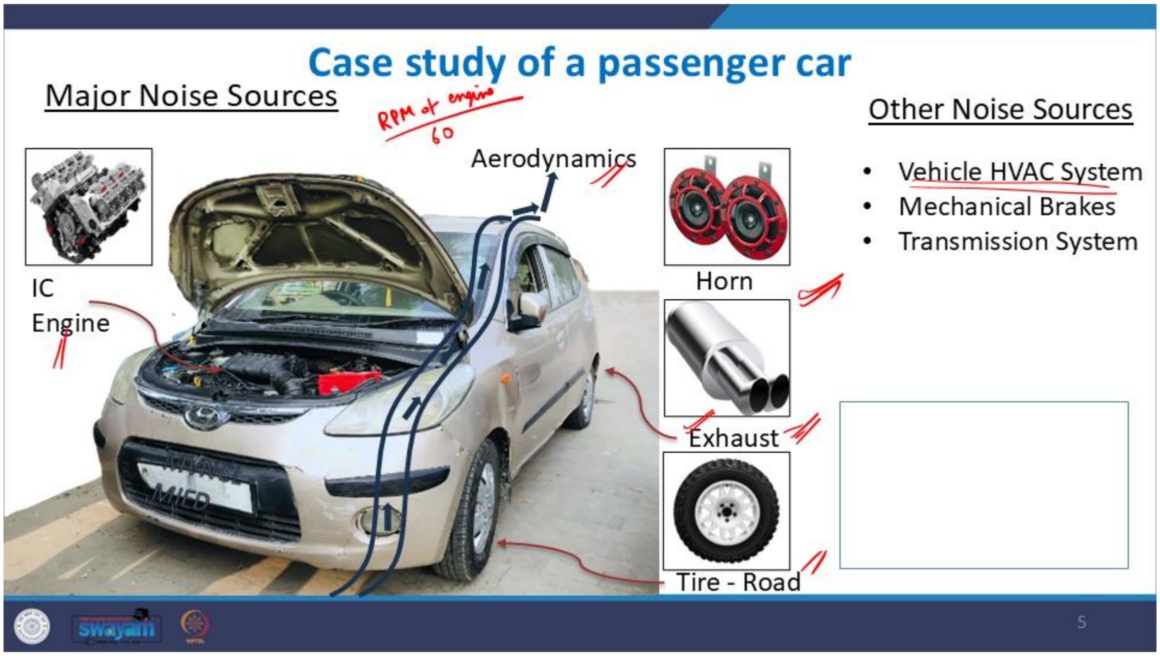
In the commonly found machinery. We know the previous lecture—the previous module—was to give you an overview of what happens in common mechanical systems or common machinery: how the noise is created, how this noise propagates, and what kind of spectral and temporal content we usually find in various mechanical systems parts and the various common mechanical machinery and subcomponents, and what could be the typical strategy to control these noises, depending on how they are created and how they propagate. You can devise the strategy for controlling this noise in commonly found machinery and mechanical systems. With this overview and with this generic knowledge about how noise comes in mechanical devices and how it can be controlled.



This is the last module of this lecture series, and in this module, we will do some case-by-case study. We will do the case study of some typical mechanical systems. We will analyze what the sources are, how they propagate, and what the typical measures applied to them are. case studies will be done to apply the knowledge gained in all the previous lectures—whatever knowledge has been gained till now in this particular course. Now it is time to apply them to some real-life mechanical systems and see how you can apply your knowledge and be able to better control the noise in such systems. Here the first case study would be a passenger car—a very common mechanical system—and a case study of how noise comes in the car and how it is controlled in a passenger car. And if time permits, we'll just introduce the second case study, which is the case study of a passenger train.



Let us see. A quick summary of these are the various common mechanical systems that create noise. You have road vehicles, railways, HVAC systems, some construction activities, wind turbines, vessels, drones, aircraft, electric vehicles, various kinds of I mean almost every mechanical machinery or mechanical system unfortunately is always a source of noise. For this kind of course let us consider some of the very common mechanical systems like road vehicles, railways, HVAC systems and the construction activities and one by one we will be taking up the case studies for these four types of mechanical systems. The very first case study is of a passenger car you can see. This is a passenger car. Now, what are the common methods or common kind of noise sources in this kind of passenger car?

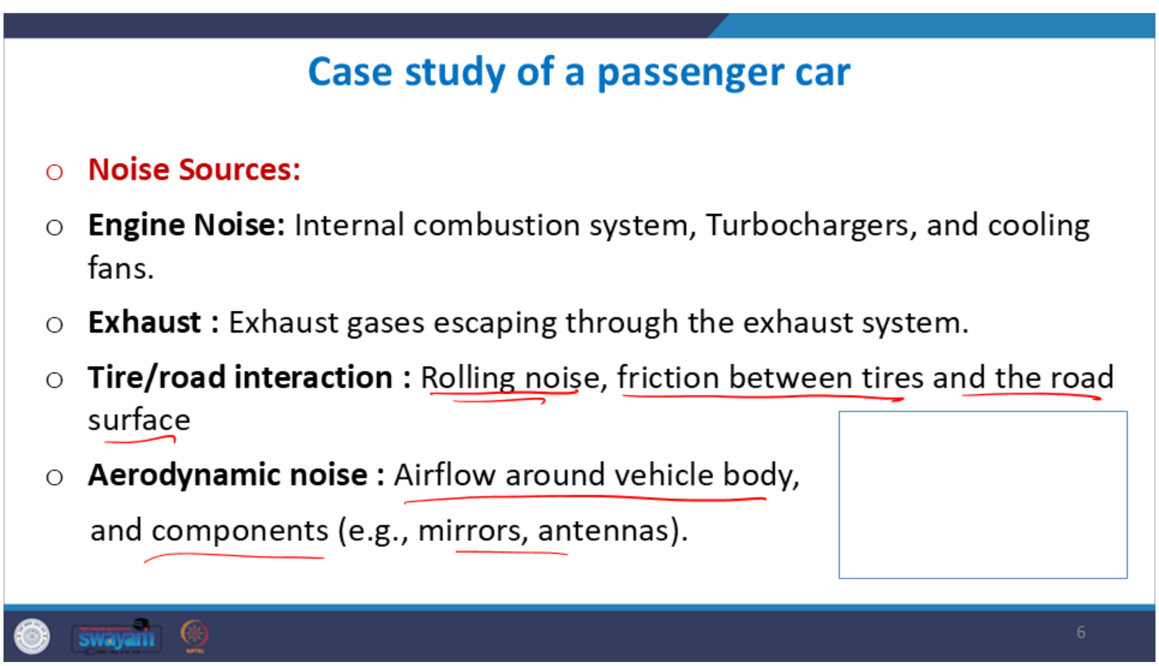


You can see that obviously, if you open the bonnet, you can see the engine that is operating. The internal combustion engine is a major noise source.

And usually, as we have seen before, the engine noise is kind of low frequency tone with higher harmonics. the noise has got peaks, which corresponds to the multiple the peaks they are same as the rotational frequency of the engine so whatever is the rpm of the engine based on that you can find out the frequency of the engine's operation which would be the rpm of the engine divided by 60 will give you the number of cycles per second and your sound waves will have the frequencies content having this fundamental frequency and its higher order harmonics typically the engine noise. Then you have other sources because it is a complex mechanical system and there are a lot of things inside a car.

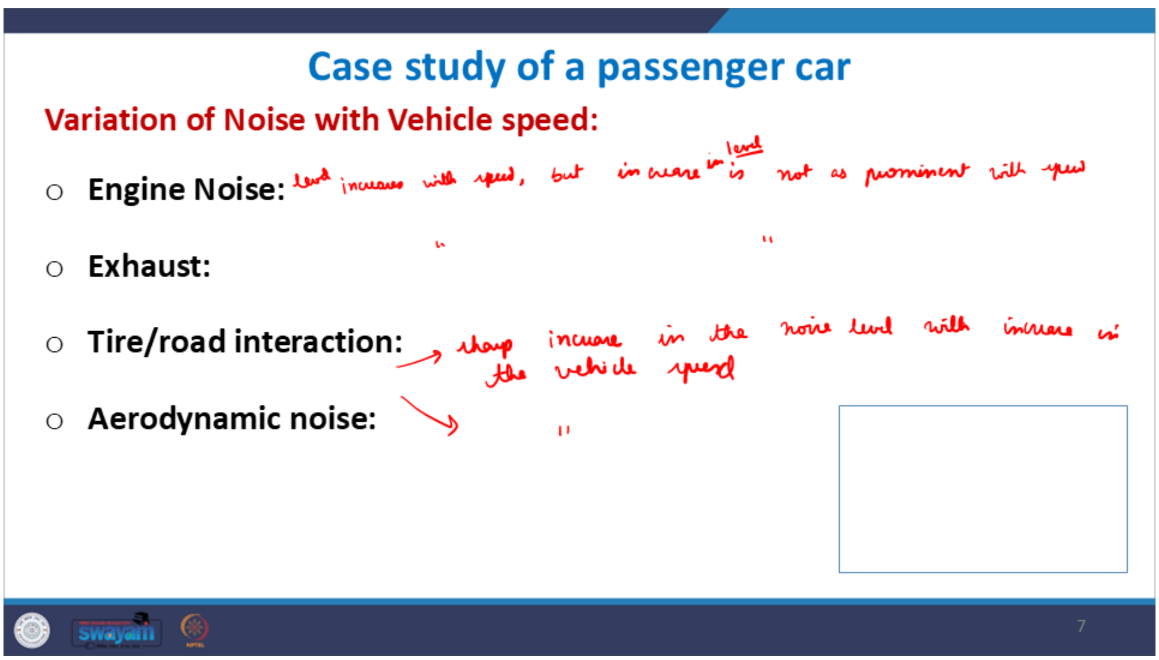
The other very dominant noise source is the tyre road interaction noise the tyre they are rolling over in this hard surface. and they create noise. If you have seen just an observation that suppose when you're driving in the road you hear more noise especially coming from the tire and when you're driving from a softer ground you hear less sound from the tire so obviously you can make a guess that the tire road noise must be dependent on the type of surfaces that are coming in contact in this case it is the rolling noise and the surfaces coming in contact are the tyre treads and the roadway on which the car is moving and that is creating your rolling noise then the engine is operating and the exhaust is being emitted from the back side from the tail pipe this is also a very common noise source and the content of it is very much similar to the engine noise there is like a very strong correlation between the engine noise and the exhaust noise because the exhaust is automatically being released in sync with the engine operation. In the combustion cycle the combustion is happening and the exhaust gases are then being released in the exhaust cycle of the engine so that is this noise is very much in sync with the IC engine noise then you have various internal components these days horns are becoming one of the major noise sources especially in the busy streets in the cities. People are just honking, and this is becoming a very common nuisance and a very common noise source. There is yet another noise source. If you see, for example, suppose you are driving on a passenger car and at a very high speed and you slightly open your windscreen or your window, the glass of your window down, you can see a lot of air passing and you can hear the noise of the air, the air blowing over the car's body. that is your aerodynamic noise it's the it's a noise created by the means of the air flowing over the car's body and the higher would be the speed of your car the higher you can the more noisier will this aerodynamic noise get by the observation you can see the slowly moving vehicle very slowly moving in a slow speed you don't hear that but, suppose you're going in a highway at the speed of more than 80 kilometers per hour and you just open your window glass for a little bit you will see the gush of air and the blowing of the wind that is creating a lot of noise.

Then there are some other sources as well. Vehicles have their HVAC systems, but these are more secondary sources. They are not as dominant as these noise sources, which are very common. The transmission system, the braking, the HVAC systems, even the embedded vehicle electronics these days and various other auxiliary components are also secondary sources of noise.



Already discussed in the engine noise you have majorly it is because of the internal combustion system the turbochargers are also used these days which are once again although the turbochargers are giving more power to the engine and they are making the car capable of driving in adverse conditions, but they are also creating more noise in their operation. The cooling fans that are being used to cool down the engine and support it are also becoming a source of noise. Exhaust gases that escape through the exhaust system are obviously the exhaust. The tyre-road interaction, as I told you, is the rolling noise. It is typically created because of the friction between the tyres and the road surface.

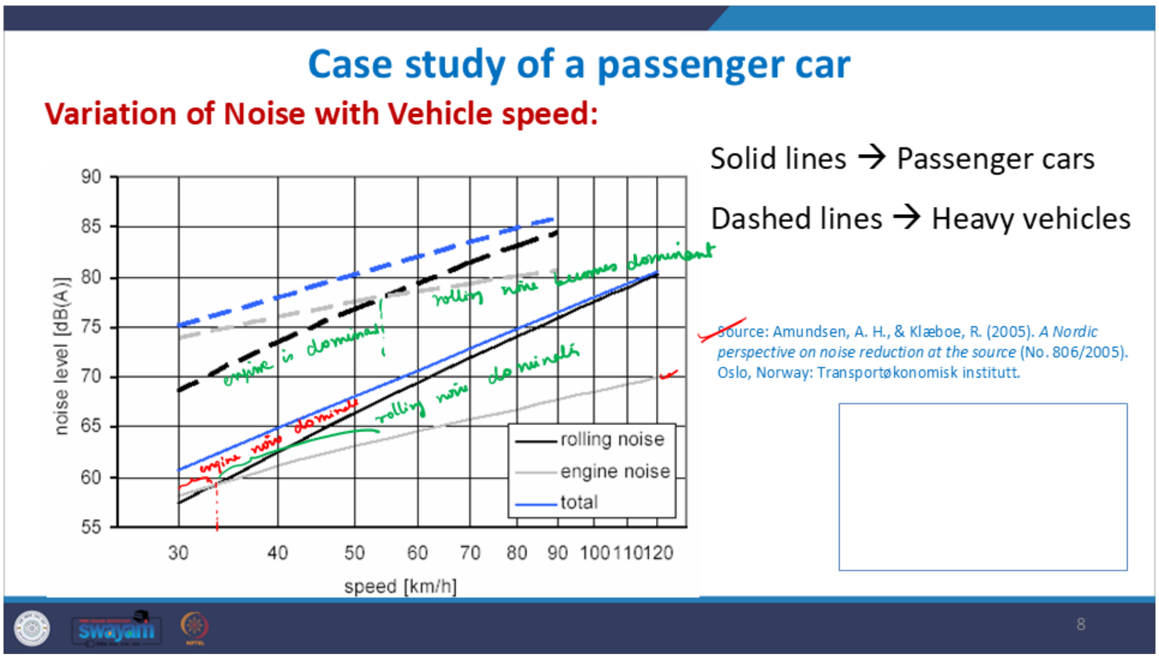
This friction or resistance creates the noise, or the rolling noise. Aerodynamic noise occurs when air flows through the vehicle body and its components, creating a wind gushing sound. This is like a fluid-structure interaction noise, as aerodynamic noise is a typical fluid-structure interaction noise.



How do these noises vary with the vehicle conditions?

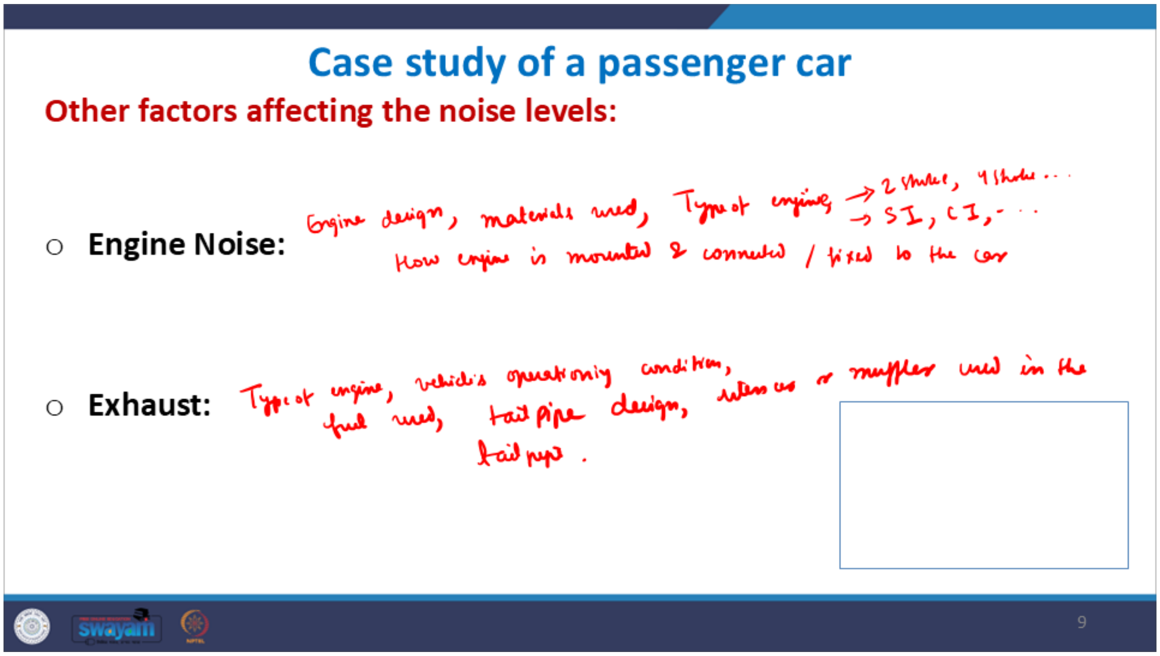
The noises vary with changes in the vehicle conditions, one of the most common being the speed of the vehicle. The speed of the vehicle determines which noise will be more dominant. For example, engine noise is mostly steady and increases with speed, but the increase is not as prominent. It increases slightly with speed; the level increases with speed, but the increase in level is not very prominent, almost constant with speed. The same goes for the exhaust.

It's very much in sync with whatever is happening in the engine. There is obviously a slight increase in the level with an increase in the speed because when you increase the speed, you need more power. The engine is working more, and hence a slightly higher level of noise is created. But the increase is not as prominent with the vehicle speed. But these two noise sources here there is a sharp increase in the level of the noise level with the increase in the speed of vehicle speed or the car speed. The same happens for both the both these cases there is a very sharp increase in the noise level with the increase in vehicle speed.



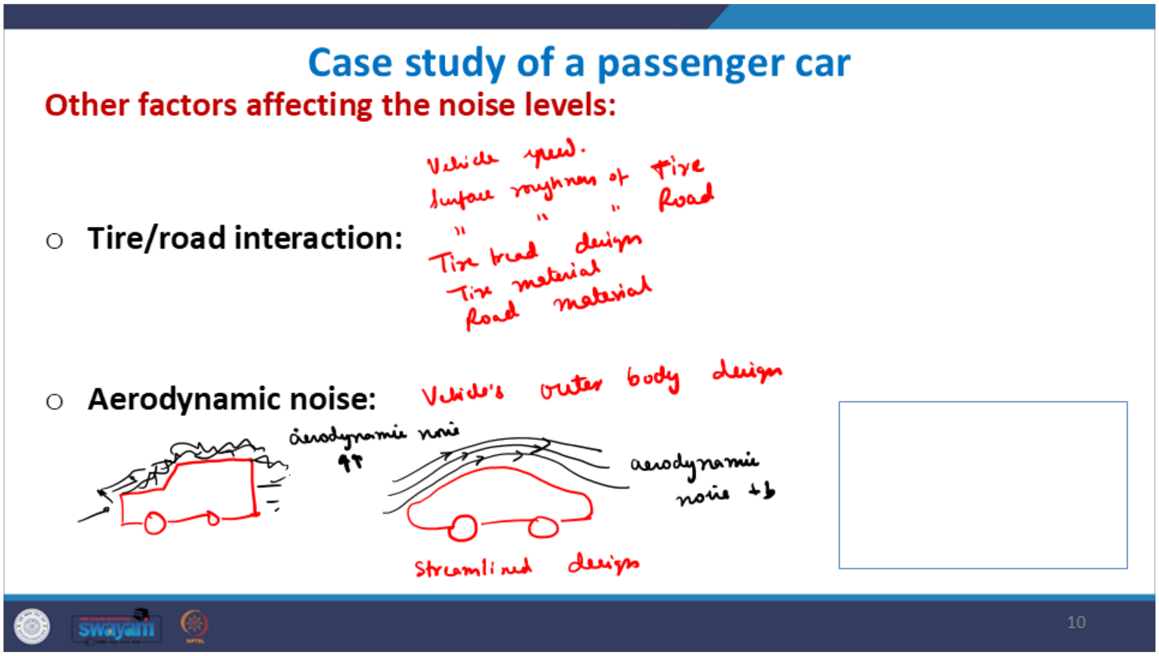
So this shows this is one of the graph from this particular source here from this book and you can see what is there in case of passenger cars and then in the case of heavy vehicles in this passenger cars what you see is that these days the passenger cars they are designed to go for a higher speed what is happening is that this gray line is your engine noise it is also increasing. For till this speed here what you observe is till this speed the engine noise is dominating till this speed till this zone and then beyond that from here onwards In the highest speeds what is happening is that the tyre rolling noise dominates because the increase in the tyre road interaction noise or the rolling noise is much sharper and higher.

Only at low speeds is engine noise the dominant one and then as the speed increases the most dominant noise becomes this rolling noise or the tyre road interaction noise. And the same thing can be observed for heavy vehicles where for a certain speed the engine noise is dominating. Here engine is dominant and after this speed the rolling noise becomes



dominant, becomes the most dominant one. what are the some of the other factors affecting these noise levels in case of engine if you can think about it it would be the engines design for any system it would definitely boil down to how it is designed what materials are used in making it and what type of engine it is whether it is a two stroke four stroke etc whether it is spark ignition compression ignition so what type of engine you're using that will also decide what is the noise level and how engine is mounted and connected to the body and fixed to the car that will also decide what kind of engine noise will be there so all of this is going to decide the noise level from the engine and in the exhaust the type of engine because engine the vehicle's operating condition also decides condition and the fuel you are using fuel used. Because of the kind of exhaust gases they create, suppose you are using more quieter fuels or cleaner fuels, there will be less emissions and less exhaust. Whereas if you use petroleum products, direct petroleum products, there will be more exhaust emissions and hence there would be more exhaust noise. So, all of this will decide your exhaust noise. Then the tailpipe design and the kind of silencer or muffler used in the tailpipe all of this is going to decide what will be your type of exhaust noise.

Then the tyre road interaction noise other than the vehicle speed we already know that it sharply increases with the vehicle speed but other than the vehicle speed it is typically a rolling noise where one surface or one solid surface is rolling over another solid surface the surface roughness of the tire and the surface roughness of the road on which it is moving is going to decide.

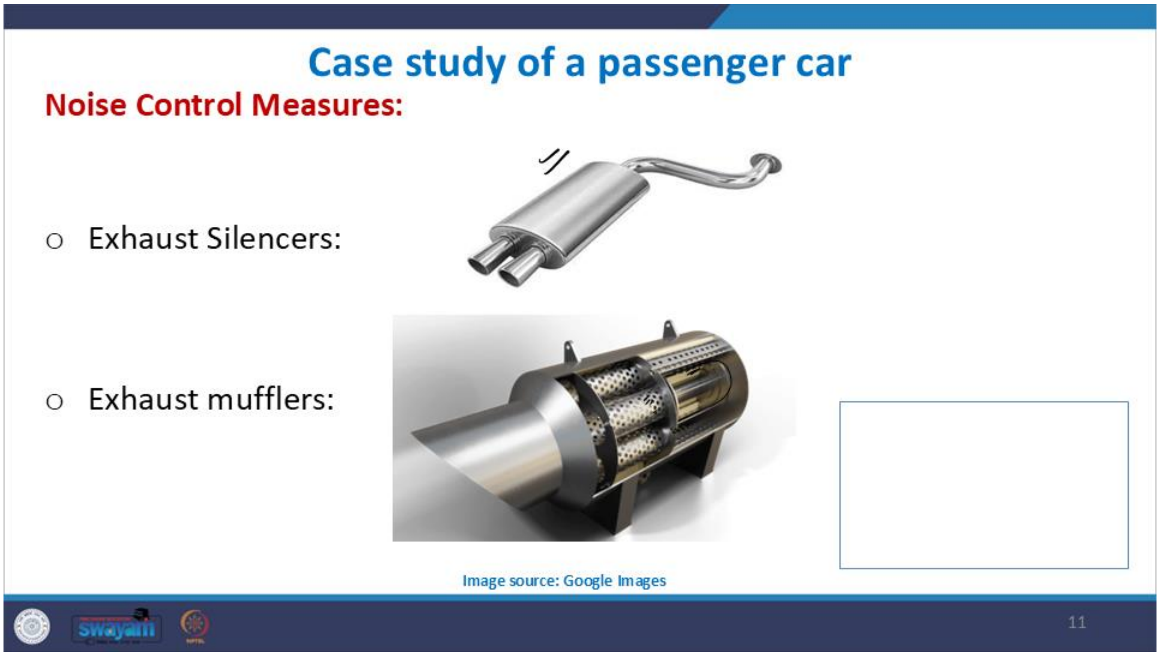


Your tire road interaction noise and the tire tread design and the tire material the road material all of this is going to decide your tire road interaction noise. Aerodynamic noise will depend upon the vehicle's outer body's design. What you see is that these days you can see previously you had these kinds of cars like jeep form of cars.

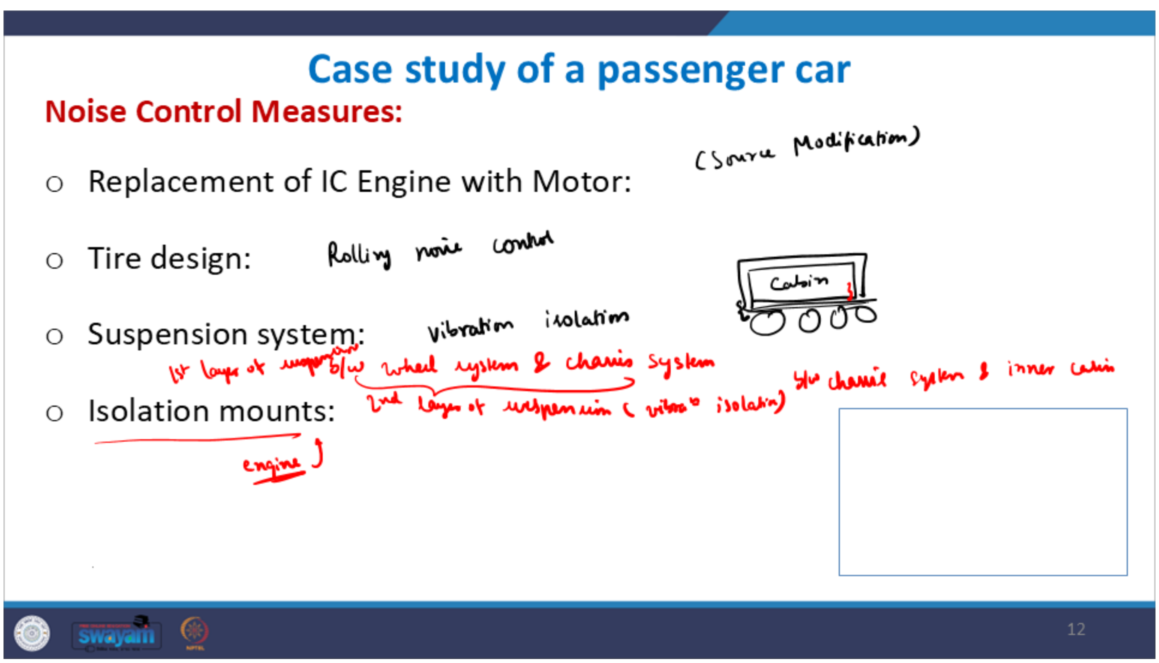
And then these days you have these more premium cars designed in this way. here this is a streamlined design. What is happening is that here the air is getting obstructed more there is lot of obstructions in the air and the aerodynamic noise it rises because of the lot of obstructions to the air flow that is being offered by this car. But if you have more streamlined flow then the air can flow without getting turbulent

Over the car's body, the aerodynamic noise will be much less, and hence these days, especially, we are getting more streamlined body designs for vehicles. The reason is to control the aerodynamic noise so that the outer shape offers as little resistance as possible to the streamlined flow of air through the car's body.

Some of the measures that used—the most common measure—and this is installed in every commercial passenger car. Every commercial passenger car these days has silencers and mufflers. This shows the outer body of a muffler. You can call it a silencer or a muffler.



Inside, as you can see, these are the perforated components. Then you have the Helmholtz resonator cavities, and based on these perforations and resonance phenomena, it is able to absorb the noise. The purpose is to absorb the noise and reduce the back pressure.



Now, you are getting quieter vehicles as the combustion engine is being replaced with a motor. A long time ago, vehicles like some trains and ships had external combustion engines, which were way noisier. From the external combustion engine technology, mankind progressed into internal combustion engine technology, where the engine and its operation became internal and embedded within an enclosure, making it quieter than the external combustion engine.

Now, from internal combustion engines, we are shifting to the use of electric motors and batteries to power our vehicles. These hybrid electric vehicles are way quieter. here we are doing source modification. We are simply changing the source creating the noise. We are replacing the engine with a quieter source, mechanical source—and shifting to an electrical source. Then, with the tire designs—you can see the commercial advertisements of various tires. The tire is a very essential component; its design will decide how much the rolling noise can be controlled.

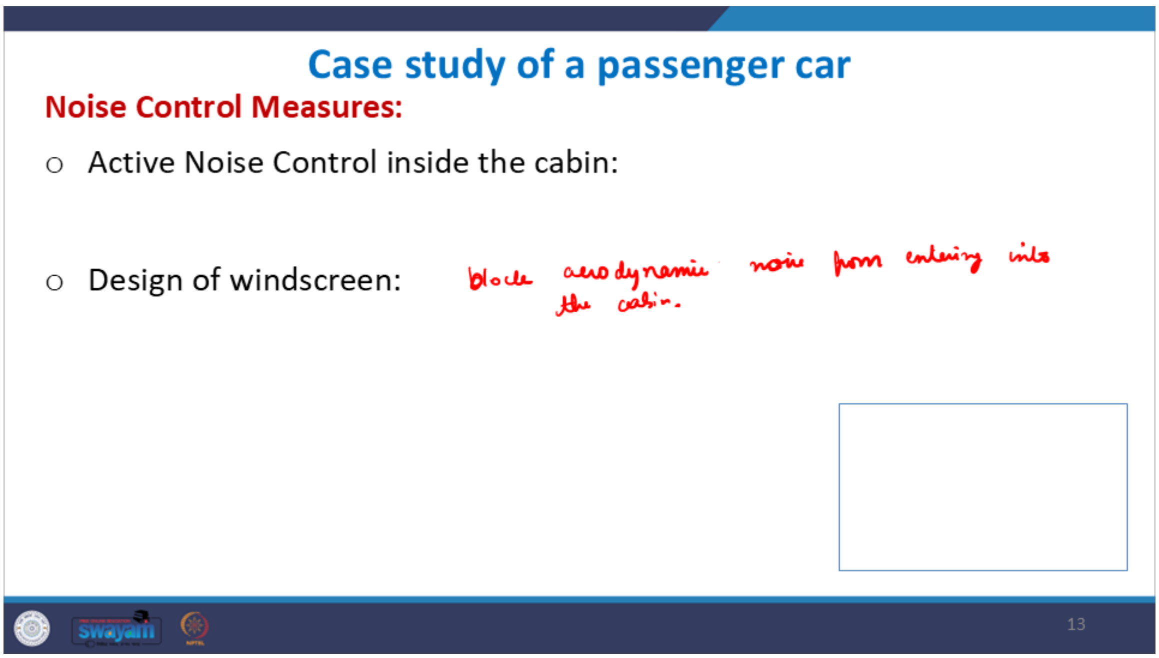
It can control the rolling noise or the tire interaction noise. It's the same thing. Then it also provides sturdiness to the vehicle and determines the kind of speed it can attain on different terrains and roads. The suspension system becomes a very important aspect, typically used for vibration isolation. It provides vibration isolation. Basically, This is your inside cabin where the person is sitting, and these are the outside structures of the vehicle.

And then you have, between the cabin and the chassis, you have suspension systems. Typically, you can find them between the tire or the wheel system, I should say. between the wheel system and the chassis or the body or the frame of the vehicle, so the chassis system you will have a suspension. It curbs the vibrations that might be induced due to road inputs or whatever. Suppose the road has bumps or roughness; that will induce vibrations.

We have a suspension system that is going to curb these vibrations from reaching the chassis from the wheels. That will be the first layer of suspension, or vibration isolation. the first layer of vibration isolators is between the wheel system and the chassis system. Then, the second layer of the suspension system or the vibration isolation system is found between the chassis system and the inner cabin.

Ultimately by the time it reaches the passengers, the vibrations have dampened out. They have reduced a lot because they are going through two levels of suspension. There is a suspension between the wheel and the chasis and then there is another suspension between the chasis and the cabin. And whatever road vibrations were causing whatever road inputs were causing the vibrations they are getting isolated, and they are not able to reach, or they are almost getting stopped from reaching inside the cabin and causing discomfort or creating noise inside the cabin. Then these various isolation mounts that are used the engine is typically now can be mounted using the isolation mount so that the engine noise

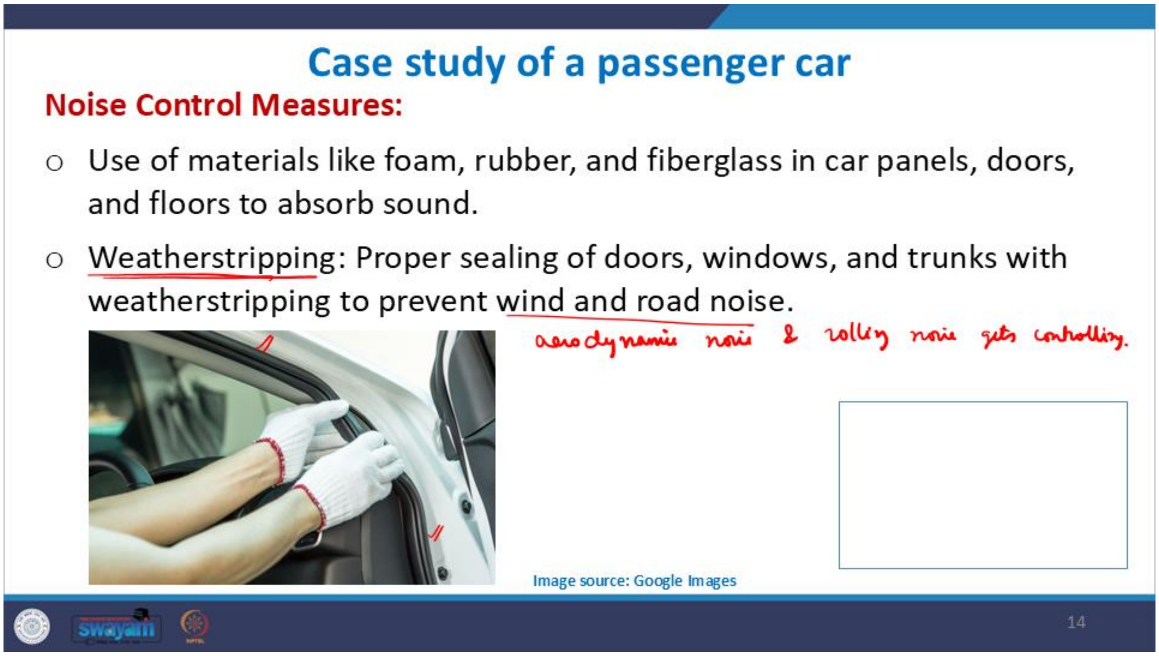
Which could be both air bond and structure bond so at least to control the structure bond component of the engine noise you can use the isolation mounts. If you have any other part of the automotive that is creating a lot of noise you have to make sure that the way through which it is mounted into the rest of the body. you have proper isolation on those mounts.



Then active noise control has taken up a hit in the controlling the cabin noise inside the car where the sensors installed inside the car to measure the noise level and then you have the speaker systems inside the car and the ANC system is directly in sync and connected with the speaker systems of the car and it is playing the anti-phase noise to dim out all the low frequency noise inside the cabin.

Then the windscreen these days are also designed so that they are sturdier, and they are able to block the aerodynamic noise. They can block the aerodynamic noise from entering into the cabin and causing discomfort to the driver and the passengers.

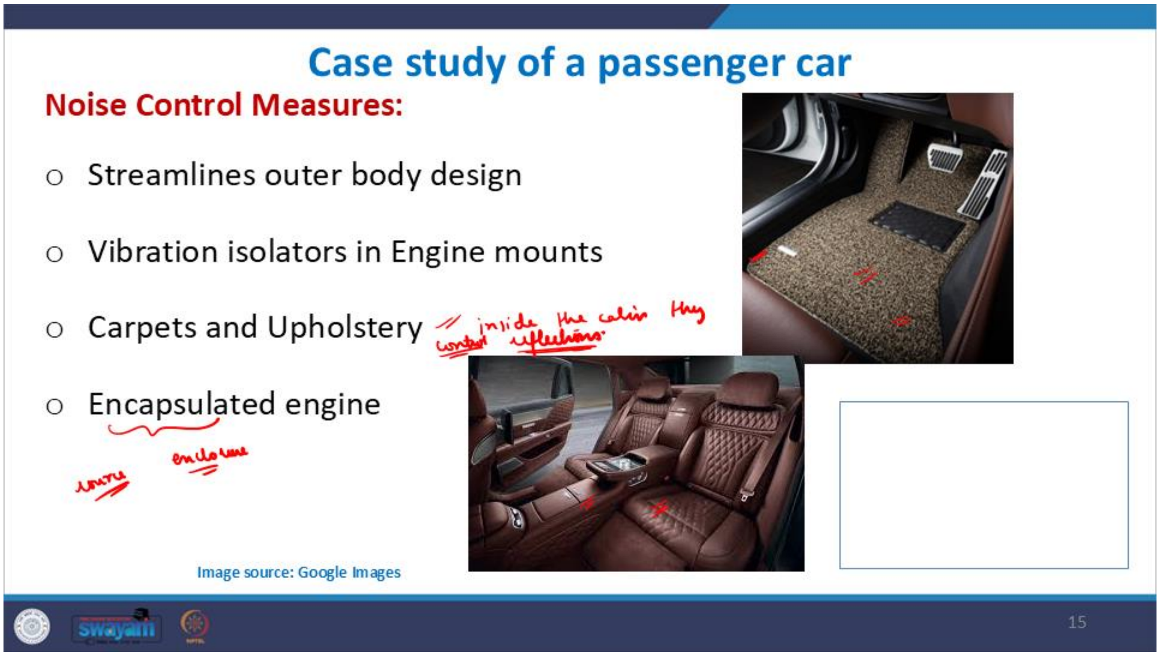
Then use of materials like foam, rubber, fiberglass all of this in the car panels, doors and the floors they can all help in absorbing of the sound. Weather stripping is yet another means through which although weather stripping which is lining up this shows the weather stripping.



What is it? It was usually developed for using the car in colder countries. And the rainy regions where you line up all the doors and the windows, you are lining up with these ceiling devices, and then when you close it, it becomes an air-tight ceiling. so you are airtight, the car becomes airtight, and there are no gaps. This was done to avoid the harshness of the weather by using the car in cold regions and in rainy regions. You have these rubber tubes and gaskets which help to make an airtight seal when the doors and the windows are closed.

And they also help with sealing and dimming out the tyre-road interaction noise and the aerodynamic noise from entering into the cabin. Both the aerodynamic and the rolling noise get controlled. It gets controlled because of this airtight sealing that is provided using the weather strippers. Then we have the streamlined outer body design, which helps in controlling the aerodynamic noise.

We have various vibration isolators in the engine mounting, so the engine is mounted, and that structure has vibration isolators. Then you can notice various kinds of premium cars; they have a lot of carpeting and a lot of upholstery. These paddings and carpetings are there. All of this not only adds to the comfort of the passengers but also helps in dimming



down the noise inside the car because, when you close the car, it becomes a closed indoor space, and within the closed indoor space, it is a reverberant field. And in the reverberant field, absorption becomes a good mechanism to control noise. Inside the car, if you can line up a lot of absorbing materials like this rubber, these kinds of padded pads, these kinds of carpets, etc. If you line the inside body of the car with these absorbers, they are going to control the reflections and bring the noise level inside the car's cabin down. These kinds of things help in controlling the reverberant field inside the cabin. They control reflections, and then the engine is usually encapsulated. Usually, engines these days are under some boxed covering, and you open the box and then you can examine your engine. They are now encapsulated. This again acts like an enclosure.

The source enclosure, here the source enclosure principle is used, and here you have the absorption principle where deflections are controlled.

This closes the case study on the passenger cars. The next case study is on a passenger train, and these are the various sources. I think it would be better to do the case study of the passenger train as part of the next lecture.

Thank you for listening.