Fundamentals of Automotive Systems
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Lecture- 27
Emission Control Systems - Part 01

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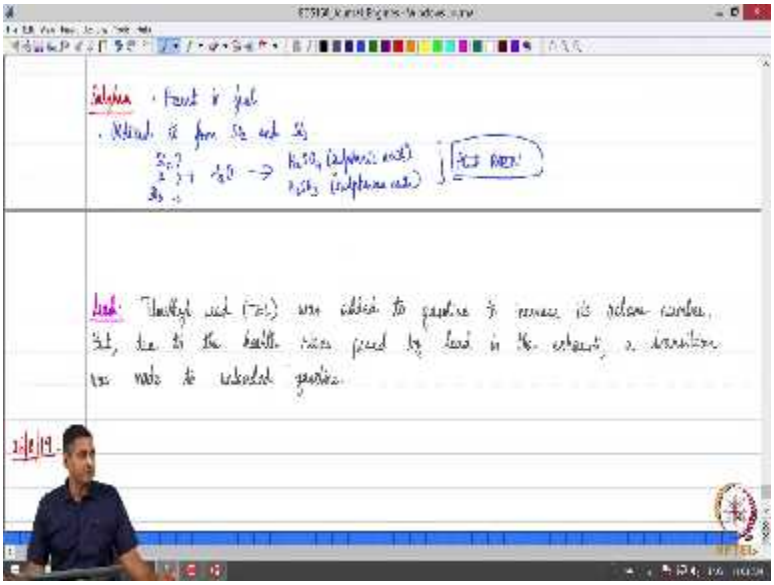

Okay greetings, so welcome to today's Class a just a quick recap of what we did in the previous lecture we looked at the emissions right. So we identified what were the different types of engine emissions that came about and what were its mechanisms and effects. So in today's class we are looking at what are the different tools and techniques available for regulating these engine emissions. So, what we are going to learn today are about emission control systems.

So that is the broad topic which we are going to look at today. So the major emissions from the automotive exhaust are unburned hydrocarbons partially oxidized carbon in the form of carbon monoxide and NOx and essentially some oxides of sulfur. So the question is how do we decrease the content of these unwanted gases in the engine exhaust. So that is what we are going to look at.

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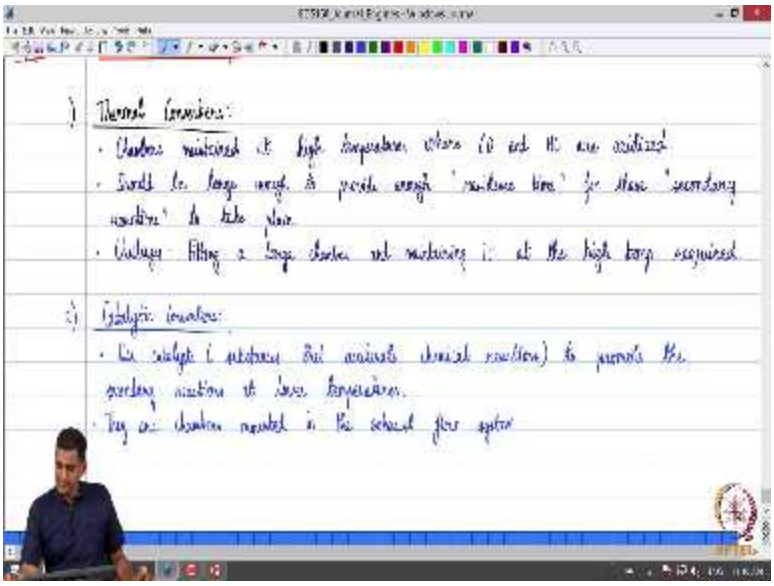

And we have already looked at what is a broad mechanism or set of mechanisms by which you know these gases are created engine exhaust and what factors affect them. So consequently we are going to look at some devices and techniques which would be helpful in regulating the quantity in the engine exhaust. So the first one is what is called as a thermal converter please recall that you know in the engine exhaust we have partially oxidized carbon and also like unburned hydrocarbons because the fuel may not get enough time to get oxidized.

So a thermal converter is nothing but a chamber which is maintained at sufficiently high temperatures such that the unburned hydrocarbons and carbon monoxide get completely oxidized. So that is the purpose of a thermal converter. So let me write down the key points of a thermal converter. So a thermal converter or thermal converters are chambers maintained at high temperatures where CO and HC are oxidized okay. So the main requirement as we have seen you know like as far as a combustion is concerned being we also require oxygen for proper oxidation to take place and a mechanism to initiate and sustain this combustion.

So one important requirement of a thermal converter in addition that you know we should provide for sufficient amount of oxygen is that the gases should have enough residence time such that they get time to react with oxygen and then get oxidized. So consequently these thermal converters are these chambers must be large enough to enable these partially oxidized compounds to remain in these chambers for sufficient amount of time.

So these chambers should be large enough to provide enough residence times for the so-called secondary oxidation reactions to take place okay. So that is a challenge right is it not because we need to fit these sufficiently large chambers downstream of the engine in the engine exhaust part and allow for sufficient what to say time for these gases to get oxidized and not only that these chambers have to maintained at significantly high temperatures right to enable this oxidation to take place.

So those are the main challenges that one needs to face. So one challenge is fitting a large chamber and a large chamber at the engine exhaust and maintaining it at the high temperature required. So that is a challenge behind the use of a thermal converter. So what is an alternative? So what is being used popularly or widely today; so, instead of having high temperatures to enable the secondary oxidation reaction to take place.

Now we utilize catalysts; catalysts essentially promote these secondary oxidation reactions and so that these oxidation reactions can take place at relatively lower temperatures okay. And the devices or the class of such devices which enable these secondary oxidation reactions to take place what are called as catalytic converters. So what is a catalytic converter the catalytic converter in a catalytic converter one uses catalyst

Catalysts are substances that accelerate chemical reactions to promote the secondary oxidation reactions at lower temperatures okay. So that is an important aspect of a catalytic converter. So they are chambers mounted in the exhaust flow system where the exhaust gases are treated for the various components.

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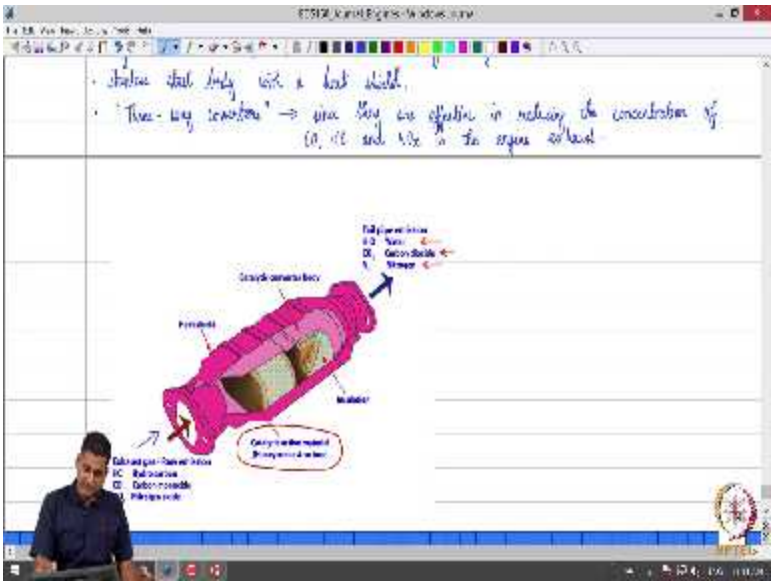

So, let us see how it works and then like what factors affect the performance of a catalytic converter. Typically catalytic converters have a stainless steel body with a heat shield to insulate the same okay and that they are going to have what is called as a honeycomb structure you know through which the exhaust gases pass. And in these structures the catalysts are embedded so when the exhaust gases pass through these structures through these passages in the catalytic converter the catalysts promote the oxidation of various components and so that is one important advantage.

So let us look at what happens in a catalytic converter. So this is a simple schematic of a catalytic converter so we can see that the exhaust gas from the engine enters into the catalytic converter and exhaust gases that we wish to treat are hydrocarbons, carbon monoxide and NOx. So these are the gases that we want to address right in the emissions. So this catalytic converter has a stainless steel body and which is insulated by a heat shield.

And we can see that the active material in the catalytic converter has a honeycomb structure. So there are passages through which the exhaust gases go and the catalysts are essentially embedded in these structures okay. And as the exhaust gas passes through these passages ideally the carbon monoxide is completely oxidized to carbon dioxide. The unburned hydrocarbon is completely oxidized to water vapor and carbon dioxide and NOx should be reduced to nitrogen.

So that should be the ideal byproduct of a catalytic converter. So the question becomes you know like whether we actually get them and if at all we want to achieve this ideal set of reactions or what are required so that is something which we will look at now okay. So these catalytic converters are also called as three-way converters typically people refer to them as a three-way catalytic converter because they are effective in reducing the content or concentration of three gases CO, carbon monoxide, unburnt hydrocarbons and NOx in the exhaust in the engine exhaust.

So they are also called as a three way converter okay. So they oxidize hydrocarbon and carbon monoxide and they reduce NOx. So that is the reason being, now these catalytic converters contain porous ceramic honeycomb structures with flow passages through which the exhaust gases flow okay. So and catalysts are embedded on the surface of these ceramic passages and promote the reactions.

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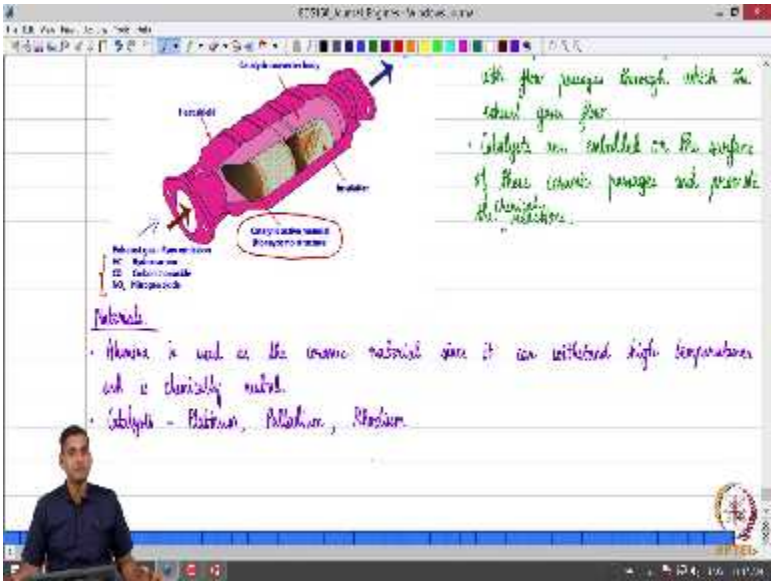

Of course chemical reactions obviously right yeah. So that is what happens in a catalytic converter. So now the question becomes you know like what are the materials that are used in this catalytic converter you know like how do they help in these chemical reactions. And also what are the factors or conditions under which we get very good conversion efficiency okay. So we are going to look at those two questions. So the first question is the following?

So what materials are used in this catalytic converter? So typically alumina is used as the ceramic material for the honeycomb structure okay, since it can withstand high temperatures and is chemically neutral. So that is for the material like the honeycomb structure. So what are the catalysts that are used? So the typical catalysts that are used are platinum, palladium and rhodium okay. So these are the catalysts used in the catalytic converter.

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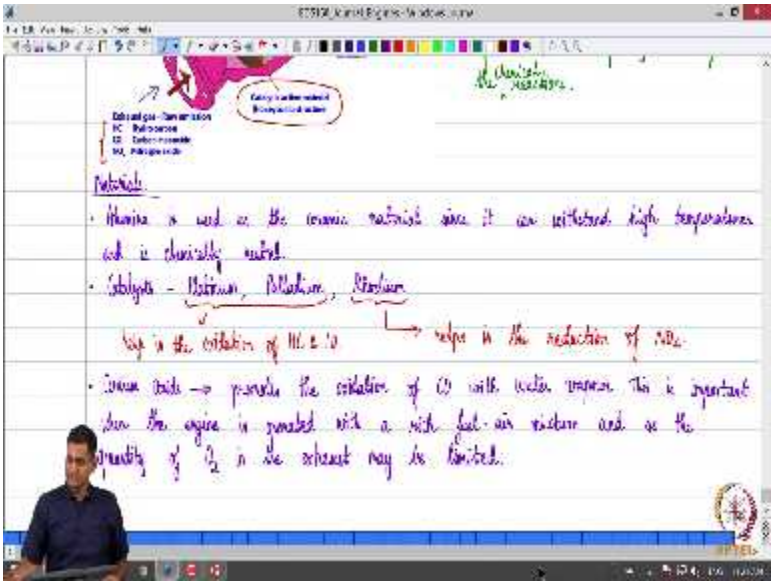

So what do platinum and palladium do? Platinum and palladium they help in the oxidation of hydrocarbons and carbon monoxide so that is the role of platinum and palladium. Now what about rhodium? Rhodium assists in the reduction of NOx. So these are the roles of the catalysts present in the catalytic converter. So sometimes cerium oxide is also used, so cerium oxide essentially promotes the oxidation of carbon monoxide with water vapor, so this is particularly useful when the engine is operated with a rich mixture, why?

Because when the engine is operated with a rich mixture the oxygen content available in the exhaust gases may be small right and these are oxidation reactions because unburned hydrocarbons and carbon monoxide need to react with oxygen to get completely oxidized. So if we do not have enough oxygen particularly when the engine is operated with the rich mixture. Cerium oxide would enable the oxidation of carbon monoxide with water vapour.

So that is the role of cerium oxide right. So this is critical or important when the engine is operated with a rich fuel air mixture the rich fuel air mixture and so the supply or quantity of oxygen in the exhaust may be limited. So that is the role of cerium oxide, so water vapor is used to oxidize CO. So those are the materials used in this catalytic converter.

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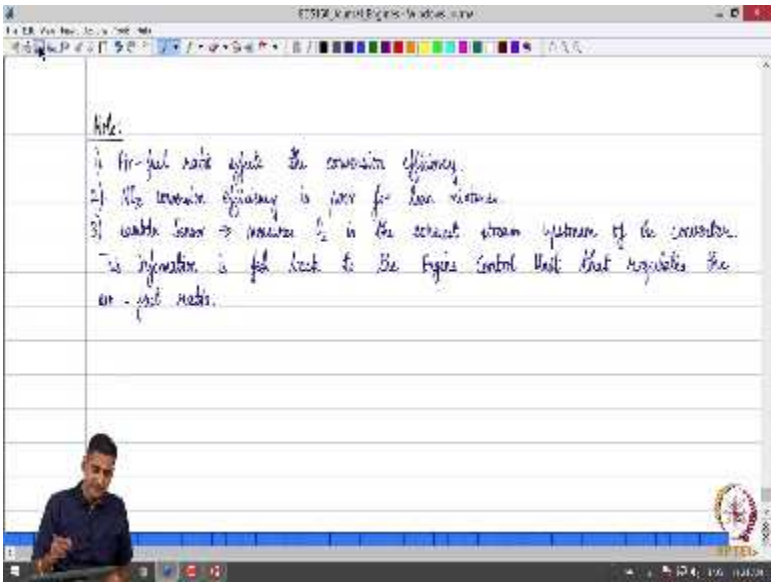

So, one important aspect you know as far as the operation of the catalytic converter is that the air fuel ratio used in engines plays a very critical role in the efficiency of the overall conversion process. So how does the air fuel ratio you know like affect the conversion process? So the air fuel ratio which we will shortly observe affects the conversion efficiency that is conversion means in this catalytic converter that is conversion of HC and CO their oxidized components and reduction of NOx.

So that process efficiency is affected by the air fuel ratio and typically the NOx conversion efficiency is poor for lean mixtures okay and there is something called as a lambda sensor. So what happens is that in this catalytic converter typically at its at its upstream. So what is called as a lambda sensor is used to measure the oxygen content available in the exhaust and that is also fed back as a measurement to the engine control unit which then takes it as one of the inputs to adjust the air fuel ratio when the engine is an operation oaky.

So there is something called as a lambda sensor that measures oxygen in the exhaust stream upstream of the converter. This information is fed back to the engine control unit that regulates the air fuel ratio of course it uses information from other sources also but this is one source. So these are the some critical points attributed to what to say a catalytic converters.

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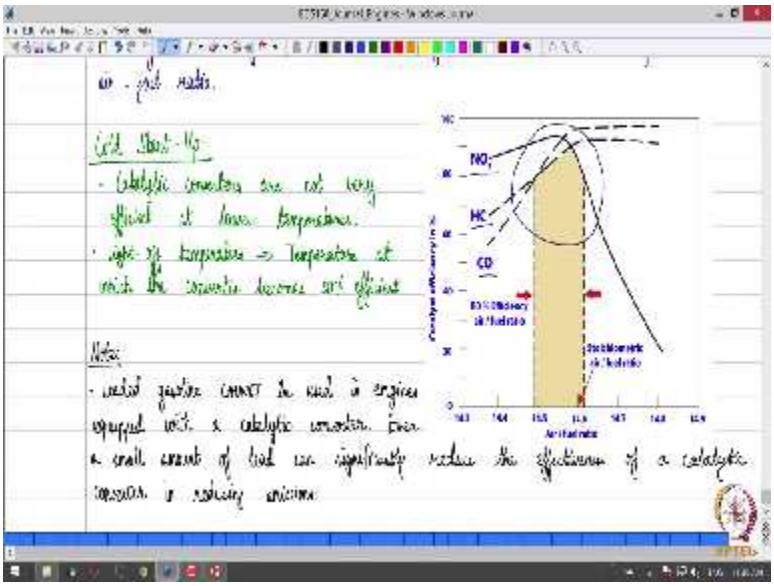

So, if you look at the actual performance of a catalytic converter; and if you look at some performance maps a typical map may look something like this. So if you look at this figure so what the; efficiency of the conversion process has been plotted against the air fuel ratio okay. So considering the efficiency of the conversion process so one can observe that the efficiency of the catalytic converter is maximum for all the three components NOx hydrocarbon and carbon monoxide in a small range of this air fuel ratio.

If we go either richer or leaner we are going to have less efficiency in one component or the other as far as its conversion is concerned. So that is something which we need to keep in mind. And another issue with the catalytic converter that we need to be aware of is a so-called cold startup. So what is cold startup? So catalytic converters or not very efficient when cold ok so they need some although they do not require as much temperature as a thermal converter right.

So they need some what to say a temperature for enabling these reactions to become efficient right. So at very low temperatures catalytic converters are not that efficient. So, for example

when the engine is started when we start a vehicle and start operating it so the catalytic converter may not be very efficient. So this makes the conversion efficiency poor at those temperatures and so there is something called as a light off temperature at which it is a temperature at which the catalytic converters efficiency reaches around 50%.

Converter becomes around 50% efficient okay in the conversion process so that is what is called as a light off temperature. So obviously if you look at low distance operation this makes the catalytic converter less efficient over lower distances suppose I want to just drive a car for let us say 2 or 3 kilometers right from one place to another. So the conversion efficiency of the catalytic converter is going to be pretty small during that travel.

So that should be something which should be kept in mind another important fact that we need to keep in mind when using a catalytic converter is that lead although now we use unleaded gasoline. We in the previous lecture we looked at what were the pitfalls of using lead and why it was stopped. Suppose if by accident even a small fraction of lead dispersant that can damage the catalytic converter.

So that is why today it is very important to use unleaded gasoline ok along with catalytic converters okay. So suppose if the entire engine system has a catalytic converter very critical to ensure that we use unleaded gasoline. So an important point to note is that like leaded gasoline cannot be used in engines. Of course we are anyway going to use we are using unleaded gasoline but this is an point to remember engine equiped with a catalytic converter.

So, even a small amount of lead can significantly reduce the effectiveness of a catalytic converter in reducing emissions okay. So essentially there's one more reason why we need to use unleaded gasoline within vehicles where we have a catalytic convertor okay. Yeah so catalytic converters play a very critical role today you know like in reducing the engine exhaust emissions right.