Fundamentals of Automotive Systems
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Lecture - 25
Engine Emissions Part 01

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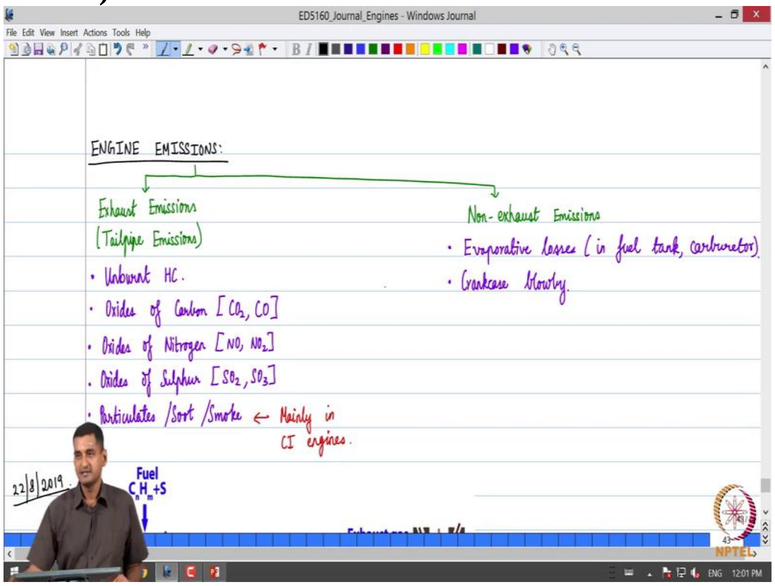

Greetings so start let is start get started with today is class. So, looking at engine emissions, so broadly emissions from IC engines you know like, can be classified as what are called exhaust emissions that come from the tailpipe, which include all these gases unburned hydrocarbons, Oxides of carbon Oxides of nitrogen, Oxides of Sulphur and also like emissions in the form of particularly particulate matters.

So, in addition to exhaust emissions there are what are called as non-exhaust emissions, which are mainly unburned hydrocarbons that come in into the atmosphere a due to evaporative losses in the fuel tank and other elements like carburetors. And you can also have what is called as crankcase blowback which where you know some fuel escapes through the crevices in the piston cylinder assembly between the piston rings oil rings on the cylinder surface.

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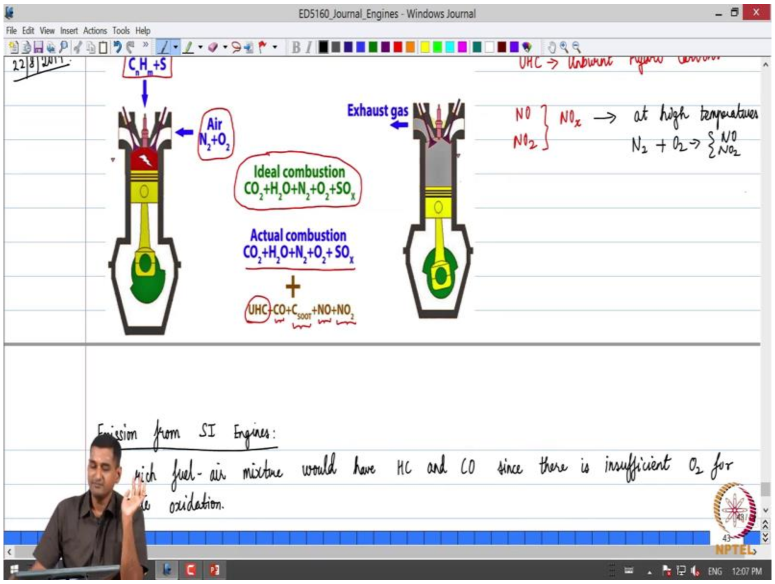

So that constitutes those constitute non exhaust emissions. So, we are going to look at both categories of emissions and we are going to look at each component of these emissions in today is class and we will also look at what happens in various types of engines like 4 stroke SI and CI engines and also in 2 stroke engines. So, if we look at the ideal combustion process in any internal combustion engine, we provide fuel which is a hydrocarbon sometimes many times you know Sulphur is present in the fuel.

And we take in air predominantly a mixture of nitrogen and oxygen and when we combust them and when we burn them together in the combustion chamber chemical reactions occur and in the ideal scenario we should get these as the byproducts of combustion that is the exhaust should contain carbon dioxide, water vapor, nitrogen acid is as N2 any excess oxygen as O2 and maybe some oxides of Sulphur.

So, that is as close to the ideal process that we can expect. So, in other words, all the hydrogen and carbon in the fuel must be completely oxidized, so that we also avoid other exhaust emissions and also ensure that we are able to retrieve the maximum possible chemical energy from the fuel converted into thermal energy. So, that is the ideal scenario in the real combustion process more often than not, we will get these gases, CO2 H2O N2 O2 and oxides of Sulphur.

But in addition, we would also get unburned hydrocarbons, you had C stands for unburned hydro carbons. We will get carbon monoxide CO carbon in the form of particulate matter what is called a soot we may get NO and NO2 are typically combined and represented us NOx people some people refer to as NOx as a terms. So, we are going to get all these additional gases as byproducts of the conversion process in the exhaust.

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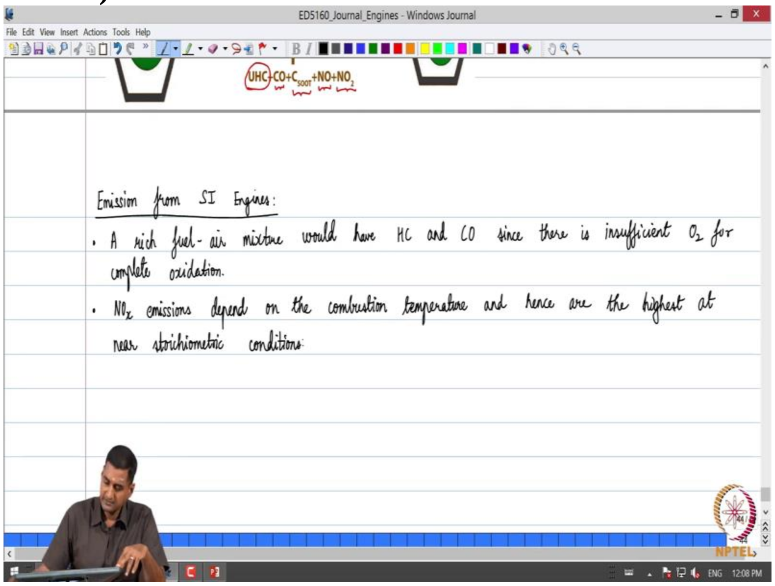

And these as severe implications on the environment. And in addition to that, we are also going to see what impact they have on the engine perceive, So that is something which we are going to look at so, this is the actual scenario. So let is start looking at what happens in each type of engine and then like we will also discuss each component of this emissions. So, first starting with emission from SI engines.

Typically what happens is that in spark ignition engines and also like in what to say both 2 stroke and 4 stroke what is going to happen is it a rich mixture rich fuel air admixture would not have would have enough what to say HC and CO since that is insufficient oxygen for complete oxidation. So the oxidation process is not complete, so, if the oxidation process is not complete you know like, essentially we are going to have this unburned hydrocarbons and oxidation process unburned hydrocarbons and carbon monoxide present in the engine exhaust.

And when would this NOx emissions also come into play in fact the oxidation of this one no make so, let me call this solution. So the knock knocks gets form if an oxidation of NOx happens or nitrogen happens you know like at high temperature in the cylinders N2 will result with O2 to form this NO and NO2 So, whenever we have this condition of high temperatures in the cylinder.

We are going to have NOx formation and when what the cylinder temperature be the highest when the fuel air mixture is close to the stoichiometric mixture when we have fuel air mixture to be at the stock close to the stoichiometric ratio our what to say combustion process is going to be pretty efficient as far as the conversion of chemical energy to thermal energy is concerned and the cylinder temperatures would peak.

So NOx emissions depend on the combustion temperature and hence are the highest at near stoichiometric conditions that is when.

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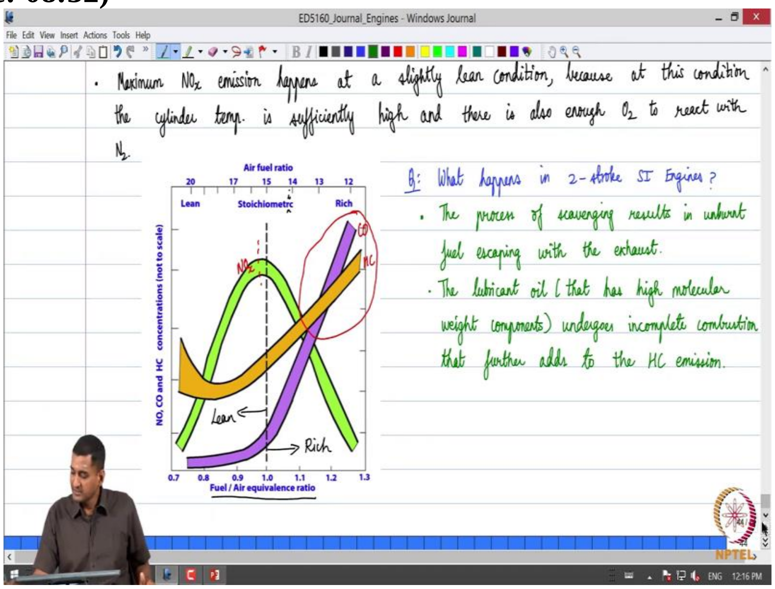

So that is when the NOx emissions become the highest of course typically, maximum NOx emission or happens at a slightly lean condition. So, if you compare it, happens at a slightly lean condition because at this condition the cylinder temperature is sufficiently high and there is enough excess oxygen also so, we need oxygen to reactive nitrogen so if you have exactly stoichiometric so there is only enough oxygen to react to the hydrocarbon and oxidize them.

So there would not be any oxygen left. If the fuel air ratio is exactly stoichiometric so slightly lean mixture, so their enough heat energy that is released to ensure that the cylinder temperatures are sufficiently high and also there is enough oxygen to react with nitrogen. So, if we take it consider a typical what to say distribution of these gases you know like in a spark ignition engine on again it looks something like this so, of course this should be stoichiometric.

So if we plot the fuel air ratio, so, and essentially look at how the emissions get affected in spark ignition engine. So let is consider the equivalence ratio. So, as we know this side is lean to what to say the vertical line at 1 it is going to be a rich mixture. Unsurprisingly in a rich mixture the hydrocarbon content and the carbon monoxide content increase. So hydro carbon and carbon monoxide.

So, HC and CO content increase in a rich mixture because obviously we are going to have more unburned fuel and we can see that NOx emission, which is represented by these curves you know like become a maximum slightly lean mixtures, near stoichiometric conditions and that is where they become the maximum. So, this is typically in emissions in 2 is, what it is say SI engines in addition, question is what happens in 2 stroke SI engine, so this is a general trend in SI engines.

But what do you think will happen in 2 stroke SI engines in compared to the 4 stroke SI engine in 2 stroke SI engines we can immediately see that the process of scavenging would result in more unburned fuel escaping with the exhaust. So if we recall how 2 stroke engines operate, we can recall that the exhaust port is open during the down stroke and during the same phase fresh fuel air mixture is going to come from the crankcase through the transfer port to the combustion chamber.

So, there is a good chance of not only exhaust gas dilution of fresh starts and also fresh start escaping into the exhaust port. So, due to these reasons, the chances of unburned hydrocarbon being more increase in a 2 stroke engine. So in a 2 stroke engine the process of scavenging results in unburned fuel escaping with the exhaust, so that is what happens in a 2 stroke engine. And not only that, please recall that in a 2 stroke engine we add lubricants along with the fuel.

And the lubricating oil has a different chemical composition when compared with the fuel and that is also going to go into the cylinder undergo combustion to varying extents and whatever is left behind is going to be exhausted through the exhaust port. So, we have to look at that aspect of the lubricate the lubricants oil or the lubricant fluid that has a higher molecular weight, is also going to undergo incomplete combustion, the combustion chamber that further adds to the hydrocarbon emissions.

So that is what these are 2 important factors that we need to keep in mind when we look at emissions in 2 stroke engines. So, in addition to whatever we have already seen about essence 2 stroke essence. So, now we will come to CI engine shortly but before that let is look at each component 1 by 1.

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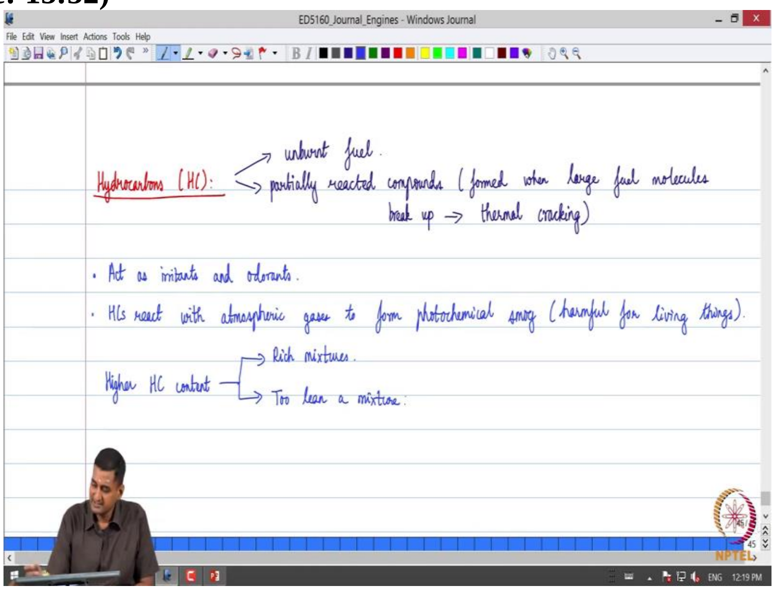

So and then like that will also give us an idea as to which component is going to be important and what type of engines. So let is first look at the first component that we are going to look at is hydrocarbon unburned hydrocarbons. So let is ampersand HC. So, what as we already know, hydrocarbons we can have 2 aspects. So, this is we can have unburned fuel compounds as they are in the exhaust.

But also like partially reacted compounds particularly when we have high molecular mass hydrocarbons they can be oxidase partially they can go to a different chemical structure and still be released along with the exhaust so, partially reacted compounds they form when large fuel molecules break up due to the heat energy during the combustion process and this is what is called as thermal cracking.

So, thermal cracking is this phenomenal where these larger molecules break down into smaller hydrocarbon molecules and these are also released and what are some limitations with hydrocarbons obviously, the act as irritants for us and odorants some are carcinogenic 2 and hydrocarbons react with atmospheric gases to form photochemical smog. This is once again very harmful swag as harmful for all living things.

So, essentially higher hydrocarbon content can be present in rich mixtures because why because obviously they can they have less oxygen to completely oxidize the fuel particles and unburned hydrocarbons are also present into lean a mixture why because they may not have enough fuel to even like sustain the combustion process. So, either too lean as we can observe too lean a mixture would also increase the hydrocarbon content because we essentially cannot sustain the combustion process.

So that is why that is a reason for increasing hydrocarbon content when we go to very lean mixtures, so neither is invisible too rich or too lean, from an emission hydrocarbons emission perspective. Now let us look at a cause for HC emission. Let me quickly run through them in SI engine you will see that even in CI engines, you know, like many of these costs are going to commit but first let is look at what happens in spark ignition engines.

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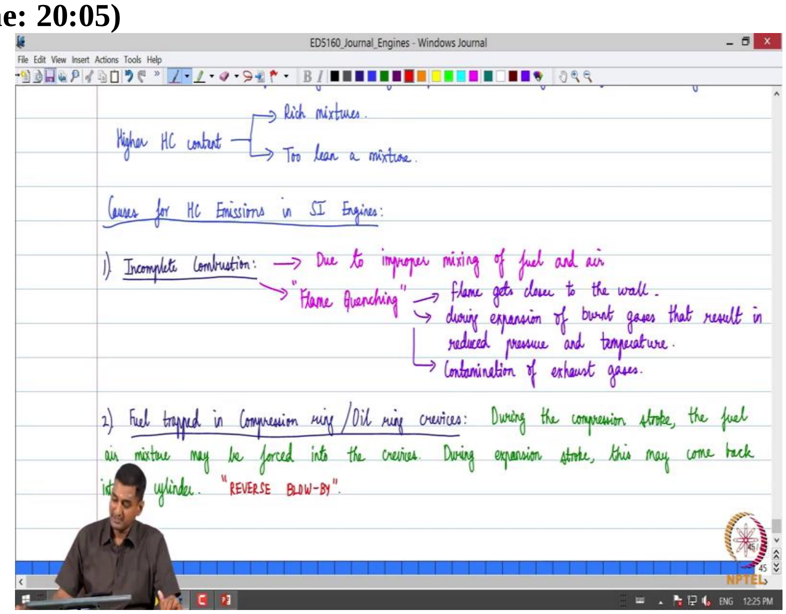

And what factors are result in significant hydrocarbon emissions. So, the first one is due to incomplete combustion obviously. So, the combustion process is not incomplete needs to not complete and there are multiple reasons for this of one as due to improper mixing of fuel and air because of the fuel and air do not mix properly to form a homogeneous mixture we are going to have incomplete combustion.

So, that is 1 reason second factor is what is called as flame quenching. So, what has been the flame quenching the flame gets put out before it can burn all the fuel you know like unburned fuel so, why does flame quenching happen. So, when the flame gets closer to the wall it can get quenched and the flame quench hits a wall it can get quenched. So that 1 reason flames also get quenched during expansion of burn gases that result in reduced temperature and pressure.

So, when the combusted gases expand. So, the pressure and temperature are going to decrease in the combustion chamber and due to that a flame may get quenched. Temperature and another potential reason is contamination with exhaust gases so, because typically that is that may be exhaust gases that may mix with the fresh air a part of exhaust gases may also remain in the cylinder from the previous cycle and where the concentration of these exhaust gases is high the flame may get quenched.

Because it cannot have enough what to say fresh oxygen to carry out the combustion process the fuel air mixture may not be combustible. So, incomplete combustion predominantly happens due to these reasons and that increases the level of hydrocarbons in the exhaust. So, what is what can be another reason there are multiple reasons so essentially fuel trapped in piston ring compression oil ring crevices.

So, what happens as we already seen a compression ring or a piston ring provides the scene and an oil ring also install on the piston 33. So now although like these are carefully manufactured and assembled still we are going to have small crevices and the fuel air mixture is going to be forced through these crevices and during the compression stroke. So, the fuel air mixture may be forced into these crevices so at high pressures.

So, now when expansion happens what is going to happen the pressure in the cylinder is going to drop down then there is a pressure difference in the opposite direction is it none. So, this fuel unburned fuel air mixture which is which are essentially captured in the crevices may come out because now the pressure is lower in the cylinder. So, during expansion stroke this may come back into the cylinder and this increases the what is say unburned hydrocarbon this can potentially increase. So, this process is what is called us reverse blow-by.

So, if you encounter this term what is reverse blow by you know like essentially, we look at crankcase blow by unburned hydrocarbons blow pause the rings and then into the crankcase and then escape. So, this is like a part of it you know like comes in the reverse direction. First they are forced into crevices but a part of it comes back, so that is why it is called as reverse blowing. So that is one reason for hydrocarbon emissions.

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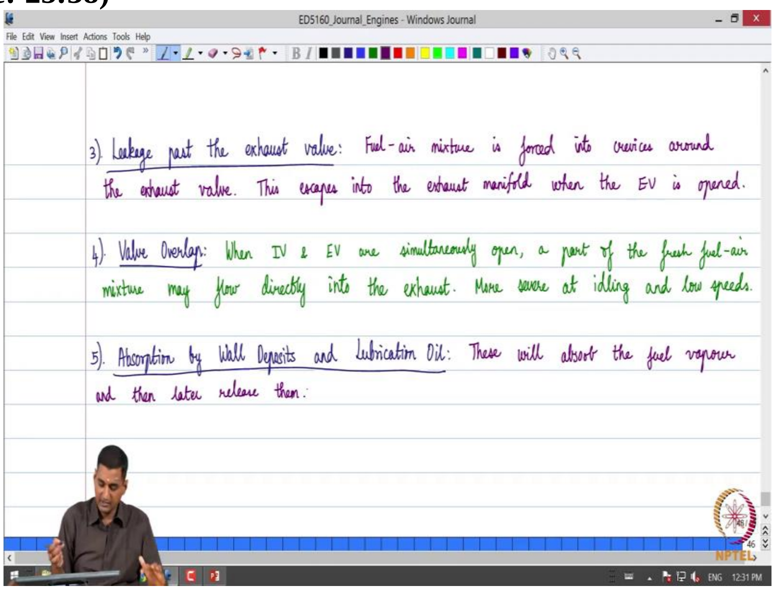

So let is go ahead so, another reason for unburned hydrocarbons is leakage past the exhaust value see that and the exhaust wall can have crevices. So, fuel air mixture is forced into the crevices around the exhaust value components exhaust value C is formed so exhaust value so now when the exhaust value opens this will escape and throw it into the exhaust manifold. So, that is why essentially, we have leakage pass the exhaust value.

So, this fuel air mixture which is stored in the crevices escapes into the exhaust manifold when the exhaust wall is open so, EV in this context means exhaust value. So, that is another reason. So, let is look at more reasons. So, in any engine, there is a significant amount of wall overlap. So, because when the, if you recall the 4 strokes and a 4 stroke engine, there is always some overlap between the exhaust vault closing and the inlet vault opening and that is going to result in and 2 things.

You know like some exhaust vault polluting the fresh charge and also what is called an exhaust gas dilution and some what to say fuel air mixture escaping also both can happen. So, that is what to say, that happens it can be minimized with careful design, but there may be some components. So, that is why it is called us valve overlap and when will this be more significant at lower RPM, if you recall at lower RPM, there will be more time available for each stroke.

So, then as far as time interval is concerned each stroke will have more time and consequently the overlap may occur over a larger time interval and that will promote this fresh fuel air mixture escaping into the exhaust what to say manifold. So, when the inlet valve and exhaust valve are simultaneously open a part of the fresh fuel air mixture may flow directly into the exhaust that is due to valve overlap. So, this is more severe at idling and low speeds due to longer time off valve overlap so, that is another reason.

So, another reason due to higher what to say behind hydrocarbon emissions in the exhaust is due to absorption by valve deposits and lubrication oil. So, see any way on the cylinder you know like we are going to have also other chemicals other components other components coming in with the fuel there are going to be other reactions and we will have valve deposits forming on the cylinder valve and even will have these lubrication oil deposits what will happen is that typically these will absorb the fuel vapor during compression combustion and so on and then later release them.

And as the engine keeps on aging, as the age of the engine keeps on increasing what may also happen is that the lubricating oil filum may just be may become thick with age and a part of it may get peeled off with continuing operation and that will also come through the exhaust. So all those will contribute to the hydrocarbon emissions. So all these factors contribute to hydrocarbon emissions in engine exhaust.