Fundamentals of Automotive Systems
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Lecture - 26
Engine Emissions Part 02

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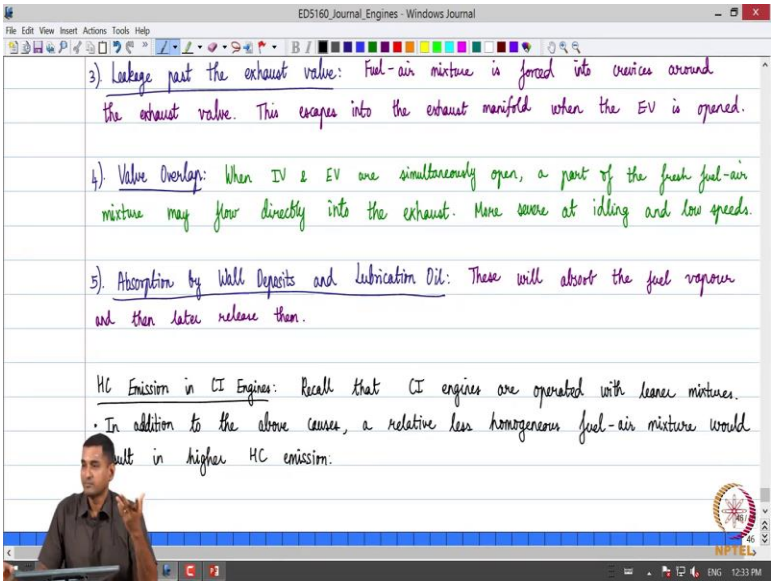

These are the factors which are also common to CI engines almost all of them but in CI engines. Please note that the mixture itself is lean if you recall from our discussion on the combustion process and compression ignition engines recall that CI engines are operated with linear mixtures in the first place. So, the hydrocarbon emissions become lower because there any operated with linear mixtures.

So, of course, there factors that we have discussed for SI engines carry over to CI engines also, in addition to these reasons, in addition to the above factors or above causes, a relatively less homogeneous fuel air mixture would contribute to higher hydrocarbon emissions would result in higher HC emission because we did not burn the fuel properly.

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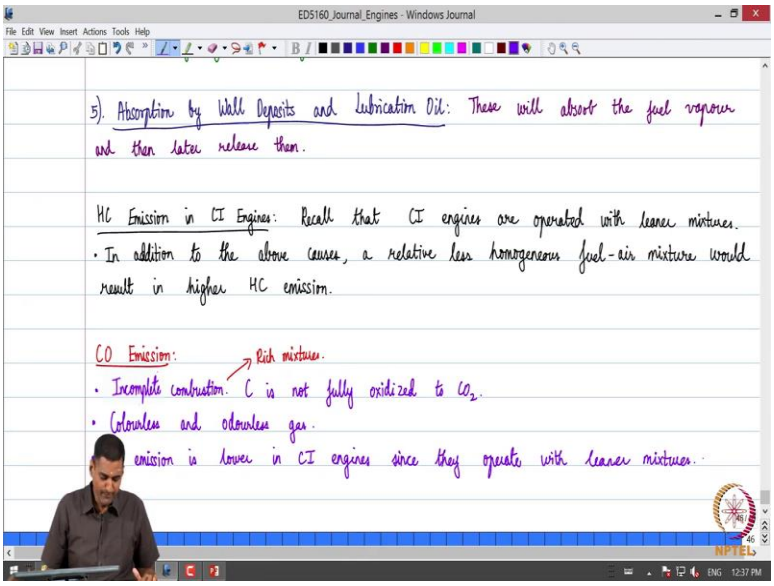

So, if you did not have proper mixing, of course in modern CI engines due to high injection pressures you know like it, we are essentially having very good optimization and vaporization. So, this has been addressed to a certain extent logics and please note that the 1 of the most important things in diesel engines or CI engines that we are going to discuss shortly is the formation of soot more than hydrocarbon due to the larger molecular mass of the fuel compounds unburn carbon is a problem. So carbon does not get oxidized and unburned carbon which is obtained by when the hydrocarbons splits up is a significant product in the exhaust off CI engines.

We will come to them shortly. So that is as far as hydrocarbon emissions concern. Let us look at carbon monoxide emissions. So, we are going to look at each gas 1 by 1 and then like we are going to relate you know like how various factors affect these emissions. So, if you look at carbon monoxide, it comes in what to say? Incomplete what to say burning, incomplete combustion, of course, because carbon is not fully oxidized to CO2. So, it is partially oxidized to CO.

So carbon monoxide is a colorless and odorless gas and its formation typically happens with rich mixtures because when you have rich mixtures, we have incomplete combination because we are going to have locally rich regions of fuel and a both hydrocarbon emission is going to be a problem and carbon monoxide is also going to be an issue. And please remember carbon

monoxide formation is also detrimental from an engine performance viewpoint because when carbon is fully oxidized to CO2 do we get more heat energy.

So, if it is partially oxidized to CO, you know like we are essentially not retrieving as much thermal energy as we could have potentially done so, that is also another aspects aspect that we need to look at and CO emission once again is relatively lower in compression ignition engines for the same reason since they operate with the leaner mixtures, so that is as far as carbon monoxide is concerned.

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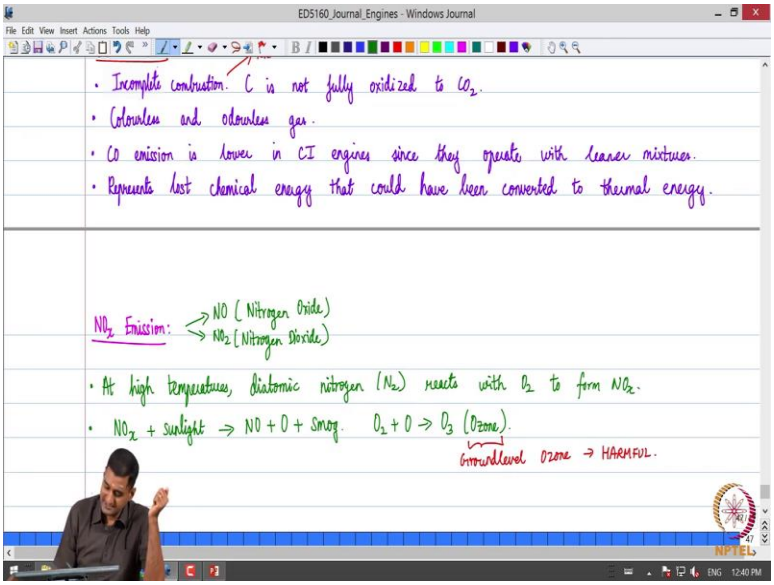

So carbon monoxide as I mentioned in on it also represents last chemical energy that could have been converted to thermal energy so, that is 1 limitation. So, the next component in the engine exhaust that we are going to look at is NOx. So as we discuss, we are going to have NO, NO2 under this category NO what is called us Nitrogen Oxide and in NO2 is Nitrogen Dioxide so these are formed at high temperatures.

So, NOx emission results at high temperatures in the cylinders at high temperatures diatomic nitrogen present in air diatomic nitrogen breaks down into monatomic nitrogen reacts with O2 to form NOx so that is the chemistry behind it. So what is the problem with NOx no NOx is also like harmful for the environment? So, when knocks in takes an energy from the sunlight, it can

essentially lead to NO + O and smog. And this what to say monatomic oxygen when it reacts to the diatomic oxygen it leads to ground level ozone is harmful.

So, this is also not very safe. So, you can see that NOx has all these detrimental effects. Of course, ground level ozone is also found when other emissions like hydrocarbons reacted atmospheric gases. So, that is not a very safe thing. So we can immediately see that we can decrease NOx by decreasing the cylinder temperature. So that is the way to do it. But then, like, we already seen from engine analysis, that if I decrease the peak temperatures, what is going to happen to my engine performance? It reduces, so there is a trade-off between engine performance and NOx reduction.

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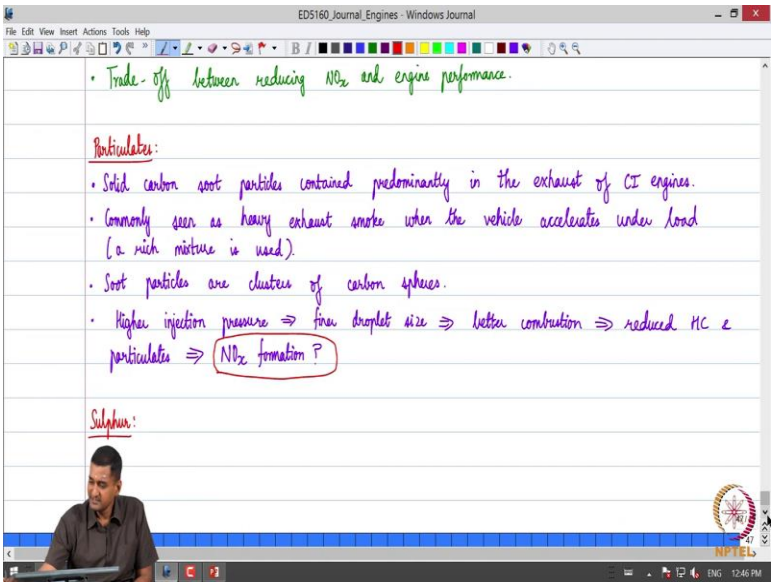

So this is what is a challenge for us because there is always a trade-off between reducing NOx and engine performance, so that is something we need to keep in mind. So we will also look at what are the various emission control systems shortly. So, the next component that we would have the engine exhaust are particularly it is matter particulates are nothing but they are solid carbon particles.

Soot particles contained predominantly in the exhaust of CI engines, particularly when CI engines are operated rich mixtures. So, 1 would see that particularly its arrays, you know like when you when we observe a bus or a truck you know which is starting from rest, or even like let

us say a bus slows down due to some water reason and it starts accelerating under load we can see the black smoke coming out of the tailpipe, the exhaust pipe.

So that is those are the soot particles they are this carbon particles. So, essentially, they are unburned carbon particles they come out of CI engine exhaust, particularly when we operate under such operating conditions. And it is of course harmful for the environment and it is commonly seen us heavy exhaust smoke, when the vehicle accelerates under load under, of course, we will also discuss how these are addressed.

So using emission control so, under these conditions as we already know, a rich mixture is used, during idling and low speeds when we accelerate we need a rich mixture, so, that is been so, soot particles are clusters of carbon spheres unburned carbon there is colleagues they form this carbon spears and then they come on. So how can we reduce the soil particles? If we allow more time for them in the combustion chamber and significantly increase the cylinder temperature? Then the carbon will have more chances of getting oxidized.

But what is the flipside? knocks because if we burn and if you oxidize carbon, what is going to happen we are going to release more heat energy more than heat energy more the cylinder temperature and higher the cylinder temperature larger is the potential for NOx formation. So, essentially, this is a trade off so if you want to oxidize this particular method by having more residents time, the combustion chamber we can reduce soot particles but that will lead to more NOx formation.

So we are going to discuss what is called as exhaust gas recirculation which is typically used to address this. What does it reduce particular zones, like we will see how a particular exhaust gas recirculation is used to decrease NOx, but then like that has a counteracting effect on unburned hydrocarbons and particulates? We are going to discuss that in the next class. So, but particularly it is 1 way is to also have higher injection pressure, so, people have figured out that if you increase the injection pressure, what is going to happen? We are going to have finer fuel droplets.

They are going to be like a spray so, better combination but then this will reduce hydrocarbons and particulates, but then what can what happens? NOx formation is a problem that is a question mark so because we have better combustion you know like better higher cylinder temperature the potential for NOx is higher that becomes a severe problem in CI engines. So, we will see how these are addressed. So, 2 more components of engine exhaust, the first 1 is sulphur.

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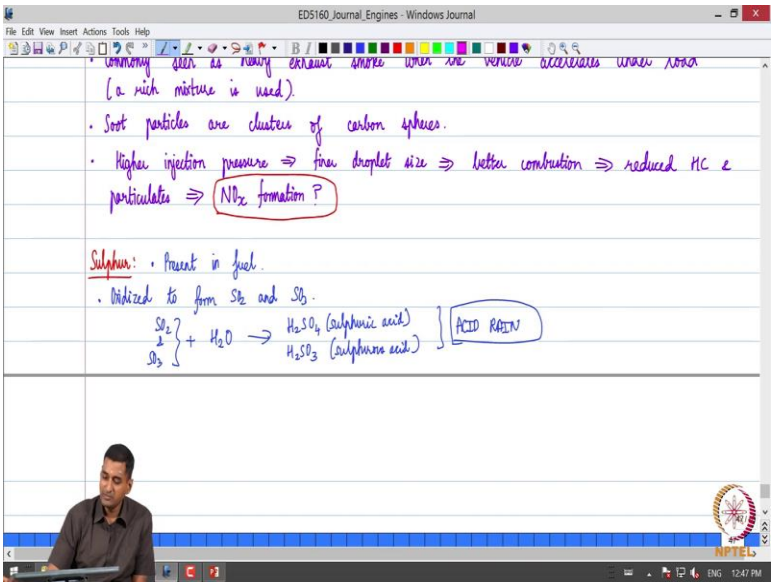

So, Sulphur is typically, what is a present as part of the fuel mixture. So, this is a Sulphur can be found in fuel. So they get oxidized to form SO2 and SO3. And this is SO2 and SO3 what happens is that they react with water vapor in the atmosphere to form sulfuric acid and sulphurous acid. So colloquially this what is called us acid rain, so in comes along with rain. We have what is called us acid rain so that is the impact of Sulphur in all languages present in the fuel and come so, when it gets oxidized.

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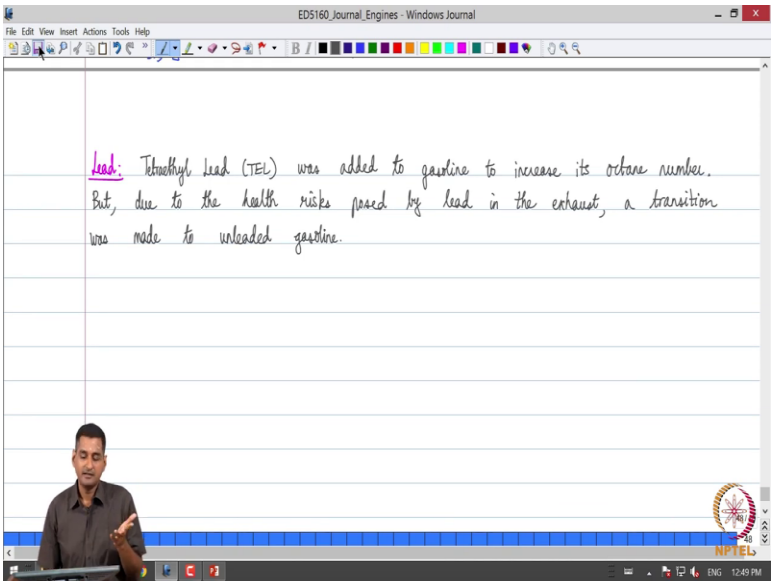

It comes on another important component which has since now been addressed, it is no longer there is the present of lead. Lead was initially used to Tetraethyl Lead (TEL) was added to gasoline to increase its octane number. So, if I increase octane number what is the advantage? So, I can use a petrol engine have a spark ignition engine have higher compression ratio, I can get better efficiency, and so, but however it was then found that lead has severe health hazards.

So, subsequently due to the health risks posed by lead in the engine exhaust, a transition was made to unleaded gasoline. So, today we use unleaded gasoline or unleaded petrol for this reason. So, I just wanted to introduce this as why lead was added in the first place because to essentially increase octane number notes on that. So, these are the various components of engine exhaust.

So, what we have discussed is a just a broad way of various components and what factors influence them. And in the next class, we are looking at how we can regulate them? What are the various ways in which emissions can be controlled? So that is something which we will discuss in the next class. Thank you.