Fundamentals of Automotive Systems
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Lecture - 26
Engine Emissions Part 02

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 right, if you recall from our discussion on the combustion process and compression ignition engines recall that CI engines are operated with leaner mixtures in the first place. So, the hydrocarbon emissions become lower because there any operated with leaner mixtures right.

Okay so, of course, the 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 do not burn the fuel properly.

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 right large extend 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 unburned carbon okay is a problem okay. So carbon does not get oxidized and unburned carbon which is obtained by when the hydrocarbons splits up right is a significant product in the exhaust of CI engines.

We will come to them shortly okay. So that is as far as hydrocarbon emission is 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 emission right. So, if you look at carbon monoxide, it comes in what to say? Incomplete what to say burning, incomplete combustion, of course right, because carbon is not fully oxidized to CO_2 right, So, it is partially oxidized to CO right.

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 combustion 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 CO_2 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.

So carbon monoxide as I mentioned you know like it also represents lost chemical energy that could have been converted to thermal energy so, that is 1 limitation alright. So, the next component in the engine exhaust that we are going to look at is NOX okay. So as we discuss, we are going to have NO and NO_2 under this category NO is what is called us Nitrogen Oxide right and in NO_2 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 O_2 to form NOX so that is the chemistry behind it. So what is the problem with NOX you know like NOX is also like harmful for the environment? Right so, when knocks in takes in energy from the sunlight, it can essentially lead to NO plus O and smog. And this what to say monatomic oxygen when it reacts to the diatomic oxygen it leads to ground level ozone, ground level ozone is harmful okay.

So, this is also not very safe right. So, you can see that NOX has all these detrimental effects. Of course, ground level ozone is also found when other emissions like hydrocarbons react with atmospheric gases. So, that is not a what to say very safe thing. So we can immediately see that

we can decrease NOX by decreasing the cylinder temperature right. 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 right, so there is a trade-off between engine performance and NOX reduction right.

So this is a what to say 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 particulates it is matter particulates are nothing but they are solid carbon particles.

Okay soot particles contained predominantly in the exhaust of CI engines, particularly when CI engines are operated at rich mixtures. So, one would see that particulates arise, you know like when you observe a bus or a truck you know like which is starting from rest, or even like let us say a bus slows down due to some whatever 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 just carbon particles okay. So, essentially, they are unburnt carbon particles will know like 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 okay, when the vehicle accelerates under load under, of course, we will also discuss how these are addressed.

So using emission control right 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 okay, so, that is when so, soot particles are clusters of carbon spheres unburned carbon they just collage they form this carbon spears and then they come out. So how can we reduce the soot particles? If we allow more time for them in the combustion chamber and significantly increase the cylinder temperature? Okay 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 the heat energy more the cylinder temperature and higher the cylinder temperature larger is the potential for NOX formation right. So, essentially, this is a trade off right so if you want to oxidize this particulate matter by having more residents time in, the combustion chamber we can reduce soot particles but that will lead to more NOx formation okay.

So we are going to discuss what is called as exhaust gas recirculation okay which is typically used to address this. What to say reduced particulate also okay, like we will see how sorry a particular exhaust gas recirculation is used to decrease NOX, but then like that has a counteracting effect on unburned hydrocarbons and particulates okay We are going to discuss that in the next class okay. So, but particulate one way is to also have higher injection pressure okay, 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 okay.

They are going to be like a spray so, better combustion but then this will reduce hydrocarbons and particulates, but then what can what happens? NOX formation is a problem okay that is a question mark right 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 okay. So, we will see how these are addressed. So, two more components of engine exhaust, the first one is sulphur.

So, Sulphur is typically, what to say present as part of the fuel mixture. So, traces of Sulphur can be found in fuel okay. So they get oxidized to form SO_2 and SO_3. And this is SO_2 and SO_3 okay 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 right, so when comes along with rain okay. We have what is called as acid rain okay so that is the impact of Sulphur you know like which is present in the fuel right and come out, when it gets oxidized.

It comes out another important component which has since now been addressed, it is no longer there is the presence of lead okay. 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 or a spark ignition engine have higher compression ratio, I can get better efficiency right, and so on, but however it was then found that lead has severe health hazards right.

So, subsequently due to the health risks posed by lead in the engine exhaust, okay 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 now it is not. So, these are the various components of engine exhaust.

So, what we have discussed is a just a broad overview 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 okay. Thank you.