Fundamentals of Automotive Systems
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Module No # 05
Lecture No # 21
Fuel Introduction Systems - Part 01

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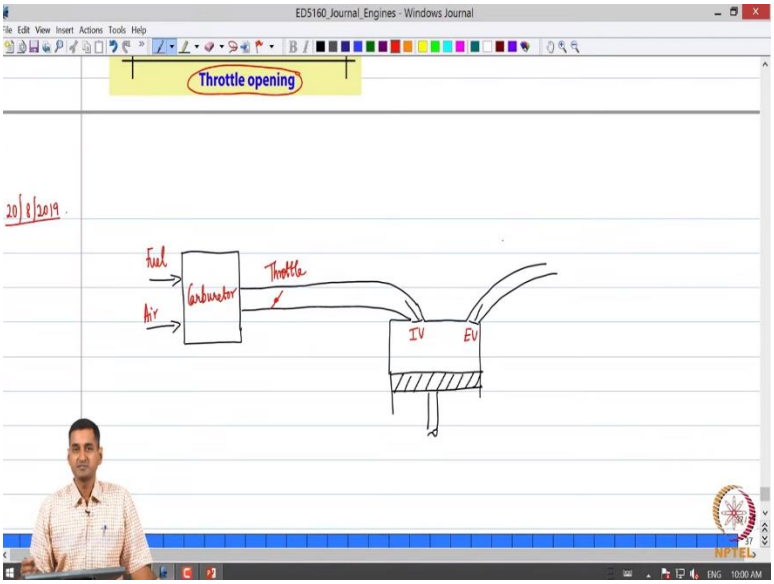

Okay greetings so welcome to today's class a quick recap of what we discussed yesterday.

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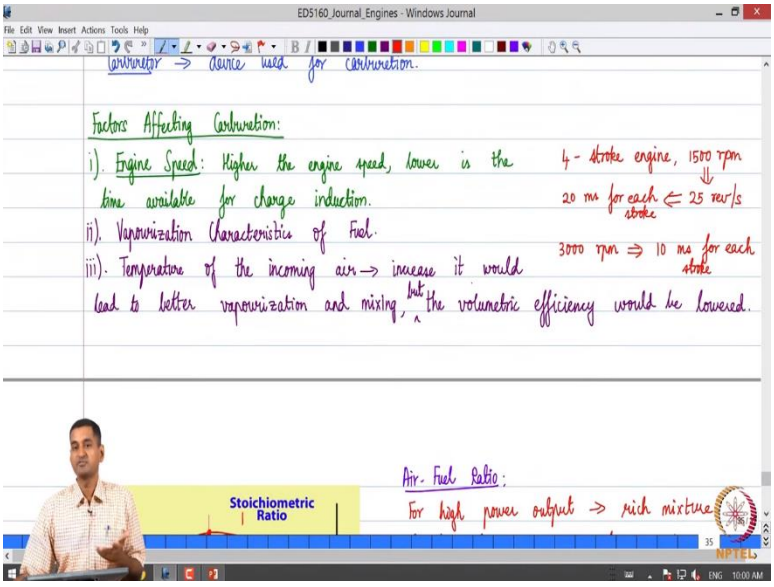

So yesterday we started with the process of carburetion which is nothing but the process of formation of a combustible fuel air mixture and it is subsequent introduction into the combustion chamber right to enable combustion.

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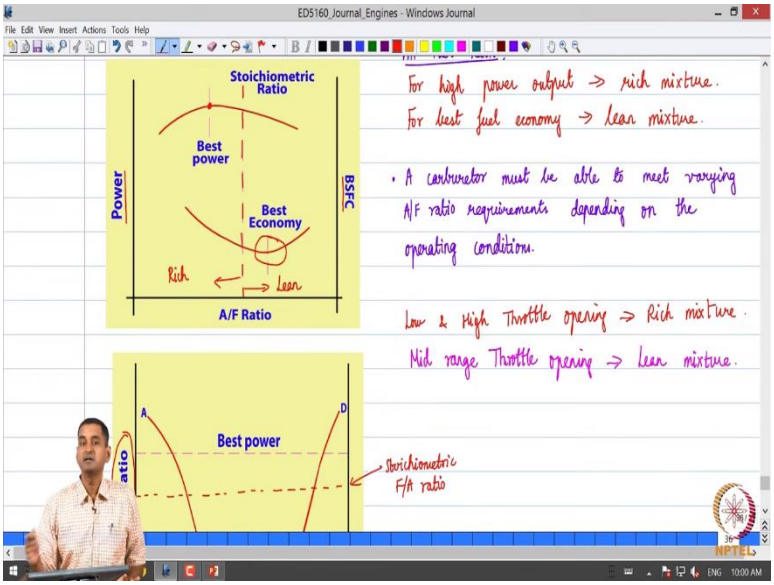

So we looked at what are the factor that affected carburetion and what types of mixture are required for getting the best power output and the best fuel economy right. So and we also saw that a carburetor needs to allow for a certain regulation of the fuel air ratio depending on the amount by which the driver presses the throttle pedal right in a car or in a motor cycle we rotate the throttle hand mechanism right.

So now the question becomes how do we map the throttle opening to the fuel air ratio that is expected out of the device. So this figure you know like shows a qualitative picture right of what is to be expected with respective the throttle opening.

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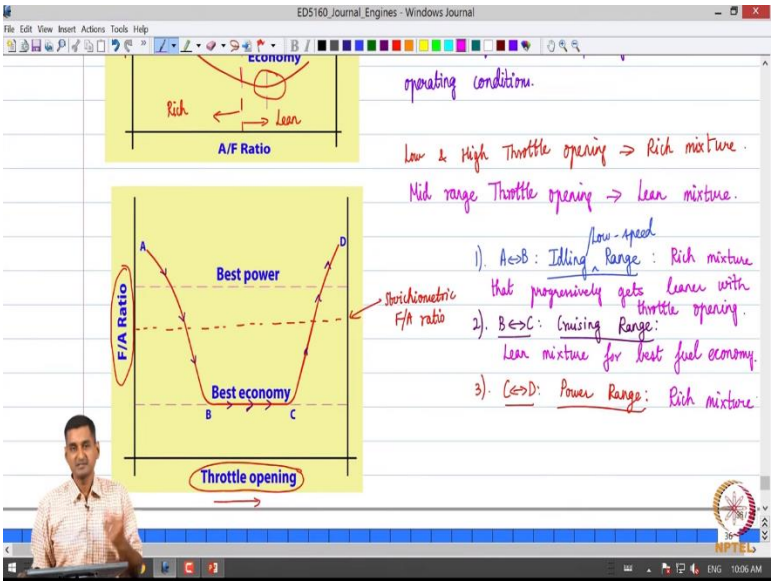

So as we can observe on the horizontal axis we have throttle opening and the vertical axis we have the fuel air ratio. Let us say the this the stochiometric fuel air ration the line horizontal line indicated by the red dashed line and the solid line ABCD gives a qualitative picture of what is to expected of the carburetor. So the region A to B is what is called as a idling range ok. And idling range and of course if you see low speed range ok so or the initial acceleration range and so on right.

So what is this idling range you know so essentially let us say suppose you know my car is parked at a signal so the vehicle is not moving but the engine is idling right. So at some low rpm to and we need to ensure that the combustion process is sustained in the engine so that I can pickup anytime I want. So but as I go from idling and then like I start accelerating we can see that the fuel air mixture becomes progressively leaner right.

It starts form a very rich mixture and then we see that the mixture becomes progressively leaner right as we keep on pressing the throttle opening. See what happens typically when we drive a car from rest, we put it in first gear we press the throttle opening gently right. So what we are doing is that from idling we are essentially accelerating right. So during the initial phase you know like we want a rich mixture which gets progressively leaner as you keep on pressing the throttle paddle right.

And let us say I go to a constant cruising speed then we settle down into a leaner range where we get the best economy okay. So the region what I will write it as a second region which is B to C is what is called as the cruising range ok. So a cruising range is where you know the vehicle going at almost constant speeds ok and you know like we want a lean mixture there right so just to sustain the vehicles motion.

Even when we look at the vehicle transmission, we also look at what are the forces that the powertrain needs to overcome when the vehicle is being operated under various condition. That is when it starts from rest, when it accelerates, when it is cruising and so on ok. And as we keep on pressing the throttle pedal you know and let us say we are cruising on a highway and suppose like I want to overtake a slower moving vehicle in front of me what we do?

We go to the adjacent lane if free and then like we press the throttle even further right. And then what I want is that like we I want high power output from the engine such that even at high speeds I get enough acceleration to overtake the vehicle and go ahead and so that is what is called as the power range. So the third range goes from C to D is what is called as a power range. So once again a progressively richer mixture is required as we go from C to D.

So during idling we need a rich mixture that progressively gets leaner with throttle opening ok. So that is what we would want from the fuel delivery system or the carburation system. Now when we are cruising, we want a lean mixture for best fuel economy. When we want to go the power range once again, we require rich mixture so that like we are able to get the required energy to provide the necessary forces right to essentially accelerate the vehicle at high speeds.

So these this is what one would want the carburetion system to look ok in terms of fuel air ratio. Now the question becomes why do we want a rich mixture during idling ok. So that is the question which we would naturally ask. So what happens is a following right.

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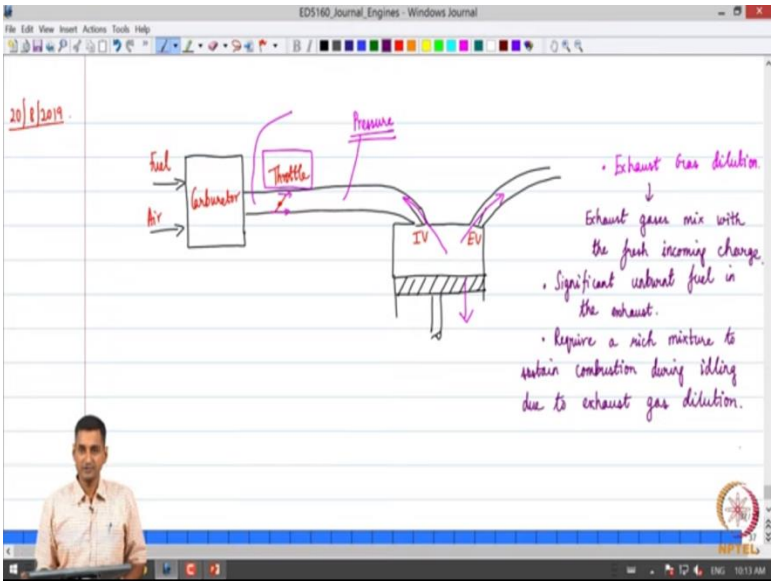

So let us say we consider this simple schematic wherein you know like we have fuel and air mixed through a carburetor and provided to the intake manifold right and to the inlet intake valve or the inlet valve right. Now this is the throttle opening ok or the throttle valve which is controlled by the driver. Imagine a scenario where let us say we are driving a car and we park the car at a signal the car is stationery at a signal ok.

So all of us would have remove our feet from the accelerator pedal. So the throttle pedal displacement would be zero but the throttle valve will have a small opening so that some air is still flowing into the engine but the opening would be the minimum possible right. And you know like the combustion process has to be sustained right because we do not want the engine to switch off right.

Now why do we require a rich mixture during this process? Imagine that in the fuel air mixture and air is taken at atmospheric pressure and then like brought into the combustion sorry brought into the carburetor. Now the throttle valve is completely what to say the throttle displacement is minimum is at zero and the throttle opening is at its minimum possible value ok. So and imagine a scenario where the piston is moving down so what can you say about the pressure here?

The pressure in this downstream of the throttle right with the throttle valve being at its minimum opening and when the piston is being pushed downwards ok this pressure is going to be small right it is not because this throttle is closed right. So there is only small very small opening. So

the mass flow rate of the fuel and air is also limited because the throttle opening is small ok. So the pressure here is going to fall down and the speed of the engine is also low so for each stroke there is more amount of time that is available.

Typically, what happens is that when these pressure is small and when the exhaust stroke happens for previous cycle and the exhaust gases are being pushed out please remember the exhaust gases will be a higher pressure and no process is perfect right. So and typically there may be a small amount of overlap between the time at which the exhaust valve is closing and the inlet valve is opening.

So during idling this time interval is also a little bit higher because the speed of the engine is also low. So what may happen? This exhaust gas pressure is high, this intake manifold pressure is low. So what can happen? This exhaust gases can also get into the intake manifold and that can be significant exhaust gas dilution. So what do I mean by exhaust gas dilution? Exhaust gas dilution means the exhaust gas mixes with a fresh charge right.

So this means the exhaust gases mix with the fresh charge, charge of fuel air mixture ok charge means fuel air mixture right. So obviously this is going to affect the combustion of the fresh charge right. So because for the combustion we need fuel, we need oxygen, and we need a mechanism for initiating the combustion process. But if I mix exhaust gases the amount of fresh air that is available will also reduce in proposition and the chances of the fuel not getting burned properly also may increase so the engine may shut down right.

So in order to prevent that or even in order to overcome that we have a rich fuel air mixture in the expectation that although all the fuel may not combust at least a significant part of it will still combust and sustain the combustion process. So idling is not beneficial because in idling we are going to have significant unburned fuel in the exhaust okay. But in order to sustain the combustion process due to exhaust gas dilution you know like we require a rich mixture ok to sustain the combustion process due to exhaust gas revolution.

So the primary reason for the behind the requirement of a rich mixture during idling is exhaust gas dilution ok. So we require a rich mixture to sustain combustion during idling due to exhaust gas dilution or in other words you know like the dilution of the fresh charge due to exhaust gases

mixing with them ok. So that is what is called exhaust gas dilution is it clear. So that is the those are the three regions the idling range, the cruising range and the power range ok.

And we have a qualitative map read with respect to the mixture expectations as far as throttle opening is concerned. Now having seen the requirements we will also see how these are actually realized in practice ok. We look at various fuel introductions system now ok. And then we will analyze one in detail ok. So that is going to be the flow of information.

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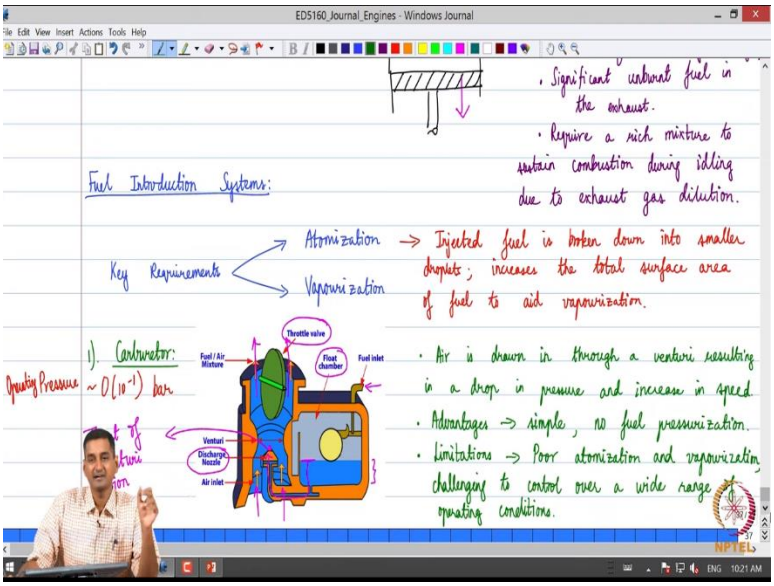

So if you look at the actual fuel introduction systems please recall that there are two key requirements right. In addition to other requirements broadly there are two key requirements one is atomization of fuel as we already discussed atomization means you know like we want the fuel droplets to be broken down into finer particles right. So and then we want those fuel particles to be vaporized right.

The liquid fuel must be changed into its gaseous states and mix with air so those are two key requirements right of any fuel introduction systems. So in atomization as we saw as we have already observed the injected fuel is broken down into smaller droplets. This increases the total surface area of the fuel exposed to air right to aid vaporization ok. So that is the bottom-line right.

So you break it down into smaller droplets smaller what to say fewer particles so that like we increase the surface area of the fuel particles and that can be vaporized right. So now the question becomes you know like what are the different devices you know like that are typically used to achieve this achieve these requirements. The first one although in general we call any device that does this carburetion as a carburetor, but you know like we will look at different would say generic names given to these devices ok.

The first one is what is called as a traditional carburetor or a conventional carburetor ok. So what is this device let us discus what this does. So a traditional carburetor you know like nowadays used in maybe some two wheelers and so on right is a following. So what happens is this so we have what is called as a flow chamber ok. You can visualize what is called as a flow chamber and we have fuel coming from the fuel tank and this is a float arrangement to ensure a sufficient amount of fuel level is always maintain in the float chamber ok.

So we will discuss this carburetor in more detail and analyze them. And what happens is this fuel is taken out and then like brought to what is called as a fuel discharge nozzle whose tip is in the throat section of a venturi. So what is a venturi, a venturi is a smooth reduction in the cross sectional area of a flow chamber right. So that is a venturi. So what is the throat of a venturi it is the place at which this the cross sectional area is the minimum right.

So this fuel discharge nozzle tip is placed at the throat of the venturi. Now what happens is the following let us say air is being sucked in you know like to the carburetor and air flows when air flows to the venturi at the throat the pressure drops right and the kinetic energy of the air increases so speed of air increases. So due to pressure difference between this fuel level right at the top and the throat the fuel starts flowing ok.

And it gets mixed with the air because the air is moving at certain speed it essentially takes the fuel atomizers it and then like takes it downstream. So the throttle wall is downstream of the venturi and the fuel air mixture goes out of the carburetor ok. So that is how the carburetor functions it. You know we will shortly look at a detailed discussion on carburetor ok. We will discuss it in more detail and also analyze them ok.

So these are the main attributes of a typical carburetor ok. So the main points are the so the air is drawn in through a venturi ok resulting in a drop in pressure and increase in speed ok. So that is what happens. So the fuel particles come out of the discharge nozzle and mixes with air ok. So that is what happens. So what are the main advantages? The main advantages is that like it is simple in construction and design ok and no external fuel pressurization is required ok.

So it the process happens by itself you do not need a separate pressurization device like I like a other mechanism that will shortly see to pressurize the fuel and then introduce it ok it happens by itself ok. So the flow of fuel happens on its own duel to this venturi reaction so the pressures typically in a carburetor or of the order of one tens of bars ok. So that is the range of pressure difference ok.

The operating pressure difference that means, that the pressure difference between the discharge nozzle tip and the flow chamber surface is the order of one tens of a bar ok. I am only talking about orders because the actual number varies from design to design right. So this is all the order of one tens of bar right. So no fuel pressurization so it is simple but there are few limitations. So compared to other design the atomization and vaporization are going to be a relatively poor.

Because anyway the higher the pressure difference you know like better is the atomization here the pressure difference is the lowest. So relatively you know like this going to result in poor atomization and vaporization and it is challenging to control over a wide range of operating conditions ok. Like so because we will see that you know like when we do analysis of a simple carburetor so it is going to be a challenge to accurately control it ok over a wide range of operating condition which is possible in other mechanisms. We will come to other mechanism shortly ok. so that is the simple carburetor ok right.

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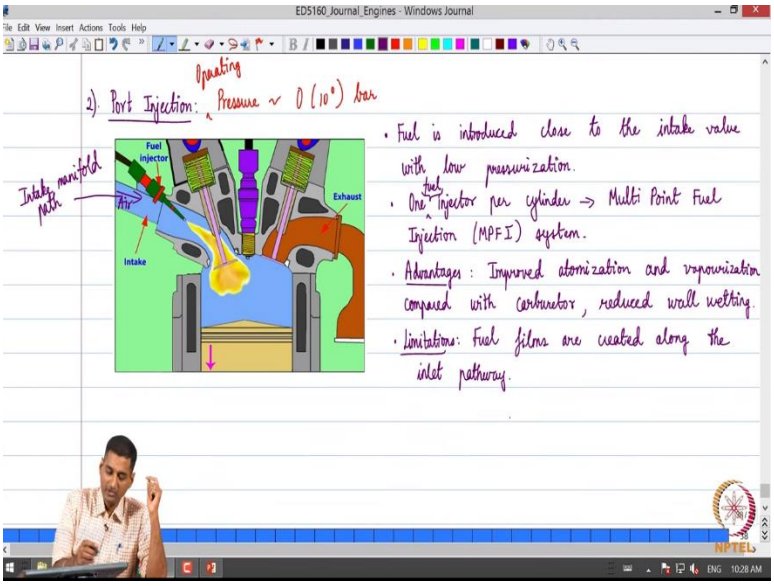

So now what is the next option that is available? The next option is available is what is called as port injection ok. So what is port injection you know like so we will look at it ok. So the first one is a simple carburetor I hope it is clear ok. So now let us come and look at what is called a port injection. So what happens in a port injector or a port injection system. So in this system what happens is that we have the piston and the cylinder and we see that this is the intake path right manifold path right.

So it comes from the intake manifold let us say we consider a multi cylinder engine or even a single cylinder engine you know like the air has to come from the intake system ok. The air starts flowing through the intake system and starts coming here. Now just before the inlet valve the fuel injector essentially sprays fuel at the appropriate time ok. So that is what is called as a port injection system.

So here the fuel is not mixed with air before the intake system ok as in a simple carburetor right. In a carburetor we have a carburetor where the fuel air mixture is prepared and then given to the intake manifold right. So here the injection of the fuel takes place after the throttle ok. The throttle will control the amount of the air which will come through into the intake system. And the fuel injector sprays fuel at the appropriate time instant in to this what is a intake area ok.

Just upstream of the intake valve so that is what is called as a port injection system ok. And the pressure range the operation pressure range of this port injection is of the order of 10 power 0 bar

ok like typically ones of bars ok. So you can see that it is one order of magnitude more than the simple carburetor. So higher the pressures what will happen the injection pressure the atomization of the fuel will be better right. And it will mix better with air and then like atomization and vaporization will what to say become more efficient ok.

So the main attributes of this system are that the fuel is introduced close to the intake valve with what to say low pressurization. So that in a simple carburetor there is no external pressurization it is a so here it is low pressure ratio ok so this enables better atomization. So typically, the most common configuration is essentially using one injector one fuel injector of course per cylinder in a multi cylinder engine.

So this system is what is called as a multi-point fuel injection system ok. So that is what is abbreviated as MPFI. So if you look at an if you encounter what is called as an MPFI engine that is what they use right. If you have a 4 cylinder engine you have four such injectors which inject fuel just upstream of the intake valve ok in a multi cylinder engine. So that is what it is called as an MPFI system ok injection system ok. So what are the advantages of this port injection?

So of course, improved atomization due to higher pressure and vaporization ok compared to compared with carburetor and it also has what is called as compared to your carburetor reduced wall wetting. So what is wall wetting you know like the fuel which has introduced can just settle on the walls or walls of the intake pipe right or the intake system right and that is going to be wasted right it is not correct.

So when you spray the fuel with some pressure we are going to reduce it ok when compared with the simple carburetor. So we are talking with respect to the carburetor ok. So it results in reduced wall wetting. But of course there are still some limitations ok. So, still fuel films are created along the inlet pathway ok. Although it is the fuel is introduced close to the intake valve still fuel films are a cost in the inlet pathway ok. So that is still a limitation ok of a port inject systems.