Fundamentals of Automotive Systems
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Module No # 05
Lecture No # 23
Analysis of Carburetor - Part 01

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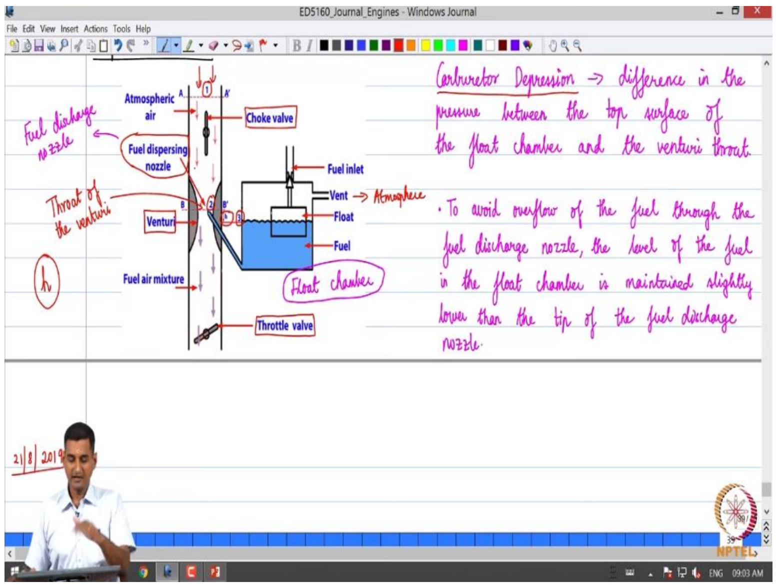

Ok good morning so let us get started with todays class ok. So a quick recap of where we stopped this in the last class. We were looking at the simple carburetor and this is a schematic of the same. So we have air taken from the atmosphere entering to the section labeled as A prime and that flows through a venturi which is a restriction in the cross section and the pressure drop drops when the air flows through the venturi ok.

And the pressure drop is a maximum when the throat of venturi right and that the air speed will be highest ok. And what we have is that like we have something called as a fuel dispersing nozzle or a fuel discharge nozzle placed at the throat of the venturi and that is connected to this flow chamber which contains fuel right. The flow chamber ensures that the fuel level is maintained at almost a constant value.

And essentially the as the air flow and the pressure drops there is a pressure difference that is created between the top surface of the fuel in the flow chamber and the pressure at the throat of the venturi. And that essentially results in the flow of fuel through the fuel discharge nozzle if the pressure drop is significant enough. So today we are going to derive some simple expressions to figure out first of all when will the flow happen and then what will be flow rates of the mass and the fuel. Because the flow rate of the mass and the fuel is going to affect the fuel air ratio right. So that is something which we are going to analyze today.

And as we discussed the top surface of the fuel in the flow chamber is placed a little bit below the tip of the fuel dispersing nozzle or the fuel discharge nozzle to ensure that there is no accidental leakage of the fuel right when there is a pressure drop ok. So we want to carefully regulate the amount of fuel you know like through the fuel discharge nozzle. So today we will also figure out the role of the throttle valve and the choke valve as we do the analysis.

And the term carburetor depression is a used to referred to the difference in the pressure between the top surface of the fuel in the flow chamber and the tip of the fuel discharge nozzle that is at the venturi throat ok. So just a few quick notations we define the section A prime as the section at the entry to the carburetor which we also label as section 1 ok. And the throat is labelled as BB prime which is also referred to as section 2 and section 3 is the top surface of the fuel ok in the float chamber.

So we will write down the corresponding equation as we go along. So before we begin our analysis let us look at the main components of the carburetor ok.

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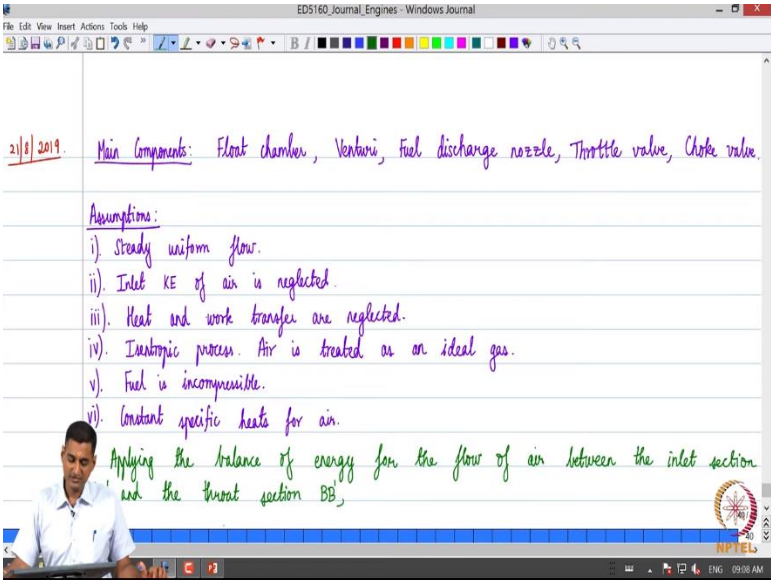

Just a quick recap to clearly list what are all the main components. So the main components include the float chamber where the fuel is stored and then we have the venturi ok then we have the fuel discharge nozzle or the fuel dispersing nozzle and then we have the throttle valve and the choke valve. So please note that the section downstream of the throttle valve is connected to the intake manifold and then to the intake valve ok so and thereby to the cylinder ok.

So that is the downstream connection ok from the throttle valve. So let us make a few assumptions in our analysis. So let me state all the assumptions that we are going to make. So the first assumption is that we are going to assume the flow process to be steady and uniform. Please note that these are all approximation ok. So the second one is the inlet kinetic energy of air is neglected ok.

So that means that section 1 is when air is taken from the atmosphere the speed of air is assumed to be small such that kinetic energy is negligible ok. So the next assumption is a heat and work interactions between the carburetor and its surrounding are neglected ok. So this is another assumption. So the next one is that we assume all the processes at least involving air to be isentropic ok and air is treated as an ideal gas ok.

So that like we can use the ideal gas equation of state PV equals MRT ok. The next assumption is it like we will assume that the fuel is incompressible and when we want to analyze the motion of the fuel the flow of fuel will use the Bernoulli's equation. Bernoulli's equation makes use of other assumption also right. Bernoulli's equation we write for flow along a streamline right. So we are going to make all those assumptions. And we will take constant specific heats for air ok.

So these are some assumption which we are going to make in this analysis ok. So now let us go and apply the balance of energy or the conservation of energy for the flow of air ok. So between the inlet section AA prime and the throat section BB prime. So let us apply the balance of energy ok between these two sections. So if I go up this is my inlet section AA prime and then we are going to look at what happens in the BB prime ok which is the throat section ok. So we are going to apply the balance of energy under all these assumption ok.

So this is where you know like as I mentioned as one of the outcomes of this course right is to use what we learnt in basic first year thermodynamic, fluid mechanics, dynamics and so on right for the analysis of automotive system. So under all these assumption we have already learned that the balance of energy can be rewritten in the form.

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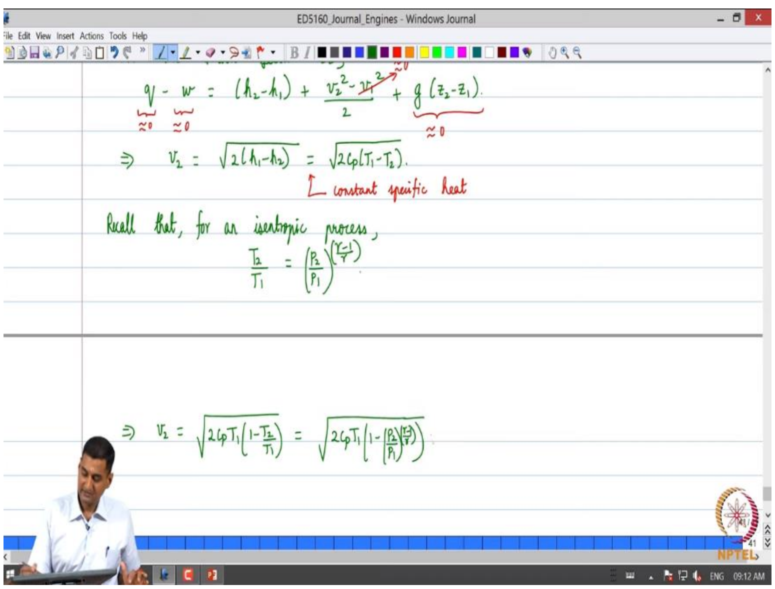

So it is going to be q - w = h2 - h1 + v2 square - v1 square by 2 + g times z2 - z1 ok. So this is the equation for the balance of energy. So now here applying all the approximation that we are assumption made we have neglected heat and work transfer. So we will take all those both terms of the left hand side to be almost 0. So and then we are neglecting the inlet kinetic energy of air ok and for the flow of air we will neglect the change and potential energy to be negligible ok. So considering the flow of air right so these are some approximation that we are making.

So if we do this so the speed of air at section 2 which is the throat we are going to get it as square root of 2 times h1 - h2. So assuming constant specific heat I can rewrite this as square root of 2 times cp times T1 -T2. So here we assume constant specific heats ok. So this is the simplification that we have ok. Now recall that for an isentropic process so we are going to use the isentropic equation of state what do we have for an isentropic process we know PV power gamma equal constant ok.

Intern if I want to write in terms of temperature so what we are going to get is it like we are going to get T2 / T1 is going to equal to P2 / P1 to the power gamma - 1 by gamma ok. So that is going to be the process relationship for isentropic processes relating pressure and temperature. So if we make use of this so the speed of air at the section 2 can be rewritten as square of 2 cp T1 - T2 let us take T1 outside so we are going to get 1 - T2 / T1 ok.

So we are just take we are just written T1 - T2 as T1 time 1 - T2 / T1 ok. So now we substitute for T2 / T1 we are going to get 2 cp T1 1 - P2 / P1 to the power gamma - 1 by gamma right. So this what we get as the expression for the speed of air at the venturi throat.

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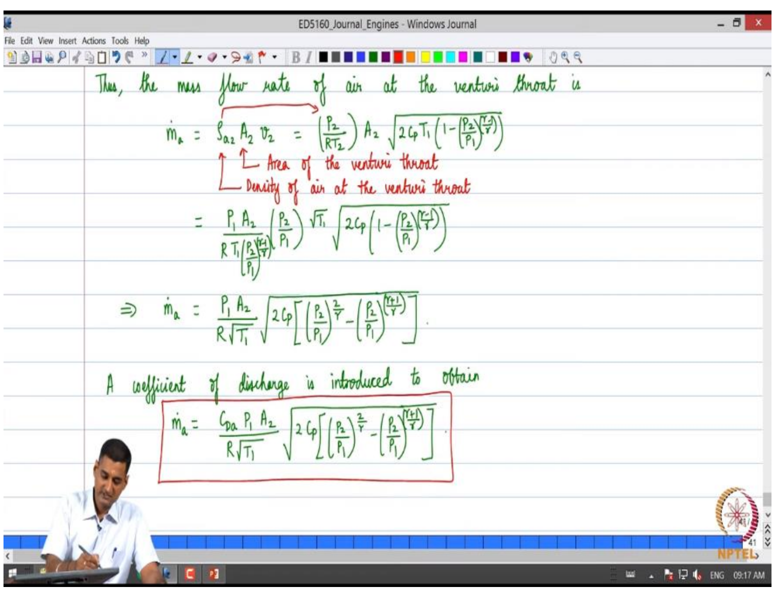

Now the mass flow rate of air at the venturi throat is of course this is obtain from applying the conversation of mass right. So I am directly going to write down the equation. So it is going to be Rho a2 A2 v2. So what is this what are these parameter? So this is the density of air at the throat section ok. So this is the cross section area of the venturi throat ok through which the air flows ok.

So the cross section area of the venturi throat through which the air is flowing ok. And v2 we have anyway evaluated above. So what are we going to get Rho a2 I can rewrite as P2 / RT2 correct. So this we are writing as P2 / RT2 right using the ideal gas equation of state. A2 you will keep it as it is then we will essentially substitute for v2 which will be cp T1 times 1 - P2 / P1 to the power gamma - 1 by gamma.

So now we are just going to make a few algebraic simplifications to get the final equation. So what we are going to do is that we will write this equation as P1 A2 multiplied by P2 / P1 to begin with right. So then we will get P2 A2 which was there in the numerator outside the square root right. So I am writing P2 as P1 times P2 / P1 I can do that and then like R times T2 we already know the process relationship right that is going to be P2 / P1 to the power gamma -1 by gamma correct.

So I am substituting for T2. Then what can I do I can take square root of T1 outside the square root ok. The T1 outside the square root then I will get square root of T1 then we are left with 2 cp 1 - P2 / P1 to the power gamma -1 by gamma right. We are almost set now. So if we simplify this we will see that we will get m dot a which is the mass flow rate of air through the venturi is going to be equal to P1 A2 divided by R times square toot of T1 ok.

So that we get because there is a T1 in the denominator and square of T1 in the numerator so we get square root of T1 in the denominator then if we simplify and take all the factors involving P2 by P1 inside the square root what we are going to get is a following. So we will get 2Cp P2 / P1 2 power gamma - P2 / P1 gamma + 1 by gamma ok so this is what ok. This is how this expression would be simplified.

So please note that we have made a quite a few assumptions in this analysis right and typically there are always going to be energy losses right. So what we is typically done in fluid mechanics is that once we derive such ideal expressions we introduce what is called as a coefficient of discharge which lumps all the losses and discrepancies which are encountered due to the simplifying assumption made in the analysis process right.

So a coefficient of discharge is introduced to obtain m dot a as CDa. So CDa is the coefficient of discharge for this flow of air ok times P1 A2 divided by R square root of T1 times square root of 2 Cp multiplying P2 / P1 2 power gamma -P2 / P1 gamma +1 by gamma. So this is the equation for the mass flow rate of air ok. So immediately one can observe that the mass flow rate of air through the venturi section depends on the ambient air condition right.

Because it is dependent on P1 and T1 which is which is represent the ambient air temperature or the intake air pressure and temperature right. So that is the first observation. The second observation is that like the mass flow of air obviously depends on the venturi throat area which is by and large fixed. Now more importantly how can I regulate this mass flow of air by regulation P2 because if you look all other parameter CDa is we have to calibrate based on experiments are is fixed ok.

T1 P1 are fixed once you give me an ambient source right, they may slightly vary ok depending on the local ambient conditions ok A2 is fixed once we fix the carburetor design. So the main what to say parameter or variable in this equation which can be changed with the engine operation to vary the mass flow rate of air is P2 ok. And that is where the role of these valves come into play ok.

Let us say the choke valve is completely open this throttle valve you know it can be rotator ok. When we apply the accelerator pedal, we are essentially going to rotate this throttle valve. So we are going to increase and decrease the opening downstream. And please note that throttle valve is connected to the intake manifold and thereby to the cylinder through the intake wall right. So what is going to happen?

If I open the throttle valve by varying extent I am going to adjust P2 right because let us say I open the throttle valve by a great extent what will happen the pressure at point 2 will further drop down right. Because it is going to be connected to the cylinder and during the suction stroke right. So the pressure at point 2 will drop. So once P2 drops we are going to have more mass flow rate of air into the cylinder right.

So then what will happen to the fuel flow rate? We are going to look at that now ok. So we can immediately observe that adjusting the throttle valve will essentially ensure that we get a variable flow rate of air ok depending on the operating condition ok. So let us go back yeah ok.

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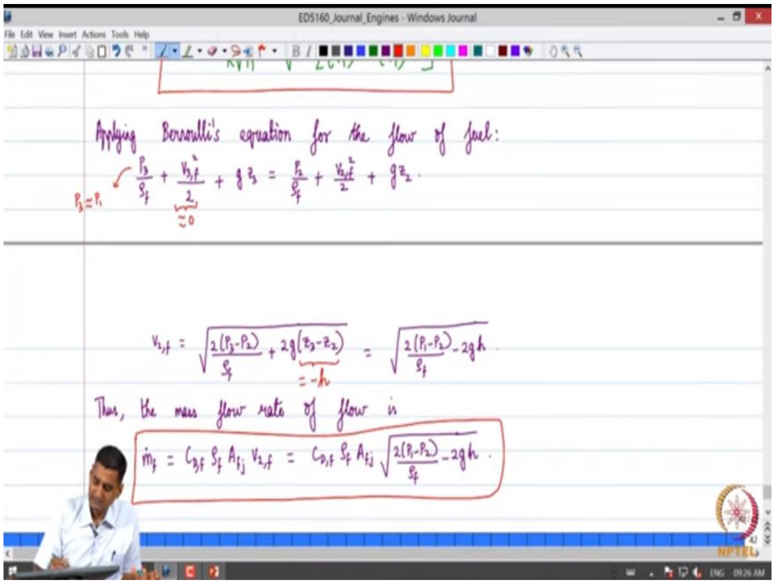

So now let us apply the Bernoulli's equation for the flow of fuel. So if we apply the Bernoulli's equation for the flow of fuel please note that we are going to apply the Bernoulli's equation between the throat section and the top surface of the fuel in the float chamber ok. So those are the 2 points between which we are going to apply the Bernoulli's equation. So if we apply the Bernoulli's equation what is going to happen?

We will get P3 / Rho f + v3 f square. Let me put the subscript f to indicate that is the speed of the fuel right by 2 + gz3 is going to be equal to P2 / Rho f + v2 f square / 2 + gz2 ok. Please note the subscript 2 indicates the section of the venturi throat, 3 indicates the what to say top surface of the fuel in the flow chamber ok. So that is the labeling that we are using and we the subscript f indicates fuel ok.

So once again we are going to make a few assumptions. The first assumption is that like in the flow chamber of the top surface the speeds are low so we neglect the kinetic energy of the fuel ok. So that is something which we are going to neglect. So if we do this and please note that P3 what can we say about P3 it is almost going to be equal to P1 right. So P3 is vented to the top surface of the fuel is vented to the atmosphere in the float chamber right.

So P3 is going to be near atmospheric and that is going to be a pressure at the intake section to the carburetor also. So P3 is approximately going to be equal to P1. So if we make all these approximations what we are going to get is the following. So v2 f is going to be equal to square root of 2 times P3 -P2 divided by Rho f + 2g z3 - z2 correct I am just rearranging the term. Now what does z3 - z2 it is going to be -h because z point 3 is below point 2 ok z3 - z2 going to be -h.

You remember that parameter h that we marked in the schematic. So this was h right it is the difference between the top surface of the fuel and the tip of the fuel discharge nozzle ok. So that is going to be h as a result. So this equation will simplify as 2 times square root of we are replacing P3 with P1 to a - 2 gh ok. So thus, mass flow rate of fuel is including a coefficient of discharge is going to be CDf.

So CDf is going to be coefficient of discharge for the fuel flow system ok. So CDf time Rho f which is the density of the fuel times the area of the fuel discharge nozzle ok I cannot take A2 that is the throat of the venturi right that the cross sectional area of the throat. So now I need to take the area of the fuel discharge nozzle which we are calling as Afj ok times v2f. So if we get this we will get CDf time Rho f time Afj multiplied by square root of 2 P1 - P2 / Rho f -2 gh ok. So this is what we will get ok. So this is the expression for the mass flow rate of fuel ok.

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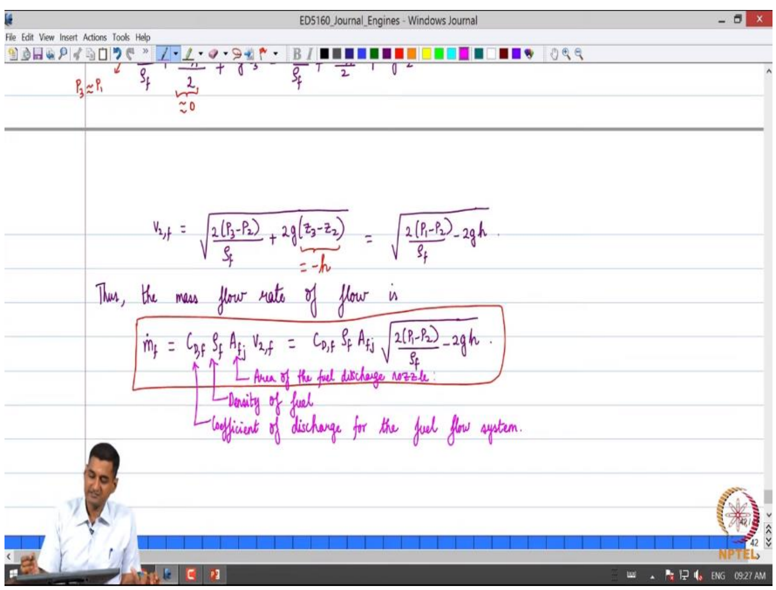

Please note that CDf is the coefficient of discharge for the fuel flow system ok. Rho f is the density of fuel ok Afj is the area of the fuel discharge nozzle ok at the tip ok that is Afj ok. So these are the various parameters.