Fundamentals of Automotive Systems
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Lecture - 27
Analysis of Carburetor Part 01

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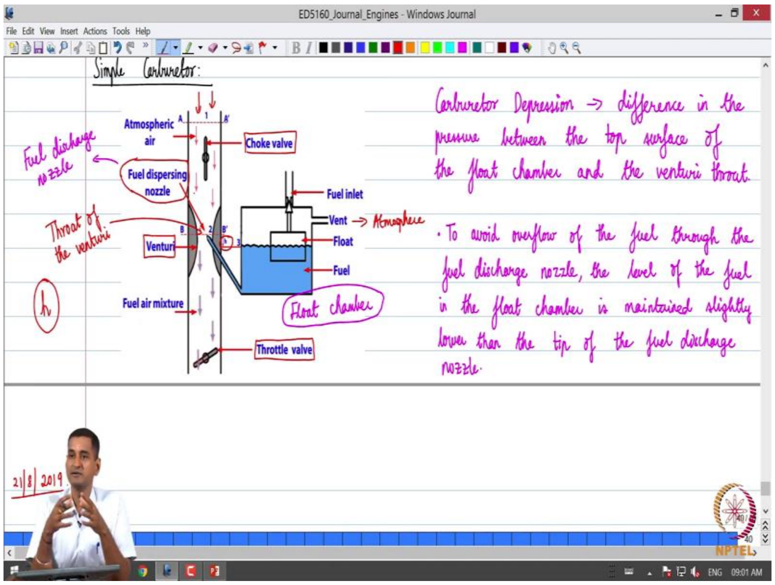

So let is get started. So a quick recap of where we stopped this. In the last class, we were looking at the simple carburetor and this is a schematic of the same. So, we have had taken from the atmosphere entering to the section labeled as a prime and that flows through venturi which is a restriction in the cross section and the pressure drop when the air flows through the venturi and the pressure drop is a maximum when the throat of the venturi and there the as speed will be the highest.

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 century and that is connected to this flow chamber, which contains fuel. The flow chamber ensures that the fuel level is maintained at almost a constant value and essentially the as air flows and the pressure drops there is a pressure differential which is created between the top surface of the fuel in the flow chamber and the pressure are the throat of the venturi.

And that essentially resulted 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 the flow rates of the mass under fueled because the flow rate of the mass and the fuel is going to affect the fuel air ratio. So, that is something which we are going to analyze today.

And as we discussed the top surface of the fuel in the float chamber is placed a little bit below the tip of the fuel dispersing nozzle or the fuel distance nozzle to ensure that there is no accidental leakage of fuel when there is a pressure from. So, we want to carefully regulate the amount of fuel to the fuel discharge nozzle. So, we will Today we will also figure out the role of the throttle wall on the choke wall as we do the analysis and the term carbureted depression is used to refer 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 a veturi through.

So, just a few quick notation We define the section A prime as the section or the entry to the carburetor which we also label as section 1 and the throat is labeled as BB prime which is also referred to as section 2 and section 3 is the top surface of the fuel in that flow chamber So, we will write down the corresponding equations as we go along.

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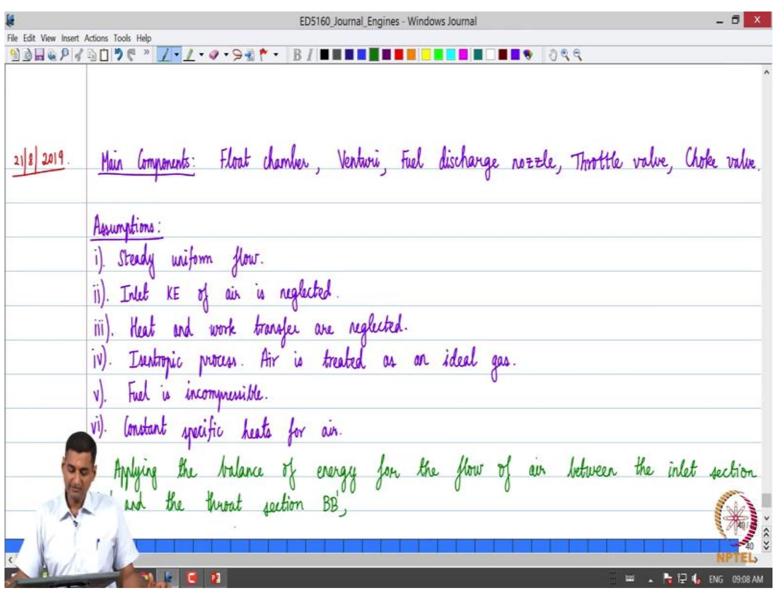

So before we begin our analysis, let is look at the main components of the carburetor. Just a quick recap to clearly list what are all the main components. So the main components include the flow chamber where the fuel is stored and then we have the Venturi. Then we have the fuel discharge nozzle or the fuel dispersing nozzle and then we have the throttle valve and the Choke valve So, please know that the section downstream of the throttle valve is connected to the intake manifold and then to the intake valve.

So on their way to the cylinder. So that is the downstream connection from the throttle valve. So let is 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 approximations. So the second one is that the inlet kinetic energy of a is neglected so that means that at section 1 when the air is taken from the atmosphere the speed of air is assumed to be small such that the kinetic energy is negligible.

So the next assumption is that heat and work interactions between the carburetor and its surroundings are neglected so there is another assumption. The next one is that we if we assume all the process says at least involving air to be isentropic, and air is treated as an ideal gas so that like we can use ideal gas equation of state PV = MRT. The next assumption is that like we all assume that the fuel is incompressible and when we want to analyze them motion of the fuel the flow of fluid we lose the Bernoulli’s equation makes use of other assumptions also Bernoulli’s equation we write for flow along this streamline.

So, we are going to make all those assumptions and we will take constant specific heat for air. So, these are some assumptions which we are going to make in this analysis. So now let is go and apply the balance of energy or the conservation of energy for the flow of air, so between the inlet Section A prime and the throat section BB prime so let is apply the balance of energy between these two sections. So, if I go up, so this is my inlet Section A prime and then like we are going to look at what happens at BB prime okay which is the throat section.

So, we are going to apply the balance of energy under all these assumptions so this is where, you know, like as I mentioned as one of the outcomes of this course it use what we learned in basic first year thermodynamics fluid mechanics dynamics and so on for the analysis of automotive systems. So, under all these assumptions, we are already learned

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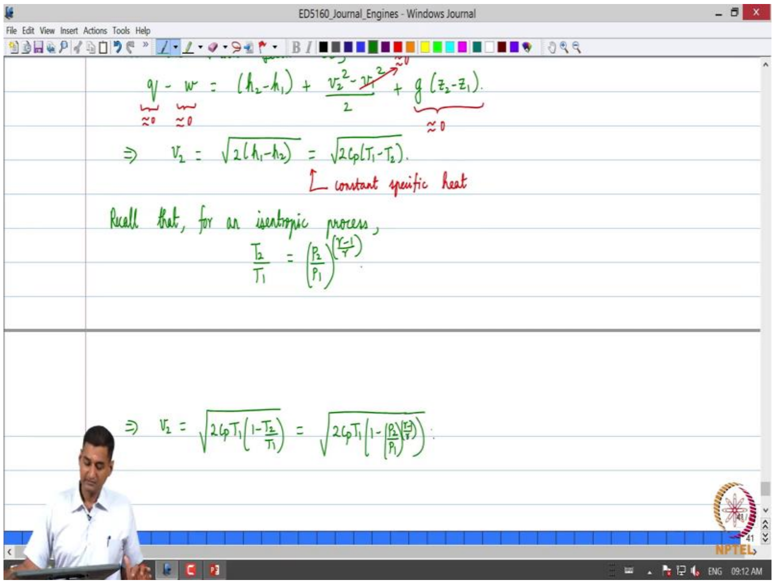

That the balance of energy can be rewritten in this form. So, it is going to be q - w = h 2 - h 1 + v 2 squared - v 1 squared by 2 + g times z 2 – z 1. So, this is the equation for the balance of energy. So, now here are applying all the approximations that we are assumptions made, we have neglected heated work transfer So, we will take all those both terms on the left hand side to me almost 0 so and then we are neglecting the inlet kinetic energy of a and for the flow of air, we will neglect the change in potential energy to be negligible. So, considering the floor of air.

So, these are some approximations that we are making. So, if we do this, so the velocity speed of air at section 2 which is the throat, we are going to get that as 2 square root of 2 times h 1 - h 2. So, assuming constant specific heats I can rewrite this square root of 2 times Cp times the T1 – T2. So, here we assume constant specific heats. So, this is the simplification will be happen. 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 equals constant if I want to write in terms of temperature, so what we are going to get is it like we are going to get T 2 by T 1 is going to be = P2 by P1 to the power gamma - 1 by gamma. So that is going to be the process relationship for isotropic process relating pressure and temperature. So, if we make use of this, so, the speed of air at section 2 can be rewritten as squared off 2Cp T1 – T2 let is take T1 outside. So, we are going to get 1 – T2 by T1.

So, we have just taken we have this return T1 – T2 as T1 times 1 – T2 by T1. So, now we substitute for T2 by T1 we are going to get 2Cp T1 – P2 by P1 to the power gamma - 1 by gamma.

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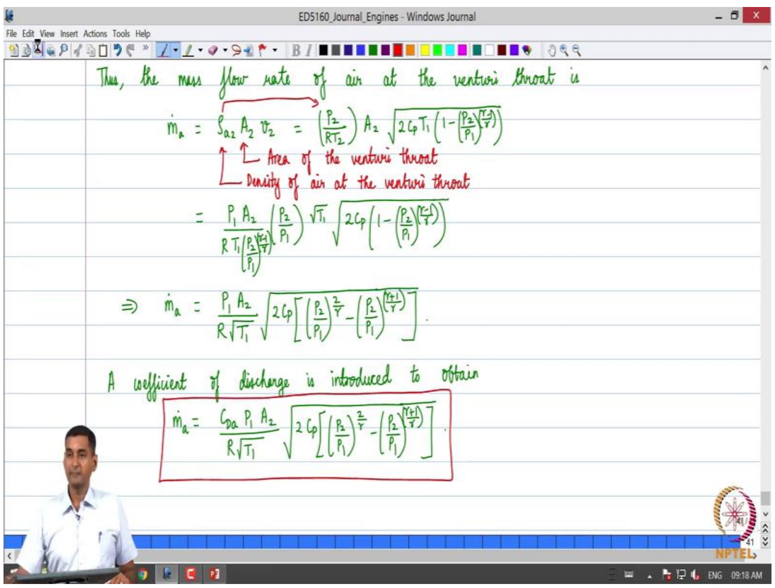

So, this is what we get as the expression for a speed of air as the venturi throat. Now the mass flow rate of air at venturi throat is of course this is a pain from applying the conservation of mass, so I am directly going to write down the equation. So it is going to be row A2 A2 V2 so what is this what are these parameters, so this is the density of air at the throat section. So this is the cross section, area of the venturi throat through which the air flows so cross sectional area of the venturi throat which the air is flowing. And we do we have any way of elevated ago. So, what are we going to get row A2 I can relate us P2 by RT2 correct.

So, this we are writing as P 2 by RT 2 write using the ideal gas equation of state yet we will keep it as it is then we will essentially substitute for V2 which will be CP T1 times 1 – P2 by 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 then we will write this equation as P1 A2 multiplied by P2 by P2 to begin with right.

So, then we will get P2 A2 which was there and that numerator outside A square root, so I am writing P2 as P1 times P2 by P1 I can do that and then like R times T2 we already know the process relationship, That is going to be P2 by P1 to the power gamma - 1 by gamma. Correct. So I am substituting for P2 then what can I do I can take square root of T1 outside the square root the T1 outside the square root and I will get square root of T1 then we are left with 2CP 1 – P2 by P1 to the power gamma - 1 by gamma we are almost set down.

So, if we simplify this, we will see that we will get m dot a, but just mass float off air through the century is going to be equal to P1 A2 divided by R time square root of T1. So that we get because there is a T1 in the denominator and squared of T1 in the numerator so we get squared off the one 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 as a following.

So we will get 2CP P2 by P2 2 power gamma - P2 by P1 gamma + 1 by gamma. So there is one, so there is this expression will be simplified. So please note that we have made a quite a few assumptions and this analysis 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 assumptions made in the analysis process right.

So, a coefficient of discharge is introduced to obtain m dot a as CDa is the coefficient of discharge for this flow of air times P1 A2 divided by R square root of T1 times square root of 2CP multiplying P2 by P1 2 power gamma - P2 by P1 gamma + 1 by gamma. So, this is the equation for the mass flow rate off air. So, immediately one can observe that the mass flow rate of air through the venture resection depends on the ambient air condition because it is dependent on P 1 and T1 which is which represent the ambient temperature or the intake air pressure and temperature.

So, that is the first observation. The second observation is that like the mass of air obviously depends on the venturi throat area which is by and large fixed. Now more importantly how can you regulate this mass flow of air by regulating P2 because if you look at all the other parameters CDa as we have to calibrate based on experiments R is fixed T1 P1 are fixed once you give me an Ambien source right and they may slightly vary depending on the local ambient conditions, the A 2 is fixed once we fixed 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 of air is P2. And that is where the role of these valve come into play let us say the choke valve is completely open this throttle wall in all it can be rotated. When we apply the accelerator pedal we are essentially going to rotate the throttle wall so, we are going to increase and decrease the opening downstream and please know that the throttle all is connected to the intake manifold and thereby to the cylinder through the intake wall.

So, what is going to happen you find open the throttle wall by varying extents, I am going to adjust P2 right because let is say I open the throttle valve by a great extent what will happen the pressure at point 2 will further drop down, because it is going to be connected to the cylinder During the suction stroke 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.

So, then what will happen to the fuel flow rate we are going to look at that now so we can immediately observe that adjusting the throttle wall will essentially ensure that we get a variable flow rate off air depending on the operating conditions. So, let us go back.

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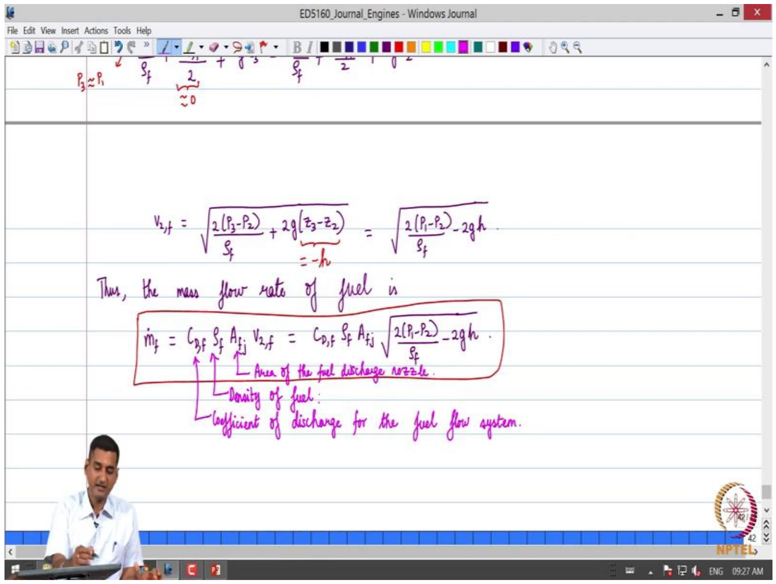

So now let us apply the Bernoulli's equation for the flow of fuel. So, if we apply the Bernoulli equation for the flow of fuel, please know that I we are going to apply the Bernoulli equation between the throat section and the top surface of the fuel in the flow chamber. So those are the 2 points between which we are going to apply the Bernoulli equation. So if we apply the Bernoulli equation what is going to happen we will get P3 by rho f + V2 f square.

Let me put the subscript F to indicate that that is the speed of the fuel by 2 + g z3 is going to be equal to P2 by rho f + V2 f square by 2 + g please note the subscript two indicates the section at the venturi throat. Three indicates the what is the top surface of the fuel in th flow chamber. So that is the labeling that we are using and the subscript f indicates fuel. So, once again we are going to make a few assumptions.

The first assumption is that like in the flow chamber or the top surface, the speeds are low. So we neglect the kinetic energy of the fuel. so that is something that we are going to neglect. So if we do this, and please note that P3 what can we say about P3 is almost going to be equal to P1 because P3 is vented to the top surface of the fuel is vented to the atmosphere in the flow chamber.

So P3 is going to be near atmospheric and that is going to be the pressure or 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 a following. So V2 f is going to be equal to this square root of 2 times P3 – P2 divided by rho f + 2 g z3 – z2 correct and rearranging the terms. Now what is the 3 - R by 2.

It is going to be - h because .3 is below .2, this was the 3 - 2 it was going to be - h you remember that parameter h that we marked in the schematic. So this was h the difference between the top surface of the fuel and the tip of the fuel discharge nozzle. So that is going to be h so as a result, this equation will simplify as 2 times square root of we are replacing P3 with P1 – P2 g h. So that is the mass fluid of fuel.

Including a coefficient of discharge is going to be CD f. So, CDF is the coefficient of discharge for the fuel flow system, so CD f times rho f, which is the density of the fewer times the area of the fuel discharge nozzle, I can take A2 that is the throat of the venturi 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 Afg times V2 f.

So, if we get this will get CD f times rho f times Afj multiplied by square root of 2 P1 - P 2 by rho f – 2gh. So this is what we will get so this is the expression for the mass flow rate of fuel please note that CD f is the coefficient of discharge for the fuel flow system rho f is the density of fuel AfJ is the area of the fuel discharge nozzle and that is safety. So these are the various parameters.