Thermal Engineering: Basic and Applied
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Lecture - 49
Mass Flow Rate of Fuel and limitations of Simple Float Type Carburettor

I welcome you all to the session of thermal engineering basic and applied. Today we sell try to derive the expression of mass flow rate of fuel through the carburetor. In the last class we have discussed about the simple float type carburetor and we could establish the expression of the mass flow rate of air. For a simple flow type carburetor though we had the expression of the Mass flow rate of air we also need to calculate the mass flow rate of fuel.

And then we can figure out the fuel air ratio which is important for the operation of the internal combustion engine particularly for the SI engine because this particular element is essential for the operation of spark ignition engine. And then also we will try to discuss the limitations of this simple flow type carburetor and you know that the carburetor is sample flow type.

So, it may not be always possible to provide required air fuel mixture or fuel air mixture by using this carburetor to the engine at varying load and we shall discuss those aspects even in today's class. So, if we try to obtain the expression of the mass flow rate of fuel we need to draw the simple flow type carburettor again.

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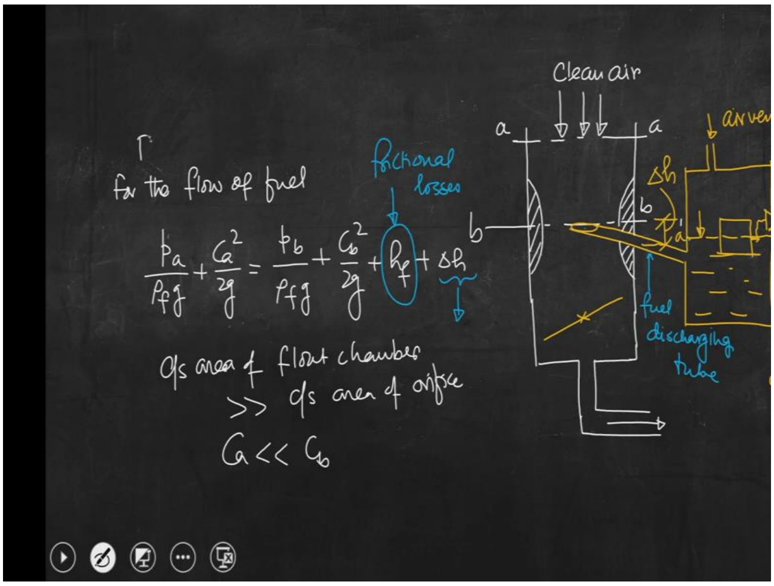

So, if we try to draw this simple float type carburetorr. So, this is the orifice and fuel discharging tube. And if we provide the Venturi like this because we had seen in the last class, this Venture is provided only to have a pressure difference in the course of flow of air through the carburetor. So, this is section a-a.

So, we have this is 2 engine cylinder and we have one throttle valve here and this is the float chamber and that is connected like this. So, this is fuel Supply, this is air vent and now this is the height difference Δh. So, we could establish the expression of the mass flow rate of air.

So, today we shall try to have the expression of the flow rate of the fuel. So, now see this is again you know open to atmosphere. So, this is also atmospheric pressure acting on the fuel surface and if we consider this is surface a-a, this is also atmospheric pressure of air, this is also the atmospheric pressure acting on the fuel surface and this section you are considering a-a while this section is b-b.

So, if we write the equation foe flow fuel between section $a' - a'$ and section b-b

$$\frac{p_a}{\rho_f g} + \frac{C_a^2}{2g} = \frac{p_b}{\rho_f g} + \frac{C_b^2}{2g} + \Delta h + h_f$$

So, in this case this is you can see this is the energy equation steady flow. Now you are familiar with this equation because you have studied in fluid mechanics this is modified form of the Bernouli equation. So, this is valid for the inviscid incompressible fluid. So, now this is basically the height difference between the surface of the fuel in the float chamber and this orifice. So, this is orifice, this is fuel discharging tube.

So, the orifice of the fuel discharging tube and this height of the fuel in the float chamber is Δh, then that is taken care in this equation. So, this particular height difference is also very important because what we have discussed in the last class that we would like to have a drop in pressure of the air while it is flowing through this passage.

And that pressure difference is responsible to have the flow of fuel from float chamber to this particular orifice point. So, while we are considering flow of fuel from float chamber to that particular point that is fuel discharging point, we also need to take the static height difference. So, that particular static height difference is already taken care of while you are trying to establish the expression of mass flow rate of fuel and this particular term is the frictional losses.

I mean we are writing frictional losses because internal friction is the friction between the fluid layers while external friction refers to the friction between solid wall and the adjacent liquid layer. So, again if we see that the cross sectional area of the float chamber is much higher than the cross sectional area of the orifice point and then we can consider $C_a \ll C_b$.

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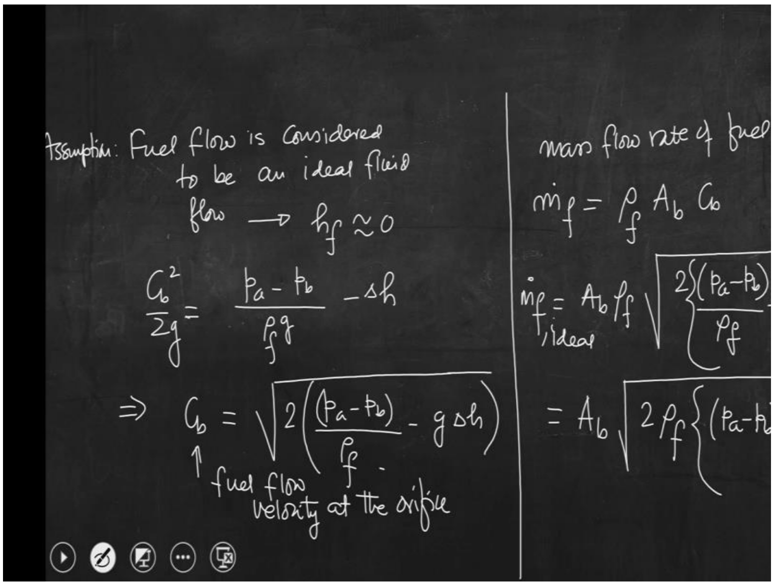

And if you assume that fuel flow is considered to be ideal fluid flow, then $h_f = 0$

$$\frac{C_b^2}{2g} = \frac{p_a - p_b}{\rho_f g} - \Delta h \rightarrow C_b = \sqrt{2\left(\frac{p_a - p_b}{\rho_f} - g\Delta h\right)}$$

So, this is the velocity of fuel at the orifice point that is the at the discharging point. So, now if we know the fuel flow velocity then we can calculate the mass flow rate of fuel

$$\dot{m}_f = \rho_f C_b A_b = \rho_f A_b \sqrt{2\left(\frac{p_a - p_b}{\rho_f} - g\Delta h\right)} = A_b \sqrt{2\rho_f\left((p_a - p_b) - \rho_f g\Delta h\right)}$$

So, this is the expression of the mass flow rate of fuel but we had taken an important assumption is that we have considered the flow of fuel to an ideal fluid flow that is not possible in reality, also try to understand that you know while we have established the expression of mass flow rate of fuel, we also did not consider the effect of surface tension that would be there why it is important because if we try to go back to the schematic depiction we can see that fuel will flow, this fuel will flow through a tube or a flow path which is very small. So, when the length scale of the fluidic pathway is reduced the surface tension force will be an important force to be considered in the analysis.

But we did not consider that, we have also ignored the frictional losses that is both internal and external frictions and accounting these factors, the expression that we have established here is not the actual mass flow rate of fuel that we are going to get. So, this is Δp that is the pressure drop between section b-b and $a' - a'$.

And I have considered that pressure at section $a' - a'$ and $a - a$ is p_a that is atmospheric pressure in both sections. So, the pressure difference is important to have a flow of fuel from float chamber to that orifice or fuel discharging point and that pressure difference is created by the flow of air and that is why this Venturi is provided. But the expression that we have obtained today is not the actual expression of the mass flow rate of fuel.

Why, in the last class if we try to recall we assume that the process is modeled by an isentropic process but we can see that the flow area is reduced and if the flow area is reduced there will be kind of several losses. So, we cannot ignore all those losses trivially and the isentropic flow behaviour will not be the actual scenario. So, the mass flow rate of air that we had in the last class again was the ideal mass flow rate and to obtain the actual mass flow rate we had to multiply with discharge coefficient c_{da}. And as we have discussed accounting for the frictional losses, accounting for the surface tension effect that will be there because of small orifice and also the specific gravity of the fuel, actual mass flow rate of fuel should be less than the ideal mass flow rate that we have established in today's class.

And that means our analysis that is the ideal fluid flow will deviate in real practice accounting for these factors that is the specific gravity of the fuel, surface tension effect as well as frictional losses and hence the mass flow rate of fuel is obtained here is the ideal mass flow rate.

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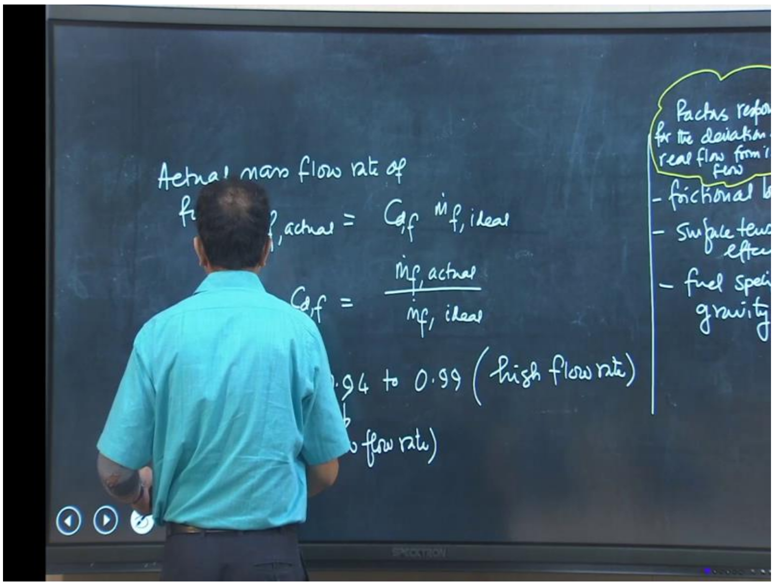

So, that means if we write the actual mass flow rate $\dot{m}_{f,actual} = \dot{m}_{f,ideal} \times C_{d,f}$. So, C_{df} discharge coefficient varies from 0.94 to 0.99. So, that means this particular coefficient is responsible for the deviation of actual flow. So, frictional losses, surface tension effect and fuel specific gravity, all these three factors are the responsible factors for the deviation of ideal flow and for the deviation of the flow which is there from floor chamber to the orifice point from the ideal flow behaviour.

So, though could establish the expression assuming the flow to be an ideal flow but all these factors are responsible for the deviation of actual flow from the ideal one and it is because of these factors, this coefficient is defined and the value of this coefficient is varying from low flow rate to high flow rate that is from 0.94 to 0.99. So, these are the factors responsible for the deviation of real flow from idle flow.

So, now let me discuss an important point. So, we had assumed that this is steady state steady flow, even we had written that energy equation. So, we are assuming whether it is flow of air or flow of fuel from floor chamber to the orifice point, flows are steady.

So, that means steady flow behaviour whether it would be case in real applications or not that we need to know, the flow will be steady if there are certain points. And if we can fulfill all those points while the flow is taking place whether it is a flow of air or flow of fuel. You know that if that particular carburetor is responsible to supply air fuel mixture or fuel air mixture to a cylinder and if the cylinder is single cylinder and four stroke what we had seen in a four stroke single cylinder engine we need to supply airflow mixture only during intake stroke remaining three other Strokes are the ideal stroke and we do not require to supply air fuel mixture. So, that means it is a kind of periodic supply of air fuel mixture to the cylinder during the operation of the engine and that periodic supply of airflow mixture to a cylinder and that is single cylinder four stroke engine will bring unsteadiness in the flow of air. If that particular aspect induces unsteadiness in the flow of air, the flow of fuel also will be unsteady. So, the assumptions that we had taken in the last class to arrive at the expression of the mass flow rate of air that is steady state steady flow. So, this would be valid if we need to supply fuel air mixture using this simple flow type carburetor to multi cylinder engine and if it is two stroke engine.

So, the steady state steady flow assumption is more valid for the multi cylinder engine and two stroke engine, why? for the multi cylinder engine say we are having four cylinders then if we design in such a way that when there is intake stroke if the intake stroke is in the first cylinder remaining three cylinders are having or are executing different other strokes and when intake stroke is over in the first cylinder, may be in the second cylinder intake stroke is started.

So, what we can do we can have more or less a continuous supply of air fuel mixture from this carburetor to the engine cylinders. And that will lead to almost steadiness of the airflow mixture. Also if it is four stroke engine only one intake stroke vis-a-vis there are three different other Strokes but for the 2 stroke engine in one intake versus one other stroke.

So, the periodic filling even if it is a single cylinder engine the time gap between 2 consecutive intake strokes is very less and we also can approximate the flow of air to be almost steady. So, unsteadiness in the flow behaviour will be there if a simple flow type carburetor is designed to supply fuel to a single cylinder engine and four stroke engines instead if it is designed to supply airflow mixture to multi cylinder engine and 2 stroke engine the approximation steady state steady flow is more valid.

So, basically no assumptions behind the flow of air that we had taken the last class except we had considered that frictional losses are negligibly small but we had started our discussion from the steady state steady flow equation, and we have also assumed that the process is modeled by an isentropic process.

But if we assume that a to be an incompressible fluid and if we write the equation between these 2 sections.

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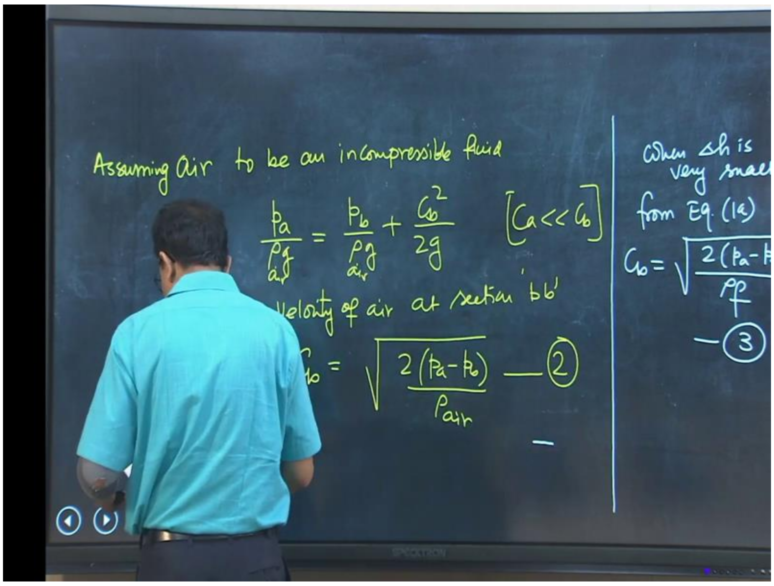

$$\frac{p_a}{\rho_a g} = \frac{p_b}{\rho_a g} + \frac{C_b^2}{2g}\ (C_a \ll C_b)$$

$$C_b = \sqrt{\frac{2(p_a - p_b)}{\rho_a}}$$

So, if we consider that Δh is very very small then from eq 1(a)

$$C_b = \sqrt{\frac{2(p_a - p_b)}{\rho_f}}$$

So, that means if Δh is very small, then very small pressure difference is needed for the flow of fuel from float chamber to the orifice point or fuel discharging point. And if this is the case and if we assume that air have to be an ideal fluid then the flow, then we can see by looking at equation 2 vis-a-vis this equation 3, these two expressions are almost identical except this is ρ_a here and this is ρ_f. So, that means flow of fuel at section b-b and flow of here at section b-b these 2 are constants.

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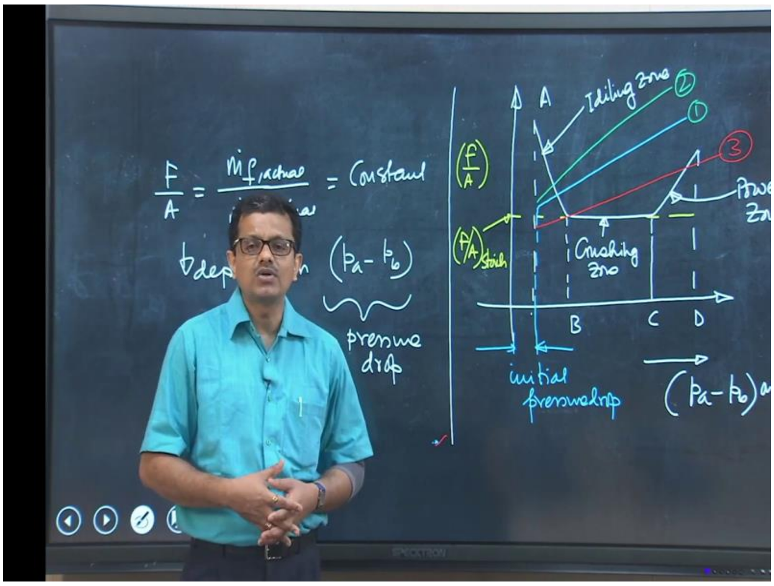

So, fuel air mixture that is mass flow rate of fuel by mass flow rate of air is almost constant and that depends on the pressure difference Δp. So, higher the pressure drop higher the velocity and I have the pressure drop added with the velocity of fuel because our intention is to obtain the mass flow rate of fuel. So, this is multiplied by density of fuel and area of fuel discharging tube. So, area is constant, density is also constant and. So, basically C_b for constant mass flow rate of fuel is remaining constant and that is function of $p_a - p_b$. similarly mass flow rate of air at section b-b is area at section b-b and the density of air section b-b and this is the function.

So, we can say that the mass flow rate of fuel and mass fluid flow rate of air, the ratio is also constant and the function of Δp. So, basically this is the area of orifice at fuel discharging point you should not be confused.

So, what we had seen that the mass flow rate of air and fuel is constant and that depends on Δp. So, we had discussed regimes of internal combustion engine operation and we had seen that this is the pressure drop, now this is the atmospheric pressure that is acting over here. So, higher the pressure drop across the throttle valve, then we could establish that there are three different regimes and say this is C this is B this is A and this is D. So, this is power zone, this is crushing zone and this is idling zone and this is Δp.

So, basically crushing zone, higher the throttle opening area that means we need to have higher Δp. So, this is fuel air stoichiometric, if we increase the pressure difference we can see that we need more amount of airflow mixture.

So, we are trying to move from idling zone to the cruising zone and the power zone. Now if we use this simple float type carburetor what we can say we have expressed that mass flow rate of fuel that is fuel air mixture is almost constant it is a function of Δp and it is a linear function of Δp. So, initial pressure drop is needed for the real application because the fuel will not flow until unless the driving force is sufficient to overcome the frictional effect as well as the surface the effect that is there due to surface tension. So, this initial pressure drop is needed for the flow of fuel from float chamber to the fuel discharging point.

So, if a simple flow type carburetor is designed to supply airflow mixture or fuel air mixture which is good enough for the idling Zone; So, if we increase Δp it will increase. So, suppose we are super imposing another one case say a simple float type carburetor is designed to supply like these three different cases. We can say that if a simple float type carburetor is designed to supply fuel air ratio for the idling zone, that is the line 2. So, it will increase with change in pressure drop; maybe it is good enough to supply airflow or fuel air ratio during idling zone then we can see the fuel air ratio that would be supplied by the carburetor is far too reach during cruising zone and power zone. So, that is unnecessary wastage of fuel. On the other hand if we design a sample type carburetor to supply adequate fuel air during power zone that is line-3 then the same carburetor will supply fuel air ratio during idling zone which is far too lean from the required ratio. So, if a simple flow type carburetor is adjusted to supply fuel air ratio during idling zone. So, we can see that there are a few limitations with this simple float type carburetor.

Because simple flow type carburetor cannot supply fuel air ratio as needed by the engine during its operation in three different zones. So, this is what is very important and I can say these are the drawbacks of the simple float type carburetor. So, that is what we have understood, now since simple float type carburetor is unable to supply required fuel air ratio during the operation of engine in three distinct zones we need to modify the carburetor design.

So, if we try to summarize in today's class we have tried to discuss about the mass flow rate of fuel in a simple flow type carburetor. And then we have discussed about the factors which are responsible for the deviation of the flow from the ideal one that means the real flow is not the ideal flow and establishing the expression of the mass flow rate of fuel, we had seen that the ratio of the mass flow rate of fuel and mass flow rate of air is constant and it is the function of Δp that is pressure drop. And we had seen that a simple flow type carburetor cannot provide a required fuel air ratio to the engine during its operation following three distinct zones and we need to modify the design of the simple flow type carburetor. We shall discuss all these limitations alongside the modifications which are needed for the design of simple type carburetor in the next class, thank you.