Thermal Engineering: Basic and Applied

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Lecture - 48
Simple Float Type Carburetor and its Analysis

I welcome you all to the session of thermal engineering basic and applied. Today we sell discuss about a simple float type carburetor by depicting the geometrical configuration of this particular type of carburetor, we shall discuss the flow analysis. Because we have seen carburetor is a special device and this particular device is integrated with the internal combustion engine that is the spark ignition engine.

And the sole purpose of this device is to supply homogeneous mixture of air and fuel. So, we have understood by this time is that carburetor is provided to ensure that engine will get chemically correct or the stoichiometric air fuel ratio. In the last class we have also discussed it is very unlikely that engine will always get stoichiometric airflow ratio instead considering several regimes of engine operation, we have discussed that carburetor would be able to provide airflow mixture or fuel air mixture in a given range and that is the combustible range of any particular type of fuel. So, sometimes it may be higher than this stoichiometric ratio or it may be lesser than the stoichiometric ratio. So, today we shall draw a simple float type carburetor then we shall go for its analysis.

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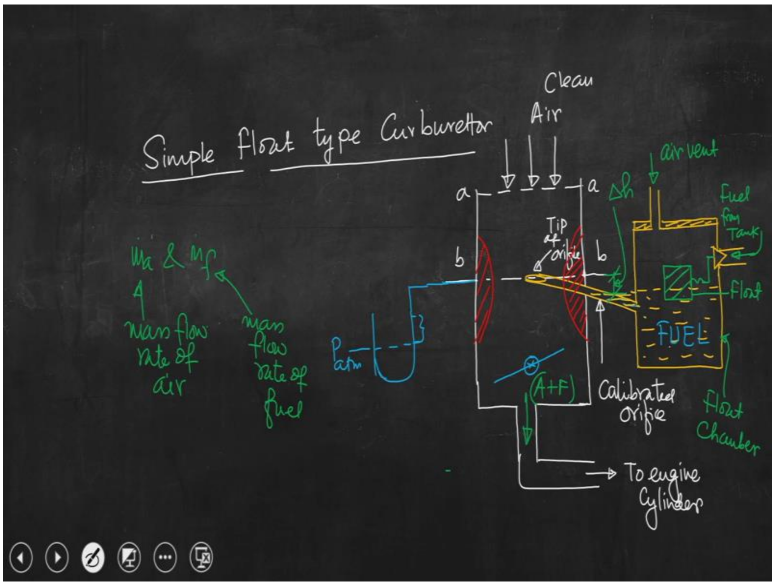

So, if we try to draw the simple float type carburetor, this is section a-a through this section air is taken, this is float valve, this is air vent, this is fuel tank. So, basically fuel is open to atmosphere. So, the pressure acting on the fuel surface is atmospheric pressure, this is the path through which fuel from tank is taken to this reservoir and this is basically float chamber. So, this is the float, you have seen in daily life the application of float valve.

So, we have one throttle valve and then two engine cylinder. So, this is basically intake manifold. Now let us briefly discuss idea, air will come through this manifold. So, that air will flow through this flow path and while air is flowing you can understand this is open to Atmosphere, this is also air vent. So, the pressure acting on the fuel surface is also atmosphere. So, while air is flowing we also need to have simultaneous flow of fuel from float chamber into this particular system and that is known as orifice. So, this is tip of orifice and this is section b-b.

So, when air will flow through this pathway, the flow of air also will try to induct certain amount of fuel that is required for the specific operation from float chamber into this pathway through this calibrated orifice and it will be discharge at the tip of the orifice. So, we need to make some arrangement through this simple float type carburetor that air and fuel will have simultaneous flow.

Because this is also open to atmosphere this is also open to atmosphere, so, we need to have some kind of pressure difference. So, when air is flowing through this particular pathway, if we can somehow make an arrangement that the flow of air will also create a pressure difference between the floor chamber and tip of the orifice and that pressure difference will allow liquid fuel to flow through this calibrated orifice and fuel will be discharged at the tip of the orifice.

So, to have this we need to have some constricted passage and that constricted passage will reduce the pressure and it will increase the velocity. So, that means air is coming from top if we can somehow increase the velocity of air in this location where tip of the orifice is there. And that increased velocity will lead to a drop in pressure and that will allow liquid fuel to flow from floor chamber through the calibrated orifice and up to this point that is tip of the orifice. So, you have studied in fluid mechanics that what we need to provide Venturi.

So, we are providing Venturi, Venturi is essentially reducing the flow area. So, when the air will approach this Venturi, velocity will increase that is flow will accelerate, at the cost of the accelerated flow, pressure will drop. And the drop in pressure should be such that the pressure difference between floor chamber and at the tip of the orifice is the driving force for the flow of fuel from floor chamber up to this point.

Now we need to know the drop in pressure exactly at the tip of the orifice, we can measure this drop in pressure by connecting manometer here. So, this is p atmospheric and pressure at this junction will be less than atmospheric by this height and we can measure what is the pressure by measuring the rise of the manometric liquid in this manometer and we can calculate what is the pressure drop and whether that pressure drop is sufficient to have flow of fuel considering fuel viscosity, surface tension etc. Because when fuel will flow from floor chamber through this calibrated orifice up to the tip of the orifice accounting for the frictional loss due to viscosity of the fuel as well as surface tension, we need to design the venturi accordingly. So, basically this is the fuel initial height. So, this distance is Δh. So, we need to overcome this static height Δh together at the frictional loss as well as surface tension effect.

So, clean air is flowing; simultaneously inducting liquid to be metered from fuel chamber into this Venturi and the fuel that is being injected will be atomized and will be convected by the airflow. So, good thing is the reduction in pressure will allow liquid fuel to flow from this chamber to this particular point the moment when fuel is getting injected, here the velocity of air is even more; so, the high velocity of air will try to atomize the fuel which is being injected here not only that and that will also be convected. So, basically that fuel evaporation will start from this particular part of this carburetor and that atomized fuel also will be convected by the Airstream further Downstream and it will go to the engine cylinder.

So, this is basically the throttle and we need to have almost closed throttle valve during idling condition. So, by tuning this throttle valve opening area, we also can control the pressure difference. So, when piston will come from TDC to BDC we are creating pressure drop inside the engine cylinder provided this throttle valve is fully open, if the throttle valve is not fully open though we are creating pressure difference inside the cylinder by you know bringing Piston from TDC to BDC that pressure difference will not be felt by the air which will flow from air cleaner to through venturi towards the engine cylinder.

So, that is that is given because to meter the amount of fuel air mixture to be supplied to the engine depending on the load. So, this is all about the simple flow type carburetor, idea is we need to supply air fuel mixture. So, we are getting clean air we are getting fuel from this and ultimately in this position we are getting air + Fuel.

So, now let us quickly do the analysis. So, basically what would be the mass flow rate of air and mass flow rate of fuel. So, these 2 quantities are very important to know whether this simple flow type carburetor is able to meet the demand of the engine or not.

So, let us now look at the mathematical expression of the mass flow rate and what we have understood that flow rate will be also controlled by the size of the Venturi because we need to calculate mass flow rate of air and mass flow rate of fuel exactly at this Junction. So, the geometrical configuration or geometrical dimension of the venturi will dictate the mass flow rate of air which in turn will also control the mass flow rate fuel. And whether mass flow rate of fuel is sufficient or not that is determined by the pressure drop and to do that we have connected one U tube manometer over here.

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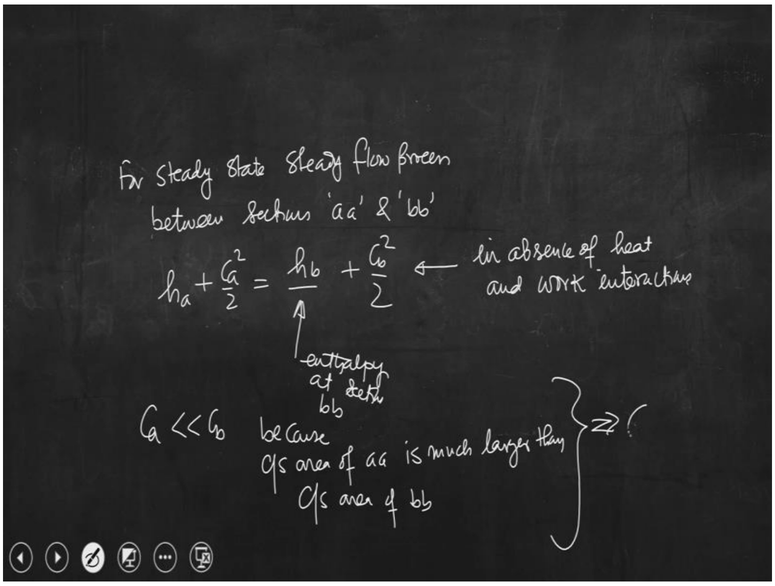

For steady state steady flow process
between sections 'aa' & 'bb'

$$h_a + \frac{C_a^2}{2} = \underline{h_b} + \frac{C_b^2}{2} \longleftarrow$$

in absence of heat and work interactions

enthalpy at secth bb

$C_a << C_b$ because c/s area of aa is much larger than c/s area of bb $\Rightarrow$ (

So, if we apply steady flow energy equation between sections a-a and section b-b to calculate what is the mass flow rate of air as well as mass flow rate of fuel at section b-b. So, let us now write for steady state flow passes between sections a-a and b-b.

$$h_a + \frac{C_a^2}{2} = h_b + \frac{C_b^2}{2}$$

So, this is enthalpy of the flowing air Stream, there is no heat and work interaction. Now this is the velocity of your steam at section a-a that is obviously higher than the velocity at section b-b. Because we need to increase the velocity of air at section b-b and that is why we have provided Venturi. So, now $C_a \ll C_b$ because cross sectional area of a-a is much larger than of b-b and also at this section air is in atmospheric condition and this section a-a is far away from section b-b, though we could not show it properly in this schematic depiction but section a-a is far away from section b-b. So, the consequence of this is that we can write C_a is almost equal to zero as compared to C_b.

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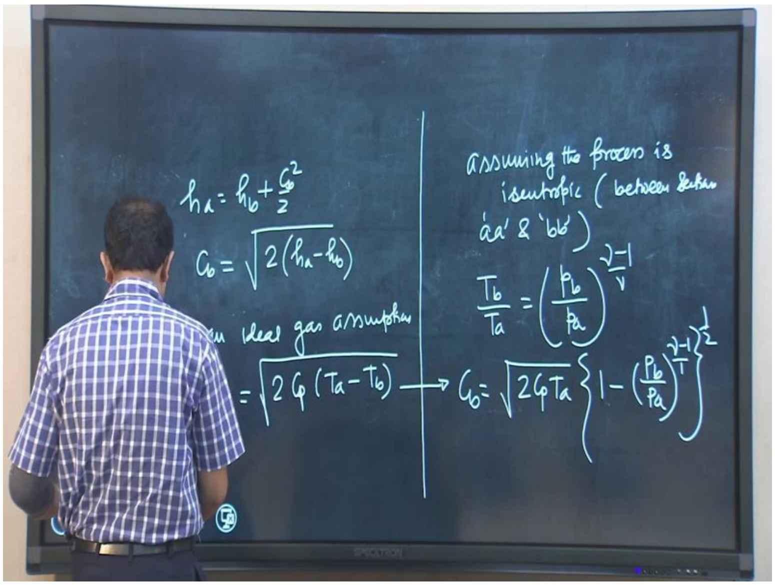

$$h_b + \frac{C_b^2}{2} = h_a$$

$$C_b = \sqrt{2(h_a - h_b)}$$

So, if we assume here though it is not purely air, rather air fuel mixture but we can assume that the working fluid is behaving just like an ideal gas.

$$C_b = \sqrt{2C_p(T_a - T_b)}$$

See T_a is the atmospheric you know temperature of air but T_b we need to calculate. So, we really do not know what is the temperature of air at section b-b. So, now we had seen that we have connected a U tube manometer at section BB. So, we can measure the pressure drop. So, if we measure the pressure drop then perhaps we can measure the pressure at section b-b.

By measuring pressure at section b-b, we can relate Tb or in other way this Ta is known but Tb can be written in terms of the pressure at section b-b. So, assuming the process between sections a-a and b-b can be modeled by an isentropic process then

$$\frac{T_b}{T_a} = \left(\frac{p_b}{p_a}\right)^{\gamma-1/\gamma}$$

$$C_b = \left[2C_pT_a\left\{1-\left(\frac{p_b}{p_a}\right)^{\gamma-1/\gamma}\right\}\right]^{1/2}$$

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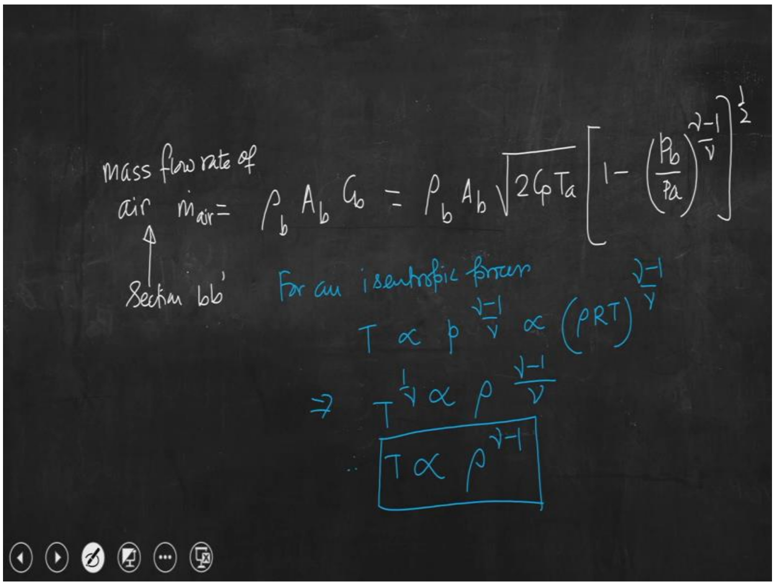

mass flow rate of air $\dot{m}_{air} = \rho_b A_b C_b = \rho_b A_b \sqrt{2C_pT_a}\left[1-\left(\frac{p_b}{p_a}\right)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{1}{2}}$

Section bb'

For an isentropic process

$$T \propto p^{\frac{\gamma-1}{\gamma}} \propto (\rho RT)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow T^{\frac{1}{\gamma}} \propto \rho^{\frac{\gamma-1}{\gamma}}$$

$$\therefore \boxed{T \propto \rho^{\gamma-1}}$$

So, now we are interested in calculating the mass flow rate of air at section b-b.

$$\dot{m}_{air} = \rho_b C_{b,air} A_b$$

So, area we know because we are designing the venturi, ρ_b we also need to know but we can calculate from pressure by using the manometer that is connected at section bb and already you have calculated C_b. So, if we write this expression eventually we are getting

$$\dot{m}_{air} = \rho_b A_b\left[2C_pT_a\left\{1-\left(\frac{p_b}{p_a}\right)^{\gamma-1/\gamma}\right\}\right]^{1/2}$$

So, this expression is not complete because we cannot calculate mass flow rate provided we do not calculate ρ_b. So, in this expression you can understand that we know cross sectional area of section bb and that is obtained from the design of the venturi, everything is known but we also need to know ρ_b to close this equation.

So, at section b-b may be after a few cycles of operation at that section it is not purely air rather it is fuel air mixture. So, we are assuming that that particular fluid that is mixture of air and fuel can be considered to be an ideal gas. And we are assuming that the entire process can be modeled by an isentropic process.

$$T \propto p^{\gamma-1/\gamma} \propto (\rho RT)^{\gamma-1/\gamma}$$

$$T^{1/\gamma} \propto \rho^{\gamma-1/\gamma}$$

$$T \propto \rho^{\gamma-1}$$

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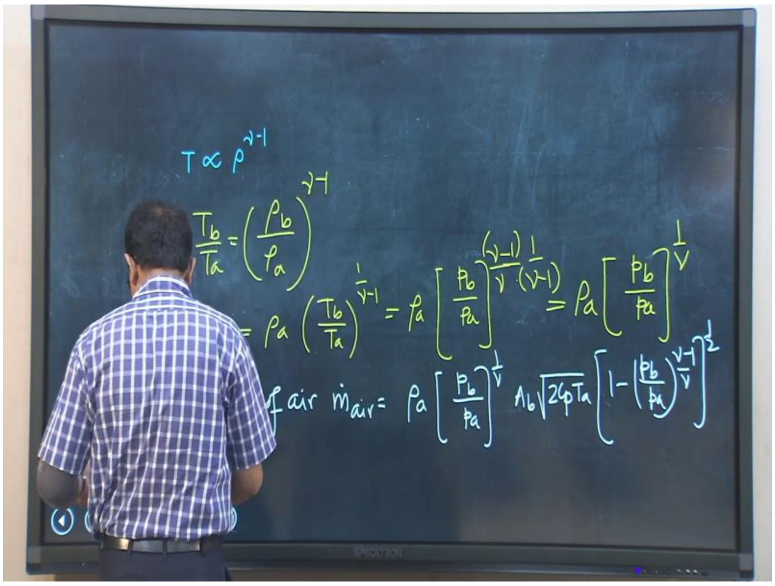

$$T \propto \rho^{\gamma-1}$$

$$\frac{T_b}{T_a} = \left(\frac{\rho_b}{\rho_a}\right)^{\gamma-1}$$

$$= \rho_a \left(\frac{T_b}{T_a}\right)^{\frac{1}{\gamma-1}} = \rho_a \left[\frac{p_b}{p_a}\right]^{\frac{(\gamma-1)}{\gamma}\cdot\frac{1}{(\gamma-1)}} = \rho_a \left[\frac{p_b}{p_a}\right]^{\frac{1}{\gamma}}$$

$$\rho_{air}\ \dot{m}_{air} = \rho_a \left[\frac{p_b}{p_a}\right]^{\frac{1}{\gamma}} A_b \sqrt{2C_pT_a\left[1-\left(\frac{p_b}{p_a}\right)^{\frac{\gamma-1}{\gamma}}\right]}^{\frac{1}{2}}$$

$$\frac{T_b}{T_a} = \left(\frac{\rho_b}{\rho_a}\right)^{\gamma-1} \to \rho_b = \rho_a \left(\frac{T_b}{T_a}\right)^{\frac{1}{\gamma-1}} = \rho_a \left(\frac{P_b}{P_a}\right)^{\frac{\gamma-1}{\gamma}\times\frac{1}{\gamma-1}} = \rho_a \left(\frac{P_b}{P_a}\right)^{\frac{1}{\gamma}}$$

$$\dot{m}_{air} = \rho_a \left(\frac{P_b}{P_a}\right)^{\frac{1}{\gamma}} A_b \left[2C_pT_a\left\{1-\left(\frac{p_b}{p_a}\right)^{\gamma-1/\gamma}\right\}\right]^{1/2}$$

So, this is the expression of mass flow rate that we wanted to have. So, for a given dimension of the venturi, we have ambient condition, we can measure pb by connecting this manometer that we had seen in the schematic depiction. We can calculate what would be the mass flow rate of air at section bb. We can write this expression further in a closed form.

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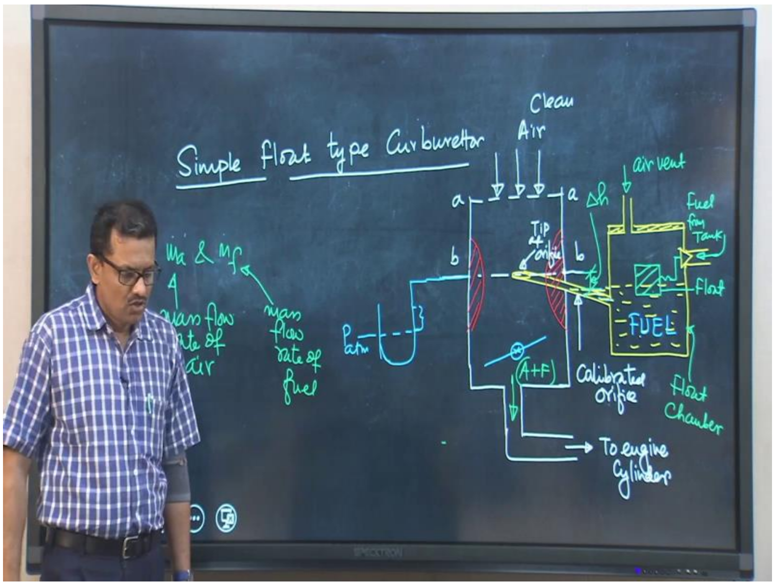

$$\dot{m}_{air} = \rho_a\, A_b \sqrt{2C_pT_a}\left[\left\{\left(\frac{P_b}{P_a}\right)^{\frac{2}{\gamma}} - \left(\frac{p_b}{p_a}\right)^{\gamma+1/\gamma}\right\}\right]^{1/2}$$

So, this is the mass flow rate of air. So, as per the requirement of the load or demand of the engine we can design Venturi so, that we can get the desired mass flow rate and again let me tell you we have assumed that the mixture of fuel-air which is neither purely air at section bb to be an ideal gas and we have assumed that the flow is an isentropic process. But you have studied in thermodynamics that a process is isentropic that is frictionless process and there is no heat interaction, no heat transfer.

Though the process is not involved with any type of heat and work interaction but we cannot trivially ignore the frictional effect because though the viscosity of air is very small still it is bounded by the solid walls. So, if we go to the schematic depiction that when air is trying to flow over this. So, there is a constricted passage moreover solid surfaces are there. So, boundary layer will form. So, basically we cannot trivially ignore the frictional effect. So, accounting for this particular aspect the mass fluid that we could write over here is not the actual mass flow rate rather this is the ideal mass flow rate. So, this mass flow rate is the ideal mass flow rate. Now to get the actual mass flow rate we need to multiply this quantity with one coefficient that you have studied in your fluid mechanics course about Venturi meter, orifice meter.

So, this is as good as Venturi meter that you are providing eventually to reduce the flow area so that the velocity of the flowing fluid can be increased to reduce the pressure. So, that pressure difference is needed to have a flow of fuel from floor chamber to the venturi. So, to obtain to obtain actual mass flow rate that is $\dot{m}_{air,actual} = \dot{m}_{air,ideal} \times C_{d,a}$.

So, $C_{d,a}$ is known as discharge coefficient. So, we could establish the expression of actual mass flow rate that we are going to get at section b-b. And if that mass flow rate is obtained ensuring that the flow rate of fuel should be sufficient to meet the demand of the engine.

So, we are getting this much amount of mass flow rate and to obtain this mass flow rate we had to provide Venturi that we had seen in the schematic depiction. So, the carburetor is provided with this Venturi to reduce the cross sectional area section BB and the mass flow rate that is obtained at this section bb should be sufficient to make the demand as well as to ensure that the fuel that would be supplied from the float chamber to this particular section is also sufficient.

So, basically we need to design the venture in such a way that there will be flow of fuel from float chamber to this Venturi that means mass flow rate of fuel should be adequate for the requirement that will vary with the load of the engine and also a reduction in cross sectional area will increase the velocity, but if the area is reducing, so, basically mass flow rate also will reduce but we also know the designers should be careful while designing the system that mass flow rate of air should not be compromised.

So, this is what is important to have the optimum design of the Venturi. So, to summarize what we have discussed in today's class we have discussed about the operation of a simple float type carburetor. Then we have analyzed the flow of air as well as fuel from float chamber into the Venturi and finally we could establish the expression of the mass flow rate of air. And with this I stop here today and in the next class we shall discuss about the mass flow rate of fuel which is also important to know pertaining to this.