Thermal Engineering: Basic and Applied

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Lecture – 50
Limitations of Simple Float Type Carburettor, Problem on Carburettion

I welcome you all to the session of thermal engineering basic and applied and today we shall discuss about the limitation of a simple float type carburettor. And then finally we will solve 2 problems from the carburattor part, if we try to recall in the last class we have discussed about the operation of the sample float type carburettor and we could establish the expression of mass flow rate of fuel and mass flow rate of air.

From these expressions we could write the ratio of fuel air mixture. Now we had seen that if we try to superimpose the ratio of mass fluid of fuel and mass of air for varying pressure difference. We had seen that increasing the air fuel ratio is increasing linearly with a change in pressure drop. And by plotting that variation in the regimes of operation of internal combustion engine, we had seen that if a carburettor is designed for the satisfactory operation of engine in its idling condition, the same carburettor will provide fuel air ratio to the engine at the cruising zone or also during power zone which is far too rich mixture and that is not needed. So, let us draw that variation and from there you can discuss again today.

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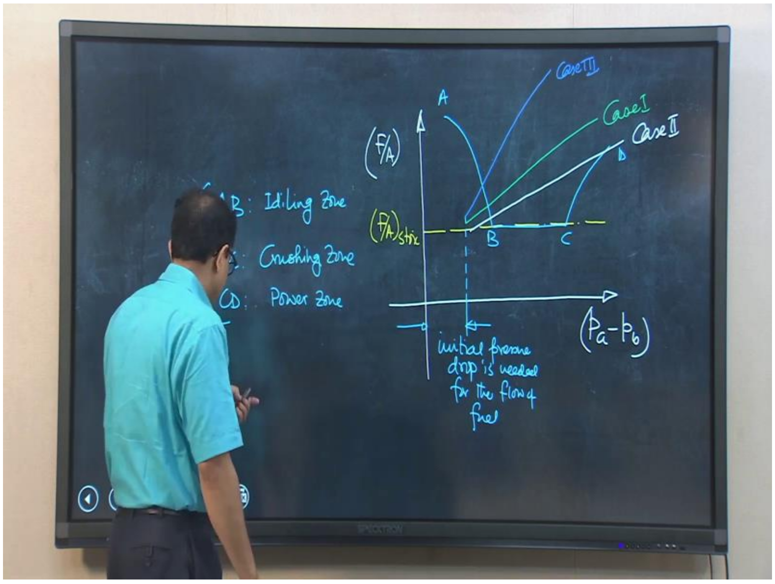

So, if this is the pressure difference $p_a - p_b$ this is as good as throttle opening area because by tuning this particular pressure drop, we can vary the flow rate of fuel air ratio which would be drawn into the cylinder and this is the fuel air ratio. So, this is fuel air stoichiometric and if we draw three different regimes of internal combustion engine operation, we can see these are the three different regimes.

So, this is A, this is B, this is C, this is D and we had seen in the last class this AB regime is the idling zone, BC is the crushing zone, and CD is the power zone. So, these three distinct regimes we could identify and the required fuel air ratio for these three different regimes we can see from this plot.

Now this is the requirement to the engine but that fuel air mixture to be supplied by a carburetor to the engine and if we try to draw the characteristic curve of the carburetion. So, we know that initial pressure difference is needed, say if this is the initial pressure drop for the flow of fuel. So, the fuel will start flowing from floor chamber to the discharging Point through that orifice provided this initial pressure drop is there.

So, this is required to overcome the frictional losses as well as the surface tension effect. Now if we try to draw the fuel air ratio that would be supplied by a carburetor. So, this is case one we also can draw another curve like this, this is case 3 and if we draw another curve say this is case 2. So, if this particular carburetor which is again a simple float type carburetor is designed to supply fuel air ratio for the satisfactory operation during power zone. We can see using the same carburetor the fuel air ratio to be supplied to the engine during idling zone is far too lean. So, it is not suitable, maybe the same carburetor is suitable for the adequate fuel air ratio as needed by the engine during the power zone but the carburetor is not capable to supply the required fuel air ratio during idling zone. So, I can say it is one of the limitations.

Similarly if we somehow design the carburetor to supply adequate fuel air ratio during idling zone. If we look at case three, then you can see the fuel air issue to be supplied during crushing zone as well as during power zone is far too rich mixture. So, it is unnecessary wastage of fuel air ratio. So, that means we can see there are a few limitations of the simple float type carburetor.

And now we need to list down what are the several drawbacks associated with the operation of a simple float type carburetor and if we need to overcome those drawbacks we need to modify the design of simple carburetor.

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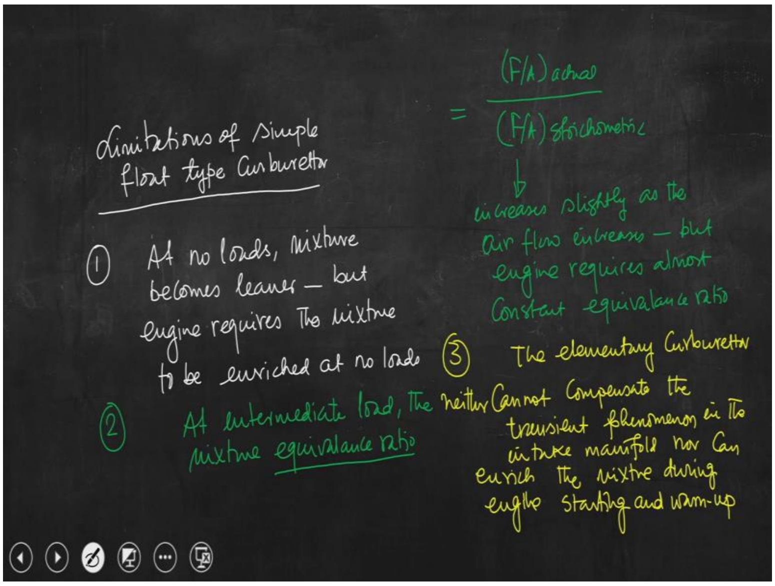

So, now we shall discuss about the limitation of a simple carburetor. So, we can write that 1) at no loads right the mixture becomes linear but engine requires the mixture to be enriched at no loads. So, you now look at case three. So, maybe this carburetor is providing adequate fuel air ratio during power zone but using same carburetor the fuel air ratio to be supplied during idling zone is not adequate.

So, at no load, idling zone engine is running in this zone that means we are not extracting any load any power from the engine. So, there is no load as such. So, during that condition that fuel air ratio to be supplied by a simple type carburetor is not adequate. So, the carburetor is unable to meet the demand of the engine.

2) At intermediate load, the mixture equivalence ratio which is fuel air actual divided by fuel air stoichiometric increases slightly as the air flow increases but engine requires almost constant equivalence ratio. So, this is intermediate stage of operation that is the cruising zone, most of the time engine should run in this zone that is we get best economy of the fuel.

And whether the carburetor is designed or adjusted to supply satisfactory fuel air ratio either during idling zone or during power zone, in both cases we can see the equivalence ratio that is the fuel air actual by the fuel air stoichiometric which is slightly higher than the requirement and we can see that if we increase the pressure drop. So, air flow will increase as a result of which the equivalence ratio is not exactly constant.

And which is supposed to be you can see that the blue line is almost lying on the yellow line. So, these 2 lines are coinciding that means this equivalence ratio is almost one. So, at this particular stage, equivalence ratio is one but what we can see in either in case 1 or case 2 or case 3, the equivalent ratio is increasing. So, this is again one of the limitations of the simple flow type carburetor.

3) Elementary carburetors cannot compensate neither the transient phenomena nor can enrich the mixture during engine starting and warm up. So, idling zone this is the zone in which engine runs either during starting or warm up. So, basically no load is extracted but still engine is running and we need rich fuel air ratio. We had discussed that we need to supply more amount of fuel.

Now what we can see that this elementary carburetor neither can compensate the transient phenomena in the intact manifold nor can enrich the mixture during engine start and warm off. Try to understand even if we can adjust the carburetor to supply the fuel air ratio which is though not perfect but satisfactory. So still it can run but say that if we design the carburetor in such a way that it is running following this curve that is shown in case 3, in that case it cannot enrich by supplying more amount of fuel that is needed during warm up or starting. So, these are the limitation. So, someone is trying to design the modern carburetor, the designer must consider all these issues and these issues should be addressed by suitably modifying the design of a simple flow type carburetor.

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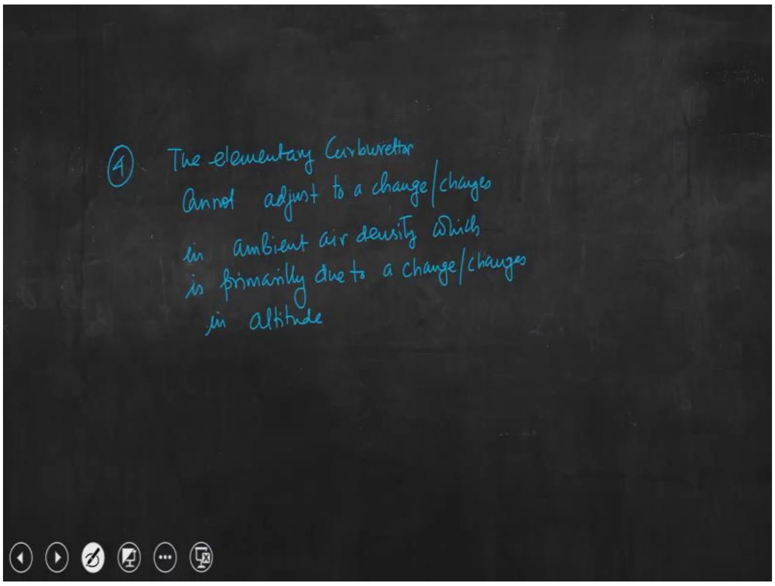

4) Elementary carburetor cannot adjust to a change or changes in ambient air density is primarily due to change or changes in altitude.

So, this is again an important drawback if the engine is attaining certain height with a change in altitude, ambient air density will change, if that is the change then perhaps engine needs the required mass flow air for its efficient operation but simple carburetor cannot adjust that due to changes in ambient air condition. So, this particular aspect also should be taken into account while modern carburetors design.

So, now I am not going to write again the objectives of the modern carburetor design. So, basically if we can understand the limitations and this limitation should be addressed while a designer is designing a modern carburetor. So, now with this now let us move to solve 2 problems from this particular module that is carburation.

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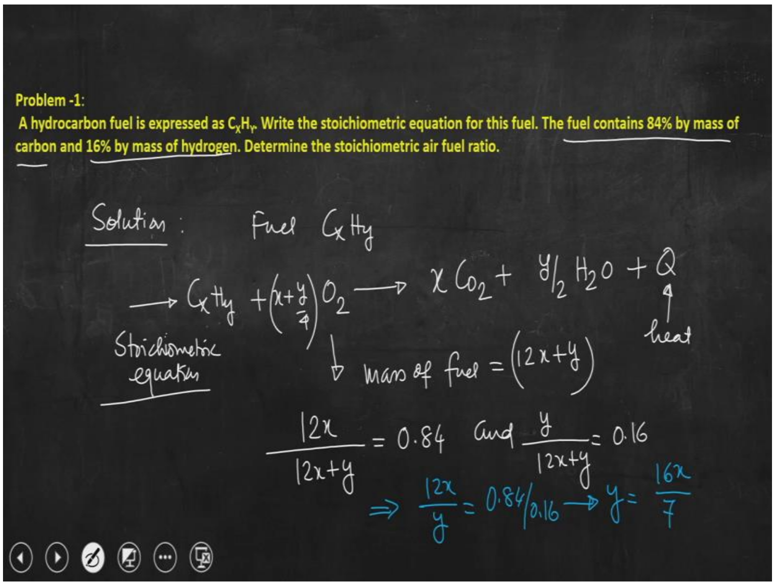

And the first problem that I would like to solve is from the stoichiometric airflow ratio. You know while we have discussed about this stoichiometric or chemically correct air fuel ratio, if we know the composition of the fuel basically hydrocarbon and then to burn that fuel we need adequate air because of the amount of oxygen needed for the complete combustion of the fuel that oxygen will come from the air being supplied to the engine. So, what is the actual amount of air that we need per cycle to be supplied to the engine for the efficient combustion that is very important if we can figure out that would be this stoichiometric airflow ratio now that means per kg of fuel see if we can calculate what is the amount of air needed, now let us solve this problem.

So, a hydrocarbon fuel is expressed as CxHy. So, write this stoichiometric equation for this fuel that means we need to write the chemical reaction with oxygen.

From there we can calculate what would be the amount of air needed to be supplied by the carburetor to the engine, the fuel contains 84 percent by mass of carbon and 60 percent by mass of hydrogen, determine this stoichiometric air fuel ratio. So, first what we need to write we need to write the stoichiometric equation. So, the chemically balanced equation and then by writing that particular equation we can quantify the amount of air needed to burn that fuel in an efficient manner that is the combustion should be efficient.

So, let us solve this problem first. So, we are supplying air because the oxygen present in the air will help to burn that fuel other constituents present in the air will create several combustion gases Nox, SO_2, CO, CO_2.

$$C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O + Q \text{ (As the reaction is exothermic)}$$

This is the stoichiometric equation of this fuel. So, next it is given that fuel contains 84 percent by mass of carbon and 16 percent by mass of the hydrogen.

So, writing this stoichiometric equation of this particular fuel what we can do is, from this particular equation we can write mass of fuel equal to $12\,x\;+\;y$. So, this is stoichiometric and it is given fuel contains 84 percent by mass of carbon and 16 percent by mass of hydrogen that means

$$\frac{12x}{12x+y} = 0.84;\;\; \frac{y}{12x+y} = 0.16\;\rightarrow \frac{12x}{y} = \frac{0.84}{0.16} \rightarrow y = 16x/7.$$

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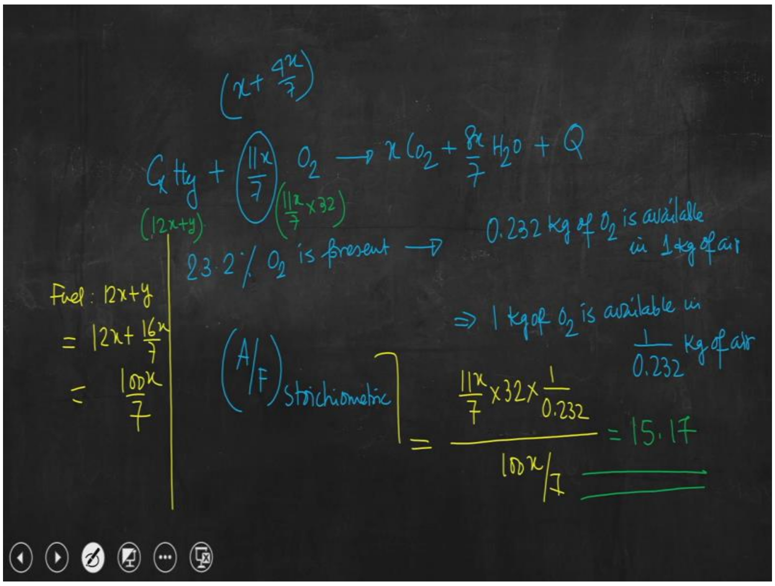

$$C_xH_y + \left(\frac{11x}{7}\right) O_2 \rightarrow xCO_2 + \left(\frac{8x}{7}\right) H_2O + Q$$

So, we know that 23.2 percent oxygen is present in air that means if we consider one kg of air, 0.232 kg of oxygen is available. So, 1 kg of oxygen available in $1/0.232$ kg of air.

$$\left(\frac{A}{F}\right)_{stoichiometric} = \frac{\frac{11x}{7} \times 32 \times \frac{1}{0.232}}{\frac{100x}{7}} = 15.17$$

$$\text{As } Fuel = 12x + y = 12x + \frac{16x}{7} = \frac{100x}{7}$$

So, we can see about $\frac{11x}{7}$ grams of oxygen is needed per kg of fuel. so, So, $\frac{11x}{7} \times 32$ oxygen is needed to burn this much amount of fuel which is present in $\frac{11x}{7} \times 32 \times \frac{1}{0.232}$ amount of air.

So, this is the process of calculating the stoichiometric equation as well as stoichiometric air fuel ratio.

So, another problem that we will solve today is again from the carburetor and we had tried to establish the expression of mass flow rate of fuel and mass flow rate of air. Now the most important part of a simple flow type carbonated that we had seen is the Venturi. Because a proper design of the Venturi is needed to ensure that the pressure drop that would be there at that particular section should be good enough to ensure that a flow of fuel from float chamber to that particular fuel discharging point can be initiated.

And that that is why I would like to solve another problem wherein we can calculate the Venturi diameter as well as the diameter of the orifice tube.

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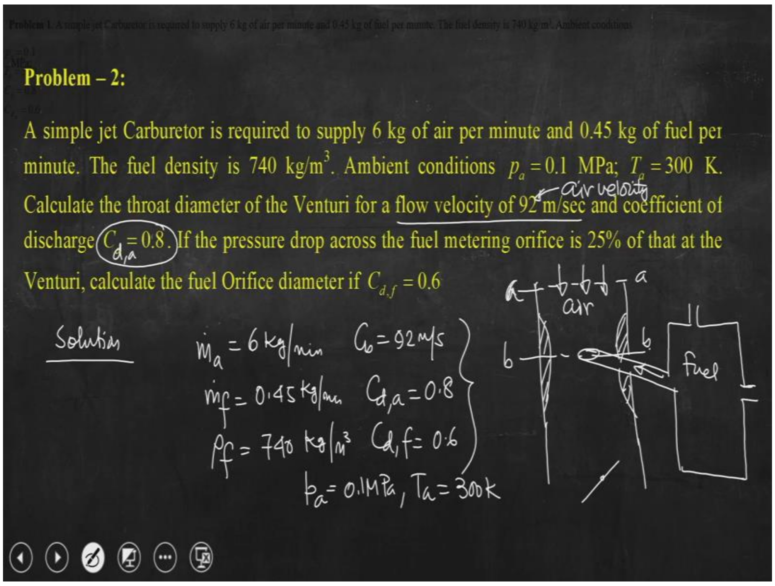

So, a simple jet carburetor is required to supply 6 kg of air per minute that is mass flow rate of air and 0.45 kg of fuel per minute, the fuel density is 740 kg per meter cube, ambient conditions that is pressure is given 0.1 megapascal, temperature is 300 degree Kelvin, calculate the throat diameter of the Venturi for a flow velocity of 92 m/s. As I told that the pressure drop at the Venturi should be such that the adequate flow velocity can be maintained. And the coefficient of discharge (C_{da}) is given 0.8. If the pressure drop across the fuel metering orifice is 25 percent of that at the venturi, calculate the fuel orifice diameter if the coefficient of discharge of fuel is 0.6. So, this is the orifice tube, fuel discharging tube and this is the fuel discharging point and this is the Venturi.

If we give this section this is b-b and this is section a-a. So, air is coming from top and this is fuel. So, we can write down the data which we can read from the problem statement that is

$$\dot{m}_a = 6\left(\frac{kg}{min}\right); \dot{m}_f = 0.45\left(\frac{kg}{min}\right), \rho_f = 740\ \left(\frac{kg}{m^3}\right); C_b = 92\left(\frac{m}{s}\right), C_{d,a} = 0.8, C_{d,f} = 0.6$$

$$P_a = 0.1\ MPa; T_a = 300K$$

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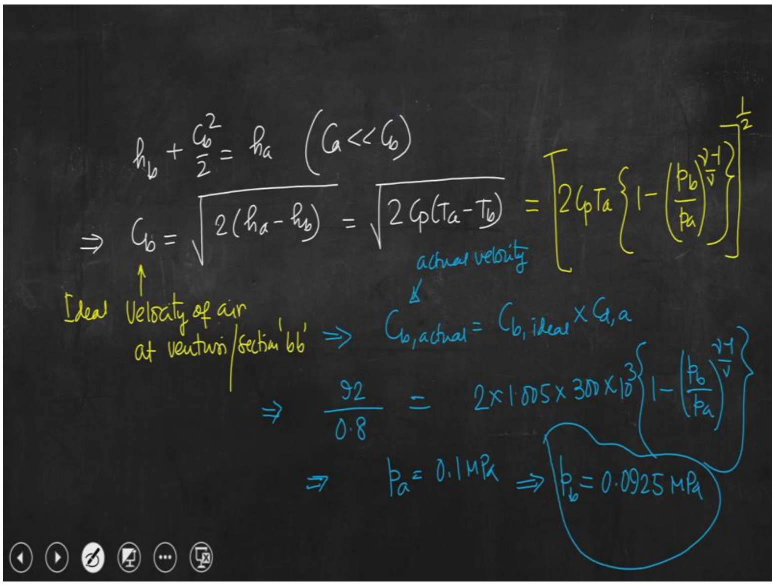

So, we had applied steady flow energy equation between section a-a and section b-b to calculate the velocity of air at section b-b. So, at b-b section Venture is provided. So, if we apply that steady flow energy equation we can write

$$h_b + \frac{C_b^2}{2} = h_a \quad (C_a \ll C_b)$$

$$C_{b,ideal} = \sqrt{2(h_a - h_b)} = \sqrt{2C_p(T_a - T_b)} = \left[2C_pT_a\left\{1 - \left(\frac{p_b}{p_a}\right)^{\gamma-1/\gamma}\right\}\right]^{1/2}$$

So, we have assumed this is the flow of an ideal gas and the process is modeled by an isentropic process. So, this is the expression that we did it in the last class. So, we are calculating using the flow of an ideal gas and the flow is model by an isentropic process. So, definitely the flow velocity of air at section b-b is not the actual flow velocity.

But we need to have the actual flow velocity of 92 meter per second. But the velocity expression that we have here is the expression for the ideal velocity. So, now I am writing this is the ideal flow velocity ok. So, if we now write $C_{b,actual} = C_{b,ideal} \times C_{d,a} \rightarrow C_{b,ideal} = 92/0.8$.

So, now we can calculate from the expression resulting in $p_b = 0.0925\ MPa$. So, there is one order less and accounting for this drop in pressure, we can have a flow of fuel from float chamber to the discharging point.

So, if you just calculate you will be getting this value. So, now if we apply continuity equation in venturi throat.

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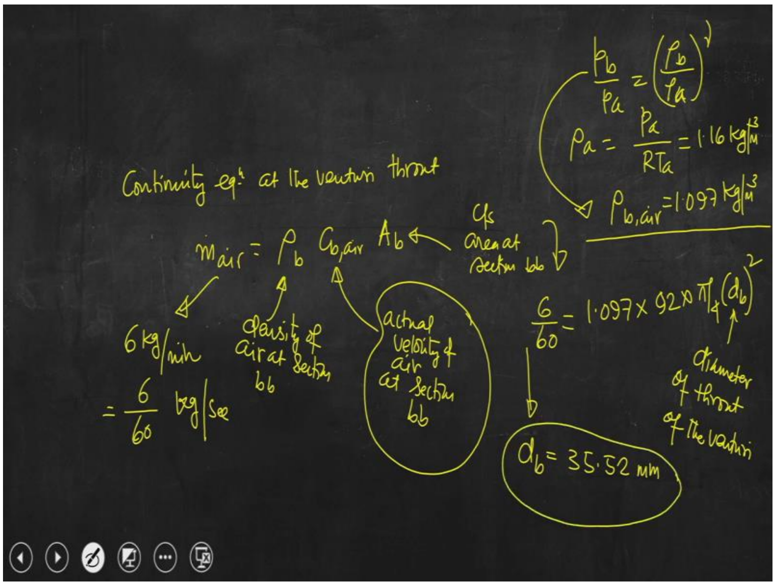

So, if we apply the quantitative equation mass flow rate at the Venturi throat

$$\dot{m}_{air} = \rho_b C_{b,air} A_b; \ \ \dot{m}_{air} = \frac{6}{60}\left(\frac{kg}{s}\right); \frac{p_b}{p_a} = \left(\frac{\rho_b}{\rho_a}\right)^\gamma; \rho_a = \frac{p_a}{RT_a} = 1.16\left(\frac{kg}{m^3}\right)$$

$$\rightarrow \rho_b = 1.097\left(\frac{kg}{m^3}\right)$$

$$\frac{6}{60} = 1.097 \times 92 \times \frac{\pi}{4}(d_b)^2$$

So, this is the diameter of throat of the venturi that is 35.52 mm. So, this is the final expression. So, if we go back to the problem statement. So, next is this is the flow of air, for such a flow of air what would be the flow of fuel and that is also given now if we need to have a continuous flow of fuel from the float chamber to the failed discharging Point what would be the diameter diameter of the orifice. So, fuel metering orifice that we need to calculate.

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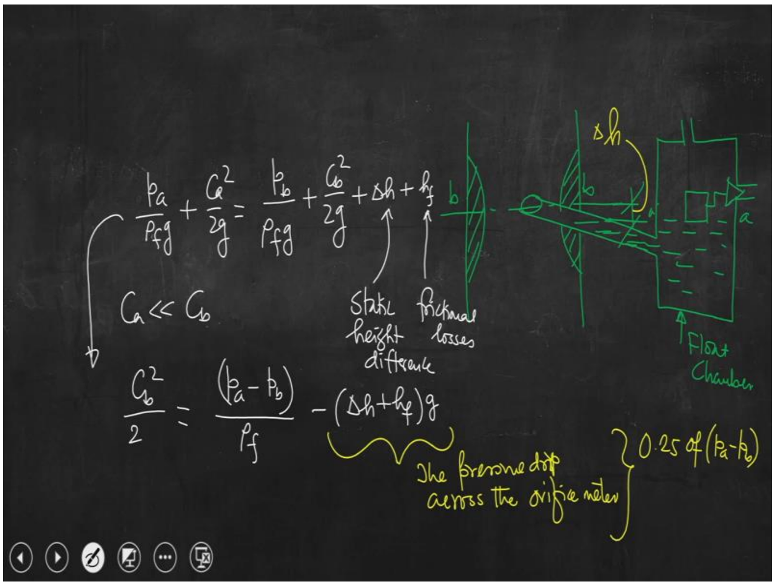

So, let me draw again the schematic.

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

So, this is the frictional loss and this is the static height difference and we know that $C_a \ll C_b$.

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

So, this is the pressure drop across the orifice accounting for these 2 effects; static height difference and frictional losses and it is given as 25 percent of pressure drop across the venturi.

$$\frac{C_b^2}{2} = \frac{p_a - p_b}{\rho_f} - 0.25\left(\frac{p_a - p_b}{\rho_f}\right) = 0.75\left(\frac{p_a - p_b}{\rho_f}\right)$$

So, at the Venturi pressure drop is p a – p b and if the orifice is 25 percent. So, I can write this is the pressure drop across the orifice meter and that is given that is only. So, this quantity is 0.25 of p a - p b. So, that is given right. So, if we write C b Square.

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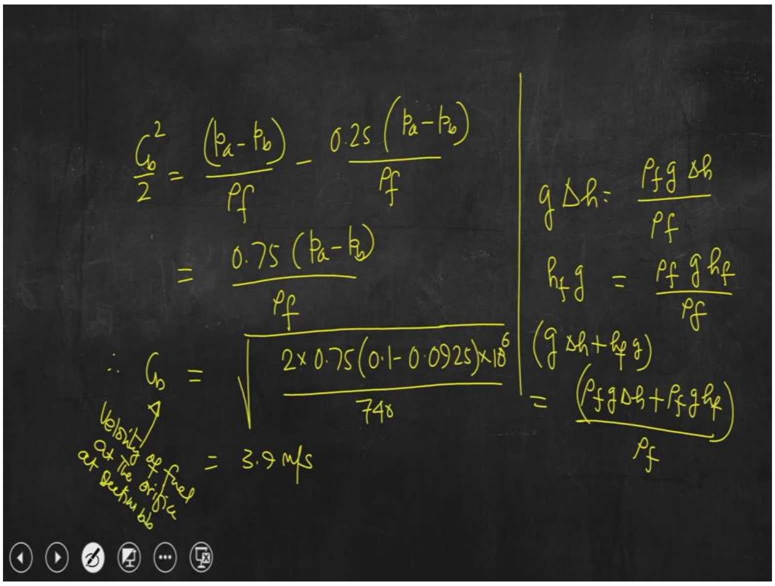

So, we can calculate

$$C_b = \sqrt{2 \times 0.75 \left(\frac{1 - 0.0925}{740}\right) \times 10^6} = 3.9 m/s$$

So, now this is velocity of fuel at the orifice at section bb.

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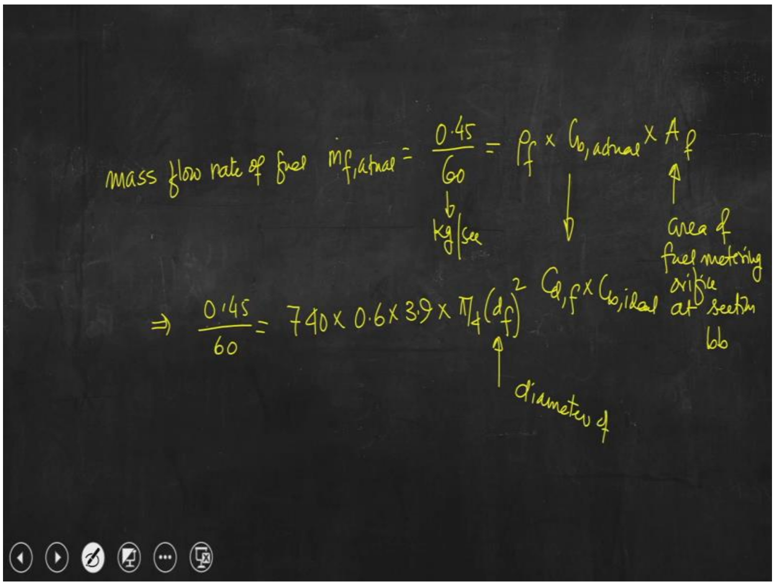

So, once we know this

$$\dot{m}_{f,actual} = \frac{0.45}{60} = \rho_f C_{b,actual} A_{f,b-b} = \rho_f C_{d,f} C_{b,ideal} A_{f,b-b}$$

So, the velocity that we have calculated following previous expression is again the ideal velocity because when there is a flow of fuel through this particular arrangement that this is sudden contraction. Also we did not take the effect of surface tension into account, we did not consider the losses due to sudden contraction, maybe we have considered the losses due to friction but these 2 effects we did not consider.

$$\frac{0.45}{60} = 740 \times 0.6 \times 3.9 \times \frac{\pi}{4}\left(d_f\right)^2 \rightarrow d_f = 2.35\ mm$$

So, you know that in the last class we had discussed about the calculation in a procedure of calculating the mass flow rate of air and mass flow rate of fuel.

We had discussed several issues involved with this particular task that is the calculation procedure, today we had solved one problem and this particular problem will help us to understand the phenomenon in a better way. So, to summarize today's discussion we have discussed about the limitations of a simple flow type or an elementary carburetor.

Identifying those we have discussed that a designer should consider all these issues for the design of a modern carburetor. Then we have solved one numerical problem for the calculation of stoichiometric air flow ratio considering a generic formula of fuel and lastly we have solved another problem wherein we could solve the problem in such a way that knowing the mass flow rate of fuel and air, We could calculate the diameter of Venturi at section bb and also the fuel orifice diameter for a flow of certain quantity of well for a given pressure drop. So, with this I stop here today and we shall continue our discussion in the next class, thank you.