IC Engines and Gas Turbines

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Lecture – 13
Idling, cruising and power ranges (Contd.)

We will continue our discussion on I C engine. Today, we will continue our discussion engine operation that is idling, cruising and power zones. We have discussed that if we have a simple float type carburettor and using a simple float type carburetor, if you would like to supply the a required fuel air mixture or charge depending upon the load which varies during idling condition also in the crushing zone and power range.

We have seen that if simple float type carburettor is designed to supply required amount of fuel air mixture in idling condition probably, the carburettor will be supplying fuel air mixture which is you know beyond I mean too high as compared to the requirement during power range and cruising range.

Similarly, if a carburettor is adjusted for satisfactory operation during power range, probably the carburettor is supply tool in other very less amount of fuel air mixture which is required during idling condition. So, we have seen that if we have a simple float type carburettor ah, there are a few problems. So, we need to note down what are the problems associated with the simple float type carburettor and if you would like to design a new or modern crburetor, then what would be the objectives of having a of the design of a modern carburettor.

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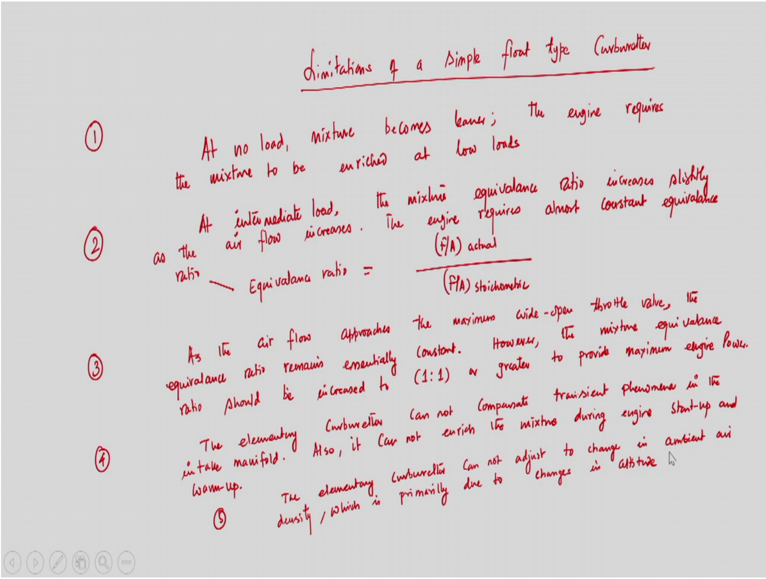

So, today, we will discuss the limitation of simple float type carburettor. So, we will discuss the limitations of a simple float type carburettor. So, limitation of a simple float type carburetor we have seen in the last lecture, I have discuss about that you know fuel air ratio versus pressure drop. During the discussion we have seen that if, I mean the requirement of fuel air mixture is very high during idling condition although we are not extracting in load from the engine but still engine is in running condition.

And on the other hand, again we need to supply relatively higher fuel air ratio during power zone which is quite obvious because we need to extract in relatively larger load from higher load from the engine. On the other hand during pushing zone engine is operated most of the time and where we required almost stoichometric air fuel mixture or that is it is known as economy range I mean during this range, we need to supply only the fuel air ratio which is close to stoichometric or chemically correct air fuel ratio.

So, what are the limitation of a simple float type carburetor, that is we need to not down. So, number 1 is very important that at no loads mixture becomes leaner, at no load mixture become mixture becomes leaner. The engine requires the mixture to be enrich at this load. The engine requires the mixture to be enrich at low loads. The engine requires mixture to be enriched at low load low loads. That is what we are saying in idling condition that mixture becomes really linear but at no loads no I mean load is not higher, I mean in that case if we have a simple float type carburettor, so, we the fuel air ratio or the mixture becomes leaner on the.

But we have seen from the diagram itself and we have explained that at no load or low loads where you know carburettor is almost closed, I mean you know I mean it is partially open during that time engine requires high the mixture to be enriched and we have explained the reason behind it. So, this is the problem if we have a simple float type carburettor. Then number 2, because simple float type carburettor cannot be adjusted to supply, I mean required amount of fuel air ratio during three different ranges, that is what we have discussed.

At intermediate load; at intermediate load; at intermediate load the mixture equivalence ratio; the mixture equivalence ratio very important, what do you like mixture equivalence ratio increases slightly at the ratio increases slightly as the air flow increases; as the air flow increases. The engine requires almost but the engine requires almost constant equivalence ratio, constant equivalence ratio. In this context, I will discuss what do we mean by equivalence ratio? Equivalence ratio is defined as the ratio of fuel air actual by fuel air stoichometric. It is define that the fuel air mixture actual divided by fuel air mixture stoichometric. So, this is known as equivalence ratio.

So, at intermediate load the mixture equivalence ratio increase slightly as the air flow increases because intermediate load; that means, we are opening the carburettor slightly you know relatively opening area relatively higher. So, air flow will increase and the engine, but the engine will requires almost constant equivalence ratio intermediate load, that is almost all the time engine runs I mean during pushing zone, but we require engine equivalence ratio to be constant. And equivalence ratio is defined as the ratio of fuel air mixture at which is supplied actual divided by fuel air ratio stoichometric. So, this is another important problem which you are having if we use a simple float type carburettor in a internal with engine internal combustion engine.

3 very important as the airflow approaches; as the air flow approaches the maximum wide open throttle valve the equivalence ratio remains essentially constant the equivalence ratio remains essentially constant. However, the mixture equivalence ratio should increase to 1 is to 1 or greater to provide; however, the mixture equivalence ratio; the mixture equivalence ratio should be increased to either 1 is to 1 or greater to provide

maximum engine power. So, this is important. So, this is again another problem you are having of which, this is another problem you are having if you use a simple float type carburettor and so, these are the limitation we are having.

Another important problem is so the third problem is as the air flow approaches, the maximum wide open throttle valve the equivalence ratio remains essentially constant, but it is not the case; however, the mixture equivalence ratio should be increase to 1 is to 1 or greater to provide maximum engine power that is required during power zone. That is what we have discussed that if a simple float type carburettor is designed or it is adjusted for the satisfactory operation during power zone, it will supply tool in mixture that is required during idling condition.

On the other hand, if a simple float type carburettor is exhausted to design satisfactory operation during idling condition, maybe it will supply too high you know too rich mixture that is not required even during power zone that is a unnecessary wastage of fuel. So, is a simple float type carburettor cannot adjust to supply the desired or required amount of fuel air ratio which is needed for engine which is needed during different ranges of operation.

Number 4 is very important that the elementary carburettor; whatever we have discuss a simple float type carburettor, the elementary carburettor cannot compensate transient phenomena. In the intake manifold, the elementary carburettor, cannot compensate transient phenomena in the intake manifold it also it cannot; also it cannot enrich the mixture; enrich the mixture during engine start; during engine startup and warm up.

So, at the elementary carburetor cannot compensate transient phenomena in the intake manifold. So, it cannot enrich the mixture during engine startup and warm up that is during idling condition. So, this is another important problem associative with the simple float type carburettor operation. So, if we need to overcome all this limitation and what will be the design criteria of a modern carburettor. By the way, I mean nowadays almost all the modern engines are not having you know all are having fuel injection system, direct injection system but still only to have an idea how a carburettor is working, what is the function of carburettor? And we have discuss in detail and while we are discussing a simple float type carburettor we have seen what will be the problem, what will be the you know difficulties associated with this simple float type carburettor as well as the engine operation is constant and then we have to today, we are trying to list down those. And if someone would like to design a modern carburettor, what will be the design criteria that we also need to know.

So, another problem is 5, this is also very important that the elementary carburettor cannot adjust to change the ambient air density which is due primary altitude. So, it is very important I am writing and then, I will discuss. The elementary carburettor; the elementary carburettor cannot adjust to change in ambient to change the elementary carburettor cannot adjust to change in ambient air density; ambient air density which is due to, which is primarily due to change in altitude, changes in altitude.

It is very important because if we if internal combustion engine is equipped with a simple float type carburettor and if that engine at in certain altitude, then probably there will be a changing at density that effect a simple float type carburettor cannot compensator cannot adjust, but which is very important effect while we are discussing the mass flow rate of air and mass flow rate of fuel as well.

So, these are the limitation with a simple float type carburettor or elementary carburettor. So, to overcome this, I mean these are the problems and we have seen the problems are really importance. So, important problems, so, we need to overcome whether we need to while we are designing a modern carburettor, we need to overcome all these problems so that a modern carburettor should not have this limitations and what will be the design criteria. So, now, we will discuss that modern while you are thinking about a design of modern carburettor.

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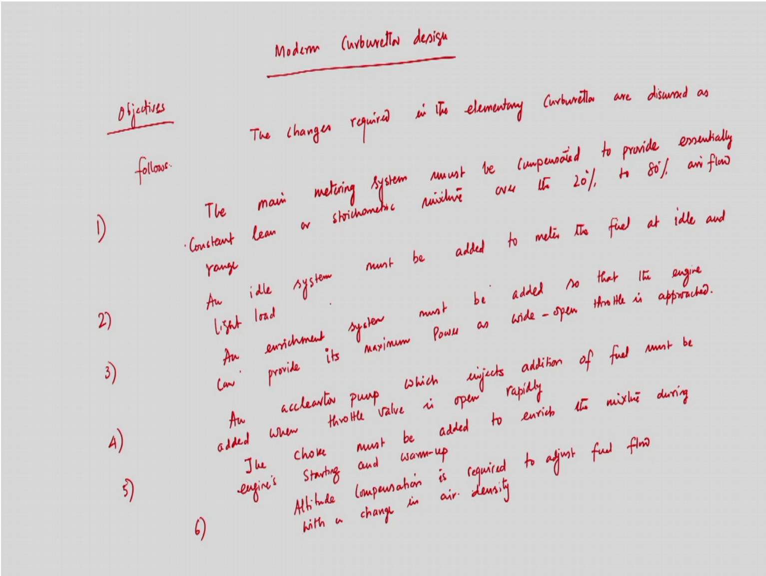

So, modern carburettor design modern carburettor design, what will be the objectives? So, we have seen the difficulties or limitation associated with a simple float type carburettor. If you need to overcomes circumstances all those problems then, what will be the; what will be the objective that what will be the objectives while we are thinking of designer modern carburettor?

So, the changes required; the changes required in the elementary carburettor elementary carburettor are discussed as follows, right. So, what are the changes we need in a simple float type? Carburettor so that the limitation can be avoided can be removed. Number 1, the main metering system which is used to supply you know different percentage of fuel air ratio, three different zones must be compensated, main metering system must be able to compensated, must be compensated to provide other must be able to compensate or must be compensated to provide essentially constant lean or stoichometric mixture to provide essentially constant lean or stoichometric mixture over the 20 percent to 80 percent air flow range, this is very important.

So, we need to supply different percentage of air flow during different range of ranges of operation. So, the main metering system must be compensated to provide this lean or stoichometric mixture over the 20 percent to 80 percent air flow range.

So, whatever will be the amount of air flow depending upon the engine requirement, the main metering system which is used to supply fuel that should be able to supply lean or stoichometric mixture. An idle system; an idle system must be added; must be added to meter the fuel must be added to meter the fuel at idle and you know light load.

3, very important, so dealing idling condition, we need to supply you know relatively higher fuel air ratio that is your what that is what we have seen. So, an idle system must be added to provide the fuel at idle and light load the required amount of fuel during idle or light load.

Similarly, an enrichment system must be added; must be added so that the engine can provide it maximum power as wide open throttle valve, so that an engine, so that the engine can provide it maximum power as wide open throttle as wide open throttle; as wide open throttle is approached. So, if it is similar to what requirement is they are doing idling condition. So, an enrichment system must be added, so that engine can provide maximum power when throttle valve is widely open.

Number 4 is an accelerator pump which injects additional edition of the fuel when throttle is opened rapidly. So, there will be an accelerator pump; an accelerator pump which injects addition of fuel. Accelerator pump must be added which injects addition of fuel must be added when throttle is open rapidly; when throttle valve is opened rapidly.

5, the choke must be; choke must be added to enrich the mixture during engine starting in warm up, to enrich the mixture during starting during engine starting warm up. And similarly, last is, so what are the problems we had we have seen today. So, we need to have changes in the elementary carburettor so, what are the changes required that we have listed down.

Number 6 is very important, that altitude compensation; altitude compensation is required is required to adjust fuel flow to change to adjust fuel flow with change in your density; that means, is very important. So, altitude compensation or altitude compensator will be required, altitude compensator should be there to supply or to adjust fuel flow with the change in density of the air because as I said that if engine need to attain certain altitude, then probably there will be a change in air density to whenever the density of the air will be changed, then probably mass flow rate of air will be changed and to take that effect into account an altitude compensator will be there to supply required amount of fuel.

So, these are the changes which are required in the elementary carburettor , so that the limitation which are there with elementary carburettor can be removed and engine can be operated with almost required I mean fuel air ratio which is needed during different ranges of operation. So, we have discussed about the limitation. Also, we have discussed what are the objectives of designing a modern carburettor ; that means, what are the changes required to overcome the limitation those are there with the simple float type carburettor? So, now we will work out an example with a simple jet carburettor then, we will proceed toward the next.

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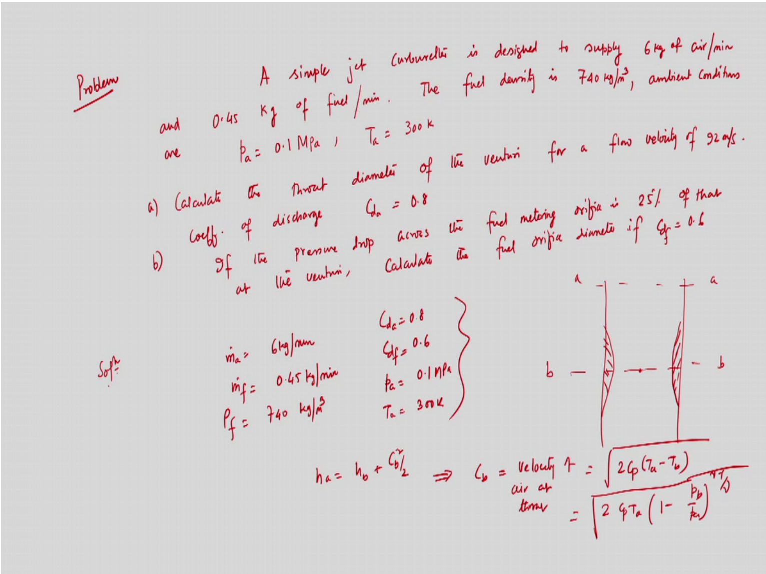

So, the problem with a simple jet type carburettor; a simple jet carburettor , a simple jet carburettor is designed is designed to supply 6 kg of air; 6 kg of air per minute per minute and 0.45 kg of fuel per minute. So, this is a simple float type carburettor which is designed to supply 6 kg of air per minute and 0.45 kg of fuel per minute. The fuel density; the fuel density is 740 kg per meter cube, ambient conditions ambient conditions are atmospheric pressure is 0.1 mega Pascal, ambient temperature is equal to 300 Kelvin.

So, you have to calculate, calculate the throat diameter throat diameter of the Venturi throat diameter of the venture Venturi for a flow velocity of 92 meter per second; for a flow velocity of 92 meter per second. Coefficient of discharge is given of air coefficient of discharge of air C d a is 0.92 it is given coefficient of discharge is given 0.92 and coefficient discharge is given 0.92.

So, next problem is if the effective pressure drop across the fuel metering orifice. If the pressure drop coefficient of discharges given 0.8 sorry coefficient of discharge is given 0.8 and if the pressure drop across the fuel metering orifice is 25 percent of that at the Venturi; of that at the Venturi, calculate the fuel orifice diameter if coefficient discharge of fuel is 0.6 that is given here.

So, we have to solve the problem so, we have to solve the problem. So, if you try to recall that this is this you know which are the this is the venture, right. So, this is section b, b and this is section a, a and this is the Venturi. So, it is given mass flow rate of air is given that is 6 kg per minute, mass flow rate of air is given 6 kg per minute mass flow rate of fuel is given 0.45 kg per minute; rho fuel is given 740 kg per meter cube C d a is equal to 0.8, C d f is equal to 0.6, p a is equal to 0.1 mega Pascal Ta is equal to 300 k so, all these are given.

So, if you try to recall the analysis by how we have calculated the mass flow rate of air and fuel in the context of simple float type carburettor , then we can see that h a is equal to h b plus c b square by 2. From there, we can write c b that is velocity of air at throat is equal to twice C p into Ta minus T b and that is that can be written in terms of twice C p Ta in into 1 minus p b by p a to the power gamma minus 1 upon gamma under root. So, this is the velocity of air at the throat.

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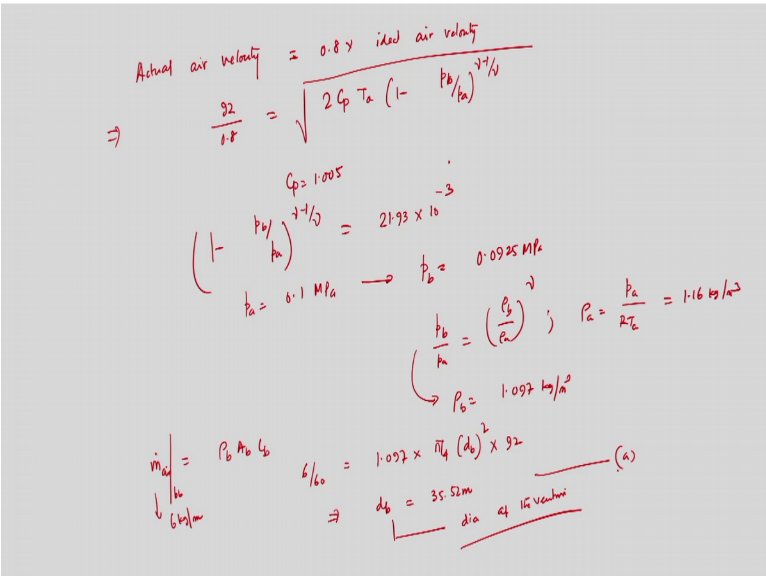

So, actually air velocity should be the actual air velocity that is ideal air velocity because we did not take the frictional effect into account. The actual air velocity should be that 0.8 into ideal air velocity; ideal air velocity 0.8 is equal coefficient discharge of air. So, actual air velocity therefore, actual air velocity is given that for which we have to calculate the Venturi diameter of the throat right. Calculate throat diameter of the Venturi for 92 meter per second flow of air.

It the flow a 92 meter per second, so 92 meter divided by 0.8 that equal to rho twice C p Ta into 1 minus p b by p a to the power gamma minus 1 by gamma of root so, this is the expression. So, p a is equal to given; p a is equal to given C p we can take; C p we can take 1.005. Then from there, we can calculate what would be p b minus p a power to the gamma. So, if we calculate 1 minus p b by p a to the power gamma minus one upon gamma will be equal to 21.93 into 10 power minus 3.

So, from there, we know p a. So, I we know pa is equal to 0.1 mega Pascal from there we can calculate p b will be equal to 0.0925 mega Pascal. So, in we have seen what is p a and what is p b? So but density of air at section p b will changed. That is what we need to know what is p b, then if we know p b. So, you know p b by p a is equal to rho b by rho a to the power gamma. From there, we can calculate rho a will be equal to rho a is equal to p a by RT a. So, if we calculate, it will be coming now rho is equal to coming it is coming 1.16 kg per meter cube right. So, I know p b and I have we know p b we know pa we know rho a. So, from there we can calculate rho b will be equal to 1.097 kg per meter cube. So, there is a drop in density at section d b of course, because there we are having velocity is higher fine pressure is less.

Now, then mass flow rate of air at section b b, at section b b that equal to rho b area b into C b. So, mass flow rate of air is given, mass flow rate of air is 6 kg per minute; 6 kg per minute. Therefore, 6 by 60 that will be equal to 1.097, this is 6 kg per minute. So, that is 1.097 into pi by 4 into d b that square into 92. So, from there we calculate d b that is 35.52 millimeters. So, d b is equal to diameter at the Venturi. So, we have calculated by how, we have calculated pressure at section d b from there, we have calculated density using idle gas relationship.

Mass flow rate of air at section d b is equal to density there area and velocity of air there the velocity of air should be 92 meter per second actual condition. Then, mass flow rate of air is designed to supply 6 kg of air per minute, then it will be 6 by 60 per second. From there, we have calculated what will be the mass flow rate diameter of the Venturi at the throat.

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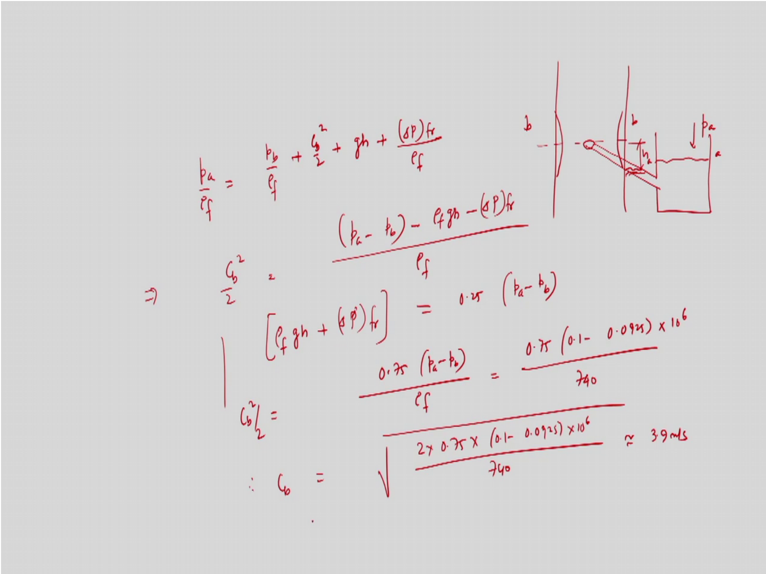

Now, second part, so this is part a answer of part a so while, we are come to second part again we have to we have draw the schematic. So, this is Venturi right and we are having one fuel metering orifice over here so, this is fuel metering orifice. So, now and this height is let us say h so, this height is h. So, here we are having atmospheric pressure, this is section b, b. So, again we have seen know that we have apply steady flow energy between section so, this is section a again. Then, I can write p a by rho f is equal to p b by rho f because now we are handling fuel. So, we have to consider density of the fuel plus C b square by 2 plus g into h plus frictional assets delta p due to friction divided by rho f, right.

So, therefore, we can calculate what will be C b square by 2 that equal to p a minus p b minus rho f g into h minus delta p frictional divided by rho f; divided by rho f. So, now, this rho f into g into h plus delta p delta p frictional, this quantity is 0.25 of p a minus p b. This is given 25 percent of the pressure that are the Venturi. So, therefore, we can calculate C b is equal to C b square by 2 is equal to 0.75 into p a minus p b divided by rho f, right.

So, we know what is pa and what is p b that we have calculated from the previous calculation, from the previous analysis. So, C b that will equal to 0.7 into 0.1 minus 0.0925 divided by density of the fuel that is given 740 into 10 power 6; into 10 power 6. Therefore, C b will be equal to twice of 0.75 into 0.1 minus 0.0925 into 10 power 6 divided by 740 and it is coming near around 3.9 meter per second so, this is a velocity of the fuel.

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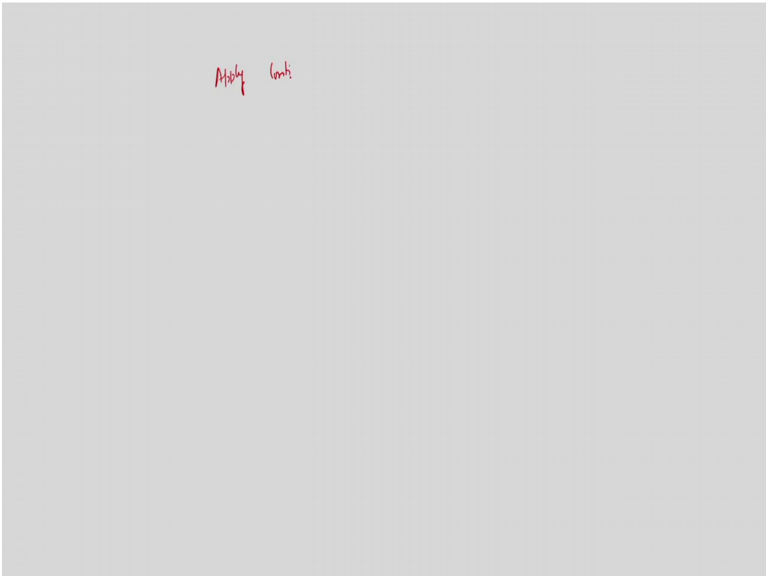

So, again if we apply, so this is the velocity of the fuel at section b b.

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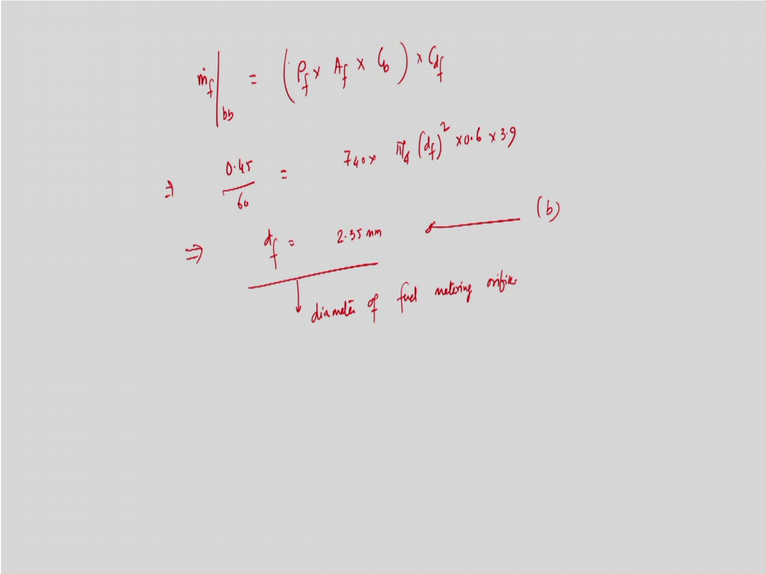

Now, if we apply continuity at the nozzle, if we apply continuity equation right rather just mass flow rate of fuel; mass flow rate of fuel at section b b; I mean through the fuel metering orifice that will be rho f into area of fuel metering orifice into C b into C d f coefficient of discharge because the velocity we have calculated that we multiplied by C d f, that is not actual.

Because we did not take the effect of frictional loss that is called surface tension effect all those things. So, coefficient of discharge of fuel that is coefficient discharge of fuel that we need to take into account so, now, this is given 0.45 kg per minute. Therefore, there by 60 equal to 740 into pi by 4 into fuel metering was d f square into 0.6 into 3.9. So, from there if we calculate d f will be around 2.35 millimeter. So, this is the answer for part b that is the diameter of fuel metering orifice.

So, this is the diameter of the fuel metering orifice. We have discussed the theoretical part last in my last, my last lecture. So, today we have worked out on example how to calculate diameter of the fuel metering orifice and diameter of the venture at the throat because diameter of the Venturi is the throat of very important this key. Because depending upon the diameter of the Venturi at the throat, are the mass flow rate of fuel will depends and pressure drop will be the pressure drop that will be there that will be that also will depend upon the diameter of the throat at the Venturi and what will be the amount of pressure drop? The pressure drop will be the driving force for the fuel to flow from float chamber to the Venturi.

So, from there, we have calculated what will be the diameter of the Venturi as well as diameter of the fuel metering orifice to supply the required amount of fuel that is that we need to that we know from a engine requirement. So, from there you have calculated what will be the diameter of the fuel metering orifice and the diameter of the Venturi.

So, today we have discussed about the limitation of the carburettor and simple flow type carburettor. Then, we have discussed that it would like to remove the would like to eliminate those limitation. Then, if you would like to design a modern carburettor what should be the objectives and then, we have worked out and a numerical example numerical problem for a simple float type carburettor. So, with these, I stop here today and I will continue my discussion in the next class.

Thank you very much.