IC Engines and Gas Turbines

Dr. Pranab K. Mondal
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture - 28
CI engine injection systems, Air-cooled and liquid-cooled engines, Modern trends (Contd.)

We will continue our discussion IC engine and today will initially will discuss about the C I, C I engine injection system and probably we are left with only one part of this injection system, and then will briefly discuss about the cooling, whether it is air cooled and liquid cooled engines. You know we have discussed about, for C I engine injection system, we have discussed about that you know common rail system. Then last class I have discussed about the individual pump and nozzle or individual pump and injector.

So, if common rail system and individual pump and injector, both these you know systems you know fall into the category of solid injection system, and then we have understood that in a common rail system we need to maintain a in a constant pressure in the common rail, but again it, we cannot supply required amount of fuel through that particular injector for varying loads or varying demand; that is what we have analytically established the problem what is their.

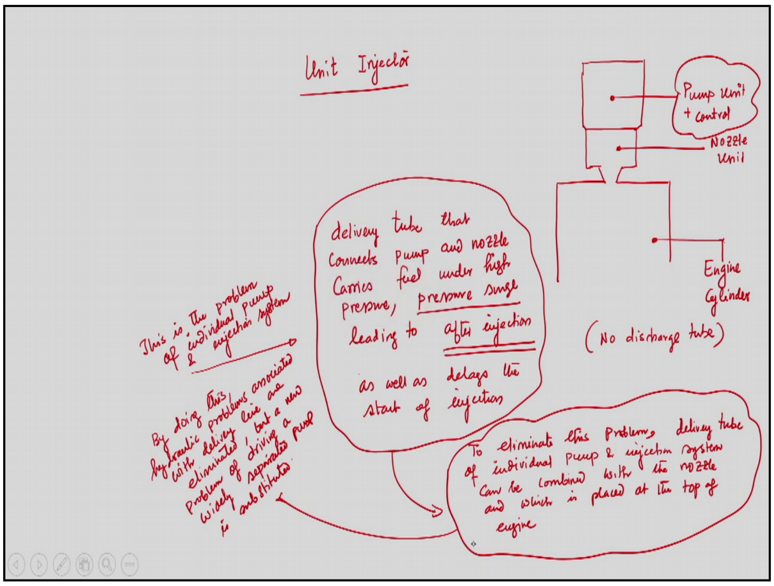
If speed changes, then probably you know injection time, we need to ensure that the theta will remain, theta will increase otherwise the mass flow rate of will, will not be, will not remain same.

So, that is that is why is, you know now a days this common rail system is up solid, it is not used, but then again we have seen that in a individual pump and injector system, we can supply the fuel depending upon the requirement of the load by byby controlling the you know that movement of the cylinder, that is true, but on the other hand we are also inviting other problem of having know that delivered pipe that is a pressure surge when needle suddenly stop because of low pressure, then surge will transmit from that needle side to the pump side or injected injector side to the pump side.

Since delivery valve is closed then again that surge will come back from the delivery valve include the needle, and as a result of with there will be a small amount uplift of the needle and through which fuel will be injecting to the cylinder and that is known as after injection. So, it creates problem, not only after injection is only these. This is only the problem for the system, but also if it delays the injection, total injections it delays

So, now to remove that, you know start of injection it delays. So, what is done that if we remove the delivery pipe, rather if we place the pump on the top of the injector and that is known as inject you know unit injector.

(Refer Slide Time: 03:01).



So, today we will discuss about unit injector which is also, unit injector. So, this is also kind of you know solid injection system where the problem associated with the delivery pipe; that is they are in case of a individual pump and injection system will be eliminated, will be replaced and the pumps will be, you know pumps sized will be placed on the top of the injector side.

So, that we can supply liquid fuel without having after injection or the delays of the you know injection. But we will see now that now the schematic is that, suppose we have. So, this is unit injector, no discharge tube and the nozzle valve unit on these we will have, then on the top of that we will have one pump unit. So, this is pump unit, this is nozzle unit and this is engine cylinder. So, this is engine cylinder. Now here no discharge tube, no discharge tube, hence that problem can be eliminated. So, this is nozzle unit, this is pump unit, pump an of course, control unit, pump unit, pump plus control unit.

So, this is pump plus control unit and this is nozzle unit and then. So, now, as I said that the delivery line, delivery tube that connects that connects pump and nozzle carries fuel under high pressure, that connects pump and nozzle, nozzle carries fuel under high pressure, pressure surges that is what we have seen pressure surge, pressures surge. I am under lining this pressure surge leading to after injection by lifting and needles, by small amount after injection, and as well as delays the start of injection, delays the start of injection.

So, that is what we have seen from last, from the discussion what we had in the last class that delivery tube connects the pump and nozzle which carries fuel under high pressure, because of sudden stop of the needle and the delivery valve, there will be a pressure surge which will leads to an undesirable phenomenon of after injection. And not only that it also delays the start of injection. So, now, what is done? So, this is the problem associated with the. So, this is the problem. So, this is the problem of individual pump and injection system.

Now, to eliminate the tubing. So, to eliminate this problem, to eliminate this problem delivery tube, delivery tube of individual pump, of individual pump and injection system can be combine with the nozzle, can be combined with the nozzle, nozzle and located in the, and an which can be, which is placed and which is placed at the top of the nozzle alright on the head of, located in the nozzle positions. So, to eliminate this problem deliberating of individual pump injection system can be common with the nozzle and which is placed at the top of the engine.

So, this is the remedy or to what of the problem of the individual pump and injection system. So, if do, if we do like this; that means, if I now write from here, that by doing this hydraulic problem associated with the delivery lines are eliminated.

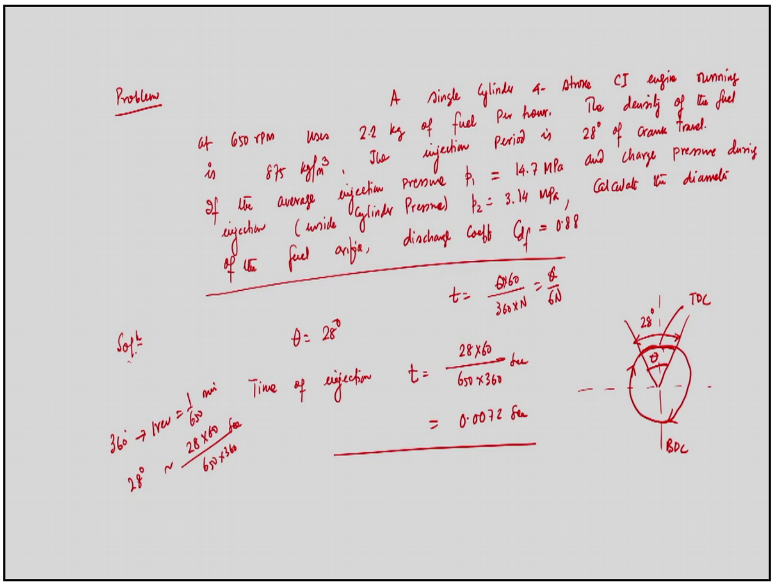
So, by doing this hydraulic problem associated with, by doing this hydraulic problem associated with the, associated with the delivery line, problems associated delivery lines are eliminated, but new problem, but a new problem of driving the widely separated pump is substituted, driving widely substituted, widely separated pump, widely separated pump is substituted.

That means maybe we can, we are eliminating the problem the hydraulic problems that is of, that you know the movement of pressure surge from needle to delivery line again delivery valve to the needle, and because of what will have a uplift of the nozzle wise small amount and from there will have a small amount of fuel that we introduce in the cylinder that is known as after injection.

So, we can eliminate that problem, if we place the entire unit on the head of the engine, but since the operation of pump is not so easy. So, we are introducing another problem that is a driving of, driving widely separated pump is again substituted into the system. So, this is total is known as unit injector, as a total unit is placed in on the head of the engine, and maybe you can remove the problems hydraulic problem, but we are also again inhibiting other problem of having in the operation of the pump fine.

So, with these I stop my discussion about the C I engine injection system. Now I will take up an example numerical problem to solve the problem.

(Refer Slide Time: 11:43)



So, now will solve one problem of C I engine injection system. So, I am writing a single cylinder, a single cylinder, 4 stroke C I engine running at 650 r p m, running at 650 r p m uses 2.2 k g of air for fuel per hour, uses 2.2 k g of fuel per hour.

The density of the fuel is 875 k g per meter cube, meter cube. The injection period is 28 degree of the crank travel the injection period is 28 degree of the crank travel. If the average injection pressure is p 1, if the average injection pressure p 1 is equal to 14.7 MP a calculate.

And the change, you know charge pressure during injection and charge pressure during injection; that is inside cylinder pressure, inside cylinder pressure p 2 is equal to 3.14 MP a, calculate the diameter of the fuel orifice, of the fuel orifice where discharge coefficient of fuel orifice of the orifice is C d f, discharge coefficient of the, discharge coefficient C d f is equal to 0.88 it is given.

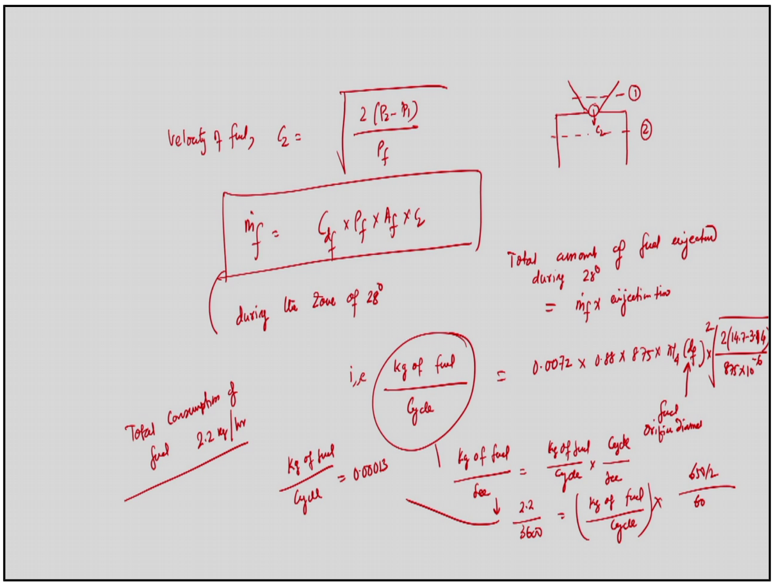
So, we have to solve this problem. So, it is given, if we try to solve the problem, shown it is given that you know injection period, if I write the injection period which is injection period is 28 degree, injection period is 28 degree. So, this is, this is B D C location and this is T D C location, and this is the injection period theta that equal to 28 degree. So, injection period theta equal to 28 degree given.

So, what I can write. We can write the time of injection, time of injection, if you can recall that we have calculated that is theta n divided by. If I try to recall that last class we have drive that 360 degree is equal to 360 degree is for per evolution we have 360 degree that is 1 by 650 1 by 650 minute.

That is 1 by n 650 minute. So, 28 degree evolution will be equal to 28 into [Fl] divided by 650 into 360 second. So, that is equal to t is equal to 28 into 60 divide by 650 into 360. So, that is second, 60 n by.

If I try to recall that t is equal to we have drive in the last class in the context of discussion of common rail system, t is equal to, we have discussed theta n divide by 360 you know into. Sorry theta into 60 theta divide, 60 into theta divide by 360 into n or theta by 6 10 that is what you are discussed. So, now, I can write this is as good as theta by 6 n. So, it will come around 0.0072 second. So, this is the total time of injection we have calculated, because it is given that the injection period is 28 degree of the crank travel fine.

(Refer Slide Time: 16:55)



Now, I go to the next slide and I try to recall that if you try to recall. So, this is nozzle orifice, maybe this is the nozzle orifice. So, this is the nozzle orifice diameter right. So, here velocity is C 2, and maybe here pressure is 2, here pressure is 1.

So, P 1 and P 2is given. So, from there we can calculate C 2 is equal to twice of P 2 minus P 1 divided by rho f root. So, that is without considering frictional losses we can calculate velocity. Therefore, mass flow rate of fuel, it is when a velocity of the fuel, velocity of fuel using Bernoulli's equation. So, mass flow rate of fuel will be equal to, because this equation does not take care of the, does not you know take the effect of fictional assisting to accounts. So, this is C d f into rho f into Af into C 2. So, now, so, this is the mass flow rate during. So, this is the mass flow rate during the zone of 28 degree right.

So, the total amount of fuel injected during 80 degree is equal to. So, the total amount of fuel injected, injected during 28 degree will be equal to m dot f into injection time. So, now, k g, it is given that is k g of fuel per cycle. What is the total amount of fuels injected per cycle equal to 0.0072 injection time into mass flow rate 0.88 into 875 into pi by 4d f square.

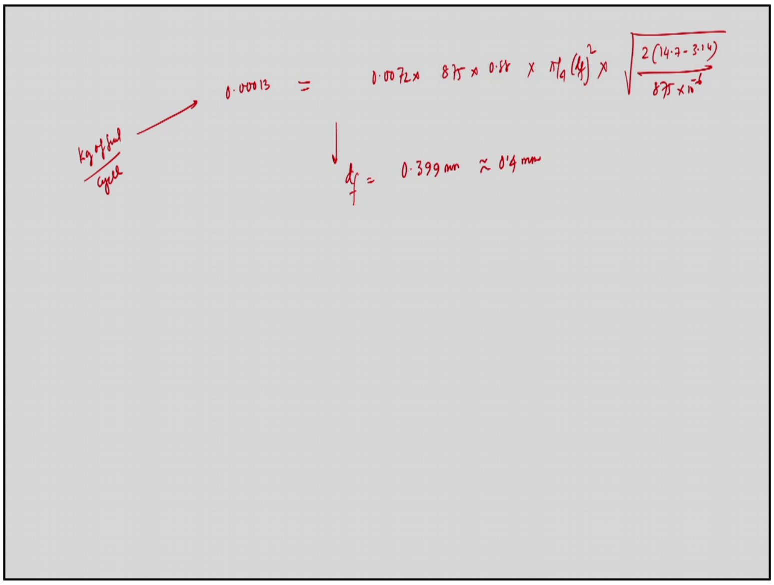
So, these d f is the know, you know that, that is this is the you know nozzle orifice diameter, is call, this is call orifice fuel or diameter of the fuel orifice. So, this is fuel orifice diameter into 2, 2 into 14.7 minus 3.0, 3.14 divide by 865 into 10 power minus 6 root of.

So, that k g of fuel per second, total consumption of the engine the 62.0 k g of fuel per hour right. So, k g of fuel, now this k g of fuel per cycle I can decompose heat into k g of fuel per second. I can write this k g of fuel per cycle into cycle per second I can write anyway. So, you know the total consumption of the engine is k g of fuel.

So, this total consumption of fuel 2.2 k g per hour, it is given. So, k g of fuel per second 2.2 by 3600. So, this is, this quantities 2.2 divide by 3600 k g of fuel per cycle, that is very important, k g of fuel per cycle that we like to calculate. So, k g of fuel per cycle we will calculate into cycle per second that is 650 divide by 2 divide by 60.

So, now, it is now 4 stroke engine it is given a running at 650 r p m. So, there is two evolution per in a cycle. So, 4 stroke engine there we two evolution in a cycle. To complete the cycle there are two evolution and that is why you have divide by 2650 by 2 into 60 and from there we can calculate, from there we can calculate k g of fuel divide by per cycle will be equal to 0.00013. Now if you know this k g of fuel per cycle that is very important, that is a total amount of fuel injected during the 28 degree and that the right hand side of expression is known.

(Refer Slide Time: 21:37).



So, now I can write that this you know 0.00013. So, this is the k g of fuel per cycle; that is equal to that is what the expression you have written 0.0072 into 875 into 0.88 into 5 by 4 d f square into root of twice into 14.7 minus 3.14 divided by 875 into 10 power minus 6.

So, because that was given in m p a, pressure was given in m p a. From there we can calculate that is why we have divided into minus 6 if we calculate. So, d f we will come, it is coming around 0.3inch99 millimeter ; that is equal to 0.4 millimeter. So, this is the answer of the problem. So, in the fuel, diameter of fuel orifice 0.4 millimeter.

So, if force for cylinder engine, so if it is given single cylinder engine. Now if you are multi cylinder engine than 2.2 that is given, 2.2 k g per hour that will be a divided by number of cylinder present. So, now, I am telling in the context of this solution, in the context of the solution of this problem that if we have. It is given single cylinder engine, but if it is a multi cylinder engine then if the number of cylinder is n then 2.2 k g per hour that is a fuel consumption, total consumption rate that will be divide by the number of cylinder, that is that is all.

So, with these I stop my discussion about the C I C I engine fuel injection system. Now I will briefly discuss about the you know air cool and water cool engine I have discussed. So, far I can recall that I have discussed this issue a long back while I was discussing about the, you know about the engine C I engine and C I engine details.

So, we know that we are, there might be two different cooling system. As I we have seen that cooling is an important, very important you know part of the internal, operation of internal combustion engine, because we need to take away certain amount of heat from the engine cylinder to save the engine out of the, cylinder out of excessive heating or that on the. At the same time you have to remember that we cannot take huge amount of heat otherwise the, you know volumetric efficiency, rather there is a thermal efficiency of the engine will drop.

Now, there might be two different of cooling system that is what I have discussed that is air cooled or water cooled. Air cooled engine; that means, engine outside the engine structure is may have some extended surface. So, that they whenever engine is in, engine is running right. So, I mean, it is very important that air cooled engine that is very important that when engine is running.

Then the forward movement the engine itself, the forward movement of the engine itself, allow certain amount of air to be introduced in into the cylinder into the engine. So, the forward movement of the engine or the movement of the engine will allow the air to be introduced inside the engine cylinder. So, that if we have engine with extended surface out at the, along the outer surface the cylinder then we can reduce the temperature of the engine cylinder because of the convection which is having, because of because of the convection due to the flow of air.

So, this is air cooled engine, question is. See you know to have a better heat transfer rate we have to increase surface that is why, that is what the word I have used there is enough extended surface that is field surface will be there. And sometimes maybe the movement of the speed of the engine is not good enough to such certain may required amount of air that is why you need to have lowered to is, to increase the rate of air which is being introducing the cylinder. This is all about their cooled engine.

And on the other hand we have another engine water cooled engine. Water cool engine you know that we can use we can reuse water, because we will have a radiator. So, engine cylinder through. Along the purified the engine cylinder we have a cooling water jacket that is what we have seen. And we also have seen the sensing, the temper of the cooling water jacket, the amount of fuel or amount of air to be, amount of fuel to be supplied into the engine that is electronically controlled unit, that is what we have discussed will change.

Now, water from cooling water jacket is taken to the radiator. So, water from the cooling water jacket is taken to the radiator through a centrifugal pump which is driven by a V belt pulley on the engine crank. So, we have discussed, know that this is the parasite load of the engine, we have discussed again when discussed about the load engine. So, parasite load is to run their sea and also this pump.

So, water from the engine jacket is taken to the radiator, through a centrifugal pump and that pump is you know run by a V belt fully which is connected to the engines. You know engine crank accept then water which passes through the radiator or water is cooled by air drone. So, we have to cooled the water, because whenever you are taking water from the radiator that water is having high temperature.

So, when the water is taken into the radiator of course, through a pump, and then we need to bring down the temperature of the water in the radiator and that is done using a another heat exchange process. So, you know we need to pass air over the radiator so that the whenever air is passing through the radiator, because of the convection cooling it will reduce the temperature, the water and then again that cold water, relatively cold, cold water is taken from you know radiator into a cylinder through again pump. So, that cooled water is again taken from radiator into the engine cylinder through again a pump and which is connected to the V belt pulley.

Now, question is, when water is coming to the radiator we need to have a sufficient amount of air flow to reduce the temperature of the hot water, and what for that. We may have you know I mean we can draw water using you know pen or the forward or inflow, developed by the forward motion of the curve, may be used to or reduce the temperature of the water. So, the inflow of air, because of the forward movement of the curve can be used to bring down the temperature of the water, but if that amount of air is not good enough to reduce the temperature we need to have one fan which will be used to supply air into the radiator, so that the water temperature can be reduced to explain extend which is good enough to reduce the temperature of the engine cylinder in then next cycle.

So, these two types are commonly used, as a you know as a cooling medium or as a coolant in an internal combustion engine. We need to mind it that in a, sometimes we can use water, because maybe we can get higher efficiency, but water if we use as a coolant we cannot use water all times, because there might be a situation, an engine or is you know approaching a temperature which is even close to zero degree Celsius or something then the water in the radiator will starts freezing and it will rupture the radiator, also the cooling water jacket. So, sometimes what is done. We need to ensure, we need to mix certain amount of you know resin; like ethylene glycol which, which will increase the.

I mean which will reduce the freezing temperature of the water. So, that even you can use that water as a coolant in the places are temperature is given below zero degree Celsius. So, these are the you know basic which is used to reduce the temperature of the water temperature of the engine cylinder.

Of course, to run engine cylinder in a smoothly and also to ensure the efficiency, maximum efficiency, because these two things are simultaneously you need to ensure that we will reduce the temperature to save the engine cylinder, because of thermal cracking. On the other hand we should not reduce the temperature drastically also that the thermal efficiency will drop down.

So, this two of the aspects we have discussed, and we have discussed about the C I engine injection system in details. And we have discussed that solid injection system and that Doctor Rudolf Diesel, who introduced part is a, you know air injection system, I mean that is not.

Now, it is used, because of the cost associated with the you know high size, mix size compressor and also its the running cost. So, in this solid injection system is used common rail; that means, if we have a single form that high pressure pump used to supply fuel in a common commons, you know reserver are there, pressure is maintained constant and from there we supply water is fuel into the multiple cylinder.

But, but this is not you know you know very good solution in hand, because if the load changes, then of course, if speed will change and for that we need to ensure that we need, engine will supply in your variable or varying rate of fuel depending upon the load and speed.

So, in that to remove that problem we had you know individual pump and injection system, where we have one individual pump to supplying to individual injector, but again we have seen one hydraulic problem associated with the pressure surge that leads to an undesirable phenomenon of after you know after injection.

And not only that it also delays the you know start of injection as. So, it ultimately to remove that problem, you again we have unit injector, but we have, if we have unit injector maybe it is good, because you can remove hydraulic problem, but at the same time to run the pump as you know a separated widely separated pump we that creates another problem.

So, these three are the major injection system used in a C I engine and then you have discussed little bit about the coolant, because I have discussed this issues again. I mean I can, I repeat that long back while at the beginning of this course, I have discussed about these cooling system. So, today I have again discuss about the air cooling and water cooling and what are the problems associated with this two types of cooling.

And of course, I discussed that water if used as a coolant in for internal combustion engine, we need to makes ethylene glycol the to reduce the freezing temperature of the water. So, that I can use water in the places or temperature is given below zero degree Celsius. So, with this I stop here today and I will continue one lecture for, to solve a few problems associated with the water cycle, the diesel cycle and because engine power and efficiencies and for I will discuss that aspect in the next class.

Thank you very much.