IC Engines and Gas Turbines
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Lecture – 29
Problems on IC Engine

We will continue our discussion on IC Engine and today, we will work out few example from the different topics that, we have discussed in the last you know couple of lectures. So, you know that we have discussed if I try to recall that starting from the you know basic difference between spark ignition, and compression ignition engine then 4 stroke, 2 stroke engine.

We have discuss about the thermodynamic analysis of different cycles like auto cycle, diesel cycle, and dual cycles. Then we have discuss about the carbureted that is another important part of spark ignition engine because, in a SI engine it is very difficult to it is used that the fuel and air will be supplied into the cylinder during intake stroke instead of only air the case which is you know occurring in a compressing machine engine.

So, and also we have discussed about the spark plug and then, how it can get you know the volt is equal to you know you know brake the gap huge resistance to have a spark; so, that we can initiate combustion. Also we have discuss about the combustion about spark combustion of the spark ignition compression ignition engine separately. Then we have discuss about other different aspects like cooling, than what are the fuel, and what are the characteristics of a fuel. And then we have discuss about the SI engine injection system also the injection system for the compression ignition engine.

So, today I will work out a few example which are pertinent in the context of a SI you know IC internal combustion engine. So, I will start my discussion with a one problem that I will solve.

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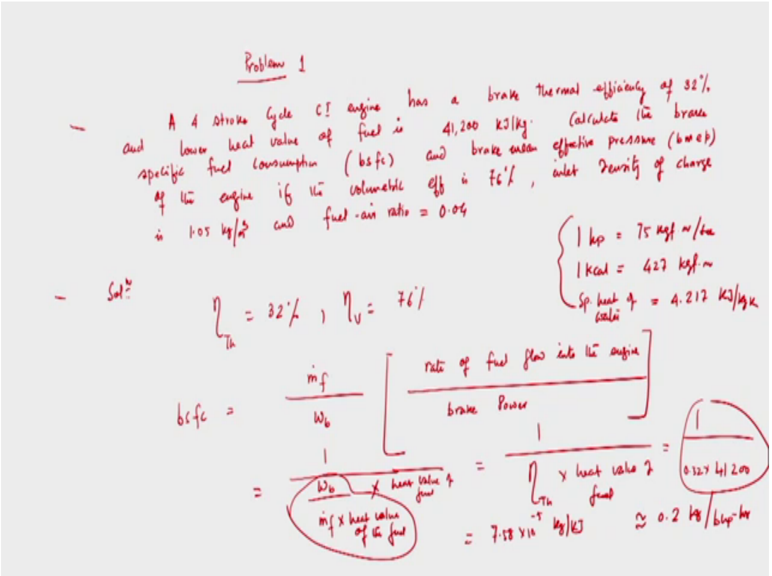

So, will work out one first problem; the first problem 1 very important that 4 stroke CI engine, I am writing 4 stroke cycle SI engine CI engine has a brake thermal efficiency; has a brake thermal efficiency of 32 percent, and a lower heat value of fuel is and fuel is 41,200 kilo Joule per kg. Calculate the brake specific fuel consumptions, and brake mean effective pressure of the engine if the volumetric efficiency 76 percent inlet density of the charge.

So, we have to calculate; we have to calculate the brake specific fuel consumptions, the brake specific fuel consumption which is written bsfc in short and the brake mean effective pressure of the engine and brake mean effective pressure. We have discussed this what is effect mean effective pressure and if I in you know you know use b as a prefix then become bmep brake mean effective pressure if I use I that is a indicated mean effective pressure like this.

So, bmep of the engine if the volumetric efficiency of the engine; if the volumetric efficiency is 76 percent inlet density of charge is given and fuel air ratio is given. So, inlet density of charge inlet density of charge is 1.05 kg per meter cube, and fuel air ratio is equal to 0.04. So, this is the problem we have to you have to find out the solution. So, this is the problem I can take that you know specific heat of water and 1 kilo calorie. So, I can write these data may be required 1 horsepower equal to 75 kg force meter per second. Similarly, I can give 1 kilo calorie is equal to 427 kg force meter and specifics and specific speed of water. Specific heat of water is equal to 4.217 kilo sorry kilo Joule per kg Kelvin.

So, these are the you know important you know parameters, which may be required while solving problems of internal combustion engine. So now, from this solution it is given that eta thermal 32 percent brake thermal efficiency. Brake thermal efficiency because it is very difficult because I know we have discussed that the powered which is produced or the top of the piston phase is known as indicated power. But, the power will get at this act is brake power because, we need to work on the fictional losses when you know piston is moving up and down between two locations that is top dead centre and the bottom dead centre.

So, maybe because of the combustion we are having we are getting certain amount of thrust, but that thrust is not getting into converted to the work network which we are getting from the engine because some amount is lost to overcome the frictional losses. So, that is the brake thermal efficiency given 32 present and it is given that the lower heat value of the fuel, that is given 41200 kilo Joule per kg and also eta volumetric, it is given that 76 percent and so, we have to calculate.

So now, brake specific fuel consumption bsfc is very important that is mass flow rate of fuel divided by you know brake mass flow rate of fuel divide by brake work that is, you know rate of fuel flow into the engine; rate of fuel flow into the engine divide by brake power. So, bsfc brake specific fuel consumption is mass rate of fuel flow into the engine divide by brake power. So, maybe to obtain how much the what is the brake power that you are getting, and to obtain what is a mass flow rate of fuel is required the ratio of these two quantities I mean m dot m by w is a brake specific fuel consumptions.

So, that is equal to you know w brake divide by mass flow rate of fuel into this you know if I multi mass flow rate of fuel into, I can write now eta in a bit; I can rearrange this term in different way W b divide by brake power divide by m dot f into heat value of the fuel heat value of the fuel. So, you have to multiply we are we have to multiply again. So, heat value of fuel. So, that is 1 by these quantity is essentially the thermal efficiency, eta thermal into heat value of the fuel.

So, we are getting 1 by 0.32 into 41200 and ultimately you are getting 0.2 kg per bhp hour. If I make it in a conversation ultimately this quantity will be equal to 7.58 into 10 power minus 5 kg kilo Joule. And then from there we can calculate, in terms of brake you know h p because from conversion we can calculate that 0.2 kg per bhp hours. Now, it is given that volumetric efficiency.

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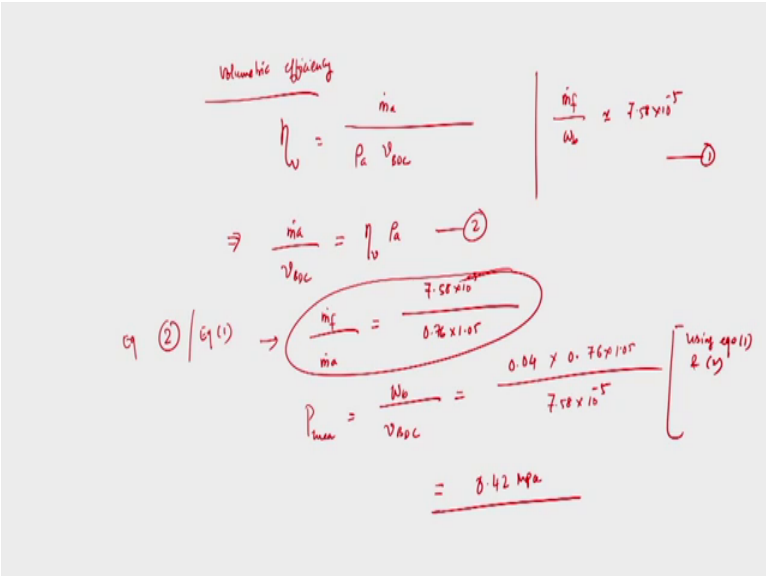

So, what is volumetric efficiency? Volumetric efficiency, we have to calculate mean effective pressure. So, what is volumetric efficiency is very important. Now volumetric efficiency eta v is equal to mass flow rate of air divide by rho a into v at BDC, you know that see we have discuss this issue for perhaps in the context of discussion that, what is the mass flow rate of air and divide by rho a into v BDC. That is the what is the, it is again some mass amount of you know volumetric volume flow rate.

So, these two are not equal certain amount will be there. So, m dot a divide by rho a v BDC, this is a volumetric efficiency and is very important m dot f by W b is equal to. So, and we have calculated that m dot f by brake power is equal to 7.58 into 10 power minus 5 right. So, from there is equal to, so from here I can calculate m dot a by v BDC is equal to eta v into rho a, that is what you are getting.

And this is from equation 1 right and through therefore, mass flow rate of fuel divide by mass flow rate of air that equal to 7.58 into 10 power minus 5 divide by you know because mass flow rate of air we can calculate, that is what is mass flow rate of air? Because, it is given that the problem if I try to recall the problem it is given that, what is the mass flow rate of m dot a density is given right.

So, we can calculate mass flow rate of air from there. So, it is coming around 0.76 into 1.05, why 0.76? Because, 76 percent is volumetric efficiency; so, m dot f by m dot a is equal to 7.58 into 10 power minus 5 divided by 7.76 into; actually if I do like this, I mean if this is equation 2 and this is equation 1, then if I divided equation 2 by equation 1.

We get like this, so m dot f by m dot you know 2 divided by 1, we get m dot f by m dot 1 will be equal to this quantity and then P mean effective, P mean pressure will be equal to W b divided by v BDC. So, that will be equal to 0.04 into 0.76 into 1.05 divided by 7.58 into 10 power minus 5. So, from there we can calculate because W b that is the, that I can calculate because W b will be equal to if I rearrange. In fact, using equation 2 and 1, then I can calculate that v BDC. In fact, I need not to write this expression again rather, if I can just calculate that if I write P mean is equal to W b by v BDC so, mean effective pressure.

So, that is 0.04 if I write the expression of W b from equation 1, that is using equation 1 and 2 using equations 1 and 2. So, m dot d divided by 7.58 m dot f by m dot a that is essentially, that is given 0.04 because you know that fuel air ratio is 0.04. And from there, I can calculate what will be mean effective pressure that is coming 0.42 mega Pascal. So, this is the final answer of this first problem ok.

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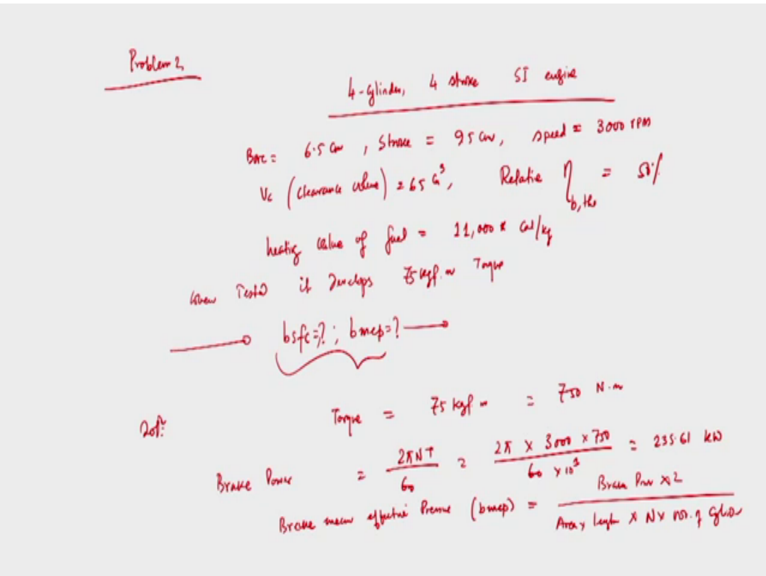

So, now we will move to solve another problem that problem 2 is very important that are; 4 stroke, 4 cylinder engine, I am writing 4 cylinder, 4 stroke SI engine; 4 cylinder, 4 stroke SI engine; 4 cylinder, 4 stroke SI engine has the following particular data. What is that bore? Bore is given, 6.5 centimeter right stroke is given, stroke is given 9.5 centimeter, speed is given is equal to 3000 rpm and clearance volume V c, V c that is clearance volume, clearance volume is given 65 you know centimeter cube. Relative efficiency based on the brake thermal efficiency.

So, this is, eta brake thermal relative eta brake thermal rather relative eta brake thermal that is given you know 50 percent heating value of fuel is given, heating value of fuel 11,000 Kelvin kilo calorie per kg, when tested on load it develop 7 kg force meter toque. So, when tested it develops you know 7 meter toque. We have to calculate specific fuel consumption at the brake mean effective pressure. So, bsfc, brake specific fuel consumptions and brake mean effective pressure.

So, these two quantities we need to calculate. So, this will be equal to how much? And this is how much? So, these two quantities you need to calculate. So, you know now you can proceed to solve. So, we can start solving. So, it is given torque is given torque is equal to 7 kg force meter that equal to 750 sorry 75 I think it is given, torque is given 0.69 MPa, 75 not 75 kg force meter, but then 75 kg force meter that is 70 Newton meter is given. So, what is brake power? If I know the torque brake power if I try to recall that is equal to twice pi NT divided by 60.

So, that is twice pi into r p m is given 3000 into 750 divided by 60 into 10 cube because that is you know, we are obtaining 23561 kilowatt. So, this is the we are getting brake power. So, brake mean effective pressure therefore, brake mean effective pressure will be equal to brake mean effective pressure bmep equal to brake power into 2 divide by area into length into N in number of cylinders. So, this is area into length into N into number of cylinder. So, brake power into 2 because why your multiplying 2 it is given 4 stroke, 4 cylinder, 4 stroke SI engine because in a par in a cycle there are two revolution of the crank.

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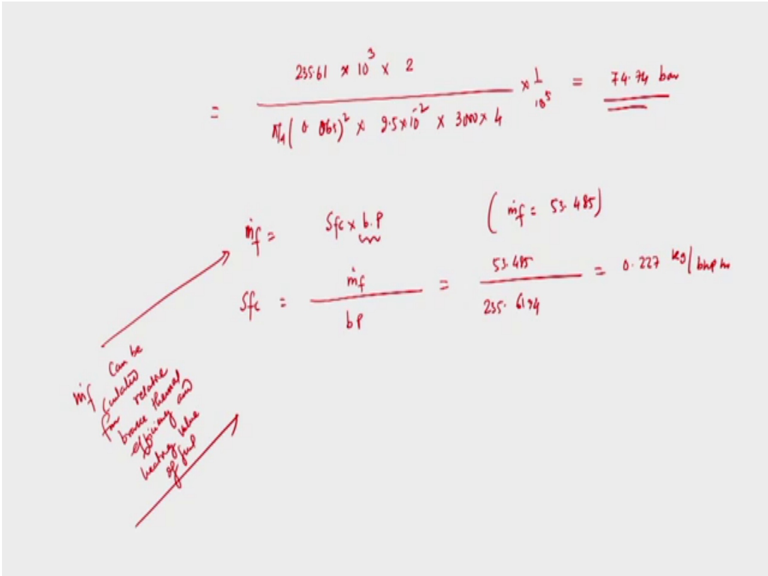

So, the brake mean effective pressure will be like this and if you try to calculate, if I know everything and it will be so, this will be equal to you know brake power it is 235.61 into 10 cube watt into twice into you know this is divided by what is area pi by 4 into it is given 0.065 area into length that is the stroke you know bore is given know bore is given 6.5 centimeter. So, this is 0.065 square into 9 9.5 into 10 power minus 2, that is 9.5 is the stroke that is given l into 3000 is the rpm and number of cylinder is equal to 4 you now that is given. So, if I divided into 1 by 10 power 5, then perhaps will get this is 74.74 bar so, this is the mean effective pressure.

Now, we have to calculate the brake specific fuel consumption that is another important thing. So, you know that, we know that mass flow rate of fuel that will be equal to specific fuel consumption rate into brake power. So, you know mass flow rate of fuel equal to 53.485. So, from there mass flow rate of fuel we can calculate from the um, how can I calculate mass flow rate of fuel 53.48650. It is given, that the you know heating value of the fuel is given. So, from their specific fuel consumptions that will be calculated mass flow rate of fuel divided by brake power brake power.

So, mass flow rate of fuel it is 53.485 divided by brake power that is given 235 into 6194. So, this will come around 0.227 kg per bhp hour. So, this is the expression for the you know makes specific fuel consumptions, but we have to you know this is the total expression for the I mean expression for the brake specific fuel consumption and the brake mean effective pressure you have calculated. So, mass flow rate of the fuel, how can we calculate mass flow rate of the fuel? Because is a brake thermal efficiency is given 50 percents. So, from there we can calculate mass flow rate of fuel. So, I did in solve that part because brake thermal efficiency relative that is given 50 50 percent from there we can calculate an heating value is given.

So, this mass flow rate of fuel these quantity so m dot f can be calculated I am not solving these, calculated from relative efficiency is relative brake thermal efficiency and the heating value of the fuel heating value of fuel. So, from there we can calculate mass flow rate of fuel probably I am not going to discuss the same part I have discuss in the context of the solution in the last part. So, how can I calculate mass flow rate of fuel because has their I can obtain, the specific fuel consumption rate and this is bsfc because I have divided with the brake power.

Though the specific fuel consumption whatever, I have calculated that is essentially brake specific fuel consumption because I have divided by brake power. Now, we will solve another problem that is related to one carburetion.

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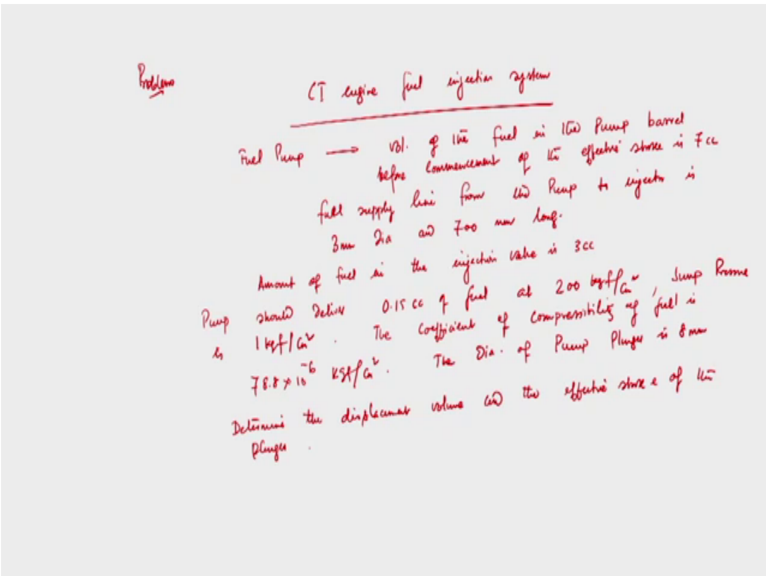

So, I have to solve one problem that is related to coagulation then, we will solve one IC you know CI engine fuel injection on. So, and then problem on carburetion so, I can solve. In fact, carburetion problem I have solved of problem. So, I am not going to solved carburetion problem, carburetion problem I have solved one or two problem I have solved while we have discuss about the carburetor. So, straight away I can discuss on the problem on CI engine fuel injections. So, problem on CI engine fuel injection. So, I now, solve that CI engine fuel injection system; CI engine fuel injection system right. So, the fuel pump we have a fuel pump fuel pump, the volume of the fuel in the pump barrel before commencement of the effective stroke is 7 cc.

So, it is given volume of the fuel in the pump barrel before commencement, commencement of the effective stroke, of the effective stroke is 7 cc it is given. The fuel line from the pump to injectory (Refer Time: 23:55) in diameter and 700 meter long. So, fuel line, fuel supply line from the pump into the fuel to injector to injector is 3 millimeter dia and 700 millimeter long and the amount of fuel in the injection valve is 3 cc. Amount of fuel in the inject in the injection valve is 3 cc. The pump should deliver; pump should deliver 0.15 cc of fuel at 200 kg force per centimeter square, the some pressure is; some pressure is 1 kg force per centimeter square.

The coefficient of compressibility of the fuel; the coefficient of compressibility of fuel is 78.8 into 10 power minus 6 kg force per centimeter square. Diameter of the pump plunger, the dia of pump plunger is 8 millimeter. Determine the discussion volume and effective stroke of the plunger; determine the displacement volume and the effective stroke of the plunger so, you have to calculate. So, this is the problem associated the individual pump and injection system that is what you have discussed. So, now, we have to solve this problem very important problem so, we have to solve how can I solve?

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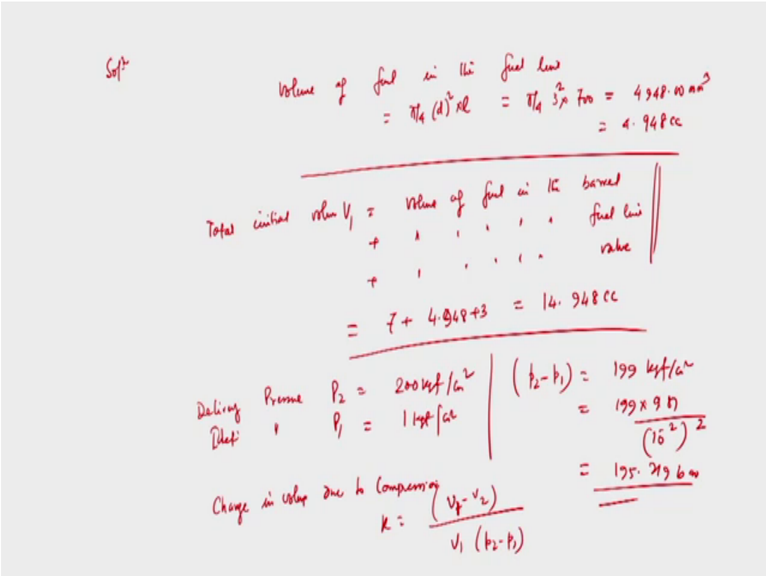

So, a solution is I can calculate volume of; volume of fuel in the fuel line, we have to calculate volume of fuel in the fuel line is equal to pi by 4 into d square into l therefore, pi by 4 into 3 square into 700 that is coming 4948.00 millimeter cube that is 4.948 cc. So, this is the volume of the fuel in the fuel line.

So, the total initial volume; total initial volume is equal to V 1 is equal to volume of fuel in the barrel, pump barrel plus volume of fuel in the fuel line plus volume of fuel in the valve. So, these 3 are the volume. So, and if I add this 3 we will get 7 plus 4.948 plus 3 that is 14.948 cc so, this is the total initial volume. Now, delivery pressure p 2 200 kg force per centimeter square and inlet pressure inlet pressure p 1 is equal to 1 kg force per centimeter square. Therefore, p 2 minus p 1 that equal to 199 kg force per centimeter square.

So, 199 into 9.81 divided by 10 power minus 2 square, I can calculate 195.219 bar so, this is the p 1 minus p 2. So, changing volume due to compression, that is change in volume we have to we have compressing a liquid so, there will be change in volume. So, change in volume due to compression that is why it is given the in as a problem it is given the coefficient of compressibility of the fuel. So, efficient of compressibility fuel is given so, that is equal to k. So, V 2 minus sorry V 1 minus V 2 divided by V 1 into p 2 minus p 1.

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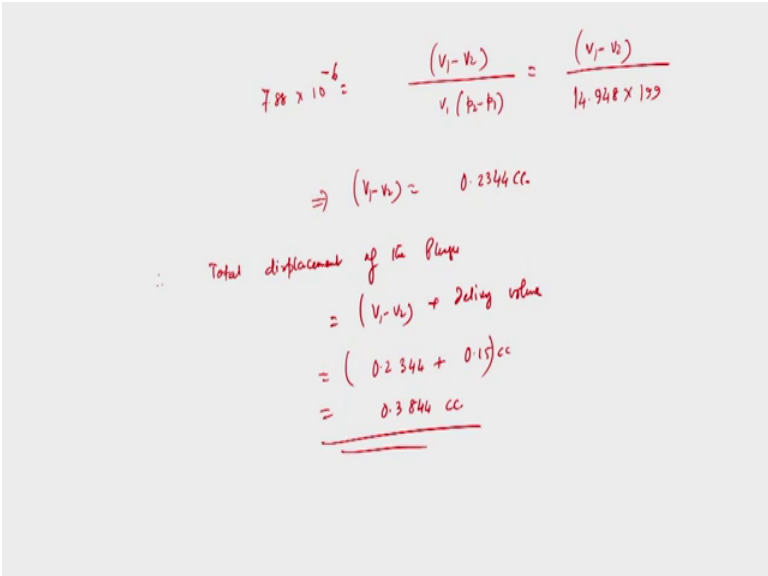

So, from there I can calculate what is, so k is equal to given 7.88 into 10 power minus 6 is equal to V 1 minus V 2 divided by V1 into p 2 minus p 1. So, that is V 1 minus V 2 initial volume V that what I have calculated 14.948 cc into p 2 minus p 1 that is what we have calculated 199 kg force per centimeter square. So, from there I can easily calculate V 1 minus V 2 that equal to 0.2344 cc. So, this is the you know change in volume due to the compression.

So, from you have calculated from the you know compressibility of the fuel it is given, the total displace into the plunger. Therefore, total displacement of the plunger of the plunger that is important pump plunger that is V 1 minus V 2 that change in volume plus delivery volume. So, the change in volume in the given, that is V 1 minus V 2 of the fuel plus delivery volume. So, that is 0.2344 plus 0.15 cc so, this is coming 0.3844 cc. So, this is the total displacement of the plunger because delivery volume is 0.15 cc that is given in the problem. Now, the effective stroke that is you have to calculate.

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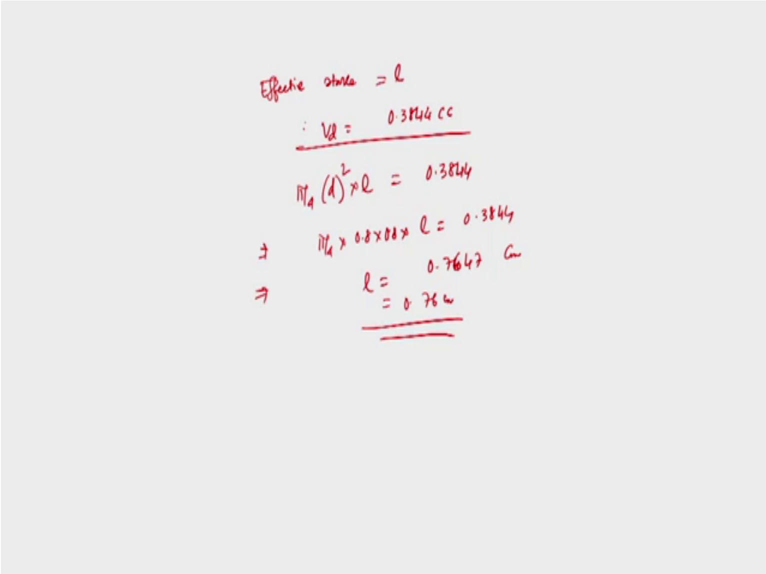

So, effective stroke that effective say effective stroke is, effective stroke let us say it is l. Therefore, displacement volume V d is equal to 0.3844 cc enough in a stroke. So, pi by 4 into d square into l that equal to 0.3844 so, we have a stroke length of the pump that is true, but what is the effective stroke to obtain that amount of fuel to be supplied considering the compressibility effect of the fuel. Then d is given pi by 4 so, pi by 4 into effective stroke of the plunger that you have to calculate because diameter of the pump plunger is given d that is 8 millimeter.

So, 0.8 into 0.8 eight into l is equal to 3 0.3844.So, from there I can calculate l is equal to 0.747647 that is 0 centimeter that is 0.76 centimeter so, these two are the answer for the problem. And a last problem I will solve is very important that related to problem on combustion.

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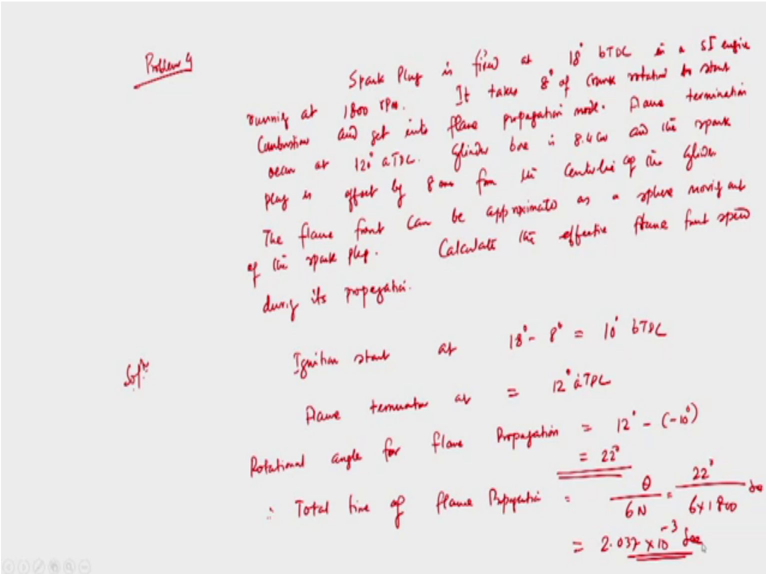

So, the last problem I will solve problem 4, that is problem on combustion. So, it is a given that SI engine spark plug; a spark plug is fired, it is given at 180 degree before TDC; whenever, sorry 80 degree before TDC sorry 80 degree 18 degree before TDC. When piston is 18 degree before TDC, then spark plug is fired in a; in a SI engine running at 1800 rpm.

It takes 8 degree of crank rotation to start combustion; to start combustion and get into flame propagation mode; and get into flame propagation mode; that means, spark plug is fired at 18 degree before TDC and SI engine running at 1800 rpm. It takes 8 degree of crank rotation to start combustion and get into flame propagation mode.

This is important that maybe even piston is 18 degree before TDC, then we spark fired the spark plug, but even after 1 piston is travelling from TDC an 8 degree crank rotation then combustion starts and we get a visible flame. So, flame termination occur at 120 degree at TDC; so, flame termination occur at 120 after TDC aTDC. Cylinder bore is; cylinder bore is 8.4 centimeter and the spark plug is offset by 8 millimeter from the central and the cylinder; and the spark plug is offset by 8 millimeter from the centre line of the cylinder.

The flame front can be approximated as a sphere; the flame front can be approximated as a sphere moving out; moving out of the spark plug. Calculate the effective flame front speed during the flame front propagation during its propagation.

So, this is the problem we have to solve right, how can I solve? So, it is solution it is given that spark ignition occurs at 18 degree TDC. So, ignition start; so, ignition start; ignition start at 18 degree minus 8 degree that is 10 degree before TDC. Spark plug is fired 18 degree TDC and it takes 18 degree 8 degree of crank rotation to start combustion; that means, maybe we have started at when piston is air from 18 degree air from b DC aTDC, but eventually the ultimate flame starts when it is 8 degree air from the TDC.

So, eventually ignition start and 10 degree before TDC and flame termination, at 12 degree after TDC, so this is rotational angle for the flame propagation. So, rotational angle for flame propagation is 12 minus; minus 10 degree that is 22 degree. So, this is the flame propagation which is equivalent to the injection period in SI CI engine. So, ignition start when piston is 18 degree above from TDC I am in bottom TDC below TDC, but ultimately flame start at when it is 8 degree I have TDC, so it will flame terminations. So, the total ignitions start when it is 10 degree at the below TDC and termination occurs when it is 12 degree after TDC.

So, the total angle of rotation angle during the flame propagation is 22 degree flame rotation. So, total therefore, that is what the total time of flame propagation; flame propagation that is what we have calculated again in my last two lectures that is, theta divided by 6 into N. Therefore, theta is 22 degree divided by you know N is it is; it is given 1800 rpm.

So, it is 1800 divided by 60 into or I can straightaway write 6 it is to be second 6 into 1800 second. So, it is coming 2.037 into 10 power minus 3 second so, this is the total time of flame propagation. Now, this is a total time of flame propagation and ultimately I can now obtain the flame speed, but I have obtain so, maximum flame travel distance.

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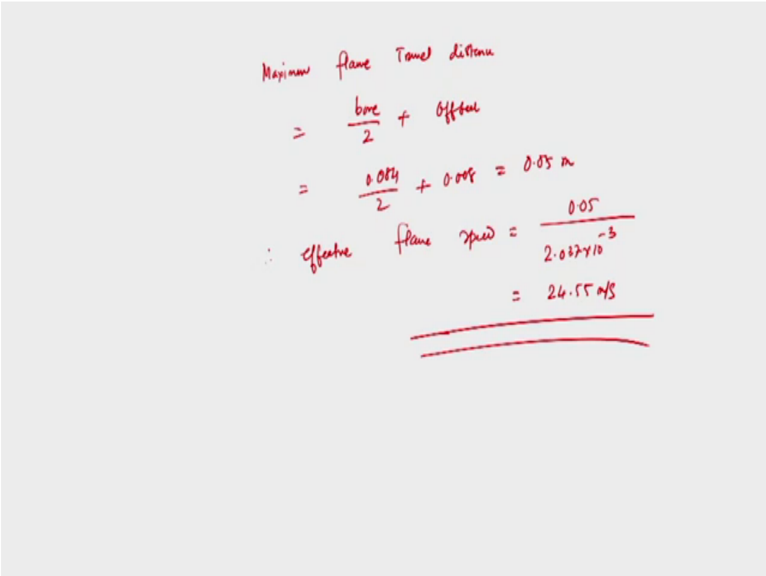

And now have to calculate maximum flame travel distance. How much? That is bore by 2; bore by 2 plus offset. So, it is you have you have approximating it is a last like you know spherical sphere moving. So, bore by 2 plus offset is a maximum flame travel distance and that is coming 0.084 by 2 plus 0.008 that is 0.05 meter.

So, effective flame speed is equal to 0.05 divided by 2.037 into 10 power minus 3 that is 24.55 meter per second so, this is another answer. So, the maximum flame travel distance is offset because, spark plug is it is given the spark plug is offset 8 millimeter from the centre line the cylinder. And what is a bore? Bore by 2 is the total flame speed, flame travel distance.

So, now, bore by 2 plus offset is a total maximum flame travel distance and I have I know the distance, I know the total you know flame total time t because total time of flame propagation so, there I can calculate the velocity. So, with this I stop my discussion today and we have and probably this is the last class of this lecture and this course particular this is last lecture of for this course.

And we have discussed theoretical part as well as I have today, solve a few examples which will help you to work out are that to practice and we will provide you know assignment. And thus worked out example to whatever, I have done today that will help you to solve the problem of from the assignment. So, this theoretical part as well as this you know a few example, that you have solved during my discussion of theory of this particular course as well as today's worked out example; I am completing this course.

And I hope that you have enjoyed this course a lot and you will learn few things at least related to internal combustion engine operation, as well as the you know it a few aspects of it design. So, with this I stop my discussion today and then will provide the assignment and the some worked out example.

Thank you very much.