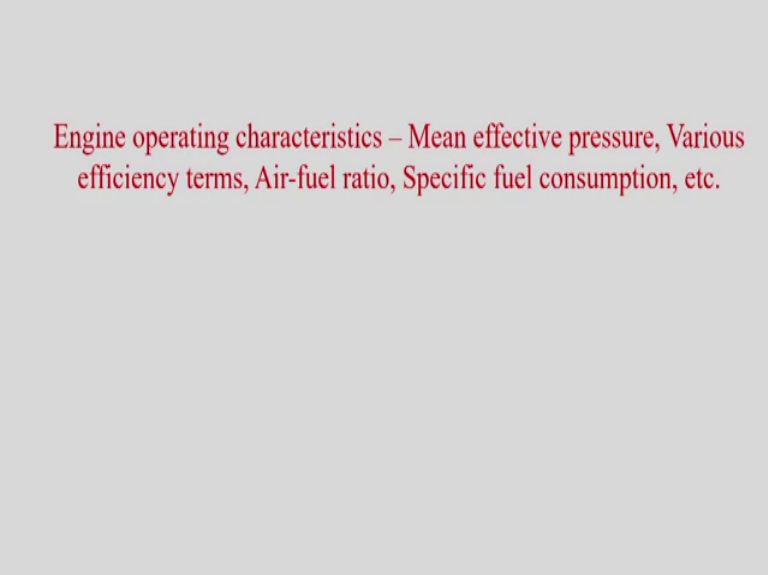
IC Engines and Gas Turbine
Dr. Pranab K. Mondal
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati

Lecture – 04
Engine operating characteristics

So, we will continue our discussion on IC Engine and today we will discuss about Engine operating characteristics and deleted issues; that is Mean effective pressure, Various efficiency term, Air- fuel ratio, Specific fuel consumption, etcetera.

(Refer Slide Time: 00:35)



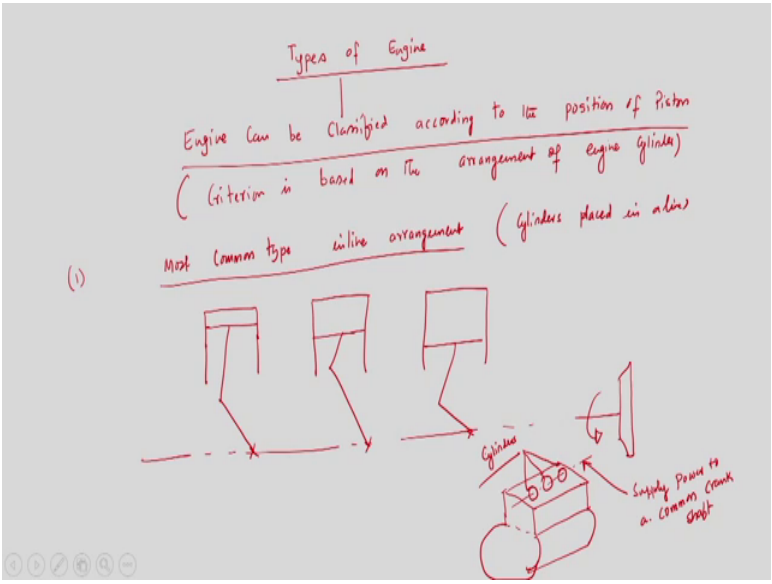
Before I go to discuss about engine operating characteristics, I would like to discuss a few important points that we could not complete in my last lecture; that is the you know engine classifications. I mean based on the cylinder arrangement this is very important that we have discussed so far that IC engine can be classified based on the you know type of ignition or type of combustion. Whatever it is SI engine and CI engine and then number of strokes that is 4 stroke engine, 2 stroke engine

We have disused in detail about what are the different strokes in a 4 stroke engine. We have identified that in a 4 stroke engine we had you know 1 power stroke versus 3 idle strokes. On the other hand in a 2 stroke engine only we had 2 strokes, I mean 1 is power stroke another is compression, but while power stroke is occurring we can have inlet and

exhaust simultaneously and, and for that we need not to have two different strokes separately.

So, to continue with that today I will discuss about that engine, can be further classified based on the arrangement of cylinder that is based on the position of the piston.

(Refer Slide Time: 01:49)



So, I am, I will just write that you know types of engine that is what we have discussed. Types of engine, it is very important that we have discussed 4 stroke, 2 stroke, spark ignition and compression ignition, but today I will discuss that the engine can be classified according to the position of the piston. So, apart from those I mean 4 stroke, 2 stroke based on the types of ignition and sorry based on the you know number of strokes, and based of the types of ignition; that is SI and CI we have discussed, but today I will discuss about that engine can be classified, you know according to, according to you know position of the piston.

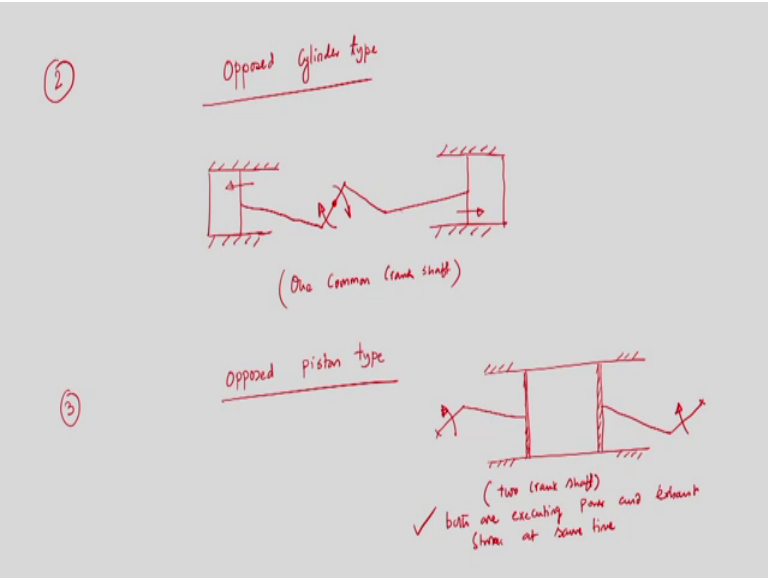
This is very important that according to the position of the piston engine can be classified. So, here while we are talking about that if we can classify engine based on the position of the piston, this criterion is based on the arrangement of the engine cylinders. Essentially this criterion each based on the, based on the arrangement of, arrangement of you know engine cylinder, engine cylinder, right. So, this is very important that we can classified engine based on the position of the piston that at this criterion is based on the arrangement of cylinder. So, I will discuss one by one.

Number 1 is very important, most common type is, most common type is inline arrangement most common type is inline arrangement that is cylinder placed in a line here, cylinders are placed in a line. So, this is known as inline arrangement which is most common type and I will draw the schematic. Also there will be a you know there will be a common shaft. So, so, last class I have discussed that.

So, we have a common shaft and this is rotating, may be you will be having one flywheel and so, this is most common type indel inline arrangement that all cylinders are placed in a line. And we have discussed that if it is a multicylinder engine then only to reduce the power fluctuation, I mean arrangement is done in such a way that may be when power stroke is occurring in one cylinder. There might be you know there has to be ideal strokes in other cylinders.

So, in that way you can reduce to power and power fluctuation can be minimized and this common subtest connected with the flywheel. So, this is flywheel. So, if I this is inline arrangement and the if I draw again a schematic suppose. So, these are the cylinders, these are the cylinders and these supply power to a common crank shaft, this is a ex you know shaft which is connected to the common crank shaft. So, this supply power to a common cap crank shaft. So, this is most common type inline arrangement.

(Refer Slide Time: 06:57)



Next we will discuss about that another arrangement which is 2, I mean it is also very important that is opposed cylinder type. There might be a arrangement based on the

opposed piston or cylinder type, based on the position of the piston criterion, is essentially based on the arrangement of the engine cylinders. So, opposed cylinder type this is very important that.

Again I have to draw the schematic so, here this is, this is opposed cylinder type, there is cylinders are opposing each other cylinder phase are phases are opposing each other. Now specification is that here, here we have only one common crank, one common crank shaft. So, this is known as opposed cylinder type, only we have one common crank shaft and both the cylinders are arranged in such a way that they are opposing each other, but we can run both the cylinders at a time, so this is opposed cylinder type.

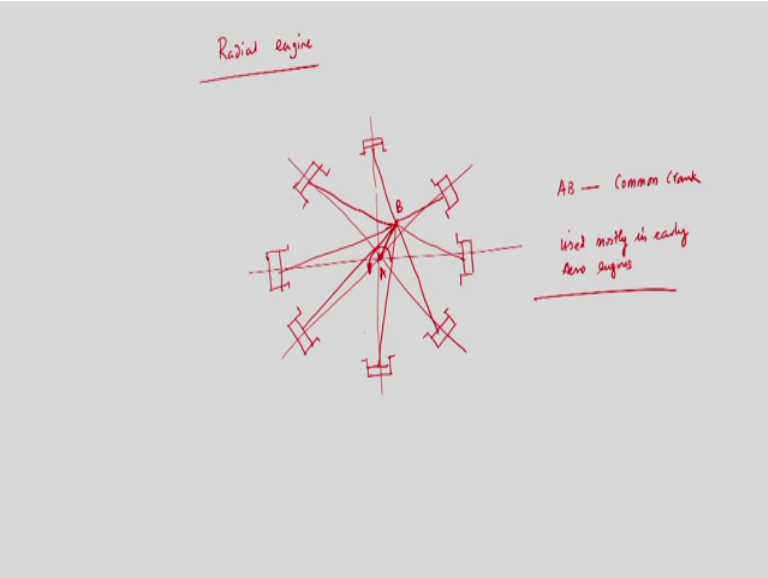
Similarly, we have opposed piston type. So, number 3 is again I am writing opposed piston type. So, now, we have seen that cylinders are placed in such a way that their faces are opposing each other. Now, we might have another arrangement where a pistons might face a, a pistons are opposite to each other. So, arrangement is like this, I am drawing again.

If it is a SI engine, I am not going to discuss about spark plug or fuel injector, because it depends upon the, you know types of ignition. We required, because if it is SI engine, we should have spark plug and carburetor, but if it is CI engine instead of spark plug, we should have fuel injector. And we can take air through air intake manifold. So, this is maybe these are the piston. So, these are piston, two pistons you know, this is opposed piston type and both are executing power exhaust stroke at same time two crank shafts.

So, here we have two crank shaft and both are executing and both, both are executing power and exhaust strokes at same time. So, this is very important that here we have two crank shaft, both are executing power and exhaust stroke at same time. this is call opposed piston, here is pistons are opposing each other, but power or ex exhaust will be at the same time.

Next is very another important type is, I will discuss that known as radial type, radial engine. So, this is very important Radial engine.

(Refer Slide Time: 11:39)



So, radial engine is like this, I have to draw again the schematic I mean schematically, I have to draw what is radial, radial engine, I am, I will draw now. So, this is the crank and it is rotating in this direction. So, you have a multicylinder common crank, this AB, this AB is the common crank. So, we have seen that we have common shaft, this is common crank, you know all engines are connected with this common crank and connecting rod. And this is suitable, we have multicylinders, this is suitable for, this is suit, I mean suitable whether I can write use mostly in earlier engines. So, this is radial engines used mostly in early aero engines.

So, this is radial engine, so, we have discussed that based on the cylindered arrangement the position of the piston, we can classify engine into different categories. We have discussed that most common type; common type is inline arrangement, where you know cylinders are connected in, in a line and supply for to a common crank shaft. Then we have seen opposed piston type opposed cylinder type where cylinders faces are opposing each other. And one common crank shaft opposed piston type, we do not have common crank shaft, we have two crack crank shaft, but both are executing power and exhaust stroke at a time.

And lastly radial engine where you know radial engines very important, rather it is used mostly in earlier radial engine where we have multicylinders and we have only one common crank AB.

So, with this, we have seen that apart you know apart from the classification based on the types of ignition and number of strokes, we can classify engine based on the arrangement of cylinder that a rather position of the piston. So, with this, we now move to C another important is types of cooling which is used in a IC engine.

As I said you that probably, I will discuss in detail about this, but as I said that in a IC engine, in internal combustion engine whenever combustion is taking place idea is to essentially to use, you know in case of a SI engine, we are normally having one spark plug which ignites the fuel. On the other hand, in case of a CI engine, we are utilizing the high pressure temperature of the air.

At the end of the compression to ignite the fuel without having any external agent, fine. So, the ultimate objective is to that we have 1 power stroke, where we had 3 idle strokes in a 4 stroke engine or 2 idle, 2 another one idle strokes in 2 stroke engine. And we have discuss about that having 3 idle strokes versus 1 power stroke. I mean what is the, what are the advantages added, but power stroke; that means, the stroke from where you are getting energy.

Out of these 4 strokes, only power strokes from power strokes, we are getting energy. And for other 3 remaining strokes, we need to supply energy from the flywheel; that is whenever we are getting energy from the power stroke, the energy is remaining stored in a flywheel, I mean we need to run engine, we need to run vehicles.

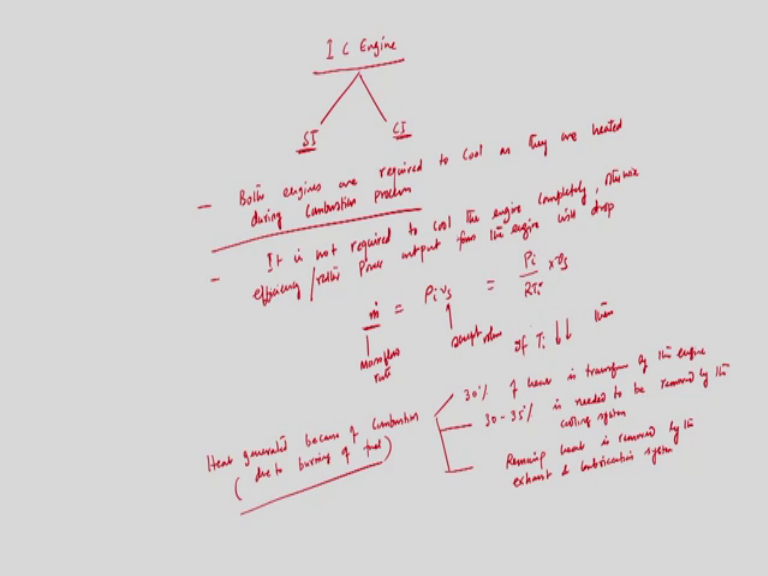
Of course, a part of the energy will be utilized to rotate a wheel rather a as portion of the energy will be stored in a flywheel, because you need to borrow energy for occurring 3 other different strokes, but whenever you are having power stroke; that means, we had combustion and because of the combustion we have high pressure and temperature and that will create a thrust on the piston phase and that is what we have a power stroke.

Whenever we are having high pressure and temperature in the inside the cylinder of course, engine cylinder or valves, valves of the cylinder piston phase will be heated. Now, we need to reduce, because may be we cannot reduce temperature to a severe extent; otherwise efficiency will drop. On the other hand, we have to have a cooling system, so that we need to you know, we need to make sure that I mean the temperature should not go beyond the limit for which may be lubrication system and will bunt off. And also I mean there will not be in a thermal crack in the cylinder wall or the piston

phase anyway. So, to there is a very you know judicial choice, because we should not have too much of cooling; otherwise temperature is reduced in such extent that it will drop down the efficiency of the engine.

On the other hand, we should not allow engine. I mean we should not allow that temperature should go beyond a limit otherwise there will be a problem I mean that is what we have discussed. So, whatever it engine, it is SI engine or CI engine. Normally, in internal combustion engine we need to cool down.

(Refer Slide Time: 18:33)



So, we have seen that IC engine internal combustion engine broadly SI and CI, where which we talk about, because whether it is different, whether it is classified based on the number of strokes or different you know position of the piston, but spark ignition engine and compression ignition engine. For both the cases, we need to cool down, because it in both the cases we have combustion, I mean we should have, I mean we will have combustion and because of the combustion there will be a huge pressure rise to, to reduce the pressure and temperature you should, I mean have proper cooling system.

So, that is why both the engines both engines are required to cool required to cool as they are heated during their combustion process, as they are heated during combustion process, so this is an important we need to cool down. Now question is, we cannot I mean this is very important, but we need to make sure that it is a required to cool the engine completely, because efficiency or the power to from the engine will be

decreasing. So, I mean it is not required, it is not required to cool the engine completely otherwise, otherwise efficiency rather power output from the engine will drop.

So, because very important, because we know, know that a mass M dot is equal to rho I into Vs; that is swept volume mass flow rate. So, this is mass flow rate and this is swept volume.

Since this rho I, I can write Pi by RTi into vs so, if Ti drops. So, now, if Ti drops, then what will happen? So, I mean mass flow rate of coolant will increase through the engine cylinder and as a result although swept volume is remaining same. If Ti reduces then mass flow rate of I mean coolant, I mean that will increase. So, it will create you know again to have higher heat transfer that is not a desirable one.

So, we need to take a you know judicial you know choice that what will be the, what max what will be the amount of temperature, you need to reduce from the engine cylinder that is very important. So, temperature should not be. I mean if you drastically, then mass flow rate will increase and because as I said you that you know since coolant I mean this is swept volume Vs is swept volume for a swept volume is remaining same. So, what will happen that I mean you know efficiency rather power output will drop.

So, I am writing that the heat engine, heat generated by IC engine due to burning of fuel, 30 percent transfer engine. So, whatever amount of heat generated in IC engine. So, heat generated, whatever amount of heat generated um, because of the combustion heat generated, because of combustion here 30 percent of heat, 30 percent of heat is transformed by the is, is transformed, transferred by the engine, you know transform by the engine due to, because heat generated, because of combustion or rather I can write due to burning of fuel; that is combustion due to burning of fuel we will discuss. So, 30 percent of heat is transformed by the engine and 30 to 30 percent, has to be you know removed by cooling system and remainder by exhaust and lubrication system.

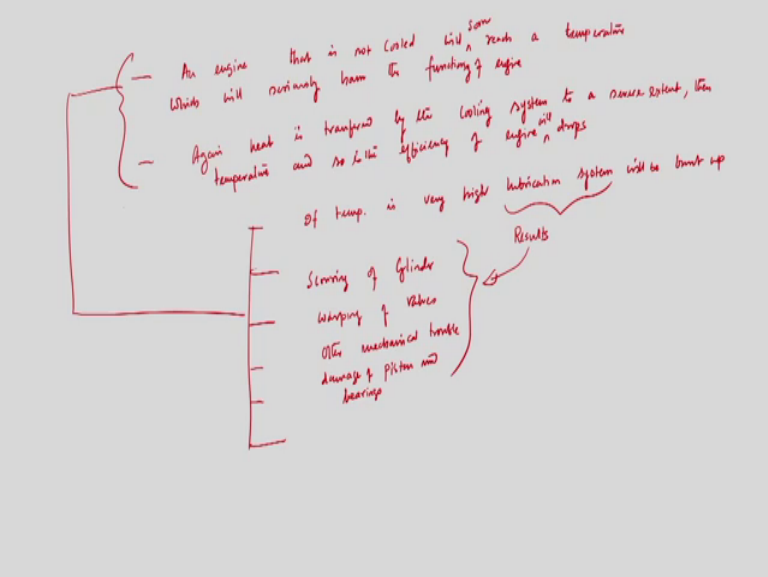
So, 30 percent of heat is transfom, transformed by the engine 30 to 35 percent is needed to be you know trans, you know removed or in is needed to be removed by the cooling system.

While remaining heat, remaining heat you know is removed by the exhaust and lubrication system, exhaust and lubrication system. So, this is very important that 30

percent of heat is transformed by the engine, 30 to 30 percent heat, we need to be you know we need to transfer by cooling system while remaining heat is trans removed by exhaust and lubrication system, it is very important.

Now, an engine that is not cooled what will be happen, I mean whenever we are having engine no matter whether it is SI or CI. So, if we do not cool the engine, this is very important, if we do not cool the engine then what will happen? So, an engine that is not cooled will soon reach a temperature which will seriously harm, it is functioning; that means, a engine, an engine that is not cooled, that is not cooled right, we will soon, so we need to cool simultaneously. So, we will reach at, we will reach a temperature that which will seriously harm the, which will, this temperature will seriously affect rather harm the functioning of the engine.

(Refer Slide Time: 24:53)



So, an engine we need to cool, if we not, if we do not cool, it, it will reach a temperature will soon a reach a temperature, which will seriously harm the functioning of the engine. This is functioning of the engine how, on the other hand this is very important again that is what I said that again if the heat is too much then lubri, I mean again, again if heat is transferred by the lubrication system by the cooling system, sorry by the cooling system, you know heat is transferred by the cooling system to a severe extent then temperature and efficiency and shows the efficiency temperature. And so, is the efficiency of engine

drops then temperature. So, the efficiency of the engine will drop so, this is very important.

So, out of this two, we need to make sure that, we will have a you know proper amount of heat needs to be transferred from a engine cylinder. And that is what we need to have a design calculation anyway. So, as I said is that if your engine that is not cooled will reach to a will reach soon a temperature, will reach soon a temperature, I mean will you know soon reach a temperature which will just seriously harm the functioning of the engine. So, which will soon reach at temperature which will affect the, what seriously harm the functioning.

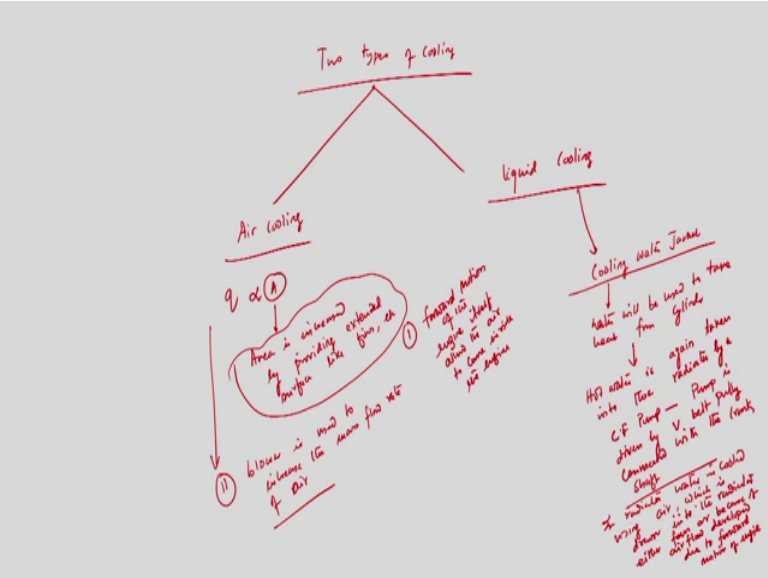
How, it is very important, because if it heat is now if I come to the first point by how there are many other points, I am writing fast if temperature is. So, high if temperature is very high, if temperature is very high, I mean this is you know beyond the a tolerance level of the you know cylinder material or something else. Then what will happen lubrication will be burnt up and resulting lubrication system, this is very important lubrication system will be burnt up and it results this lubrication system will results what scoring of cylinder you know blinding of piston bearings and warping of valves.

So, scoring of scoring of cylinder, right then, then, then known as you know warping of valves or any other mechanical travel. So, and that is known as of pistons and bearing. So, I am writing rather it will scoring of cylinders and that is very important that of valves and will create other mechanical travel other mechanical travel.

So, if temperature is very high lubrication system will burnt off and it will eventually results in this, in this other problems like scoring of cylinder that you know warping of valves. And other mechanical travel rather you know piston and, you know bearing will be and also you know damage of piston and bearing these are the volume.

So, we need a cooling system to get to keep the engine from getting. So, hot as to cause this difficulties and yet permit to soon the engine to ensure maximum efficiency. So, considering these we need to cool down the engine so, that the engine temperature should not be hot enough. So, and eventually we will get this kind of difficulties, but at the center we need to be you know very cautious. So, that the temperature should not be transformed for the engine to a severe extent otherwise temperature and it ultimate's effects on the efficiency of the engine will drop down.

(Refer Slide Time: 30:39)



So, now question is, so, we have seen that we need to have cooling now types of coolings is a where two types of cooling system is normally. Two types of cooling, one is air cooling another is water cooling, a liquid cooling not water a liquid cooling. So, air cooling we know that since we know that heat transfer rate is proportional to the area you know, so we need to increase area.

So, this area is increased by increasing by providing fin we, we have seen a heat transfer by providing extended surface like fins, etcetera., now how you can get air, because you know that the forward motion of the engine cylinder itself allows the air to sucking in the engines, engine and, if we have a proper path rather, if we can direct that incoming air through proper path. So, that it can be you know ultimately taken to the engine cylinder and by providing fin surface we can eliminate here, because it proportionately depend upon the area.

Now, another important is cooling or sometimes apart from this you know forward motion of the engine itself allow the air to come in, but on the other hand sometimes blower is provided. Sometimes a blower is used to increase the rate of which air is increased the blower is used to increase the mass flow rate of air very important. So, when we talk about area is increased by surface area, so number 1 is, this is number 2, number 1 is forward motion of the engine, forward motion of the engine itself. You

know, allow the air, air to come inside the engine, or in sometimes we need to increase a mass flow rate then we can use blower.

On the other hand we talk about liquid cooling, so air cooling is fine. So, we sure ensure that whenever you are having engine movement that forward movement itself will allow the you know liquid to air to come in and we can supply air by (Refer Time: 33:24). So, that mass flow rate to increase on the other hand, we can have liquid cooling.

So, normally we have seen that normally cooling water jacket is provided cooling water jacket is provided. So, when you are having cooling water jacket, we need to supply continuous rate of water and water should not be you know. I mean, we can use water and that is we recycled I mean whenever water is going to engine cylinder through some you know flow passage and eventually when it will takes heat from engine cylinder, we can leave this water.

So, we can take water again in, in some place and we can have cooling. So, this is called recycling. I mean we can recycle water, so cooling water jackets,, so water from cooling water jacket is taken. So, normally whenever it, it is going to cooling water jacket, it takes heat from the cylinder and then from cooling water jacket that is hot water. So, cooling water jacket water will you know rather water will be used to you know take heat from cylinder. Then this hot water is again, hot water is again, this is very important, this hot water is again taken into the hot water is again taken into the radiator 1 another small device by a centrifugal pump.

This pump, pump is driven by V shaft you know V belt pulley on a engine by a v belt pulley connected with the crank shaft. This is very important, we are taking water into a water cooling, water jacket, water text, I will heat from the cylinder and that upon taking heat it the temperature water will increased, water will be increased. And then hot water is taken again hot, hot water is again taken to the radiator using a centrifugal pump and centrifugal pump is run by a V shaft pulley which is connected to the crank shaft.

Now, question is, now whenever we are taking water to radiator; that means, there we need to so very important. So, in radiator water is cooled using air which is drawn in this a which is drawn, which is drawn you know through the into the radiator, into the radiator either by a fan, either fan or by the by the air flow developed or, because of air flow developed due to forward motion of the engine.

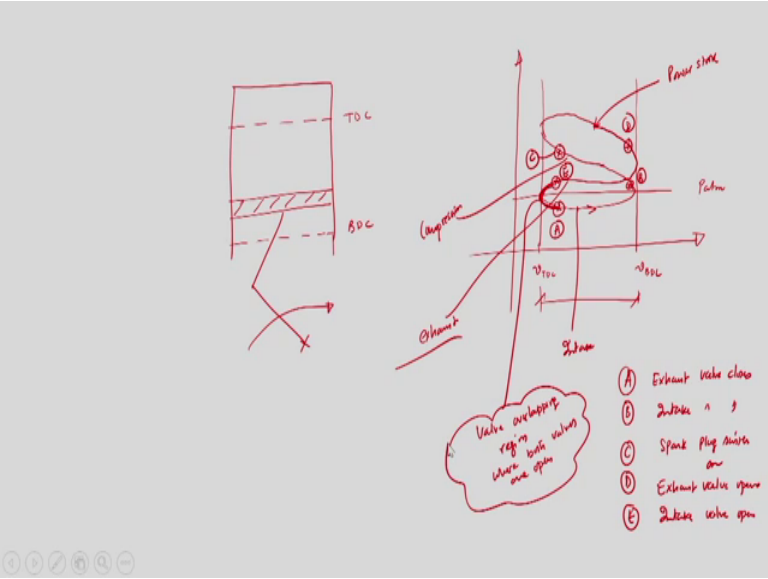
So; that means, we are taking hot water into the radiator, but radiator we need to cool down the water, because process is very continuous. So, what is done in the radiator? normally again it is heat exchanger. So, we can use fan to supply (Refer Time: 37:31), you know cooled air which will be supplied surroundings the radiator. So, it will take the air, you will take, have a heat from the coolant from the water or sometimes the air flow is developed, because of the forward motion of the engine that is what I told in case of air cooling system.

So, these are two normally, two different types of cooling used in the IC internal combustion engine by mind it when you use water as a coolant, it is not always possible that we can take, we cannot use water always, because water you now freezing point is very low.

So, what is done normally, if we even use the car in a area where temperature is very less even minus less than 0 degree that time we need to mix here is in which is known as ethylene glycol with water and which will increase the I know freezing point, I mean. So, that water cannot be water will not freeze otherwise, if the water freeze then it will, there will not be cooling at all rather the radiator. And cooling water jacket, because upon you know freezing it volume will expand and it will try to you know create a crack rather breakage of the cooling water jacket and the radiator.

So, with this we next to we will next move to discuss about the engine operating characteristic this is very important, but today I will discuss a few important thing that what is the engine operating characteristic. So, I will draw a schematic again and we have identified the suppose we have a engine cylinder, and this is top dead center and this is bottom dead center. So, this is piston and piston is connected with crank and connecting rod mechanism and ultimately you are getting power.

(Refer Slide Time: 38:53)



So, I am not go to going to draw, because there might be a spark plug carburetor all those things I am not going to draw. So, now, question is, if I would like to draw the you now as I said you that there will be a change in pressure and volume whenever the piston is moving from TDC to BDC, BDC to TDC, for the in the in different strokes. Now question is you know that whenever piston is coming from TDC to BDC, I have discussed we are creating a vacuum inside the piston. So, suppose if it is atmospheric pressure, suppose this is the atmospheric pressure pa tm, right and if we have two different volume; this is V BDC and V TDC. So, this is V TDC and this is V BDC, so volume of the cylinder.

Now, whenever piston is at BDC, the volume will be this and whenever piston is coming to TDC volume will be like this and so this is the swept volume. So, you can see that this is the swept volume, this is V TDC and V BDC, this is the swept volume that is VS. So, this is swept volume and this is the clearance volume.

Now when piston is coming from TDC to BDC where having a negative pressure inside the cylinder. So, if I try to draw there may be volume is increasing, but pressure will drop, I mean pressure inside the cylinder will falls. So, pressure will fall and it will be like this and again when piston is coming from BDC to TDC; that means, during the compression stroke, pressure will be increased, volume will try to decrease and ultimately we will get pressure will increase and when pist volume will come to. So, this

is, so may be whenever piston is coming to TDC at the end of the compression strokes pressure will be high. So, pressure is high and volume reduces.

And next stroke is you know power stroke. So, again piston will come from TDC to BDC and at the same time again pressure will fall pressure will fall and, but it will be again a atmospheric pressure higher than atmospheric pressure. So, pressure will fall, right. So, this will be I mean like this. So, these moments this is intake stroke. So, this is intake stroke I know this is intake, this is compression, this is power stroke and finally, this is exhaust, exhaust stroke.

Ah I will discuss of the important issue may be when piston is coming from BDC to T TDC to BDC. During intake stroke as I said you that exhaust valve is remaining closed, intake valve opens, but in exhaust valve closes not exactly when piston is departing from TDC exhaust valve closes, when piston is little bit away from the TDC during intake stroke. So, this is very important, so may be intake this is the position a, that is in exhaust valve closes.

So, ideally whenever piston is coming from TDC to BDC where allowing inlet valve is open, but exhaust valve is re will be closed that is what we have discussed. So, through inlet valve, we are introducing air fuel mixture, in case of a SI engine or only air in case of a CI engine. And exhaust valve is remaining closed, but this is not the case in a practical situation, a practical scenario, because exhaust valve will start closing when piston is little bit away from the TDC rather when piston is approaching BDC little bit away from TDC.

And we are opening exhaust valve purposefully, because whatever amount of fresh charge or fresh air is coming, because, because it is not always possible that whenever piston is coming from BDC to TDC during exhaust stroke all the combustion product will go out. So, there might be some amount of residue that we need to expel out and that will be expel out using the incoming air in case of a CI engine or incoming charge in case of a SI engine and that is why when piston is coming from TDC to BDC, we do not close exhaust valve exactly when piston is at TDC rather, we close it when it is little bit away from TDC. So, that inlet valve since it is since the inlet valve is opened. So, the fresh air which is coming during intake stroke will allow the residue to go out.

Ah. So, I mean some portion I am doing. So, some portion of the air some part of the fresh air or some part. So, you know some part of the fresh charge will be lost through the exhaust product that is true, but we need to we are doing like this because we need to kick open exhaust valve little bit, and for a small time and by that time piston will travel from TDC to towards BDC little distance and it will and then we will close the exhaust valve.

Second thing normally when piston is coming from BDC to TDC, we should close during the compression stroke, we should close we have discussed that the when piston is exactly at the BDC, we should close exhaust valve is closed, but we should close intake valve, but it is not the case rather we allow a an intake valve to close here let us say this is point B. So, this is point B, this B is intake valve close intake valve closes.

So, piston diverting from BDC towards TDC, we should not close intake valve immediately because in the previous just are we have seen that we are allowing exhaust valve to remaining to remain open up to even for a for small time even after piston is travelling from TDC towards BDC. So, some part of the charge rather some part of the air will be going out with the remaining you know rather a residue of the combustion product.

So, if we do not compensate that amount of air or charge combustion should not be efficient. So, what is done even when piston is travelling back to TDC during compression stroke from BDC, we should not close the intake valve immediately departs from the BDC rather we should allow fresh charge or charge fresh air or charge to come in even when piston started travelling from BDC. And we will keep open intake valve for a little while for sometime. So, these the intake valve closes that is when piston is departing from BDC not exactly at the BDC and then what is done maybe we use we whenever piston is approaching TDC, I will discuss this issue again. So, with spark plug, so maybe this is spark plug switch on this is C.

So, C is spark plug switch on, right and, so combustion will takes place. So, we should switch on spark plug when piston is not reached exactly at the TDC rather little bit away from the TDC, we will discuss this issue again in detail, but for the time being you should know that at the point C, we are switching on the spark plug. So, combustion will

take place, there will be huge pressure and temperature and because of what piston will travel back from TDC to BDC this is known as power stroke.

So, when piston is coming from TDC to BDC what will happen? Now, whenever piston is we have understood that this is a power stroke. So, at the end of the power stroke piston at BDC and that time inlet valve is already closed, but now we should open the exhaust valve when an exactly at the piston BDC, but it is not the case rather we should open exhaust valve when piston has not reached at BDC rather this is D.

So, D is exhaust valve open. So, ideally Pisto exhaust valve should open when piston is at BDC that is the, at the end of the power stroke, but this is not the case rather, we should open exhaust valve when piston has not reached at BDC at the end of the power stroke. And this is done we will discuss, because whenever we are in the huge pressure and generator. So, if we and the next stroke is the after the exhaust stroke after the power stroke next stroke is the exhaust stroke.

So, when exhaust stroke is happening, we are borrowing energy from the flywheel and there will be a if we there will be a huge pressure and temperature there will be huge resistance. So, what is done piston before piston reaching at BDC, at the end of the power stroke we open the exhaust valve. So, that as little bit amount of combustion product will go out and did and what will be the you know consequence in the next stroke when piston is coming from BDC to TDC, it will create less resistance because already some portion of the combustion product has gone out. So, piston will face less resistance and that is why we call less we need to borrow less energy from the flywheel.

So, that is why the exhaust valve opens when piston has not reached at BDC at the end of the power stroke. Next is next is piston is coming from BDC to TDC, again pressure is high and eventually piston will come to a BDC. And now when at we are understood when piston exactly at the TDC, we may open intake valve again to complete the cycle, but this is not the case we allow you know again intake valve to open when piston has got reached let us say this is E. So, E is you know intake valve open, this intake valve open. So, ideally should allow that the, you know intake valve should open when piston is exactly reaching at the TDC.

But this is not the case before piston reaching at TDC, we are opening the intake valve and again it is done, because the whenever piston is reaching towards TDC, at the end of

the com you know exhaust stroke, we are allowing intake valve to open and incoming air, I mean we are allowing some air to come in. So, I mean that incoming air may again help to remove the combustion product, I mean may remove the combustion product. So, that is why this is done.

Now, mine note it that A and E, this is the portion where this is the portion I am write again I am highlighting it. So, A E, this portion is known as you know this is known as valve overlap, this is known as valve overlap overlapping regime valve, overlapping regime, because this is the regime where both the valves are open, both valves are open, right. So, this is known as valve overlapping, this is in where both valves are open intake is open exhaust is open.

So, air is coming little bit, air is coming and that fresh air will be allowed to you know combustion product to go out and only that some fresh air will be used to mix with the combustion product only to dilute that, so that the efficiency will increase. So, this is what is the, you know as valve timing diagram.

So, as I said you that today our discussion was on the operating characteristic of the other of the engine performance or engine operating characteristics. So, we have started our analysis, we have started our discussion on this with this valve overlapping diagram. And then we will see how, we can specify what is the work done and then what is the you know you know mean effective pressure which is very important to specify the total power, I mean output. And then we will discuss about what is the torque output from a I mean from this diagram and for that we need to exercise little bit mathematical calculation, fine.

So, towards up to this, we have understood that that whatever we have discussed in the last lecture that the you know valve opening time and movement of the piston in the engine cylinder that is not exactly the case from that is what we can understand from today's discussion. And whenever why we are opening and closing an intake and exhaust valve when piston is exactly not at the BDC or TDC that is what we have discussed. So, with this I stop my discussion today and I will continue our discussion in the next class.

Thank you.