IC Engines and Gas Turbines
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Lecture – 05
Otto Diesel and Dual Cycles

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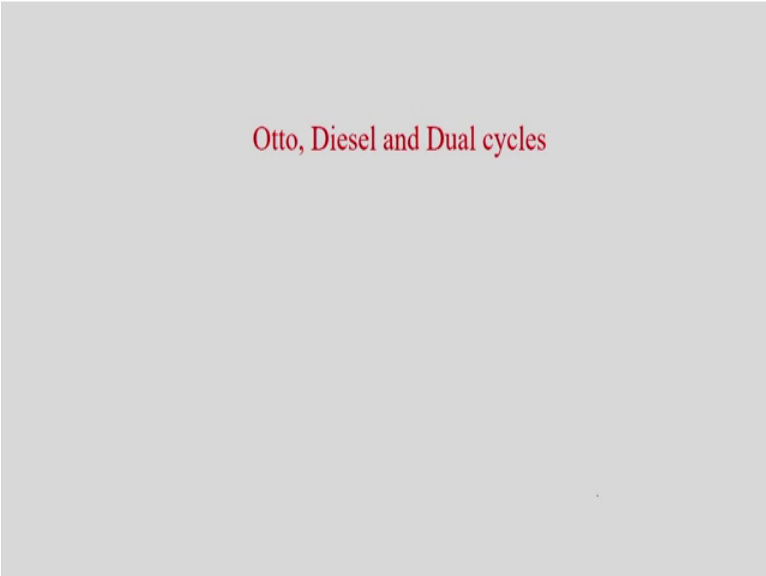

So, we will continue our discussion on IC Engine. Today, we will discuss Otto Diesel and Duel Cycles. So, but we would like to discuss a few important issues that we could not discuss in my last lecture. So, before I go to discuss about Otto diesel and dual cycles, so I will recapitulate those I mean which are very important before I we go to discuss we go to discuss about auto cycle, diesel cycle, and dual cycles.

Because, when we will discuss about Otto diesel and dual cycles, of course we need to know what is a work output from the engine, and then we have to quantify efficiency. And of course, in as I said you that Otto diesel and dual cycles that I will today I will diss tell that, but in case of SI and CI engine we have seen that whether it is four stroke or two stroke, we are having a continuous changing pressure and volume.

So, whenever we are having change in pressure or volume, then of course some ironic states of the working substance will be changed. So, whenever the thermodynamic state of the working substance is getting we is getting changed, then we need to (Refer Time:

01:30) you know the thermodynamic stress at the each and at the end of each and every strokes in a thermodynamic plane.

And probably the change in pressure and volume rather the change of thermodynamic states is approximated by the air standard cycles. So, in case if it is an SI engine, then I mean whether if it is a four stroke SI engine, this you know it is an air standard cycle, but this is approximated by an air standard cycle which is known as Otto cycle. Similarly, in case of a four stroke CI engine, you know again we need to compare rather we need to (Refer Time: 02:09) those, you know changes of thermodynamic state I mean using a air standard cycle.

And probably diesel cycle is also an air standard cycle, I mean whenever we are you know would like to whenever we are interested to calculate the efficiency work output, and also the change in pressure and temperature at the end of each and every stroke, we need to you know again follow air standard cycle. And this is the air standard cycle, which is approximated you know diesel cycle is an air standard cycle, which is used to you know map the thermodynamic states change in pressure and volume of a four stroke CI engine.

So, before I go to discuss in detail about these Otto diesel and dual cycle, just I would like to recapitulate very important you know points which are you know, we can say that engine operating characteristics are there that whenever we are because internal combustion engine, it is similar to heat engine. So, it is very important that work is only the output. So, we need to quantify that the output work from the for engine, so we need to know how we can calculate work.

And probably last lecture, we have discussed about the, you know change in pressure and volume in a four stroke engine. And probably that diagram whatever I have discussed in the in my last lecture that is known as indicated diagram or sometimes it is known as valve timing diagram. So, from this diagram we need to quantify the work output from the you know from that cycle, I mean whether it is Otto cycle or diesel cycle four stroke engine.

Because, you have seen that in a four stroke engine, we are having only one power stroke versus there are three idle strokes. So, we will get work output only from the power stroke rather for three different other strokes, we need to supply work or supply energy from the a flywheel, so that is why you need to quantify a few important terms which are related rather which are directly related to performance of an internal com internal combustion engine.

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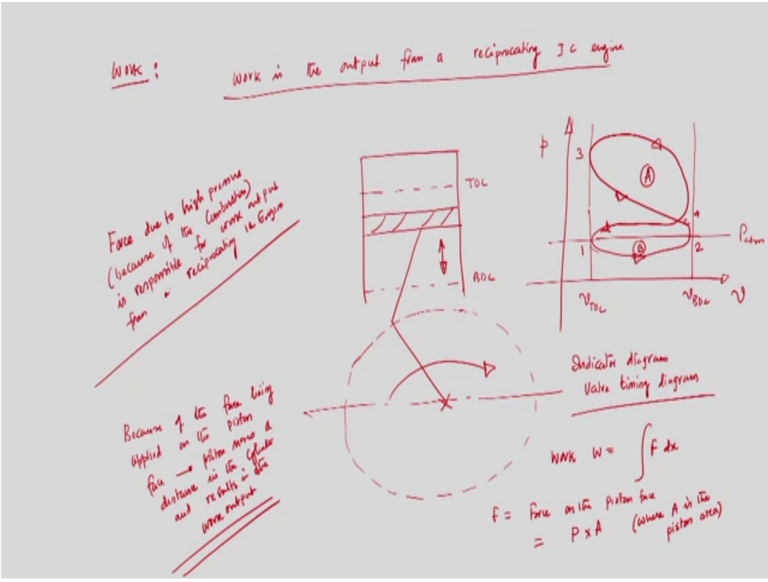

So, initially I will discuss about the work, what is work. So, this is very important what is work that is work is only the output for the heat engine or internal combustion engine right, it is very important in a reciprocating IC engine. So, work this is very important. So, work is the output from a reciprocating IC engine, because whenever we are having work is the output work is only the output rather work is the output of a reciprocating IC engine.

Because, we have seen that in a four stroke engine, we are having a reciprocating motion of the piston. And somehow we are converting the reciprocating motion to rotor you are using a crank and connecting rod mechanism. So, we are getting some amount of work inside the cylinder. And maybe it is not always possible that, whatever the amount of work, we are getting inside the cylinder is not transferred to the crank shaft. So, maybe the amount of work we are getting at the crankshaft is less than that produce inside the cylinder. So, we will discuss all those issues. So, work here is the output from internal combustion engine.

Now, question is how work is produced? As I said you that if I try to recall again, say that you know the diagram we have drawn in the last lecture that is known as valve timing diagram or indicator diagram p, v. So, if it is atmospheric pressure, so if it is p atm, then we have seen that we are having this is v T D C, and we are having v B D C, so this is volume, and this is v B D C.

So, we are we have plotted that so you know this is the process and so 1, 2, 3, and if I tell it 4 1 4. So, this is very important that whenever this is known as indicator diagram indicator diagram or sometimes it is known as valve timing diagram. We have discussed in detail that opening and closes, opening and closing of different valves or two different valves are intake and exhaust valves.

And we have identified that there is a you know small time provider with both the valves are remaining open, this is known as valve overlapping reason. So, this is valve timing diagram. Question is so we have seen that in a four stroke engine only power stroke is a stroke from where you are getting power, and for three other remaining stroke we need to supply power from the flywheel.

So, how whenever we are having you know we are getting power output, then how we can quantify rather why work is produced from an engine cylinder. There of course, we have to have work you know output from the engine, otherwise why how can you know drive you know Otto you know four wheelers, two wheelers whatever it is.

And if I see if I draw the you now schematic of a you know internal combustion engine again, so we have seen that if this is the TDC top dead center, sometimes it is known as inner dead center, and this is outer dead center BDC. And this is piston, and I am going to draw the piston ring again. So, if this is the engine cylinder, so what is happening we are having reciprocating motion of the piston inside the cylinder? So, we are having a reciprocating motion, piston is coming and piston is travelling from TDC to BDC again going back to TDC.

And we will have a suppose we will have a piston reci rotary motion. So, this crank and crank and connecting rod mechanism, we will have a rotary motion. So, this is the rotary motion of the crank. And whenever there is a compression stroke of course we need to supply energy, because we need to travel, we need to allow piston to go back from BDC to TDC.

And air fuel mixture in case of SI engine and only face they are in case of a CI engine will be compressed. And before piston reaches at TDC, we will discuss again while discussing the Otto and diesel cycle. Rather while we are mapping the change in pressure volume using an air standard cycle, which are known as Otto and diesel cycle for you know SI and CI engine respectively, that there will be a few approximations. And we will discuss those that those approximations are not very you know are not bad approximations.

So, whenever piston is coming back from BDC to TDC, and probably in case of a SI engine we need to switch on spark plug, which is an external agent which initiates combustion or if it is a CI engine, then we are utilizing the high pressure temperature of the compressed air itself. And whenever a piston is reaching closer to TDC, we have already the high pressure temperature of the compressed air. And the moment when you are you know spraying fuel, rather we are injecting fuel through a fuel injector into the cylinder, it will initially it will automatically you know start combustion.

So, whenever combustion is there that means, we are already we are we have you know compressed air and fuel or only fresh air then, if we ignite either through a spark plug or a we are utilizing high pressure temperature of the compressed air itself, then again combu you know combustion will start, and it there will be a huge pressure and temperature rise, so that high pressure we try to create a thrust on the piston phase.

And piston phase will try to come back from TDC to BDC that is known as power stroke, so because of the generation of high pressure that is acting on the piston phase. So, there will be a force acting on the piston phase, and because of that force piston will come back from TDC to BDC. From there we can quantify work, because there is a really you know whenever piston is coming back, so that means a force is generated, and that force due to high pressure of course. Of course, either high pressure because of combustion, and that force is essentially responsible for the work output from a internal combustion engine.

So, force is very important, force due to high pressure because of the combustion because of the combustion force due to high pressure because of the combustion is responsible for work output from a from a reciprocating from a reciprocating IC engine that means, force is acting on the piston phase, and because of that you know piston piston travels.

So, because of the force being applied on the piston phase piston moves a distance in the cylinder, and you know you know results in a this results in the work output results in the work output. This is very important that because of these force acting on the piston phase, piston will traverse a distance in the cylinder, and because of that we can have work output that means, I can write that work if work is W, and then if I interrogate F is a force, and piston is having a instantaneous rather small you know distance through which very in fine small distance whose distance traversing dx, then W is equal to F dx.

So, F is equal to force on the piston phase; piston phase that is essentially pressure developed into area of the piston, so where A is the piston area. So, if I write this, then work output W is equal to p A dx, this is very important p A dx. And x is the distance through which piston moves, where dx is the distance this is the distance the pistons moves. So, this is very important.

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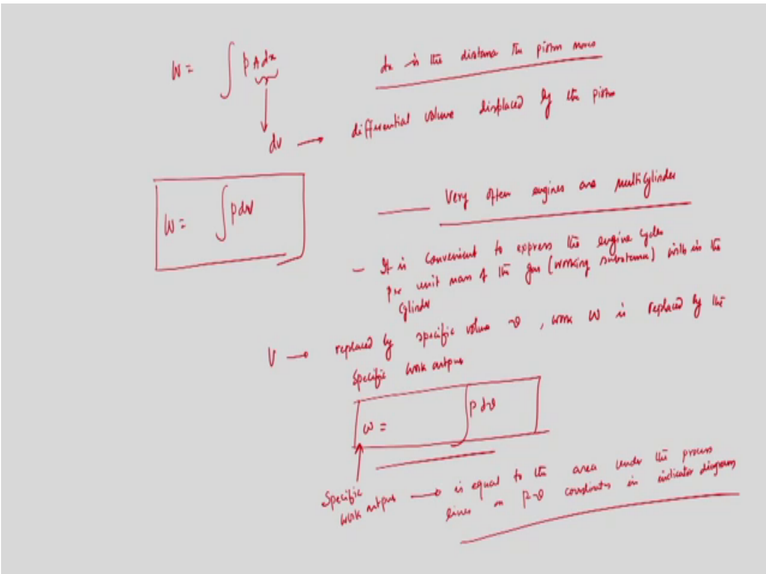

Now, so this is the work output from an engine that we are getting very importantly, this you know see A into dx, this is essentially dv this is volume that is the differential volume discussed by the piston. So, dv is the differential volume displaced by the piston right. So, W is equal to p dv p dv work that you are getting.

So, if it is p dv work, then from the you know from you know that indicated diagram that is what we have drawn from here that I know the change in volume. So, essentially you know area under the process curve from the indicated diagram or valve timing diagram, we can directly ca you know measure the work output from engine. So, if I calculate the area under the process curve, because as I said you that while we are having inlet exhaust and compression stroke, we need to supply work to the engine cylinder to the you know piston, why we are getting work output from the piston in the power stroke.

So, since it is p dv work, we can calculate work from the indicated diagram, because this is area under the you know this is very important this has because this is the area under the process curve. So, very important that, we have to calculate that what will be the total area, because it is always advisable that we should quantify p dv. So, this is the work output from the reciprocating IC engine, because now we can directly get it from p v diagram, because area under the process curve will give us the work output from the engine, this is very important.

Importantly, see sometimes very often that not sometimes very often engines are multi-cylinder you know very often engines are multi-cylinder very often engines are multi-cylinder very right. So, since it is an mul I will very op we need to get huge, you know high workout from the engine. So, it is quite common that we have a multi-cylinder engine.

If that is the case, so it is convenient to under engine cycle per unit mass. Since it is very often that we need to get you know power high huge power output. So, it is convenient to express to analyze the engine cycle, so it is convenient it is convenient to express the engine cycle.

Since engines are very often multi-cylinder, it is convenient to express engine cycles you know per unit mass of the gas per unit mass of the working substance of gas rather or I can write working substance, because it is only air fuel mixture in it is only air in case of a CI engine, where it is air fuel mixture in case of a SI engine. So, working substance I can write within the cylinder within the cylinder.

So, now to do so what is done that V and to do that V is replaced by specific volume that is capital V by term specific volume v, and what is work W is replaced by the specific work output by the specific work output by the specific work output that means, small w that is specific work specific work output from the cylinder will be p into dv, this is very important. Rather I can write as is p p into dv.

Since engines are very often multi-cylinder, it is convenient to analyze engine cycle for a unit mass of the working substance of gas you know within the cylinder, then because we are having multi-cylinder engine. So, the total work output will be will come from different cylinders. So, in that case it is always convenient that how much amount of work that we supplied to the engine or how much amount of failure sub we have supplied to the engine, and then that volume v is replaced by the specific volume, and works will be the specific work output. So, specific work output will be equal to p small dv. And this is very important for the multi-cylinder engine fine.

Again I am telling this is the work output for engine, and we can directly get it from the p v diagram only by calculating the area under the process line. And we need to know that again I am repeating that intake exhaust and compression stroke, which absorbs work from the cylinder. On the other hand power stroke provides work to the engine cylinder. So, from there we can I mean whether it will be added or it will be subtracted that is quite you know straight forward. And from there from the area under the process line p v line p v diagram, we can calculate the work output ok.

So, now this is the work output very important, very importantly that is what I was telling that may be that so the specific work is equal to the area under the process line on p v coordinate that is what I am telling. It is very important that the specific work output is equal to the area under the process line on p v coordinate in on p v coordinate in indicator diagram right. So, specific work output is equal to the area under the process lines on p v coordinates in a indicator diagram fine.

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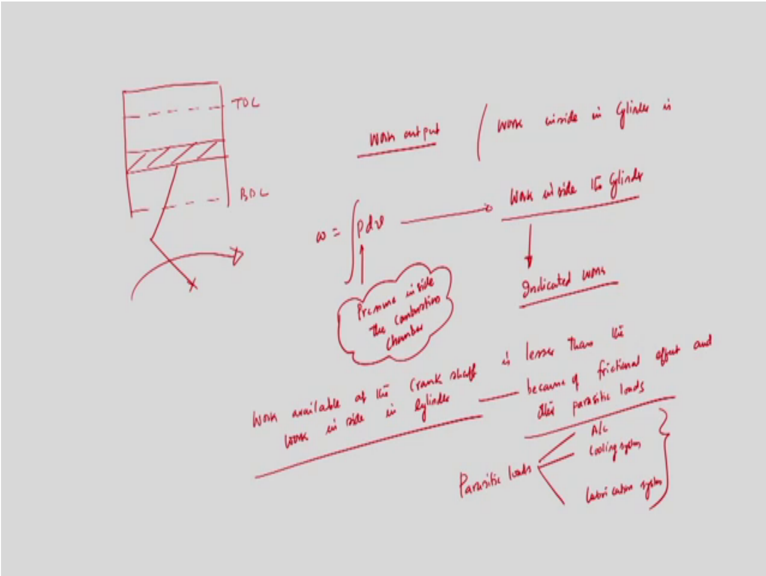

Next I would like to discuss that again if I draw the again you know engine cylinder, this is very important. So, if I draw the engine cylinder, suppose this is this piston, and this is TDC, this is BDC, and piston will move in this direction. So, we may have you know air supply I am not going to draw the supply line of air exhaust manifold all those things, but this is the indicator this is the engine cylinder.

Whatever amount of work we are getting inside the engine cylinder? So, work output very important, so that is work generated work generated work or rather work developed is very important, you know work inside the combustion cha chamber. So, work you know inside the cylinder is you know called indicated diagram, because you know p pay the presence of the cylinder combustion chamber, then you know whatever areas, so then w into p d v.

So, if I have calculated specific work, work out this is p input d v, if the p is the pressure inside the combustion chamber, so this is the pressure inside the combustion chamber, so this is the pressure inside the combustion chamber. Then work output using this expression or if I try to get it from the area under the process line p v coordinate on the p v coordination from a indicated diagram that is if I try to calculate work using this expression or even if I try to calculate work from the area under the process lines on p v coordinates in a indicator diagram, this we this is the work inside the cylinder.

So, this is the work inside the cylinder right, and this work is known as indicated work so this work is known as indicated work very important, so that means work with what we are calculating using this expression p d v or else if I try to calculate work under the area of processed lines p v on processed lines on p v coordinates in an indicator diagram that is the indicated work that means, the work available work available at the crank shaft at the crank shaft is lesser than the work inside the cylinder inside the cylinder this is very important, because this is quite obvious because work available at the crank shaft is always lesser than the work inside the cylinder that means, you know because of what may be we are getting work output from the engine cylinder is indicate in indicated work, because p is the pressure inside the combustion chamber.

So, if I try to calculate work using that formula that would be indicated work, but the work available at the crank shaft is always the work available at the crank shaft is always less than the indicated work indicated work because of some you know parasitic loads, this is because of frictional effect. And other parasitic loads this is very important when it know other parasitic load loads, what are the parasitic loads. So, parasitic load different, because we should know this is very important, because parasitic load what do you mean by you know we should know about it, because parasitic loads that means, when we are having suppose we have a four wheeler, so always we are very much we always try to find out comfortable gem.

So, maybe we need to in certain AC air condition. So, to run that air conditioner, again we need to borrow work from the engine cylinder on the top of that. Yesterday I have discussed that we need to have a proper cooling system, so cooling should not be so stringent that the temperature reduce drastically, and in that case efficiency might drop or the efficiency should drop.

On the other hand we should also have proper cooling, otherwise lubrication system will burnt up, there might be a generation of thermal crack. And I mean failure of different valves all those things, so again that should not be the case. So, you need to have a proper cooling of the engine cylinder that means, if you need to have proper cooling, it maybe of air cooling or water cooling that is what we have discussed.

In case of a water cooling system, we need to supply water. And for that it will be you know water to be supplied to a in the cooling water jacket from there again it will be taken back to the radiator using a centrifugal pump. And to run that centrifugal pump, we need to connect one you know that pump you need to connect using a V belt pulley with the crank shaft that means whatever amount of work is generated in the engine cylinder a part of the work is taken to run all those things.

I mean we need to air conditioner, we need to have operate continuous cooling system maybe lubrication system for that you know that is a air conditioning AC, then cooling system, then lubrication system for those we need to supply work, because we need to run all those. So, these are known a parasitic loads that means very important.

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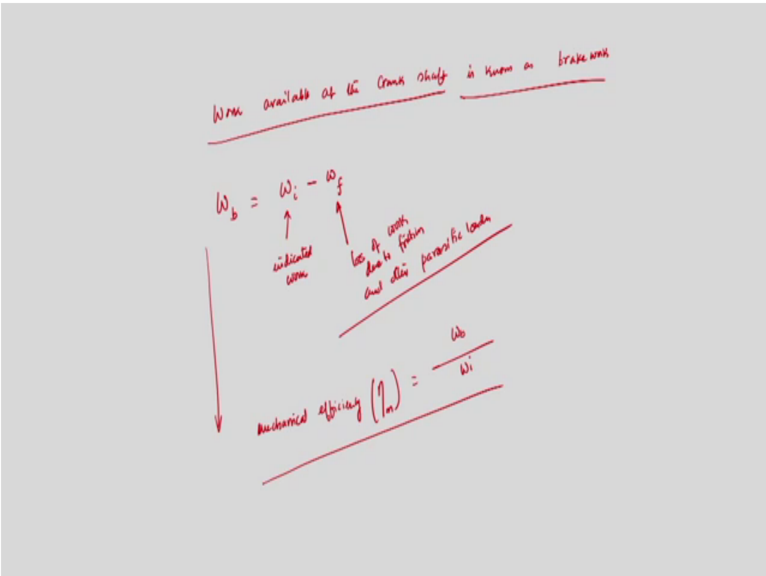

That means work available at the crank shaft at the crank shaft work available at the crank shaft is known as brake work brake work w b. So, w brake is equal to w indicated, I am writing the you know I am writing the specific work available at the crank shaft at the crank shaft is known as brake work, and that will be w indicated minus w f.

So, this is indicated work this is indicated work, and this is very important this is the specific work lost this is loss of work lost of work due to due to friction and other parasitic load other parasitic loads. So, brake work is always less than indicated work by an amount, which is equal to the loss of work the loss of work not lost loss of work due to frictional effect, and other parasitic loads fine. This is very important. So, this is very important that that what is the brake work or what is indicated work.

Since the work available at the crank shaft is always less than the indicated work, we are defining one efficiency which is known as mechanical efficiency of the engine, which is known as we will discuss about thermal efficiency. But, mechanical efficiency of the engine eta n which is defined, because brake work is always brake work is a work that we are getting at the crank shaft, so that work is responsible to drive to run the wheel.

And because of what we can drive on one place to other place, but actually the work developed the work produced inside the cylinder is a indicated work, which is greater than the brake work. So, this mechanical efficiency is defined as the ratio of brake work to the indicated work. So, this is known as mechanical efficiency very good.

Now, we will discuss about a few things that again I told you that, that work can be obtained from the indicator from the process lines on p v coordinates in the indicated diagram. As I said you that what is the gross indicated work, because you know gross indicated work is the work. So, we are getting work output the work we are getting only because of the power stroke. For three other remaining strokes in a four stroke engine, we need to supply work to the crank shaft, and we are getting it from the flywheel. So, from there we can easily calculate, what is the net work output from the engine fine. So, this is very important that what is the work and mechanical efficiency that is what we have defined.

Now, we will discuss another important issues that fine. So, we have discussed about the work and what is so it if we need to calculate pump work, then easily I can calculate. Because, as I said you that if I go back to my previous slides, where I have drawn the indicated diagram see what is the pump work. Intake and exhaust stroke which absorbs work.

So, if I try to calculate, so this is the intake stroke 1 to 2, and this is the exhaust strokes for 2 1. So, you know this area, if I try to give you know this area B and C. Suppose, if this is B, so this is B total is B this is A, and this is C. So, you know B is the work, where we need just go for this is called pump power that is you are observing work, where A is the work which is produced that is the you know work we are getting from the gross indicated work.

So, sometime there might be a case that the intake is taken intake is introduced. The intake process is conducted even at the pressure, which is higher than the atmospheric pressure, so that issue we will discuss may be I mean in one of our subsequent lectures. But, for the time being you should know that intake exhaust and compressions for which we need to absorb energy rather absorb work while in case of a you know power stroke, we are getting in power work from the engine cylinder. And that we can get from the process line that is area under the process line some p v coordinates in a indicated diagram.

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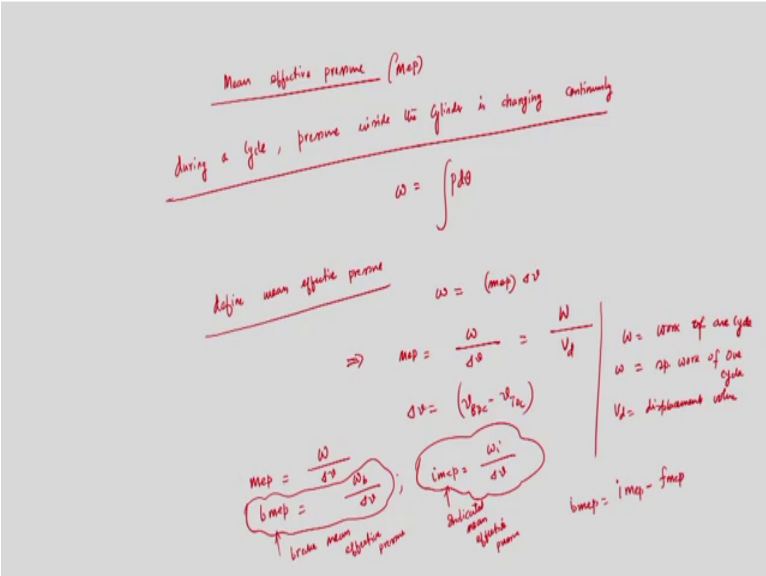

Mean effective pressure. So, this is known as mean effective pressure. So, what is the mean effective pressure? We have seen if I recall say if I go back to the you know actual p v diagram, we have seen that the pressure inside the cylinder is changing continuously it is not a fixed. So, pressure and volume rather it is a you know continuously changing right. So, this is the cycle, during a cycle pressure inside the cylinder is changing continuously, this is very important.

So, pressure is continuously changing, so that integral of p v d, it is not so easy to calculate. So, we need to take help of a computational method rather we can invoke an idea of mean effective pressure, so that the an average or mean effective pressure we can define. So, w mean specific work output is equal to P into d v, P is the pressure inside the cylinder which is continuously changing during a cycle. So, it is not easy to calculate instantaneous pressure inside the cylinder. And for that we need to invoke we the for that we need to invoke the computational method.

So, instead of invoking computational method, we can you know we can you know define the concept of mean effective pressure, so that so we can define the mean effective pressure rather we can you know introduce mean effective pressure which is known as mep. So, we can define mean effective pressure, that means, we are introducing the concept of mean effective pressure such that the specific work output can be retained mean effective pressure into delta v change in volume, that means, mean effective pressure will be W by delta v.

So, if I write in ins instead of writing specific quantities, if I write in the total, then W by capital V, where delta v is essentially V TDC minus V BDC, V BDC minus V TDC, the change in volume during one cycle. So, here W is the work on cycle. So, here W is the work of one cycle, then W is the specific work of one cycle, this is specific work of one cycle and delta rather small capital V or this V d I am writing the V d is equal to displacement volume, this is displacement volume

So, now this is very important work of a one cycle, we can introduce the concept of mean effective pressure only to get out only to you know that you know relieve to get relief out of calculating the instantaneous pressure inside the cylinder because pressure inside the cylinder is changing continuously.

So, if you would like to obtain pressure at a given instant is not so easy, we have to invoke the computational method of computational treatment is required. Instead of doing so we can introduce the concept of mean effective pressure which is defined as. So, the specific work output will be equal to mean effective pressure in the changing volume delta v that is V BDC minus TDC from there I can calculate mean effective pressure.

So, from there I can write mean effective pressure is equal to W by W by you know you know delta v. So, if I would like to calculate brake mean effective pressure that is only b mep that will be called to brake power by changing volume or if would left to calculate you know indicated mean effective pressure that is W indicated by change in volume I know the change in volume. So, this is brake mean effective pressure, and this is indicated mean effective pressure right. So, this is indicated mean effective pressure, and this is brake mean effective pressure. So, b m p and i m p, we have calculated. So, this i m, b m e p will be called to i m e p minus, there will be another which is known as f m e

p. So, this is brake mean effective pressure is equal to indicated mean effective pressure minus frictional mean effective pressure that is very that is from the definition it is coming ok.

So, this is very important that you know mean effective pressure you can introduce. For this context, I would like to say that the mean effective pressure is a good parameter a good choice parameter for comparison of the engines for comparing engines we required to the design of the, or output. Because whenever you are comparing engines so that means mean effective pressure is a good parameter for comparing the engine why because it is independent of the engine speed and size right. So, if I use so there might be a different parameter.

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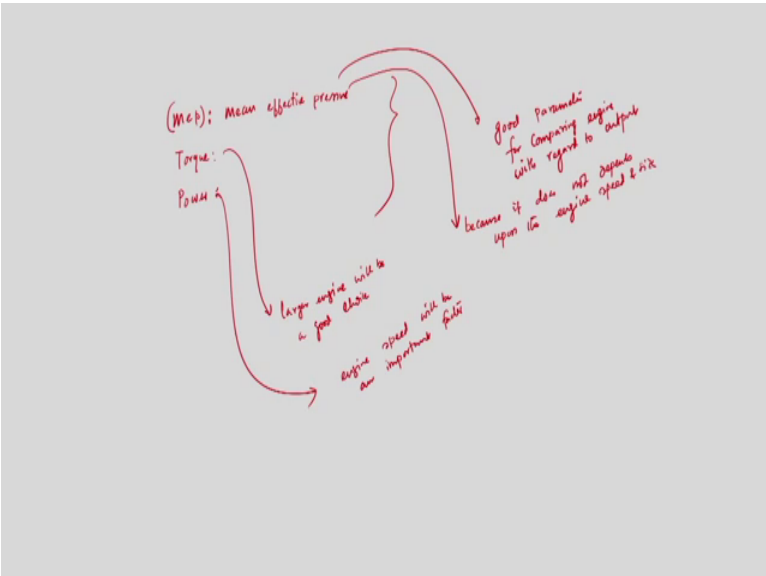

Now, that there is a mean effective pressure m e p or mean effective pressure or I So, I am writing can use torque or I can use power. These three quantities can be used to compare the engines, but mean effective pressure is a good parameter for comparing the engine because it does not depend on the engine size and engine speed. So, this is a good parameter for comparing for comparing engines with regard to design com engine with respect to or with regard to output. So, we had to you know compare which engine gives better output. So, mean effective pressure is a good parameter for comparing engine with regard to output.

Why, because it does not because mean effective pressure because it does not because it does not depends upon the engine speed and size, because it does not depend on the engine speed and size. Suppose, if I use torque as a comparing parameter, then a larger engine will have a better choice. On the other hand, if I use power as a comparing parameter, then speed becomes very important. So, if toque if I use as an engine parameter, then larger engine will be a good choice will be larger engine will be always will be a good option or good choice.

On the other hand, if I use power as an in you know comparing parameter, then engine speed will be an important term rather will be an important factor, so that is why mean effective pressure with good parameter for comparing engine with regard to the output because it does not depend upon the engine speed and the size.

On the other hand, if I can use torque and power as an in comparing parameter for that case, we have to have you know that will be very much you know very much you know biased that means, if a larger engine will have be a good choice, if I use torque as a comparing parameter on the other hand engine speed will be a important factor if I use power as a comparing parameter. So, from this from this point of view in a mean effective pressure is a me is always a good parameter and good choice ok.

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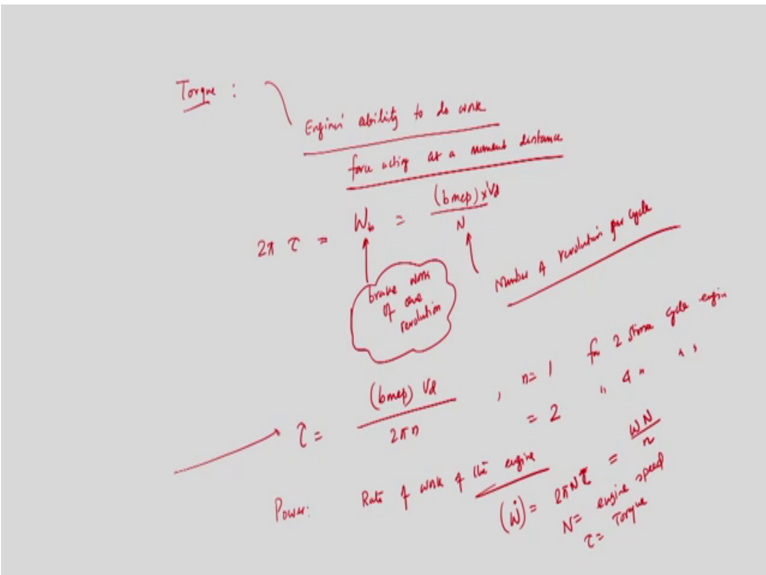

Now, I will discuss I what is torque and power because again we need to calculate torque. Torque is a good indicator of an engine ability to do work right. What is torque;

because this is the engine, engines ability engine ability to do work. So, what is torque? So, difference of torque if force axing force acting at a moment distance. So, engines ability to do work. And what is the definitions force acting force acting at a moment distance force acting at a moment distance.

So, if tau is the torque, then twice pi tau is equal to brake power W b is equal to brake mean effective pressure divided by n right. If tau is the torque, then 2 pi into tau is equal to brake power you know brake work of 1 revolution this is brake work for I this is not the this is not a specific W b this brake work of 1 revolution, this is brake work of 1 revolution that is brake mean effective pressure into displacement volume V d divided by N, where N is equal to number of stroke number of strokes sorry this is N is equal to number of revolution per cycle number of revolution per cycle. So, brake work of one revolution that is brake mean effective pressure into V d by N, where N is equal to number of revolution per cycle.

So, if it is a four stroke engine, that means, tau is equal to brake mean effective pressure into V d by twice pi into n. This is very important. Now, n is equal to 1 for two stroke engine or two stroke cycle engine; for two stroke cycle engine or n is equal to 2 for 4 stroke cycle engine. So, from there we can calculate easily torque. Now, what is power? Now, power we need to calculate torque and power, because what is the power output one engine. So, power is essentially the, you now rate of work of the engine. So, this is defined rate of work of the engine.

So, this is the torque that is force acting at the moment distance twice by torque is equal to W t brake work of 1 revolution and that is brake mean effective pressure into V d by N, N is a number of revolution per cycle. Why we are calculating power that is rate of work of the engine, and if it is, if I write W is equal to pa that is that is W dot, so that will be equal to twice pi N T, where N is equal to number where N is equal to revolution right N is a engine speed.

So, I where a tau torque, so W dot is equal to twice pi N T or that is equivalent to n into N divide sorry this is equal to W N by n, so where N is equal to engine speed and tau is equal to torque. This is torque, N is equal to you know engine speed or I can write in terms of W into so rate of work of the engine that is a power.

So, from there I can calculate, what is the power output from the engine. So, with this I would like to move into the, you know next part that whatever I have discussed that brake work essentially indicated work minus frictional work, we have calculated what is brake mean effective pressure. Why it is so important we have discussed that brake mean effective pressure is important from the perspective of you know this is very important because is a good comparing parameter it does not depends on the engine size and speed.

So, if I use torque as a comparing parameter probably a you know large engine would be a good choice. On the other hand if I use power as a comparing parameter probably speed might be a big role. So, from this point of view, it is always better to use mean effective pressure as a comparing parameter because it is you know it does not require engine size and the load fine. So, with this I would like to move to discuss about Otto cycle.

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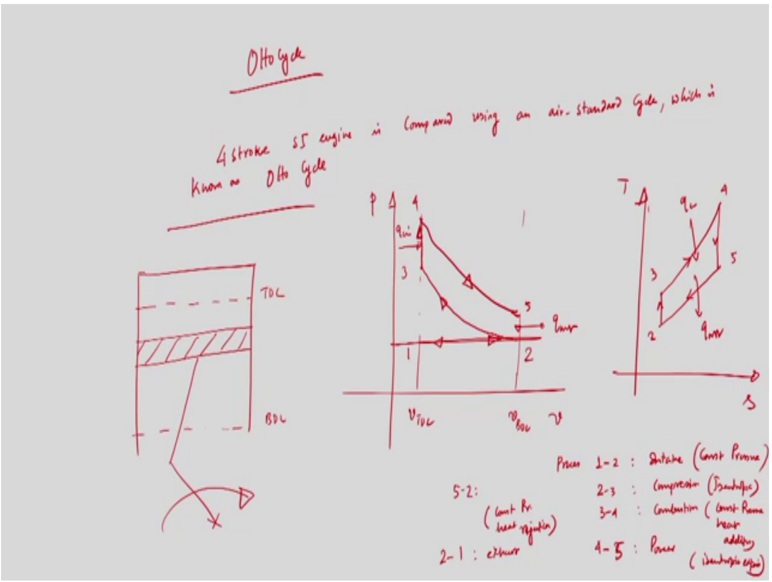

So, I will take about Otto cycle. So, what is Otto cycle? As I said you that whenever we are talking about four stroke engine and two stroke engine we have discussed in detail about four different strokes and two different strokes. So, normally we cannot call it as a thermodynamic cycle that is what also we have discussed is a mechanical cycle, but essentially we have seen that the pressure and temperature is continuously changing in a cycle.

So, when you are discussing four stroke engine, we have seen that a piston movement is from BDC to TDC coming back again going there and coming back. So, the processes which is there I mean in a inside the cylinder we need to compare using an air standard cycle. So, a four stroke engine a four stroke SI engine is compared with an air standard cycle which is known as Otto cycle.

So, four stroke SI engine, four stroke SI engine is compared using an air standard cycle, because you need to compare there is a continuous change in pressure and volume we need to know the thermodynamic states at the end of each and every strokes. So, we need to maps all those process in a thermodynamic plane. And for that we need to compare all those processes using a cycle. And what is done a four stroke SI engine is compared using in a air standard cycle which is known as Otto cycle which is known as Otto cycle.

So, if I draw the p v and SI diagram, so again I have to draw the you know schematic of the engine cylinder. So, there is a top dead center, this is bottom dead center. And piston is having reciprocating motion. And the reciprocating motion is converted to the rotary or using a crank and connecting rod mechanism. So, if I like to draw you know pressure and temperature in a thermodynamic plane that is p v plane and then what are the you know processes.

So, if I try to recall intake process is occurring probably we are approximating the pressure inside the cylinder is remaining constant, and if it is this is this is V BDC and this is V TDC top dead center and bottom dead center. So, suppose when piston is coming from TDC to BDC during intake stroke, so I am approximating this is this process 1 to 2. And it is occurring at constant pressure that is atmospheric pressure inside the cylinder. This is an approximation we will discuss that how good these approximations are we will discuss one by one

So, piston is coming from TDC to BDC during intake stroke, and we are approximating that the pressure inside the cylinder is remaining constant rather volume is changing from TDC to BDC that is what we can see from the pv diagram. And pressure inside the cylinder is remaining constant and is approximated as a atmospheric pressure fine.

Next stroke is compression stroke. So, again piston will move from BDC to TDC. So, while piston is moving from BDC to TDC, volume will be compressed, the pressure will go high. So, pressure will be high, at the same time volume will decrease. And I am we are approximating this process by an isentropic process 2 to 3. So, this is process 1 to 2, process 1 to 2, I am writing rather I will write TS diagram, I will draw the temperature-entropy diagram again, this is temperature-entropy diagram.

So, process 1 to 2 is the intake. So, constant pressure process, volume is changing. Process 2 to 3 is compression, so this is constant pressure. This is compression stroke, this is we are approximating by an isentropic process, isentropic process that pressure is continuously pressure is also changing, volume is changed. So, 2 to 3 is a isentropic compression process where pressure each changed as well as volume decreased, pressure increases volume decreases fine.

See isentropic process again is an approximation, we will discuss that how good approximation this is because we will have a continuous supply of heat from the engine cylinder. So, we will have a heat transfer, we cannot minimize the frictional loss to be a 0. So, if frictional effect is there, frictional loss is there and we will have a continuous heat supply from the engine cylinder to the coolant, then whether this process is a good pr a good this approximation is good approximation or not that we will discuss. So, 2 to 3 is a isentropic compression.

Then whenever piston is reaching very close to the TDC, and then we switch on the spark plug and combustion takes place. Now, question is again when there will be a combustion there will be huge pressure generation and pressure will be pressure will go high.

So, this is 3 to 4, and sorry this 3 to 4 is known as 3 to 4, this process is known as constant pressure heat addition, so that means, whenever piston is reaching at TDC, we need to switch on the spark plug to initiate combustion, combustion will complete. And as a result of combustion there will be a huge amount of you know heat generation rather there will be a high pressure and temperature rise and rather pressure rise and temperature rise, there will be high pressure.

So, this process is you know I am rather this entire combustion process is you know we are approximating using a constant pressure heat addition process. So, as if we are adding heat q in, in this process 3 to 4, 3 to 4 is the combustion process. And it is approximated as constant pressure heat addition. So, we are approximating pressure is remain constant, and this is known as constant pressure head addition. So, of course, piston will go to the TDC, combustion will take place and pressure will go high.

Next stroke is piston is coming from TDC to BDC, of course pressure will fall, volume will change. Here I would like to you know discuss another important point that when you are approximating that the process 3 to 4 is a constant plus heat addition process that is whatever amount of heat is generated because of the combustion and there will be high pressure that we can see that from 3 to 4 pressure will be high and there will be huge amount of temperature rise and that process is you know approximated by a constant pressure heat addition.

Note it note that the, we are not thinking about a change in volume. So, we are thinking there should not be a change in volume as if whenever piston is coming exactly at the TDC, and whenever piston will be there at the TDC at by that time entire combustion will be completed, but this is not the case.

Because movement of the piston; piston is very eased you know you know a very continuous I mean its it is not possible that piston will go to TDC, and it will wait about there for a for a se for a few minutes and for a few time, and it may be millisecond of the order of millisecond and by that time entire combustion will be completed this is not the case. That means piston is coming to TDC we are switching on the spark plug and whatever time is required to complete the combustion and for that duration, piston will remain you know the will remain at TDC that is not the case because the movement is very you know the movement is continuous, we cannot stop you know the piston travel.

But again on the other hand it is also true that we require a finite amount of time, switching on the spark plug complete of the our entire combustion it will take some finite amount of time although of the order of millisecond. But still during that time, it is not possible that the piston will remain what they are exactly at the TDC. So, how the volume will remain you know constant? So, again this is an approximation we will discuss in detail about this issue. So, this is a constant pressure heat addition.

Now when piston is coming from TDC to BDC, so volume will decrease, pressure will fall and that is again approximated this 4-2 4 to 2 this is known as you know expansion, expansion. And it is known as rather it is power stroke this is power stroke in a four stroke engine and this is approximated by constant pressure rather isentropic expansion sorry this is isentropic expansion. So, we are approximating this will be like this say let us say four to 4 to 5, this is 5. And then 5 to 2 is exhaust, 5 to 2 that is piston again it coming from BDC to TDC. When piston is coming from, no, 4 to 5 is the I mean 3 to 4 is the combustion process that is the power stroke and sorry you know 5 to 2, 3 to 4 is combustion there is constant pressure heat addition, this is power stroke.

And while 4 to 5, I mean whenever 4 to 5 is coming, this is power stroke and 5 to 2 is exhaust 5 to 2 is exhaust that is it is approximated by constant pressure heat rejection. So, 5 to 2 is a process which is exhaust process which is approximated by a constant pressure heat rejection. And as if because of the exhaust piston is coming from what, piston I mean and this is q out right. So, 4 to 5 piston is coming from TDC to BDC right, so it will I mean there will be power stroke and then 5 to 2 is exhaust that is constant pressure heat rejection.

This is not a rejection, this is this is exhaust that some amount of combustion product will go out, and because as I said you that this is not exactly exhaust rather after power stroke whenever piston is travelling near to BDC we should open the exhaust valve. So, amount of exhaust combustion product will go out immediately after opening the exhaust valve. Why we are opening so because whenever piston has not reaching at BDC open the exhaust valve intake valve is remaining closed, so we open exhaust valve to expel out a certain portion of the combustion product, so that the when piston is coming from BDC to TDC did exhaust stroke will expensing will explains a relatively a lesser the resistance.

So, 5 to 2 is known as you know ex not exhaust this is a you know constant pressure heat rejection, because before piston coming at a BDC, we open the exhaust valve some portion of the combustion product go out. So, this is constant pressure heat rejection. Now, process 2 to 1, each exhaust; this is exhaust where piston will come from BDC to TDC, volume will decrease and this process 2 to 1 is exhaust. So, this is you know again constant pressure process.

So, we have approximated all the processes which are there in a four stroke engine SI en four stroke SI engine ee in a pv diagram. And the corresponding T TS diagram will be like this because 1 to 2, from 2 to 3, 2 to 3 is a process of isentropic compression. So, entropy will remain same we are assuming. Then 3 to 4 temperature will rise, this is constant pressure heat addition. And then this is 4; this is 3. 4 to 5 again you know isentropic expansion, so temperature will fall and ff you know 4 to 5. And 5 to 2, again this is this is constant pressure heat rejection, because some portion of the combustion product will go out even when piston has not reached at the BDC, because we need we open the exhaust valve. This is done only to reduce the resistance when piston is again coming back from BDC to TDC during exhaust stroke.

So, this is the TS diagram you know in a you know diagram in a TS plane. So, you know 2 to 3 is the isentropic compression; 3 to 4 is constant pressure heat addition that is that is mimicking the combustion process, then 4 to 5 is the constant you know isentropic expansion that temperature fall. And 5 to 2 is a you know heat rejection and that is what we have we have shown over here, so 2 to 3, and 4 to 5 entropy remaining same.

So, there is called isentropic process while 3 to 4 and 5 to 2 are the constant pressure heat rejection heat addition or heat rejection process. So, this is heat rejection q out, and this is heat addition q in. So, now we need to calculate what is the, you know total work output from the engine and what is the heat supplied to the engine? From there we can quantify the thermodynamic efficiency of the cycle, so that part we will discuss in the next class.

So, far today I have discussed about the you know a basic quantities that you need to know about the engine you know performance that is work output torque and power. And then we have introduced the concept of mean effective pressure is very important as a good parameter for comparing the engine you know output as in regard to the engine performance in regard to the work output.

And then we have discussed about why torque and power is you know they are not the good parameter for comparing the engine performance. Then we have discussed about Otto cycle. We discussed that four stroke SI engine is compared using an air standard cycle which is known as Otto cycle. Then we have tried to map the processes which are there in a four stroke engine SI cycle you know four stroke cycle SI engine in a pv plane.

We have discussed about the intake compression combustion product combustion process and then expansion and the exhaust in a pv and TS diagram. We have seen that we have approximated, but these approximations are not whether these approximation are good approximations or bad approximation that we will discuss systematically in our next lecture. And we have seen that the valve opening times are not exactly at the TDC or BDC. And there are a slight change I mean we are delaying or we are opening earlier.

And whenever we are opening valve when piston has not reached at BDC during you know comp the den a power stroke only to expel out certain amount of combustion product from the engine cylinder, so that the when piston is coming from BDC to TDC during the next stroke that is exhaust stroke we will explains a relative less resistance.

Since certain amount of combustion product is going out, so we are having heat rejection from the system and that is approximated by a constant pressure heat rejection in a pv diagram by process line 5 to 2. And these approximations are I mean not very bad that we will discuss in the next lecture. So, with this I stop here today, and we will continue our discussion in the next lecture.

Thank you.