Indian Institute of Technology Kanpur

National Programme on Technology Enhanced Learning (NPTEL)

Course Title
Engineering Thermodynamics

Lecture – 31
Gas Power Cycles 1

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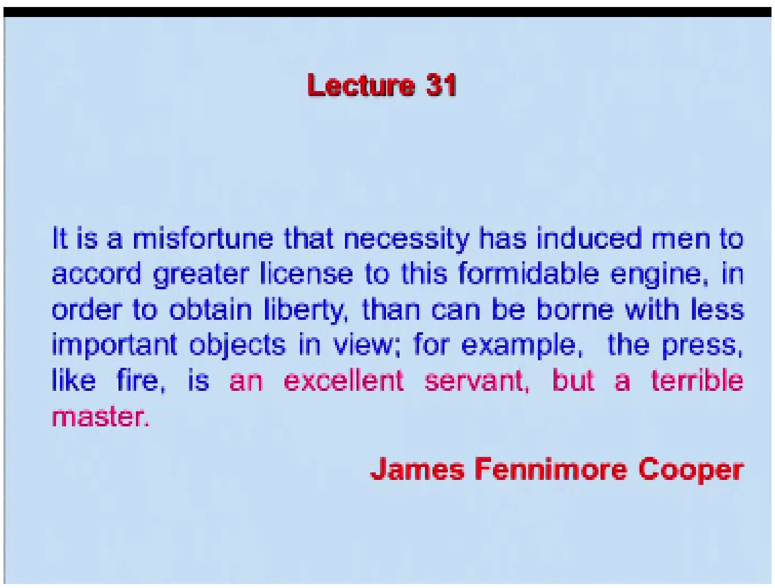

Let us start this lecture with a thought process from James Fennimore Cooper who says it is a misfortune that necessity has induced man to accord greater license to this formidable engine, I mean heat engine, in order to obtain liberty, than can be borne with the less important objects in view; for example, the press, like fire, is an excellent servant, but a terrible master. I would like to give an example of your mobile right maybe mobile can be excellent servant.

But it is a terrible master that it looks to me now mobile is taking over us right you people are indulging in that too much and is spoiling our mind in the process. So let us now look at what we have learned in the last few lectures which we spend on basically vapor power cycles right, and which is the work horse for the power generation that is the steam power plant as I told earlier.

And of course you can use some other fluids like mercury, sodium, or potassium and other thing but those are not being used because of toxic in nature particularly the mark.

But what we will be doing today is will be now looking at a engine and how to analyze that which will be not based on the vapor you being produced, but rather the gases like that we use in our day-to-day basis, because of the problem is that with the vapor power cycle it is quite bulky right, and because of what because of the what you call the boiler, boiler is a very bulky in that of course if you look at we are handling in Rankine cycle a pump which is liquid which is a compact when smaller one right, because the liquid density is very, very high particularly the water.

And so therefore, but we therefore we cannot use that vapor power cycle for what for the transportation which is a very important today I think on an average people do move a lot span of their life earlier days it was not it was people were living in a village and they are happy with the bullock cart and then maybe they need to all the needs being met in the village itself particularly an Indian village which was self-sufficient right in the all respect.

But unfortunately in the modern life we will have to move around like better burn and then getting the food for the food right. And anyway that is the part of the life we cannot really change it, but for the transportation we cannot use the vapor power cycle right, and also but transport you need a very smaller unit right is power level will be very small few kilo watt whereas this kind of paper power or the cycles are being used for the larger power level.

It is not that steam power plant was not used for the local nation or their movements or the transportation right, maybe I have seen I mean like at least 30, 40 years back we are having the steam engines right which was being used in railways particular right, you must have seen in old movies steam engines which is coming out steam some noise is coming out of that okay. So it is not that it is being used, but I have my personal feel that steam engine again it may come up right because that is a very benign through heed what we use as a working fluid right water is a very benign very nice fluid.

So but however, we will be looking at some kind of engines right which will be using the gases that.

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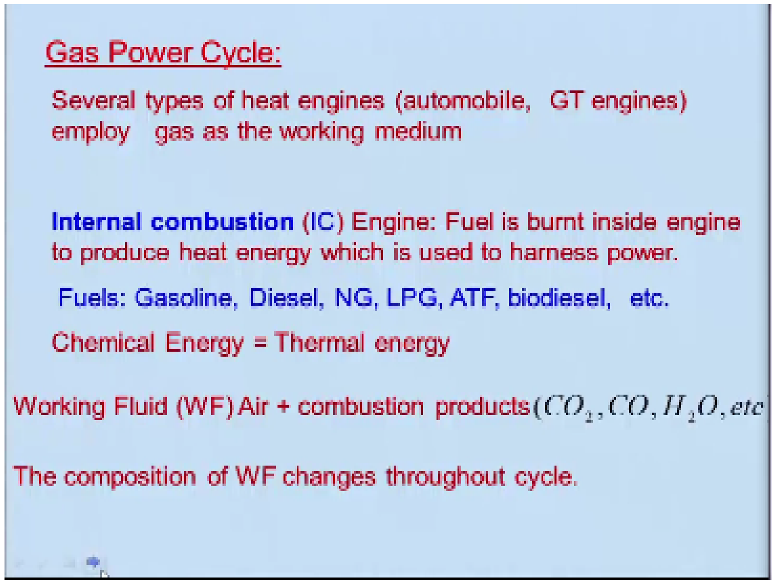

And so therefore we need to look at gas power cycles right because we will be understand that several types of heat engines and are being employed by us for meeting our power requirements and not only the what you call transportation, but also the power generation like your genset and other things where the temporary power is required we do use it and these engines basically use the gas as the working medium right, unlike there we use a vapor and also the liquid is there, liquid vapor is there all the time.

But here it is only the gas which is being used therefore we call it as basically the gas power plant you can say. And we will be discussing about basically internal combustion engine right, where the fuel you will be burned inside the engine to produce the heat energy which can be utilized for harnessing the power. But under the gas power plant or the engine right one can also use the external combustion system like I think I had mentioned earlier the starling cycle which we would not be discussing.

Starling engine which we would not be discussing is a very beautiful engine rather I would call because these efficiencies closer to the Carnot engine right you can look at it, it is not a part of course so I would not be dealing with that, but I had a very what you call sub Carnot's for that engine. So we will be basically dealing with the internal combustion engines this thing and various fuels are being used like some of them are gasoline, gasoline means basically the petrol what we use and diesel, natural gas, LPG, that is liquid petroleum gas ATF that is aviation turbine fuel pier diesels and even like you can use your vegetable oils or non vegetable oils from the, what you call what we get which is renewable in nature.

Because we can produce some kind of grow it and we can do that and there are several host of fuels one can use of course that I have not mentioned nowadays people are talking about hydrogen gas as a fuel right. And you can think of the bio gas, producer gas the several cans coke oven gas and then like several other gases we can use as a fuel which of course will be having calorific values. So that it can produce the heat.

And what we do here basically we burn this fuels and it can work in the process the chemical energy which is part of this thing will be released and the thermal energy being produced and we will be using those thermal energy to operate the heat engine that is the basic idea. And if you look at the working fluid is mainly the air and then we use the, what you call fuel and when you burned it and you will be getting several products like your carbon dioxide, carbon monoxide, water, NOX, SOX, NOX nitrous oxide, nitric oxide there are several kinds of things un burnt hydrocarbons, there are several things will be coming out of the this heat engines during the combustion process.

And earlier if you look at we are using the water in the case of steam power plant what it can happen like water can liquid, and it became vapor it can be two phase flow right, but here it is a single phase there is nothing which in only gas, but however the constituents will be several of gases. So and the composition of this working fluid okay air and the combination of all other gases will be changing throughout the cycle thermodynamic cycle which we are going to discuss. So therefore it is a very important and I mean one has to be very careful in this analyzing it.

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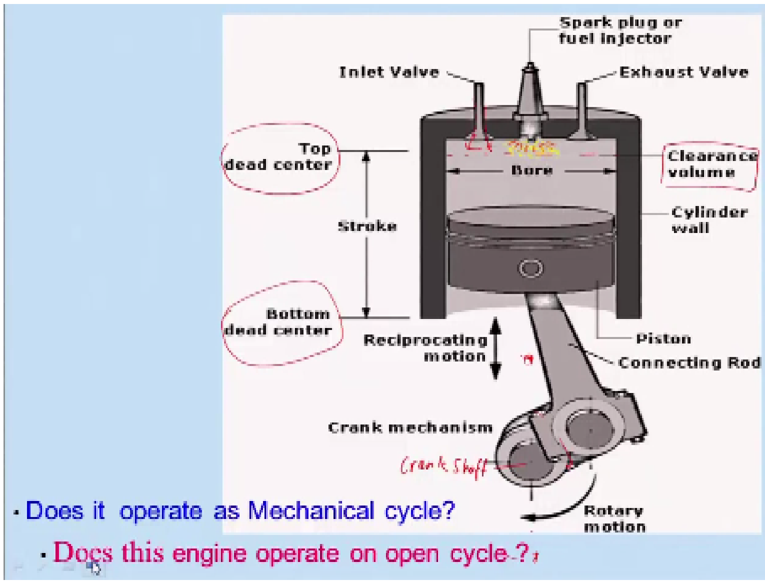

So let us look at a typical piston cylinder engine right which is being employed by basically for automotive applications right. And both the, what you call petrol engine or the spark ignition engine or you call it as a gasoline engines right is being used and it is a very, what we call the arrangement a piston and cylinder and this is your piston like if you look at this is your piston, and if you look at this piston is connected with a connecting rod here right.

And this connecting rod is connected to the crank and this is known as a crank shaft this is known as crank shaft which will be rotating right as this rotates and the connecting rod is basically connecting the crankshaft and the piston and what will happen, piston will move up and down in the cylinder and this is your cylinder. Suppose the piston at the top here suppose the piston is here existing like kind of things.

So when the piston reaches here right this we call it as a top dead center that means beyond that piston cannot move. As a result there is a certain volume is given and that volume is known as clearance volume that is very much essential that to keep this gases or whatever it will be there under the compression. And then after let us say a piston is here at the top dead center and then it can go down as it the moves this crankshaft moves and then it will reach a bottom that is known as bottom dead center this is known as bottom dead center.

That means the piston will be moving between the top dead center and the bottom dead center that clear and the distance between the top dead center okay, and the bottom dead center is known as the stroke, that means piston has moved from that, what you call top dead center to bottom reason that distance is known as stroke, one stroke that means if you look at crankshaft point here and it has gone half circle kind of things right, it has gone here let us say it is here and it will be somewhere here.

So it will be and then again it will move, again it will be go from bottom dead center top dead center and then it will go on and another feature what you should keep in mind at least for visualization see there is a inlet wall right through which the air will be entering right it will be open and then it will be entering the air particularly let us say the piston is at the top dead center when the piston will move downwards what will happen it will create a what suction because the pressure will be low piston is moving the gas is same.

So when is moving of course there is a cam arrangement that is I think you know arrangement by which the valve will go up and ball will be coming to here somewhere right kind of thing so there will be air will be entering right now as if the piston moves down you know the air will be sucked in and then it will be compressed again go up piston will move up from the bottom dead center to top dead center and it will be compressed air will be compressed and then there is of course a spark plug.

Which will give you the energy initial energy and that will ignite let me tell you that when this inlet valve opens in this case not only the air but the fool along with that means fuel air mixture comes in and once it is ink and once you know compress it right before that even just before that of course not exactly that you give some ignition energy and what will happen the combustion will take place and one combustion will take place it will try to expand the gas and give the force to the piston right and then again piston will move from the top dead center to the bottom dead center right.

And after that of course again it will go from bottom dead center to the top dead center and during that the exhaust valve will be opened right and the gases which are burnt out will be getting out and again this will go on this is the one cycle you know like basically it is not one cycle rather the toosh title because if you look at once the top dead center you know piston moves from center to bottom the center this is one from you know here top and this is the bottom then again it will go this is one cycle in the mechanical way.

And then the another cycle in the mechanical way it will be again it will go from here to the again come back to the top dead center then that we call it as a that means total four stroke you know being completed for the one power stroke and that is known as a four-stroke engine right okay so this is a mechanical cycle what which being used but in thermodynamic sense is a little different we call so as I told this operates on a mechanical cycle this is the what I have explained to you the mechanical cycle does this engine operate an open cycle naturally because the you know you are taking the fuel-air mixture and compressing it and then igniting it and expanding it and then what you call exist out.

And then you your you know piston is ma what you call pushing the gas from the cylinder to the out of course if it will come back again because it is already product or I cannot really use it okay because can I use the combustion product and again enter into that like the way we did for the vapor power cycles the water will be you know condense and then again it will be you know go back to the boiler and work it is not possible for this kind of okay because the product is already having carbon dioxide and then you know like very least amount of this thing oxygen level will be low.

So you cannot really use it of course that has been explored in you know modern engines to maximize the efficiency which you will not be discussing about it because is not a part of your course and those people who are interested to look at ice engine internal combustion engine courses they may learn about it so just to explain that thing a little further just to make this point embedded in your mind I have let us look.

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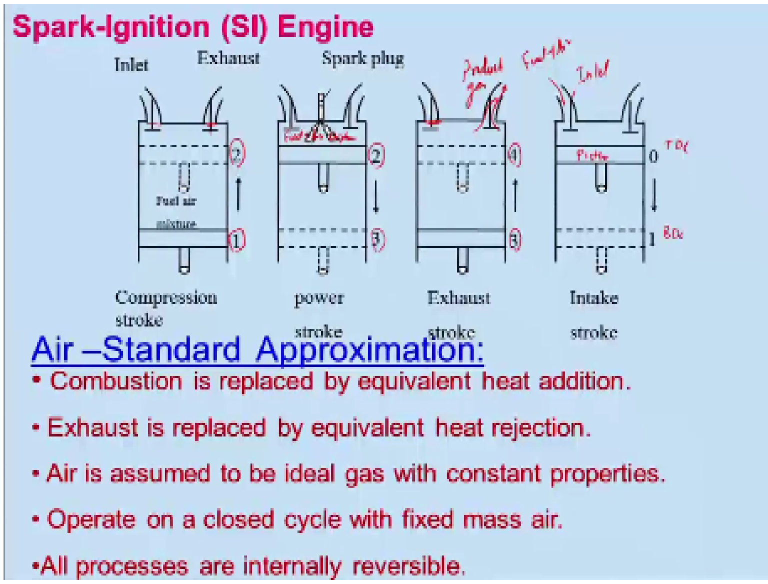

At what is happening that means let us say piston is here this is your piston right and when it is this is your Inlet what we call inlet valve right this wall and it is open so that the fuel plus air mixture right comes into here this is and then as the piston will move from 0 to 1 here then the it will feel suction will be there that we call it as an intake stroke or the suction stroke because this is the your top dead center TDC this is your bottom dead center right this is a one stroke and then it will go the piston will move from one right.

To the two and containing the fuel-air mixture right then it is known as compression during that time this both the valve will be closed is it impressing upon oh my if it is a exhaust valve is open then gas will go out it will be closed is that clear right and then it will become pressed and then you know then there will be a spark plug which will give you the ignition energy and this is already fuel air mixture this is well plus air mixture of course with certain proportion which will make it to ignite otherwise no it should be between the flammability limits you know things.

And then what will happen that will be gas will be expanded and the piston will move from you no state 2 to the state three and that will give you the power because it is because of combustion you know because of energy being released and pressure will go up then you will try to push the piston down and it will give you the power stroke that means that you are getting power right and then once it is reach this bottom dates and again the piston will move up from 3 to 4 and this time of course.

This will be close this valve is closed and the exhaust valve is open to gas will go out this is your product gas product gas right because these are all useless why should you keep we just you know remove it from the cylinder you know volumes so that it will that if you look at 1 2 3 4 like you know 1 2 intake stroke compression stroke power stroke and exist row you know all together will be known as four-stroke engine of course there is two-stroke engines also but nowadays not being used earlier you know like the scooters.

Were being run on the two-stroke engine because it is a simpler one you will get a power and there is a lot of advantages also and there are a lot of decide when particularly pollution point of it was disadvantage that is why it was abundant but also even nowadays also it is being used in what you call in the sheep and other places like for marine applications being used in the bigger engines right.

So basically what we are discussing over to the four-stroke engines but if you look at it is a quite you know complex to analyze it because if you if you look at inlet stroke we are taking the fuel-air mixture if I taking let us say methane you know cng you know compressed natural gas and the air there is a tube constituents like one is air of course AF condensed oxygen and nitrogen mainly and then we do 3 and then once it is compressed and combustion occurs in the power stroke.

What happens it is having several products you know several species are there like your carbon dioxide carbon monoxide un burnt hydrocarbons then you know NOx and then S0X if it is having and several other gases then how you will hand it is quite complex you know like to handle that what we will be doing will be taking a very simple model we call it as a air standard that means we are assuming the air is all that they are right so what we are talking about basically air standard approximations.

All the time air will be there inside and then we are saying that combustion is taking place and some heat transfer only taking place and in other words the combustion is replaced by equivalent heat addition right we have done the similar way also for your paper power cycle right and it just is replaced by the equivalent heat rejection right because heat is going out in the exhaust plot of you know who it will be going out which is the high temperature here is assumed to be ideal gas with constant properties you know properties will be changing.

We know the CP changes because there are several you know molecules which are coming like a Co2 right at I atomic and then see your by atomic and other things molecules and as you know that even mono atomic molecules will be you know CPU will be remaining constant with temperature here the temperature also changes right yes or no the compression temperature will be changing with the hideous and temperature will be there for CP will be changing so we are considering the for the simplicity case.

That air is assumed to be an ideal gas and the gas need not a waiter because the pressure will be higher right but we are assuming it to be ideal and with a constant properties and it is and basically open cycle but here in this case we are assuming that as a closed cycle with a fixed mass of at that means you know we are modeling it as it is an approximation okay because all the time exhaust gas is going out of the engine but we are saying that look it is recycle because we are assuming it to be air as a medium.

So all processes are internally reversible that we are saying which is not possible at all in actual engine for our simplicity for a simple simplification of the analysis we are assuming that so if you look at this is the basis for the engines but in 1876.

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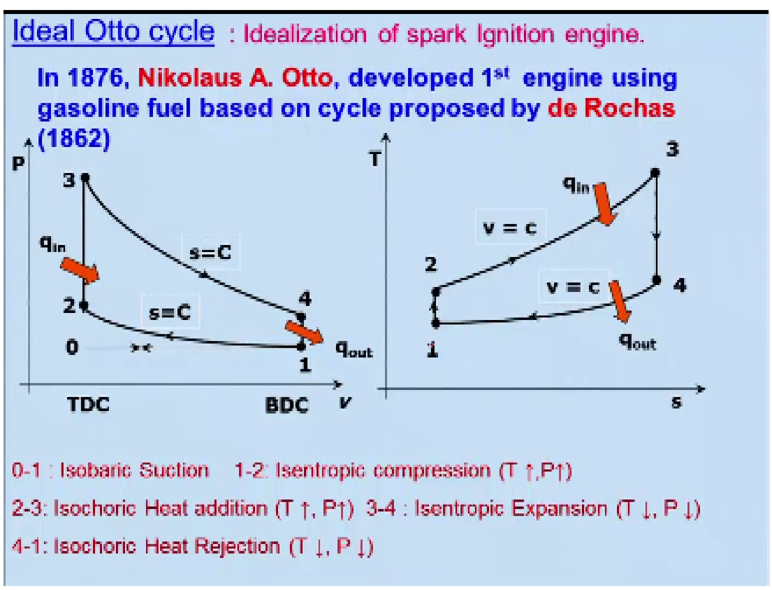

There is Nikolaus A. Otto, develop first engine heat engine using a gasoline fluid what we call petrol and based on a cycle proposed by the day Rochas in 1862 right kind of things so after what you call 14 years you know people could do that and that engine what we call it as a gasoline engine and it is basically idealization of the spark ignition engine right we use a spark plug for the initiation of the combustion therefore we call it as a spark ignition engine right and that engine also you know that cycle is known as ideal Otto cycle of course we are already assuming the air standard kind of assumptions

There for that analysis what we will be doing is known as ideal auto cycle actual cycle is Otto cycle okay we will be discussing about ideal Otto cycle and if you look at the processes what we discuss is like 0 to 1 right it is the suction if you look at we are assuming the pressure change he negligibly small in reality it is not how can that possible you know like where pressure is not changing and there is a section not possible.

But we are assuming for the simplest it is and then one to two is basically the compression isentropic compression where not only it will be adiabatic also the reversible right 1 to 2 and 2 to 3 is your heat addition in a constant volume if you look at volume is not changing 2 to 3 which is also quite difficult you know like what ideal sense we are using and 3 to 3 is your expansion isentropic expansion and this is 3 to 4 is basically the power stroke where we will be getting power by the engine.

Because 1 to 2 you will have to give to the engineer to come you know compress it right, and that means externally allowed to give of course in this case engine will be giving because of you know it is already producing power and 4 to 1 is your you know constant volume heat rejection of course the 1 to 0 will go back to the again outside so this is your what you call the processes and in the P_v diagram but if you look at the T_S diagram will be looking like that and what I have done in case of T_S diagram.

I have what you call change you know neglected this 0 to 1 is not making any sense to put that thing you know like because we are using it ideally 1 to 2 if you look at that not only the pressure is increasing but also the temperature is increasing because of compression and similarly with the heat addition temperature will be increasing and so also the pressure and of course when it is expanded isentropically you know entropy is remaining constant.

And then of course there will be decrease in the pressure and also the temperature and heat rejection you know like both the this is a isochoric process heat rejection both the pressure and temperature will be reduced so this is basically the ideal auto cycle kind of thing we will see how we will analyze will be the do the same thing what we had done earlier for the vapor power cycle. But is it that will be you know using the same thing or not.

For example, if I take an auto engine or the piston engine in this case right or piston engine then what kind of you know a system will have to take is it a control volume system or a control mass system if you recall that in case of vapor power cycle what we had done we had basically looked at what we have taken the control volume approach, right. In this case can we do that or not.

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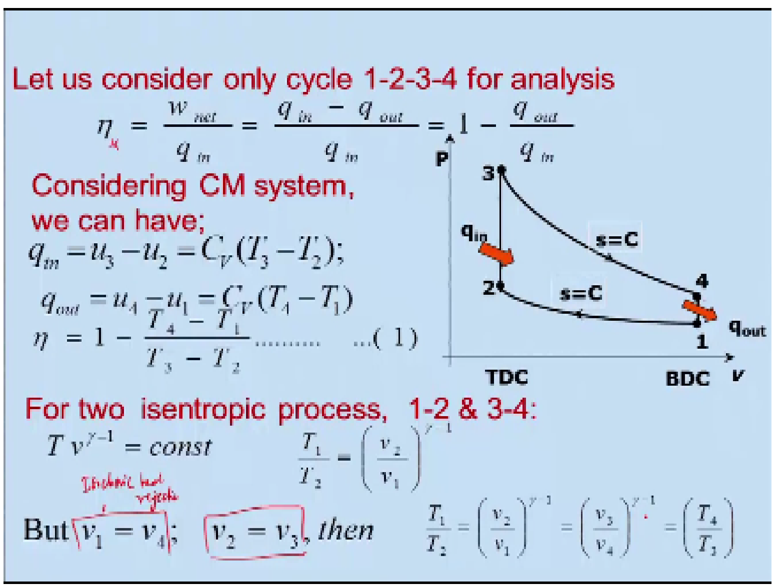

Yes or no, we cannot because here the mass is remaining same constant so we are considering a control mass system in case of vapor power cycle we have considered the control volume system okay, is that clear the very important lot of people do not get it but it is very important to keep that in mind and for these analysis let us consider the cycle 1,2,3,4 only and we have neglected the 0,1 that is not a part of our analysis because the we have assumed in the constant pressure process but that is not true in real situation.

So the thermal efficiency will be equal to basically if you look at this is thermal efficiency w_{net}/q_{in} and what is your double unit nothing but your q_{in}-q_{out} right, and which is equal to 1-q_{out}/q_{in}. So let us look at what is q_{in} you know we can find out by considering a control mass system and there is nothing but change in the internal energy right, why because it is the heat addition right and we know from the first law of thermodynamic DU=DQ-DW and DW is 0.

In this case there is no work done in the during heat addition therefore the heat addition is nothing but you were changing internal energy and of course this is for unit mass and that is equal to change in $C_v(T_3-T_2)$ okay, and similarly q_{out} will be change in internal energy between the state 4 to 1 and that is equal to $C_v(T_4-T_1)$ okay. So we will substitute this q_{in} and q_{out} in the vertical expression for the thermal efficiency we will get $1-T_4-T_1/T_3-T_1$ C_v C_v will cancel it out right so you will get.

And if I will consider you know process between the 1 to 2 that is isentropic compression and 3 to 4 is your isentropic expansion process so we know that T_V γ-1is constant this is an ideal gas we have considered and we have also considered the isentropic process therefore $T_v^{\gamma-1}$ is constant so therefore for the process between 1 to 2 we can write down basically T_1/T_2 is equal to $v_2/v_1^{\gamma-1}$ right.

And similarly we can also do for the other process the what you call Pth station 3 and 4 but we know that this $v_1=v_4$ why because this is the constant volume process so therefore so this is a constant volume process right isochoric heat rejection so therefore the $v_1=v_4$ and similarly isochoric heat addition right, so therefore v_2 become equal to the v_3 and therefore we can say that $T_1/T_2=v_2/v_1$ γ-1 and the v_2 is nothing but your v_3.

If you look at $v_2=v_3$ we have seen here and $v_1=v_4$ so then power to the γ-1 is nothing but your T_4/T_3 that means $T_1/T_2=T_4/T_3$ you might be knowing why we are doing this right, why do we want to simplify this thermal efficiency and express it in such a way that we can do a what do call parametric analysis right.

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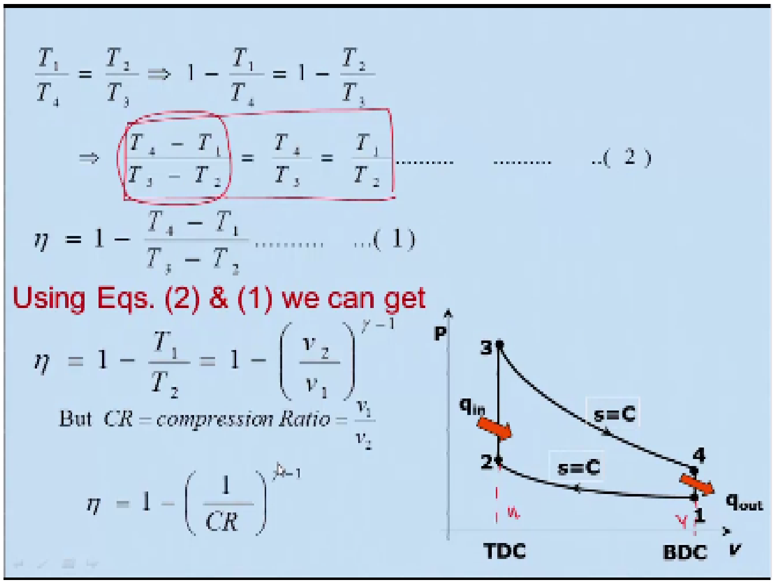

So if you look at that basically $T_1/T_4=T_2/T_3$ and which is nothing but $1-T_1/T_4$ which is equal to $1-T_2/T_3$ and then if I simplify this thing then I will get $T_4-T_1/T_3-T_2=T_4/T_3=T_1/T_2$ if you recall I mean this is the term which was there in your thermal efficiency expression right, so this is your thermal efficiency expression which is nothing but your what you call the T_1/T_2 the T_4-T_1/T_3-T_2 nothing but T_1/T_2 and the T_1/T_2 is nothing but your v_2/v_1 for a nice entry process between station 1 to 2 and this is you know the thermal efficiency now expressed in terms of a volume ratio.

That is what, that is basically if you look at v_1 is very high right and v_2 is very small is it not it because the volume is here this is your v_1 and this is your v_2, so I can write down that v_1/v_2 is nothing but your compression ratio because the compression is occurring here from volume v_1 to volume v_2 so that we call it as basically compression ratio that is $CR=v_1/v_2$ so therefore we can express the you know thermal efficiency expression in terms of the compression ratio that is equal to $(1-1/CR)^{\gamma-1}$.

See if you look at we have simplified that means the thermal efficiency is function of you know two terms one is compression ratio other is you specific heat ratio right, so if you look at we are you know if could have not simplified then it could have been very difficult which one that means we are having total four variables to the T_4, T_1, T_3, T_2 but now it is only the two variables and which is says that it is dependent on the thermal efficiency basically is dependent on the properties of the fluid as well.

Because the γ represents the properties of the fluid if it is mono atomic gas gamma will be 1.66 right for air it is 1.4 for other things it will be you know different values right, so therefore it is depend on the properties of fluid and also it depends upon the compression ratio what is being used in the in.

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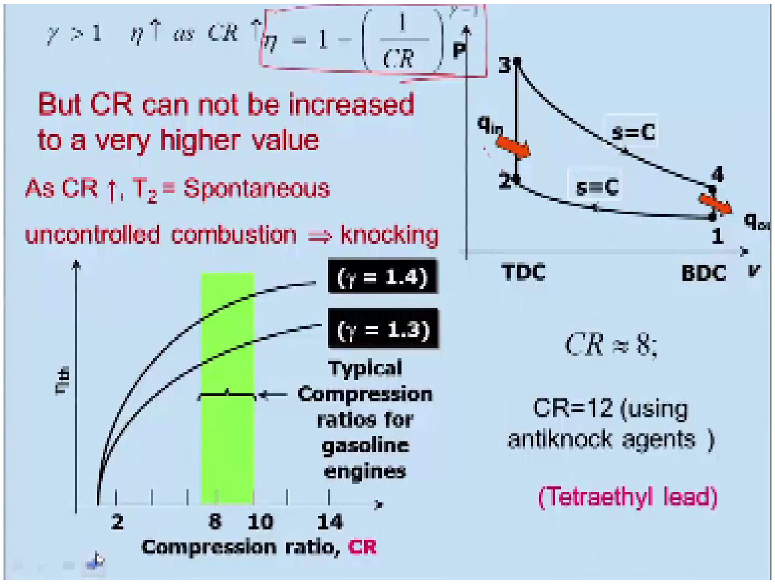

So what it says that if γ is greater than always 1 it will be and then the if CR that is compression ratio is increasing what will happen to the thermal efficiency, thermal efficiency will go up yes or no from this expression just look at this expression. If CR you know for γ is greater than 1 so therefore this will be a positive quantity right and the CR will going up if it is going up this becomes smaller if this term is smaller the natural thermal efficiency will be higher right, that means by increasing the compression ratio for a particular fluid or a particular γ then I can go on increasing my what you call thermal efficiency.

So if you do that plot that thermal efficiency versus compression ratio you can see that for you know γ 1.4 it increases and if γ is 1.3 which is basically you know typical product mixtures what we use for the combustion so you will find that it is of course in the initially it increases very first the slope is very high after that it goes on at a little lower rate slope is lower and naturally a person will be tempted to use the higher compression ratio because always we want to have higher thermal efficiency, right.

But however if you increase this compression ratio so what is happening here right if you increase the compression ratio further if I go here you know then the temperature goes up right temperature will be going up and the temperature goes up then there might be a situation where it will reach the auto-ignition temperature and already fuel-air mixture are there already and if it is auto-ignition temperature it will be un controlled right and it will be creating a knocking that we call a lot of noise and then it may be lead to the catastrophic explosion and other things right.

So therefore that is not being used so that is the reason why you know compression ratio between something maybe around 7.5 to 11 or 12 you know people use it and generally in the lower side otherwise you know lot of noise will be coming and then you know kind of things and then also it will affect the life of the engines right and you may get also the other problems of the engine vibrations. So therefore the compression ratio cannot be increased to a very higher values a valid told and this is you know the auto ignition will occur therefore the spontaneous uncontrolled combustion will always we want to have a control right over the combustion.

So also you should have a control of your life not get swayed by your mobile you know or an internet or this thing, so similarly engine also is like that and one has to do a control and we call it as a knocking right and CR is tentative number is around eight we will use it and of course the compression ratio for12 is being used by adding some antiknock agents and earlier days people were using tetraethyl lead which is you know being banned maybe ten years back in our country but in may be something around known and not ten rather 15 years back and maybe 30 years back it was banned in USA around that but unfortunately we go on using this lead which can increase the thermal efficiency of the engine.

And if you look at like and nowadays people are using some other agents and in our agents and also people use alcohol into that so that you can reduce that anti knocking properties and go for that, so and if you look at like we will have to look at like the how much power is being you know if we look at the actual engine will be not that way that what I say there is a error it is not a constant if you look at the ideal one will be like that.

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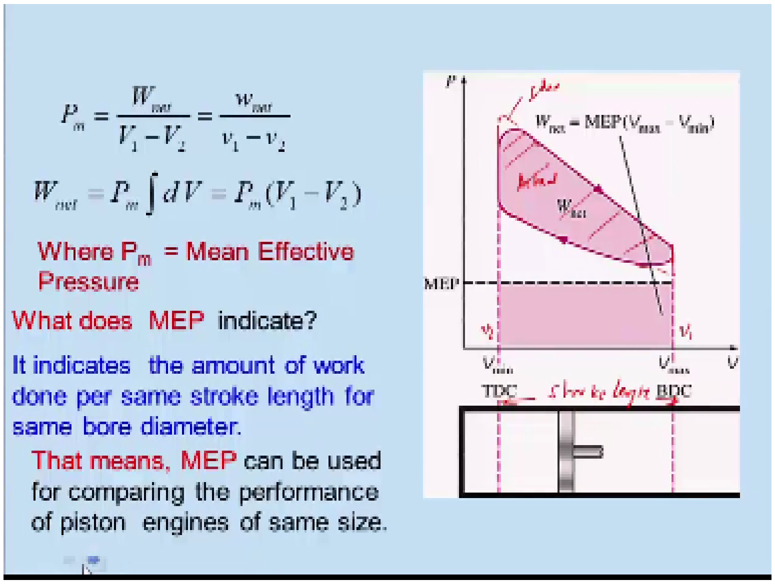

Is not it that is your ideal one right but this is the actual engine what will be this is the actual engine what it would be in a PV diagram this one is your cortical ideal and this is actual right and you want to find out what is the what you call mean effective pressure what if we be giving right. So of course you have to integrate this one this area and then you will get the network output is not it this area will give me the net work output this network output I'll can get just you me and of course the pressure is keeps on changing and therefore it is very difficult to you know like do that what we can do we can find out the mean effective pressure that is P_m mean effective pressure and we can do that this area will be cool to this area and it is the V maximum that is the maximum volume and this is the minimum volumes right.

And in our case this is basically in our example what is this is v1 and this is v2 and W net /basically v1 - v2 or if you can take per unit mass divided by v1 - v2 that will give me the what you call mean effective pressure and which is equal to if you integrate you know this PM you will take and then you know average in which is remaining constant rate mean effective pressure then v1 minus the network is will P_M into the change in the volume between state 1 to state 2.

So what does it mean effective pressure indicate why we will be looking at it that question might be coming to your mind because that will tell you basically amount of work done for the same stroke length for the same bore diameter bore diameter mean cylinder diameter other you can say a piston diameter right and this is your what you call stroke length so if you look at stroke length is here this is your stroke length right so that will tell you how much and then you can compare the various engines how much it is mean effective pressure will be you know higher then naturally work output will be higher for the same stroke length and same bore diameter.

Because more diameter will be different that also will be different even though the stroke length, so the mean effective pressure can be used for comparing the performance of the piston engine of same size for example some engine produced by the Honda somebody is the produced by Maruthi switch key right then you can compare which is having the higher mean effective way so that work output will be higher so this is being used.

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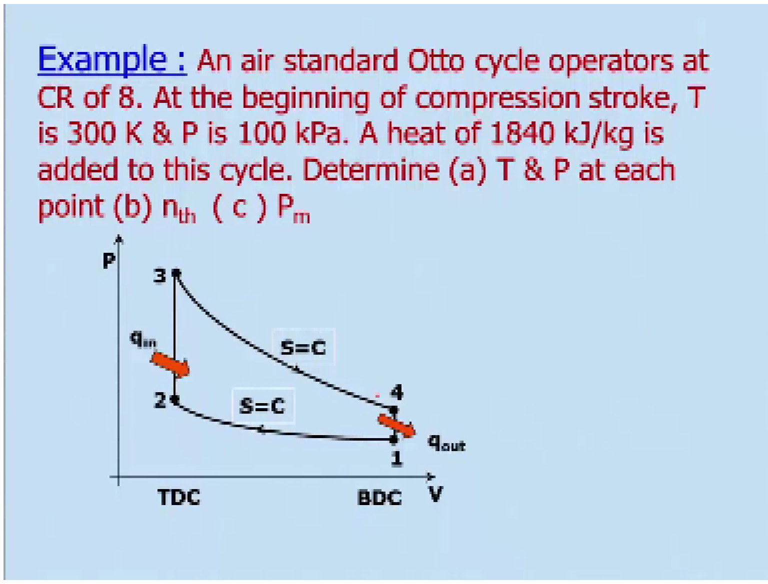

So we will take an example and that a standard Otto cycle operates the compression ratio of eight at the beginning of the compression stroke temperature is 300 Kelvin and pressure is 100 kilopascal and the heat input that is 18 40 kilo joule per kg is being given to the cycle and will help determine the temperature pressure at each point and thermal efficiency and mean effective pressure right.

And which is a very simple this thing and will be basically finding out all these properties over here station 12 3 4 that is the thing determine temperature and pressure everywhere just to have a field what is happening, so that you can have of course you can solve this problem without really getting into the all the temperature without calculating the temperature pressure and each point.

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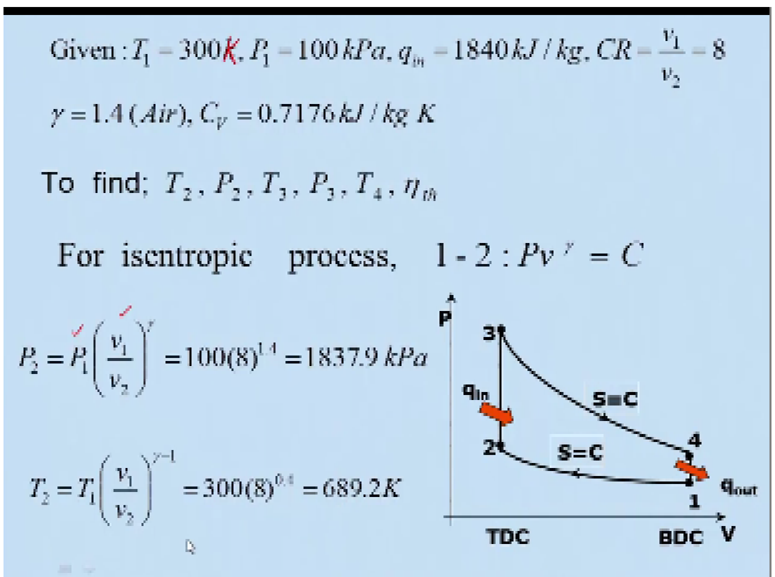

So if you look at this is t 1 is given that is 300 Kelvin this should be capital andp1 is 100 kpa and Q in is given 18 40 kilo joule per kg and compression ratio is already given v1 by v2 8 and we are considering air standard cycle, so therefore γ is 1.4 and CV is given7176 kilo joule per kg Kelvin if it is not given in the this thing you can calculate because they are you know the γ then you can calculate very easily what will be the CV values.

So we love to find out basically because T 1 p 1 is given here you will have to find out basically he pressure at the station 2 and temperature similarly T 3 and 3 3and T 4 right and thermal efficiency you can find out so we know the eccentric process PV power to the γ is constant right and we can very easily find out what will be p2 because we know this v1 and v2 that is a right v1 v2 is 8 and p1 is given under, so I can you know calculate because this is given and this is given so you will get 18 37.9kilo Pascal it is a very high pressure if you look at right.

If something 1.8 mega Pascal right and similarly I can find out using the same isentropic relationship t2 = p1 v1 / v2 and you will find out 689.2 Kelvin right even temperature also a has gone almost more than double you know like it has gone up because of only the compression ratio of eight right.
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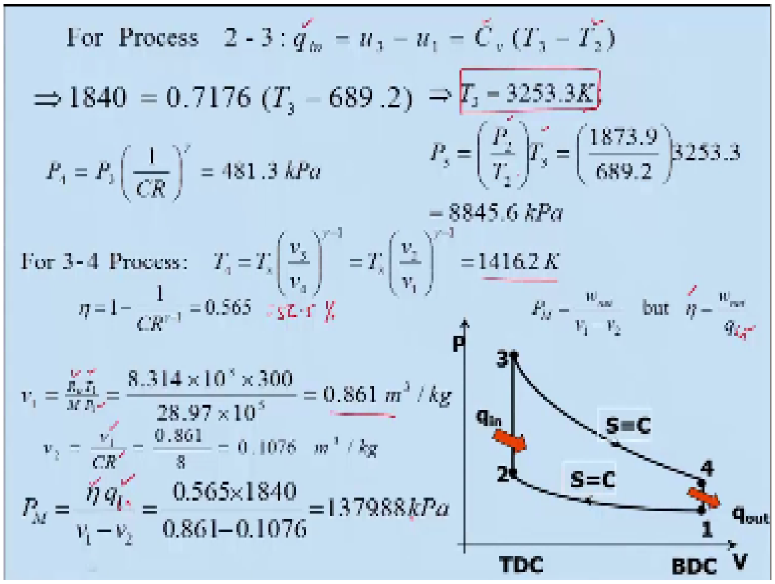

And for the process 2 3 which is a constant volume heat addition that is you know you three minus u2 = C T $_3$ - T_2 and this is given to you is not it q in is given and C_v you know and you already know this t2, so you will have to find out what will be t3so you know like t3 you can find out very easily that is the T_2 53.5 Kelvin keep in mind that this is a quite a high values you would not get in actual engine okay you would not get this much of values of course I had told you that adiabatic temperature for a constant volume will be what different than the adiabatic temperature at constant pressure which will be higher any idea?

When I when I had discussed at a body temperature I had talked about it please look at that okay so and p_3 = p $_2$ u/ t2 x t3, so I can find out the pressure very easily because all are known you know all are known this thing so you can find out very easily and then that is 8845.6 kilopascal something around 8.8 mega Pascal’s and peep or of course you know the compression ratio right I sintering process between state three and four.

So therefore you will get 481.3kilo Pascal which is you know higher than the atmospheric pressure, so the gas can go out easily right so for I send a process you know for in between this station 3 and 4 this expansion I can get the temperature if you look at it is also quite higher than the ambient temperature lot of heat will be lost in the process, so and we can get the thermal efficiency very directly you know 1 - C are γ- 1.

So you know the CR that is 8 which is given and γ - 1 γ 1.4 you will get that is efficiency happens to be something 56.5% is quite high you would not get in a real engine real engine will be around maybe something around 30% or 30 35 nowadays you know a year Daisy to a 25 so and I can get the mean effective pressure network done divided by v1 -s v2 and the I can get the work done from because I know thermal efficiency I know Q in this is Qin right already given so I can find out what will be w net and I can also get the v1 because from using the ideal gas law like this is ru is known and t1 is known and you know p 1 is known and so you can get this one and see.

And then v2you can calculate very easily because if you know we want and you know see are you can get that and once you know this thing you can get the what you call a mean effective pressure which is very easy because in this case if you look at you know this thermal efficiency already you have evaluated and Q in this is you know right and v1 - v2 you have already evaluated it happens to be something 1379.88 kilo Pascal's if you look at it is much smaller than the what you call the p3 values okay this average pressure what it will be if the artificial you can say.

So by this we can calculate all the things whatever is given in this problem so what I would suggest that you please should do a problem and should also against um you know a feel for what is happening with this we will stop over in the next class will be discussing about the diesel cycles right and other also dual cycle other things will be distant thank you.

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