Basic Thermodynamics

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Lecture - 25

Gas Power Cycle-II

Good morning. We were discussing the Otto cycles. If you recall, we were discussing the different processes and the expressions for internal energy change, work done and heat added. We completed this table and showed that the delta u for the cyclic process is 0, delta w is delta Q.

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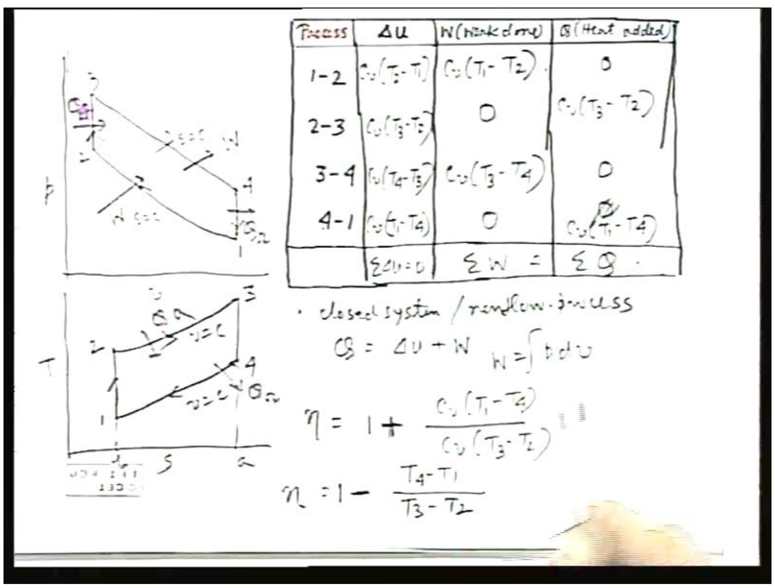

We also express the efficiency eta in terms of heat quantities. In this cycle, one very important parameter is there, which is defined as volumetric compression ratio.

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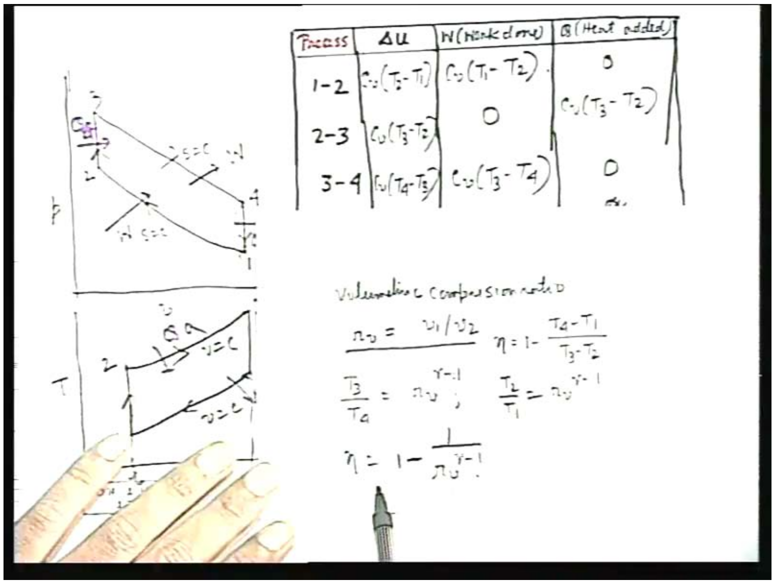

Volumetric compression ratio is denoted as r_v, which is equal to the ratio of the two volumes; that is the maximum volume to the minimum volume v_1 by v_2. This is the volumetric compression ratio. We have the expression for eta is equal to 1 minus T_4 minus T_1 divided by T_3 minus T_2.

We can relate this volume and our job is to express this efficiency in terms of the volumetric compression ratio, which is a very important parameter for an Otto cycle from practical consideration. It is a theoretic cycle for internal combustion - engine spark ignition. You should know this. These are the concepts actually

Even if you can solve the Otto cycle problem and if I ask that why volumetric compression ratio is so important? Why you are interested to express efficiency in terms of volumetric compression ratio? Many people cannot answer this question. But, if I tell you to find these you can immediately find it by the process calculation. This is because it is the volume ratio there minimum and maximum volume which is a very important designed parameter because an automobile engine, spark ignition engine is designed on the basic constant of a volume ratio because this space is fixed. It has to be designed within a limited space you cannot have an engine of very big space. Space is the criterion.

If I do so T_3 by T_4 I can write…. if you just look back to these equations that earlier we did use for an ideal gas.

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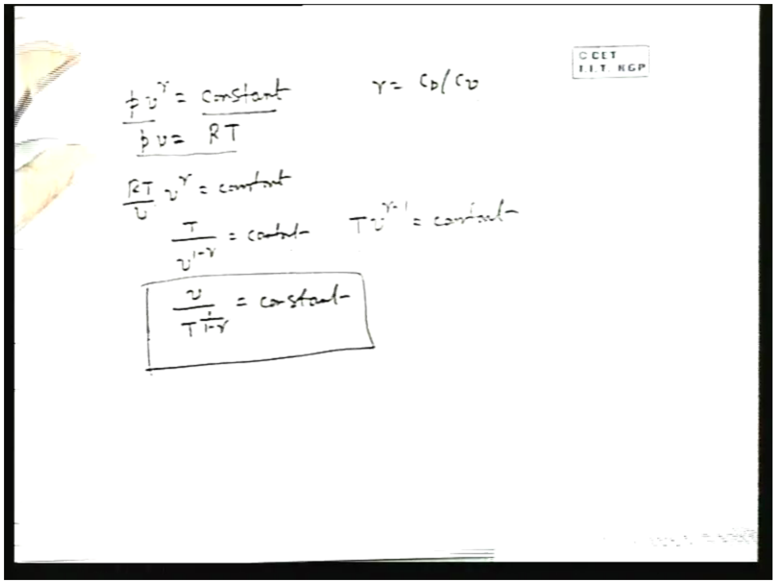

We know for an isentropic process pv to the power gamma is constant. Gamma is C_p by C_v. The equation of states pv is equal to RT, r is the characteristic gas constant, v is the specific volume.

If we eliminate p we get T by v to the power one minus gamma constant or we can write Tv to the power gamma minus 1 is equal to constant that means the ratios of T is equal to the ratios of v raised to the power gamma minus 1.

If we write for these two processes we get for this process, T_3 by T_4 is v_4 by v_3 and which is v_1 by v_2 because v_4, v_1 is same v_3, v_2 are same. That means rv to the power gamma minus 1 because Tv to the power gamma minus 1 is constant so v_4 by v_3

We can write for this process T_2 by T_1 is again v_1 by v_2 that means rv to the power gamma minus 1. If I express T_4 in terms of T_3, T_3 divided by rv to the power gamma minus 1. Again, T_1 in terms of T_2, T_2 divided by r_v to the power gamma minus 1. Then $T_3 – T_2$ as common, cancel from both the sides. We get eta is equal to 1 minus 1 by rv to the power gamma minus 1. If I express T_4 and T_1 in terms of T_3 and T_2 we get this.

This is an expression where you see that the efficiency of the Otto cycle is the function of the volumetric compression ratio, which is defined as the maximum to minimum volume of the cycles. This is clear from the cycle diagram, where this cycle works between two volume limits: the minimum volume and the maximum volume. The volumetric compression ratio is defined as v_1 by v_2, which is r_v and it is 1 minus 1 by r_v to the power gamma minus 1 that means it is a function of r_v only as we increase the volumetric compression ratio the efficiency increases monotonically. We will go to diesel cycle.

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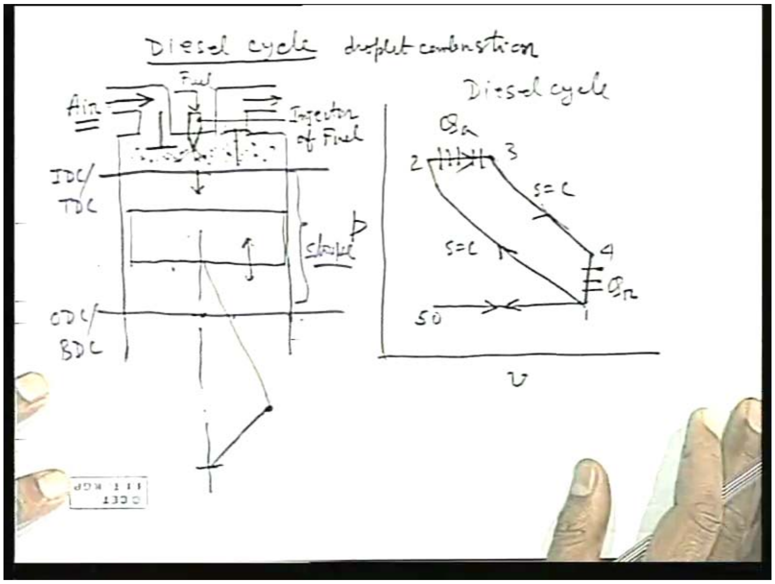

In the similar way as we started Otto cycle, Diesel cycle is again a standard cycle but this is followed in an IC engine where diesel is used and the particular engine cycle follows a compression ignition engine. That means the combustion and the admission of fuel vapor and air or fuel and air is made in a different way as done in spark ignition engine.

Let us first know the principle of operation of a diesel engine. Petrol engine works on the principle of spark ignition engine but the diesel engine works on the principle of diesel engine.

Let us first understand the geometry is same that means the physical processes are almost the same that is a piston cylinder is a close piston process. A piston reciprocates within a cylinder and there is a mechanism that is the connecting rod cranks mechanism and we have the inlet and the outlet manifold, similarly we have inlet and outlet valve. Instead of a spark, here there is an injector. This is the exhaust, this is inlet and this is an injector. I will explain this injector of fuel.

What are the differences? Similar way the piston reciprocates between two dead centre positions. One is the inner dead centre or top dead centre. If this is in vertical configuration and another is the outer dead centre or bottom dead centre and this is the stroke of the piston. What is the difference in the inlet stroke?

Initially when the piston from the inner dead centre position descends down in its fast stroke movement, if we consider from the starting point then due to the expansion of the gases which are lifted here that will do not know, that will know after the compressor of the cycle suction is created and this valve is open. In the similar way, the material comes in and the material in case of a diesel engine is not air and fuel vapor mixture. It is simple air that means the oxidizer for burning air is being admitted.

In the admission, this first stroke descending part of the piston, where simple fresh air from the atmosphere is shafting and when it reaches the bottom dead centre or outer dead centre position this is full of air. These two valves are closed and the air is then pushed and compressed as the piston ascends upward from the outer dead centre position to inner dead centre position both the valves are closed.

In spark ignition engine or petrol engine it was air and fuel vapor mixture instead of air. When it is compressed, you have to understand that the piston head, this is clearance volume and this stroke length; everything is designed in such a way that the piston ascends up and reaches its IDC or top dead centre position. The pressure due to compression is much higher as compared to that of the petrol engine and since air is a compressible fluid as you know the temperature is higher.

Pressure and temperature of the air at the end of the compression stroke that second stroke of the piston is much higher as compared to that of a petrol engine. This temperature is higher than the Otto ignition temperature of the fuel diesel which is being ignited. For all fuels to burn, there is a temperature above which no initiation is required for burning. If you wait for some time, it is known as ignition delay, the spontaneous reaction starts taking place. So, this temperature is known as Otto ignition temperature and that is a characteristic feature of a fuel.

Another thing you have to know that when you burn a liquid fuel in air the burning does not take place in liquid phase, that is the rapid exothermic oxidation reaction which is taking place with release of energy at high temperature and creating luminosity which is known as luminous flame and all things happens in gas phase reaction. Therefore these gas phase reaction means this reaction has to take place between oxidizer. For example, air with the fuel vapor not with the liquid fuel. Therefore, the primary requirement for burning any liquid fuel is to vaporize it fast and to mix this vapor and the air because the molecular mixing is important.

Molecular diffusion and molecular mixing is not possible between two phases like liquid and vapor. It is possible either between liquid to liquid or between gas to gas that means liquid to air. Therefore, these molecular mixing is only possible in the same phase, that is the gas phase and therefore the burning takes place in the gas phase.

The primary requirement of burning any liquid fuel anywhere, starting from your domestic purpose of stove and any IC engines or gas turbine engines or oil fire boiler so liquid fuel has to be vaporized first and it has to be made vapor and vapor has to mix properly with the air then only then the burning takes place. Depending upon the temperature; whether the temperature is below or above the Otto ignition temperature you require an igniter.

If the temperature is below the Otto ignition temperature of the mixture, then you require an igniter to initiate the combustion process. If it is above the Otto ignition temperature, which is a characteristic property of the fuel itself, then the reactions start after certain time, which is known as ignition delay but the chemical reaction to takes place or reaction starts.

Therefore, the vaporization of the fuel is very important. In carburetor, in a petrol engines this vaporization occurs. In the classical petrol engine carburetor fuel is injected and air is sucked. The way fuel is injected air flows and they will transverse to each other and this jet of the fuel is broken into minute drops and automatically it is evaporated or vaporized.

This mechanism is done in a diesel engine inside the cylinder that means the vaporization of the diesel and also mixing of the vapor with the air for the burning. For that what happens the diesel fuel is injected through a nozzle, it is purely converging known as injector, which directs a jet that means fuel at very high pressure is sparked is allowed to pass through a conversing passage known as injector.

It comes out through a very small or if is in the form of a very high speed jet of diesel which is due to the inner and hydrodynamic instability in the surrounding atmosphere which is a compressed gas, is broken in to spray very minute droplets. This process is known as atomization. That is why, sometimes it is told that diesel is injected into the form of an atomized spray and entire thing happens very closely to the audity or you will see a very fine spray in the form of minute liquid drops is coming out.

It looks as good as a vapor and when the liquid is broken into minute drops of very small diameter then the surface area of a given mass increases the surface area of a given mass. When the surface area increases; the rate of vaporization increases.

The basic purpose of directing into a form of an atomized spray is to increase the surface area for a quick vaporization. These are the information not much required for thermodynamic study. Immediately, vaporization takes place and burning occurs. Burning is not so homogeneous, this is because when you spray the fuel the droplets are dispersed at different location and they go on vaporizing. So, depending upon the location where the vaporization is very fast and mixing is very fast the ignition starts. Ignition starts heterogeneously at different position, not in homogeneous way because in petrol engine the mixture is homogeneous in this composition though out. Here, as this spray is injected and because of the spatial dispersion of the spray and the vaporization characterizes at different point.

The mixture ratios are varying. So, heterogeneous combustion takes place, instantaneously the burning does not take place. By that time the piston descends downward, so these are the basic difference between the combustion of a petrol engine and that of a diesel engine. There are many other points, which will be covered in an IC engine class.

The burning process which creates the temperature of this air ultimately to a very high value, because of this burning that takes place during sometime by which the piston moves downward so that this process of burning is simulated by a constant pressure heating than a constant volume heating that is the most important thing. Because of this heterogeneous combustion, this type of combustion is known as droplet combustion. That is because of the individual fuel droplet as it vaporized and makes the burning. Localized hotspots or burning zones are created. I' am not going in much detail of droplet combustion.

The temperature and pressure rises, then the piston comes downward in this descending stroke that is the power stroke. When it comes here this is opened and immediately the gases is expelled and pressure is restored to atmospheric pressure. This is being simulated in the same way as we have done in petrol engine. As the rejection process makes the heat rejection at constant volume, so that piston is almost here and then slowly piston moves up to it expels the gases out of this.

This process is simulated by an air standard cycle where this will cancel with each other. Now, this is the same cycle. I have not drawn this earlier. This is the theoretical cycle and then 1, 2, 3, 4, 1 again 5. I did similarly because this is the inlet stroke, this is the exhaust stroke so these two coincides each other. Therefore in theoretical cycle, 1, 2 is the isentropic compression. Then we considered this combustion of diesel with a similar process of constant pressure heat addition. There is a source where heat is added during which the piston moves downward, so that the pressure remains constant. This is the change in volume. Then isentropic expansion, this is isentropic compression.

The piston moves downward to this point, isentropic compression end of heat. We bring a heat sink and make in thermal contact to the cylinder so that heat is lost. Heat rejection takes place. So long the piston remains at this position, which means constant volume, the temperature is reduced and pressure is the same atmospheric pressure. We just simulate this, as if by the actual process. When the valve is open the entire hot gas goes out and the pressure equalization takes place. Again the compression process takes place to expel the remaining charges. This is by isentropic compression, the cycle starts from here.

In an air standard cycle, which is known as Diesel cycle; we just describe it again by the four processes: one isentropic compression process, and another constant pressure process, that is the heat addition process, during which the volume changes but pressure remains constant. Isentropic expansion and constant volume heat rejection process.

It considers four processes but difference is that, instead of constant volume process, one constant pressure process is there for heat addition. That is the difference between Diesel and Otto cycles as per the standard cycles are concerned. This is because of the fact, that the operation of diesel engine and operation of petrol engine are different. To make these two cycles as the theoretical cycles for these two engines, there is a difference in the ideal cycle nature.

Similarly, I will start doing that analysis, as we have done.

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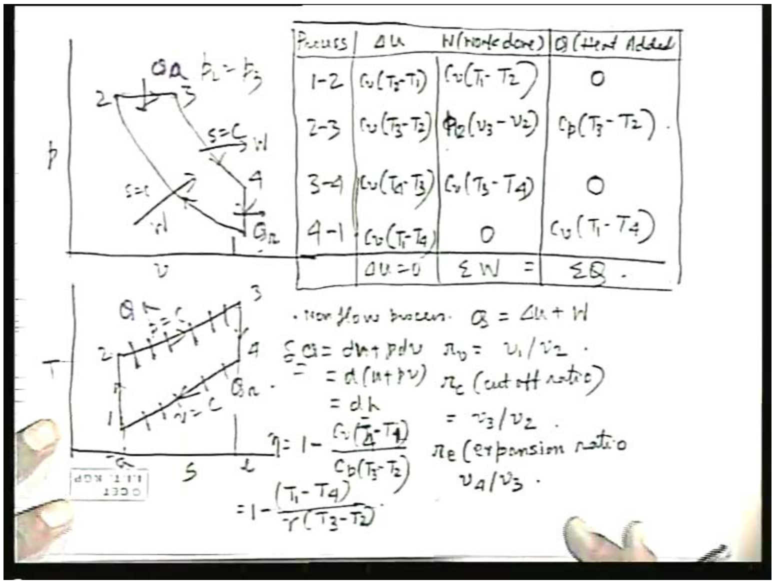

Let us draw this cycle quickly; 1, 2, 3, 4. This is the pv diagram and is important. The suction and exhaust, we are not drawing. This is Qa process, which means the heat added and heat rejected. These are the two isentropic processes. No question of heat addition and rejection. If we draw the TS diagram, it will look the same. But, to show that one is having a concept, one should do like this. This is a constant pressure process; 1-2, 2-3 then 3–4, this is a constant volume process.

What is the difference? This looks same qualitatively a constant pressure line and constant volume line, but a constant volume line is having a higher slope in a TS plain than a constant pressure line. You can prove this.

A constant pressure line is having a lesser slope or is less steep than the constant volume line. Therefore the person who will draw the diagram should have the idea that this line should be less steep than the constant volume line. These are the isentropic processes. Therefore, I can tell that, this is the heat addition process and this is the heat rejection process. The area under these 2–3, 2 a b 3 This is heat addition this is heat rejection. Similarly, the area under the curve on pv diagram shows the work transfer. So, the area of the net loop is the net work done and this is the net heat added and they are equal.

Let us go to this process, we are doing the chart Quick process and then delta u then w work done, Q heat added. The process 1–2 is there anything which is 0? Again, it is a non-flow process. So, these two things is very important and another thing is that Q is equal to delta u plus w.

Now tell me for 2-3 is the anything 0 here?

I start with 1– 2, then Q_0 delta u first you should always write C_v $T_2 – T_1$. I should write delta u first, $T_3 – T_2$, until and unless this is an isothermal process. This is $T_4 – T_3$, C_v T_1 – T4; 4-1 process. When Q is 0, then w is minus delta u so C_v (T_1-T_2) that means T_1 is less than T_2, that means, this is negative work is done on this system. 2-3 delta u, Is there anything 0 here? No.

Q_a is C_p $T_3 – T_2$, where you get it at constant pressure processes. Even for a non flow system Q=h3– h2, because du + pdv, pdv means d of pv that is, d of u plus pv that is d of h that in turn means Q. Q is delta Q is du + pdv at constant pressure process, it is d of u + pv that is d of h, means dh and since air is an ideal gas.

C_p $(T_3–T_2)$, r into $T_3 – T_2$, if you want to write that, I will be happy but I am rather inclined to write P_2 into v_3-v_2, to show them clearly that it is pdv work, it comes at constant. I do not write in terms of temperature because a beginner will see and you will get configure that work may be temperature. But you will see, p_2 and p_3 same as $p_2 = p_3$. So, a constant pressure and change in the volume is the work done. Therefore, I prefer to write this, which is nothing but, r into T_3 - T_2.

So, 3-4, is there anything 0?

3 to 4 is Q_0. Q_0 means w is just C_v(T3 –T_4) so T_3 is more than T_4. Therefore work is being done by the system. 4–1, I think this is 0. So, work is 0 means Q is delta u that means Cv (T1–T4) as we know the constant volume heat addition is, $C_v(T_1- T_4)$.

The first law that is, delta u is 0, then delta w must be must be equal to delta Q. What is Efficiency? eta is 1 minus…. If I tell minus then, $C_v(T_1- T_4)$ is the heat addition. I will write in terms of $C_v(T_1 –T_4)$, the magnitude because negative sign is taken here; divided by C_p $(T_3 – T_2)$. This becomes equal to 1 minus $T_4 – T_1$ divided by gamma $T_3 – T_2$. $T_4 – T_{1,,}$I told $T_4 – T_1$, as written I have taken minus. Otherwise it will be plus it is the magnitude.

There are certain definitions; compression ratio, volumetric compression ratio remains as it is, $v_{1/}v_2$, volumetric compression ratio. Another ratio is defined as expansion cut off ratio; that is cut off ratio what is this? Cut off ratio is $v_{3/}v_2$. Another ratio is r_e expansion ratio. What is expansion ratio? v_4/v_3…………, you can write this thing here in one diagram. This is the problem, let us solve this.

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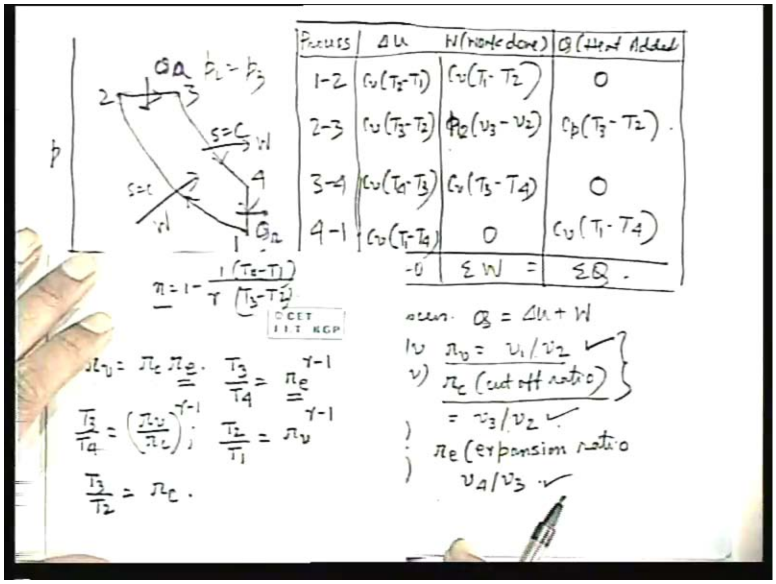

Expression for efficiency eta is 1 minus 1 by gamma. You can see that, $T_4 - T_1$ divided by $T_3 - T_2$. You can write with the definition of r_v. With this definitions of r_v, r_c and r_e, we can write $r_v = r_c r_e$ because v_2 by v_4; v_1 by v_2 $v_1 = v_4$. So, we can write, r_v is equal to r_c cut off ratio into expansion ratio.

We can relate again the same way this T and v, how can you write T and v? If we write T_3 by T_4, What is T_3 by T_4? T_3 by T_4 is v_4 by v_3 that means r_e to the power gamma minus 1 because Tv to the power gamma minus 1 is constant. You can write, T_3 by T_4 is r_e to the power gamma minus 1. Again, r_e can be expressed in terms of r_v by r_c, that means T_3 by T_4 can be written as r_v by r_c to the power gamma minus 1. Then, I can make a relationship between T_3 and T_4, another relationship I can make between T_2 and T_1.

T_2 by T_1 is v_1 by v_2. v_1 by v_2 which is r_v to the power gamma minus 1. Then in T_2, T_1, T_3, T_4 but T_2 T_3 are not the same. So, I can write another equation T_3 by T_2, this is a constant pressure process, so v and T are directly proportional. So T_3 T_2 is v_3 by v_2, which is cut off ratio.

From this, my sole intention will be to eliminate r_e, which I have done in expansion ratio. My sole objective is to express this efficiency in terms of cut off ratio and the compression ratio because these two are important parameters in actual design.

You have to know why I am going to substitute this or eliminate this? It is because, these two are the important geometrical parameters. It becomes a routine task and if you do so with this calculation then it becomes simple that all the temperatures that you express in a single temperature and a function of r_v r_c only and then temperature cancels out with this algebraic steps only with little rearrangement, we get the expression: r_v to the power gamma minus 1 this was the Otto cycle efficiency.

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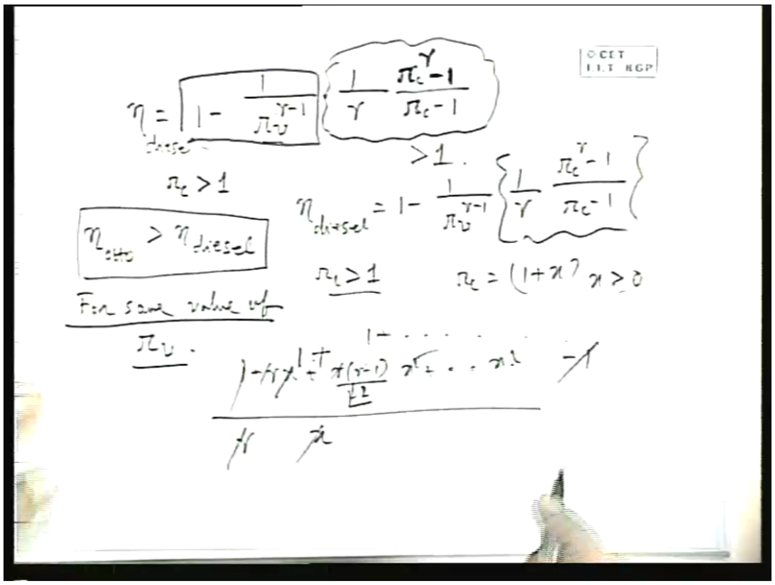

So, this part is multiplied by 1 by gamma r_c to the power gamma minus 1 divided by r_c minus 1, where r_c is the cut off ratio. Cut off ratio is this one r_c is v_3 by v_2. Therefore, one can write r_c greater than 1.

1 is not exponential it is minus 1. It is r_c to the power gamma minus 1 divided by r_c minus 1, not gamma minus 1 otherwise r_c to the power gamma minus 1, when r_c is greater than 1, this part is greater than 1. For the same volumetric compression ratio, this is eta Diesel. Eta Otto is greater than eta Diesel. This is because eta Otto is this part so 1 minus this into something greater than 1 is added so that eta Diesel is less than eta Otto.

Again I am writing eta diesel very simple to level things 1 minus r_v to the power of gamma minus 1into 1 minus gamma r_c to the power of gamma minus 1divided by rc minus 1. How can you prove that this is always greater than 1 when r_c greater than 1can anybody tell how can you prove it so we can tell that eta Otto greater than eta diesel, This is a very important result. For same value of r_v, eta Otto greater than eta diesel. Same compression ratio of Otto cycle is more efficient than diesel cycle, why this is greater 1 how can you prove this?

It is not gp series….. If r_c is greater, then r_c is 1 plus x, where x is greater than 0, there you expand x. It will be 1 plus things which are greater than 0 because r_c to the power 1 plus gamma x plus gamma minus 1 factorial 2. They are going to be divided by x and gamma and ultimately minus 1; though minus 1, minus 1 cancels gamma, gamma will also cancel and these x cancel so 1 power will be reduced, plus x square that means, 1 plus all positive quantities greater than 0. One can prove that r_c is greater than 1 so that for the same compression ratio the Otto cycle is more efficient than the Diesel cycle.

Why r_c is the cut off ratio?

What is the meaning of cut off compression ratio? I understand. This volume ratio represents the compression. If it is high, more is the compression; if it is low less is the compression. So compression ratio gives me index of how much is the compression and volume.

It is not ignited. In this cycle, we can understand that what is 2? 2 is at the end of this. When the ignition starts, it does not go continuously. There is a time after which injection is cut off. The fuel is injected during a certain interval of time during which a certain definite quantity of fuel is injected and is then cut off. It is not a continuous injection of a fuel in a gas turbine plant which I will be describing.

A gas turbine plant is a steady flow process and a non-flow process. So far, during some interval of time, after the piston reaches the top dead centre position the fuel is injected and when this injection is cut off, this is simulated in the ideal cycle as if the heat transfer processes ends. This is the volume ratio or the trouble of the piston during which injection is cut off. That is why it is known as cut off ratio that means the injection of fuel is cut off.

v_2 is the maximum pressure. You can go on increasing it such that, more and more efficient will be the combustion. v_2 v_3 represent the v_2 to v_3, the process during which the heat addition takes place or during which the burning takes place. After that there is no burning. If the injector is injecting fuel during these processes, you compare this with the ideal cycle. So v_3 by v_2 in the ideal cycle simulates the burning process during which the injection of fuel is made. Therefore, cut off ratio injection is cut off from there the work cut off ratio the injection is cut off. I usually highlight these points because there is nothing great introduce this thing that all dynamic books are there.

Anybody in this class who can deduce that eta is 1 minus 1 by r_v to the power gamma minus 1. The most important things are those things which have to be known from the concept. Next is a gas turbine plant.

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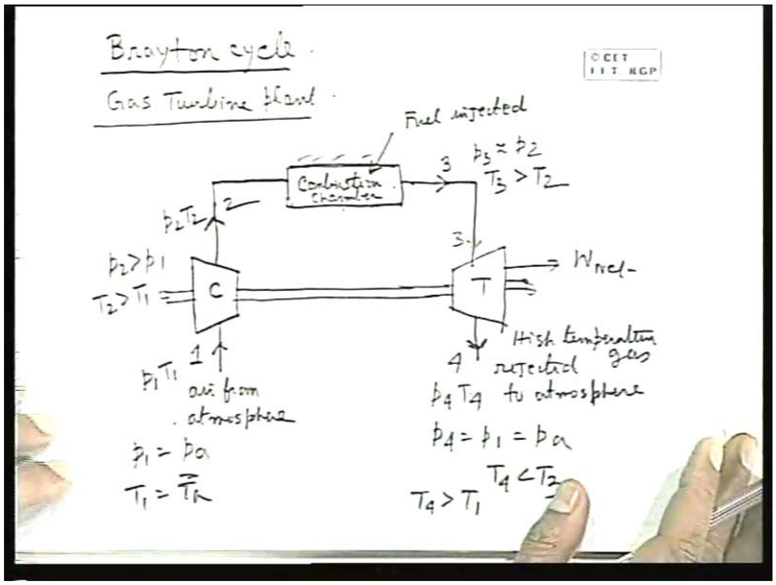

We will start with Brayton cycle. Brayton cycle is an air standard cycle which is an ideal cycle for a gas turbine plant. Therefore, we should know what is a gas turbine plant? The gas turbine plant or a gas turbine engines are used in many practical purposes, one very important practical purpose where aircraft engines and rocket engines. Another practical purpose is in the industrial power generation installation gas turbine plant. Even in thermal power stations, when the peak load has to be met by the gas turbine power plant, because of certain engineering characteristics of the gas turbine plant over that of the thermal power station.

The major use of gas turbine plant is for the aircraft engines. It is also used in marine purposes, in some automotive industries and also in automotive engines gas turbines are used. These are the practical uses of the gas turbine plant which will be taught in detail afterwards in your apply thermodynamics class. I will explain what a gas turbine plant is and what does it consist?

It consist of the compressor, where air comes into the compressor from the atmosphere and it goes at a higher pressure and temperature then it goes to a combustion chamber, it is an uniform cross sectional area duct. This is a combustion chamber, where fuel is injected from outside with high pressure and temperature. Air which is being compressed by the compressor enters and they burn the fuel and ultimately a high pressure gas which is the burnt products of the fuel with air comes out and this is passed or expanded through a turbine. The turbine and compressor are connected by the same shaft.

After expansion to the turbine, the high temperature but a low atmospheric pressure is rejected to atmosphere. Air from the atmosphere and high temperature gas; at relatively high temperature, there is a temperature drop but, still high temperature gas is rejected to atmosphere. This is a gas turbine plant; this is known as open cycle gas turbine plant. Why the cycle is open and not close? Actually the vast environment takes part of the closing link. Air is always taken a fresh from the atmosphere where the gases is being rejected to the atmosphere and even if the gas could have been cooled and send here then it is not air again.

You have to always send air. You cannot take this gas, which is why it is rejected. We require air in the compressor; this is the open cycle gas turbine plant which is used in aircraft engine automotive engines and marine engines, even in the industrial gas turbine plants. Except the nuclear power stations where a close cycle gas turbine is used which will be exactly similar to the Brayton cycle. So, this is actually gas turbine plant.

Work is being done by the turbine, because of this expansion of the high temperature; high pressure gas at some part of the work is used to drive the compressor, so that the network is coming out from here. Network and chemical energy is added in terms of the fuel injected. The chemical energy is used in burning the fuel with the air and a thermal energy is generated which creates a very high temperature of the products of combustion. Air starts with a state point 1 at a pressure p_1 and a temperature T_1 then it goes to a state two at a temperature p2 and T_2, where p_2 is greater than p_1 and T_2 is greater than T_1.

Then, it is being burnt in a combustion chamber, which is a steady flow device. Air flow and fuel injection takes place continuously. As I told earlier, there is a continuous fuel injection and continuous burning takes place.

Except very small pressure drop due to friction, the pressure remains almost constant so at the point 3; p_3 is almost equal to p_2, but T_3 is much greater than T_2 because of the exothermic reaction. The combustion chamber is totally insulated. Then T_3 is expanded p_3 T_3 that is state point 3 is coming to 4, which is p_4 T_4. When it is injected to atmospheric pressure so back pressure of the turbine is equal to p_1, which is equal to atmospheric pressure p_1 equal to p_a but T_4

is less than T_3. Though it is less than T_3 because of the expansion in the turbine but it is much greater than T_a.

T_1 is T_a that means, it is greater than the atmospheric temperature. That is why I have written high temperature, gas is rejected to atmosphere. Therefore, we see a gas turbine plant, unlike a reciprocating IC engines that is petrol engine or diesel engine, it is a steady flow device. Non flow is not a flow process it pertains to a flow process. In the steady flow device, continuous flow takes place it is not a non flow process. Mass coming in and going out and this is an open cycle gas turbine plant. In close cycle gas turbine plant things are different. In a closed cycle gas turbine plant which will be approximating the plant towards Brayton cycle, this is something different we tell this in a flow cycle gas turbine plant.

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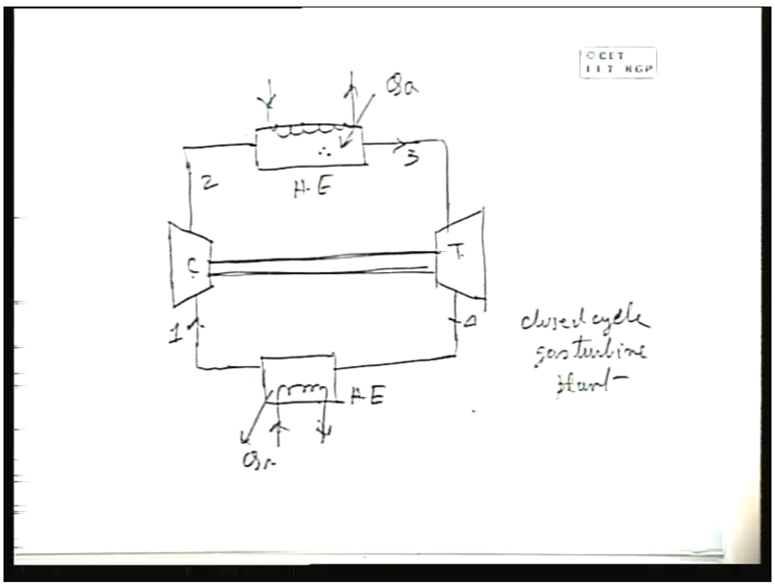

It is like this. There is a compressor and air is coming here, there is no fuel injection, that means the air is being heated from an external source that means external hot fluid comes and goes and it heats the air. This is 2, from 2 to 3 that means here the heat added is Q_a. The next part is the same that means this is the turbine part. From 3 to 4 is the turbine air, then the same air is cooled while going from 4 to 1 by a coolant.

Here the heat is rejected Q_r. Air is the working fluid, this is a close cycle gas turbine plant. This is exactly a thermodynamic closed type cycle gas turbine plant. It is a thermodynamic cycle where air is the working fluid. Working fluid does not change in its constituents. Same mass is totally circulated.

A steady flow system is circulated throughout the cycle; where this part, which is actually the combustion chamber in all practical cases it is being simulated, as heat exchanger where external sources which gives the heat to the air and similarly instead of rejecting these two atmospheres and taking the fresh air from the atmosphere, when you consider the vast atmosphere take this part of the scene.

It ultimately will make up the missing link in the cycle. Here, the heat exchanger is conceived where the air is being cooled through a coolant fluid and this happens in the cycle. This is really a thermodynamic cycle and this known as closed cycle gas turbine plant. Open cycle gas turbine plant does not resemble a thermodynamic cycle but this resembles a thermodynamic cycle and this type of gas turbine plant is being operated in a nuclear reactor where you get a high temperature heat source from the nuclear rod. Actually, the reaction takes place due to nuclear fission and similarly we have coolant. The coolants are used for cooling this gas rod.

There are sufficient coolants, which are used to cool this air. This is being made a close cycle gas turbine plant where air is the working fluid which is being heated from an external source and cooled from burned external sink. However, we see that there is a compressor, a turbine, a heat exchanger or combustion chamber and a heat exchanger for heat rejection.

In open cycle this is being rejected and fresh cold air from atmosphere is been taken so these are the two types of gas turbine power plants and this power plant is being approximated by a theoretical cycle known as Brayton cycle, which we will discuss tomorrow.

Thank you