Engineering Thermodynamics

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Week-09
Lecture-39
Gas Power Cycle

Welcome to you. We will discuss a new topic, Gas Power Cycle, which is very important for thermodynamics. In fact, this is its purpose. What we are doing is one of the most important applications of this, Power Cycle, which is of power generation. So, in this, two types of discussions will be done. First, we will understand what a power cycle is. There will be two types of applications. First, after understanding what a thermodynamic cycle is, you can generate power in the thermodynamic cycle, which will be the purpose of power generation. Second, it is also the purpose of refrigeration. So, we will try to understand both things.

In this lecture, first we will understand its fundamentals. We will understand the basic assumptions in this calculation. Later, we will try to understand the engine in the next lecture. Reciprocating engine is what we call it. To some extent, we will understand the different cycles of the engine through the example. Like, there was an auto, a diesel, a Brayton. To understand this, first of all we will know what a power cycle and a thermodynamic cycle is. Especially, what is a gas power cycle? Once you understand that, then you won't have any problem understanding the refrigeration cycle and other things. So, as I said, there are two main purposes of the thermodynamic cycle. One is power, which is of two categories, which is of power. And the second is the refrigeration. This operation is done on the thermodynamic cycle. That's why it is called the power cycle or the refresh instance cycle. There are two types of parts in the thermodynamic cycle. One is called the gas cycle. The working fluid in the gas is always in the gas form. cycle Working fluid It will always be in the gas state, always in the gas farm. because throughout gas will be firm second is your Whipple Vapor Cycle In this cycle, half of the vapor will be in the cycle and the other half will be in the liquid. So, some part of the vapor will be in the cycle and the other half will be in the liquid. So, this means that it works in saturated condition or dome. So, we will know about that. Thirdly, it should be understood that the Thermodynamic Cycle will not always be closed. Cycle means, of course, the definition we have made, like PV. If we start in a state, then we come back to that state. But, if the system is completely closed, then this is possible, what I have drawn. That the fluid we have used, we are bringing it back to that same state. And in between, we will use our three or four devices. Which are our Second law, first law, all these are valid. Second is that it is open, in which some fluid is started. And then we throw it and then we bring new fluid. So that the mechanical state in the initial cycle is the same. The thermodynamic state will not be same because the fluid has changed. So you see such things in automobiles. where the gas is always running so what you see is an open cycle where the gas is burned and after that the work is done and then it is then put into exhaust and then a new fresh gas is produced so the system will be open and the same thing is done in a practical way there are two types of internal combustion and external combustion internal combustion means the heat generated from the inside where fuel is burning inside the boundary of the system and the external combustion engine is supplied by furnace so like steam based power plant is external and the one in your automobile is internal so we will understand all these things and will go to the rest of the lectures in this course but first we will do some analysis Let's consider how to represent and describe the power cycle. Approximation is very important in this. Because you have to understand how to do mathematical analysis. We have to apply some kind of approximation. And we will understand what kind of approximation is in this lecture.

So, let's start. For example, if there is an ideal representation on any object, then sometimes we do a very vague approximation. For example, in this case, we can say that this is an oven and potato is in it, Potato has no water in it, so we can also say that it is water to approximate it. This kind of approximation is very much there. Such approximations can also be used in engineering. Because by simplifying it, analysis becomes simple. So, idealization is very important to use the ideal system. Because in this way, it will be very difficult to analyze the cycle. Normally, because the actual cycle is very complicated and all the power producing devices work on the cycle only. So, we will consider an ideal cycle which is at least closely connected to the actual cycle and internally reversible. There is no friction internally. We will not talk about external reversible in this. It should be internally reversible so that we can use the remaining expressions we have taken out. So, based on an approximation, you can see how we are doing the approximation. This is your POV diagram. The actual process is, let's assume that this is a dotted line. And this is your cycle, that's why it's rotating. And how are we doing the approximation of this? Here, there is a process that is working at a constant volume, which is why it's a vertical line. This is the second process. then there is a constant volume and then there is a process. Now this part, which is PV, we can assume that it is adiabatic or temperature constant. So, we have to approximate this. Whereas, if we look at the actual, there are some changes. The slope is a little different or this constant, this part is not exactly constant. But we will neglect it. W net out divided by Qin This is your thermal efficiency So we will take eta ratio This is the definition but we know that Carnot cycle is the most efficient And that's why when we say ideal condition We are saying internal reversible So we will use Carnot cycle And we know that Carnot cycle does not mean that it can be external reversible But Carnot cycle is Internal is more important, so we will use it because it is reversible. Now, in actual conditions, you will have heat transfer, which is due to the difference in temperature, and that is why external reversible will never happen in your real cycle. But we can do other things with internal reversible analysis. So, we will take some summary from these discussions, what are the assumptions we have to take. So, the common idealization, the things we are considering as ideals, we are considering assumptions and simplifications are these. First, there is no friction in the cycle. That is why there will be no pressure drop in the pipe or devices. And whatever is your expansion or compression process, it is happening in equilibrium. Quasi equilibrium is very slow which means it is internally reversible Thirdly, the pipes that are connected to the devices that are connected to different devices because it is in the cycle, so we have to use different devices it is well insulated it is insulated and heat transfer is negligible This is an important element to simplify your work. You can see this concept in the property diagram as well. It is very easy to do. Especially, the PV and TS diagrams are very useful to analyze. Because when you present this in the PV diagram, like you did in the PV diagram, the cycle is like this, in which you saw 1, 2, 3, 4. cycle 1 and 2 are at constant volume 2 and 3 are at constant pressure 3 and 4 are at adiabatic or at isentropic process and 1 and 4 are at constant pressure so this area under the curve will be W net so this is kind of a p-v diagram, it is very useful to find out W net similarly you can say TS diagram but in TS diagram constant This is the isentropic model It will look like this So, in this also, the area under the curve is W net but see how much difference the presentation makes When the process is different, sometimes it becomes more important to present the diagram so we should pay attention to that Because if you want to find the PV diagram, you can easily find the network produced. The same thing, if you want to find it in the TS diagram, then the area under the curve will be your total heat transfer. So, this should be according to the total heat transfer. So, this total net heat transfer will come in the cycle, this is the area under the curve. Because note that the dQ is connected to the TS. So, if you integrate it, you will get total TdS. So, in this, 2-3 things are more important. One is that heat addition, you can find out from this that if this is always in the direction of increasing entropy, and heat rejection is always in the direction of decreasing entropy. So, the property diagram becomes very important in one way to do. Now, let's consider the car and the cycle. So, Carnot cycle as we said, there will be 4 reversible processes. Okay? And as we said that when we were talking about idealization, we always said internal reversible in the ideal cycle. But in the case of Carnot, we always consider it totally reversible. So, in that case, it is important that because in the case of the external ideal, it is not necessary to transfer heat outside the boundary at a finite temperature. It will be transferred at a finite temperature. But in the case of Carnot, we consider the process to be totally reversible. And that is why your definitions come. So, in Carnot, we will take the processes and this is connected to the four devices. This is what you see here. If you see from the PVE diagram, so 1 to 2 is your isothermal turbine. Here Qin is inserted here. And this turbine is essentially operating from 1 to 2. and after that it goes into an isentropic turbine which is considered to be the constant of entropy note this in the PV diagram after that it goes into a 3 or 4 compressor which will reject heat and the temperature will be constant so it is an isothermal compressor the process goes to phase compressor where the entropy will be constant and essentially the volume will be reduced further so this as you can see there are isothermal process and isentropic process but these are in two parts first isothermal heat addition and then expansion once you add entropy, it will be constant and expand further expansion will be in this case and in this case but in the first case, the temperature will be constant in this case, entropy is constant and in this case, your isothermal is constant and in this case, S is constant but this is your two stages of expansion and compression you are putting heat in one isothermal condition, then isentropic continues expansion then you get rejection system in heat rejection but starts with isothermal and then isentropic compression now consider this cycle so this cycle's corresponding efficiency which is highest temperature Th and lowest temperature Tl so efficiency is reversible we have discussed this before that 1 minus Tl by Th so this is your eta Th reversible is 1 minus Tl by Th If you look at this in TS, you will easily understand that this 1,2 TH to heat in then isentropic 2 to 3 expansion then heat rejection on Tl 3 to 4 then 4 to 1 isentropic compress which means you are back to the same temperature So what is the value of this Carnot cycle? First of all, you can easily calculate the efficiency of the Carnot cycle by using a reference. As it is, reversible isothermal condition is very difficult to make. So, I mean, Carnot can't be made practically. So, its value comes out because you considered it as an ideal and it became a very standard reference. And this is a message to make an ideal system, which is that in its comparison, you can compare the ideal system, ideal type cycle or actual cycle to see how much you bring close. Remember that in the ideal, the internal is reversible, the total is not reversible and in the actual, it is not even internal, it is reversible. So, in such a case, you have to pay attention that the value of this is only a reference, and you have to extract the value from that reference. One value comes out very easily that if you want to increase the efficiency, what temperature you have to increase or decrease. So, if you want to increase the efficiency of the system or the cycle, then if you decrease Tl, then the efficiency will increase. Or if you increase Th, then the efficiency will increase. So, you can take such messages and such indications and apply them in ieal or in your actual cycle. We can also derive the efficiency of this. We have already done this, but we will do it again dynamically We will take a simple derivation in which we will take this system So if you take in this, then what is Qin in this? Qin is your reversible system So Qin will be your Th S2 minus S1 And your Key out will be TL S3 minus S4 and since S4 and S1 are connected and S3 and S2 are connected because they are both the same isentropic so this is TL S2 minus S1 and this means that you take out eta as here eta is Wnet which is out Wnet out divided by Qin so Wnet can be taken like this 1 minus Qout divided by Qin and Qin is yours and Qout is this so if you remove this, it will cancel because S2 is S1 so Qout is TL this part and the other Qin is TH this is the same, so it will cancel so this is the expression we wanted to derive so this was your basic Now, the important thing is that you have to understand that in the gas power cycle, the working fluid is gas. As I told you, there are two types of cycles, gas and vapor. Now we are talking about gas. And we will take some assumptions in this. and it will be a product with combustion. So, we will assume that in this case, there is a section where air comes in and heat is supplied. So, we replaced the combustion chamber with heat. So, this is a kind of idealization. We will consider it an ideal cycle. And we will also consider that the working fluid is in the air and the fuel. The composition of the air is not changing. For example, we will assume that the air is nitrogen, the composition is not changing. So, the air coming in, the composition is not changing but the temperature is changing because of the heat. The air will remain the same. So, these are the assumptions that we have to apply. This is called the air standard assumption. So, the summary of the assumptions will be that the working fluid will be continuously supplied in closed loop and will always behave in ideal gas form and all the processes in the cycle will be internally reversible the combustion process will be replaced with heat addition and the exhaust process will be called heat rejection by which the working fluid will be in the initial state So we are taking these assumptions. Another thing is that we will also assume that the air is cold air standard. We assume that the heat capacity of the air is constant, and its value is 25 degrees. The second thing is that when we say that the air standard cycle, it means that we have applied air standard assumptions on this cycle, which we have just read. So, this We will do the assumptions in every process. So, pay attention to these assumptions. Once you practice, you will understand the assumptions. But still, you have to pay attention to these assumptions. Because all these applications that we will do in this course will be related to these assumptions. In the next lecture, we will understand the reciprocating engine and how to use it. About that So when we analyze your auto cycle, diesel cycle, through the examples, we will understand it better. So, see you in the next lesson. Till then, bye-bye.