**Engineering Thermodynamics**

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**Week-04**
**Lecture-26**
**Second Law of Thermodynamics**

Welcome to this new lecture which is part 3 of the second law of thermodynamics. In this lecture we will discuss what is perpetual motion machine? How can we increase the efficiency and capacity of machines? Can we take its assumption? And we will know about reversible and irreversible processes. And finally, we will know about Carnot cycle which is an ideal system. And it will be our reference to close any machine and achieve that limit. So, we define a limit. Carnot cycle and reversible process Let's start with perpetual motion machines. Many people tried to make machines that are very efficient, that don't take any energy but give some energy in the form of work or heat. So, in this way, this machine violates the first law, here is an example of that. Here you have a boiler. Then the turbine shaft went to the generator and worked out. And created the work. And this fluid went to heat up with condenser. rigid care system.

So, the boiler system is pump is also there. But if you take the system, what will you see? You will see that E in minus E out. is equal to delta E system. And this is nothing. This is out. This is called Delta A system. Delta A system will be zero in steady state. That's why this system designed is not possible at all. It will only violate the first lock. Because it is always creating this energy. It is generating but not taking anything from anywhere. I wish it was like this, but it is valid, it is doing, and it is not practical, it is imaginary. Similarly, the perpetual motion that does the second law of thermodynamics is called the perpetual motion of type 2, PMM2. Perceptual Motion, which is the second law of thermodynamics, is called PMM2 or of type 2. This is an example of this. You have a boiler, the boiler heats from the furnace and it is boiling, and the turbine is working through the shaft. There is no rejection. the Qout has been zero because there is no device that is throwing waste energy. We have read that in such cases, the second lock is violated, the Clausius and the Kalvin lying statement are violated, the Kalvin lying statement is violated, that is why the perpetual motion of this type is also made, the machine of this type, the system is also imaginary. The question is, we talked about heat engine or refrigerent pump. And we have taken the definition of its capacity. But the question arises, in what condition these devices can achieve the highest possible, highest efficiency. To understand this, you have to understand what reversible and irreversible processes. What is that process? Which we call Reversible processes Now, if you do a process which takes you from A to B or from state A to state B and in this process if you can come back without leaving any mark on the surrounding environment then it means that it is reversible So, reversible process is without leaving any mark on the environment. In such a situation, neither the system can come back easily, nor the surrounding will come back to its original initial state without any other impact. So, at the end of the reverse process, the system and the environment both come back to their original state and there is no effect on anything else. Now, this condition is called Quasi equilibrium expansion and compression. It happens so slowly that in such a situation, if it is adiabatic or in general, then your cycle is taken.

Let's take a cycle from the PV diagram. So, you will come back in this procedure. No matter how you get it. So totally, if you come back between A and B, then the total energy and net work of the cycle is zero. So, whether you understand it like this or because this process is linear, or if there is a circle, then in this way your total energy, heat and work. This is possible when your system is expanding or compressing with very high equilibrium. This way you can understand that frictionless pendulum is also an ideal. In this way also your total energy loss is zero. In this also your system is reversible and can run forever. But because it is not like that in imaginary, you always see that it comes back after some time. But if there is no friction anywhere. So, there will be no loss and it will continue. So that is also a reversible process. Where we started and then we can come back. So, we will understand this process more. So, he is just starting with this topic. Reversible is a process in which if they start on the change, no sign leaves on coming back. So, in the situation in which we started, if we start our process, in that situation if we come back, then neither it affects the system, nor it affects the surrounding. And if the same thing does not happen, then you have a reversible process. So, what is a reversible process? It is a process that cannot be done without leaving any mark on the environment. Means some mark is left. Now you can understand this in many ways. First of all, your process will be very fast or in a non-equilibrium state. It means that it is not in a quasi-equilibrium state. It means that it is fast. They don't have enough time to come to equilibrium. There are such examples too. Like this unconstrained expansion. There is one such example. For example, you have a membrane initially. This is your gas. And it gets punctured. It ruptured. And in such a situation, the gas will expand in the other compartment. And initially, this compartment is vacuumed. Nothing happens in it. It will fill the compartment very quickly.

Now, if you want to bring this process back, what will you do? After the gas is filled, the state of the system changes. No pressure will be there. and the temperature will also be different. If you use an ideal gas, you can remove it easily. Now, what will you have to do to bring it back to that state? You will have to work. Because this part, the gas that has expanded, which has filled, after spreading, it will fill, it will fill. And you will have to compress it, which means you will have to work. In the original volume, you have to work on the pistons and the energy will increase as the pressure increases. So, you have to remove it. To remove it, you have to work and remove the heat. If you can't work with the heat removed completely, which won't be possible in this case, because you will use a heat engine for conversion and it won't be 100% convertible, then in such a case, your process will be irreversible, which is the case in this case, because it was removed very quickly. Similarly, if there is any friction, then it will make the process irreversible. because of which your additional heat will come, and it will cause you problems. An example is that if you move it from here to the bottom and then bring this box to this position, then you will have to lose some weight but in this process your heat will be lost. In this way, the surrounding environment will be affected. change will occur and leave a mark on it. This is why we will call this process irreversible. This was the topic of the irreversible process. Reversible process is an imaginary process. We want to do the maximum. But the nature of it is in an irreversible process. So, the question arises that why are you interested in the reversible process? First thing is that if you use the reversible process, then you can analyze it mathematically. And we will discuss how we can do it. Second thing is that you can consider it as an ideal model. Second, you can consider the reversible process as an ideal model. After considering it, you can use it as a model, compare it, and compare it with the actual process. And in the same way, you can improve the

actual process. You can increase its profitability. You can analyze it and improve its profitability. Some processes are more irreversible than the others. So, the question is why do we approximate the reversible process? Because we want the reversible process to be as close as possible to our process. Because in the reversible process, either the work delivers the most, in fact delivers the most, or the work consumes the least. So, if we model any process as a reversal process and want it to reach that limit, then your system will be efficient, the most profitable will be the most.
Now, this is an example that if the slow process is called the reversal process, then in this expansion, if it is expanding, like this is your ball which is a moving ball, and if it expands, then the level remains the same so that's why its properties will be the same everywhere and the pressure distribution will be the same at every point as the level increases, the pressure will decrease and the same in compression too, if we slow it down, it will remain like this if you page Notice that the pressure level will be different due to different pressure levels. The pressure value will be different, or the property value will be different. This way your process will be reversible. It means that if you do the process very slowly, then you can model it through the reversible process. So, one thing we noticed here, now let's move forward. Usually, the frictional process is the frictional process. Friction is the process of the two substances that are mixed together. You will have to process it separately for later. heat transfer between finite temperature difference. Resistance of electrical and solid deforms. Its shape changes but becomes inelastic. And later the chemical reaction. You will notice that we will discuss this later. Because of all this, your irreversibility comes. If any of these things are present, if any such effect is present in your system, then that system will be irreversible. And the same example is given to you in this form. This is the mission of two products. Here heat transfer is on a final difference. So, heat transfer is on a final difference like 20 degrees. Initially it was a 5-degree soda bottle. Here heat transfer is on a 5-degree soda bottle. So finally, the temperature of the can is 20 degrees.
Now, this is an irreversible heat process. Because if you transfer it back, then to transfer it back, to do this, you will have to lose more than 5 degrees of temperature so that your transfer remains. Because if there is loose energy, then its temperature will be less to transfer the same amount of energy. So, this process is very irreversible. And particularly, your heat transfer is always irreversible. Its direction will be the same. You cannot reverse it. with any other help, which means that you affect the surroundings. Similarly, another example of yours is fast compression and fast expansion. Compressing very fast and expanding very fast. This is also irreversible because your properties never remain in equilibrium. And because of this, this process becomes irreversible. And likewise, your unconstrained expansion. Expanding the vacuum very fast. So, these are all your processes which are irreversible. We consider two kinds of processes in this as well. And the maximum time we will solve the problem on the other side will assume that there is no irreversibility in your system. That means every point of the system has the same property. And there are no changes in it, there is no temperature difference in it. So, because of this, you have no reversibility. But it is possible that outside you have a temperature difference. There can be such a difference outside. That is why we divide it into three or two types of parts. One is called that, that is why we divide it into two types of processes. One is called internally reversible process. So, this is the internal reversible process. In this we say that the heat transfer is happening with finite difference. Here it is 30 degrees and inside it is 20 degrees. But the system boundary will be 20 degrees inside. And the boundary will also be 20 degrees. So here it is saying that irreversibility will not happen in the boundary at all. So, this is an assumption that irreversibility will not happen in the boundary at all. If there is no irreversibility within the limits of the system during the process, then we will call it an internally reversible process. And

external reversible process means that if the system is not irreversible outside the limits, then it will be called as external irreversible process.
Now let's combine both. So that happened, there is no irreversible process inside the system or outside it. So, it is a totally irreversible process. Now this system will be in general in such a time as heat transfer also happened. There will be very little difference in the temperature outside and inside. For example, if the heat transfer is happening here, and the temperature outside is 20.001 something, now the heat transfer is so less that you can assume that this process is very slow. That is why we are assuming that this is a totally internally reversible process.
Sometimes, because it is a very slow process, the temperature of delta T is almost going towards zero, in such a case, we can call this process a reversible process, which is happening in the surrounding. In such a case, both these processes are internal and external, both the processes are reversible, that is why we call it a total reversible process. So, in the entire process, there is no heat transfer due to the limited temperature. And in this way, your process is very slow, there is no friction, there is no energy loss. In this case, you will consider it totally reversible. This is important to understand. Once you understand this, your assumptions will be based on this. It is important to consider internal reversible. Because usually, you will have a final difference. But we assume that the process is still slow. So, it will be a little bit imaginary. But you can still make assumptions and draw out many things that we will practice further. Now the question arises when we talked about the reversible process. Now the question is that the heat efficiency, you know that we discussed about the heat engine. So, when we did the heat engine, there was a boiler here, It used to come out on high temperature pressure and from here your W work used to be out Correct And from here it used to go to condenser used to rigid you Q out This is your Q in which the boiler used to take And after that this pump When it condenses you, it is low pressure So, it would go to high pressure and bring it to the same pressure that the boiler operated on. So, this is high temperature, this is your low temperature on this boil. Now, what is that, if there is a pump here, then work is in. Now, the main thing is that if you want to increase its capacity, then first of all, minimum work should be done. And maximum work should be done. This is possible only when the process is reversible. So, pay attention to what we are doing. We put heat in one, in the other we work out. So, it will naturally expand a little and here again the heat is rejected. And after that, it is compressed through the pump. This process was thought of by Carnot. how to make a cycle which is an ideal cycle and, in this cycle, your reversible processes are involved so this is the reversible cycle this was proposed by Sadi Carnot in 1824 so in this process effectively 4 processes are there in this cycle which is the Carnot cycle of the heat engine which is the ideal cycle, there are 4 processes So these are the four processes. Two are isothermal constant temperature which is here you can see these two. And two are adiabatic. Now we will try to understand this in a simplified form. We will try to understand it in a very simple way. These devices will not be shown. But the comparable similar action which is being done according to which We will try to understand it through a simplified equipment, through a piston cylinder. The process is the same. That one, two isothermal and two adiabatic.
So, these are the four processes of Carnot Cycle. First, so one to two is your energy taking. As we said that boiler is working. So, energy is consumed at high temperatures. and this is TH constant, and this is your expansion 1 to 2 is reversible isothermal expansion we are taking Carnot, and the special thing is like we have a working fluid in a heat engine Carnot will have gas so it is a simple gas which we will understand as an ideal gas later, but this gas will expand at this temperature Now the temperature is here. here we insulate it now expansion is coming but still it can expand so this is reversible adiabatic expansion in this case it is expanding and TH

will expand so volume will increase and temperature will decrease but Q is zero there is no external heat transfer because it has been insulated and finally it expands to low temperature so you can understand this if you look at the heat engine so this boiler was working this is 1 to 2 and this is 2 to 3 Because it also expands and it is working effectively because of the boundary. So, it is trying to represent in a way, but don't look directly that it is exactly what we are doing, it is not like that. With these four devices, Carnot has understood the process and essentially designed that Carnot cycle. So, this is 3. Now, we have to throw away our energy. So, this is your process 3 to 4. So, this is called reversible isothermal compression. Work is going on here. We are compressing it. And we are doing it at constant temperature. Since we have to keep the constant temperature, the heat will have to be rigid. So, this is your 4 to 3. Finally, when it reached 4, it was insulated again. In this way, it became reversible adiabatic compression. The compression is continuous, but the temperature is increasing. So, these 4 processes have been done in this way. The first process is expansion, then reversible adiabatic expansion, then reversible isothermal compression, then reversible adiabatic compression. So, these 4 processes have been done in Carnot section. If you see from PV diagram, this is the first one. The first process is 1 to 2. Here your heat is coming. Volume is expanding. Here 1 to 2 is expanding. Heat is also transferring. So, this is isothermal expansion. The temperature is constant. The process is adiabatic from feed 2. This is also expansion but adiabatic. Then 3 to 4 is your isothermal compression. Heat loss is there. Then 4 to 1 is your adiabatic compression. Here the temperature changes. So, this is your cycle. And the area under the curve, which is in the PV diagram, according to this, the total work net will be W net. Now if we change the direction of this process, then this is called the refrigeration cycle. So, if you reverse the processes, they can do it, because this is a totally reversible cycle. This is the assumption. When you reverse it, it becomes a refrigeration cycle. Please note that 1, 2, 4... Hit rejection is done. In this, the thing is that 1 to 2 is your Adiabatic expansion has been done. 2, 3. Constant temperature expansion 4 adiabatic compression 4 to 1 Constant temperature compression. So, this is your inverse and reverse Carnot cycle which you can connect with the Referegent cycle. So, the main purpose and purpose of this lecture was how to define the reversible process. And how the Carnot cycle is designed according to that. Now we will discuss further what is the efficiency of the Carnot cycle, what is its capacity and how you can consider it as a purpose. process code design connects. So, we will continue this discussion in the next lecture. I hope you have learned something from this video. We will try to understand some more examples of this bike in the next class. See you in the next class. Till then, goodbye.