Engineering Thermodynamics
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Week-07
Lecture-32
Entropy

Welcome to the entropy lecture. This is the fourth lecture on entropy. In this lecture we will discuss reversible steady flow work and also about isentropic efficiency which we mostly use for steady flow devices. which we have to use. So, let's start to understand how the fluid property of the reversible steady flow work depends on and how we can express it, tell it or use it. We have already studied about work, about closed system and remember we said that we used this for boundary works related. But this was used for a very slow reversible process for the quasi equilibrium. So, this was used for this. Now, this particular work, boundary work, we were normally using it for closed work, closed system, in which the boundary is moving, but we joined the property of pressure and volume. So, the question is, can we join the property of fluids for steady flow process, steady flow work or system? So, it will be very helpful if we can join it. So, this will increase our problem-solving ability. So, for that we do this that we assume that when the system is doing positive work, it is positive. And the heat supplied is positive. So, if we consider this and a reversible, We apply an energy balancer for the study flow system.

$$W_b = \int P dv$$

Stedy flow devices,

$$\delta q_{rev} - \delta w_{rev} = dh + dk_e + dp_e$$

$$dq_{rev} = Tds$$

$$Tds = dh - vdp \rightarrow \delta q_{rev} = dh - vdp$$

$$dh - vdp - \delta w_{rev} = dh + dk_e + dp_e$$

$$\delta w_{rev} = vdp + dk_e + dp_e$$

$$w_{rev} = -\int_1^2 vdp - dk_e - dp_e$$

$$w_{rev} = -\int_1^2 vdp$$

Work input to stedy flow devices like compressible, pump etc.

$$w_{rev,in} = \int vdp - \Delta k_e - \Delta p_e$$

For incompressible flow,

$$w_{rev,in} = v(P_2 - P_1) + ln\frac{{v_2}^2 - {v_1}^2}{2} + \cdots$$

Steady flow through device with no work interaction nozzle and pipe section per unit mass,

$$0 = v(P_2 - P_1) + \frac{{v_2}^2 - {v_1}^2}{2} + g(z_2 - z_1)$$

Notice that for the steady flow system, we have written minus VdP which is work producing or in this case we have written work producing because we are saying that it is going out of the work system means it is doing it in the system surrounding so this is minus VdP similarly, we can change the sign convention and work in which will be relevant for you which is more important for the pump like in this case we have considered the turbine but notice that for steady flow this is the expression and closed system which is not flow and closed system is this expression Pdv So pay attention to this. So, these are two different expressions. And do not confuse it. These are for different systems. They are different for the flow system and different for the closed system. And similarly, if we have written W reversible out, which means the work producing device for the study flow, if we write this according to the work input, to steady. flow devices which are our compressors or pumps. In such cases, the expression comes out and basically the sign changes. all good difference. So, assume that this is kinetic energy and potential energy and assume that this is incompressible flow. Incompressible flow. Take care. incompressible flow. So, your right-hand side will be V 3 2 minus p1 plus of course the rest of the terms. And also consider that there is no work in such a device.

For example, you have a nozzle. or pipe section So in such a case, if there is a steady flow. The device through which no work is happening with no work means no work is happening If there is no work, the W on the left hand side will be zero whether it is considered for this in this one, where the work is out whether you consider it for them, in general your work is not working, so this expression in this you do delta k in which v2 minus v1 square by 2 of course in this you Let's consider the mass too. Plus, if you do it according to the minute mass, you have the potential to win. So, the right-hand side is zero, and the left-hand side is zero, and the right-hand side is P2 minus P1 plus V2 square minus V1 square plus Z2-L1 And this expression you see here This is nothing but Bernoulli’s equation. because it is used in fluid mechanics.

If there are any other kind of friction or shocks, then this equation will change. Another important thing is that the work in this case, the steady flow work, depends on the specific volume. If the specific volume is more, it will give more output. Similarly, work in, like a pump, if V is less, it will take less work for the end result. So, it becomes very important to know how to control the specific volume of the flute. whether it is for compressor or turbine work. So, this becomes very important. Now let's discuss only this: if there is liquid and gas, then how does your work change? And in this case, we have taken an example, in which there is a pump that compresses the liquid, and in the other case there is a gas that compresses the vapor. And in this you will see how different results come out the same small thing how it gets different So, when we consider liquid, we will assume that if the volume is not compressed, it is incompressible. That is why you use integral VdV in this case. in case of W pump, that simple Vdp will be V1 P2 minus P1 and in this case, which is written as steam that is 100 kPa to 1 MPa has been changed so we will assume from the beginning that this V is you can assume that the change will be very less not so much that it will affect but we can work with this assumption otherwise you can get the table of the subcult from the table of compressed fluid the reason is that it is integral then either you can do numerical integral from the data point because your equation will not be in any form in this case so you can get it from the data point or you can assume it As I have done here. So, if you see the table, since it has steam and water, then you will get the table from A5. Condition. So, this is your simple set of pressure. 1 MPa to 200 kPa. When we take out the data, it is approximately 0.94 kJ per kg. where you compressed the liquid from 100 kPa to 1 mPa okay like this is your line this is S and this is T and from this point we compressed and brought it to this isobaric condition which is 1 mPa and the second case is this where we have saturated We will compress it and bring it to this line which is 1 Mpa The question is how much volume it will get Naturally you can see that if you work carefully, the area will be under the curve Naturally you can see that the green curve will get more area So definitely your work will be more Still we will try to get it out Assume that this compressor is adiabatic. In this case, entropy will remain constant. We have already derived that Tds is dh minus Vdp. The main thing is how to do this integral. Basically, Vdp is the relation for you. You don't have any equation. So, you have taken out the table. Second option is that if you assume that the device is isentropic, which is also given in the expression, then it becomes very easy for us. Because it is TdS and most of the devices are also tried to make it adiabatic in some way. And if adiabatic is reversible, then it becomes isentropic. So, this expression should be used. And of course it is zero, so it is known that dh is equal to vdp. This means that the blue that we will rev, if there is a rev, we can use it as a VdP and basically use it as a dH. So, this is only H2-H1. So that means the W used in this is the final state enthalpy S2 and this is H1. This is the difference that comes out. Now, as for the thing, you have to take it out of the table. So, this is left. This is an easy task. If you look at the table, you will have to look at two tables. First, A5, which you have seen before, is taking steam. You have taken saturated vapor in it. H value. So, H is your state 1. In state 1, P1 is given to you, 100 kPa. And it is saturated. So, its corresponding H1 and S1 will be found. Which will be S of G and H of G. Which will be your gas phase. At 100 kPa. Now I am not writing the data because you can directly take it out of the table. Now you have to take out state 2. State 2 is nothing. Basically, the data you have already given is 1 MPa. And S1 is fixed. It means that S2 is S1. S2 is S1. Now the question is that you have to extract H2, you have to see the data of A6. There you have to see the A6 pressure of 1 MPa. And particularly you have to use S, because S is fixed. You have to use S to get the corresponding data. Because wherever S is in the middle, you have to use it to extract H. So, it is important to use this data to get H2. So H2 is the value that you get. In this case, H1 is 2675.0 kJ per kg. And H2 is 3194.5 kJ per kg. Now you have understood both these values, so use Wref to get the value of 519.5 kJ. So, the value of this is about 500 times more than this. That means you have to compress the compressed vapor and bring it to the same pressure. You have to work 500 times more in this case and the liquid comes to the pressure more easily. So, you should understand this problem solved by both of them that compressing the gas is more difficult. It takes more energy and work.

Now let's move forward with this discussion. And especially I will discuss on this that the steady flow device works the most or takes the least amount of work when the process is reversible. If the turbine is reversible, it will give maximum work. If the pump is reversible, it will take minimum energy work. How to prove this? To prove this, we will start by considering two devices. One is reversible and the other is actual. Let's move forward with this discussion. Especially, we will talk about the fact that Steady Flow Devices are the work output is reversible, or the least work input is process reversible. Both cases are for turbines like work producing device or for pumps which take work, consuming device. Now how to prove this? Let's consider two devices. One which has irreversibility. which is the actual device which you will usually get. Second, we will consider reversible which is considered as ideal. And for that we see that your actual which is are you getting reversible? So, what I have considered here is that the heat in is positive and the work out is positive. This is the convention we have done. Now in this, both the terms on the right-hand side of the equation are the same.

$$act(irr): \quad \delta q_{act} - \quad \delta w_{act} = dh + dk_e + dp_e$$

$$rev(irr): \quad \delta q_{rev} - \quad \delta w_{rev} = dh + dk_e + dp_e$$

$$\delta q_{act} - \quad \delta w_{act} = \quad \delta q_{rev} - \quad \delta w_{rev}$$

$$\delta w_{rev} - \quad \delta w_{act} = Tds - \quad \delta q_{act}$$

$$\frac{\delta w_{rev} - \quad \delta w_{act}}{T} = Tds - \quad \delta q_{act}$$

$$\frac{\delta w_{rev} - \quad \delta w_{act}}{T} \geq 0$$

So, that's why it comes like this. Whereas, it says that W reversible is always more. It means that it is for work producing. And as soon as you say that it is for consuming, it will reverse. Wref less than or equal to W actual In the case of work producing, you will have to do more actual work than reversible In the case of work consuming, you will have to do more work than reversible So W actual will be more in the case of reversible Like in the case of pump And in the case of turbine, which is work producing, the work that is reversible will be more than the actual work. In the reverse case to work it. producing device will be more compared to actual so actually the work produced will be less so you can understand this with a simple expression but what we have given in this is that we have used the convention that work out from the system is positive so work producing is derivation You can apply this in the same condition and show that it is the same expression user. Work producing devices such as turbine, deliver, more work and work consuming devices like pump, compressor require less work when it is operating reversibly. This is the description of this derivation. We will move forward in this discussion in the next lecture. In that we will raise the question that how we can minimize the work of this compressor. See you in the next video.