# Engineering Thermodynamics

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**Week-04**
**Lecture-23**
## Mass Energy Analysis and Control Volume

Welcome to the last lecture of Mass Energy Analysis and Control Volume, part 5. In this, we will talk about pipe and duct flow and after discharging or charging process, we will talk about unsteady state flow. Let's start. Pipe or duct flow is very common in the industry, in the engineering flow. It is usually used everywhere. Usually, any fluid that flows, for example, we have represented a hot fluid here, and the surrounding is at 20 degrees, and the heat is transferring from the hot fluid to the surrounding, which is at 20 degrees. The amount depends on the environment, as the environment changes, things will change. Accordingly, the loss, heat loss or heat transfer can be different so normally this is the flow but other than this there are other ducts in which additional work is involved like electrical work or shaft work there are instances where use can also be done so if we have to balance the mass of this then it is very straight we are showing only one fluid so the mass is The energy balance will be constant. But you can include the energy balance depending on how much work you are doing. Let's start with some examples. This is your electrical heating system. Just make a This is the air flow rate This is volumetric rate in this process, heat is transferred from the duct to the outside and electrical work is also done This is 15 kW electrical heating system The air is entering at 100 kPa at 17 degrees and the heat loss is 200 kPa. We have to calculate the temperature when it is exiting. So, it is a steady flow. Assume that there is a change in kinetic energy or potential energy is zero. And apply it simply in energy balance.

$$\dot{E_{in}} = \dot{E_{out}}$$

$$\dot{W_{e,in}} + \dot{m}h_1 = \dot{Q_{out}} + \dot{m}h_2$$

$$\dot{W_{e,in}} - \dot{Q_{out}} = \dot{m}c_p(T_2 - T_1)$$

So, this is done here So we know this information We know this We also know the temperature T1 So the first question is that we know Cp of air, So we have to find m. To get M dot, you have to get the volumetric flow rate M dot is simple Volumetric flow rate divided by specific volume So how will we get the specific volume? We know that the PV specific volume is like this What will be the value of R? This is the specific volume This is your meter cube per kg 287 kPa meter cube by kg. You will get this table. E1 table. So, from here you can get P1 V1 is equal to RT1. We know T1. We know P1 as well. So, this is your V1. V1 will be your 0.832-meter cube per kg. So, mass will come out. 3 kg per second Now if you plug in it here then it will come in your T2 you will enter in it you know all the information Win, Q dot out Cp you will get from the table and this information will come 1.005 kilo joules per kg degrees Celsius. T1 is 17 degrees. If you plug in this information, you will get T2 which is 21.9 degrees Celsius. There is a simple energy balance that you can do easily. It is already available on the table; we can use it directly from there. So, this is how we have completed the analysis of steady flow devices.

Now let's talk about unsteady flow. And this is common to us. This is also the most common thing. Like where your volume is changing. For example, here is a supply line and the flow is coming from here. When the valve is opened here, it will fill continuously. So, this is the unsteady process. until this changes the control volume, it becomes unsteady. The normal unsteady flow is called transient flow. We get this as discharge of fluid from the pressure vessel. If the vessel is under a lot of pressure and is discharging it, then we will call this process as unsteady flow. Or if your tire or balloon is inflating or deflating, then you call it unsteady flow or transient flow. Here is another example. and the control volume will also change as it is added so to maintain the pressure it will move so it can be fixed for example then it is different that your pressure will also increase so we can solve such problems with alarms and you have to put an assumption in it we will call that assumption as uniform flow process So we consider most unsteady flow process as uniform flow process. Assumption is that you can take any flow whether it is in inlet or exit. We will call it uniform unsteady. When it is exiting, the property there is not changing with time or position. the exit property will be same so take any cross section take inlet or outlet and in any position, it will not change so this is the result does the fluid property do not change with time or position cross section inlet as you say here If we take the cross section of the inlet, then this property will remain fixed with time. If the flow is happening, then the property of the flow will be fixed at this point or at this point. It will not change with the position. This is called uniform. If you are saying with the position, then uniform and steady, and if it does not change with time, then it is steady. Talking about the Inlet, the control volume inside will change, the system will change, no problem. Because now it has become unsteady. But if we take the cross-section of the Inlet or Outlet, take any point of the cross-section, at that point, take any point, at that point, like this, if we change its perspective view, then if it takes your cross-section, then take this, this You will change at any point, depending on the position. So, this is the Inlet. or outlet. In both, we will assume that this is uniform. Yeah, I have Australia. If you understand that if something is coming out of the tank, then when it is coming out, then its property can change with time in the outlet. But if we assume the uniform flow process, then we will assume that it is not changing. Like the temperature can change, if there is a fluid flowing in your tank. If you put a wall in the tank and release it, then the property can change. In practical terms, it will change. But we assume that it will not change. When we say uniform flow, it means it will not change. So, this was the meaning of the uniform flow process.

Now let's put an energy balance in it. In general, In the unsteady flow process, where the property of control volume is changing, in that, M in minus M out is equal to delta M system. Now delta M will not be zero, because the control volume is changing. Because the property inside it is changing.

Mass balance,

$$m_{in} - m_{out} = \Delta m_{system}$$

$$\Delta m_{system} = m_{final} - m_{initial}$$

$$m_i - m_e = (m_2 - m_1)_{cv}$$

i= in, e = exit, 1=initial state and 2= final state

Energy balance

$$E_{in} - E_{out} = \Delta E_{system}$$

$$\left(Q_{in} + W_{in} + \sum_{in} m\theta\right) - \left(Q_{out} + W_{out} + \sum_{out} m\theta\right) = (m_2 e_2 - m_1 e_1)_{system}$$

Assuming ke and pe changes of fluid stream and cv are negligible

$$Q - W = \sum_{out} mh + (m_2 u_2 - m_1 u_1)_{system}$$

Another thing to notice is that even if you are saying uniform flow, where we say that the property is not changing with time, it is not changing in any position, but you can also do external work on this. In this way, your equation will get additional work. Here, the W is the shaft work or W. Remember that flow work is always involved with the edge. Let's do an example. After this example, this topic will be closed. Because we have tried all kinds of problems and tried to understand. This is the process of charge. This is a specific example in which we have considered that your tank is an insulated 8-meter cube. which is 600 kPa at 400 K. And the valve is connected to the tank because it is pressurized. So, what is this? When we open the valve, it will come out. So, we are allowing it to escape until the pressure is 200. So, from 600 K we drop the pressure to 200 K. From 600 K to 200 K, we drop it and we will escape it by taking it out. The temperature is maintained at 400 K. That is why we have put an electrical heater. The question is how much the electrical heat should be to maintain this temperature and this process. Let's start. First of all, we can put a mass balance in it. And we will have to put an energy balance. Min minus mout is equal to delta m system how much amount is out to get that out, your m exit min minus minout M in is zero and delta is system M2-M1 which is equal to M1-M2 So this is your exit mask Now let's take out the energy balance Note that we have not set the rate because it is opening the closed system and discharging. So, what is E in? E in is Win. Is there any other energy inlet? There is nothing. What is in out? The mass of air that is going out in out. Now here the assumption of uniform flow becomes important. So here we will assume that the mass that is going out. The property of the mass is not changing. So, this is MeHe. Assume that the temperature is fixed. It is trying to give 400 K or electrical heat. The property is fixed. So, the total mass is multiplied by the exit enthalpy of the air. So, we are assuming that it is insulated, there is no additional. Now, to remove M1 and M2, we have to do that M1 was simple

P1V1 by RT1 and 41.81 cage is Temperature is fixed, volume is fixed, pressure is changed to 200 kPa So it comes out to be 13.94 kg So what is Me? The total amount is 27.8 kg So we have reduced both the values to 27.87 kg Now the second thing you have to take out is the property of this Because you have to find out U2 and U1 U2 is at 400 K and 200 KPa And U1 is at 600 KPa and 400 KPa But note that we always say that We have discussed earlier that Idle gas depends on internal energy and temperature Because the temperature is fixed So U2 and U1 are fixed So this is your ME M2-M1, U1-U2 M1 is fixed, so M2-U1-M1-U1 U1 is common, so M2-M1 is fixed So it is in minus. Minus Me. So, what is U1? Let's see on the table. On 400, what is U1? It is your U1. So, now we can insert this. Your U1 is 286.16 KJ per kg. We are assuming that H is a constant temperature, which is the same as 400 K. So, H is your temperature. 400 98 kilojoules So this is how you get your W in Me He-E1 which will give you 3200 kJ which is 0.889 kWh So this problem is solved There is only one assumption in this uniform flow that it is not valuating your temperature it is the same here If you see that the temperature is varying, like T1 and T2, suppose, because of some reason, your electrical heat is not there, and the temperature changes to T1 initial and then T2. So here we can also assume that the HE is the average of T1 and T2. You can also use this assumption. Maybe you don't have any other information. If you have exact information, then you can directly use it. There are not many changes, but you have to answer the questions according to the problem statement. You will find some examples in the books. We will give you the examples in the assignment. I hope you understood a lot about the analysis of mass and energy balance. So this is the summary of the lecture we started with conservation of mass After that we talked about steady flow and incompressible flow Then we defined flow work, how you use it in enthalpy And how you represent energy in the theta in the flowing fluid And how it is different which is stationary, which is a stop Then we analyzed the same energy analysis of steady flow We applied for many engineering devices Nozzle, diffuser, turbine, compressor, throttling valve, mixing chamber, heat exchanger, pipe and duct flow And finally in this lecture we discussed about unsteady state process I hope that this whole concept is in time and I will give you the assignments, you will get a lot of time. For now, let's stop here and start the topic in the next lecture. Till then, we take leave from you. See you in the next lecture.