Engineering Thermodynamics
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Week-04
Lecture-22
Mass Energy Analysis of Control volume

Welcome to our channel. We were discussing mass energy analysis of control volume and were trying to understand it through examples. This is the fourth part of this video. In this particular part, we will talk about throttling walls, mixer, heater and heat exchanger. Throttling wall is a device that basically prevents the flow of the fluid. and that's why you get significant pressure drop with this device Throttling valve can be of many types You can have adjustable valve as you can see here and as you can see here, this is adjustable valve It can be a porous plug or a capillary tube So this tube or plug or valve restricts the flow and thus gives you significant pressure drop. Although there is pressure drop in turbine too, but work is associated with it. In this case, there is no work associated with throttling or valve. Normally, the heat transfer is also negligible because it is very fast, and the surface area is very less. So, this is the difference between a turbine and a throttling valve. In a throttling valve, your work is not associated. There is a significant pressure drop. And in a turbine, there is a pressure drop, but it is associated with work. When there is a pressure drop, the temperature also drops. So, it is a common thing that whenever there is a pressure drop in your fluid, the temperature also drops. This is used in refrigeration and air conditioning applications. Maximum air conditioning and refrigeration is used to maintain the temperature. That is why large drops of temperature are preferred. That is why these walls are commonly used. If we balance the energy of the cube, we will find out the reason for the zero of the cubes. Because the cube is not a large surface area, and the process is very fast. So, we consider the cube to be zero. And there is no external work involved in it. Your flow work will be with you. So, there is no external work. That is why the W is also zero. And we assume that the delta P and delta Ke approximately zero. In such a case, since it is a steady flow device, your E in dot is equal to E dot out. And E in includes net mass, heat and work. Since it is a flow device, your heat and work are not associated in it. theta in will be equal to m dot theta out and in theta you will have H2 because mass is common and rest of the elements V2 by 2 plus GH is 0 so according to this equality only H2 will be equal to H1 because here also your V2 by 2 plus GH is 0 so only H2 will be left so this H1 is equal to H2 this This process leads to a balance of energy in the throttling wall. This process means that enthalpy is conserved or constant in the process. Enthalpy is internal energy plus flow energy. This is what we call flow work. If anything is changing, it is only internal energy and flow work. The only thing is that one form of energy is going to another form. So, the energy is exchanged between the two to keep it constant. For example, if we take the ideal gas, then if the temperature is T1 and H1, enthalpy, then because the ideal gas is there, then enthalpy is same and in the ideal gas, enthalpy depends only on the temperature, that's why the temperature will be the same. So, in the case of the ideal gas, there is a situation that the temperature is the same because the enthalpy is the same in the throttling valve. And in general, this situation You can use this because temperature is same, but PV expression can be changed internally. As we said that in throttling wall your U plus PV will be constant. It means H will be constant, but U can be changed internally. If u is less than pv term, then pv term will increase. If you add both the terms, then enthalpy will increase. Notice that the pressure will be less but if volume increases then pv term will increase. You can use basic intuition and common sense here. flow energy is constant but can be converted to other form one end to another end let's do an example this is refrigerant 134 we will use table for this, but it would be very easy if you have H constant and temperature constant and rest of the pv is equal to your ideal gas equation nRT or MRT you can use this which can easily extract the values. This is a special example.

In this example, this is a capillary tube. Initially, it was given that it is a saturated liquid that enters at 0.8 MPa. So, this is your H1 on Sat is at Saturation temperature and this is 0.8 MPa H1 is at HF at 0.8 MPa and this is at pressure 0.12 MPa And... We have to extract the quality from this. We have extracted the quality from here. and we have to get the temperature drop of delta T. Since this is a saturated liquid, we will get the value of T sat from the table. So, your T1 will be sat at 0.8 MPa. Let's check the table now. But before moving ahead, let's do a little analysis of this. First, we will assume that the total energy. Heat is 0 in inlet and outlet. Net Q is 0 and so is Q. W is also 0 in external work. Delta P and Delta K are also 0 and steady flow. In this case, H2 is equal to H1. This shows your energy balance. Now if you look at the table, this is your refrigeration table. and saturated refrigerant 134 in this case you have to see 0.8 MPa 800 kPa this is its T-set this is 31.31 degree Celsius and HF is 95.48, which we have already given here. So, there is no need to write it. And that is your constant. Now, what is that? The pressure has decreased. Now, what is that? 120 MPa. 120 MPa means... Sorry, 0.2. 0.12 MPa means 120 kPa. So, 120 kPa is this. This is its T-set. Okay? First, let's notice that the corresponding HF and HG are here Let's write this first, your T2 has arrived T sat at P2 This is your minus 22.32 degrees Celsius HF comes out of this table in this situation Hg is 236.0 kilo Joule per kg Now notice that H2 is fixed H2 is bigger than HF and less than Hg H2 is 95.48 2 phase system and in this case you have to find the quality of the system so you will find because we write H2 is HF plus X2 HFG so X2 is H2 minus HF by HFG so this comes out as 0.34 okay so this is the problem is solved second is temperature drop We have already calculated the temperature of the liquid in the T-Sat. So, this is 0.2. So, what is the delta T? Delta T is T2-T1 which is equal to minus 22.32 minus 31.31 degrees Celsius and this is minus 53.63 degrees Celsius. So, the temperature will drop this much. And notice that with this drop, 34% of the saturated liquid was here before. 34% of the video was vaporized So this is an example of capillary tube which is significant with pressure drop and temperature drop and also your liquid gets vaporized to a large extent. 34% in this case.

Let's move on to the other units, which are Float Device, Steady Float Device. The most common thing that you usually get at home is Mixing Shampoo. In this, two different fluids are mixed in different conditions with tea elbow. And the example is its shower, which we take. It depends on the flow rate you will use. You can keep it low or high. In this cold weather, you will naturally try to make the hot water flow more. The cold water will be colder. You can manage this. This is very useful. Both are mixed in the mixing chamber. This is the mixing chamber. This is specifically mixed. Now, what is in this? You can also do mass balance and energy balance in this. The simple thing in mass balance is that your sum of inlet is out over. You can put as many streams as you want. If there are two streams in this, then here is m dot plus m2 dot is equal to m3 dot. Isn't it? So, this is your m dot, Now In energy balance, since it is a steady flow, E in is equal to E out. In this case, as E in is there, so in E in, H1 is coming out with m dot. So, this is the contribution of this flow. The second contribution is in both the inlet and finally in the outlet, m dot 3 H3 dot. In this also, we assume that the Q is loss. W dot is 0, delta Ke Pe is 0. And unless you are told in some problems, we will assume in most of the problem statements that the control volume drawn is adiabatic. Now heat exchanger is another device which does not mix but heat transfers. For example, if you have 10 degrees and 60 degrees, then the temperature inside the fluid mixes with 60 degrees and 10 degrees. That is why the heat is transferred from one type of fluid to another type of fluid. And finally, the average temperature is obtained between these two. The second method is that the heat is not physically mixed, but it is transferred through the boundary. And that classic example is the heat exchanger. So, heat exchangers are commonly used in the industry of Hathra. And you notice that, as this is an example, if this is the control volume and this is the boundary, then the fluid comes from here and this is the other fluid, which flows from here. So, heat transfer is happening from here because it is at a higher temperature compared to this one at a lower temperature. This is high T, and this is low T. So, heat transfer is happening from high to low. Now, this control volume is If you change the set of energy balances, like in this case, the total control volume is now complete. But the heat transfer is happening inside. So, there is no heat transfer outside the control volume. That's why we say QCv is equal to zero. But if you take the control volume inside, like here, then naturally, heat is coming from outside the boundary. So here QCv is not zero. In this case, if you control volume, nothing is transferred from outside. Nothing is transferred. So, we have said that it is adiabatic from outside.

So, in the problem statement of E-Star, the choice of control volume is very important. We can always see the heat exchanger in a simplified way. And sometimes it can be understood by the use of concentric pipe. For example, you took a pipe. and there is another pipe in this, so this one fluid comes from here, goes in, and the other fluid comes out. So, this is A, and this is B. Or in this case, if you see, this is A and this is B. So, the exchange of heat is against this wall. So, this exchange of heat is through this wall, which is the boundary. And the outside, which we have considered, is that it is isoelectric, so there is no change in the Let's trying to understand it by using the example.

This is Refrigerant 134A which is a coolant condenser. Here it is shown that it is a condenser. It is basically like a heat exchanger. Refrigerant came from here. which is 6 kg per minute, 1 MPa and 70 degree and it is at 35 degree and the cooling water is at 300 kPa at 15 degree Celsius and it is at 25 degree it is saying that there is no pressure drop which means that we will consider it as 1 MPa and we have considered it as 3 kPa there is no pressure drop if there is no pressure drop, then on the basis of that, you tell me what is the mass flow rate of cooling water? This is the first question. Let's ask one question first and then we will come to the second question. So, we will assume that this is the steady flow. This is the steady flow. and if we take the control volume of this So MCv 0 is no change. Q dot is zero, W dot is zero, P is zero In this case, you can get a simple energy and mass balance First thing is that M stream is not mixing Note that this is a different stream of refrigerant Which is made of different pipe and water will be m dot water constant so if we call it as an inlet then this outlet will be same so we can apply

$$\dot{m_{in}} = \dot{m_{out}} = \dot{m_1} + \dot{m_2} = \dot{m_3}$$

$$\sum \dot{m}_{in} = \sum \dot{m}_{out}$$

$$\dot{E}_{in} = \dot{E}_{out}$$

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$$

You can rearrange this. because M1 and M2 are M.W so this is M.W H1 let's rearrange it, H2-H1 and this is M.R this is H4 M.W H2-H1 and this is H3-H4 ok So these will be your relations. S3-S4 Now what will you do to it? we will have to remove all these values if you want to calculate MW, you will have to remove these values let's try For this you need a table First thing is If you look carefully H2, H1 You will get this from the water table If we look at the water table, this is table A5. In table A5, we have to check the temperature. The temperature is 15 degrees, and this is 25 degree The question is how much is the saturation temperature at 300 kPa? 300 kPa is the temperature of this tea It is 133.52 This means that the water temperature of tea, whether it is 15 degree or 25 degree This is your tea set at 300 kilopascal is less, this means it is compressed liquid air this means we can approximate H1 HF at H1 what HF at 15 degree is and H2 we can do HF at 25 degrees. So, this is important. So, we will do this from A4 table. From here we got this information from the A4 table. So, if you go to A4 table, then this value will come out. 62.982 kilojoules per kg, which is the fluid. And this will come out. 104.83 kilojoules per kg. Now the question is how to do this with refrigerant temperature is 70 degrees Celsius and 1 mega pascal 1 mega pascal is 39.37 degree Celsius and this temperature is 70 degree Celsius The state is superheated. So, we can take it as it is. Here it is 70 degrees. This was 70 degrees. So, the enthalpy at 70 degrees will come out of you. So your enthalpy is at 70 degrees in superheated. So, this is your H3. 303.87 kJ per kg Now the second one is H4 which is at 35° Now at 35° At 35° your H is because it has gone down from T side so it is compressed So it has gone directly in compressed liquid hook It has gone down from T side so we can approximate it as hf at 35 degrees Celsius because it has gone down from T to T set the pressure is constant at 1 mega pascal so if you look at it at 35 degrees Celsius this is the 35 degree which will come here between 34 and 36 so here hf is in between this one and this is the linear you can do the interpolation and you will get 100.87 kJ per kg so in this way you will get H1, H2, H3, H4 values and after that you will plug in here so when you plug in here you will get MW this is 62.982-104.83 all these are in kJ per kg and this is 6 kg per minute 100.S3 303 S3 is 303 this will be minus of plus because S3 is 303 and S2 is 104 so this should be opposite and when you do this 303.87 So this is your MW, 29.1 kg per minute. So this was a simple problem solving session. This is part one of the questions.

The second question was, how much water will be transferred from the refrigerant to the heat transfer? For that, we will make a separate control volume. This control volume was initial, water was coming from here. So, let's say this is the water. So, this is the control panel. This is the part. And these are the connected parts. This is the water control So if we apply it, we will apply it on water You can apply it on refrigerant too But in this case we are applying it on water So we will balance the energy So E in dot E out, since we have a flow device In this case, the surface you can see This is your external surface It will look like this that this is your control volume. This is water, all this is water So this part which I am darkening, this is the boundary of the control. I am darkening this part and it is boundary No heat transactions are made from this part Of course there is inlet and outlet of water but heat is not transferred from here through this boundary so what we will do in inlet and outlet this is your inlet water so this is M3 which is M instead of 3 we write water directly M.W and this was 1 let's see what was this was 1 correct so this is your 1 plus the heat Q dot Win is equal to m dot h2. h2-h1 If we plug in here This is 29.1 kg per minute This is 104.83-62.982 kg per kg This is 1-2-1 8 kilo joules per minute. So, this is the answer. So, this way you can also do a simple energy balance. You can also simplify this. We can actually take this also. Like if we take this balance, we will take the tube directly. If we take only this tube as the control volume, then to do the energy balance, minus is E in is equal to E dot out but here what happens is that you have to take that mr dot h3 is equal to mr dot h4 plus which is qr dot which is coming out and qr out is your qw dot r so qr Out is your Mrh3-h4 and this Mrh3-h4 is the simple m.h2-h1 so this is your Mwh2-h1 and this is your simple qw in So this is the same expression, you might be thinking how to make control volume If you have a problem, you can draw the energy balance in the tube in which you have the refrigerant Make it like this So this is your control volume In such cases If the heat is too much, you will apply the energy balance in this So there is one option that you can do it on this or on water. So, make a control valve according to the water. If you want to do energy balance on the refrigerant, then make a control valve on the refrigerant. So, your equation will change according to the control valve, but the answer will come the same. So, I hope you understood how these different steady flow devices work. And the common examples we have read and tried to solve. I will see you in the next video.