Engineering Thermodynamics
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Week-03
Lecture-17
Energy Analysis of Closed System

Welcome to the last part of the energy analysis of closed systems. We will discuss incompressible substances and how to make changes in internal energy and enthalpy. So now we will try to solve an example.

Let's start. As we have discussed earlier, in the case of the ideal gas, you can write enthalpy as internal energy plus RT. In such cases, you know that h is equal to the function of temperature. This is also a function of temperature in the case of the ideal gas. Cp is only dependent on T P. This is the case with the ideal gas.

$$h = u + RT$$

$$dh = du + RdT$$

$$dh = C_p dT \text{ and } du = C_v dT$$

The difference between Cp and Cv is gas constant. We have already said that Cp is more than Cv. Because it requires more energy to expand the volume and keep the pressure constant. So, in the case of Ideal Gas, the general relation is U and PV. But we made PV in RT, then we differentiated it, and after that we have got this relation, and after that we have replaced the relation of dH and dU and put it back in that equation. So, you got this relation and from here you got this relation. So, you can use this relation in the ideal gas easily. But if it is real gas, then you can't use this relation. This unit is per unit mass, if we want to write it in molar, we have to write it as Cp bar, Cp bar plus RU. This R unit will be per unit mass. And this R unit will be per unit kilo mole. For example, air is 300 K, this is your Cp and this is your R. Pay attention to this. Kilo joules per kg Kelvin. And this is your Cp. and if we write the same in per mol, then Cv will be different in per mol because kilo mols are there and due to that, universal gas constant which is at kilo mol, 8.314 will come so this relation Cp is equal to Cv plus R is valid whether it is per unit mass or per unit mol okay, if it is in mol, then this will come like this and its unit value is 8.314 kilo joules per kilo mol Kelvin Another important thing in problem statement is the ratio of specific hit. Cp by Cv. This ratio K is equal to Cp by Cv. It varies with temperature very mildly. It means that it varies very less. We also take it as a constant for a long time. We take it as a constant, 1.667 There are many diatomic gases like O2, N2, etc. In such cases, we call it 1.4 At room temperature But as I said, since it varies from the temperature to the Cv So naturally, there will be some variation, but not so much And sometimes in the example, approximate We do it as a constant unless it is said that there are changes. Let's try to understand how to use this problem and the value of Cp and Cv.

Here, the question is to calculate enthalpy Change in enthalpy is 1 kg of oxygen which is hit at 300 to 1500 K and we have to assume it as an ideal gas As the temperature is too high as we discussed in the last lecture that we can do it in three ways Either we take a table or we take a CP value or we approximate it But since the temperature is too high, we cannot approximate it. So, we will do it in two forms. We will do delta H Cp dT. We will try this problem in one way. The second way we will use is The second way is to pick the value from the table i.e. S2 is at 1500 and H1 is at 300 K To find the CP, we have to look at the CP table which is per unit in moles Per unit is not in kg, so you can convert the mole into kg later.

$$C_p = a + bT^2 + cT^3 + dT^4$$

$$\Delta h = \int C_p dT \; = \; a + ({T_2}^2 - {T_1}^2) + (C/3)({T_2}^3 - {T_1}^3) + (d/4)({T_2}^4 - {T_1}^4)$$

Now you will get some values by taking out the values and later you will convert it into delta H which will be equal to kilo joules per kilo mole, and you will convert it into delta H kilo joules per kg and multiply it by 132 and you will get per kg .So if you put this value, then you get this value, about 1270.7769 kJ per kg. You will integrate it, so this value, rest of the values A, B, this A, B, we put it in this, and you write 1500 for T2 and you do 300 for T1 and you simplify it, calculate it, then this value comes out. So, this is the answer to 1. Similarly, you can see the table of A19 It has H bar and oxygen 300 is given as 8763 and 1500 is given as this So, you will take out delta H 8736 Now, if you do this with 1x32, you will get 1267.37 kJ per kg. So, this is the second way. In the first case, you got this and in the second case, you got this. Which is almost the same. So, you understand how much effort will be put into this integration. And if you use this table directly, you will get it easily. But you should have a table of every gas problem that you are interested in solving. So, this is one way. We have done this example. Let's move ahead. Let's try to solve one more example. This is your cylinder piston cylinder geometry. And you have an initial volume of 0.1-meter cube. So, I drew this cylinder. And it has nitrogen. Initially, This is the condition. The piston compresses the piston. Finally, the final pressure is released. So, you will get the final compression. In this process, we also give it heat, which is 20 kJ. and we also give heat in this process which we have to find out and the total work in this process is 20 kJ so, the question is how much total heat has been transferred in this process in which the final pressure is 1 MPa and the temperature is 440 K and the final geometry of the piston is this much so, this is a closed system mask is not changing, so e in minus e out is equal to delta e and if we ask for stationery, we can write delta u directly and this will be your q in minus work What is in E out? What is in E in? Q in plus work in Because work is also given but there is nothing in E out, in fact it becomes zero. This is your Net Energy Transfer. You can write it like this, or you can write it in sign convention. If you want to write a sign convention, you can write it like this. Q-W is equal to delta U. This is your Net Transfer. Write Q for Net Transfer. This is your Net Work done by the system on surrounding. Which is minus W. Minus 20 kg kilo joules. Since you are working on the system, it will come in minus. You can write it like this, or you can write it like this. So, what will happen in this case? Q in plus 20 kJ is equal to delta u Now the question is what is delta u? delta u is your we will directly take it out of the table which will be your u at 440 Kelvin minus u at 300 Kelvin Normally, the table that you have is like this. You will have UD; it will be in kilo moles. Or you can convert it to kilo joules. If you use such tables, you will get 440 or 300 Kelvin from the table. Now, the main thing is that it is available in specific energy. So, you have to take out its mass. And we can take out the mass of nitrogen. The initial pressure and temperature given by nitrogen. Since it is given in moles, we will directly take out moles. PV is equal to nRT. And here your pressure is given. Volume is given The volume is 0.1 m3 Pressure is 150 kPa Temperature is given and the gas constant is 1.314 From here you can easily extract the MOS you can also remove the mass will be removed easily finally, if you remove the mass initial mass will be 0.168 kg And now, finally, the value that comes out of this table because we have taken the oxygen table we will take the nitrogen table from the textbook and we will try to solve this. So, nitrogen table is your A18 and here you have the U it comes out 6229 kg per kilo mole This is at 300 Similarly, at 440, this comes out 8314 kilo joules per mole. So, from here you can easily get delta U Because you just have to multiply it with moles and you have to get moles from here. So you get Qe in which is 6229 minus 8314 kilojoules per kilo mole into number of moles So this will be your number of moles PV by RT is 1 volume initial 1 and PV by RT is 1 temperature 1 Multiply this and you will get PV by RT minus 20 kJ.