Thermodynamics
Professor Anand T N C
Department of Mechanical Engineering
Indian Institute of Technology, Madras
Lecture 72
Entropy Part 2

We will see how to find out entropy values of steam in a steam table.

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Figure 1.

We know how to find enthalpy, specific volume and internal energy of steam-water mixture and superheated steam using steam tables. However, we have not yet read values of entropy from the steam tables. Figure 1 shows a snippet of steam table. The last three columns list entropy of the saturated liquid (s_f), entropy difference between saturated liquid and saturated vapor (s_{fg}) and entropy of the saturated vapor (s_g). For example, at 0.1 MPa, the entropy value of the saturated liquid $s_f = 1.3028 \frac{kJ}{kg \cdot K}$, the entropy value of the saturated vapor $s_g = 7.3588 \frac{kJ}{kg \cdot K}$ and the difference between s_f and s_g, i.e., $s_{fg} = 6.056 \frac{kJ}{kg \cdot K}$. Students are encouraged to find values of entropy at different conditions for the sake of practice. Also, the entropy of a steam-water mixture can be found out in the same usual way as we did for the other properties. $s_{mixture} = s_f + x(s_f - s_g) = s_f + x s_{fg}$, where x is the quality of the steam-water mixture. All the properties are calculated with respect to some datum values which can be found in a steam table. Some steam tables consider triple point of water as the datum point. While finding out properties from the steam tables, students should use only one steam table as the datum points may be different for different tables. The values of the properties could be different at the same pressure and temperature in different tables.

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Figure 2.

We have come across processes for a system where some property remains constant during the process, e.g., isobaric process (p=constant), isochoric process (v=constant), isothermal process (T=constant), isenthalpic process (h=constant). For adiabatic process, heat transfer Q=0.

Let's look at an isentropic process for a system. In this process, s = constant or $\Delta s = 0$. We know that, for a reversible process, $dS_{rev} = \frac{\delta Q_{rev}}{T}$ or $ds_{rev} = \frac{\delta q_{rev}}{T}$. For the process to be isentropic, ds should be 0, which leads to $\delta q = 0$. Hence, the isentropic process is reversible and adiabatic.

Let's recap how different processes for a system look on a p-v diagram.

An isobaric process (a constant pressure process, p = c) is represented by a line parallel to the v axis. Similarly, an isochoric process (a constant volume process, v = c) is represented by a line parallel to the p axis. An adiabatic process for an ideal gas ($pv^\gamma = c$) is represented by a curve which is steeper than the curve representing an isothermal process for an ideal gas ($pv = c$) as shown in Fig. 2. If the adiabatic process is also reversible, then the same curve ($pv^\gamma = c$) represents isentropic process (s = c) for an ideal gas. For two-phase mixtures, isobars and isotherms are lines parallel to the v axis inside liquid-vapor dome. Hence, the nature of the curve representing a process on a p-v diagram depends on the nature of the substance.

Let's see how different processes look on a T-s diagram.

A line parallel to the s axis represents an isothermal process on a T-s diagram. Similarly, a line parallel to the T axis represents an isentropic process on T-s diagram. For two-phase mixtures, isobars and isotherms are lines parallel to the s axis inside a liquid-vapor dome. For an ideal gas, we have a relation, $Tds = dh - vdp$. For a constant pressure process, dp=0. Hence, $Tds = dh = C_p dT \rightarrow \frac{dT}{ds} = \frac{T}{C_p}$. Hence, the slope of a curve representing a constant pressure process on a T-s diagram is $\frac{T}{C_p}$. For a perfect gas, as C_p is constant, the slope increases with increase in temperature. A curve representing a constant pressure process for a perfect gas at low temperatures is less steeper than the curve representing a constant pressure process for a perfect gas at higher temperatures as the slope $\frac{dT}{ds} \propto T$.

For an ideal gas, we also have $Tds = du + pdv$. For a constant volume process, dv=0. Hence, $Tds = du = C_v dT \rightarrow \frac{dT}{ds} = \frac{T}{C_v}$. Hence, the slope of a curve representing a constant volume process on a T-s diagram is $\frac{T}{C_v}$. For a perfect gas, as C_v is constant, the slope increases with increase in temperature. A curve representing a constant volume process for a perfect gas at low temperatures less steeper than the curve representing a constant volume process for a perfect gas at higher temperatures as the slope $\frac{dT}{ds} \propto T$.

For an ideal gas (and perfect gas), $C_p > C_v \rightarrow \frac{T}{C_p} < \frac{T}{C_v}$. Hence, if a constant volume and a constant pressure process starts at the same point on a T-s diagram, the curve representing the constant volume process would be steeper compared to that representing the constant pressure process (see Fig. 2).