THERMODYNAMICS

ISENTROPIC EFFICIENCIES OF STEADY FLOW DEVICES

Irreversibilities accompany all actual processes and that their effect is always to downgrade the performance of devices. In engineering analysis, it would be desirable to quantify the degree of degradation of energy in these devices – turbines, compressors and nozzles. In order to do this we must identify and define an ideal process that will serve as a model for the actual processes.

An ideal device would be adiabatic and have no irrevesibilities i.e. an isentropic device. The parameter than expresses how efficiently an actual device approximates an idealized one is called **isentropic** or **adiabatic efficiency**.

The isentropic efficiencies of each device is discussed separately for each device.

Isentropic Efficiency of Turbines

$$\eta_T = \frac{Actual\ turbine\ work}{Isentropic\ turbine\ work} = \frac{w_a}{w_s}$$

$$\eta_T \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$$

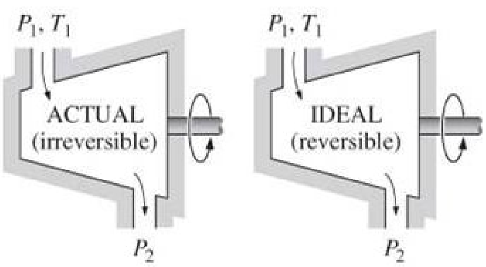

FIGURE 7–48

The isentropic process involves no irreversibilities and serves as the ideal process for adiabatic devices.

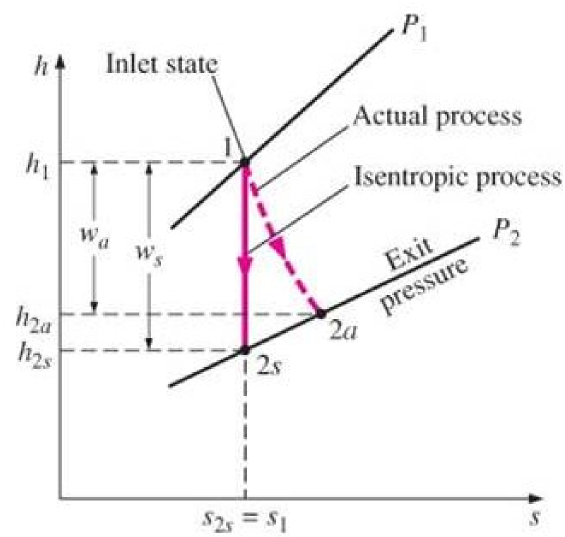

FIGURE 7–49

The *h-s* diagram for the actual and isentropic processes of an adiabatic turbine.

The isentropic work is the maximum possible work output that the adiabatic turbine can produce; therefore, the actual work is less than the isentropic work. Since efficiencies are defined to be less than 1, the turbine isentropic efficiency is defined as

$$\eta_T = \frac{Actual\ turbine\ work}{Isentropic\ turbine\ work} = \frac{w_a}{w_s}$$

$$\eta_T \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$$

Well-designed large turbines may have isentropic efficiencies above 90 percent. Small turbines may have isentropic efficiencies below 70 percent.

Compressor and Pump:

The isentropic work is the minimum possible work that the adiabatic compressor requires; therefore, the actual work is greater than the isentropic work. Since efficiencies are defined to be less than 1, the compressor isentropic efficiency is defined as

$$\eta_C = \frac{Isentropic\ compressor\ work}{Actual\ compressor\ work} = \frac{w_s}{w_a}$$

$$\eta_C \cong \frac{h_{2s} - h_1}{h_{2a} - h_1}$$

Well-designed compressors have isentropic efficiencies in the range from 75 to 85 percent.

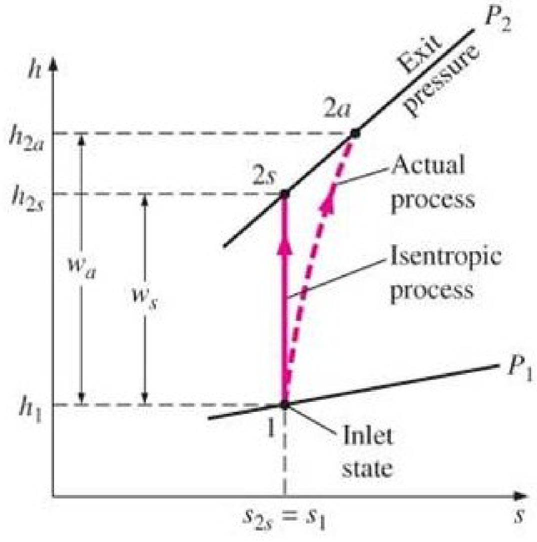

FIGURE 7–51

The *h-s* diagram of the actual and isentropic processes of an adiabatic compressor.

Nozzle:

The isentropic kinetic energy at the nozzle exit is the maximum possible kinetic energy at the nozzle exit; therefore, the actual kinetic energy at the nozzle exit is less than the isentropic value. Since efficiencies are defined to be less than 1, the nozzle isentropic efficiency is defined as

$$\eta N = \frac{Actual \quad KE \quad at \quad nozzle \quad exit}{Isentropic \quad KE \quad at \quad nozzle \quad exit} = \frac{V_{2a}^2}{V_{2s}^2}$$

For steady-flow, no work, neglecting potential energies, and neglecting the inlet kinetic energy, the conservation of energy for the nozzle is

$$h_1 = h_{2a} + \frac{V_{2a}^2}{2}$$

The nozzle efficiency is written as

$$\eta_N \cong \frac{h_1 - h_{2a}}{h_1 - h_{2s}}$$

Nozzle efficiencies are typically above 90 percent, and nozzle efficiencies above 95 percent are not uncommon.

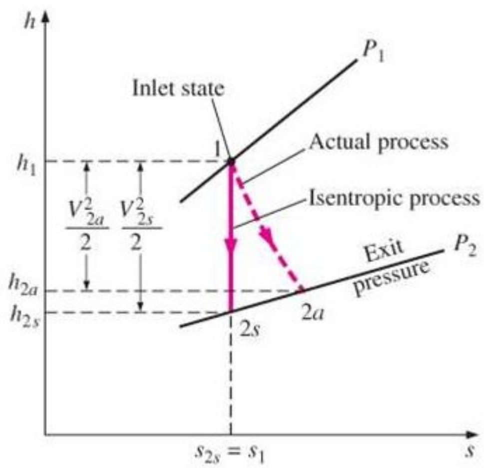

FIGURE 7–54

The *h-s* diagram of the actual and isentropic processes of an adiabatic nozzle.