1 Flow Work and Shaft Work

The net amount of work done by an open system on its surroundings may be written as:

$$W = W_s + W + fl \tag{1}$$

where W_s is the shaft work and W_{fl} is the flow work.

- Shaft work: Work done by the process fluid on a moving part within the system.
  - Ex. pump rotor
- Flow work: Work done by the fluid at the system outlet minus the work done on the fluid at the system inlet.

$$W_{fl} = P_{out}V_{out} - P_{in}V_{in} \tag{2}$$

2 Mechanical Energy Balances

- In many systems the change in potential and kinetic energy are negligible compared to the flow of heat and changes in enthalpy.
  - Ex. Distillation columns, heat exchangers, reactors, etc.
  - The energy balance for an open system becomes:

$$\Delta H = Q + W_s \tag{3}$$

- Another class of operations is when the changes in enthaply of the process fluid and the flow of heat is negligible compared to changes in kinetic and potential energy
  - These process usually involve the flow of liquids between process units.
  - We can rearrange the general energy balance equation for an open system to get the **mechanical energy balance** equation:

$$\frac{\Delta P}{\rho} + \frac{\Delta v^2}{2} + g\Delta h + \left(\Delta \hat{U} - \frac{\dot{Q}}{\dot{m}}\right) = \frac{W_s}{\dot{m}} \tag{4}$$

- Remember:

$$H = U + PV,\ \hat{V} = \frac{1}{\rho} \tag{5}$$

- The term $\left(\Delta\hat{U} - \frac{\dot{Q}}{\dot{m}}\right)$ is commonly refered to as $\hat{F}$ the **friction loss**.
- Equation 4 is valid for the steady state flow of an incompressible fluid (eg. a liquid).
- In the case where we have a frictionless process where no shaft work is performed, equation 4 simplifies to the **Bernoulli equation**:

$$\frac{\Delta P}{\rho} + \frac{\Delta v^2}{2} + g\Delta h = 0 \tag{6}$$