Thermal Energy Storage for Medium Temperature Industrial Process Heating

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Project content

• Heat storage materials
Melting temperature, latent heat capacity, thermal stability and chemical stability
LiNO$_3$–NaCl (87–13%): 193 °C, 248 kJ/kg
LiNO$_3$–NaNO$_3$ (57–43%): 194 °C, 265 kJ/kg
LiNO$_3$–NaNO$_3$ (49–51%): 208 °C, 360 kJ/kg
LiNO$_3$–KNO$_3$–NaNO$_3$ (20-52-28%): 130 °C, 150kJ/kg

• Charging and discharging parametric analyses
Thermal properties and operating parameters of HTF
Thermal properties of PCM
Heat transfer pipe diameter and arrangement

• Heat storage system
Heat storage tank

Tank: 0.2 m in width × 0.2 m in length × 0.5 m in height
Tube: ID 10 mm / OD 12 mm
Channel: a single, double or a quadruple-channel depending on the connection
Heat storage tank
Heat release analysis

Instantaneous heat storage effectiveness:

\[ \varepsilon = \frac{T_{in} - T_{out}}{T_{in} - T_m} = 1 - NTU \]

The average effectiveness for complete phase change process, \( \bar{\varepsilon} \), represents the overall heat release performance:

\[ \bar{\varepsilon} = \frac{1}{t_c} \int_0^{t_c} \varepsilon dt \]

where, \( t_c \) is the time for complete solidification. NTU is the number of heat transfer units

\[ NTU = \frac{(UA)_{eff}}{\dot{m} \times C_p f} = \frac{1}{\dot{m} f \times C_p f \times R_{eff}} \]

\[ R_{eff} = \frac{1}{h_f \pi d_i L} \left( \frac{\ln(d_0/d_i)}{2\pi L k_t} + \frac{\ln(d_i(t)/d_0)}{2\pi L k_{PCM}} \right) \]

d_0(t) is the assumed diameter of the solidified PCM

\[ d_0(t) = \sqrt{f_m (d_{max}^2 - d_o^2) + d_o^2} \]

\( f_m \) is solidification fraction and its rate of change is as a function of time:

\[ \frac{\partial f_m}{\partial t} = \frac{q}{MH} \]
1) The effect of the HTF inlet temperature on laminar flow is more obvious than on the turbulent flow.

2) In the case of turbulent flow, a temperature difference of 30 °C is enough by consideration of hugely reducing the time for complete solidification.
1) For either laminar flow or turbulent flow, a higher temperature difference results in a bit higher of the average heat transfer effectiveness.

2) For a given mass flow rate, the cases with turbulent flow pattern has much higher heat transfer effectiveness than those with laminar flow pattern.
Pressure drop can be caused by friction between the fluid and the tube wall, which can be determined by the Darcy-Weiskack equation:

\[ \Delta p = f \cdot \frac{L}{d} \cdot \frac{\rho v^2}{2} \]

Laminar flow: \( f = \frac{64}{Re} \)

Turbulent flow: \( \frac{1}{\sqrt{f}} \approx -1.8 \log \left[ \frac{6.9}{Re} + \left( \frac{\delta/d}{3.7} \right) \right]^{1.11} \)

The modified heat release effectiveness is determined as:

\[ \varepsilon^* = \varepsilon - \frac{\Delta p \cdot \dot{m}_f}{v \cdot Q} \]
The pressure drop is 1.5 atm for ID=8mm, half atm for ID=10mm, a quarter of atm for ID=12mm.
The more turbulent of the flow, the larger effective loss by the pressure drop.
Thank you. Questions?