Low Temperature Heat Recovery and Distribution Network Technologies

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Experiments — Long Cycle Mode

<table>
<thead>
<tr>
<th>Materials Used</th>
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<tbody>
<tr>
<td>(1) Silica Gel</td>
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<tr>
<td>(2) Silica Gel + 5% MgCl$_2$</td>
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<tr>
<td>(3) Silica Gel + 10% MgCl$_2$</td>
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<tr>
<td>(4) Silica Gel + 15% MgCl$_2$</td>
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</tbody>
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<td>(i) Before the first cycle, raw materials to be dried;</td>
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<td>(ii) 0-660min (11h), at 25°C and relative humidity;</td>
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<tr>
<td>(iii) 660-661 min, at 25°C with relative humidity 0%;</td>
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<tr>
<td>(iv) 661-756 min, from 25°C to 120°C with 1 °C/min heating rate;</td>
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<tr>
<td>(v) 756-816 min, at 120°C;</td>
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<tr>
<td>(vi) 816-835 min, from 120°C to 25°C with 5 °C/min cooling rate.</td>
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</tbody>
</table>

Fig 1. Long cycle experimental mode

- **Dimensionless water uptake rate** $\delta = \frac{m-m_0}{m_{\infty}-m_0}$
- **Water uptake capacity** $\chi = \frac{m_{\infty}-m_0}{m_0}$
- **Sorption characteristic time** $\tau$: $1 - \exp(-t/\tau) = \frac{m-m_0}{m_{\infty}-m_0}$
- **Initial sorption rate for the first 30min of hydration** $\sigma$:
  \[ \sigma = d \left( \frac{m-m_0}{m_{\infty}-m_0} \right)/dt \]

$m$: water uptake; $m_0$: initial water uptake; $m_{\infty}$: maximum water uptake; $t$: time.
Fig 2a. Mass change compare among materials during hydration in long cycle experimental mode. RH90%

Fig 2b. Dimensionless water uptake rate compare among materials during hydration in long cycle experimental mode. RH 90%

Fig 2c. Sorption characteristic time compare among materials during hydration in long cycle experimental mode. RH 90%

Fig 2d. Initial sorption rate compare among materials during hydration in long cycle experimental mode. RH 90%
Numerical Model

Energy conservation:

\[
\frac{\partial}{\partial t} \left[ (\eta_h + \eta_s + \eta_g)T \right] = K \nabla^2 T + D_m \chi \eta_h \exp(-E/T)
\]

\[
K = \eta_h + \frac{C_h k_s}{C_s k_h} \eta_s + \frac{C_h k_g}{C_g k_h} \eta_g
\]

Mass conservation:

\[
\frac{\partial \eta_h}{\partial t} + \frac{c_h}{c_s} \frac{\partial \eta_h}{\partial t} + \frac{c_h}{c_g} \frac{\partial \eta_h}{\partial t} = 0
\]

Decomposition of \( MgSO_4 \cdot 7H_2O \): \( \frac{\partial \eta_h}{\partial t} = -D_m \eta_h \exp(-E/T) \)

Production of \( MgSO_4 \): \( \frac{\partial \eta_s}{\partial t} = -\frac{M_s C_s \eta_{sh}}{M_h C_h} \frac{\partial \eta_{sh}}{\partial t} \)

(\( \eta_h \), \( \eta_s \) and \( \eta_g \) represents the concentration of hydrate salt, anhydrous salt and water vapour, respectively.)

Initial conditions:

\( T_0 = 0.9366, \eta_{h0} = 0.9, \eta_{s0} = 0, \eta_{g0} = 0 \)

Dimensionless \( T = \frac{T_{\text{real}}}{T_r} \) (\( T_r \) - dehydration temperature)
Results

Mesh grid:

\[ x = 0: dh: 1; nx = length(x); \]
\[ y = 0: dh: 1; ny = length(y); \]
\[ dt = 0.000001 \]
\[ dh = 0.005 \]

Fig 3a. Transient Evolution of temperature
Fig 3b. Transient Evolution of concentration
Fig 3c. Time required to initiate the reaction for different values of the heat flux.