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Review

Carbon capture by physical adsorption: Materials, experimental investigations and numerical modeling and simulations – A review

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HIGHLIGHTS

- A review on carbon capture by physical adsorption is provided.
- The review covers carbon capture materials, experimental and numerical research.
- Challenges for the post combustion adsorption materials are presented.
- Gaps are found in the research of carbon dioxide adsorption of post-combustion.
- Materials of high selectivity, CO_2 uptake with water vapor stability are needed.

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ABSTRACT

This review focuses on the separation of carbon dioxide from typical power plant exhaust gases using the adsorption process. This method is believed to be one of the economic and least interfering ways for post-combustion carbon capture as it can accomplish the objective with small energy penalty and very few modifications to power plants. The review is divided into three main sections. These are (1) the candidate materials that can be used to adsorb carbon dioxide, (2) the experimental investigations that have been carried out to study the process of separation using adsorption and (3) the numerical models developed to simulate this separation process and serve as a tool to optimize systems to be built for the purpose of CO_2 adsorption. The review pointed the challenges for the post combustion and the experiments utilizing the different adsorption materials. The review indicates that many gaps are found in the research of CO_2 adsorption of post-combustion processes. These gaps in experimental investigations need a lot of research work. In particular, new materials of high selectivity, uptake for carbon dioxide with stability for water vapor needs significant investigations. The major prerequisites for these potential new materials are good thermal stability, distinct selectivity and high adsorption capacity for CO_2 as well as sufficient mechanical strength to endure repeated cycling.

Contents

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Nomenclature

$C_{F,j}$	feed concentration of component j (mol m^3)
Cj	gas phase concentration of component j (mol m^3)
$C_{v,g}$	specific heat at constant volume for gas mixture (J kg^{-1} K^{-1})
$C_{p,g}$	specific heat at constant pressure for gas mixture (J kg^{-1} K^{-1})
C_s	specific heat capacity of solid adsorbent (J kg^{-1} K^{-1})
$C_{p,w}$	specific heat capacity of adsorption column wall (J kg^{-1} K^{-1})
D_{ax}	axial dispersion coefficient (m^2/s)
d_p	adsorbent particle diameter (m)
d_{int}	adsorption bed diameter (m)
ε	adsorption bed void fraction
$-\Delta H_j$	enthalpy of component j in gas mixture (kJ/mol)
h_f	film heat transfer coefficient between the gas and solid adsorbent (W m^{-2} K^{-1})
h_w	internal convective heat transfer coefficient between the gas and the column wall (W m^{-2} K^{-1})
$K_{L,j}$	overall mass transfer coefficient of component j (s^{-1})
$K_{o,j}$	adsorption constant of component j at infinite dilution (Pa^{-1})
l	column wall thickness (m)
n	polytropic index
P	total pressure of gas mixture (Pa)
P_j	partial pressure of component j in gas mixture (Pa)
Q_F	feed volumetric flow rate of gas mixture (m^3/s)
$\bar{q}_j$	average amount of adsorbed of component j (mol/kg)
q_j^*	the amount of component j adsorbed at equilibrium (mol/kg)
$q_{m,j}$	Toth model parameter for amount of component j adsorbed in activated carbon at equilibrium (mol/kg)
t	time of adsorption/desorption (s)
t_{st}	stoichiometric time (s)
T_s	temperature of solid adsorbent (K)
T_w	temperature of column wall (K)
T_g	gas mixture temperature (K)
U	superficial velocity of the gas mixture (m/s)
u	x-component of the superficial velocity of the gas mixture (m/s)
v	y-component of the superficial velocity of the gas mixture (m/s)
w	z-component of the superficial velocity of the gas mixture (m/s)
V	adsorption bed volume (m^3)
y_j	mole fraction of component j in gas mixture

Greek Letters

α_w	the ratio of the internal surface area to the volume of adsorption column wall density (m^{-1})
α_{wl}	the ratio of the algorithm mean surface area of the column shell to the volume of the column wall (m^{-1})
ε	adsorption bed void fraction
λ_L	thermal conductivity of gas of the gas mixture in axial direction (W m^{-1} K^{-1})
μ_g	dynamic viscosity of gas mixture (Pa s^{-1})
ρ_g	gas mixture density (kg/m^3)
ρ_p	adsorbent particle density (kg/m^3)
ρ_w	adsorption column wall density (kg/m^3)