

EXPERIMENTAL STUDYING ON GAS DEWATERING BY MOLECULAR SIEVE

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Abstract:

Gas dehydration is a common process in gas treatment plant, because water and hydrocarbons can form hydrates, which may block valves and pipelines. In addition, water is catalyst poison in some processes and must be removed before the reaction.

It is investigated effectiveness parameter of water adsorption on molecular sieve to find optimum operating condition. The obtained experimental breakthrough curves were fitted to theoretical models in order to establish the main mechanisms of mass transfer.

Keywords: *Molecular sieve, Gas dewatering, Equilibrium, Isotherm*

1. Introduction:

The presence of water in natural gas may create some problems in the gas transfer, because hydrates formation and water cause corrosion in the gas contains acid components. There are four popular methods for the dehydration of natural gas :

- Dehydration by absorption
- Dehydration by adsorption (solid desiccant)
- Dehydration by gas permeation
- Dehydration by gas refrigeration

Among these methods, dehydration by adsorption has more popularity in industrial units because of its better efficiency and the merit of continuity and the low cost of construction and maintenance.

Molecular sieves are regularly used for the drying and purification of feedstock for refinery applications such as isomerisation, alkylation and reforming, thereby improving operating performance and product quality.

These processes often use catalysts, sensitive to impurities in the feed, which need to be protected by a feed purification step molecular sieve beads. In addition, the removal of other impurities with molecular sieve can improve the quality of the final product.

Molecular sieves (also known as synthetic zeolite) adsorb moisture more strongly than either silica gel or clay.

Zeolite molecular sieves are crystalline, highly porous materials, which belong to the class of aluminosilicates. These crystals are characterised by a three-dimensional pore system, with pores of precisely defined diameter. The corresponding crystallographic structure is formed by tetrahedras of (AlO₄) and (SiO₄). These tetrahedras are the basic building blocks for various zeolite structures, such as zeolites A and X, the most common commercial adsorbents (figure.1).

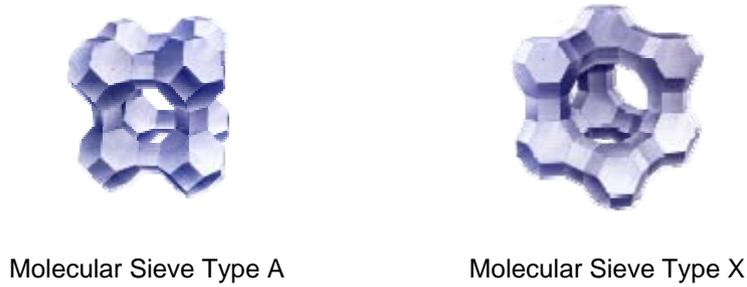


Fig (1): Zeolite structure

The water adsorption in zeolites is functions on the basis of physisorption. The main driving force for adsorption is the highly polar surface within the pores. This unique characteristic distinguishes zeolites from other commercially available adsorbents, enabling an extremely high adsorption capacity for water and other polar components even at very low concentrations (figure 2).

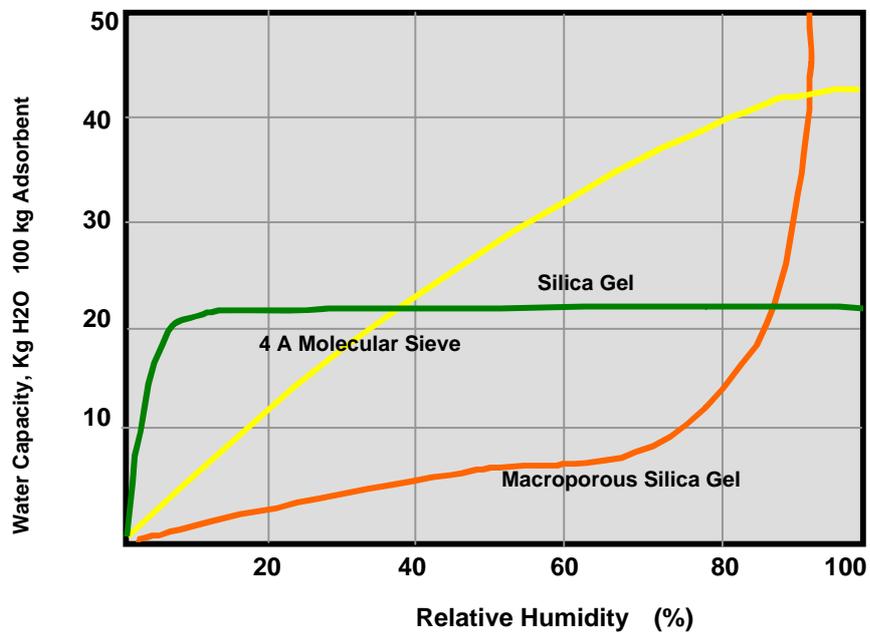


Fig (2): Water adsorption curve versus relative Humidity

In addition, the pore size plays a significant role, allowing or prohibiting the entrance of molecules to the pore system [1-6].

The flow pattern in a fixed bed can be represented by the axial dispersed plug-flow model, according to a mass balance for an element in the column, for the basic differential equation governing the dynamic behavior. The rate of mass transfer to the solid was described using a linear driving force expression. Overall mass balance:

$$\frac{\partial C}{\partial \theta} + \rho_{Ad} \frac{(1-\varepsilon)}{\varepsilon} \frac{\partial \bar{q}}{\partial \theta} = \frac{1}{Pe} \frac{\partial^2 C}{\partial X^2} - \frac{\partial C}{\partial X} \quad (1)$$

Rate of mass transfer to the solid:

$$\frac{\partial \bar{q}}{\partial \theta} = K_s \tau (q^* - \bar{q}) \quad (2)$$

Intraparticle mass transfer:

$$K_s = \frac{15\varepsilon_p D_{Eff}}{r_p^2}, \quad \frac{1}{D_{Eff}} = \frac{\tau_p}{D_m} + \frac{\tau_p}{D_K}, \quad \tau_p = 3 \quad (3)$$

Boundary and initial conditions:

$$\theta = 0: \bar{q} = 0; \quad C = 0$$

$$X = 0: -\frac{1}{Pe} \frac{\partial C}{\partial X} + C = C_{Feed}; \quad \bar{q} = 0 \quad (4)$$

$$X = 1: \frac{\partial C}{\partial X} = 0; \quad \frac{\partial \bar{q}}{\partial X} = 0$$

2. Experimental method

Figure 3 is shown experimental apparatus for the measurement of breakthrough curves. The adsorption system consists of two lines, one for circulation of the inert gas (He) as desorption gas and the other line for circulation of the adsorption gas, wet air. Each line has two flow meters to fit the flow, and the two lines of gas join and enter into the adsorption column with the Molecular sieve. The flow was also measured at the end of the column, using a flow meter of bubbles in order to check the value of the flow.

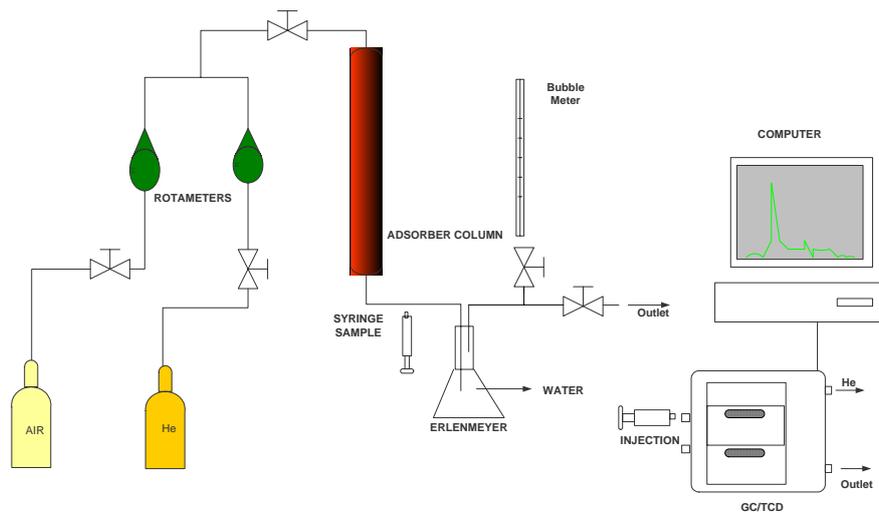


Fig (3): Experimental apparatus for the measurement of breakthrough curves

Wet gas was supplied to Adsorption column in different concentration. The physical properties of the Molecular sieve are shown in Table 1.

Table 1: Physical properties of molecular sieve

Properties	Content
Specify area (m ² / gr)	650 - 800
Pore Volume (cm ³ / gr)	0.27
Bulk density (kg / m ³)	656 - 672
Crush strength (kg)	2.2- 4.6

At certain times, a 1.0 mL sample of the eluted gas from the column was analyzed by gas chromatography. To avoid the effect of variation in pressure in the gas line during the sampling, an Erlenmeyer with water was placed at the end of the system. The samples of gases eluted from the fixed bed were analyzed in a CG-35 chromatograph using a thermal conductivity detector (TCD) and helium as the carrier gas.

3. Result and discussion

Figure (4) is illustrated the adsorption isotherm in different temperature. This curve shows the distribution of adsorbate between the adsorbed phase and the solution phase at equilibrium state. This can be seen the high initial slope of the adsorption isotherm in this condition. Molecular sieve contains a uniform network of crystalline pores and empty adsorption cavities, Because of its uniform structure; molecular sieve will not give up moisture into the package as temperatures rise.

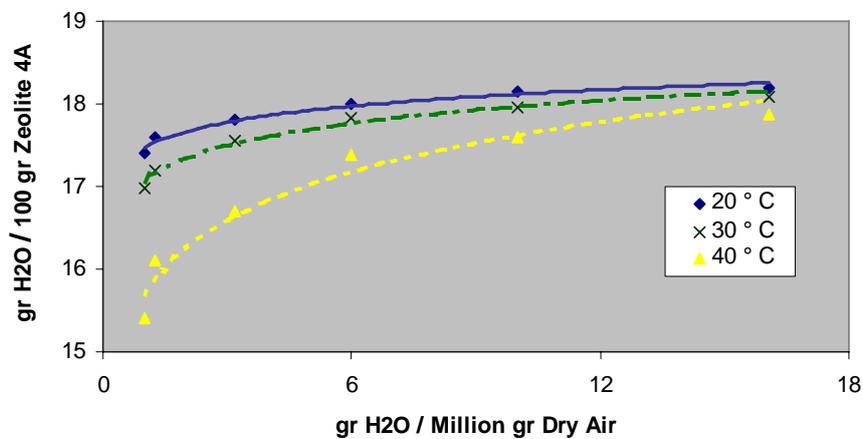


Fig (4): Comparison of adsorption isotherm in different **temperature**

Figure 5 shows the experimental results obtained from the adsorption bed with Zeolite 4A at ambient temperature (approximately 20 °C) for wet air.

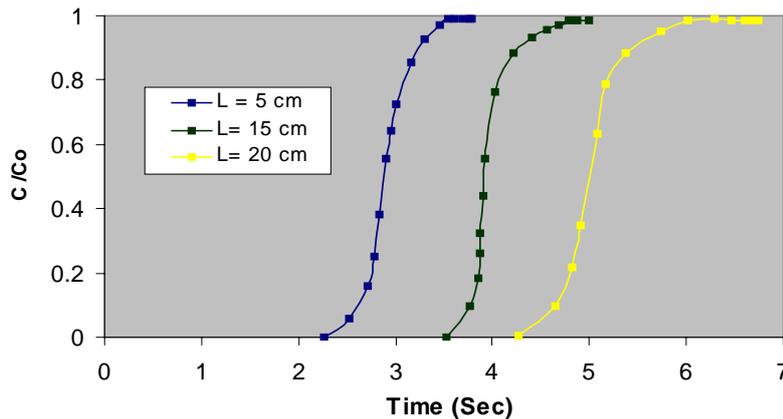


Fig (5): Breakthrough curve

It is observed that there is a short time of retention for H₂O due to the high adsorption capacity of these gases on the molecular sieve. Desorption is very slow, because when desorption with the same flow is attempted a considerable delay occurs.

In the figure 6 is presented the outlet temperature profile in the length of adsorption column (L = 5, 15, 20cm).

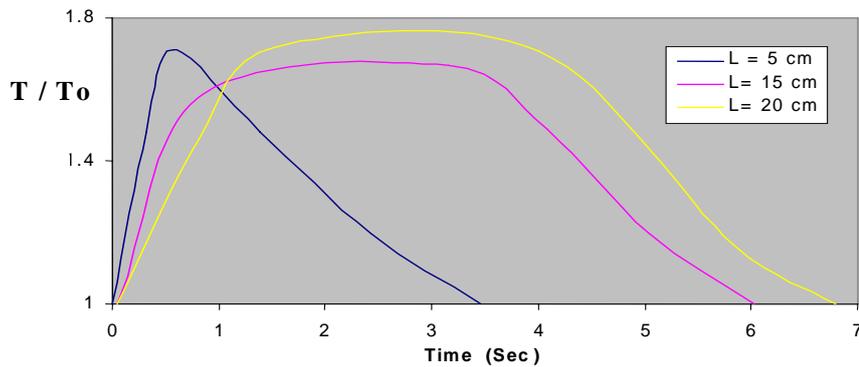


Fig (6): Comparison of adsorption isotherm in different temperature

From the results, it can be affirmed that the models predict the experimental data, confirming the validity of the proposed models.

4. Conclusions

The molecular sieves have a large adsorption capacity for gas dewatering and the molecular sieves adsorption ability is dependent on their physical molecular properties such as: size, shape and molecular polarity. They show the strong influence of intraparticle diffusion, which is specifically controlled by molecular diffusion.

The significant dispersion values are also proven by the Peclet number obtained for each breakthrough curve. Molecules with large polarity or polarisability can be adsorbed preferentially under identical conditions.

Nomenclature

D_m Molecular diffusivity, cm^2/S^{-1}	X Dimensionless axial coordinate in the bed (z/L)
D_K Knudsen diffusivity, respectively, cm^2/S^{-1}	Z Axial coordinate in the bed, m
D_{eff} Effective diffusivity, cm^2/S^{-1}	ϵ_p Pellet porosity
Pe Peclet number ($u \cdot L/D_{ax}$)	ρ_{Ad} Adsorbent density, kg/m^3
K_s Internal mass transfer coefficient, S^{-1}	ϵ Total bed porosity
q^* Adsorbed concentration at equilibrium, mol/g	τ_p Tortuosity
\bar{q} Adsorbed phase average concentration, mol/g	τ Spatial time (L/u), S
r_p Pellet radius, m	θ Dimensionless time

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