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Shell-Core Structure in Commercial Pellets Detected Using the Zero Length Column Technique

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The prediction of the performance of commercial adsorbents in separation processes requires the accurate measurement and interpretation of mass transport kinetics especially when one is trying to increase productivity by reducing cycle time. Here we report a very interesting case where mass transport in extruded pellets can be described by a single effective diffusion process (HISIV3000) and two effective diffusion processes in a shell-core structure (5A Zeolite).

The measurements are carried out using the Zero Length Column technique [1] that provides a mean for the characterization of commercial beads [2] and pellets [3] when one follows the recommended experimental protocol [4]. Two commercial extruded materials from UOP, a Honeywell company, are shown to behave significantly differently when normal paraffins are used as the probe molecules. Experiments with single HISIV3000 (silicalite) pellets show ZLC responses that are perfectly consistent with macropore diffusion control. 5A individual pellets of similar shape show a distinct "outer layer resistance" in addition to the internal diffusion process.

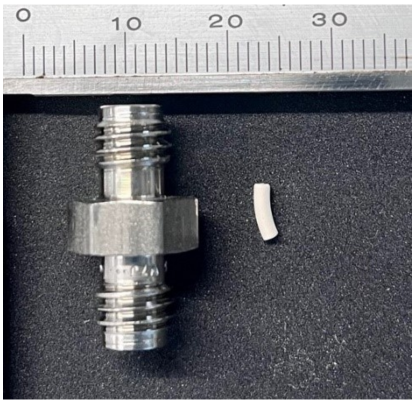

Figure 1: Zero Length Column and 5A commercial pellet used in the experiments.

The slower mass transport in the external shell is shown to be also a macropore diffusion process by performing tests with different carrier gases [4]. A core-shell model is developed to analyze the responses in greater detail and determine the thickness of the external skin by the simultaneous regression of multiple experiments (different flowrates, full and partial equilibration runs) in the whole pellet and in fragments.

The use of the ZLC provides a very efficient method to detect skin effects in commercial pellets, which is an important feature during quality control for manufacturers. It also provides the ability to determine the effect of the skin resistance, allowing to estimate physical parameters that can be used to describe more accurately mass transport in adsorption and catalytic processes.

References

[1] Eic M. and Ruthven D.M. *A new experimental technique for measurement of intracrystalline diffusivity*. Zeolites **8,** 40–45 (1988).

[2] Hu X., Mangano E., Friedrich D., Ahn H. & Brandani S. *Diffusion mechanism of CO2 in 13X zeolite beads.* Adsorption **20**, 121–135 (2014).

[3] Ruthven D. M. & Xu Z. *Diffusion of oxygen and nitrogen in 5A zeolite crystals and commercial 5A pellets*. Chem. Eng. Sci. **48**, 3307–3312 (1993).

[4] Brandani S. & Mangano E. *The Zero Length Column Technique to Measure Adsorption Equilibrium and Kinetics: Lessons Learnt from 30 Years of Experience*. Adsorption **27**, 319–351 (2021).