INTRAMICRON

Enhancing Swing Adsorption Processes Through Microfibrous Entrapment

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Pressure, temperature, and pressure-temperature swing adsorption (PSA, TSA, and PTSA) processes are commonly used to separate components by utilizing differences in their adsorption affinities for a sorbent as a function of pressure and/or temperature. For most swing adsorption processes, the adsorption cycle is conducted at room temperature and/or elevated pressure, while the desorption cycle occurs by lowering the pressure in the bed and/or passing elevated temperature gas through the bed. The performance of PSA, TSA, and PTSA units are a function of the sorbents' adsorption and desorption properties as well as the efficiency of the adsorption and desorption cycles. Since adsorption and desorption processes produce and require energy respectively, the cycling efficiency of swing adsorption units can be limited by thermal equilibration in the adsorbent bed. Since swing adsorption processes are conducted in a fixed bed configuration, the common limitations of packed beds including poor intra-particle mass transfer, because of large particles, and poor heat transfer, because of low thermal conductivity, are usually encountered. Microfibrous entrapment offers a method to reduce or eliminate heat and mass transfer limitations in swing-adsorption processes using a frozen-fluidized-bed configuration.

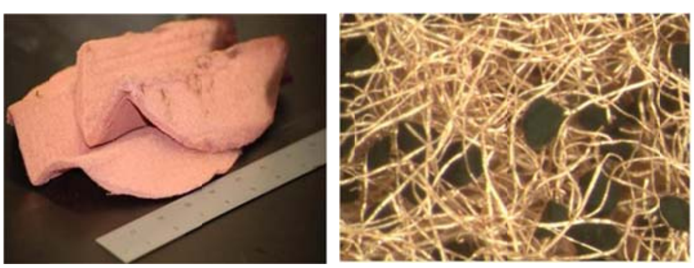

Figure 1. Left: Copper (12 µm) microfibrous media (MFM). Right: 60-80 mesh particles entrapped in Cu MFM.

The microfibrous media (MFM, Figure 1 Left), which fulfills the role of sorbent carrier, is prepared by a robust, scalable wet-lay process. This process results in a highly porous structure (~94%) that consists of randomly oriented microfibers that are micro-welded via sintering (Figure 1). The random orientation of the microfibers provides a uniform flow profile throughout the bed which minimizes channeling and assists with mixing. Furthermore, the highly porous nature of the media allows the microfibrous bed to have 1/3 the pressure drop of a packed bed of the same length containing only entrapped particles. Microfibrous Entrapped Sorbents (MFESs) are prepared using a proprietary method that locks small (40-300 µm) sorbent particles (0-35 vol.%) within the microfibrous media (Figure 1 Right, Table 1). While the microfibrous support structure can be formed from a variety of materials including metals, alloys, polymers, and glass, the best thermal characteristics are achieved when the microfibrous media is prepared from a highly conductive metal such as Ni or Cu.

Table 1. MFES and PB Composition Comparison

		MFES	PB
Fibers	Volume %	2 – 8	-
	Weight %	37 – 100	-
	Size (µm)	1.5-32	-
Particles	Volume %	0 – 35	60-70
	Weight %	0 – 63	100
	Size (µm)	40-300	1000-5000
Void	Volume %	62 – 98	30-40
	Weight %	0	0
	Size (µm)	-	-

An MFES made with Ni or Cu will have an effective radial thermal conductivity 20 to 50 times that of an alumina packed bed and an inside-the-wall heat transfer coefficient 10-times that of a packed bed (Table 2). The favorable flow characteristics in the microfibrous bed produce significant increases in the effective radial thermal conductivity with increasing face velocity (Figure 2) because the micron-sized fibers have much higher surface area for heat exchange with the fluid phase than the particles in a packed bed. These enhanced properties allow faster attainment of thermal equilibrium and decreased radial temperature gradients in an MFES compared to a packed bed.

Table 1. Radial thermal conductivity of microfibrous media (MFM) compared to an Al_2O_3 packed bed (PB)

	K (W/m-K)	K / K Al_2O_3 PB
Cu MFM	9.7	50
Ni MFM	3.8	20
Al_2O_3 PB	0.2	1

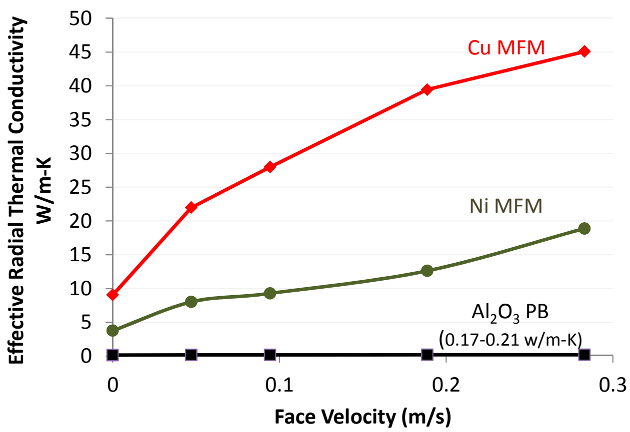

Figure 2. Effective radial thermal conductivity of Cu MFM, Ni MFM, and Al_2O_3 Packed Bed (PB) as a function of face velocity.

Since an MEFS utilizes much smaller particles than a traditional packed bed (Table 1), the sorbent particles in the MFES will have lower internal resistance to diffusion than the sorbent particles in the packed bed. The favorable flow regime produced by the randomly oriented microfibers coupled with the small particle size also significantly decreases external diffusion limitations. These improvements in mass transfer result in significantly increased contact efficiency with the sorbent so sharper breakthrough profiles can be achieved in a MFES (Figure 3). If a bed constructed of entirely of MFES does not have sufficient capacity for a given application, a composite bed composed of a packed bed upstream and an MFES downstream can be created. In this configuration the MFES serves as a polishing bed, utilizing the high contact efficiency achieved within the MFES to significantly increase the breakthrough time (Figure 3). The ratio packed bed length to MFES bed length can be tailored to maximize bed efficiency within an adsorption process.

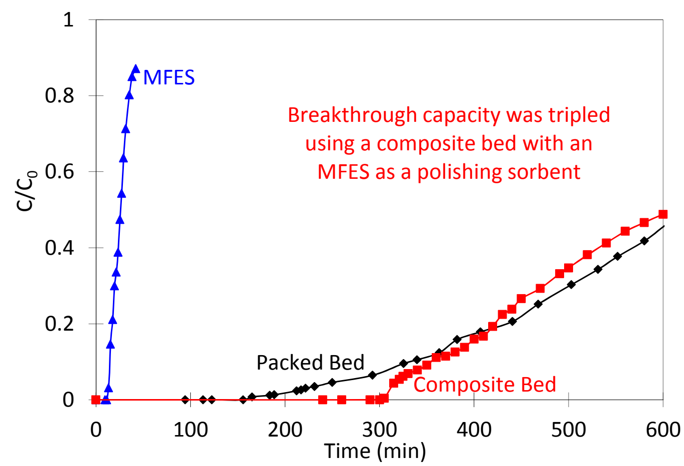

Figure 3. Breakthrough capacity improved using a packed bed and MFES composite bed

Although the adsorption capacity of the MFES will be lower than that of the packed bed because of its lower volumetric particle loading, there will be significant time savings achieved during the thermal equilibration process because of the increased heat transfer efficiency within the MFES. Furthermore, the increased contact efficiency of the MFES will allow the sorbent bed to be used more effectively than is currently possible in a packed bed. These properties will allow swing adsorption processes to occur with increased efficiency at much faster cycle times than currently possible.

In summary, microfibrous entrapment allows sorption processes to be conducted with improved contact efficiency and enhanced thermal management in a simple, scalable packed bed configuration. These benefits result in sharp breakthrough profiles and significantly decreased thermal equilibration times and temperature gradients compared to traditional packed beds. Incorporating MFESs into temperature, pressure, pressure-temperature swing adsorption processes will result in increased cycle efficiencies than currently possible in swing adsorption processes.