Characterization of porous media using network models for filtration applications

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A porous material may be represented by a rectangular network, in which the bonds represent the pores and the nodes the connections between the pores. Each pore may be represented by a straight cylindrical capillary of equal length, L, and individual diameter, d_p.

Porous materials have certain characteristics, which are of importance to the filtration of particles. These are the permeability for fluid flow, the filtration efficiency, and the change of these two parameters over time while particles are being deposited into the structure. Both characteristics are determined by the effective pore size distribution of the porous structure. It is the goal of this workshop to evaluate methods for pore size characterization and compare these to the filtration efficiency.

Porous materials may be characterized for their pore size distribution in many different ways. Examples include porometry, in which gas flow through a liquid filled structure at increasing pressure in compared to the gas flow through the dry structure. Another example is porosimetry, in which the volume of the connected pores is measured against increasing gas pressure. Porosimetry may be performed with a wetting or non-wetting fluid. In the latter case, the liquid volume penetrating the pore network is measured (which may be different from the expelled volume of a wetting liquid). Both techniques utilize the capillary pressure in the pores to determine the pore size at a corresponding gas pressure above the sample. Increasing pressure will evacuate smaller and smaller pores which will lead to higher flow or increasing volume, respectively, for these two techniques. Another technique utilizes capillary condensation to measure gas flow through a dry sample with subsequently filling pores. This technique is driven by the Kelvin effect, which increases capillary pressure with pore size for very small pores. All three methods utilize the tortuosity in the data analysis, which is difficult to determine experimentally without knowledge of the pore size distribution and is, thus, often an estimated value.

An interesting aspect of the porometry measurement is the detection of the first (or largest) pore, which can be difficult to detect due to the molecular diffusion of the gas through the liquid pores itself. The pressure, at which the first pore evacuates is called the bubble point of the material and is often used to characterize filtration material. The determination of this bubble point also depends somewhat on the measurement technique.

Questions of interest include:

For a given pore size distribution in a 2D (or 3D) network,

1. What is the observed pore size distribution using the various characterization techniques?
2. What is the corresponding permeability and tortuosity of the network?
3. What is the bubble point and what flow measurement sensitivity is needed for its measurement?
4. What is the filtration efficiency of the medium for a certain particle size?
5. How do permeability and filtration efficiency change over time with the deposition of particles?

Some References on network modeling

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