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3D-PRINTED MEDIA FOR PROCESS ENGINEERING

CONAN FEE
University of Canterbury,
New Zealand
Professor

ABSTRACT

The design of fluid-solid contacting devices has traditionally focused on the solid particle geometry, with the latter randomly packed into process vessels. Commonly, the preferred particle geometry has been spherical, for which there are well-known correlations for pressure drop, plate height, while non-spherical particles are often described in terms of equivalent spheres. However, the extra-particle channel geometry in randomly or even uniformly packed beds is far from ideal and this traditional focus on the solid phase leaves us in the position where we accept, rather than choose, the fluid flow paths. In other process engineering contexts, such as catalysis or heat exchange, traditional constraints on fabrication have resulted in designs centred around pellets, shells, tubes and plates. However, the rapid development of 3D printing now offers us the capability to fabricate highly intricate structures, allowing us to think in new ways about the design of unit operations, where both the solid- and fluid-phase geometries can be optimised. Computational fluid dynamics (CFD) simulations have shown that certain arrangements of 3D-printed non-spherical particles offer lower reduced plate heights than those of spherical particles, while simple changes in the orientation of ordered beds with respect to axial flow provide significant advantages in terms of separation impedance. Magnetic resonance imaging of flow inside TPMS structures at Re = 1.25 have validated CFD results for creeping flow, while at Re = 17.26, secondary flow features may explain enhanced heat and mass transfer rates. The question arises as to which is the most appropriate characteristic length to use when comparing performance. Use of the equivalent sphere diameter is convenient, but it is not easily defined for some non-spherical or monolithic structures and does not relate directly to the fluid flow paths that largely determine dispersion. Rather, it is the hydraulic diameter, i.e. the ratio of void volume to wetted surface area, that is the most appropriate universal characteristic dimension to use, a view that is consistent with various pioneers in porous media flow, dating back to the 1920's.

BIOGRAPHY

Professor Conan Fee was formerly Dean and Deputy Pro-Vice Chancellor of Engineering at the University of Canterbury (UC), where he is now the inaugural Head of the School of Product Design. He spent time as a postdoctoral fellow in biochemical engineering at the University of Waterloo and has been a visiting professor at Amersham Pharmacia Biotech, New Jersey; Uppsala University, Sweden; and Cambridge University, UK. At UC, he was founding Director of the Biomolecular Interaction Centre and created several degree programs, including the Bachelor of Product Design with a major in Chemical Formulation Design. Perhaps best known for his previous work on protein PEGylation, he is Science Leader of a 5-year NZ$10M research program "3D printing of Porous Media for Process Engineering". Professor Fee is a Chartered Engineer and is a Fellow of the Institution of Professional Engineers New Zealand (EngNZ) and the Institution of Chemical Engineers, UK (IChemE).