Enhanced heat transfer by cross flow-inducing catalyst structures

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Enhanced heat transfer by cross flow-inducing catalyst structures: additive manufacturing leads to process intensification

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The additive manufacturing, or 3D-printing, of catalyst materials allows for the structuring of catalytic packed bed internals with a degree of design freedom that cannot be achieved through conventional methods. Many of the present literature in this field considers so-called ‘logpile structures’ which consist of stacked cylindrical features. These structures are mostly isotropic and resemble honeycomb monoliths. Due to this similarity, it is to be questioned whether such structures exploit the opportunities of additive manufacturing to the fullest degree, and whether this enables reactor engineering benefits over conventional packed bed reactors. The latter is a requirement for application of this novel catalyst structuring technology, since in its current state, it is more expensive than conventional methods and the catalyst dilution due to significant quantities of binder need to be compensated for.
Hence, novel 3D-printed structures need to realize process intensification to provide quantitative benefits that demonstrate their viability. One process intensification strategy that is envisioned is to increase the wall-to-bed heat transfer rate. This can be done by either of two options: the use of a conductive structure or anisotropic structuring to enable a higher degree of transverse dispersion. The second option is deemed promising since the entire structure can be catalytically active, and this benefits kinetically-limited reactions.
The concept of anisotropic structuring can be envisioned as macroporous baffles within the structure which steer the fluid flow towards the wall in a cross flow-like regime. The intense contact with the wall should benefit wall-to-bed heat transfer rates. The penalty for this enhanced heat transfer is a higher pressure drop. By changing the properties of the structure, these phenomena can be balanced and flexible operating windows for chemical reactors can be obtained.

In this oral presentation, we discuss our experimental efforts which demonstrate the tunability of transport properties in isotropic logpile structures. These results show that by changing the geometry of the structure, the degree of transverse dispersion can be varied within a relatively limited range of values. To expand this range, several designs of anistropic logpile structures are proposed. The potential for intensified heating thanks to cross flow operation in these novel structures is evaluated using modelling in OpenFOAM. The effect of the design parameters of the structure on the thermal management and residence time distribution will be discussed, including considerations on the viability of implementation of these structures in reactive applications.

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