Intelligent Catalyst Carrier Concept with Reversible Wall Contact in Tubular Reactors for an Improved Wall Heat Transfer: Challenges and Opportunities

Dominik Rudolf[1], Alexander Fink[2], Paul Jollet[1], Carolin Körner[2], Hannsjörg Freund[1]

[1]TU Dortmund University, Institute of Reaction Engineering and Catalysis, 44227 Dortmund, Germany

[2]Friedrich-Alexander-University Erlangen-Nürnberg, Joint Institute of Advanced Materials and Processes, 90762 Fürth, Germany

Periodic open cellular structures (POCS) are additively manufactured, grid-like structures that are used as novel catalyst support structures. POCS are built up from a unit cell that is repeated in all three spatial directions. Metallic structures exhibit high thermal conductivity due to the continuous solid matrix [1]. However, previous work has identified material contact between the structure and the reactor tube wall as an essential factor for heat transfer [2]. In order to intensify the heat transfer, but also take into account the deactivation of heterogeneous catalysts and thus the necessity of an exchange of the POCS, the aim is to realize a reversible wall contact of POCS in tubular reactors. In this work, we propose to exploit an auxetic behavior of POCS as a promising option for this purpose. Auxetic structures exhibit a negative Poisson's number under mechanical load [3]. The principle involves designing an auxetic POCS with radial oversize, catalytic coating, compression and insertion of the POCS into the tubular reactor. If the structure is manufactured from a shape memory alloy, the POCS regains its original shape by a temperature increase, and thus a wall contact is established by an interference fit. In this regard, the high flexibility of additive manufacturing is utilized in the design and manufacturing of such POCS.

Heat transport characterization of auxetic POCS and proof of concept

At first, the effective thermal conductivity of auxetic POCS is characterized and described by an empirical heat conduction model. Underlying data were gained by means of numerical simulation using COMSOL Multiphysics®. Cubic as well as hexagonal reentrant structures are considered using the representative unit, respectively. Further studies on the radial effective thermal conductivity identify the amount of cells per tube diameter as a crucial factor in general. [paper in preparation]

Second, preliminary heat transport experiments using a double tube heat exchanger indicate that the concept ‘reversible wall contact of auxetic POCS made of shape memory alloy’ works effectively. Analysis is based on a 1D model.

Influences of auxetic behavior of POCS on the mechanical stability of catalytic coating

By means of a parameter screening, the influences of the auxetic behavior of POCS on the mechanical stability of a catalytic coating were investigated. Two geometry parameters of hexagonal reentrant POCS and two parameters of the used dip coating process are varied. The catalyst is an iron-molybdenum-oxide used for partial oxidation of methanol to formaldehyde. Figure 1 shows a coated auxetic POCS before and after compression. In total, this investigation is based on 16 coated POCS made of Ti-6Al-4V. The geometry parameters have a significant impact on the relative mass loss of catalyst.

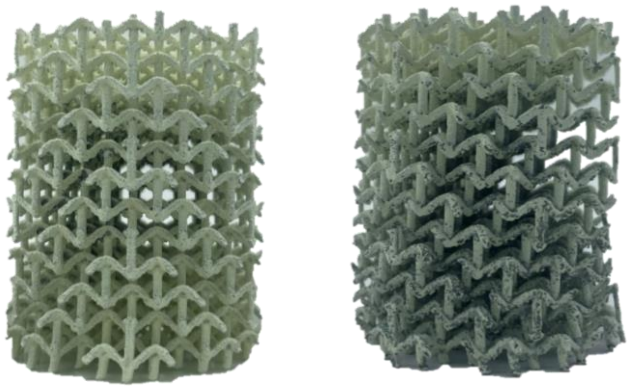

Figure 1: Hexagonal reentrant POCS coated with iron-molybdenum-oxide before (left) and after compression (right).

References

[1] Bianchi, E., Schwieger, W., & Freund, H. (2016). Assessment of Periodic Open Cellular Structures for Enhanced Heat Conduction in Catalytic Fixed Bed Reactors. *Advanced Engineering Materials*, *18*(4), 608-614.

[2] Busse, C., Freund, H., & Schwieger, W. (2018). Intensification of heat transfer in catalytic reactors by additively manufactured periodic open cellular structures (POCS). *Chemical Engineering and Processing-Process Intensification*, *124*, 199-214.

[3] Körner, C., & Liebold-Ribeiro, Y. (2014). A systematic approach to identify cellular auxetic materials. *Smart Materials and Structures*, *24*(2), 025013.