Structured micro-fibrous catalysts: mass-transfer intensification due to catalyst mechanical flexibility

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Highlights

- Micro-fibrous catalysts (MFC) use integrated multi-scale nano-to-macro structuring
- Various active components may be used with high efficiency
- Beneficial apparent reaction rate to pressure drop ratio observed
- Mass transfer intensification is directly connected with mechanical flexibility of MFC

1. Introduction

The use of the geometrical structuring approach opens the way for creation of new highly efficient types of catalysts with improved apparent activity, high mass transfer efficiency and low pressure drop. Such structuring is efficient when it involves all scale levels of the catalyst: from active component structure at the nanometer level and up to macro levels corresponding to the structured catalyst beds and catalytic reactors. The important challenge in this area is integration of all structures at different scale levels into multi-scale system with the best possible inter-level interaction.

Micro-fibrous supports may be used for creation of new catalysts with efficient integration of multi-scale structuring. The most widely known and studied systems of this class are the glass-fiber catalysts (GFCs), using the glass micro-fibers with a typical thickness of few micrometers as basic support, demonstrating advantageous performance in various catalytic reactions like deep oxidation of volatile organic compounds, selective oxidation of H_2S, oxidation of SO_2 and others [1-4].

2. Methods

The experimental study included the measurement of the apparent reaction rates in the GFC packing of different structure [5-7]. Test reaction of deep oxidation of toluene in air at Pt-containing GFC was used.

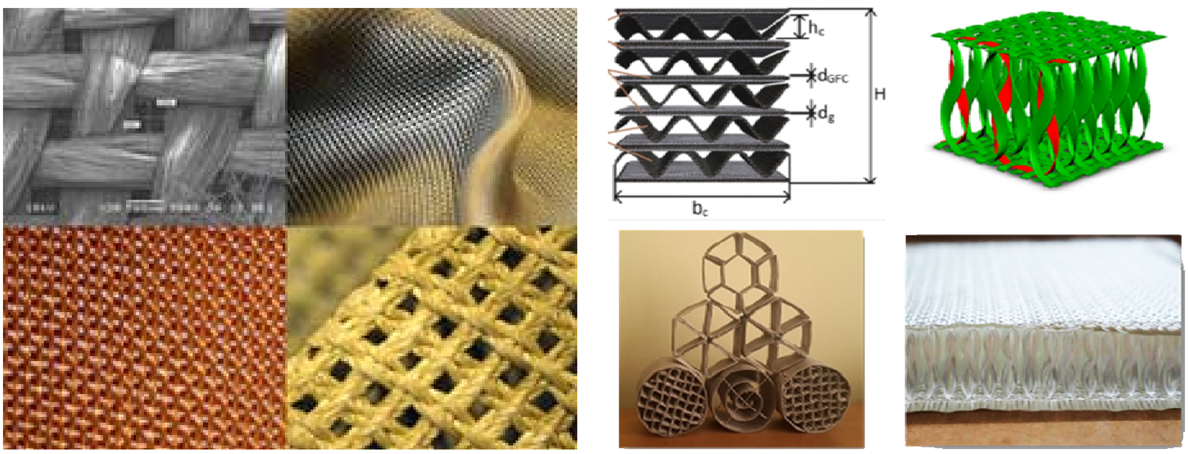

Figure 1. Different GFCs (left) and GFC packing structures (right).

3. Results and discussion

The toluene oxidation reaction appeared to be fast and, to the significant extent, limited by diffusion limitations – the apparent reaction rate visibly depended upon the gas fluid velocity and catalytic cartridge geometry. In general, in the combination of the practically important characteristics (mass transfer intensity, use of the potential of the active components, specific pressure drop) the structured GFC cartridges seem to be one of the most efficient catalyst shapes (or even the most efficient) among all known types of catalytic structures. The highest mass transfer efficiency was observed at lemniscate type GFCs [6,7].

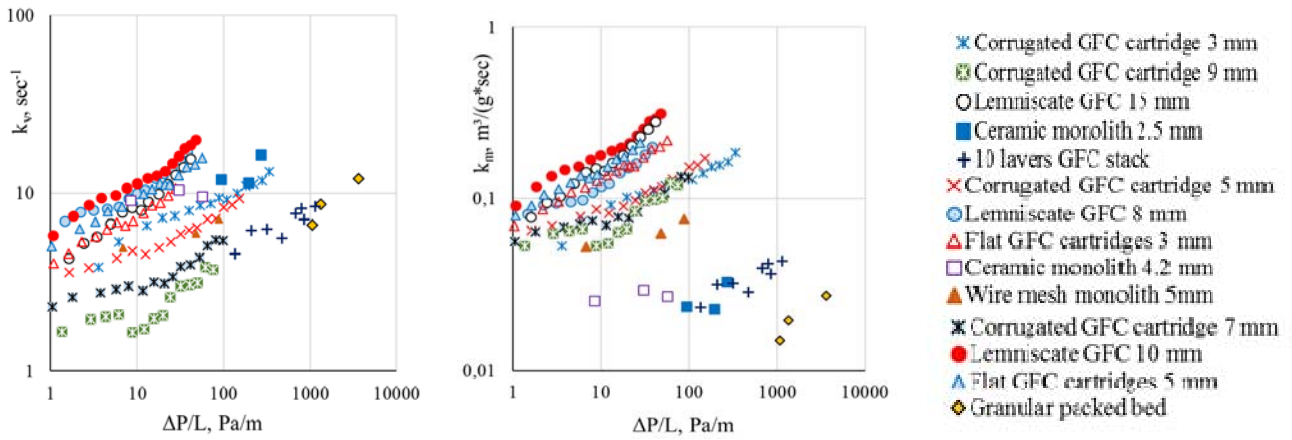

Figure 2. Volumetric (left) and mass-related (right) apparent reaction rate constants vs pressure drop for different types of GFC and conventional catalysts

Interesting that mass transfer in GFC cartridges is higher than that for wire mesh cartridges with similar geometry. It was shown that beneficial performance of GFCs is directly connected with their mechanical flexibility: under the in influence of moving reaction fluid the catalyst cloth may undergo mechanical fluctuations, resulting in the higher turbulization of the flow and, consequently, the better mass exchange. In case of lemniscate GFCs, such fluid/catalyst interaction may even lead to changing of catalyst shape, with increase of external mass transfer interface surface at higher gas velocities. Such phenomena are impossible for packed beds of any conventional solid catalysts.

4. Conclusions

In the overall performance, the catalysts on the base of micro-fibrous supports with purposeful multi-scale structuring at the different scale levels and efficient inter-level interaction seem to be of the most promising among all existing and prospective multi-scale catalyst structures. The additional gain in mass transfer efficiency is caused by their mechanical flexibility and improved interaction with reaction fluid, this being quite a novel effect in respect to structured catalyst beds.

The most promising application areas for such catalysts are the fast reaction in the gas and liquid phase, as well as reactions, where selectivity is sensible to diffusion limitations.

References

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Keywords
Micro-fibrous catalyst; structured catalyst; mass transfer; pressure drop