

Abstract

The aim of the research was to characterize the flow and transport phenomena of new generation short-channel structured carriers, the so-called streamlined structures. These are short-channel structures (short monoliths) with a modified cross-section of the walls, shaped like an airplane wing. According to the analysis presented in this work, such a geometry intensifies heat transport, thus indicating purposefulness of its use in catalytic reactors. This is the first work presenting the research on short-channel structures with streamlined walls.

The tests were carried out on carriers manufactured from 316 steel using the SLM (Selective Laser Melting) additive method. Three different channel cross-sectional shapes (square, triangular and hexagonal) with lengths of 3, 6 and 12 mm were prepared. Using computed tomography, the specific surface area and porosity of the structures were determined - these are parameters necessary to describe transport phenomena. It was confirmed that the geometry of the streamlined structures manufactured using the SLM method is highly consistent with the dimensions of the CAD model.

Experimental tests were carried out to determine pressure drop and heat transfer coefficients; on this basis, influence was determined of the channel length and cross-sectional shape on the Nusselt number and Fanning friction factor. The correlations describing the experimental results were derived. Since, so far, there is no work on short-channel catalytic carriers with a streamlined wall shape, the obtained experimental results were compared with the correlations for short-channel structures available in the literature. It was found that the the Fanning friction factors and Nusselt numbers for the tested structures are higher or close to the literature ones. Moreover, heat transport and flow resistance for streamlined structures are lower compared to a packed bed, and higher than for a monolith.

In order to better understand the transport and flow phenomena occurring in the tested structures, numerical simulations were carried out using CFD (Computational Fluid Dynamics). The analysis was performed for streamlined and short-channel geometries (with cuboidal walls) for the square channel cross-section. The obtained numerical results are presented in the forms of temperature contours of the flowing fluid, streamlines (lines tangent to the fluid velocity vectors \vec{w}), local Nusselt numbers and flow resistances. On these basis, it was found that the streamlined geometry reduces vortices and stagnation zones in the inlet part of the channels. These flow disturbances occur in short-channel structures

and reduce local Nusselt numbers in the inlet section. Outlet vortices are formed for both geometries, but for streamlined structures, they intensify heat transfer in the outlet channel section. It was confirmed that the streamlined structure is characterized by higher averaged values of Nusselt numbers and higher flow resistance in almost the entire tested range of Reynolds numbers compared to the short-channel structure.