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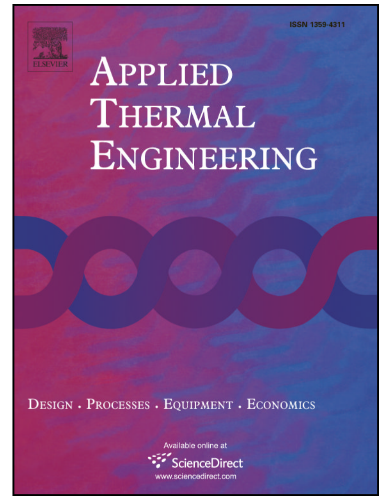

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Experimental and numerical investigation of heat transport and hydrodynamic properties of 3D-structured catalytic supports

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Abstract

In this work, heat transport and pressure drop properties of 3D-manufactured stainless steel structured catalytic supports are described based on experimental data and modelling. The effective thermal conductivity was determined at temperatures between 50 and 500°C by diffusivity measurements. For the samples with 74 % macroporosity, at temperatures from 50 to 500°C, axial and radial effective thermal conductivities range between 1.78 – 2.5 and 1.83 – 2.87 $W \cdot m^{-1} \cdot K^{-1}$, respectively. The effect of geometry (fibre stacking, fibre diameter and macro-porosity) on the effective thermal conductivity was experimentally determined and compared to the modelling results. The main parameter influencing the effective thermal conductivity was found to be the macroporosity. The effect of the geometry (fibre stacking) and the coating thickness on the pressure drop were studied experimentally. The pressure drop was measured by a manometer with air as a fluid gas. Pressure drop measurements showed that the samples with zig-zag fibre stacking (1-3 stacking) have higher pressure drop values than the samples with straight fibre stacking (1-1 stacking) at the same macroporosity due to their lower open frontal area.

Keywords: periodic open cellular structures, structured materials, effective thermal conductivity, pressure drop.

1. Introduction

Porous metallic materials offer a wide range of applications in industrial chemical processes [1], catalytic reactors [2] and automobile exhaust gas treatment [3]. So far, various metallic structures (monoliths, fibre felts etc.) and especially open-cell metallic foams have been investigated for the next generation mainly on thermal transport and heat transfer applications, but also as catalyst carriers such as in heat exchanger (HEX) reactors [2,4–6]. The optimal design of a metallic open cellular structure can offer multi-functional properties, such as high thermal conductivity, high porosity, large expanded surface area, strong flow-mixing capability and high mechanical strength [6].

Catalytic reactions are usually performed in packed-bed reactors with conventional catalytic materials due to economic reasons. In the packed-bed reactors, catalysts/catalytic materials (e.g. pellets) with large diameters (≥1mm) have poor thermal conductivities, that becomes more of an influence at large diameter of reactors. In case of exothermic reactions, the heat transport in the metal based structured catalysts was found to be 2-3 times better than in conventional packed-bed catalysts, that can significantly reduce the hot spot formation, ensure advanced temperature control even in the case of low Reynolds numbers [7]. Moreover, at high gas velocities, existing packed-bed systems can lead to a high pressure drop which is dependent on the particle size of the catalyst as well as its shape and packing [8]. Therefore,