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An experimental investigation of the Fischer-Tropsch synthesis over metallic structured supports packed with catalyst particles

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1. Introduction

In the last decades, several intensified structured reactors based on highly conductive inserts were proposed to manage the strong exothermicity of the low temperature Fischer-Tropsch synthesis ($\Delta H_R^0 \approx -165$ kJ/mol$_{CO}$) [1,2]. In our recent papers [3,4], we showed that heat transfer limitations can be overcome by adopting aluminium open-cell foams and periodic open cellular structures (POCS) as reactor internals. In this regard, our tests revealed that the packed-POCS reactor can reach extreme performances (CO Conversion≈ 80%) that could not be accessed even with the packed-foam reactor technology [4]. The strengths of the packed-POCS reactor configuration are the regular geometry of the POCS (R=d_{node}/d_{strut}≈1) which intensifies the internal heat conductivity, and the improved contact of the ordered structure with the reactor wall that governs the wall heat transfer coefficient [4].

In order to gain more insight in the role of the wall/structure contact on the heat transfer performances of a packed-POCS reactor, we have tested in the FTS a POCS with a 0.5 mm thick outer metallic skin.

2. Methods

The POCS was manufactured by 3D printing using AlSi7Mg0.6 alloy. The POCS with the skin was printed with the same cylindrical shape (O.D=2.78 cm and L=4.2 cm) and geometrical properties (d_{cell}=3 mm and ε_{POCS}=0.890) of the bare POCS reported in [4]. Two axial through holes of 3.2 mm diameter were located at the centerline and at half of the radius of the structure for the insertion of the two sliding J-type thermocouples.

Once the POCS was loaded in the tubular reactor, the system was packed like the bare POCS reported in [4] (catalyst load ≈ 7.2 g). The performances of the catalyst packed into the POCS with the skin were assessed at industrially relevant process conditions (180-240 °C, 25 bar, H_2/CO= 2 mol/mol, 6410 cm^3(STP)/h/g$_{cat}$).

3. Results and discussion

The packed-POCS with the skin reached outstanding performances (CO conversion ≈80%; volumetric heat duty (Q) ≈ 1833 kW/m3) with a remarkable temperature control.

Figure 1 compares the thermal behavior of the two packed-POCS reactors configurations (with and without the skin) by plotting the volumetric heat duty (Q) measured at different reaction temperatures against the internal radial ($T_{half\ radius}$-$T_{centerline}$) and the overall radial (T_{wall}-$T_{centerline}$) temperature differences, respectively. In this regard, the slope of the data in Figure 1a reflects the internal effective heat conductivity, whereas the slope of the data in Figure 1b is representative of an overall heat transfer coefficient including also the wall heat transfer resistance. Data for a packed foam are also included in Fig. 1 [3].

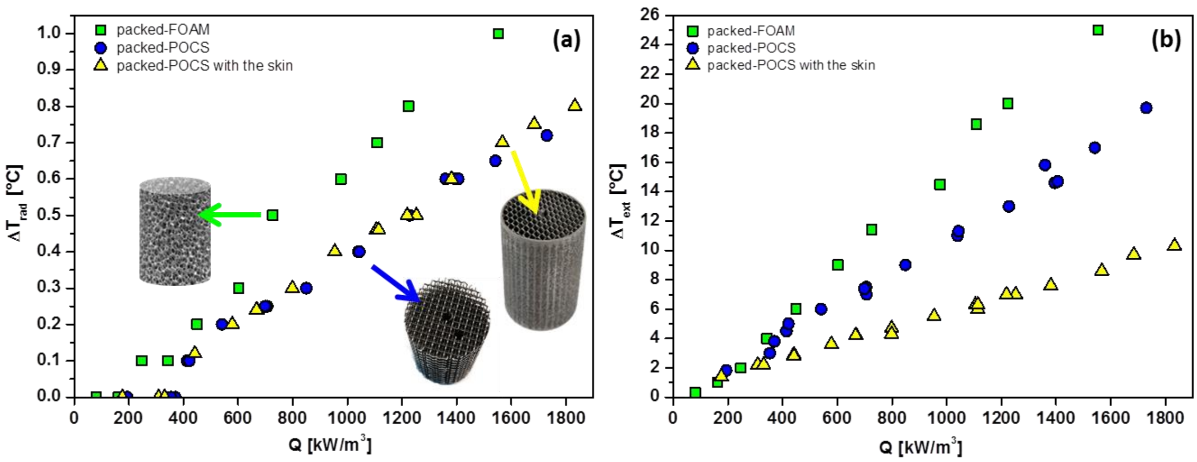

Figure 1. (a) radial and (b) external T-difference as a function of Q measured in the packed-foam (green square), packed-POCS (blue circle) and packed-POCS with the skin (yellow triangle) reactors.

The internal temperature differences measured over the two POCS configurations are very similar (Figure 1a), in line with the fact that the POCS with and without the skin have the same geometrical properties and R≈1. Strong differences are apparent instead in Figure 1b: the POCS with the skin strongly outperforms both the bare POCS and the foam. Indeed, the slope of the ΔT_{ext} vs Q plot of the POCS with the skin is about 2 and 3 times lower than the bare POCS and the foam, respectively. Such differences are reasonably explained by the maximized contact of the POCS with the reactor wall thanks to the presence of the skin. This also confirms that the internal conductive heat transfer resistance provides only a minor contribution to the overall heat transfer resistance in the reactor, which is dominated by the wall heat transfer resistance.

4. Conclusions

The intensification of the heat transfer performances of Fischer-Tropsch fixed-bed reactors is gaining considerable attention. This is due to the necessity of exploiting both associated and remote natural gas fields, as well as biomass, to produce liquid fuels, which requires scaling down the conventional packed-bed multitubular reactors to modular compact-units, for which heat management is critical.

In particular, we have shown for the first time that heat exchange in FTS fixed-bed reactors can be further enhanced thanks to the adoption of highly conductive internals based on periodic open cellular structures characterized by an outer metallic skin, which enables to maximize the reactor wall tube/structure contact.

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