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Pressure drop of structured cartridges with fiber–glass catalysts

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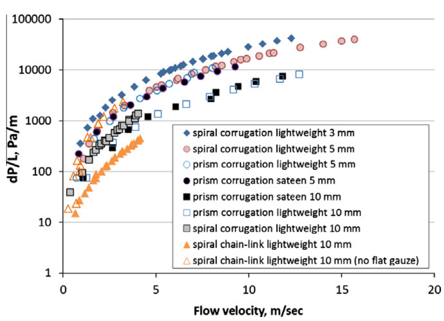
HIGHLIGHTS

- Pressure drop in gliding-flow cartridges with fiber–glass catalysts was studied.
- Cartridge internal geometry influences the pressure drop significantly.
- ΔP does not depend upon the cartridge external shape and catalyst fabric structure.
- Equation for calculation of the pressure drop for different cartridges was proposed.
- Partial hydraulic anisotropy of the cartridges was found and studied.

GRAPHICAL ABSTRACT



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ABSTRACT

The pressure drop in the structured cartridges with fiber–glass catalysts, providing the gliding flow of the reaction mixture along the catalyst fabric layers was studied. It was found that unit hydraulic resistance of such cartridges significantly depends upon the size of the flow passages and the geometry of the structuring gauzes, at the same, practically not depending upon the structure of the fabric and upon the external shape of the cartridge. The dependence of the pressure drop ΔP upon flow velocity v in all cases is close to the second order: $\Delta P = \zeta \rho v^2 L$, while pressure drop coefficient in the cartridges with corrugated gauze practically does not depend upon flow velocity and may be described by empiric equation $\zeta_{av} = 1744^* d^{-1.58}$ (m^{-1}) where d – equivalent flow passage size (m). The structured fiber–glass cartridges with structuring gauzes were found to be partially anisotropic, with commensurable pressure drops in case of flow moving along the passages and across passages, but along the catalyst fabric planes, while the pressure drop for the flow perpendicular to the catalyst fabric planes is much higher.

1. Introduction

Novel catalysts comprising noble metals (Pt and Pd), supported on fiber–glass woven support [1–3] has attained a lot of attention recently both from theoretical and applied points of view. The research investigations [3–9] showed that such catalysts demonstrate unique catalytic properties and may be used for performance of a wide range of catalytic reactions. Moreover, specific heat/mass transfer properties, original geometry, high flexibility and high mechanical strength of such catalysts give the way to develop really new catalytic processes and novel reactor designs [6–10].

Minimal structure elements of GFCs are the elementary glass fibers of 1–10 μm in diameter, serving as a support for an active component. These fibers may be structured in form of chaotic packing (glass wool or glass pads) or in form of threads (Fig. 1) which may be used for manufacturing of woven or webbed fabrics of various structures (Fig. 2).

Glass wools, pressed pads and other non-structured and chaotic fiber–glass packing may be interesting due to potentially high intensity of heat and mass transfer, but in practice their applicability may be limited by their low mechanical stability – the undesirable entrainment of fibers with the moving fluids may be inappropriately high both during manufacturing of catalysts and

Abbreviations: GFC, glass fiber catalyst; CFD, computational fluid dynamics.

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Nomenclature

d	average distance between GFC layers (m)	v	fluid velocity (m/s)
L	length of the flow passages in the cartridge (m)	ρ	fluid density (kg/m^3)
ΔP	pressure drop (Pa)	ζ	hydraulic resistance coefficient (m^{-1})
Re	Reynolds criteria (Re = $vd\rho/\mu$)		
μ	fluid dynamic viscosity (Pa s)		

their operation. Another possible drawback of the unstructured forms is substantial nonuniformity of the catalytic volume density which may lead to maldistribution of the reaction fluid in the reaction volume and, in turn, in decreased apparent catalytic performance. Therefore, the fibers structured in form of threads and textiles seem to be more attractive from the engineering point of view.

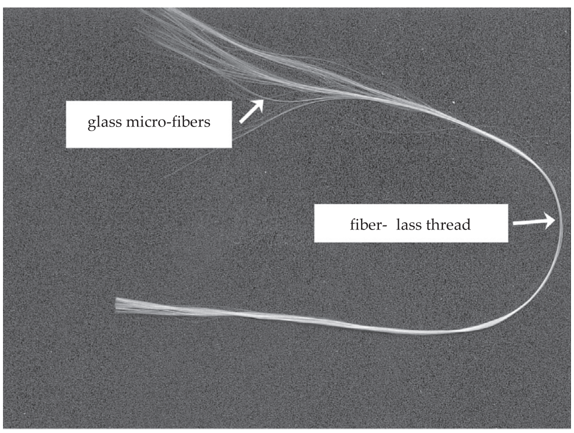

Fig. 1. Structure of the glass–fiber thread.

All methods of GFC layers arrangement may be divided into two main groups according to the orientation of the reaction mixture flow in respect to catalyst layer surface: systems with gliding (Fig. 3a) and propagating (Fig. 3b) flow.

In the gliding mode, the reaction flow glides along the catalyst threads in the longitudinal direction. External heat and mass transfer between flow and catalyst in this case have mostly convective nature, while internal transfer processes inside the catalyst threads are provided by the conductive mechanisms (heat conduction and diffusion).

GFC packing in form of a flat multi-layered packing or radial bed [11] are characterized with a high mass-transfer efficiency. At the same time, all packing designs, realizing the propagative flow through the catalyst cloth, have high filtrating ability in respect to solid and liquid particulates contained in the gaseous reaction fluid. In some cases (e.g., during combustion of gas exhausts containing combustible solid and liquid droplet admixtures) this property is definitely beneficial, while in some other cases (for example, at treatment of heavily dusty flows) it may lead to GFC clogging and thus become a serious disadvantage. Another possible drawback of the propagative-flow packing, especially in case of radial bed, is non-uniform distribution of the reaction flow across the catalyst surface.

These disadvantages may be resolved by application of GFC packing with gliding flow. To provide the gliding flow of the reac-

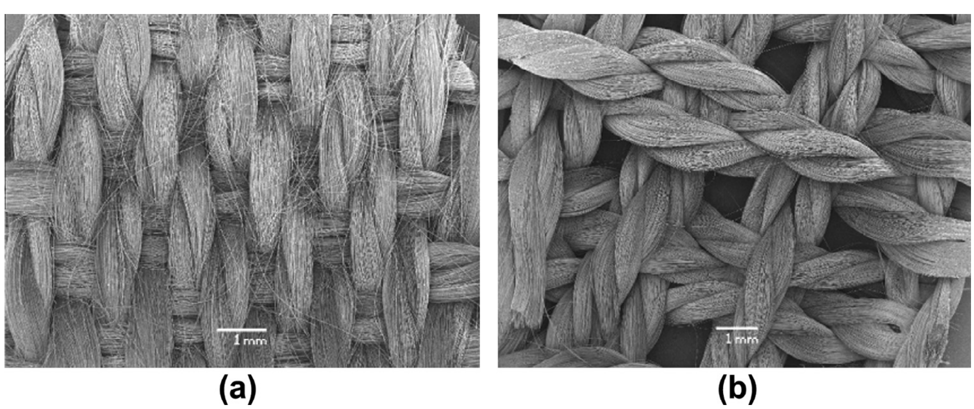

Fig. 2. Sample photo of fiber–glass fabrics: (a) sateen type and (b) "false openwork" (lightweight) type.

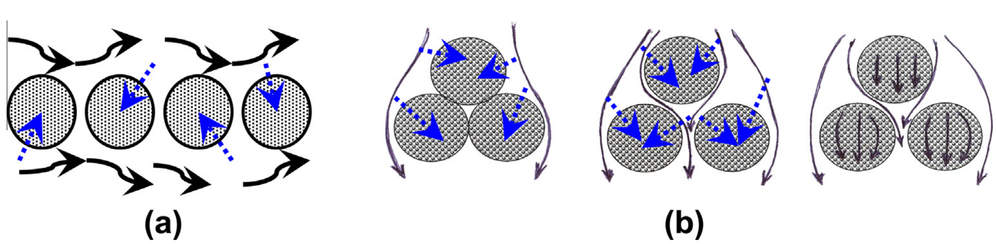

Fig. 3. The structure of the reaction mixture flow in the catalyst threads in gliding (a) and propagating (b) modes (cross-sections of threads are shown by shaded circles). Solid lines – convective flows and dotted lines – diffusion flows.