3D Foam-Printing for a novel approach to design of advanced structured packing for gas purification technology

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Column internals are critical elements of chemical plants, with packings playing a crucial role in the effective design of modern gas-liquid and liquid-liquid separation units. Recent advancements of 3D printing allows the precise design of plastic packings; when combined with foaming techniques, lighter and higher-surface-area packings can be developed. This work is part of a research activity aimed at designing and fabricating new 3D-foamed printed packings that can be easily tailored to meet specific requirements in mass transfer equipment. The 3D foam-printing method overcomes geometric complexities and constraints, offering flexible and customized prototype and surface design that balance mass transfer and pressure drops with material savings. The literature reports two packing designs, FT.X and FT.Y, were proposed and fabricated using PLA, and subsequently tested in a lab-scale absorption column with DN100 diameter. The FT.X, based on M250.X design, showed a significant improvement in SO_2 removal efficiency (up to 60%) compared with conventional structured packing. The improvement is attributed to the higher surface area of the new design, although it is accompanied by higher pressure drops, mostly due to the thicker corrugated sheets. In contrast, FT.Y design incorporated design optimizations such as multiple holes and finer sheet thickness, resulting in comparable pressure drops and enhanced mass transfer rates compared with M250.Y commercial version: up to +45% for the liquid-side coefficient and +10% for the gas-side coefficient. These advancements highlighted the potential of 3D foam-printing to enhance gas-liquid interfacial area and wettability, making it particularly attractive for gas purification technology. To further investigate the effects of surface micro-structures (textures and roughness given by foaming) on gas-liquid mass transfer, this work proposes an experimental activity using 3D-printed and foamed flat plates representing the repetitive unit of structured packing. 3D-printed PLA sheet samples with various textures (rectangular, triangular, pyramidal, wavy, and wavy triangular steps) and also replicated with CO_2-foamed filaments were tested in a lab-scale inclined falling-film absorber for SO_2 absorption tests in water. The results showed that foaming enhances mass transfer flux, with the triangular step texture outperforming other texturezed sheets by 20 – 40%. Additionally, some textures showed greater affinity to the foaming process, while others were effective due to the intrinsic design of the texture, highlighting the importance of fine-tuning texture design for industrial applications. Finally, recent progresses were also reported regarding the implementation of textures on new structured packing prototypes, which were tested in terms of mass transfer efficiency and hydrodynamics.

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