3D printed membranes for oil-water separation processes

Abstract

The oil-in-water separation process is an essential aspect of the crude oil and natural gas production sector due to the tremendous amount of produced water generated. The challenge of oil-in-water emulsion is that when an oil droplet's diameter is < 20 μm, traditional techniques, such as American petroleum institution (API) skimmers, are not efficient at breaking down this type of emulsion. Membrane separation technology provides an efficient method of breaking down the oil-in-water emulsions [1] using two techniques: rejection phase-based and coalescence-based. However, fouling propensity is a serious challenge facing the use of membrane separation technology in the crude oil production field. Further, most traditional fabrication methods are not able to fabricate a membrane with complex geometry, which would enhance the coalescence process. In this study the 3D printing technology was presented as a new technique to fabricate the 3D printed membranes. All the challenges that face the traditional fabrication method of the membranes, such as controlling productivity, membrane fouling and pore structure, have been tried to be controlled using the 3D printing technology. The 3D printing technology represents an advance approach over the current membrane fabrication methods owing to its ability to fabricate any complex geometry. However, the big challenge of this technology as a membrane fabrication method is nominal resolution. The resolution of the 3D printer used in this study was far away to print the pore size in the range of micro/ultrafiltration membranes. The characterisation results indicated that the nominal resolution of our 3D printer (i.e. 29 μm) was insufficiently precise to produce pores with geometric shape. However, hexagonal-based pore geometry was used to fabricate the 3D printed membranes and a symmetric membranes were printed with different heights.

For an antifouling membrane, a 3D wavy support structure was designed and fabricated. Further, a novel method was used to make a selective layer on the 3D structure, where a thin layer of the polyethersulfone membrane (PES) (16 ± 1 μm) was deposited on the 3D support structure using the vacuum filtration process. Compared with a flat membrane, the 3D wavy composite membrane displayed better performance. That is, after the first cycle it achieved a pure water permeance and permeance recovery ratio of 30 % and 52 % respectively.

This study further presents the fabrication process of a contactor membrane based on triply periodic minimal surfaces (TPMS). Two types of membrane contactor were fabricated: Schwarz-P-based and Gyroid-based. The contactors were used for the oil-in-water demulsification process and their performance compared with a cylindrical-based contactor. The Gyroid-based contactor showed a 5 % higher separation efficiency than the other contactors and a 22 % higher efficiency than natural demulsification. This directly related to high internal surface area and high tortuosity. The internal surface area of Gyroid-based contactor was $11.07 \times 10^{-3}\ m^2$, and for the Schwarz-P and Cylindrical-based contactors were $8.37 \times 10^{-3}\ m^2$ and $7.07 \times 10^{-3}\ m^2$ respectively. Additionally, the tortuosity of the Gyroid-based contactor was 1.5 compared to the 1 of both the Schwarz-P and the Cylindrical-based contactors.