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An experimental analysis of flow and mass transfer characteristics of cryogenic liquid nitrogen and oxygen countercurrent on the structured packing

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The structured packing is one of the core internals in the cryogenic distillation column. In the past, testing and development of packings were mostly based on ambient hydraulics and fluids, which may deviate considerably from actual cryogenic testing. Therefore, it is necessary to reveal the falling film flow characteristics of cryogenic fluid on the surface of structured packing and study the influence of microstructure of structured packing.

In this study, a cryogenic falling film visualization experimental system was designed and built. The visual images and flow parameters of liquid nitrogen（LN2）on the surface of corrugated packing were obtained. The actual cross-corrugation and inlet wetting coverage data were extracted, and compared with the results of hydraulic experiments at room temperature. At the same time, the influence of the micro-texture structure on the surface of the structured packing on the wave enhancement mechanism and mass transfer performance of the cryogenic fluid was studied, and the influence of mass transfer mode and pore size on the falling film flow characteristics of cryogenic working fluid in the hole was revealed.

The results show that within the same range of ReL numbers, the wetting rate of LN2 is approximately 2.68 times higher than that of water. Only when the ReL of water reaches a certain value(denoted as 2162.71) and develops into a fully wetted film flow on the packing surface, its wetting rate can achieve the same level as LN2. The liquid flow angle and inlet wetting coverage of LN2 are also higher than that of water. LN2 exhibits different interface fluctuations on the microtexture and flat surface, which can strengthen the interphase mass transfer. Based on a reference plate with a wavelength of 2.8 mm and an amplitude of 0.3 mm, the gas-phase mass transfer coefficient (GPTC) can be improved by 47.4% when the amplitude is increased to 0.4 mm, and the GPTC can be improved by 11.5% when the wavelength is decreased to 2.2 mm.The experimental results clarify the optimization direction of the micro-texture on the surface of the cryogenic distillation packing. Under cryogenic conditions, the existence of small holes can promote the passage of rising gas, so perforation may be a breakthrough to reduce the pressure drop of cryogenic distillation column, but the choice of pore size is also worth considering. Cryogenic distillation structured packing perforations should be less than 6mm in diameter. It can be concluded that the cryogenic liquid has good wettability. By adjusting the structured packing used in cryogenic distillation, such as using different micro-textured surfaces or changing the perforation diameter, the distillation performance of the packing can be further improved.

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