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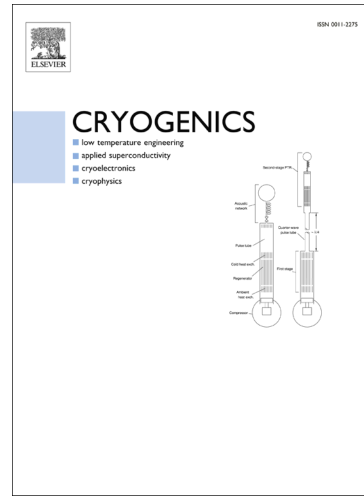

Research paper

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Free-surface flow of liquid oxygen under non-uniform magnetic field

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Abstract

The paramagnetic property of oxygen makes it possible to control the two-phase flow at cryogenic temperatures by non-uniform magnetic fields. The free-surface flow of vapor-liquid oxygen in a rectangular channel was numerically studied using the two-dimensional phase field method. The effects of magnetic flux density and inlet velocity on the interface deformation, flow pattern and pressure drop were systematically revealed. The liquid level near the high-magnetic channel center was lifted upward by the inhomogeneous magnetic field. The interface height difference increased almost linearly with the magnetic force. For all inlet velocities, pressure drop under 0.25 T was reduced by 7-9% due to the expanded local cross-sectional area, compared to that without magnetic field. This work demonstrates the effectiveness of employing non-uniform magnetic field to control the free-surface flow of liquid oxygen. This non-contact method may be used for promoting the interface renewal, reducing the flow resistance, and improving the flow uniformity in the cryogenic distillation column, which may provide a potential for enhancing the operating efficiency of cryogenic air separation.

Keywords

Free-surface flow; Magnetic field; Paramagnet; Liquid oxygen

1. Introduction

The magnetic flow control method, based on the weak magnetism of some fluids, has attracted the attention from many researchers because of its advantages of the non-contacting feature and low pressure drop [1]. The novel method has many practical applications, such as enhancing the convective heat transfer [2], controlling the flow motion of molten metals [3], treating the industrial wastewater [4] and improving the blood flow [5], etc.

Studies have explored the possibility of controlling the two-phase flow at the room temperatures by non-uniform magnetic field. Water is diamagnetic, so it has a relatively small and negative susceptibility. Lee et al. [6, 7] experimentally investigated the free-surface deformation of flowing water and NaCl aqueous solution within a superconducting magnetic field of 0-6 T. They demonstrated that the gas-liquid interface at the magnetic center began to cave downward asymmetrically. However, their experiment did not provide sufficient information to clarify the variation in the flow pattern and pressure drop, which are important for understanding the mechanism of magnetic two-phase flow control.

Cryogenic liquids have some unique physical properties compared with the room temperature ones. For example, the liquid-vapor density ratios, latent heats and surface tensions of liquid oxygen and nitrogen are much smaller than those of water. Moreover, liquid oxygen is paramagnetic, and has a positive and high susceptibility [8],

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