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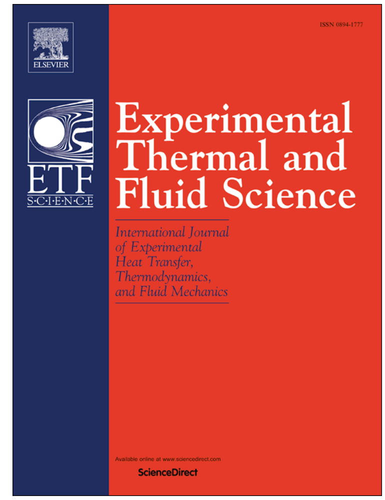

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ACCEPTED MANUSCRIPT

Sloshing effect on gas-liquid distribution performance at entrance of a plate-fin heat exchanger

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ABSTRACT

The maldistribuiton of gas-liquid mixtures has serious influences on the heat-transfer characteristics of plate-fin heat exchangers (PFHEs) and restricts the development of PFHEs in the floating liquefied natural gas (FLNG) field. To efficiently use PFHEs for FLNG, it is necessary to investigate the gas-liquid distribution at the entrance of PFHEs under sloshing conditions. In this study, an experimental gas-liquid distribution system was built, and the distribution characteristics of a PFHE distributor were investigated under sloshing conditions using air and water as mediums. The influence of sloshing form, sloshing amplitude, and sloshing period on the gas-liquid distribution is discussed with flow ratio m^*_k and standard deviation STD_k as the distribution index. The results showed that in the experimental condition the non-uniformity of two-phase mixture under sloshing conditions increase by 1.25% - 18.03% on the basis of steady condition with the increase of sloshing amplitudes and decrease with the increasing sloshing periods. The variation range of two-phase uniformity under mixed sloshing conditions is 14.8% - 27.9% on the basis of steady condition. These results provide constructive instructions for the design and safe operation of PFHEs in the FLNG field.

Keywords: liquefied natural gas; plate-fin heat exchanger; distribution performance; sloshing conditions

1. Introduction

As one of the clean-energy chemical fuels, natural gas is playing an increasingly important role in our lives. The growing demand for natural gas is causing more companies in many countries to transfer the exploitation of nature gas from land to sea [1]. The floating liquefied natural gas (FLNG) platform is applicable to the exploration of offshore natural gas [2]. The cryogenic heat exchanger is a key component in FLNG platforms as it controls the natural gas liquefaction process and determines the capacity of liquefied natural gas production [3–4]. Cryogenic heat exchangers are highly effective and have a compact structure and multi-stream arrangement. Plate-fin heat exchangers (PFHEs) are generally used because of the above advantages [5–8]; however, the performance of heat transfer and pressure drop in PFHEs can be easily influenced by the maldistribution of gas-liquid mixtures [9, 10].

Many investigations have explored the factors influencing the maldistribution of PFHEs. Initial non-uniformity research studied the effect of PFHE structures on the flow velocity of single-phase flows. Jiao et al. [12] and Zhang et al. [13] experimentally studied the influences of the configuration parameter h/H (h is the width of a single channel, and H is the width of the inlet port), inlet angle, and flow Reynolds numbers on flow distribution with water and air as mediums. It was found that these factors had significant effects on the distribution characteristics of PFHEs. In Zhang's study, the inlet conduct, the core, and the outlet conduct were studied as impact factors of flow distribution. The experimental and numerical results showed that channel pitch played an important role in the flow distribution of PFHEs; when the channel pitch was larger than 2 mm, the maldistribution was quite large [14]. Kim et al. [15] studied the relationship between flow distribution and different header shapes. Based on their study, a triangular header had the best flow distribution regardless of the Reynolds number compared to rectangular and trapezoidal headers. Based on the research of influence factors, some modified structures were suggested to improve the maldistribution performance. Jiao et al. and Zhang et al. studied the distribution performance of a new header with a second header. According to their investigations, the new header had better flow distribution performance than the conventional header [16–19]. Wen and Li numerically researched the flow distribution of a new PFHE inlet structure in which the header had embedded baffles with holes. The results showed that the header improved the flow distribution performance and was verified by particle image velocimetry experiments [20–21]. Ismail et al. investigated the uniformity of three different PFHEs with and without suitable baffle plates using numerical simulations. The results indicated that a baffle plate placed at the core inlet improved the flow distribution [22]. Tong et al. performed a quantitative systematic study based on numerical simulations to explore strategies that could attain better uniformity. They found the four most promising strategies for better

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