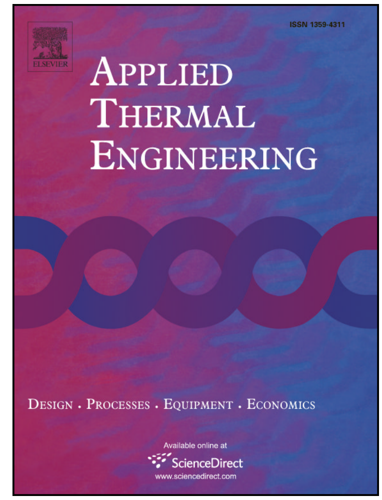
Accepted Manuscript



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PII: S1359-4311(18)31519-9
DOI: https://doi.org/10.1016/j.applthermaleng.2018.09.058
Reference: ATE 12667

To appear in: *Applied Thermal Engineering*

Received Date: 9 March 2018
Revised Date: 10 September 2018
Accepted Date: 12 September 2018

Please cite this article as: W. Sha, J. Ren, C. Wang, M. Bi, Y. Bo, Dynamic Characteristics of the Initial Interface in Stratified Multi-composition Liquid Tanks during Rollover, *Applied Thermal Engineering* (2018), doi: https://doi.org/10.1016/j.applthermaleng.2018.09.058

Dynamic Characteristics of the Initial Interface in Stratified Multi-composition Liquid Tanks during Rollover

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Abstract

Density stratification and rollover have been generally seen in multi-composition liquid tanks. In this study, numerical simulation was conducted to research the dynamic characteristics of the initial interface during rollover and the inducement of interface instability in stratified multi-composition liquid. The effect of the buoyant flow on the evaporation rate, as well as the evolving process of thermal stratification and solute transport during rollover was investigated. Through the quantitative analysis of local buoyancy ratio, it has been found that the reciprocating horizontal flow and the buoyant flow with high temperature was the mainly driving effect of the interface instability in the central region and near-wall region respectively. The evaporation rate in the local region near the wall was increased significantly when the energy was carried to the liquid level by the buoyant flow. Due to the conversion between the kinetic energy and gravitational potential energy, the local convective circulation near the wall and the uneven horizontal distribution of temperature will be formed.

Keywords: Density stratification, rollover, multi-composition liquid, double-diffusive convection

1 Introduction

Density stratification in liquid tanks refers to that the liquid with nonuniform density evolved into some liquid layers with different density under the gravity. In general, density stratification can be divided into the thermal stratification with the temperature difference alone and the narrow density stratification caused by the difference of temperature and concentration.

Thermal stratification can be usually observed in the tanks [1,2]. It will cause the rise of temperature at liquid level, which is going to evaporate more boil-off gas, and consequently it may be an adverse effect on the safety of liquid tanks [3,4]. With the improvement of CFD method, the numerical models were widely adopted to simulate this problem.

Khurana et al found that thermal stratification can be significantly weakened by ribs on the lateral wall [4]. Kumar et al developed a homogeneous two-phase model to evaluate the effect of the evaporation of liquid hydrogen on thermal stratification [5]. With the one-dimension lumped parameter model, Joseph et al found that the thinner adiabatic layer will lead to higher vapor pressure and stratified mass [6]. Ren et al have researched the flow characteristic and the temperature distribution at stratified stage and de-stratified stage in a liquid tank with lateral heating [2, 7]. Wang [8] and Liu [1] numerically studied the temperature distribution in gas and liquid phases and pressure response in tanks filled liquid hydrogen and oxygen respectively. The study by Liu et al indicated that thermal stratification in LH_2 tanks developed slower under microgravity than normal gravity, and some stream cycles in liquid layer were similar to the plumes [9, 10]. Liu et al. also have investigated the influence of the slosh baffles and the initial height on the thickness and temperature of the stratified liquid by a CFD model [11, 12]. Fu and Sunden reported that the flow circulation in