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P27

マランゴニ効果により駆動される高アスペクト比液柱内の時間依存対流

Time-dependent convection in high-aspect-ratio liquid bridge induced by thermocapillary effect

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So-called half-zone liquid bridge[1] has been employed as a physical model to investigate a transition of thermal-flow field from two-dimensional time-independent 'steady' state to three-dimensional time-dependent 'oscillatory' one especially for high Prandtl number fluids[2,3]. Whereas a variety of research have been hitherto conducted on such transition via numerical and theoretical approaches[4,5], little knowledge has been accumulated especially in the case of tall or high-aspect-ratio liquid bridges [6,7]. We focus on the effect of the heat transfer between the liquid bridge and the ambient gas [8,9] on the thermal-flow field in the half-zone liquid bridge of the aspect ratio (height/radius) $\Gamma = 3.0$ (**Fig. 1.**) via numerical approach.

A series of simulation are conducted by considering the non-dimensional Biot number Bi as a free parameter under zero-gravity condition. The condition of the thermal-flow transition is examined in terms of the critical Reynolds number Re_c for $0 \leq Bi \leq 3$ via the direct numerical simulation as well as the linear stability analysis. We indicate by the simulation that the thermal-flow field after the onset of the oscillatory state exhibits a traveling-wave-type one convection under a fully developed condition. The Biot number affects the scenario of the development of the oscillatory convection as a function of time. We will discuss the thermal-flow field by making comparisons with the results by the on-orbit experiments in the International Space Station[10].

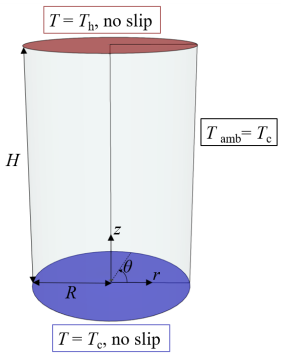

Figure 1. Half-zone liquid bridge.

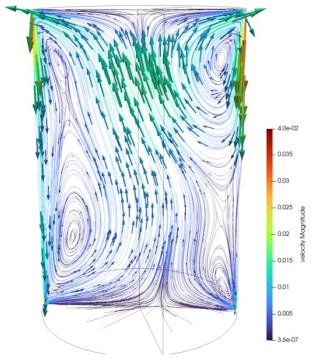

Figure 2. Streamlines with vectors of developing flow field of standing-wave-type convection in middle plane under Bi = 2.0 and Re = 1300.

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References

1) D. Schwabe, A. Scharmann, F. Preisser, R. Oeder: Experiments on surface tension driven flow in floating zone melting. J. Cryst. Growth, **43** (1978) 305, DOI: 10.1016/0022-0248(78)90387-1.
2) M. Wanschura, V. M. Shevtsova, H. C. Kuhlmann, and H. J. Rath: Convective instability mechanisms in thermocapillary liquid bridges, Phys. Fluids, **7** (1995) 912, DOI: 10.1063/1.868567.
3) D. Schwabe and A. Scharmann： Some evidence for the existence and magnitude of a critical marangoni number for the onset of oscillatory flow in crystal growth melts, J. Cryst. Growth, **46** (1979) 125, DOI: 10.1016/0022-0248(79)90119-2.
4) J. J. Xu and S. H. Davis: Convective thermocapillary instabilities in liquid bridges, Phys. Fluids, **27** (1984) 1102, DOI: 10.1063/1.864756.
5) I. I. Ryzhkov: Thermocapillary instabilities in liquid bridges revised, Phys. Fluids **23** (2011) 082103, DOI: 10.1063/1.3627150.
6) I. Ueno, H. Kawasaki, T. Watanabe, K. Motegi and T. Kaneko: Hydrothermal-wave instability and resultant flow patterns induced by thermocapillary effect in a half-zone liquid bridge of high aspect ratio, Proc. International Heat Transfer Conference **15** (2015), DOI: 10.1615/IHTC15.fcv.009489.
7) J. Fan and R. Liang: Numerical simulation of thermocapillary convection in a half-zone liquid bridge model with large aspect ratio under microgravity, Symmetry, **14** (2022) 452, DOI: 10.3390/sym14030452.
8) Y. Kamotani, L. Wang, S. Hatta, R. Selver, and S. Yoda: Effect of free surface heat transfer on onset of oscillatory thermocapillary flow of high Prandtl number fluid, J. Japan Soc. Microgravity Appl., **18** (2001) 283, DOI: 10.15011/jasma.18.4.283.
9) Y. Kamotani, L. Wang, S. Hatta, A. Wang, and S. Yoda: Free surface heat loss effect on oscillatory thermocapillary flow in liquid bridges of high Prandtl number fluids, Int. J. Heat Mass Transf., **46** (2003) 3211, DOI: 10.1016/S0017-9310(03)00098-X.
10) T. Yano, K. Nishino, H. Kawamura, I. Ueno, and S. Matsumoto: Instability and associated roll structure of Marangoni convection in high Prandtl number liquid bridge with large aspect ratio, Phys. Fluids, **27** (2015) 024108, DOI: 10.1063/1.4908042.