Flow pattern and free surface deformation caused by coupling effect of ambient airflow and thermocapillary convection

Ruquan Liang

Key Laboratory of National Education Ministry for Electromagnetic Process of Materials,
Northeastern University, Shenyang, 110819, China
e-mail: liang@epm.neu.edu.cn, web page: http://www.epm.neu.edu.cn/

ABSTRACT

The floating zone method was proposed in order to produce the silicon crystal of high quality in the early 1950s, and the thermocapillary convection is the main reason of micro-impurity striation in the monocrystalline silicon formed using the floating zone method. In recent years, the shear airflow has been adopted to suppress the thermocapillary convection.

The influence of shear airflow on the free surface deformation and the flow structure for large Prandtl number fluid has been analyzed numerically as the parallel airflow is induced into the surrounding of liquid bridge from the lower disk or the upper disk in the present work. Present results indicate that the formation of cell flow is due to the induced shear airflow in the isothermal liquid bridge. The flow cell is very close to the free surface, and the flow direction of flow cell depends on the shear airflow. The speed of shear airflow decides the effect degree of shear force. The accelerated shear airflow also affects the location of vortex center and the free surface deformation. The shear airflow induced from the upper disk of isothermal liquid bridge presses the convex region of "S"-shaped free surface down. The convex region of free surface shrinks and extends continually towards the ambient airflow, which increases the possibility of fracture of liquid bridge. The shear airflow induced from the lower disk of isothermal liquid bridge lifts the convex region of "S"-shaped free surface up. The free surface also extends toward the ambient airflow side and the shape of free surface changes into the "M"-shape, which doesn't increase the possibility of fracture of liquid bridge. For the non-isothermal liquid bridge, the flow state is more complex due to the coupling effect of shear airflow and thermocapillary convection. As the shear airflow is induced from the hot disk of non-isothermal liquid bridge, the shear force and the thermocapillary force have the same direction. The thermocapillary convection appears near the free surface at the hot corner, and the surface flow is intensified with the accelerate shear airflow. Therefore, the reverse flow cell near the cold disk of liquid bridge appear and the free surface is still the "S"-shape. As the shear airflow is induced from the cold disk of non-isothermal liquid bridge, the shear force and the thermocapillary force are in the opposite directions. The reverse small-scale flow cell is driven by the shear airflow. Meanwhile, the shape of free surface depends on the competitive results between the shear force and the thermocapillary force. The free surface changes gradually from the "S"-shape into the "M"-shape.

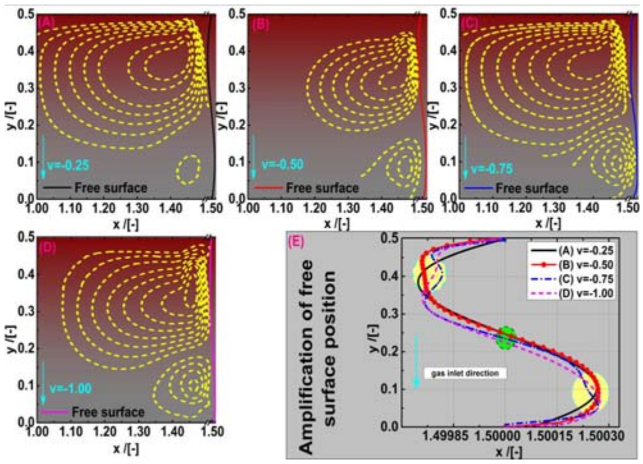

Fig.1 Deformation of dynamic free surface in the non-isothermal liquid bridge with the shear airflow induced from the upper disk. (Pr=111.67, g=9.81m/s2, Γ=1, ΔT0=25)

REFERENCES

[1] T. Matsunaga, A. Mialdun, K. Nishino, and V. Shevtsova, “Measurements of gas/oil free surface deformation caused by parallel gas flow”, *Physics of Fluids*, **24**, 062101 (2012).