**AUTHOR'S POST PRINT** (Romeo Colour: Green)
JASMA: Journal of the Japan Society of Microgravity Application (ISSN: 0915-3616), 18 pp.27 (2001).
Publisher version available at
http://ci.nii.ac.jp/naid/10007123477

# Numerical Simulation of Three Dimensional Marangoni Convection in Non-cylindrical Liquid Bridges of Low Pr Fluids

Shouichi YASUHIRO and Nobuyuki IMAISHI
Institute of Advanced Material Study Kyushu University
Marcello LAPPA* Naples University, Italy Shinichi YODA NASDA
*current e-mail address: marcello.lappa@strath.ac.uk

## Introduction

Three dimensional unsteady numerical simulations of 3-D Marangoni flows were conducted to understand effects of the statically deformed free surface and the buoyancy forces for low Pr fluids, by means of the finite difference method on body fitted coordinate.

## Mathematical Model

Calculation model is a half zone liquid bridge of molten silicon (Pr=0.01) formed between the top and bottom heated disks of the same radius *a*=5 mm; the length is L=10 mm. The temperature difference is denoted by $\Delta T$. Fundamental equations are the Navier-storks, the continuity and the energy equations. The liquid surface is assumed adiabatic. The static shape of this surface is obtained from the Laplace's condition.

## Results and discussions

In liquid bridges of low Pr, when Marangoni number exceeds a certain threshold value ($Ma_{c1}$), the steady axi-symmetric flow becomes unstable and steady 3-D flow arises. The effect of the buoyancy forces on flow pattern was almost negligible regardless of the heating condition (from top or from bottom) in liquid bridge of this size. Fig. 1 shows velocities and temperatures in liquid bridge for As= (L/*a*) =2, Ma=15 and Bi=0. In the case of heating from bottom and 1g condition b) steady 3-D Marangoni flow with wave number m=1 similar to the case of 0g condition a) appeared, but in the case of heating from top and 1g condition steady 3D flow with m=2 appeared.

These results are similar to those by Lappa (private communication)

Beyond a second critical Ma ($Ma_{c2}$), the steady 3-D flow becomes unstable and oscillation starts. As shown in Fig. 2 oscillatory flow occurs. In Fig.2-a) (the case of heating from bottom and 1g condition), the oscillatory mode is featured by the torsional oscillatory (twisting) of m=1 flow.

In Fig. 2-b) (the case of heating from top and 1g condition), the oscillatory mode is featured by the torsional oscillatory m=2 flow.

## Conclusion

3-D numerical simulations were carried out for liquid bridges of Pr=0.01 fluid The results explained that the static deformed shape plays a critical role for the 3-D flow pattern and Critical Marangoni number.

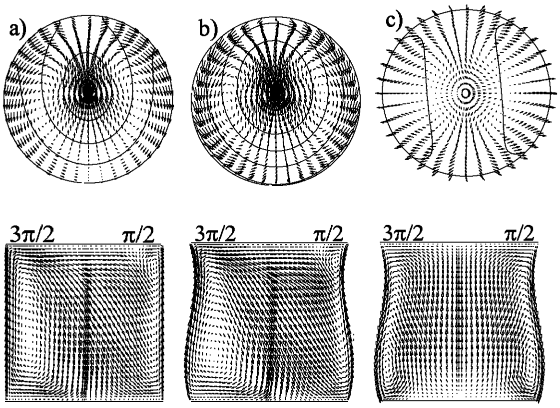

Fig. 1 Structure of the steady 3-D Marangoni flow in liquid bridges of Pr=0.01 fluid with As=2, Ma=15 and Bi=0.
a) 0g, b) 1g bottom heating , c) 1g top heating .

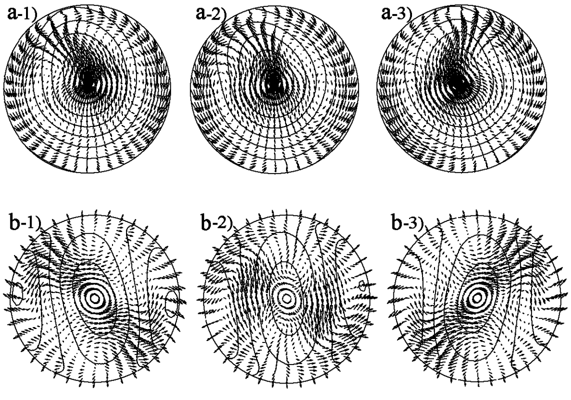

Fig. 2 Structure of the oscillatory 3-D Marangoni flow in liquid bridge of Pr=0.01 fluid with As=2, Ma=40 and Bi=0: Isothermal lines and velocity vectors on Z=0.5As.
a) 1g bottom heating , b) 1g top heating .

[Acknowledgements]

This work was performed as a part of the Project Research on Marangoni Convection of NASDA.