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試料幅減少に伴う上部高温液体中の速度・温度場変化

Influence of Narrowing the Cavity Length for Velocity and Temperature in Liquid Heated from Above

折笠勇 [1], 鈴木進補 [1], 稲富裕光 [2], 上野一郎 [3]
Isamu ORIKASA[1], Shinsuke SUZUKI[1], Yuko INATOMI[2,3] , and Ichiro UENO[4]
1　早稲田大学，Waseda University
2　宇宙航空研究開発機構，Japan Aerospace Exploration Agency, Sagamihara
3　総合研究大学院大学，The Graduate University for Advanced Studies
4　東京理科大学，Tokyo University of Science

1. Introduction

Thermophysical property measurements such as Soret coefficient measurements1),2) are often conducted in microgravity environment to avoid buoyant convection. However, the opportunity of microgravity experiment is limited, so it is effective to construct an environment suppressing buoyant convection on the ground. Osada *et al*. revealed experimentally that narrowing cavity length of liquid container heated from above suppressed buoyant convection, although the temperature distribution was not observed, and sample solution was only salol3). The objective of this study is to reveal general relationship between the intensity of buoyant convection and temperature distribution with different cavity length in order to estimate the intensity of buoyant convection for any measurement conditions.

2. Numerical Analysis

Figure 1 shows the 3D model for the previous study3) developed in COMSOL Multiphysics® version 5.5 in this study. Velocity and temperature distributions of several different organic solvents including salol were calculated. The cavity length L was changed from 0.1 to 26 mm. The temperature of the top and bottom sides of the container were held at 60°C and 30°C, respectively. The heat flux was set based on Newton's cooling law with heat transfer coefficient h on the surfaces of the container. The governing equations were incompressible Navier-Stokes, continuity and energy balance ones.

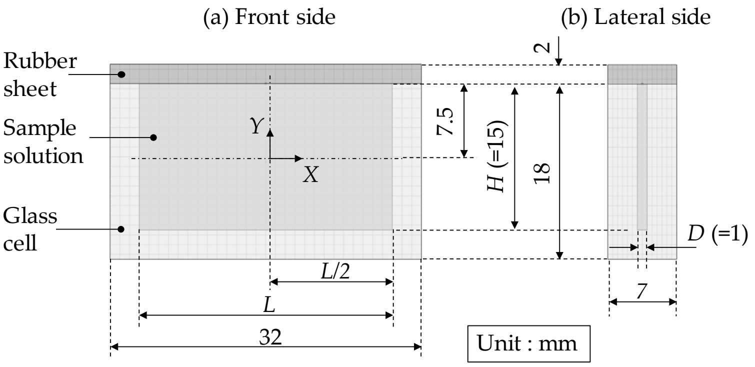

Fig. 1 3D model for the previous study3) developed in COMSOL Multiphysics® version 5.5: (a) Front and (b) Lateral side views: L, H and D correspond to the cavity length, height and depth of the container, respectively.

3. Results

The validity of numerical calculations was confirmed because numerical results of the mean velocities V_{mean} and flow patterns shown in **Fig. 2** were almost the same with that obtained in previous study[3]. It was found that the mean velocity V_{mean} decreased since the horizontal temperature differences ΔT_{ho} between around center and around wall of sample solutions decreased as the cavity length L was narrowed in several different organic solvents including salol. However, in each cavity length L, the values of ΔT_{ho} and V_{mean} did not necessarily have a positive correlation, and it was thought that the viscosity acted as a resistance force.

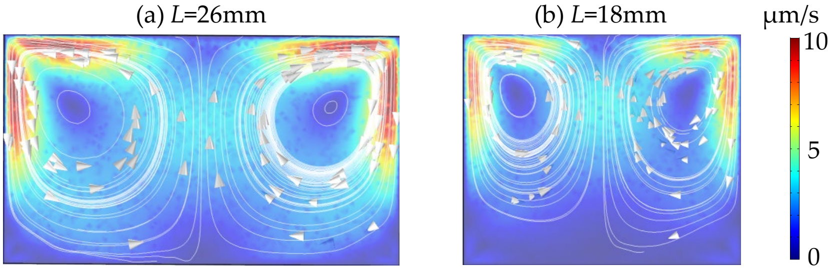

Fig. 2 Calculated flow patterns and velocities in salol heated from above with (a) cavity length L = 26 mm, and (b) L = 18 mm: arrows and colors correspond to the directions of flows and velocities, respectively.

4. Discussion

In order to express uniquely the interrelationship of these parameters, the Reynolds number Re which was a dimensionless element of the value of V_{mean} was plotted with respect to ($Gr^m \cdot Pr^n$). Here, Gr is the Grashof number which is a dimensionless element of buoyant including the value of ΔT_{ho} and viscosity; Pr is the Prandtl number; m and n were the power-law indices. As a result, it was found that there was a significant positive correlation in the appropriate combinations of multipliers m and n, and the Reynolds number Re could be expressed generally as a power function of product of Grashof number and Prandtl number ($Gr^m \cdot Pr^n$). Therefore, it was suggested that mean velocities at any sample solutions, cavity lengths and heating conditions could be estimated easily.

5. Conclusion

It was confirmed that the mean velocity V_{mean} of the sample solution decreased since the horizontal temperature differences ΔT_{ho} in the solutions decreased as the cavity length was narrowed. Then, it was revealed that the Reynolds number Re including the value of V_{mean} could be expressed as a power function of ($Gr^m \cdot Pr^n$) where Gr was the Grashof number; Pr was the Prandtl number; m and n were the power-law indices. These results suggested the feasibility of estimation of the intensity of buoyant convection for any sizes of liquid containers and kinds of sample solutions.

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