JASMAC Conference of the Japan Society of Microgravity Application

PS23

3 方向ノズルを用いたガスジェット浮遊法による Pt 融体の高精度密度計測

High-Precision Density Measurement of Molten Pt Using Aerodynamic Levitation Method with a Three-Directional Nozzle

加藤蒼 [1], 高橋勇太 [1], 清宮優作 [1], 白鳥英 [2], 小畠秀和 [3], 杉岡健一 [4], 石川毅彦 [5], 小澤俊平 [1]
So KATO[1], Yuta TAKAHASHI[1], Yusaku SEIMIYA[1], Suguru SHIRATORI[2], Hidekazu KOBATAKE[3] Ken-ichi SUGIOKA[4], Takehiko ISHIKAWA[5], and Shumpei OZAWA[1]
[1] 千葉工業大学, Department of Advanced Materials Science and Engineering, Chiba Institute of Technology
[2] 東京都市大学, Department of Mechanical Systems Engineering, Tokyo City University
[3] 同志社大学, Organization for Research Initiatives & Development, Doshisha University
[4] 富山県立大学, Department of Mechanical Systems Engineering, Toyama Prefectural University
[5] JAXA, Institute of Space and Astronautical Science, JAXA

1 Introduction

Accurate and precise measurements of the density of high-temperature melts are crucial for simulating phase transitions, such as crystallization and vitrification. These values serve as fundamental ordering parameters. To avoid sample contamination from the container during density measurements, containerless techniques such as electrostatic levitation (ESL) and electromagnetic levitation (EML) are commonly employed. However, ESL faces challenges with high-vapor-pressure samples due to its requirements for high-vacuum conditions. Meanwhile, EML can only be used with conductive samples and necessitates the application of a strong static magnetic field to a levitated droplet to suppress its deformation.

In the present study, we employed an aerodynamic levitation (ADL) to control the rotation of levitated droplets using three different gas jet nozzles: a standard conical nozzle (SCN), a tri-directional converging nozzle (TDCN) and a tri-directional non-intersecting nozzle (TDNIN). The aim of this study was to develop and establish a novel method for measuring the density of high-temperature melts using ADL.

2 Experimental procedure

Figure 1 shows schematics of the three types of gas jet nozzles (SCN, TDCN, and TDNIN) used in this study. In the TDCN (Fig. 1 (b)), three gas jets converge into a single point at the top of the nozzle, levitating a droplet at this convergence. In the TDNIN (Fig. 1 (c)), the three gas jets do not directly intersect, creating a valley between the gas jets where a droplet is levitated.

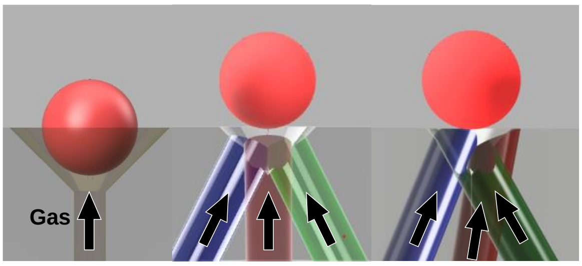

Fig.1 Schematic diagram of the gas jet nozzle

To eliminate the effects of oxidation and adsorption of the sample by atmospheric oxygen, chemically stable platinum was selected as the sample in this study. A spherical sample with a diameter of 1.6 to 2.0 mm was placed on the nozzle and levitated using argon gas jets. A semiconductor laser beam was irradiated from above to heat and melt the sample. The sample temperature was recorded with a monochromatic pyrometer. The sample image was continuously observed from the horizontal direction using a high-speed video camera (1000 fps for 5 seconds) in conjunction with temperature. The rotation axis of the droplet was confirmed using aluminum powder as a tracer. To determine the accurate sample contour, backlight from a semiconductor laser was employed along with a high-pass filter placed in front of the camera. The volume of the droplet was calculated from each numerically fitted contour, assuming rotational symmetry. The density of the droplet was calculated by dividing the sample mass, measured after the experiment, by its calculated volume.

3 Results and discussion

When observing a levitated droplet with the SCN from the horizontal direction, the nozzle obscures almost the entire bottom half of the droplet, as shown in Fig.1 (a). The droplet was observed rotating horizontally, as schematically illustrated in Fig. 2 (a).

With the TDCN, the visible area of the droplet is increased, as shown in Fig. 2 (b). Furthermore, the droplet was rotated quickly horizontally and slowly vertically at the same time as schematically in Fig. 2 (b).

Using the TDNIN, the visible area of the droplet is significantly increased; only 6 % of the projection area is obscured by the nozzle. Moreover, the rotation of the droplet could be controlled only around the vertical axis.

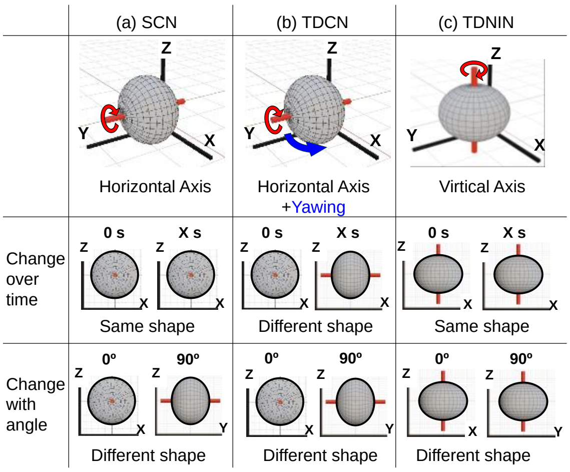

Fig.2 Shape change of a rotating droplet

Figure 3 illustrates the relationship between the calculated density and the elapsed time for platinum droplets maintained at 2000 K. The volume of the levitated droplets using the SCN and TDNIN was calculated assuming rotational symmetry around their respective axes; it is the horizontal axis for the SCN sample and the vertical axis for the TDNIN sample. For the droplet levitated using the TDCN, the volume was calculated under the assumption of symmetry around the horizontal axis, reflecting its rapid rotation.

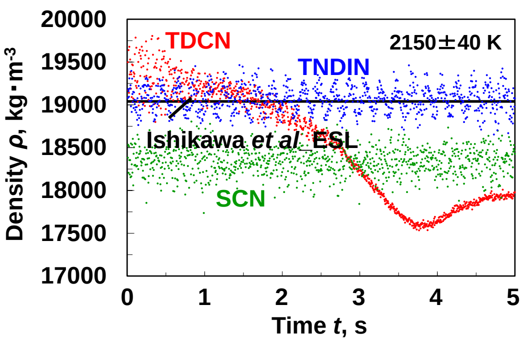

Fig.3 The relationship between the density of a Pt droplet and elapsed time

The calculated density of the droplets using the SCN remains comparatively constant, regardless of the elapsed time. However, it is lower than the data reported by Ishikawa et al. using the ESL technique. This discrepancy could be attributed to the limited visible area of the droplet, potentially leading to inaccuracies in determining the correct contour of the droplet image.

The calculated density of the droplet using the TDCN gradually decreases over time until the levitation time reaches 3.8 seconds, after which it begins to increase. This trend correlates with variation in the apparent volume of the droplet due to its slow vertical rotation co-existing with its rapid horizontal rotation. The slow vertical rotation causes the apparent volume of the droplet to oscillate slowly when assuming only horizontal symmetry.

When using the TDNIN, the calculated density of the droplet aligns well with the data by Ishikawa et al. This is attributed to the significantly enlarged visible area and the controlled rotation axis on the vertical. A small oscillation of the calculated results at 5 Hz was attributed to a translational oscillation of the levitated droplet. The droplet image appears smaller or larger as it moves away from or closer to the HSV camera.

From these results, it is clear that the method for measuring the density of high-temperature melts using Aerodynamic Levitation (ADL) with the tri-directional non-intersecting nozzle (TDNIN) has been successfully developed and established.

4 Summary

This study explores the development of a novel method for measuring the density of high-temperature melts using Aerodynamic Levitation (ADL) with three different gas jet nozzles: a standard conical nozzle (SCN), a tri-directional converging nozzle (TDCN), and a tri-directional non-intersecting nozzle (TDNIN). Experiments conducted with chemically stable platinum samples revealed that while the SCN and TDCN had limitations in terms of visible area and rotational dynamics affecting density measurements, the TDNIN showed significant improvements. It provided a larger visible area and controlled rotation, resulting in density measurements that aligned well with established data.

Acknowledgement

This research was partially funded by the Japan Society for the Promotion of Science (JSPS) KAKENHI under Grant No. P20H02453, and by the Grant-in-Aid for Front Loading Research, which is supported by the Advisory Committee for Space Utilization Research in the Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency (ISAS/JAXA).

References

1) T. Ishikawa, P. F. Paradis, and N. Koike. Non-contact thermophysical property measurements of liquid and supercooled platinum. J. Appl. Phys, **45** (2006) 1719, DOI: https://doi.org/10.1143/JJAP.45.1719