Development of a Convenient Drop Tube System for the Measurement of Thermophysical Properties†

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Abstract

A drop tube-type short-time microgravity system was developed to measure the thermophysical properties using an oscillating drop method. The oscillation of a falling droplet was precisely recorded using the combination of a line sensor and a laser backlight. The measured surface tension values of pure water agree quite well with the reported value.

KEY WORDS: (Microgravity) (Surface Tension) (Droplet) (Surface Oscillation) (Free Fall)

1. Introduction

A microgravity environment is very suitable for measuring thermophysical properties because no lifting force is necessary to levitate a sample and no convection flow occurs. Some researchers have measured thermophysical properties in a microgravity environment and excellent results were reported [1-3]. However, it cannot be commonly used because of its extremely high cost. In this study, an inexpensive and convenient drop tube-type microgravity system was developed for the measurement of the thermophysical properties using an oscillating drop method.

2. Theoretical Background

The oscillation of a droplet was investigated by Rayleigh [4].

$$\nu = [n(n-1)(n+2)\gamma / 3\pi M]^{\frac{1}{2}},$$

where γ is the surface tension, M is the droplet mass, n is the frequency of the oscillation and n is the label for the oscillation mode. The damping constant of the surface oscillation was calculated by Lamb's equation [5].

$$1/\tau = (n-1)(2n+1)\eta / \rho r_0^2 ,$$

where τ is the damping constant, η is the viscosity, ρ is the density and r_0 is the radius of the spherical droplet.

3. Experiments

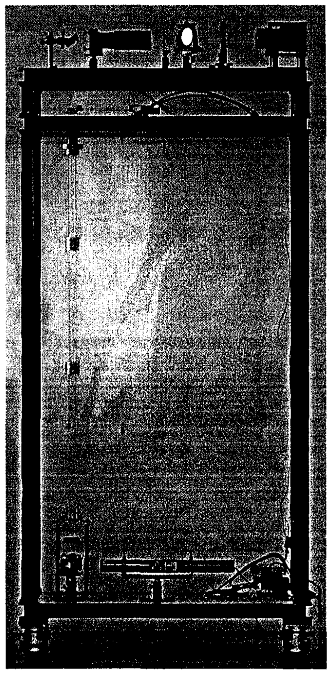

Fig. 1 Apparatus for the short time microgravity oscillating drop method.

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The appearance of the measurement system is shown in Fig.1. A droplet falls for 1.5m in about 0.55 seconds. The surface oscillation of the falling droplet is recorded during this falling period by a line sensor using a laser backlight and a cylindrical lens. The recording speed and resolution of the line sensor are 84000line/sec and 2048pixels, respectively. The frequency and the damping constant of the surface oscillation are obtained from the recorded data, and the surface tension is then calculated.
Pure water was used as the sample material and the atmosphere was air. The drop weight was determined immediately after falling.

Table 1 Surface tension of pure water.

No	Mass (mg)	Surface Tension (mN/m)	Temperature (℃)
1-1		72.8±2.7	27
1-2	1	72.3±2.5	23
1-3		73.2±2.7	23
2-1		73.9±2.4	26
2-2	3	70.3±4.9	27
2-3		72.9±4.9	27
3-1		71.5±3.7	28
3-2	7	73.1±3.8	28
3-3		70.9±3.7	28
		72.75	20
ref 6		71.96	25
		71.15	30

4. Result

The calculated surface tension of pure water is shown in Table 1, along with previously reported values [6]. The measured values show good agreement with the reported values.

5. Conclusion

An inexpensive and precise method for surface tension measurements using a short-time microgravity environment was developed. The reliability of this method was confirmed by comparing the measured surface tension values of pure water with the reported values.

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