Pt-Ir 질량원기와 스텐레스 표준분동을 이용한 공기밀도 직접측정

In Situ Direct Determination of Air Density Using Pt-Ir and Stainless Steel Standards

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1. Introduction

In the field of mass metrology, a Pt-Ir kilogram has been the national peak reference standard of traceability hierarchy in many countries. The mass standard is then disseminated to the standards of stainless steel. In mass comparison of two weights of different densities such as of Pt-Ir and stainless steel in the air, a major uncertainty arises from the determination of the air density. In the comparison of a Pt-Ir kilogram prototype with stainless steel standards, the buoyancy effects of air in kg is about 0.8×10^{-4} ρ, where ρ is the air density in kg/m^3. On the other hand, the relative uncertainty of the Bureau International des Poids et Mesures (BIPM) equation for ρ estimation could be used in the order of 10^{-4}. An uncertainty of about 10 μg in the buoyancy correction is expected in such comparisons [1,2,3].

At present Korea Research Institute of Standards and Science has maintained three Pt-Ir kilogram prototypes. One of them is the peak standard and the others are check standards. The other prototype kilograms could be used for other purpose not simply as a check standard. The long term stability of BAs of stainless steel has not been well established. Therefore, we propose a new method of direct measurement of air density by employing a Pt-Ir kilogram prototype and a stainless steel kilogram weight as BAs with a density difference of about three times during mass measurement weighing. Then the in situ weighing and determination of air density could improve the measurement efficiency because weighing and determination of air density are performed at the same time.

2. In Situ Measurement of Air Density

The BAs are compared to give the apparent mass difference,

$$\delta M = (M_A - \rho V_A) - (M_B - \rho \mathrm{V}_\mathrm{B})$$

where M_A, V_A and M_B, V_B are the mass and volume of the prototype of kilogram and the stainless steel kilogram, respectively. We then have the following expression for the density of air,

$$\rho = [(M_A - M_B) - \delta M]/[V_A - V_B]$$

.

With the values of M_A, V_A and M_B, V_B we can determine the density of air by measuring the apparent mass difference. Table 1 shows the values of mass and volume of the kilogram prototype No. 39 and the stainless steel kilogram employed as BAs. The values of M_A and V_A of the kilogram prototype were determined at the BIPM [4]. While those of the stainless steel kilogram were determined by the comparison with the prototype of kilogram using the air density equation of BIPM [3].

Table 1 Mass and volume values of the BAs

	Pt-Ir kilogram	Stainless steel wt.

True mass in g	999.999206	1000.011308
Volume in cm^3, t in ℃	46.4030[1+(25.863+ 0.00562 t) x10^{-6}t]	M_B/[7.99892- 0.00036714 t]

3. Experimental Results

A mass comparator of 1 μg readability with an automatic weight exchange device (Mettler-Toledo, HK1000MC) was used in the air. The apparent mass difference between the prototype of kilogram and the stainless steel kilogram on the weight exchange pan was measured without any other weights on the remaining positions of the pan. Six measurements were conducted in 20 minutes to obtain a value of air density and the corresponding air density was also calculated from the air density equation of BIPM [4].

The differences, δρ, between the calculated air density ρ_{EQ} and the directly measured ρ_{BA} were plotted in Fig. 1

Pairs of mass values of the two stainless steel weights of 1 kg as test objects were obtained through comparing their weights with the kilogram prototype. The air densities by direct measurement and those by the equation of BIPM were simultaneously obtained for the respective buoyancy compensation. The prototype of kilogram and stainless steel kilogram weight as BAs were neighbored on the pan. The other two weights of 1 kg of test objects C and D were positioned on the remaining sites. The respective determination of the mass values of the two weights required 30 rotations of the turn table and it took 4.5 hours. The standard deviation of m_{BA} was shown to be less than that of m_{EQ} in all of the six measurements. The standard deviation of m_{BA} in the 6 measurements was found to be less than 5 μg. The result indicates that the in situ BA method produces less uncertainty than that by the BIPM equation.

4. Conclusions

A Pt-Ir kilogram prototype was used not only as the mass standard but also as BAs paired with a stainless steel weight. The BAs enabled us to measure the air density.

With a comparator equipped with an automatic turntable capable of handling four weights, direct determination of air density for the buoyancy correction is obtained to calibrate the other two weights on the same pan.

The in situ BA method produced less uncertainty in obtaining the mass values of test weights than that by the BIPM equation method

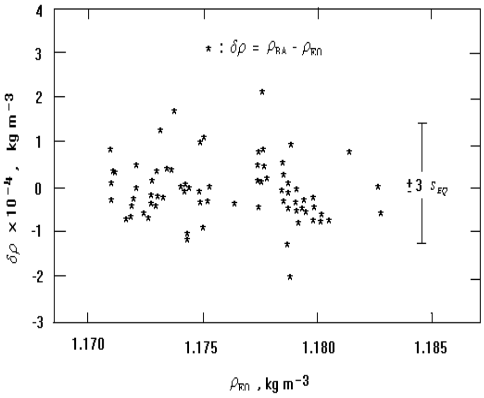

Fig. 1 Comparison of air density values via Bas with those from the equation of BIPM.

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