DENSITY MEASUREMENT SYSTEM FOR WEIGHTS OF 1 kg TO 20 kg USING HYDROSTATIC WEIGHING

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This paper presents a density measurement system to determine density of weights from 1 kg to 20 kg using hydrostatic weighing. The system works based on Archimedes principle. The density of reference liquid is determined using this setup while determining the density of the test weight. Density sphere is used as standard density ball to determine density of the reference liquid. A new immersion pan is designed for dual purpose to carry the density sphere and the cylindrical test weight for weighing in liquid. Main parts of the setup are an electronic balance, a thermostat controlled liquid bath, reference weights designed for bottom weighing, dual purpose immersion pans and stepping motors to load and unload in weighing process. The results of density measurement will be evaluated as uncertainties for weights of 1 kg to 20 kg.

Keywords: Hydrostatic weighing; immersion pan weight; density; uncertainty.

1. Introduction

Density measurement of weights is required in high accuracy mass measurement. A Hydrostatic Weighing System is used as measuring setup for a better accuracy in density

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of weight measurement. KRISS has just been measuring the density of weights by using HWA in the range of 1 g to 1 kg, and have been developing new HWA to determine the density of weights with shape of OIML IR 111 ranging from 2 kg to 20 kg with 1 kg Silicon sphere is used as Standard Density Ball (SDB). The density of the reference liquid is measured using this setup while measuring the density of the test weight. The HWA comprises a precision balance, an immersion pan, liquid bath with thermostat, reference weights and a controller for stepping motors. Density of weights from 1 kg to 20 kg is measured and the uncertainty is analyzed as preliminary test of newly designed and fabricated HWA [1][2][3].

2. The Hydrostatic Weighing Setup

In hydrostatic weighing to determine density of weights, it is required to weigh in air and in liquid. This new HWA is manufacture to determine density of weights from 1 kg to 20 kg with the shape of OIML R 111. An electronic balance of capacity of 26.1 kg and readability of 1 mg is mounted at the top of the frame for bottom weighing. Reference weights of slotted shape and nominal mass of 1 kg, 2 kg, 2 kg, 5 kg, and 10 kg are hang on weight carrier under the balance for weighing. These reference weights can be load and unload in any combination and order using 5 stepping motors. The schematic drawing of the apparatus is shown on Fig. 1 below.

Fig. 1. Schematic drawing of hydrostatic weighing apparatus in the range of 1 kg to 20 kg.

Immersion pans with material of titanium carrying bases are designed for cylindrical sample weights of 1 or 2 kg, 5 kg, 10 kg and 20 kg. Each pan is also designed to carry the 1 kg Spherical Density Ball (SDB). The sample carrier with three stages is designed to weigh the sample weights and the Standard Density Ball (SDB). Two stepping motors enable the sample carrier to rotate or move up-and-down in loading and unloading the sample weights and SDB. The stepping motors for reference weights and sample carrier are controlled by the controller and it's also computer operated. The liquid vessel is shield with water bath with thermostat control. It raise to upper position for immersion of the samples and SDB in reference liquid after loading on sample carrier for weighing in liquid

3. Preliminary Examinations

Density of weights from 1 kg to 20 kg is determined as a preliminary test using this new HWA. We use tridecane as reference liquid since the surface tension is less (about one third) than that of pure water. The density of the reference liquid is determined using silicon sphere as standard density ball. It is weighed in the reference liquid to determine the density of the liquid. The 1 kg slot weight in air is used as reference weight to weigh against the Silicon sphere for reciprocal sensitivity of the balance. Density of reference liquid is measured while density is determined for each test weight. The slotted reference weights are used to determine the reciprocal sensitivity of the balance accordingly in weighing each test weight in liquid.

The density of each weight is measured and summarized in Table 1 below.

Table 1. Summary of density value of weights.

Weight	Density (g/cm ³)	U (g/cm ³), k=2	U _{rel}
1 kg	8.005 55	0.000 62	7.70×10^{-5}
2 kg	8.011 65	0.000 65	8.10×10^{-5}
5 kg	7.999 74	0.000 74	9.28×10^{-5}
10 kg	8.013 27	0.000 83	1.04×10^{-4}
20 kg	8.004 54	0.000 87	1.09×10^{-4}

The source of uncertainty and their contribution is analyzed and summarized below from Fig. 3 to Fig. 7, where the sources d_l , SDB is liquid density by SDB, $d_{l,temp}$ is liquid density by temperature. m_t is mass of test weight, R_t is balance reading of the test weight, m_s is mass of the standard weight, d_{ms} is density of standard weight, R_{ms} is balance reading of the standard weight and d_a is air density.

Fig. 2. Relative uncertainty of sample weights.

Fig. 3. Standard uncertainty of 1 kg weight.

Fig. 4. Standard uncertainty of 2 kg weight.

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Fig. 5. Standard uncertainty of 5 kg weight.

Fig. 6. Standard uncertainty of 10 kg weight.

Fig. 7. Standard uncertainty of 20 kg weight.

4. Conclusion

This newly designed hydrostatic weighing apparatus use to determine the density of weights 1 kg to 20 kg with a shape of OIML R111. The main source of uncertainty is the density of the reference liquid. Both the uncertainty value and the relative uncertainty is found to increase with the mass of the weight. The uncertainty of density measurement of the weights is with the order of 10^{-4} or less that satisfy density requirements of weights of OIML class E₁.

References

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