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Some Thoughts on the Quality of the Special Weights for the Electronic Balance Verification of the Piston Pressure Gauge

Hua Li, Li Shen

Yunnan Institute of Measurement and Testing Technology, Kunming, Yunnan, 650228, China

Abstract

The accuracy of the mass of the weight is related to the accuracy of the pressure value of the piston pressure gauge. This paper firstly introduces the calculation method of the theoretical value of the mass in the vacuum of the mass converted by the weight of the piston pressure gauge, and the principle of the electronic balance weighing the converted mass. Then, the calculation methods and precautions when using electronic balances to weigh weights under different working conditions are introduced from various aspects. When the air density of the laboratory and the air density of the weight used are both 1.2kg/m 3 , the weight can be directly weighed by the balance to convert the mass. When the laboratory air density or the air density where the weight is used is not 1.2kg/m3 , it needs to be corrected according to the weight density and air density. For the special weight of the absolute pressure plug, the density of the weight must be known when verifying or calculating the pressure.

Keywords

Electronic Balance; Special Weight Converted Mass; Air Density Weight Density.

1. Preface

As we all know, the physical meaning of the pressure unit Pascal is the pressure generated by a Newtonian force acting vertically on an area of one square meter. Piston pressure gauge is an instrument that generates pressure based on the principle of pressure unit definition. When working, the gravity generated by the supporting weights is corrected by air buoyancy, viscous force and other forces and acts on the effective area of the piston, thereby Produces a pressure value of the corresponding magnitude. Based on this principle, the piston pressure gauge has high accuracy and stability, and is in the status of the benchmark or standard level in the pressure verification system table. From the definition of pressure, it is not difficult to see that in order to ensure the accurate measurement value of the piston pressure, the mass transmission of the special weight for the piston is a very important link. According to the existing verification procedures for various types of pistons, standard balances and mass comparators are used for the weighing of special weights. With the advancement of science and technology, electronic balances are used more and more in the process of weight verification due to their advantages of convenient reading, fast operation, and higher and higher accuracy. However, there are some differences between the verification of special weights for piston pressure gauges and the verification of normal standard weights. Therefore, this article will discuss in depth some problems when calibrating special weights for piston pressure gauges with electronic balances.

2. Mass in Vacuum and Converted Mass of Special Weight for Piston

To verify the quality of the piston-specific weight is to compare the difference between the theoretical calculated value and the actual value of the weight. Therefore, the calculation method of the theoretical value of the piston-specific weight is introduced first. Theoretically, when the effective

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area of the piston and the pressure generated by the weight are known, the product of the two can be divided by the acceleration of gravity to obtain the theoretical weight of the weight. However, due to the existence of air buoyancy, the weight needs to be corrected for buoyancy, namely Get the mass of the weight in vacuum. Therefore, according to the verification procedures of the piston pressure gauge, the theoretical mass in vacuum for the weight whose nominal value is the pressure value can be expressed by the formula):

$$m_s = P \bullet A \bullet \frac{1}{g} \bullet \left(1 + \frac{\rho_a}{\rho_m}\right) \tag{1}$$

P - nominal pressure value of the piston weight, Pa;

A - effective area of the piston, m ^{2};

g - The weight uses the ground acceleration of gravity, m^2 / s;

ρ_a - the density of the air where the weights are used, kg / m^3;

ρ_m - the density of the special weight for the piston, kg / m^3;

The definition of the converted mass of the weight can be interpreted as the kg / m^3 test weight in the air with the agreed air density and the standard weight with the agreed weight density of 8000 kg / m^3 reach a balance on the balance, and the mass of the standard weight is the The converted mass of the checked weight m_c, namely:

$$m_c = \frac{1 - \frac{\rho_0}{\rho_m}}{1 - \frac{1.2}{8000}} \bullet m_s = \frac{m_s\left(1 - \frac{\rho_0}{\rho_m}\right)}{0.99985} \tag{2}$$

ρ_0 That is to say, the air density is agreed, and the formula (2) is put into the formula (1), and the formula (3) can be obtained, that is, the converted mass of the piston weight whose nominal value is the pressure.

$$m_c = P \bullet A \bullet \frac{1}{g} \bullet \frac{1}{0.99985} \bullet \left(1 + \frac{\rho_a}{\rho_m}\right)\left(1 - \frac{\rho_0}{\rho_m}\right) \tag{3}$$

For the piston-specific weight whose nominal value is mass, usually its nominal value is its theoretical converted mass, and its mass in vacuum can be inversely calculated according to formula (2), namely:

$$m_s = m_c \bullet 0.99985\left(1 + \frac{\rho_0}{\rho_m}\right) \tag{4}$$

3. The Principle of Electronic Balance Weight Mass

Electronic balances measure the mass of weights based on the principle of electromagnetic force balancing the force generated by the gravity of the measured weights: before use, electronic balances need to be calibrated with built-in or higher-accuracy standard weights loaded on the tray. The nominal value of the density of the standard weight and the density of the standard weight are respectively ρ_{a1} and ρ_m, and the electronic balance indication value is calibrated to the nominal value of the weight. Since the nominal value of the standard weight is the converted mass m_c, the

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combined formula (4) can obtain the force generated by the standard weight on the balance after the buoyancy correction F :

$$\begin{aligned} F &= m_s g\left(1-\frac{\rho_{a1}}{\rho_m}\right) \\ &= m_c g \bullet 0.99985\left(1+\frac{\rho_0}{\rho_m}\right)\left(1-\frac{\rho_{a1}}{\rho_m}\right) \end{aligned} \tag{5}$$

According to the temperature, humidity and air pressure conditions of the laboratory in the plain area of China, the air density can be approximately 1.2 according to the empirical formula kg/m^3. Since the weight density is (3-4) orders of magnitude higher than the air density, the above formula can be simplified as:

$$\begin{aligned} F &= m_{cg} \bullet 0.99985 \bullet \left(1-\frac{{\rho_0}^2}{{\rho_m}^2}\right) \\ &= m_{cg} \bullet 0.99985 = m_c^{'} \bullet k \end{aligned} \tag{6}$$

In the formula $m_c^{'}$ - the indication value of the balance; k - the correction coefficient of the balance reading corrected to the nominal value of the weight.

When the indicated value of the balance is equal to the nominal value of the standard weight after calibration, it is not difficult to see from the above formula that the correction coefficient is only related to the acceleration of gravity. If the location and environment of the electronic balance are not changed, it can be regarded as a constant value. This value is automatically corrected in the electronic balance after calibration. Therefore, for any weight of any mass and any density, when the air density of the electronic balance is 1.2kg/m3, it can still be obtained by formula (5) and formula (6) $m_c = m_c^{'}$, that is, it can be directly weighed by the electronic balance And display the converted mass of the weight. If the density of the balance is not 1.2kg/m ^{3} during calibration, the k value will change with the density of the weight. The weighing method of the electronic balance in this situation will be introduced in the next section.

For piston pressure gauges of class 0.01 or higher, the maximum allowable error of matching weights is close to the sum, class. At this time, it is difficult to meet the accuracy requirements by directly weighing with a general electronic balance, and a mass comparator should be used to verify the weight. The mass comparator is a special type of electronic balance. That is, the error of the tested weight is measured by comparing the difference between the displayed value of the standard weight with the same nominal converted mass and a higher grade and the tested weight on the electronic balance.

4. Discussion on the Quality of Special Weights for Electronic Balances to Verify Piston Pressure Gauges under Different Working Conditions

For a weight with a nominal pressure value, the theoretical value of its converted mass can be expressed by formula (3). When the air density of the place where the piston is used is 1.2 kg/m^3, the theoretical value of its converted mass is simplified to (7):

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$$m_c = P \bullet A \bullet \frac{1}{g} \bullet \frac{1}{0.99985} \tag{7}$$

It is not difficult to see from equation (7) that for a weight whose nominal value is the pressure value P, its converted mass is only related to the pressure value, the effective area of the piston and the acceleration of gravity, but not to the density of the weight. For piston manometers, the starting pressure is created by the weight of the piston and its connections. Although the density of each part of the piston and its connecting parts is different, since the converted mass has nothing to do with the density, the piston and its connecting parts can directly weigh the indication value of its converted mass on the electronic balance, and compare the error with the theoretical value. Weights with uneven density distribution such as hollow weights are also suitable.

If the air density of the place where the piston pressure gauge is used is not 1.2kg/m ^{3} , the density of the weight needs to be known when calculating the converted mass of the weight. For example, when the density of the air used is 1.0kg/m ^{3} and the density of the weights is 7800kg/m ^{3} , the relative error of the weights calculated by the formulas (3) and (7) is as high as 0.002%. The above piston pressure gauge is not negligible. For the piston and its connecting parts, it is necessary to calculate the converted mass according to the density of each part and weigh it with an electronic balance.

For weights with a nominal value of mass, when the air density in the laboratory is 1.2kg/m ^{3} , an electronic balance can be used to directly weigh its converted mass. When using the weight mass to calculate the pressure value generated by the piston, the force used to act on the piston can be calculated using equations (5) and (6). If the air density in the place of use is 1.2kg/m ^{3} , the pressure generated by the piston can be calculated according to the effective area of the piston without considering the influence of the weight density on the force generated by the piston pressure gauge. That is:

$$P = \frac{F}{A} = \frac{m_{cg} \bullet 0.99985}{A} \tag{8}$$

If the air density of the place of use is not 1.2kg/m3 , the weight density and air density need to be known, and the force generated by the weight on the piston after the buoyancy correction is calculated by formula (3). For example, when the density of the air used is 1.0kg/m ^{3} and the density of the weights is 7800kg/m ^{3} , the weights calculated by the formulas (3) and (6) generate the force, which is for a piston type of class 0.02. For pressure gauges, the error is not negligible. For the piston and its connecting parts, it is necessary to calculate the generated force according to the density of each part to calculate the initial pressure of the piston.

If the air density is not 1.2kg/m ^{3} when the electronic balance is in use, the displayed value will deviate due to the change in the force of the electronic balance. At this time, the measurement method of the mass comparator should be used to correct the measurement results to eliminate the influence of air density changes as much as possible, as shown in formula (9):

$$\Delta m = \Delta m' + m \bullet (\rho_a - \rho_0) \bullet \left(\frac{1}{\rho_m} - \frac{1}{\rho_r} \right) \tag{9}$$

Where: Δm - Actual error of the checked weight, kg;

$\Delta m'$ - The indication error of the tested weight and the standard weight on the balance, kg;

m - the nominal mass of the standard weight, kg;

ρ_m - Density of the tested weight, kg/m ^{3} ;

ρ_r - Standard weight density, kg/m ^{3} .

For an absolute pressure piston manometer, if the nominal value of its weight is the mass in vacuum, it is necessary to know the density of the weight to calculate its nominal converted mass according to formula (2), so as to verify the weighing with an electronic balance under normal pressure. . If the nominal value of the weight is the converted mass, it can be directly weighed with an electronic balance under the gauge pressure, but when calculating the pressure generated by the absolute pressure piston, it is necessary to first calculate its mass in vacuum according to the formula (4) and the density of the weight.

5. Conclusion

This paper introduces the precautions and calculation methods of using electronic balances to verify the quality of special weights for piston pressure gauges from the perspective of nominal weight, air density, weight density, laboratory air density and other influencing factors. When the air density used and the air density of the electronic balance is 1,2kg/m ^{3} , the indication value of the electronic balance can be directly read to measure the mass of the special weight. When the air density at the place of use or the air density when the electronic balance is used is not 1.2kg/m ^{3} , it needs to be corrected according to the weight density and air density. The weighing and calculation methods of weights with nominal pressure and nominal mass are also very different. For the weight of the absolute pressure piston, the density of the weight must be known when using it. The relevant calculation methods and laws are of great guiding significance for the verification of the piston pressure gauge in the future.

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