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INVESTIGATION OF INFLUENCE QUANTITY FOR READING STABILITY ON MAGNETIC SUSCEPTOMETER

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Abstract − According to the measurement principle of weight magnetic parameter, the influence of reading stability for measuring magnetism is analyzed, and the key influence of reading stability is presented in the measurement process. The magnetism of weight is measured by the magnetic susceptometer with capacity of 5.1g and resolution of 0.1 g. At the same time the change of environmental vibration at the laboratory and the fluctuating of ambient magnetic field are measured respectively. The experimental results show the fluctuating of ambient magnetic field that is the key influence of weight magnetism measurement.

Keywords: magnetic susceptometer; magnetism; vibration; influence quantity; weight

1. INTRODUCTION

The magnetic susceptibility and permanent magnetization are two significant influence quantities in the measurement of mass standard. The magnetic measurement of mass standard is prior to the mass measurement of mass standard in the specification of international recommendation OIML R111 2004(E)[1][2]. If the results of magnetic measurement is not conformable with the specification of magnetic properties in the OIML R111, the mass measurement of mass standard should not be done. The accuracy of magnetic measurement for the mass standard affects directly the accuracy of mass measurement. The susceptometer method is the primary measurement method for magnetic properties. To be recorded the readings of susceptometer which are or not accuracy depends on the stability of indication on the display. It is important to analyze the reading stability of measurement process. It is available for the accuracy of magnetic measurement to judge the effect of influence quantity in the magnetic measurement of mass standard[3][4][5].

Due to the variety of non-control environment around the laboratory affecting the magnetic measurement of mass standard, the readings of magnetic measurement which vary irregularly from up to down are instable on the display. So the indication can not be record accurately by the operator. The environmental influence quantities of magnetic measurement which is composed of the change of vibration and the varying of ambient magnetic field are analyzed thoroughly in the paper. The experimental results have verified that the readings stability is affected by two influence quantities.

2. THE MEASUREMENT PRINCIPLE ON SUSCEPTOMETER

Magnetic forces can adversely affect the weighing process, since without systematic investigation, these spurious forces cannot be distinguished from gravitational forces in the determination of mass. Magnetic forces can arise from the mutual interaction of two mass standards, as well as between a mass standard, the mass comparator being used for the weighing, and other magnetic object in the vicinity.

2.1 The operation principle

This method may be used to determine both the magnetic susceptibility and the permanent magnetization of weakly-magnetized weights through measurement of the force exerted on a mass standard in the magnetic field gradient of a strong permanent magnet [1].

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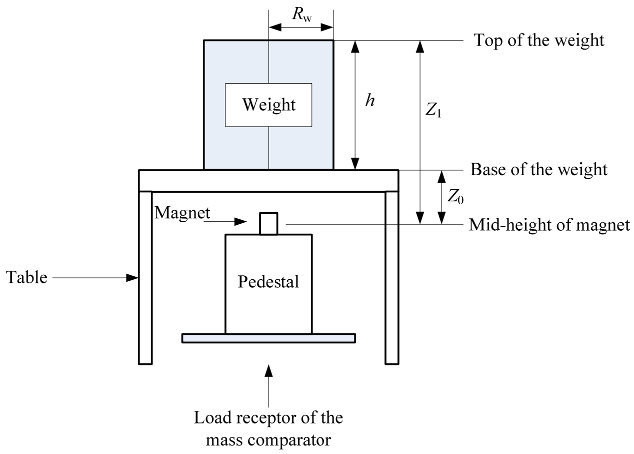


Fig. 1. The structure of susceptometer

Where h is the height of the magnet, Z_1 is the distance from the mid-height of the magnet to the top of the weight, Z_0 is the distance from the mid-height of the magnet to the base of the weight. R_w is the radius of the weight.

This method is only applicable to weights where the magnetic susceptibility, $\chi < 1$. The susceptometer method is not recommended for multi-piece weights. To use this method, familiarity with reference [2] is required. In a typical arrangement, the susceptometer has a measurement volume that is limited in extent (some 10 cm^3) on the table, close to and vertically above the magnet. Normally the weight should be upright. For measurement of the magnetic properties of the sides or the top, more elaborate methods [2] are required.

2.2 Measurement procedure and formula

Measurement procedure:

a) Measure the different parameters (Z_0, R_W, h), see the illustration of the apparatus, Figure 1, see also [6] for measurement of Z_0.

b) The value of the acceleration due to gravity, g, needs to be known to about 1 %.

c) Place the magnet with its north pole pointing down (the north pole of a cylindrical magnet is the end which repels the north pole of a compass needle). The dipole moment, m_d, will be needed.

The magnet produces a maximum field at the top surface of the table of:

$$H = \frac{m_d}{2\pi \times Z_0^3} \quad (1)$$

Where H is in units of A m^{-1}, for m_d in A m^2 and Z_0 in m.

d) Set the instrument to zero.

e) Place the weight on the table such that its axis coincides with the magnet's vertical axis, and take a reading. Turn the weight around its vertical axis repeatedly with increasing angles and take the readings at each position. For the following procedures, turn the weight to the angle where the reading shows the maximum deviation from zero.

f) Place the weight on the table, normally three times, directly above the magnet. Be sure weight is centered.

1) Record the time at which the load is placed, the time at which a reading is taken and the time when the load is removed.

2) Calculate Δm_1 from the repeated readings. Normally Δm_1 will be negative, indicating that the magnet is slightly attracted to the weight.

3) The force, ,is determined as

$$F_1 = -m_1 \times g \quad (2)$$

g) The measurement should be repeated with the magnet turned upside down.

1) The distance Z_0 is to be kept constant.

2) Set the instrument to zero.

3) Again, place the weight on the table, normally three times, directly above the magnets. Be sure the weight is centered.

4) Record the time at which the load is placed, the time at which a reading is taken and the time at which the load is removed.

5) Calculate Δm_2 from the repeated readings. Normally Δm_2 will be negative but may be significantly different from .

6) The force, F_2, is determined as

$$F_2 = -m_2 \times g \quad (3)$$

h) Repeat steps d-g above.

Calculate the magnetic susceptibility, χ, and permanent magnetization, M_z, of the weight by inserting the different parameters in the equations given below. Assume that the susceptibility of air is always negligibly small.

If measuring both F_1 and F_2 , the expression for the magnetic susceptibility is given by

$$\chi = \frac{F_a}{I_a \times F_{\max} - 0.4 \times F_a} \quad (4)$$

where:

$$F_{\max} = \frac{3\mu_0}{64\pi} \times \frac{m_d^2}{Z_0^4} \quad (5)$$

$$F_a = \frac{F_1 + F_2}{2} \quad (6)$$

$$I_a = 1 - \left(\frac{Z_0}{Z_1}\right)^4 - \frac{1 + \frac{(R_w/Z_0)^2}{3}}{[1 + (R_w/Z_0)^2]^3} + \left(\frac{Z_0}{Z_1}\right)^4 \times \frac{1 + \frac{(R_w/Z_1)^2}{3}}{[1 + (R_w/Z_1)^2]^3} \quad (7)$$

and for the magnetic polarization by:

$$\mu_0 M_Z = \frac{F_b}{\frac{m_d}{Z_0} \times \frac{1}{4\pi} \times I_b} - \frac{\chi}{1 + 0.23\chi} B_{EZ} \quad (8)$$

where:

$$F_b = \frac{F_1 - F_2}{2} \quad (9)$$

$$I_b = 2\pi \times \left\{ \frac{(R_w/Z_0)^2}{[1 + (R_w/Z_0)^2]^{3/2}} - \frac{(R_w/Z_0)^2/(Z_1/Z_0)^3}{[1 + (\frac{R_w/Z_0}{Z_1/Z_0})^2]^{3/2}} \right\} \quad (10)$$

B_{EZ} is the vertical component of the ambient magnetic induction in the laboratory. Usually, B_{EZ} can be taken as the vertical component of the earth's magnetic induction at the location of the laboratory, in which case $-48\ \mu T \le B_{EZ} \le 60\ \mu T$ depending on latitude. The magnitude of B_{EZ} is zero at the earth's equator and maximum at its poles. The sign of B_{EZ} is positive in the northern hemisphere and negative in the southern hemisphere.

3. ANALYSIS OF INFLUENCE QUANTITIES ON SUSCEPTOMETER

According to the operation principle of magnetic measurement, the susceptometer is comprised of mass comparator, permanent magnet, and measurement table. Because mass comparator is a measurement instrument with high accuracy, the indication of weight measurement will be affected by environmental parameters such as temperature, humidity, and air pressure. The magnetic field formed by the permanent magnet in the measurement area will be affected by the change of ambient magnetic field, which results in the change of readings on susceptometer. Due to the stable laboratory environment which parameters such as temperature, humidity and air pressure is stable, assume that the reading stability of susceptometer is always negligibly small. Therefore, the reading stability is affected by the fluctuating of vibration amplitude and the change of ambient magnetic field.

There is one susceptometer with maximum capacity 5.1 g, resolution 0.1 μg in the experiment of reading stability of magnetic measurement. The experiment includes two parts. One part is the reading stability experiment of magnetic measurement against the fluctuating of vibration amplitude. The other part is the reading stability experiment of magnetic against the change of ambient magnetic field. The experimental places are the city which the change of laboratory ambient is larger and the suburb which the change of laboratory ambient is smaller respectively. If the indication fluctuates from -1 mg to 1 mg in the measurement, the reading of magnetic measurement is unstable.

3.1 The effect of vibration fluctuating against reading stability

Figure 2 is the indication change of susceptometer (nonloaded). The test time is from May 19, 2008 11:50 Am to May 20, 2008 6:00 Am. The test place is the city which the change of laboratory ambient is larger. Figure 2 shows the indication of susceptometer from May 20, 2008 0:45 Am to May 20, 2008 4:52 Am that is stable, whereas the indication of other time is unstable. Due to stopping the bus, the subway, passenger car and so on, the change of the laboratory ambient at night is smaller than that at day in the city. The indication of susceptometer is stable at night.

Figure 3 shows the change of time domain of vibration and the change of frequency domain of vibration. The test time is from May 19, 2008 11:50 Am to May 20, 2008 11:50 Am. The test place is the city which the change of laboratory ambient is larger. Figure 3(a) is the change of time domain of vibration. X-coordinate is time. Y-coordinate is the amplitude of vibration acceleration. Figure 3(a) shows the indication of susceptometer from May 19, 2008 17:00 to May 20, 2008 5:00 that is stable. The change of vibration does not conform to the stable time of indication on susceptometer. So the change of vibration is not primary influence quantity of indication stability.

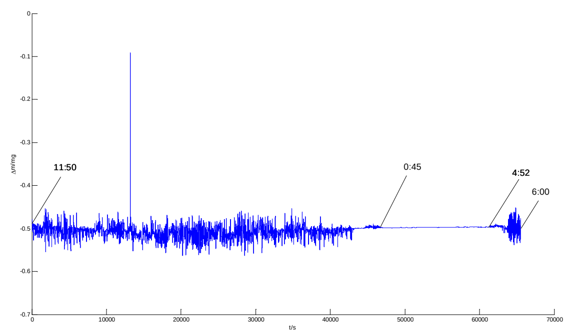
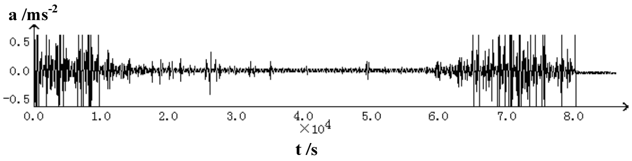
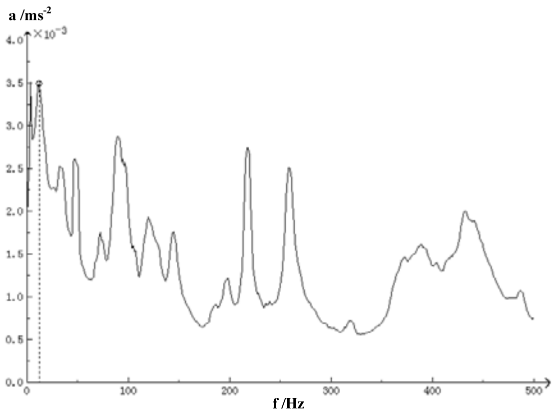


Fig. 2. The change of indication on susceptometer (for comparing

with the change of vibration)



(a)



(b)

Fig. 3. the change of vibration amplitude

3.2 The effect of ambient magnetic field against reading stability

Figure 4 is the indication change of susceptometer (nonloaded). The test time is from May 28, 2008 16:30 to May 29, 2008 5:30. The test place is the city which the change of laboratory ambient is larger. Figure 4 shows indication of susceptometer from May 28, 2008 23:52 to May 29, 2008 4:35 that is stable, whereas the indication of other time is unstable.

Figure 5 is the change of ambient magnetic field. The test time is from May 28, 2008 16:30 to May 29, 2008 9:30. The test place is the city which the change of laboratory ambient is larger. Figure 5 shows the change of ambient magnetic field from May 28, 2008 23:52 to May 29, 2008 4:35 that is smaller than that of other time. So take it as stable and no change. The change of ambient magnetic field conforms to the stable time of indication on susceptometer. Thus the change of ambient magnetic field is the primary influence of indication stability. Figure 5 shows also that the change value is between -48 μT and 60 μT, but the effect of indication stability arising from continue irregular change is very large.

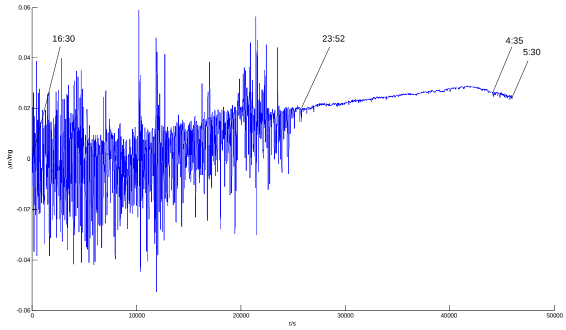


Fig. 4. The change of indication on susceptometer (for comparing with the change of magnetic field in the city)

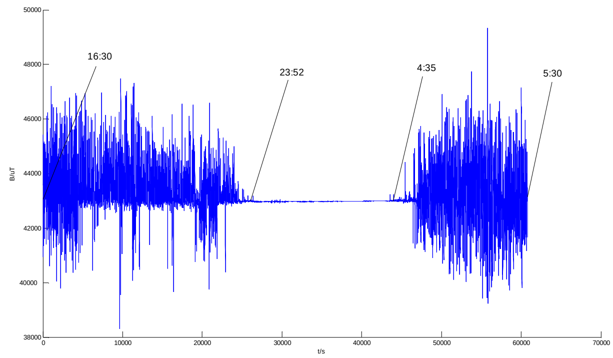


Fig. 5. The change of ambient magnetic field

Figure 6 is the indication change of susceptometer (nonloaded). The test time is from August 26, 2008 13:34 to August 26, 2008 13:49. The test place is the city which the change of laboratory ambient is smaller. The indication of susceptometer is stable in the figure 6 during test.

Figure 7 is the change of ambient magnetic field. The test time is from August 26, 2008 13:34 to August 26, 2008 13:49. The test place is the city which the change of laboratory ambient is smaller. The change of ambient magnetic field during test is very small in the figure. Comparing with figure 6, when the change of ambient magnetic field is small, the indication of instrument is easy to read, that is the reading stability is better.

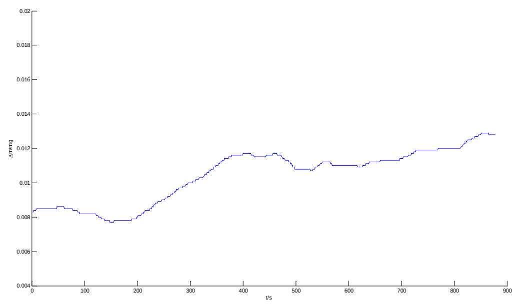


Fig. 6. The change of indication on susceptometer (for comparing

with the change of magnetic field in the suburb)

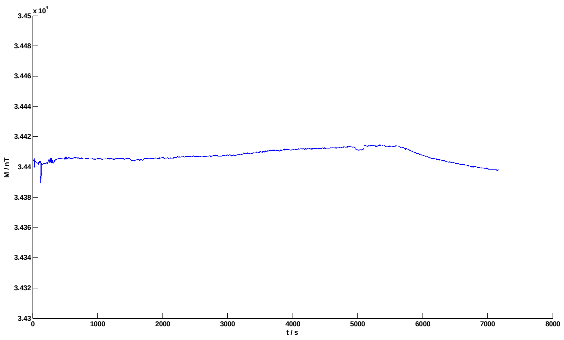


Fig. 7. the change of ambient magnetic field (measuring in the suburb)

4. CONCLUSIONS

Due to the change of environment parameter affecting the accurate measurement in the laboratory such as the reading stability, the measurement uncertainty and so on, it is very important to investigate the effect of influence quantities in the magnetic measurement of mass standard. According to the measurement principle of susceptometer, influence quantities of magnetic measurement which include the change of vibration amplitude and the varying of ambient magnetic field is proposed. The effect of reading stability for the magnetic measurement due to two influence quantities is analyzed thoroughly by a lot of experimental data. The experimental results show that the primary cause of reading stability on susceptometer is the change of ambient magnetic field.

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