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Research on measuring magnetism of weight using gaussmeter

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Abstract: Magnetism is very important for high accuracy class weights. There are several ways to measure magnetism of weights according to OIML R111. In NIM, a new magnetism measure device has been set up to measure magnetism of weights by using gaussmeter. This device compose of a rotation platform, stick pole, control panel , computer and gaussmeter. The gaussmeter is installed on the stick pole. The platform can move horizontally and let the center of the weight just below the probe of the gaussmeter. Also the platform can rotate around and the gaussmeter can detect the largest indication, and the result can be calculated by computer. The support capacity of the platform is 50 kg, so the magnetism of large weight can be measured by this device. The effectiveness of this device is showed by several tests.

Keywords: magnetism, weight, gaussmeter

1. INTRODUCTION

Magnetic susceptibility and permanent magnetization of a weight should be measured and make sure that the effect caused by magnetism of the weight can be negligible before the mass calibration. According to the specification of international recommendation OIML R111 2004(E), there are two accepted methods for determining the magnetization of weights, one is by Gaussmeter, the other is by susceptometer. Nowadays some manufactures have developed susceptometers to measure susceptibility and permanent magnetization of weights, but the maximum load they can measure is 20 kg, However, for large weights above 20 kg, there are no suitable devices can be used to measure permanent magnetization.

In this paper, a permanent magnetization measurement device is setup using a Gausssmeter. The measuring device and measuring principle is discussed section 2, and an initial measuring result is given in section 3, based on the result an conclusion is drawn in section 4.

2. MEASURING DEVICE AND MEASURING PROCEDURE

Fig 1 is the configuration of this system. It comprises a Gsussmeter with a probe, rotation pan with 3 motors, a sleeve, a pole and a computer. The Gaussmeter is used to measure the permanent magetizaiton of a weight. The rotation pan is used to support weights. It can move in X and Z orientations, and also it can rotate around the axle which is perpendicular to its surface and penetrate its center. Since different weights may have different height, to facilitate its use, the probe of the Gaussmeter is installed in a sleeve which can change its position along a pole.

When this device is used, the weight is put on the rotation pan, the probe can be adjusted to the position just above the weight by moving the sleeve to its appropriate position according to the height of the weight. Then with X and Z orientation motors, It is very convenient to put the weight put just below the probe.

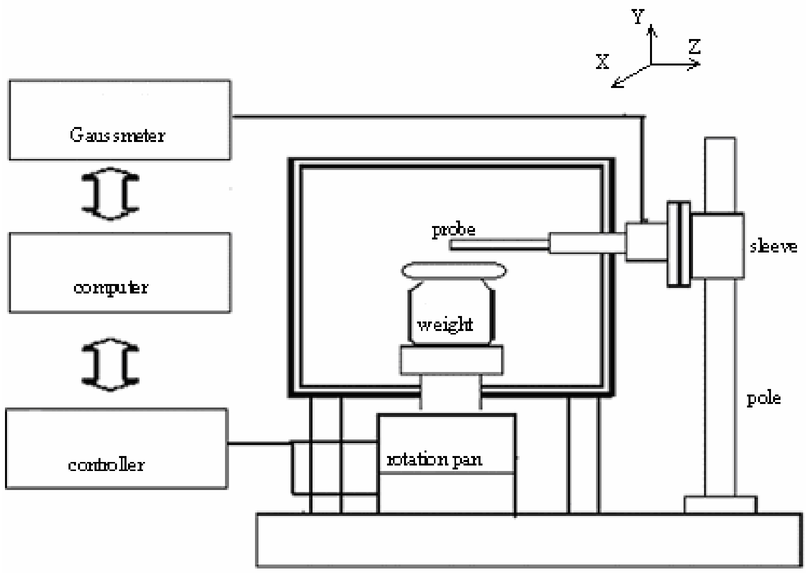

Fig1 configuration of measuring device.

2.1. measuring device

Figure 2 is the photo of the measuring device. In this device, a Gaussmeter with 3 axle probe is used. 3 axle probe can measuring the magnetizations of X, Y and Z orientation simultaneously. The type of the Gaussmeter used here is 7030. Different type of probe may have different measuring range and resolution, according to the requirements of permanent magnetization of weights(table 1), the range of the probe chose here is 3 mT, and the resolution is 10 nT. Usually it may be sufficient to measure polarization of Y orientation, but for this device, we want to supervise other orientation, so we chose a 3 axle probe.

Fig 2. Measuring Device.

Table 1. Maximum polarization(μT)

Weight class	E_1	E_2	F_1	F_2	M_1
Maximum polarization(μT)	2.5	8	25	80	250
Weight class	M_{1-2}	M_2	M_{2-3}	M_3	
Maximum polarization(μT)	500	800	1600	2500	

The rotation pan of this device can support 50 kg weights. The shell of the pan is made by aluminium. There are two ways to operate the device, one is to use control panel, and the other is to use a computer. There are 3 pairs of control button to control the position of the pan, two pairs for controlling X and Z orientation movement, and one pair for controlling rotation. All the movement of the pan can also be controlled by software.

2.2.measuring procedure

The measuring procedure is as follows:

a) Zero the meter.

b) Place the probe to a suitable height.

c) Take a reading of the magnetic field with a particular orientation of the probe. The value is a measure of the ambient magnetic field. This reading will be subtracted from any future reading taken on or near the weight.

d) Rotate the pan for a certain angle(typically chose 30 °,60 °, 90 °), and take a reading. Repeat this step until the pan rotate 360 °.

e) Place the weight on the pan while maintaining the probe orientation. Check for homogeneous magnetization by moving the weight from the center to the border of the bottom and observe the changes in the reading. If it does not decrease smoothly, the weight may be inhomogeneously magnetized.

f) If the weight is homogeneously magnetized, measurements may be carried out at the center of the top, close to the surface of the weight, without contact and in accordance with the specifications of the Gaussmeter.

g) Read the indication. Record in μT.

h) Rotate the pan to each angles corresponding to d), read the indication.

i) Reverse the weight for measuring the bottom (only for weights with a flat top), then repeat steps e–h above.

j) Put off the weight,

j) Correct the probe reading and estimate the polarization, $\mu_0 M$,

$$\mu_0 M = \frac{2B}{\frac{d+h}{\sqrt{R^2+(d+h)^2}} - \frac{d}{\sqrt{R^2+d^2}}} - f(B_E) \qquad (1)$$

with: $f(B_E) = 5.4 B_E$ (2)

for class M weights , and $f(B_E) = \frac{\chi}{1+0.23\chi} B_E$ (3)

for class E and F weights.

Where:

B = Gaussmeter reading with the weight present (ambient field subtracted, see c);

B_E = Gaussmeter reading of the ambient magnetic field with the weight absent;

d = distance between the center of the sensing element (which is embedded within the probe) and the surface of the weight;

h = height of the weight;

R = radius of a cylindrical weight or, in the case of a rectangular weight, the radius of a circle with the same area as the measured plane of the weight.

3. MEASURING RESULT AND ANALYSIS

In this section, a 5 kg cylinder shape weight is used to measure the permanent magnetization. It is made of stainless steel. The radius of this weight is 42.1 mm, the height of the weight is 125.0 mm, the d is 20 mm. Since the weight is class E_2, the Maximum susceptibility χ of the weight is 0.0038

From OIML R111, first we need to measure the ambient magnetic field, and then measure the polarization of the weight. However, since different orientation of the weight may have different polarization, we take a reading after the pan rotated every 30 º. After that, the weight is put on the pan, and also the indication is recorded after the pan rotated every 30 º. Then the weight is reversed on the pan, and still measured every 30 º. In order to see the change of ambient magnetic field, at last we measure the ambient magnetic field once more.

The measuring result is listed in table 2.

Table 2. Measuring Result

Degree (º)	Indication of ambient magnetic field (B_{01}) (µT)	Indication with the weight (B_1) (µT)	Indication with weight reversed (B_2) (µT)	Indication of ambient magnetic field (B_{02}) (µT)
0	-0.69	-0.29	-0.48	-0.43
30	-0.73	-0.18	-0.50	-0.35
60	-0.87	-0.29	-0.65	-0.39
90	-1.06	-0.48	-0.83	-0.59
120	-1.28	-0.73	-1.09	-0.82
150	-1.56	-0.95	-1.38	-1.00
180	-1.64	-1.10	-1.47	-1.14
210	-1.67	-1.12	-1.47	-1.18
240	-1.52	-1.10	-1.40	-1.11
270	-1.31	-1.10	-1.13	-0.90
300	-1.04	-0.95	-0.84	-0.59
330	-0.67	-0.81	-0.61	-0.42

From equation (1), first we need to get B. In this situation, we get B following equation (3):

$$B = [(2B_1 - B_{01} - B_{02}) - (2B_2 - B_{01} - B_{02})]/2 \qquad (3)$$

Because each degree has different B, only we need to do is to choose the largest one, in this case, the B is 0.215 µT, and the final result of permanent magnetization is 0.67 µT. from table 1, we can see that it meets the requirements of class E_2.

However, there are still some problems need to be studied further. From the test data, we can see that for different angle, the ambient magnetic is changed also, the maximum change is about 1 µT. This may bring some influence on measuring high accuracy class weights. But for lower class, the influence is trivial. A weight made by cast iron is used to see the indication, it reached about over 10 µT. So for weights with large permanent magnetization, this method is quite effective.

Typically the reading of the GAUSSMETER is not as stable as mass comparators. The reading bellow 0.1 µT is not stabled. So for very small permanent magnetization weights, it is very hard to measure the exact value of the permanent magnetization. However in this case, we only care that the permanent magnetization of the weight is within the limited range in table 1.

4. CONCLUSIONS

Gaussmeters can be used to measure the permanent magnetization of weights. In order to measure large weights, a measuring device is designed in NIM. The structure and the measuring procedure is discussed in this paper. From the measuring result, the effectiveness of this device is proved. However, the repeatability and the uncertainty of this method is need to be studied further.

REFERENCES

[1] International Recommendation OIML R111-1 Edition 2004(E), “Weights of classes E1, E2, F1, F2, M1, M1-2, M2, M2-3 and M3”, pp: 35-38, 2004.

[2] Davis, R. S., “Determining the magnetic properties of 1 kg mass standards” J. Res. National Institute of Standards and Technology (USA), 100, 209-225, May-June 1995.

[3]7030 GAUSS/TESLA meter instruction manual. F. W. BELL Company.