Supplement 2. The Measuring magnetic field of permanent cylindrical magnet

Contents

For the purpose of testing the computation program shown in Chapter 2 we have performed an experiment described below.

1. Measuring device description

Fig. 1. Measuring device.

Fig. 1 shows the photo of measuring device, and Fig. 2 – a sketch of a milling machine (which is an essential part of the device: it is used for moving the measuring transducer with high accuracy). It is divided into three parts: A - frame, table, vise unit, B - stand, C – spindle head with motor and mount. Summary weight (A, B, C) is approximately 15 kg each (mainly instrumental steel, in motor – electro technical steel). Measurements were performed in zone D using non-magnetic (wooden) layer. Additional information about this device is available in [5].

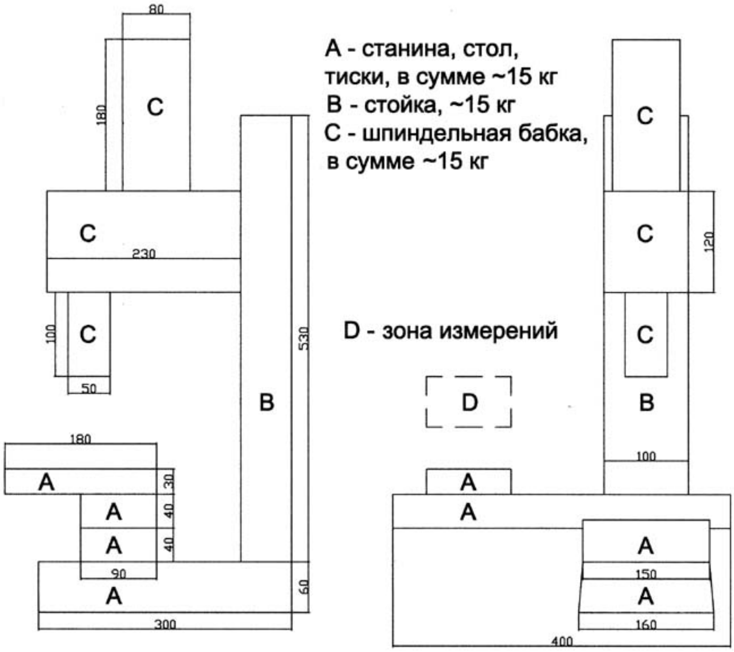

Fig. 2. Sketch of milling machine.

2. The magnet

The tested magnet - neodymium-iron-boron – of cylindrical form, assembled of five magnets of diameter 14.5 mm and height 4 mm. So., the magnet's height is - 20 mm, diameter – 14.5 mm. Residual induction is equal to 1.1 Tl – it is a nameplate value for this lot of magnets. It may vary rather significantly for various magnets of the same lot.

Induction in the center of the face plane of a long cylindrical magnet is around half of the residual, i.e. is equal to 0.55 Тл. Mind that for these magnets due to the peculiarities of their production the induction on one face plane differs from the induction on the other face plane (density heterogeneousness).

3. Scanning method

The scanning was performed with the ad of milling machine. The magnet and the transducer were maximally removed from the steel parts by wooden layers.

The used instrument was a teslameter with Hall transducer [6]. The transducer's size was 2 x 1.5 mm^2, the size of transducer's working zone - 0.45*0.15mm^2. The magnetic induction measuring accuracy for the used teslameter is 2.5 %, the indications instability (drift during an hour) is not more than 0.1 mTl. Notice that for the used measurement scheme (teslameter +digital voltmeter) these 2.5 % may be caused by

- calibration inaccuracy, i.e. systematic inaccuracy (the true values are equal to measured values multiplied by a constant coefficient, lying within the limits 0.975 ... 1.025)
- incidental inaccuracy 0.1 mTl + 1 count unit = 0.2 mTl.

The accuracy of initial coordinate position setting is 0.2 мм. In the corner points this leads to significant differences between the values measured along different lines due to the large gradient of magnetic induction in this area. Unfortunately the construction of the prod didn't allow scanning uninterruptedly along the perimeter.

4. The scheme of scanning and calculation

The general scheme of scanning is shown on Fig. 3. The coordinate system used is cylindrical, axis Z coincides with the magnet's symmetry axis, **Z** – axial coordinate (height), **X** – radial coordinate (radius). On this figure

1 – Hall transducer for scanning the axial component of magnetic induction,

2 – Hall transducer for scanning the radial component of magnetic induction,

the dotted lines are scanning lines; perimetrical outline of the scanning is formed by four lines – (x, 11.5), (9.0, z), (x, -11.5), (-9.0,z); the size of this outline are conditioned by the prod's thickness in the zone of Hall transducer– 3 mm.

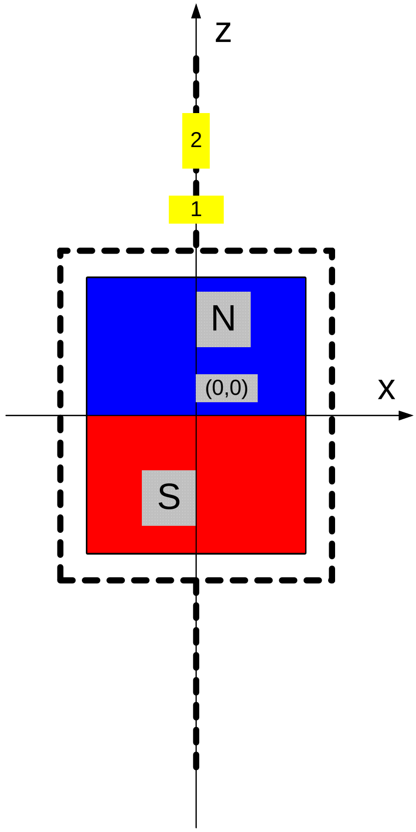

Fig.. 3. General scheme of scanning.

5. The results

The results of this experiment show that the intensities of magnetic field close to face plane may be approximated by the functions whose graphs are shown on Fig. 4 and 5. On these figures the graphs of the first harmonics of these empirical functions trigonometric series expansions are shown by dot lines.

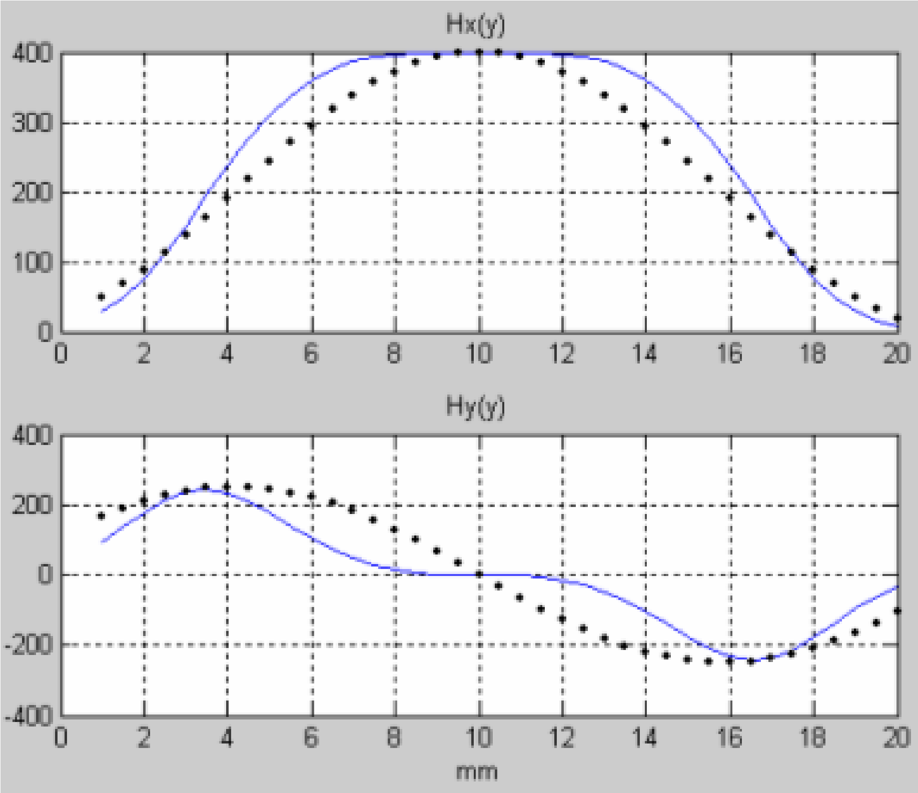

Fig. 4. The higher window - $H_x(y)$, the lower window - $H_y(y)$, the full lines – approximation of experimental measurements, dot lines– the first harmonics of trigonometrical series expansion.

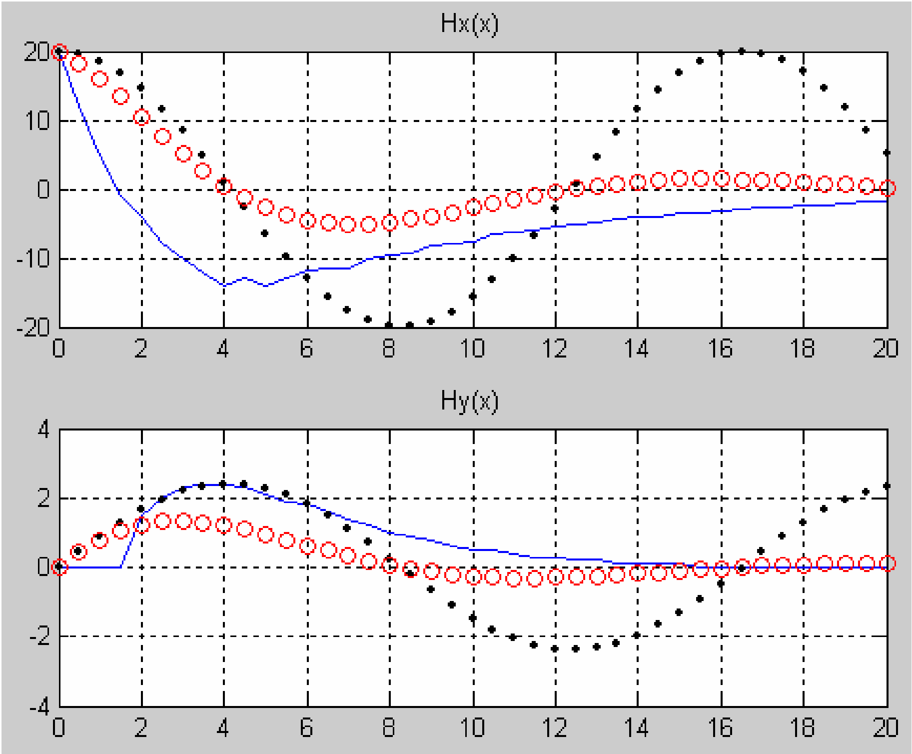

Fig. 5. The higher window - $H_x(x)$, the lower window - $H_y(x)$, the full lines – approximation of experimental measurements, dot lines– the first harmonics of trigonometrical series expansion, line of circles - "weakened" first harmonic of trigonometrical series expansion.