https://doi.org/10.46813/2024-151-042

LONG-TERM MAGNETIC STABILITY OF SmCo MAGNET FOR THE ACCELRATOR APPLICATIONS

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A comparison of measurements of the topology of the magnetic field of a permanent magnet made using the rare earth alloy Sm_2Co_{17}, carried out at an interval of 5 years, was made. The data obtained in 2023 indicate that the metrological characteristics of the magnet remained within the limits that were determined in the studies conducted in 2018.

PACS: 85.70.Sq; 75.50.Ww

INTRODUCTION

The considerable use of permanent magnets in accelerator technologies has been started with progress in the development of magnetic materials on the base of SmCo and NdFeB alloys in the mid of the XX century. The high-energy product of these materials made it possible to create dipole and quadrupole magnets, which are the basis of optical systems of accelerators. The parameters of permanent magnets systems are not inferior to and in some cases superior to designs of magnetic systems created on the basis of traditional technologies [1].

The advantages of permanent magnets considerably outweigh the electromagnetic equipment with high energy consumption and give reduced costs for commercial technological accelerators. The use of permanent magnets leads to a significant energy savings and cost-effective production for a large class of beam devices. Permanent magnets do not require the manufacture of complex power systems and offer zero maintenance and operational costs.

At the same time, the use of magnetic materials in accelerators requires the study of the behavior magnetic systems' parameters under the influence of the radiation of beams of charged particles, neutrons, gamma quanta and other factors [2, 3]. Thus, when the design of magnetic system for the beam energy measurement at LU-10 m in the NSC KIPT was carried out, the main attention was paid to the selection of a magnetic alloy that magnetic characteristics were stable under the influence of radiation in the accelerator [4]. Experimental studies showed the superiority of samples made of Sm_2Co_{17} alloy. It was confirmed that magnetic field of the system did not change within the accuracy of measurements for the maximum radiation doses [5].

The external dimensions of the magnet yoke of the system were 90x73x24 mm. It was made of soft magnetic steel ST3. Accuracy of manufacturing and adjusting of magnet elements was 5 μm. Magnetic samples made of Sm2Co17 alloy with the size of 30x24x12 mm were attached to the bars using aluminum clamps. The gap between the poles was 25.25 mm. The upper bar of the magnet was removable. This allowed easy installation and de-installation of the dipole magnet on the output flange of the accelerator during the procedure of measuring or adjusting the energy of the accelerator.

The magnetic characteristics of the designed and manufactured dipole magnet were comprehensively investigated in 2018 [4]. The general view of the dipole magnet is shown in Fig. 1.

One of the critical factors when using permanent magnets is the stability of the magnetic parameters over time. A series of repetitive measurements carried out for this dipole magnet in 2023 was devoted to the study of the long-term stability of the magnetic field.

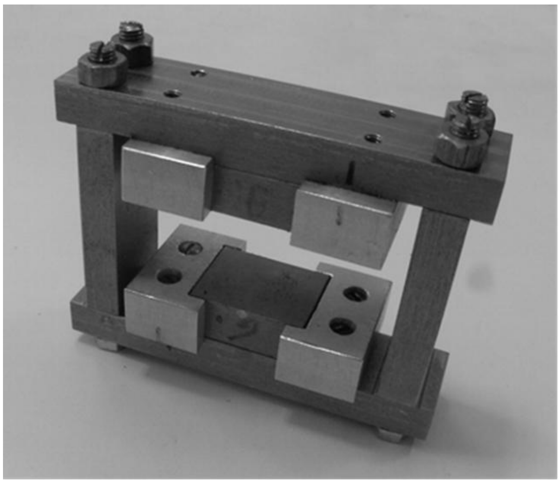

Fig. 1. Dipole magnet for linear accelerator LU-10m

METHODOLOGY AND RESULTS OF MEASUREMENTS

The distribution of the magnetic field was studied using a line of seven Hall sensors fixed in a massive copper matrix. The relative error of measurements was no worse than 0.01%. The accuracy of magnetic field measurement, which is ensured during the measurement process, was no worse than 10^{-3}. The method of magnetic measurements was described in details elsewhere [4].

The distribution of magnetic field in the median plane was measured and compared with the data of the primary measurements carried out in January 2018 [4]. During these measurements, the main attention was paid to the maximum reproduction of the geometry of the experiment. The dipole magnet was oriented with respect to the sensors similarly to the 2018 measurements (Fig. 2). The distribution of measurement points and the magnitude of the field in the median plane are shown in Fig. 3. The results of data processing using cubic interpolation are shown in Fig. 4. Fig. 5 shows interpolation data for measurements made in 2018.

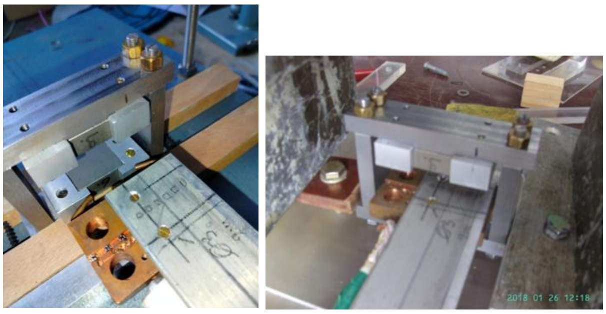

Fig. 2. Geometry of measurements, from the left – December 2023, from the right January 2018

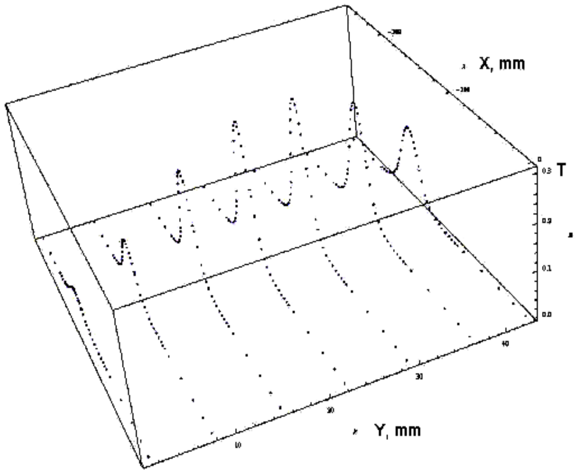

Fig. 3. Exsperimetally measured magnetic field distribution in the dipole magnet, December 2023

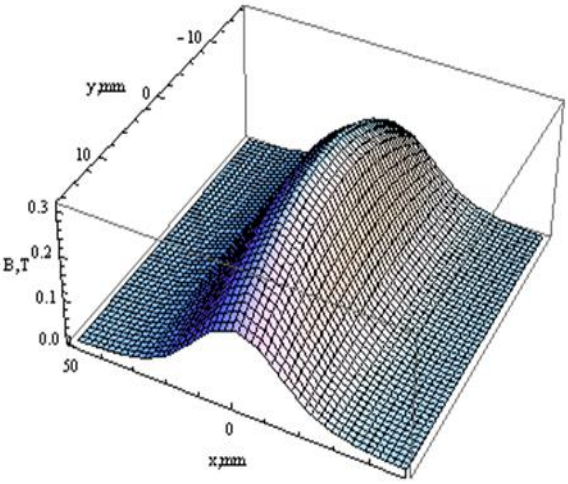

Fig. 4. The distribution of the magnetic field (interpolation) 2023

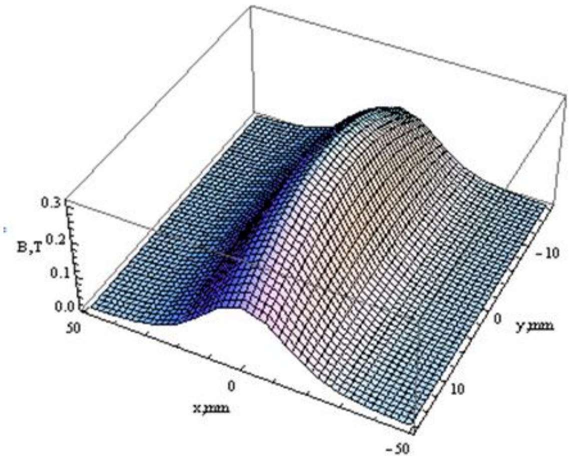

Fig. 5. The distribution of the magnetic field (interpolation), January 2018

The distribution of the field along the center of the magnet is presented in Fig. 6. The effective length of the magnet along the path Y = 0, X = -100…+100 mm is 33.54 mm. The maximum field value is 0.3115 T.

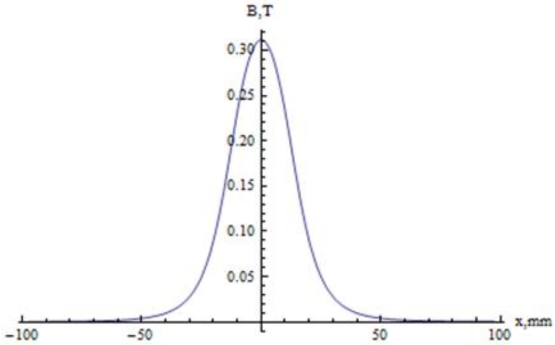

Fig. 6. The distribution of the magnetic field along the line Y = 0, X = -100…+100 mm, 2023

The difference in the magnitude of the field along the line Y = 0, X = -100…+100 mm in the measurements of 2023 and 2018 is presented in Fig. 7. The maximum field measured in 2018 was 0.3110 T, the effective length of the magnet was 33.49 mm.

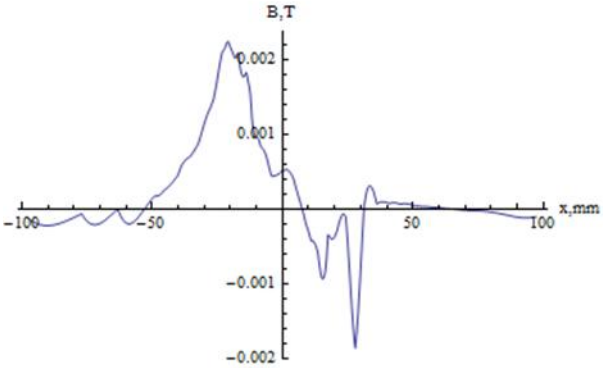

Fig. 7. The difference in the magnitude of the field along the line Y = 0, X = -100…+100 mm

The distribution of the field across the axis in the center of the dipole magnet is presented in Fig. 8.

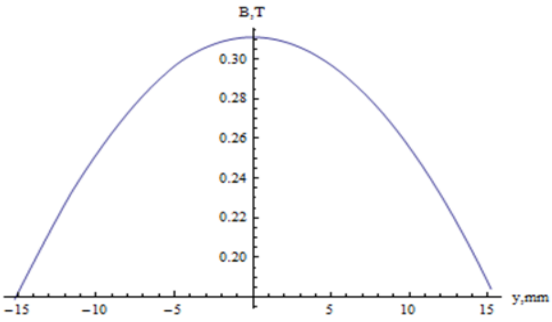

Fig. 8. The distribution of the magnetic field along the line X = 0, Y = -16…+16 mm, December 2023

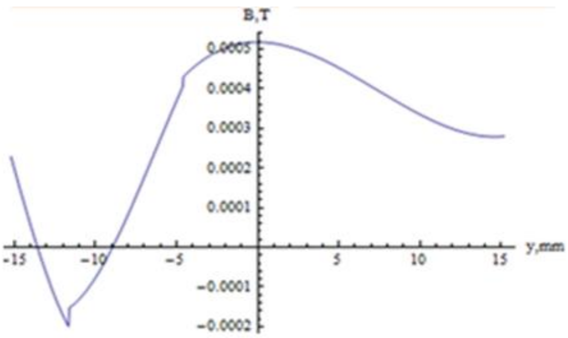

Fig. 9. The difference in the field along the line X = 0, Y = -16…+16 mm in 2023 and 2018

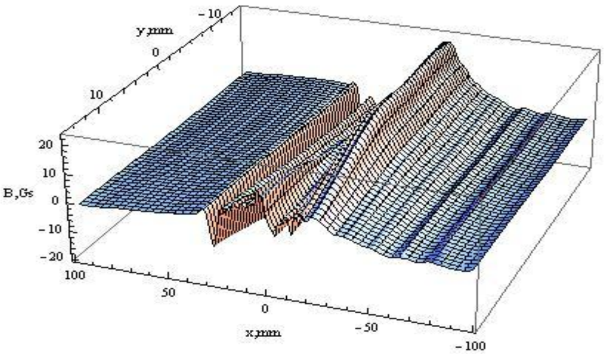

Fig. 10. The difference between the magnitudes of the interpolation models of 2023 and 2018

The difference in the magnitude of the field along the line X = 0, Y = -16…+16 mm in the measurements of 2023 and 2018 is presented in Fig. 9.

A comparison of the field distribution of interpolation models for the entire measurement area is shown in Fig. 10.

CONCLUSIONS

It was shown that the metrological characteristics of the manufactured magnet have not undergone significant changes in five years. This makes it possible to use it for a long time to determine the energy of a technological electron accelerator.

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Article received 30.04.2024

ДОВГОТРИВАЛА СТАБІЛЬНІСТЬ ПОЛЯ МАГНІТУ ІЗ SmCo-СПЛАВУ ДЛЯ ПРИСКОРЮВАЧА

В.О. Бовда, О.М. Бовда, І.С. Гук, В.М. Лященко, А.О. Мицикoв, Л.В. Онищенко, В.М. Подорожкін

Виконано порівняння вимірів топології магнітного поля постійного магніту, виготовленого з використанням рідкоземельного сплаву Sm_2Co_{17}, з інтервалом 5 років. Одержані у 2023 році дані свідчать про те, що метрологічні характеристики магніту залишились у межах, які були визначені у дослідженнях, їх проведені у 2018 році.