THE MAGNETIC MEASUREMENT OF CONVENTIONAL MAGNETS FOR ELECTRON BEAM ACCELERATOR OF NORTHWEST INSTITUTE OF NUCLEAR TECHNOLOGY*

Zhuo Zhang#, Yang Li
Institute of High Energy Physics, CAS, Beijing 100049, China

Abstract

The project of electron beam accelerator is worked together completed by NINT (Northwest Institute of Nuclear Technology) and IHEP (Institute of High Energy Physics, China). Conventional magnet of the project includes a total of three dipole magnets, four quadrupole magnets, six solenoid magnets, and four correction magnets. All of magnets to completed the measurement by IHEP hall measuring equipment. The integrated magnetic field measurement of the arc-shaped dipole magnet requires simultaneous movement by the X-axis and the Z-axis, using Labview software written a new measurement procedure, the new measurement procedure has been completed by setting the measuring angle and the measuring radius. All measurement results of conventional magnets have reached the physical design requirements, and each magnet were carried out more than twice the measurement, the reproducibility of the measurement results are better than one-thousandth, fully meet the design claim of NINT.

INTRODUCTION

NINT accelerator is the strongest low-energy high-energy electron beam accelerator in China, which can produce uniform large area low energy electron beam and pulsed hard X-ray. It is mainly used for material thermodynamics effect, hard X-ray ionizing radiation effect, nuclear testing technology, Beam physics and other physical experiments.

In order to improve the electron beam energy to obtain the pulse hard X-ray which satisfies the electromagnetic pulse effect of the system, the magnetic system is improved and the magnetic field strength and uniformity are improved [1]. This can produce less than 30ns, the pulse width is less than 60ns, the average photon energy is less than 100keV Pulsed hard X-ray, which in line with the system of electromagnetic pulse effect research needs. The main technical indicators of accelerator are shown in Table 1. Four types of magnets are shown in Figure 1.

Table 1: Parameters of the Accelerator

	Design specifications	Test Results
Diode impedance/ Ω	2	2
Diode peak voltage/V	0.9	0.92
Diode peak current/MA	0.55-0.65	0.72
Pulse Width/ns	70-80	70-80
Beam spot diameter/mm	≥50	80-100

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#zhangz@ihep.ac.cn

Fig.1 Four types of magnets (Note:From left to right, first line, the dipole magnet, the quadrupole magnet; second line, the solenoid, the correction magnet).

Conventional magnet of the project includes a total of three dipole magnets, four quadrupole magnets, six solenoid magnets, and four correction magnets. Among them, the path of integral magnetic field measurement for dipole magnet is curved

According to the physical requirements of this experiment, first, a new program of measurement has been written by Labview software. The completion of the measurement of the arc path requires the Hall probe X axis and Z axis to move together. According to the formula of polar coordinate, we need to set the parameters including the angle and radius of the magnet, the step size measured at each step. The procedure can be calculated X axis and Z axis need to move the distance for each step; you can complete the arc measurement. Second, the preparation for hardware, the device of measurement and collimation. The device about measurement includes the Hall-probe measurement facility, the power supply and the magnets;

the device of collimation includes theodolite, Level and collimation target.

THE DESCRIPTION OF PROGRAM

First, the measurement angle, the step angle, the radius had been determined, and then compile the program by the formula of polar coordinate, so that the program can determine the distance of the Hall probe needs to move, and finally, the data is read into the program, we can start measuring.

The Tesla meter is via RS-232 serial port to communicate with the computer. The main program consists of several parts, the serial port is defined, write, read, close, data acquisition (temperature and magnetic field values).The main structure of the program is the while loop and conditional structures.The program flow diagram and the front panel of the program is shown in Fig. 2.

Program initialization

↓

Enter the measurement angle, the step angle, and the measurement radius

↓

Read the measured points and collected the data of magnetic field

↓

Save the data and close the program

Figure 2-a: The program flow diagram.

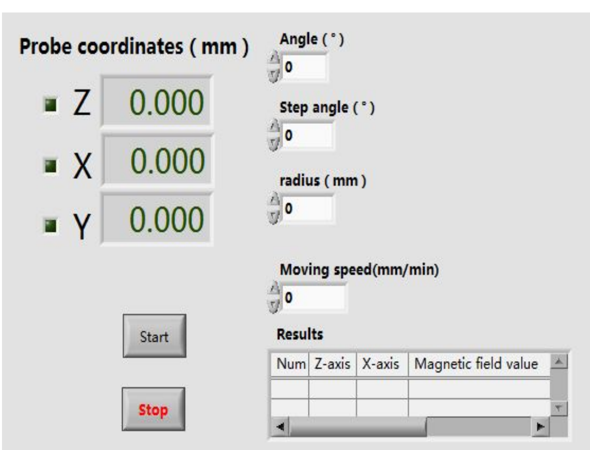

Figure 2-b: The front panel of the program.

THE DESCRIPTION OF HALL-PROBE MEASUREMENT FACILITY

The Hall-Probe measurement facility is a 3-axises motion bench. The movement of 3-axises(x, y and z) can be operated by computer. The positioning accuracy of x, y and z axis is ±0.001mm and the positioning repeatability accuracy is ±0.01mm. In addition, this machine can be also used to adjust the rotation and pitch adjustment probe ensure that the probe can measure the magnetic field perpendicular to enter the area of the magnet, so that the total is a five-dimentional adjustment system. The Teslameter and Hall probe are produced by Group3 Led. The sensitive of the MPT-141 Hall Probe is 1×0.5(mm).

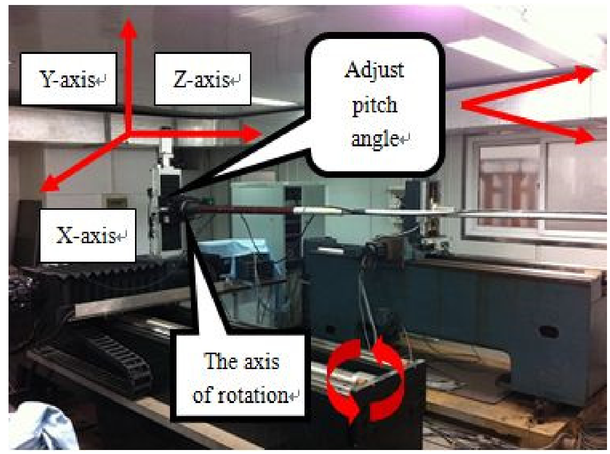

Figure 3: Hall-Probe Measurement Facility.

The DTM-151 Digital Teslameters offer accurate, high resolution measurement of magnetic flux densities, with direct readout in tesla or gauss, and serial communications by fiber optics or RS-232C for system applications.The instruments are light and compact, and the probes are easy to use. The DTM-151 has been engineered to withstand the severe electrical interference produced by high voltage discharge [2].

Group3 Hall probes are built to be as robust as possible for a small, precision device.However, it is most important that certain precautions be taken when handling and installing probes so that they are not damaged or destroyed [3].

Table 2: The Performance Overview of DTM-151 and MPT-141

Hall Probe	MPT-141	The measurement of maximum magnetic field	3T
Sensitive area(mm)	1×0.5	Zero drift(μT/ºC)	±1
Accuracy/25 ºC	±0.01%		

THE PROCESS OF MEASUREMENT

The Content of Measurement

The angle of the dipole magnet is 45°. The measured current is 232A. The requirements of measurement include the distribution of the excitation curve and the integration field. And then the uniformity distribution of the magnet can be calculated by the result of the integrated field distribution.

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The diameter of the quadrupole magnet is 20 mm. The measured the current is 15A, the horizontal range of integral measurement path is (-8mm)-8mm.

The measurement of current for Solenoid Magnets is 210A. Integral magnetic field requires three integral lines; the horizontal position is ± 10mm and 0.

The measuring current of the correction magnet is 15A. The measurement mainly includes excitation curve, integral field distribution (Bx direction and By direction).

The Process of Collimation

The collimation of magnet is by Theodolite and Level. These devices are shown in Fig. 4.

(1) The theodolite has been levelled, and then the probe has been moved back and forth along the Z axis for alignment of the theodolite.

(2) Adjusted the level of the magnet by the Level and the engraved lines of the magnet.

(3) Adjusted the rotation of the magnet by the theodolite and the engraved lines of the magnet.

The collimation of the magnet has been completed by the above steps.

Figure 4: The Theodolite and Level.

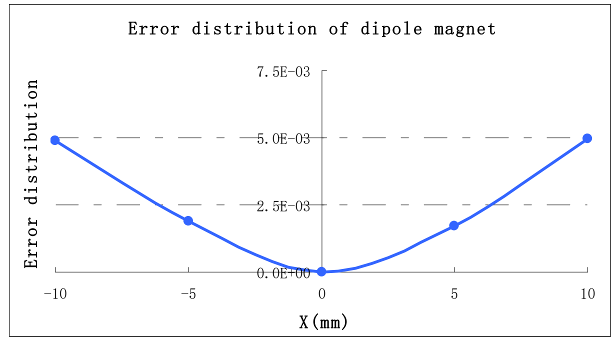
THE RESULTS OF MEASUREMENT

The part of the results of measurement is shown in Table 3 and Fig 5.

Table 3: The part of results for measurement

	Effective length/mm		Center field value/Gs	
Magnet	**Theoretical**	**Measured**	**Theoretical**	**Measured**
Quadrupole	≥145	147.6	≥1020	1026.6
Correction	≥228	230.2	≥113	116.2

	Excitation efficiency	
Magnet	**Theoretical**	**Measured**
Correction	≥90%	91.6%
Solenoid	≥95%	99.6%



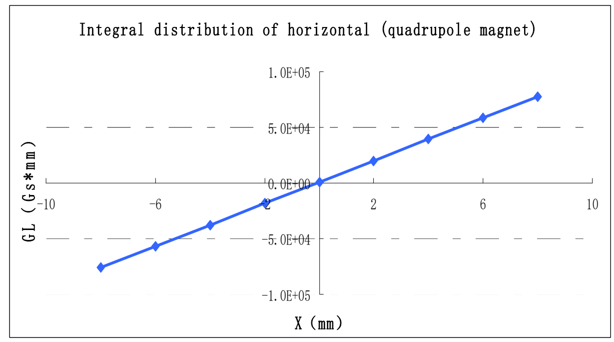


Figure 5: The part of results for measurement.

CONCLUSION

According to the measurement results, the effective length and the center field value of the quadrupole magnet are in the theoretical value.

The four sets of coils for the solenoid, when the magnet loads 240A current, the central magnetic field value and the integral value also meet the design requirements, the error field distribution is better than 7.0E-05.

The integral error distribution of the diamagnetic and correcting magnets is less than 5.0E-03 (the error distribution required by the theory).

The excitation efficiency of all magnets more than 90%.

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REFERENCES

[1] S.Yang, “*Transformation of the Flash II accelerator*”, Oral Report, Beijing, (2016).

[2] Group 3, DTM-151DIGITAL TESLAMETER with serial communications User’s manual, (2007).

[3] M. Musardo, etal, *“3D Hall Probe Calibration System at Insertion Device Magnetic Facility at BNL”*, IPAC’2013.