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THE MAGNETIC MEASUREMENT OF ENHANCER-DIPOLE MAGNET FOR CEPC*

Zhuo Zhang#, Hai-Jing Wang,
Institute of High Energy Physics, CAS, 100049 Beijing, China

Abstract

The CEPC (Circular Electron Positron Collider) project is in the pre-research stage. When the beam energy of booster is 120 GeV, the magnetic field of deflection magnet is 640 Gs. In order to save funds for scientific research, we also consider the injection energy of 6 GeV, the magnetic field of deflection magnet is 32 Gs. At the different current, the magnetic field value of the enhancer-dipole magnet can reach the beam energy range of 6 Gev-120 GeV. In such a requirements of magnetic field, the stability of the magnetic field value, repeatability, magnet magnetism, has become an important data for the design parameters of enhancer-dipole magnet. The magnet is measured with the Hall-Probe measurement facility by IHEP. In this paper, first written the procedure of motor control and collection by Labview software, then hen the excitation curve（repeat the measurement six times）, transverse field distribution（repeat the measurement three times）, and integral field distribution are measured. Based on the results of the analysis of large amounts of data, the stability and repeatability of the enhance-dipole magnet in different magnetic fields has summarized and analyzed.

INTRODUCTION

The Standard Model (SM) of particle physics can describe the strong, weak and electromagnetic interactions under the framework of quantum gauge field theory. The theoretical predictions of SM are in excellent agreement with the past experimental measurements.

After the discovery of the Higgs particle, it is natural to measure its properties as precise as possible, including mass, spin, CP nature, couplings, and etc., at the current running Large Hadron Collider (LHC) and future electron positron colliders, e.g. the International Linear Collider (ILC). The low Higgs mass of ~125 GeV makes possible a Circular Electron Positron Collider (CEPC) as a Higgs Factory, which has the advantage of higher luminosity to cost ratio and the potential to be upgraded to a proton-proton collider to reach unprecedented high energy and discover New Physics [1].

The Circular Electron Positron Collider (CEPC) is a long-term collider project, which will be divided into two phases. The first phase will construct a circular electron-positron collider in a tunnel with a circumference of 50 – 70 km, and detectors installed at two interaction points. The machine is expected to collide electron and positron beams at the center-of-mass energy of 240 – 250 GeV, with an instantaneous luminosity of 2×1034 $cm^{-2}\,s^{-1}$. The baseline design considers a single ring in a 50/70 km tunnel and electron/positron beams following a pretzelled orbit in the ring. CEPC will serve as a Higgs Factory where precise measurement of Higgs properties will be its top priority. In addition, CEPC will allow stringent tests of the Standard Model (SM) with precision measurements at the Z pole and WW thresholds. The second phase of the project will upgrade the machine to a proton-proton collider with an unprecedented center-of-mass energy of 50 – 70 TeV. The accelerator parameters are shown in Table 1.

Table 1: Parameters of the Accelerator

Accelerator Parameters		
Beam energy[E]	GeV	120
Circumference[C]	Km	53.6
SR power[P]	MW	50
Filling Factor[K]		0.71
Bending radius[ρ]	m	6094
Lorentz factor[k]		234834.66
Magnetic rigidity[Bp]	T·m	400.27
N_{IP}		2
N_B		50

There are 5,120 dipole magnets in the Booster. Each magnet is 8 m long; it has two C-shaped steel-concrete cores of about 4 m length, which are installed end to end in groups. The field in the magnet gap will change from 32 Gauss to 614 Gauss during acceleration from injection energy to extraction energy, as shown in Fig.1. Due to this very low field, the cores are composed of stacks of low carbon steel laminations, 1.5 mm thick, spaced 6 mm apart. The gaps are filled with a cement mortar. The filling factor of 0.2 gives a small drop of ampere turns at the maximum field.

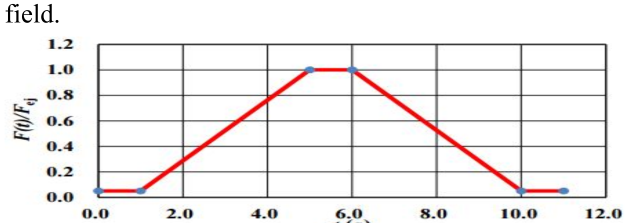

Figure 1: The magnetic field cycle of the Booster.

*Work supported by IHEP
#zhangz@ihep.ac.cn

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According to the physical requirements of this experiment, first, a new program of measurement has been written by Labview software. The measurement of the integration of the field distribution requires that the X axis and Z axis of the Hall probe be moved together. In the program, set the way through the cycle and the order of execution, to solve this problem. The program can calculate the number of completed steps to make the two axis measurements. So we can complete the 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 distance, the steps had been determined. Then The program can determine the range of X axis and Z axis which needs to be measured, 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-a and b.

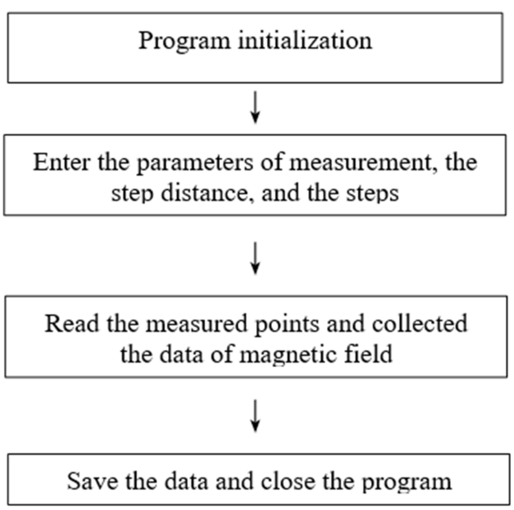

Figure 2-a: The program flow diagram.

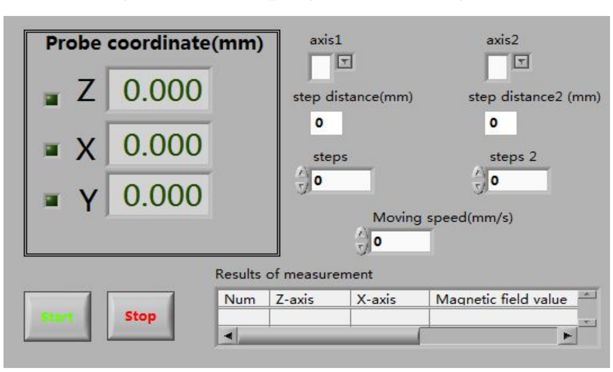

Figure 2-b: The front panel of the program.

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).

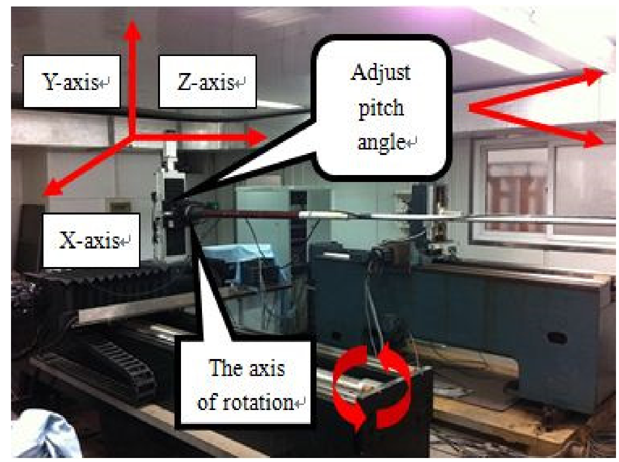

Figure 3: Hall-Probe Measurement Facility.

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

The Performance Overview			
Hall Probe	MPT-141	Maximum field	3T
Sensitive area	1×0.5	Zero drift (μT/ºC)	±1
Accuracy/25 ºC	±0.01%		

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THE PROCESS OF MEASUREMENT

The Content of Measurement

The Magnet is divided into high stacking coefficient and low stacking coefficient of two parts. The requirements of measurement include the distribution of the excitation curve, the integration field, the distribution of transverse magnetic field. And then the uniformity distribution of the magnet can be calculated by the result of the integrated field distribution. The excitation efficiency can be calculated by the excitation curve.

The excitation curve measurement current from 25A to 900A, the probe is placed in the magnet's mechanical center, a total of six measurements.

The current of transverse magnetic field and the integrating magnetic field is 50A, 100A, 150A, 200A, 520A, 900A. The horizontal range of the distribution of magnetic field path is (-30mm)-30mm.The measuring distance of each integrating line is 860mm. The horizontal range is (-30mm) to 30mm.

The Process of Collimation

The collimation of magnet is by Theodolite and Level. These devices and the magnet 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 magnet, theodolite and level.

THE RESULTS OF MEASUREMENT

The part of the results of measurement is shown in Fig. 5 to Fig 7.

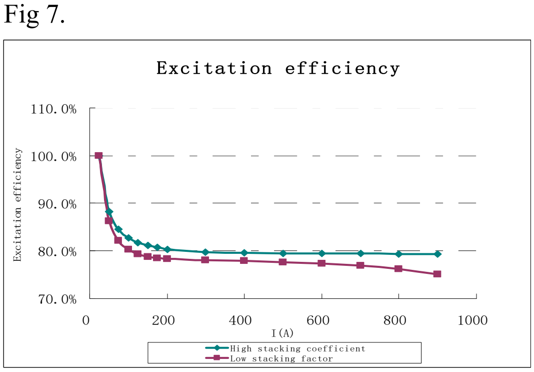

Figure 5: The excitation efficiency calculated by excitation curve.

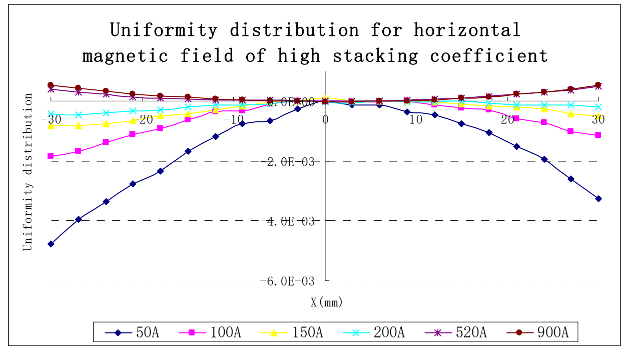

Figure 6: Uniformity distribution for horizontal magnetic field of high stacking coefficient.

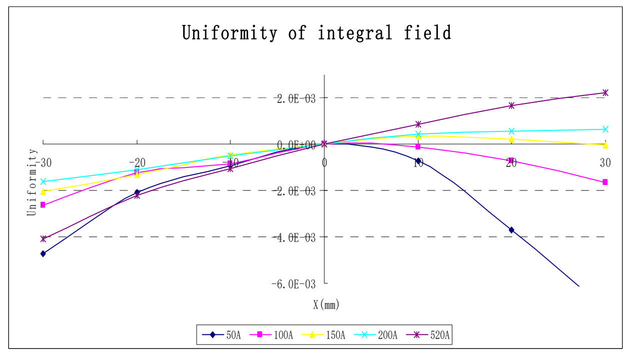

Figure 7: Uniformity of integral field.

CONCLUSION

According to the measurement results, the magnetism of the high stacking coefficient part of the excitation efficiency is 80%; the stacking coefficient part of the excitation efficiency is 75%.

The uniformity of horizontal magnetic field for magnet within 5 ‰.

The uniformity of integral magnetic field for magnet within 5 ‰.

The uniformity distribution required by the theory.

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