MAGNETIC FIELD MAPPING SYSTEM FOR SSRF*

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Abstract

A 3-D Hall probe magnetic field measurement device and the data acquisition system used to measure the prototype magnets of Shanghai Synchrotron Radiation Facility (SSRF) is briefly described in this paper. The measuring shaft, which is 2 meters long, consists of a carbon fiber rod with a rectangle Aluminium alloy tube, is driven by an AC servomotor. It can be made point by point and "on the fly" to measure the magnetic field. The motion ranges are X=400mm (Horizontal), Y=150mm (Vertical), Z=2600mm (Longitudinal). The positioning accuracy is less than 5 micrometers. The accuracy of the magnetic field mapping system can reach to $1x10^{-4}$.

1 INTRODUCTION

The 3.5GeV Shanghai Synchrotron Radiation Facility (SSRF)[1] is a 3rd generation synchrotron radiation light source. In project blue print there are 40 C-type dipoles in the electron storage ring and 36 H-type dipoles in the booster respectively. According to the schedule of the project, several prototypes of magnets of the storage ring and the booster have been researched and developed in order to optimize the performances of the magnets. It is necessary to measure the parameters of magnets, such as the field strength, the field uniformity, the field integral and so on. In order to meet the project schedule and the technical requirements of the measurements[2], A high precision magnetic field mapping system based on Hall probe has been developed. The mapping system includes a mechanical motion bench, a motor controller, a high precision DC power supply, a data acquisition and control system as well as operation software etc.

2 HARDWARES

2.1 Mechanical Design for Motion Bench

In order to enable the measuring rod to move steadily during measurements, we select a used-screw lathe bed with high rigidity as measuring bench. The motion ranges of the bench are as follows:

X = ±200mm (Horizontal),
Y = ±75mm (Vertical),
Z = ±1300mm (Longitudinal)

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2.2 Ball Screw and Slide Guides

We select a commercial ball screw and slide guide with high precision. As we know, the ball screw has high efficiency on transmission due to low friction (rolling frictions) between the screw axis and the nut. The energy consumption is about 2/3 of the conventional feed screw. The ball screw has very small torque because of the rolling contact. It do not bring the stick-slip as in the conventional feed screw. Therefore, accurate operation and fine motion are possible with this ball screw. Slide guides are highly precision with a good rigidity, and linear guide blocks based on the "rolling motions" of steel balls and cylinder rollers. These guides have a variety of advantages such as small frictional coefficient, no stick slip, and smooth linear motion enabled under high loads. Since they can also maintain their high efficiency and advanced performance for a long lifetime, they can meet a wide range of applications, from general industrial to precise machinery. The model of ball screw and slide guides which we selected are BNFN5005L-5RRG2+ 300LC1 and LGR35-L300-CA-Z1, respectively.

2.3 Servo System

We choose an economic, commercial CNC as the power motion controller. The CNC adopts 32-bit high-performance microprocessor and high-speed memory. It has ample CNC functions with high speed, high precision, high performance and intelligent digital servo system. It is easy to communicate with external industrial PC via serial interface RS232. The motor adopts brushless AC servomotor instead of step motor. It has

Figure1: The photograph of Measuring Bench

many features such as running smoothly, low noise, high load capacity and high torque etc. A high-reliability pulse encoder is used inside the motor. The resolution of encoder is 8192/rev. The nominal longitudinal velocity is 1m/minute during in the measurements is selected.

2.4 DC Power Supply

The specifications of the power supply are as follows:

Model:	Danfysik 853T
Maximum current	1000A
Voltage:	50V
Stability class:	3ppm
Interface:	RS232/422 and IEEE488
Size:	1.1 x 0.61 x1.8 m^3
Weight:	~700Kg

2.5 Hall Probe

The Hall probe system is designed to measure the magnetic field at discrete points in the magnet. The Hall Probe can be scanned in all three linear axes with a resolution of 0.005 mm in the longitudinal and horizontal direction and 0.01 mm in the vertical direction. The Hall probe and Tesla-meter supplied by LakeShore 450 are used. The resolution of Hall probe is 0.05 Gs and the sensitive area is 1.0mm in circular. The probe's response is calibrated against NMR probes in a standard dipole magnet. Only the vertical (Y) component B_y is mapped with the Hall probe system. Field maps are taken in the media plane (y=0) at X=0, ±10, ±20, ±30mm.

2.6 Measuring Rod Design

To ensure the measuring rod with higher rigidity, the lowest sag and no falter during the measurement, a carbon fiber rob combine several piece of rectangular aluminium alloy tube and they have different cross section is used. The Hall probe is throughout the centre of the rod. The sketch of the measuring rod is shown in Figure 2.

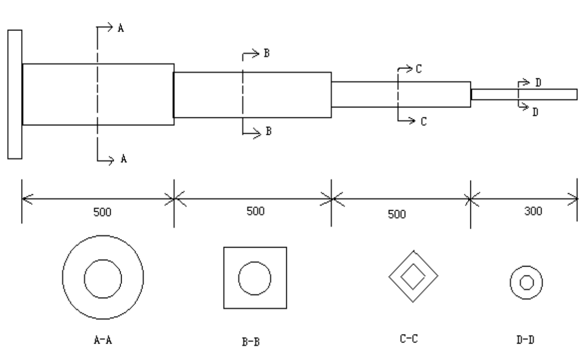

Figure 2: The sketch of the measuring rod

3 SOFTWARES

3.1 Control and Data Acquisition System

An Industrial PC is used in this system. It communicates with the CNC via a RS232 to control the measuring bench to move, and then interface with the Hall Tesla-meter and DMM (HP34970A) via GPIB to read data, such as the field strength, the magnet current from DCCT, the temperature of magnet and press of cooling water for magnet and power supply etc. The Hall probe is normally oriented to measure vertical magnetic fields as required. The probe moves to the desired location and then takes the data once it stops. The time taken for a 1.2 meters long range with a reading every 5-mm is approximately 28 minutes (less than 3s per point). The raw data is logged to a hard disk. A hardcopy output summarizing the field parameters is produced for each magnet. The block diagram of control and data acquisition system is shown in Fig. 3.

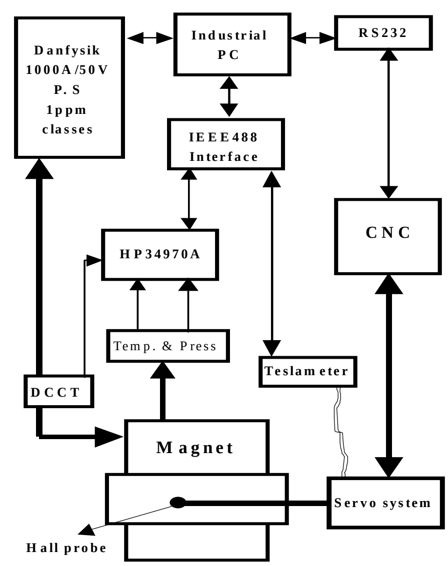

Figure 3: The block diagram of control and data

3.2 Operator Interface

The system is fully automatic. The data acquisition and the instrument commands are controlled by a local Industrial PC through the software called HP Vee based on a commercial software package. HP Vee is a visual programming language for developing programs in instrument control and data acquisition. We can easily create a visual program by linking together functional objects to form a block diagram. The function of the program is similar to that of NI LabView.

The visible parts of the control system and data acquisition are the operator interface, i.e. the consoles and the displays. A highly resolution colour control panel provides a friendly communication for the operator. The operating page layout for the magnet power supply is shown in Figure 4.

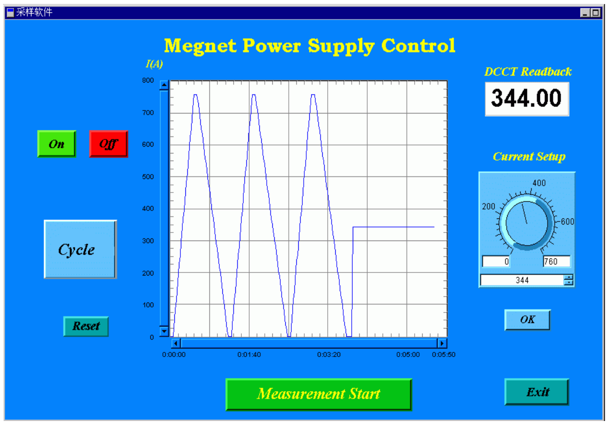

Figure 4: Operating page of the magnet power supply

3.3 Field Measurements

Before measuring, three standardization cycles are performed The standardization procedure ramps the magnet current from 10 amps to 770 amps at a rate of 5amps/sec, and then settle at the 770 amps for 10seconds before ramping down to 10 amps in the same way. The magnet is allowed to settle for 60seconds before proceeding. The flowchart of the control and the measurement is illustration in Figure 5.

Before measurement, the chip plane of Hall probe has

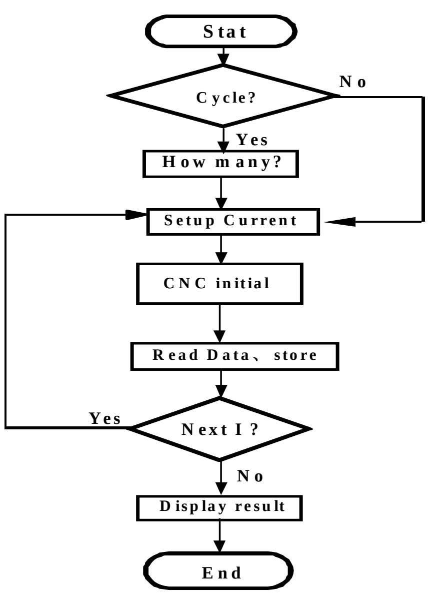

Figure 5: The flowchart of the control and measurement

to be installed perpendicular to the vertical component of magnet field. The measuring rod with Hall probe is placed in the area of maximum magnetic field and then rotated back and forth slowly until the maximum signal appears on the Tesla-meter. The measuring rod is then fixed in this position.

The Hall probe moves along the median plane of the magnet. At the same time, the Tesla-meter readings, the probe's positions and the local time etc. are saved in the hard disk with the same file name. As the measuring finished, by proper computer post-processing of the data, one can obtain the magnetic field distribution, the inhomogeneity and the field integrals etc. The operating page layout for magnet measurement is shown in Fig. 6.

Figure 6: Operating page of the magnet measurement

4 CONCLUSION

The magnetic field mapping system based on the Hall probe has been developed for SSRF and successfully tested. The advantages of this system are running smoothness, high reliability and higher positioning precision. The field integral of the prototype magnet was measured. The repeatability of the field integral is less than 1×10^{-4}. The accuracy of the positioning in X and Z directions is less than 5 micrometers, calibrated against laser Interferometer in room temperature with temperature compensation and Y direction is less than 10 micrometers. They are all agreement with the requirements of the magnets[1].

5 ACKNOWLEDGMENTS

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