APPLICATION OF MAGNETIC FIELD INTEGRAL MEASUREMENT OF MAGNET MODULE TO RESEARCH ALTERABLE GAP UNDULATOR

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Abstract

A set of magnetic measurement system and a suitable magnetic field optimization method for an In-Vacuum Undulator (IVU) with alterable gaps have been developed. The method is based on assembling orders and directions of all magnet modules for correcting rms optical phase error, electron trajectory and multipole components of the IVU. Magnetic field distributions on axis and off axis of every magnet block module are measured. Then the appropriate magnetic block modules will be chosen from measured magnet modules according to a sorting algorithm and assemble them to two inner girders of an IVU. This paper will describe a magnetic field measurement system, magnetic field optimization method and optimized results of an IVU with a period of 20 mm.

INTRODUCTION

Five IVUs with different periods designed to deliver high brightness photo beam have been running at Shanghai Synchrotron Radiation Facility (SSRF). In order to get high quality synchrotron radiation and reduce the influence to beam from IVUs, the magnetic field property of the IVU must meet strict designed physical requirements. The requirement of optical phase error is less than 2.5 degree. The normal and skew multiple components including quadrupole, sextupole and octupole are less than 50 Gs, 60 Gs/cm and 100 Gs/cm^2 respectively. The transverse magnetic field integral distribution is nonlinear under different gaps, so the optimization to magnetic field integral distribution is extremely important before assembling magnet block modules to inner girders. In addition, the flatness of magnet block array has obvious influence to beam, so shimming values to the IVU must be as small as possible. Accounting to above two issues, we must accurately measure the magnetic field integrals of every magnet block module and optimize these magnetic field data according to a proper algorithm.

MAGNETIC MEASUREMENT BENCH

A complete magnetic field measurement system for measuring magnetic field parameters of every magnet block module has been built. A pair parallel translation coils strung between two mirror towers are used to scan the vertical and horizontal integral field strengths in the x-y plane such that it will provide us the multipole field components. One tower has a manual lead screw to tension the coils. The translation coil measurements provide only relative values of magnetic field integrals of the magnet module [1] [2]. The precision of the translation coil system is 5 Gs.cm. A mini coil with a half of IVU's period length is used to measure the on-axis integral field strength and its precision is 3Gs.cm. The above measured data are inserted into the sorting code to optimize the integral multipole field components and optical phase error respectively. Monte Carlo algorithm [3] is used in the sorting code. As Fig.1 shows, two translation coils (horizontal coil and vertical coil) are setup on two translation stages with parallel each other, and a half period coil embedded in a G10 staff is setup a translation table which is orthogonal with another two stages. A picture of the measurement coils and magnet block module is shown in Fig. 2. A magnet block and four iron poles are installed aluminum keepers in the magnet modules. The poles are fixed on keepers. The measured magnet block can be freely inserted into the gap between two middle iron poles.

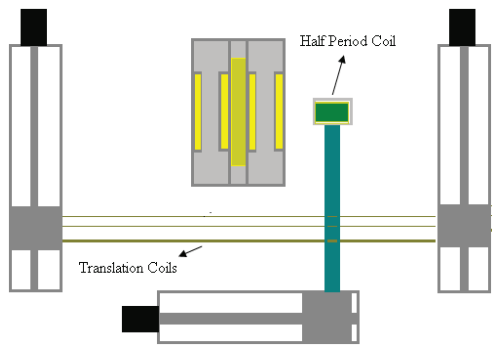

Figure 1: Layout of magnetic measurement system

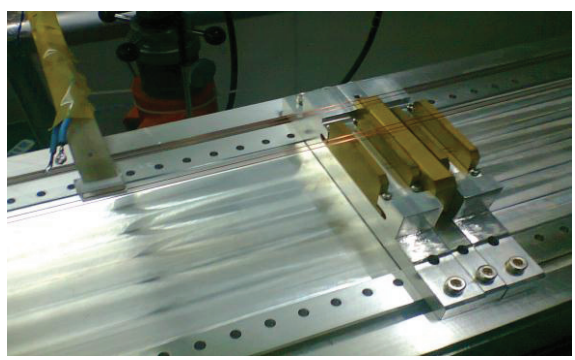

Figure 2: Picture of the measurement system

Fig. 3 shows the schematic layout of the system control and data acquisition (DAQ) architecture. Two translation coils are with turns 20 and width 3 mm respectively. The half period coil is with turns 30 and

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width 5 mm. We choose these parameters of measuring coils in consideration to a ratio of signal to noise and an appropriate spatial resolution. The translation stages are drove by step motors. Linear encoders are used as position feedback. The motion control and DAQ system for the magnetic field measurement consists of a high precision digital integrator PDI5025, servomotors and an industrial PC. The integrator is used to integrate induced voltage signal from coils. The induced voltage from coils is preprocessed using low pass filters before connected to PDI5025 for filtering low frequency noise. Pulses from LPT of the computer are used to trig the measurements of the translation coils. The internal Timer of PDI5025 is used to trig the measurements of the half period coil.

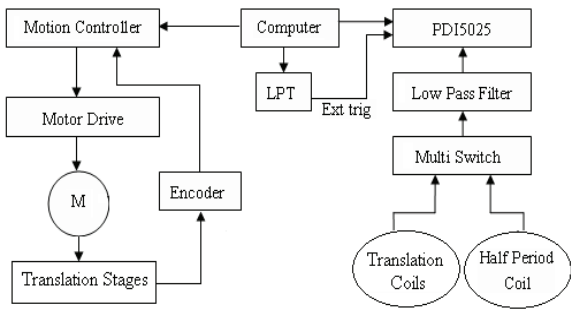

Figure 3: Schematic layout of motion control and DAQ

The National Instruments LabVIEW is used to program the human machine interface and control logic for the magnetic field measurement system [4]. Fig. 4 shows the program's interface. Its functions include motion control, data acquisition and data processing and analysis. The program interface is also able to display warning and error message, record detailed real-time parameters of total system.

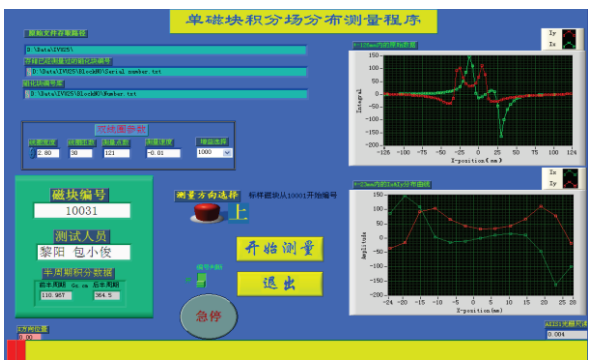

Figure 4: Interface of measurement program

In addition, the total measurement system is in a temperature-controlled laboratory with a stability of ± 0.3 ℃ for making sure high measurement repeatability.

MEASUREMENT AND OPTIMIZATION

Two surfaces of every block module will be measured with translation coil system and the half period coil system. The translation coil or half period coil will park a rest position when one of them starts measuring in order to avoid position confliction each other. The distance between two centerlines of translation coils is 20 mm. So, initial measured data from vertical coil and horizontal coil must be shifted for getting same starting and stopping point in the same coordinate system. After measuring all magnet modules, the appropriate magnetic block modules will be chosen from these block modules according to Monte Carlo algorithm and assemble them to inner girders of IVU with a designated order. Fig. 5, 6 show the measured results of a part of magnet block modules.

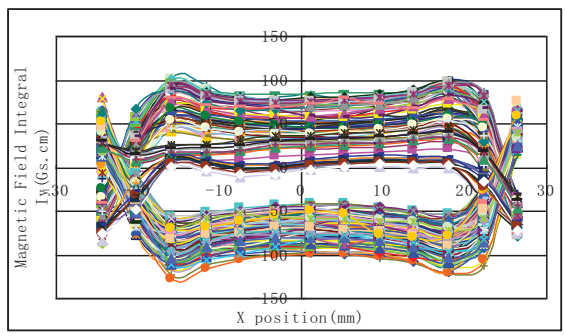

Figure 5: Magnetic field integral distribution of By

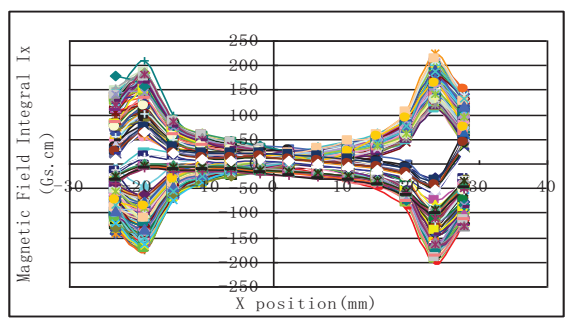

Figure 6: Magnetic field integral distribution of Bx

Fig. 7 shows half period field integral of some magnet modules, and we can observe a big discreteness in these data. The discreteness will generate notable phase error if the optimization is not done before assembling magnet modules to inner girders. As Fig. 8 shows, the theoretical shimming values of one magnet array are more than ±0.1 mm before phase error optimization. And the values are controlled into the range of ±0.03 mm after the optimization. As Fig. 9 shows, there is a very big theoretical quadrupole component before multipole components optimization. And after that, the quadrupole component obviously decreases and almost meets with the designed requirements. A big theoretical sextupole component occurs before optimization and it greatly decreases after optimization, as Fig. 10 shows.

After multipole components optimization, some components can not meet the physical designed requirements yet, so magic fingers as Fig. 11 shows are used to correct the multipole field errors [5-6]. The magic fingers are located on the two ends of inner

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girders. The last measured results show that magic fingers are efficient to make multipole components to satisfy the requirements of designed specifications. Fig. 12 shows a picture of magic fingers with three rows of holes used to assemble cylindrical magnets. Simulated Annealing Algorithm is used to get the best arrangement of the cylindrical magnets.

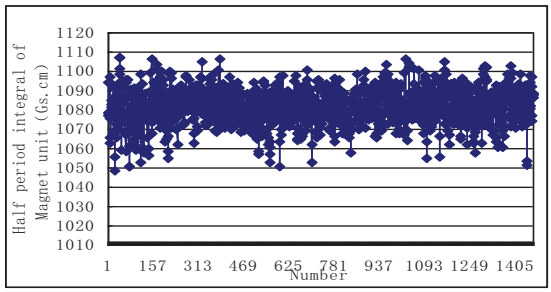

Figure 7: Half period field integral of magnet modules

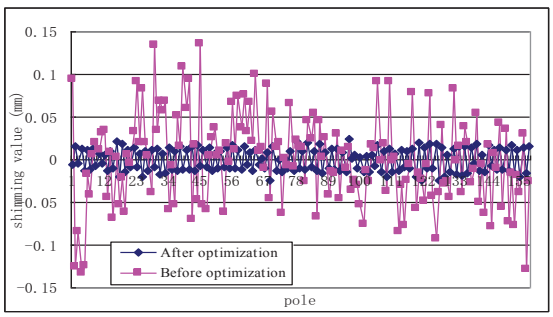

Figure 8: Theoretical shimming values before and after optimization of a single magnet array

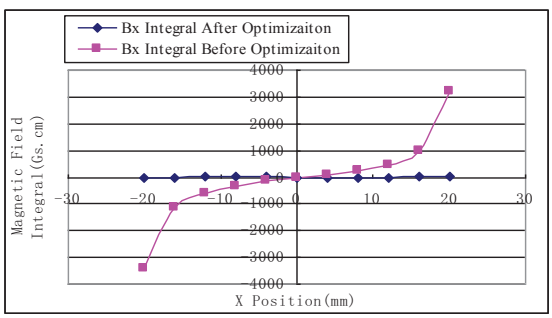

Figure 9: Magnetic field integral (Bx) before and after optimization

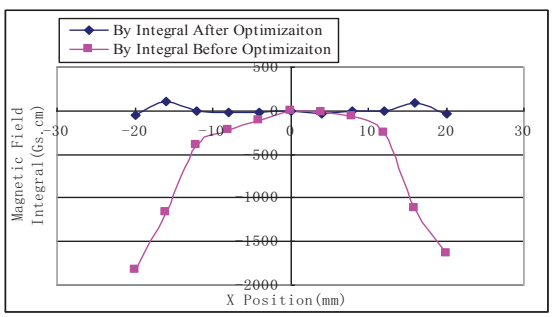

Figure 10: Magnetic field integral (By) before and after optimization

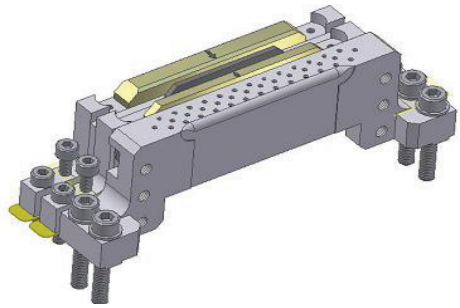

Figure 11: 3D model of Magic Fingers

Figure 12: Picture of Magic Fingers

CONCLUSION

This article has described the experimental process of the field correction of an IVU20 installed in storage ring of SSRF. The results have been satisfactory because both the phase error and total multipole components have been reduced. Magic fingers are also necessary to make the magnetic performances of IVU to satisfy last designed specifications. However, we also found that the bad mechanical tolerances and assembly errors result in some obvious additional phase error shimming values after assembling all magnet modules to inner girders. Considering this issue, the present optimization method and magnetic measurement system should be modified in future IVU research.

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