MAGNETIC FIELD MEASUREMENT SYSTEM FOR CYCHU-10*

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Abstract

A 10MeV H- compact cyclotron (CYCHU-10) is under construction in Huazhong University of Science and Technology (HUST). This paper presents a magnetic field measurement system for measuring the cyclotron magnet. A Hall probe and a granite x-y stage are adopted in the project. The Cartesian mapping will replace traditional polar system. The motion control and data acquisition system for the magnetic field measurement consists of a Teslameter and Hall probe, servomotors, a motion control card, optical linear encoder systems and an industrial PC. The magnetic field will be automatically scanned by this apparatus, and a flying mode will be the main running mode to reduce measure time.

INTRODUCTION

With the growing demands in medical applications, especially for Positron Emission Tomography (PET), the research and development of low energy compact cyclotrons becomes more and more important in China. A 10MeV H- compact cyclotron (CYCHU-10) is under construction in Huazhong University of Science and Technology now.

The main parameters of CYCHU-10 are listed in Table 1. A Tosca magnet model of CYCHU-10 is shown in Figure 1.

Table 1: Main Parameters of CYCHU-10

System specification	Value	Unit
Maximum energy	10.0	MeV
Ion source	Internal PIG source	
Hill angle	48-53	degrees
Hill/valley gap	2.4/9.6	cm
Average magnetic field	1.63	T

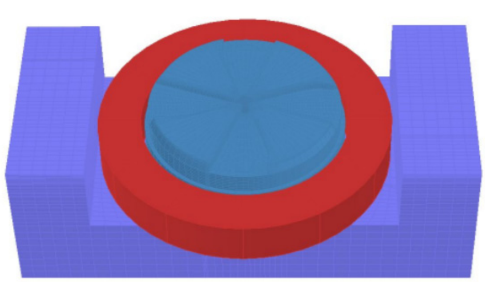

Figure 1: Tosca magnet model of CYCHU-10.

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Considering that the main purpose of PET cyclotrons is to produce short-lived isotopes and it is supposed to be compact for locating in hospital, the cyclotron magnet adopts the design of small valley gap (SVG) which can provide higher average magnetic field that reduces magnet pole size [1]. On the other hand, we adopt internal PIG source, so it's difficult to use traditional polar magnetic measurement system [2]. In this case, a Cartesian measurement system is adopted to replace the polar system, and the measurement stage will be located beside the cyclotron.

A similar design scheme, which gives us a lot of help, has been developed for the KIRAMS-13 cyclotron in South Korea [3].

The main parameters of the magnetic field measurement system are listed in Table 2. And Figure 2 illustrates the mechanical structure of the granite x-y motion stage.

Table 2: Main Parameters of the Magnetic Field Measurement System

System specification	Value	Unit
X scan capability	1100	mm
Y scan capability	1100	mm
Mechanical resolution	5	μm
Range of magnetic field	2.0	T

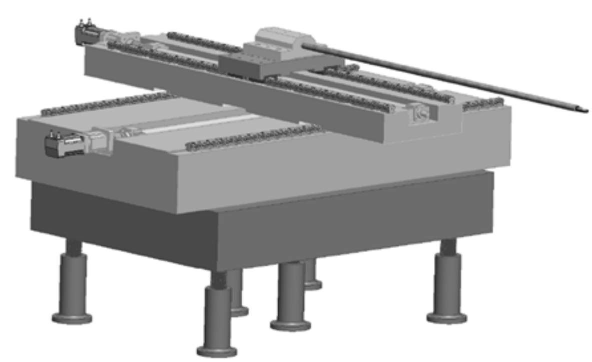

Figure 2: Assembling view of measurement stage.

MECHANICAL STRUCTURE

The concise view of the magnetic field measurement system is shown in Figure 3. The mechanical structure can be divided into three parts: the alignment support, the reference plane, and the x-y motion stage.

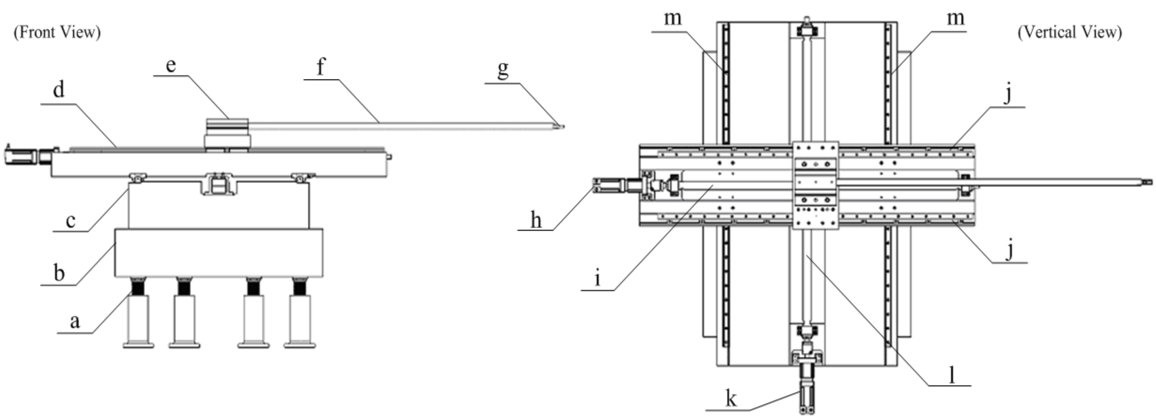

Figure 3: Concise view of the magnetic field measurement system. a: the alignment support; b: the reference plane; c: x-axis plane; d: y-axis plane; e: Hall probe carrier; f: supporting rod; g: Hall probe; h: y-axis motor; i: y-axis ball screw; j: y-axis guide rail; k: x-axis motor; l: x-axis ball screw; m: x-axis guide rail.

The alignment support is designed to adjust the height of the reference plane. The reference plane can provide an extremely high-precision planar. The x-y motion stage consists of x-axis stage and y-axis stage. Each of them has one motor, two guide rails, and one ball screw. The y-axis stage is mounted on the x-axis stage. The hall probe carrier is installed on the y-axis stage. A supporting rod, which is made of carbon fibre material, is fixed on the probe carrier. The hall probe is placed on the end of the supporting rod. The x-axis stage and y-axis stage are driven by the x-axis motor and y-axis motor separately. So the hall probe is able to scan a square area of 1100mm×1100mm.

A special attention is paid to the choice of material for the measurement system. Since granite is relatively stable, impervious and inflexible, it is widely used to build high-precision coordinate platform and reference plane. So we decide to use granite for the reference plane and the x-y motion stage of the magnetic field measurement system. It is able to provide higher accuracy during the measurement. Unlike the probe carrier of mapping system for KIRAMS-13 [3], a supporting rod is used to mount the hall probe. Comparing with the epoxy-fibre-glass, the supporting rod made of carbon fibre will cause less deformation at the end of it.

MEASUREMENT AND MOTION CONTROL SYSTEM

General Description

The block diagram of measurement and motion control system is shown in Figure 4. It consists of a Teslameter and Hall probe, two servomotors and drivers, one motion control card, two optical linear encoder systems and an industrial computer. The Group 3 DTM-151 Teslameter and MPT-141 Hall probe were employed. Panasonic A4 servomotors and Advantech motion control card PCI-1240U are used to drive the x-y motion stage. Renishaw optical linear encoder systems are installed on the x-y motion stage to provide precise position signal of the Hall probe. The magnetic field will be automatically scanned by this apparatus, and the flying mode will be the main running mode to reduce measurement time.

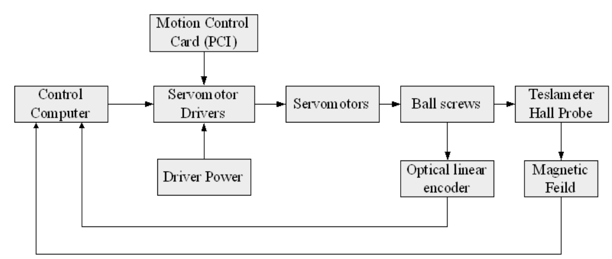

Figure 4: Block diagram of measurement and motion control system.

Hardware

The main hardware used in the measurement and motion control system is as below:

- Teslameter and Hall probe: DTM-151 Teslameter and MPT-141 Hall probe can offer accurate, high resolution measurement of magnetic flux densities, with serial communications by RS-232C for system application. It also provides ASCII control commands for users to manipulate the Teslameter remotely [4].

Table 3: Main Parameters of Teslameter

System specification	Value
Max measurement range	3T
Max Resolution	0.000001T (at 3.0T range)
Temperature Stability	±10ppm/□
Measurement rate	10 measurements per sec
Basic accuracy	0.01% of reading+0.006% of full scale

- Motion control system: IPC and PCI-1240U from Advantech Co. Ltd. are adopted to realize the motion control and data acquisition for the magnetic field measurement. Optical scale RGS20 and digital readhead RGH22 from Renishaw Co. Ltd are used to offer high resolution and high speed with stability and reliability to meet the requirement of our precision controlled movement.

Table 4: Main Parameters of PCI-1240U

System specification	Value
Max pulse output	4MPPS
Pulse output type	Up/Down or Pulse/Direction
Max encoder input	1 MHz
Encoder pulse input type	Up/Down or Pulse/Direction

Software

National Instruments LabVIEW is used to program the human machine interface (HMI) and control logic for the magnetic field measurement system. Figure 5 shows the motion control interface during the debugging LabVIEW gives a wide range of application cases of the motion control and measurement systems. The main functions and requirements are as blew:

- Provide a friendly HMI for the operator to use the measurement system. The operator interface can display the real-time parameters of the system and show the warning and error clearly.
- Provide a manual/auto dual-mode. Using the manual mode, we can drive the specified axis to make a point-to-point moving from the current position to the specified position. While using the auto mode, the program can drive x-axis and y-axis to move properly so that the measurement of a specified area can be completed automatically.
- Magnetic Field data taken by hall probe can be read accurately and saved properly for further analysis.

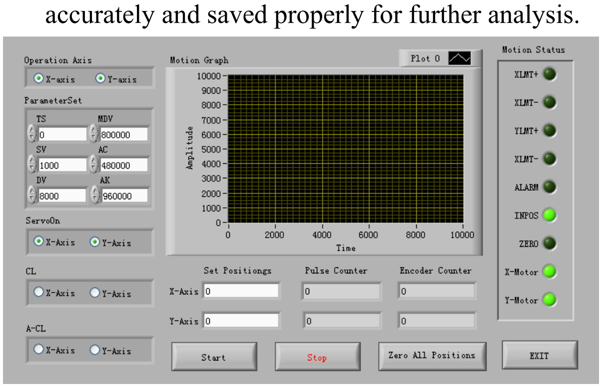

Figure 5: Motion control interface.

PROGRESS AND FUTURE PLAN

Until now, the granite structure of the measurement system has been manufactured. And the motion control system is completed too. Figure 6 and 7 show the general view of the granite x-y motion stage and the control cabinet for the measurement system. During the debugging work, the whole system runs well.

For the cyclotron magnet is still in the factory now, the magnetic field measurement will begin in June, 2009 on schedule.

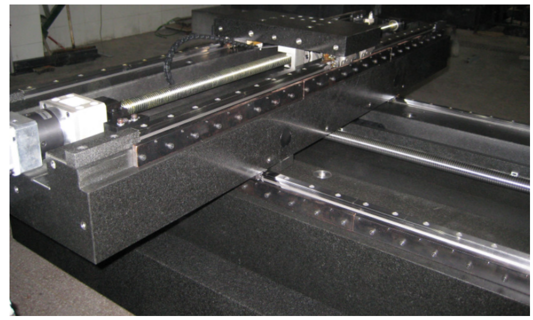

Figure 6: Granite x-y motion stage.

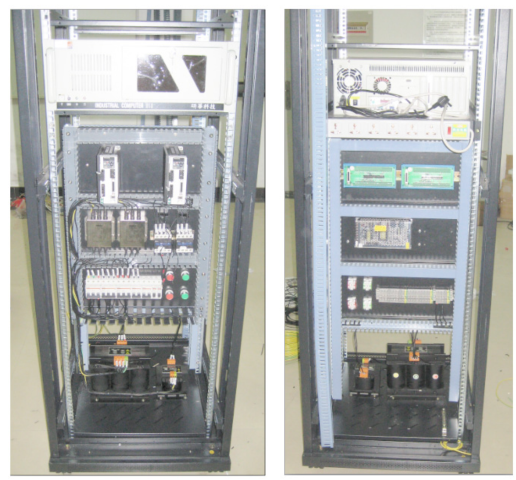

Figure 7: Control cabinet for the measurement system.

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