Control System Design

for High Precision Magnetic Analyzer

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ABSTRACT

High precision magnetic analyzer is one of key points in technologies of Chinese space solar telescope, which is under pre-investigation. Magnetic analyzer needs a modulation component to change its polarization state. For ground-based use, usually electroptics crystal KD*P is a good option. However KD*P needs a power supply as high as thousands volts. In space environment, such a high pressure source is hardly available. Therefore we have to use an alternative, an optomechical modulator. In the modulator, the related optical components rotate precisely to realize modulation. This raises a crucial request for position accuracy and positioning times of optical components rotation.

This paper describes our developing process of the electric control for the magnetic analyzer. Firstly, hardware facilities, control software design and test results as well are given. Then, some problems in manufacture and adjustment are analyzed and discussed. After overall optical, mechanical and electric tests, it shows that the accuracy of rotation position of the optical components is better than 10’’(p-p)(checking with a precise 24 sides’ standard); while time for rotating 90 degrees is less than 2 seconds. The results demonstrate that the magnetic analyzer has met the design requirements.

Keywords: magnetic analyzer, PCI-1751 Control Card, stepping motor, induction synchronizer

1. INTRODUCTION

In order to get rid of the restriction of earth atmosphere on solar observations, Space observation has become an important part of solar investigation. In recent 10 years, Chinese scientists have been planning to build a high accuracy space-based Solar Telescope, aiming to measure polarization of the magnetic fields at the precision of 10^{-4} .For this reason, some key techniques have to be settled in advance. Described below is one of them, a high accuracy magnetic analyzer.

A crucial part of magnetic analyzer is a modulation device to alternate its polarization detection mode. Those, working in ground-based system, usually use electric-optical crystal, such as KD*P. KD*P asks for power supply as high as several thousands volts. It would be somewhat troublesome to offer in space environment. In view of the fact that magnetic analyzer for space use requires relatively low time-resolution, we decide to utilize a rotating optical component instead.

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Although the rotating speed is slow compared to the KD*P, it is fast for mechanical components. So its positioning speed should be faster and positional accuracy should be very high. For this sake, mechanically we try close configuration ball bearings and linear ball track and electrically precise fine-divided stepping motor and high accuracy induction synchronizer to form a closed-loop. At the same time, a 24 sides optical standard is used to check the position accuracy so as to warrant the repeatability and reliability. This paper mainly introduces the electric control system, both hardware and software. Also given are the results of adjustment with optical, mechanical and electric coordination. Those data are believed to be very useful for future design of our space magnetic analyzer.

2. EQUIPMENT AND TECHNICAL PARAMETERS

As in fig.1, magnetic analyzer consists of four optical components, a λ/4 plate, polarizer 1, a λ/2 plate and polarizer 2 .The λ/4 plate may be taken out of optical axis or put back. Both polarizer 1 andλ/2 plate may rotate around and align with optical axis, while polarizer 2 at the front is fixed. That is, the components in the dash line block in fig.1 are moveable. They should meet the following requirements:

polarizer 1 position accuracy and repeatability after rotation ≤±10”;
λ/2 plate position accuracy and repeatability after rotation ≤±10″;
λ/4 plate position accuracy and repeatability when moving back ≤±1’.

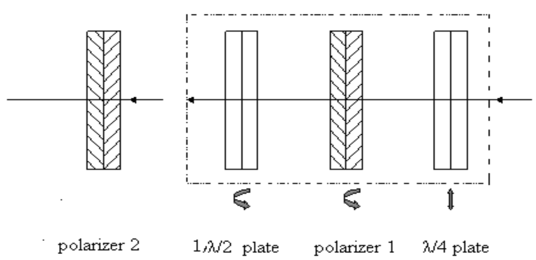

Fig.1. Magnetic analyser optical components composition

The working cycle is as follows: Starting from reset position, the rotating anger of polarizer 1 should be constantly double of that ofλ/2 plate. They are driven by a stepping motors and a speed ratio of 1:5 .The motor also drives the λ /2 plate through a two-stage speed ratio of 1:10 as shown in fig 2

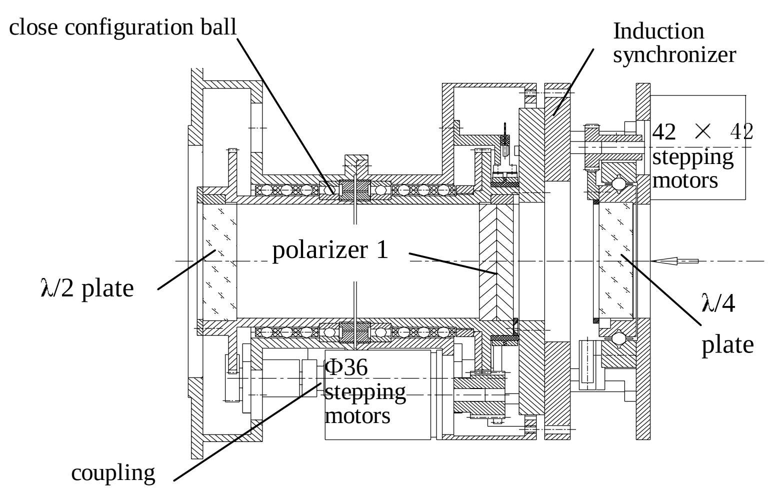

Fig. 2. optical and mechanical components installed in the magnetic analyzer

3. HARDWARE DESIGN

The block diagram of our system is in fig.3. Servo-control is composed of a PC industrial computer and a hardware interface. The PC industrial-controller adjusts the speed of two stepping motor s and inputs the parameters. The hardware interface has digital I/O ports and counters to read the positions of the induction synchronizer and to carry out the servo-control for two stepping motors.

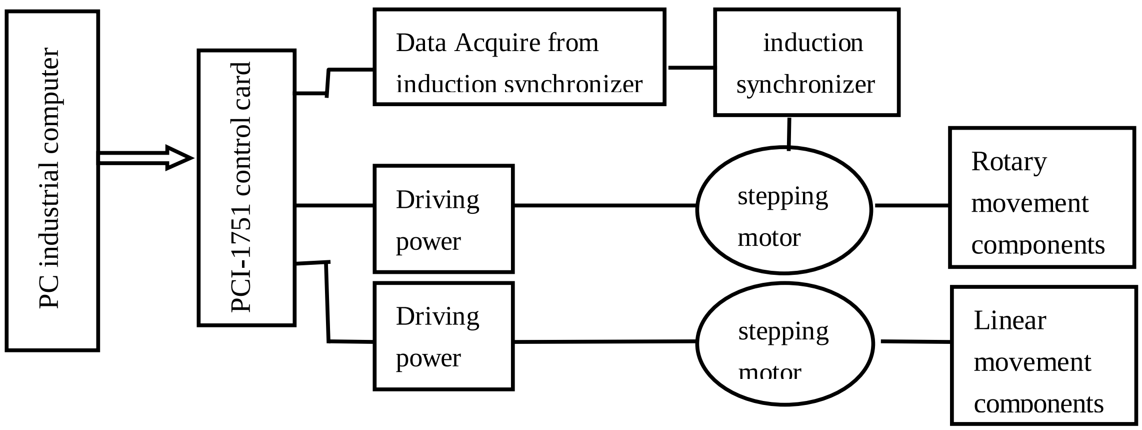

Fig. 3. System architecture block diagram

3.1. PCI-1751 Control Card

PCI-1751, supplied by Advantech Co., has a 48 (6x8) bits I/O and 3 16 bits timers, based on PCI bus. It actually is similar to 8255 Interface chip in mode 0, but strengthen with driving ability as in fig 4. In our design, 32 bits are assigned to accept the data (deg, min and sec) from the induced synchronizer. 16 bits control the direction and limit. Pulses from timers are connected to the stepping motor s. Computer closes the loop so as to drive the stepping motor s to reach the setting points precisely and smoothly.

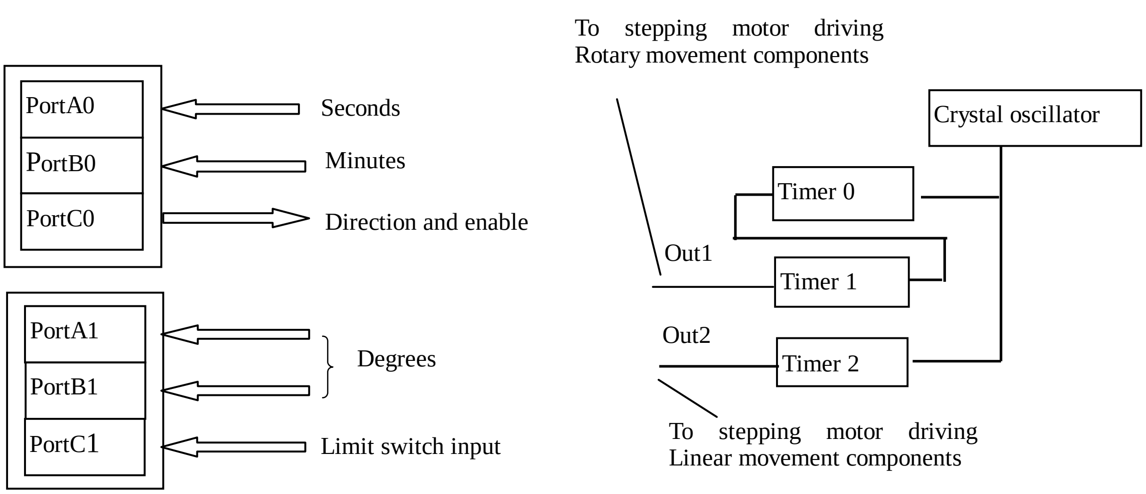

Fig.4. I/O and Timer Interface circuit schematic

3.2. Position detector

The rotating components have central holes which fit the round induced synchronizer. The induction synchronizer is specified as angle resolution 2 arcsec and maximum counting rate 120^0 /sec. However the actual rate is only 90^0/sec. Therefore it becomes the bottleneck of the positioning speed. Fortunately the components in our case need not rotate very fast.

3.3. Drivers and stepping motor s

On basis of output power, the 36-type induction stepping motors in cooperation with corresponding drivers are selected .Due to both rotating components and speed ratio are small, to improve the angle resolution, the only way is to increase the micro-step of the stepping motors. We set it 250. With speed ratio 5:1, the final angle step is 5.18 arcsec. Large micro-step also results in better stability and low noise.

There are no special demands imposed on the linear motion motor. Their work is to move components straightly.

We use 42-type induction stepping motors and corresponding driver

4. SOFTWARE DESIGN

Crosed-loop positioning for stepping motor usually has two working modes for option: damping positioning and swing positioning. In the former mode, the motor initiates at high speed, then slow down step by step gradually, until approaching the specified position at last with a moderated attitude (fig. 5). The number of step depends on the mechanical load and electric time constant.

In the latter mode, motor drives the components to the specified position, forth and back around it with damping oscillation, until finally reaching it (fig.6).

The swing mode causes more vibration to the system. In space, it might influence on the stability of telescope's attitude. And magnetic analyzer needs to position several objects rapidly, so we eventually choose first mode.

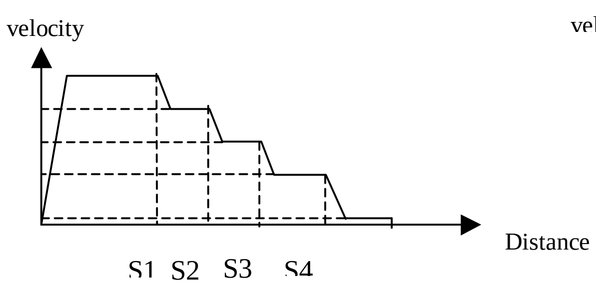

Fig.5. damping positioning schematic

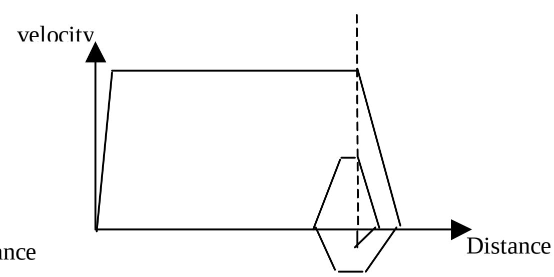

Fig.6 swing positioning schematic

Control software is written with Delphi 6 and VC6.0 mixed. Delphi is powerful and easy to program for interaction, while VC is flexible for dealing with the base of hardware. This interconnection between them carries out by calling VC dynamic library.

The DLL statement format in VC is:

```
extern "C" __declspec(dllexport) void __stdcall FloatToDMS( double position, char* dms )
```

Also def files added to VC is:

EXPORTS

FloatToDMS

Calling format in Delphi:

function FloatToDMS(position:Double; dms:Pchar):integer; far; stdcall; external 'zzzz';

// Here ZZZZ is dynamic library including this function.

Interacting with the computer, user may input parameters, control the motion of the magnetic analyzer and monitor its status. The given and real position, working status and rotating time are displayed on terminal (fig. 7). Then computer adjusts the rotating speed, fast, slow or one-shot as per user's instruction. The general software structure flowchart is shown in Fig. 8.

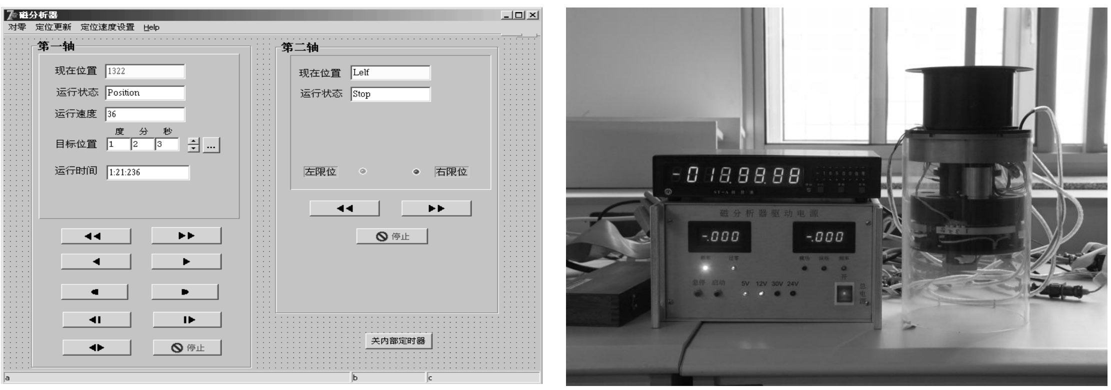

Fig.7 Control interface and Actual object of magnetic analyzer

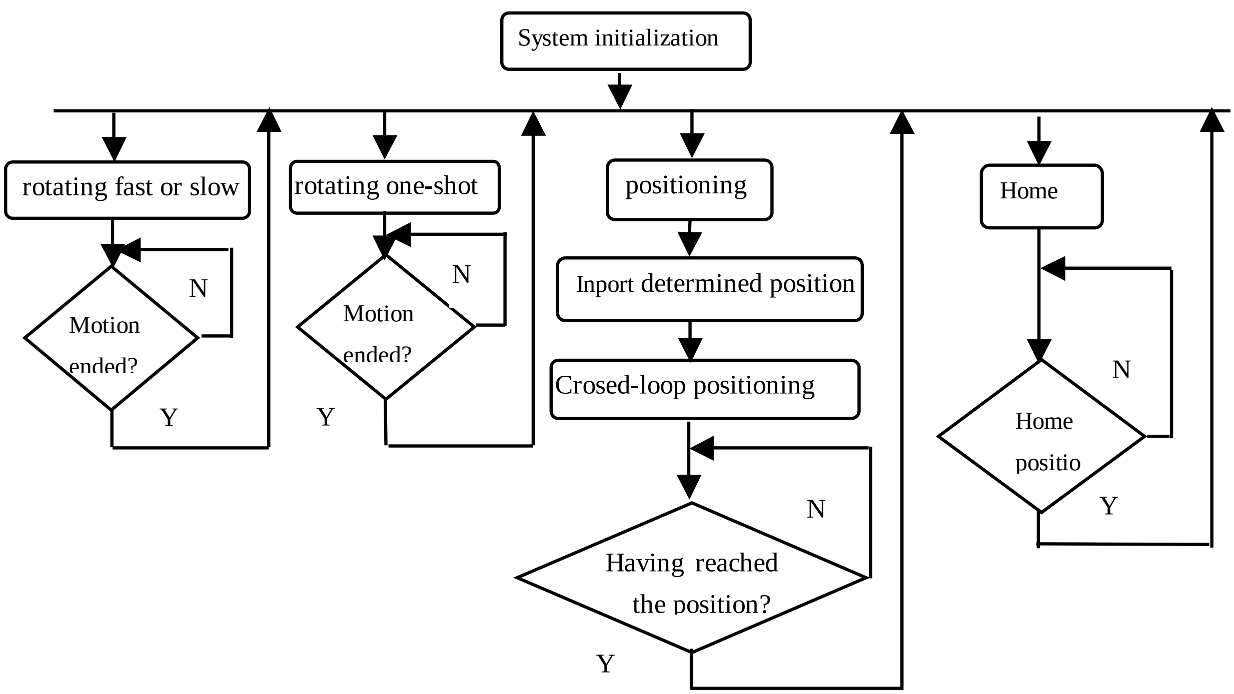

Fig.8. software structure flowchart

For speeding the adjusted process, it is necessary to let the motors rotate in high speed. In our system, 90^0/sec corresponding to driving pulse frequency 62.5 KHz, that is, 5.18 arcsec/pulse. To reach such a fast speed, regular timer in WINDOWS can not work properly. We use the timer of multi-medium which calls a callback function with an independent thread. Its priority is very high, sending a signal constantly to check the status of the system, regardless of other signals. In our case, the timer in Intel CPU can work at 1 ms accuracy. We found that the shorter the adjusting period, the smaller the overshoot of positioning, and thus. the higher the positioning accuracy would be. We now set the adjusting time interval as 1 ms. The positioning times and errors are stored in database for later use.

5. OVERALL TEST

The main test of a magnetic analyzer is to check the final positions of polarizer 1 and λ/2 plate. We check the positioning accuracy and time after rotation essentially.

5.1. Position accuracy

Attaching a high-precision (±1") 24 sides standard to the axis of the rotator, monitor the self-collimated reflected image with a micro meter-collimator. When the distance between the telescope and surface is around 206 mm, the resolvable reading of the telescope, 0.02 mm, is equivalent to the rotation angle of measured surface 10".So the actual minimum discriminative angle is about 5"which has met our requirement. Table 1 is the results for the rotating speed 30^0/sec of the induced synchronizer. The deviations are mostly within 10". A few large errors may attribute to the inaccuracy due to reading of the telescope. Testing results of position accuracy are listed in the Right table.

Table 1. Detect the position accuracy of induced synchronizer using a high-precision (±1") 24 sides standard

determined position(degree)	CW errors (arcsec)		CCW errors (arcsec)	
	Measured values	Shown values	Measured values	Shown values
0	0	0	-12	0
15	13	-7	-11	-2
30	10	-7	-11	0
45	0	3	-12	8
60	10	0	-5	0
75	13	-8	-5	7
90	7	1	0	-2
105	9	-8	-5	-1
120	13	-11	-5	-1
135	-8	2	-7	6
150	15	-9	-6	-10
165	0	2	0	8
180	-8	3	-6	5
195	8	-7	5	-11
210	10	-9	0	6
225	12	-6	0	8
240	8	-7	8	-3
255	0	-7	0	5
270	0	1	0	7
285	0	0	0	-3
300	12	-8	0	5
315	0	4	7	0
330	5	-8	13	-3
345	8	-8	7	-2
360	0	3	0	1

5.2. Positioning times

As test shows, the large inertia of the 24 sides standard would directly influence on the closed-loop of the system, then on positioning time. For simulating the real working condition, we add a high-precision (2") cube as the load of system to determine the response time of the induced synchronizer. The cube has 4 sides. What measured is the time for rotating 90^0. Iterative measurements show no detectable error at induction synchronizer rotating speed of 105^0/sec (listed in Tab 2), indicating the time to rotate the induction synchronizer by 90^0 is about 2 sec. The results above are obtained at the sampling period 1 ms. Should the period be longer, the results would be somewhat worse. Testing results of positioning times are listed in the following table.

These data are sampled in 1ms cycle of measurement. if extended sampling cycle, the results will be poor in some.

Table 2. Decteding the positioning times to rotate the induction synchronizer by 90 degrees using cube

number of times	Clockwise rotation		Counterclockwise rotation	
	positioning time(s)	errors(arcsec)	positioning time(s)	errors(arcsec)
1	1.54	-8	1.76	0
2	1.98	-9	1.81	5
3	0.929	-29	1.979	7
4	1.54	-3	0.879	23
5	1.54	-8	1.699	7
6	1.54	-9	1.809	0
7	1.589	-6	1.869	8
8	2.47	-3	1.86	0
9	1.92	-6	1.699	5
10	2.2	-7	1.699	0
11	1.49	-8	1.87	7
12	1.32	-2	2.03	1
13	1.099	0	1.87	7
14	1.81	-6	1.86	5
15	1.599	-6	1.87	5
16	3.07	-3	1.76	10
17	1.75	-8	1.809	0
18	1.87	-9	1.919	5
19	1.699	-9	1.92	7
20	2.079	0	1.929	0
21	1.65	-8	1.92	0
22	1.92	-6	1.589	0
23	1.76	0	1.81	7
24	2.03	-5	1.92	3
25	1.32	-9	1.82	7
26	2.42	-9	1.82	8
27	1.37	-9	1.81	7
28	1.71	-2	1.869	3
29	2.139	-8	1.76	7
30	1.48	-9	1.81	5

6. CONCLUSION

This is for the first time to try rotating optical components as magnetic analyzer for space use. The concept and construction in this paper is proven feasible for this program. A prototype mount has been submitted to the scientific team of Laboratory of Space Telescope at Beijing Observatory.

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