Intelligent Laser Leveling Control System for Cement Concrete Based on MCU Control

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Abstract—With the development of urbanization, cement concrete roads are laying more and more, and the requirements are getting higher and higher. The traditional leveling operation has the disadvantages of high labor cost, long time and poor precision. Based on this, a control system of cement concrete leveling based on laser sweeping technology is designed, and the cement concrete leveling control system based on laser scanning level is designed. The embedded controller STM32 is used as the control core of the system, the laser horizontal plane scanned by the laser swinger is regarded as the horizontal standard of the leveling system. Two rows of laser receiving sensor arrays mounted on the scraping shovel were used to detect the vertical relative position and tilt of the scraping shovel. The stepping motor driving chip TB67S109AFTG was used to drive two stepping motors to realize the automatic adjustment of the vertical position and inclination of the scraping shovel, and realize the automatic leveling function of the laser leveling machine. Finally, the precision reached 4mm.

1. Introduction
Traditional cement concrete floor leveling mainly uses manual methods. For example, in a construction site with a large square construction area, it is necessary to use a metal structure or square timber to form a frame and measure the height of the frame through a level. This can control the height of the concrete after laying. It not only requires the cooperation of multiple people during the operation, but also has the disadvantages of longer time and poor accuracy [1]. Leveling mainly uses a scraper to manually level the concrete in the frame, repeated corrections and adjustments, which requires a lot of manpower [2].

With the development of laser technology, especially the development of semiconductor laser technology in recent years, various laser emission systems with high precision, low power consumption, miniaturization and low price have been developed rapidly. Moreover, various practical small laser levelers, laser marking instruments, etc. have been rapidly popularized and applied in the construction industry and the home improvement industry. This has not only changed the construction status of the past "pull wire gauge", but also greatly improved the technical level of the industry [3]. Laser leveling technology is the first to be applied in land leveling. The application of laser leveling technology has greatly improved the accuracy of land leveling, and the lower leveling accuracy has been reduced to less than 2cm. The improvement of land leveling accuracy has a relatively large promotion effect on saving irrigation water, improving fertilizer utilization, and increasing yield [4]. We can apply advanced laser emission and measurement technology to the cement concrete leveling system, and cooperate with advanced embedded technology and automatic control technology to design a cement concrete laser
leveling control system. It can be used in the construction of large squares and even road cement concrete floors to replace manual operations. This completes the automation of cement concrete leveling, which has become an urgent need in the industry [5].

2. Overall System Design

2.1 Overall Design
The laser leveling control system is mainly composed of a laser emitting device, a laser receiving sensor, a microcontroller, a stepping motor, and a shovel [6]. The system block diagram is shown as in Fig. 1. The laser sweeper emits a laser horizontal plane, and the height of the laser horizontal plane can be adjusted at will through the base bracket of the laser sweeper as the system's leveling standard. Two masts are installed on the shovel, one mast is in the middle position of the shovel, which is called the main mast. The other mast is located at one end of the shovel, called the secondary mast, and a row of laser receiving tube arrays are fixed on each of the two masts. The microcontroller STM32F429 can determine the position information of the shovel including the vertical position and the inclination by querying the on-off state of the laser receiver tube, and then understand the laying of cement concrete. The system controls the two stepping motors installed on the scraper through the corresponding control algorithm. Among them, one stepping motor adjusts the height of the shovel, and the other adjusts the inclination of the shovel to realize the leveling operation of the shovel. Considering that the height adjustment of the shovel requires a certain mechanism and greater power, the system will use an electric push rod driven by a stepper motor to complete, and the tilt adjustment is directly driven by a stepper motor [7].

![System Block Diagram](image)

Figure 1. System Block Diagram

3. Control System Design

3.1 Laser Transceiver Module

3.1.1 Laser Swinger
In the laser leveling control system, the leveling standard must be set first. It is the laser plane emitted by the laser sweeper, which plays a vital role in the leveling work. The existing laser swingers come in various colors. Considering that the construction time is mostly during the day, the green laser is more convenient for observation and adjustment during the day than other colors, so the system will choose the green laser swinger [8]. The square cement concrete construction requires the scanning range of the laser swinger to be as large as possible. The farther the laser horizontal plane scans, the greater the thickness of the scanned laser surface. This will affect the accuracy of the measurement. Considering comprehensively, the system uses Bosch GRL-240HV green light sweeper with a transmission distance of 60m and a laser accuracy of ±0.2mm. The system will adjust the height and level of the base bracket of the laser beamer as needed to obtain a certain height of the laser horizontal plane [9].
3.1.2 Laser Receiving

![Schematic Diagram of Laser Receiving Tube Array](image)

Figure 2. Schematic Diagram of Laser Receiving Tube Array

The vertical position information of the shovel is determined by STM32 by querying the signal switch state of the laser receiving tube on the main mast. The inclination of the shovel is determined by the switch signal state of the laser receiving tube on the auxiliary mast. The schematic diagram of the laser receiving tube array is shown in Figure 2. The laser receiver tube is IS0203, and its width is 4mm. The receiving tubes are arranged continuously without intervals to form a measurement array, and the measurement accuracy is 4mm. The length of the main mast is 1m, and the 0.2m area in the middle of the mast is the detection window. The areas on both sides of the main mast are auxiliary adjustment areas, and the laser receiving tubes are symmetrically arranged on the mast at intervals of 8mm, 16mm, and 32mm. It is mainly used to find the laser level in a large range. On the auxiliary mast, 7 laser receiving tubes are arranged continuously and without interval in the middle of the detection window of the main mast.

![Laser Receiver Tube Circuit](image)

Figure 3. Laser Receiver Tube Circuit

The circuit diagram of the laser receiver tube is shown in Figure 3. In order to ensure the stability of the measurement signal, the output signal of the laser receiver tube will be transmitted to the input port of STM32 after passing through the Schmitt gate. The single-chip microcomputer will read the high and low level signals of the port to know the position information of the laser horizontal plane.

3.2 Stepper Motor Drive Module

The drive module uses TB67S109AFTG, which is a stepping motor drive chip recently developed by Toshiba. It integrates dual full-bridge MOSFET drivers with a maximum withstand voltage of 50V and a drive current of 4A, allowing full-step, half-step, 1/4, 1/8, 1/16, and 1/32 step operation. The system also has built-in error detection circuits (thermal shutdown TSD), over current shutdown (LSD) and power-on reset (POR). It can customize the chopping frequency of the motor through external resistance and capacitance [10]. TB67S109AFTG chip periphery and interface circuit are shown as in Fig. 4.
Figure 4. TB67S109AFTG Chip Peripheral and Interface Circuit

Need to use 3.3V and 5V power in the design, through XL1509 for voltage regulation to obtain 5V, and then through AMS1117 voltage regulation to obtain 3.3V [11]. The input signals mainly include the enable signal ENABL, the direction signal CW/CCW and the clock pulse signal CLK, which are respectively connected to the PC0, PC1, and PC2 pins of the microcontroller. DMODE0, DMODE1, DMODE2 are the subdivision setting pins, which are connected to the PC3, PC4, and PC5 pins of the microcontroller respectively. In order to realize that when the stepper motor is at a standstill, the drive current is reduced or even zero. This can reduce the heating problem when the motor stops. The circuit is designed to select the monostable circuit chip 74HC123D that can be triggered repeatedly, and the motor drive pulse CLK is used as the trigger pulse of the monostable circuit, which can connect the positive output of the monostable to the VREFA and VREFB terminals at the same time[12]. During the period of no driving pulse, VREFA and VREFB are low and the driving current is zero. During the motor driving pulse, the monostable positive output is a pulse signal, and the pulse width mainly depends on the timing resistor R16 and timing capacitor C4. In this way, the voltage values at both ends of VREFA and VREFB are further determined, and the corresponding drive current is generated. In the circuit design, the RP1 adjustable resistor appropriately adjusts the voltage value at both ends of VREFA and VREFB, and then sets the size of the drive current [13].

The calculation formula of the drive current is:

\[ I_{\text{out}}(\text{max}) = G_{\text{ref}} \times \frac{V_{\text{ref}}(\text{V})}{R_{s}(\Omega)} \]

Among them, \( V_{\text{ref}} \) is the voltage value at both ends of VREFA and VREFB, the typical value of \( G_{\text{ref}} \) is 1/5, and \( R_{s} \) is 0.2 \( \Omega \). If \( V_{\text{ref}} \) takes 4V, the maximum drive current is 4A.

4. System Software Design

The researcher can use the auxiliary adjustment of the laser receiving tube array on the main mast for rough adjustment. To find the laser level in a large range, you can adjust the height and level of the laser leveler so that the laser level is basically horizontal and located in the middle of the detection area. On this basis, the system enters the automatic operation state, which can be fine-tuned by a stepper motor [14]. The microcontroller STM32F429 first collects the switch signal of the laser receiving tube array in the detection window to obtain the position of the shovel. It can be compared with the benchmark set by the spatula [15]. Firstly, the system will adjust the height. If the shovel is higher than the preset value, the stepping motor rotates forward, and the electric push rod drives the shovel to adjust downward. If the shovel is lower than the preset value, the motor reverses and the shovel is adjusted.
upward. Secondly, the system can adjust the inclination of the shovel. The adjustment of the inclination is realized by the micro-controller by controlling the forward and reverse rotation of another stepping motor. The system will repeatedly adjust in this way until the height and inclination of the shovel reach the predetermined set value. The overall flow chart of the system is shown in Figure 5.

![Flow Chart](image)

Figure 5. Overall System Flow Chart

The system can adjust the position, height and inclination of the laser leveler by detecting the switch signal state of the laser receiving tube array in the auxiliary adjustment area on the main mast. This will not only make the laser level emitted by the laser sweeper basically level, but also enable the system to capture the laser level in the detection window area. In addition, the system will enter the automatic operation state. The laser leveling machine automatically runs and controls according to the program, so that the signal status of the two rows of laser receiving tube arrays can be read in real time. It can be compared with the set value, and then drive two stepping motors for automatic adjustment until the height and inclination of the shovel reach the set value. The system has the advantages of simple operation, high precision and high efficiency. It can significantly reduce the work intensity of operators and has obvious practical significance.

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