Research on Electrical Control and Programmable Controller Based on Laser Tracking Measurement

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Abstract: Different production technology and process have different requirements for control circuit. However, no matter what kind of control circuit, it is composed of some basic control links. Programmable controller is a common electronic data control program, which not only plays a lot of advantages in industrial control system, but also is more and more widely used in people's daily life. It is an essential basic equipment in industrial automation system at present. As a kind of high-precision three-coordinate measuring equipment, laser dynamic tracker can be used to measure the spatial position of various single parts and complete sets of equipment. This paper mainly introduces the application of laser tracking system in electrical control and programmable controller, and looks forward to the development prospect of laser tracking detection technology.

1. Introduction
Programmable controller integrates computer application technology, automatic control technology and communication technology effectively, which shows more obvious application advantages than traditional control technology. At present, the programmable controller is widely used in many different fields of society because of its stable control work, strong control level and high anti-infection ability, which greatly improves people's quality of life and promotes the development of control technology in the national industrial field [1]. Programmable Logic Controller (PLC) has been used in many fields, and it has been widely favored by virtue of its various advantages. It will play an extremely important role in industrial automation control system, especially in sequence control system.

The laser tracking measurement system is mainly composed of tracking detection, rotating mirror mechanism and servo control. The measuring system integrates laser interference ranging, photoelectric detection, precision machinery, computer and control system and modern numerical calculation, and tracks the moving objects in space and measures the dynamic geometric quantities in time [2-3]. Servo control is the operation control link of tracking and aiming system, which not only affects the stability of the whole system, but also directly affects the tracking accuracy and response speed of the system. In order to have a deeper understanding of the effect of programmable controller in electrical control, this study analyzes the concept, development, application and future development prospect of programmable controller based on laser tracking measurement.
2. Working Principle of Laser Tracker

The laser tracker is mainly composed of a tracking head, a target reflector, a control box and measurement software. There is a set of laser interference system, two sets of angle encoders, motors and photoelectric receiving devices inside the tracking head. Interferometric laser ranging system emits He~Ne laser with wavelength of 633 nm, and the laser is reflected to the target mirror by the biaxial tracking mirror, and the incident light can be returned along the original path by the reflecting angular prism [4]. When it is not in the center of the mirror, the tracking head will automatically rotate until the laser shines on the center of the mirror. The length from the center of the mirror to the tracking head and the rotation angle of the tracking head will be measured by the side length system and the angle measuring system inside the tracking head, thus measuring the coordinates of the center of the mirror. When the light reflected by the reflector passes through the beam splitter, some light enters the position detector. When the reflector moves, this part of light will generate an offset value on the position detector. According to the offset value, the position detector will control the motor to rotate until the offset value is zero, thus achieving the goal of tracking. The computer automatically sets the initial value as the distance value, and then the target mirror can be moved to measure each measured point in the space in turn [5].

If the light irradiated on the target mirror deviates from the center point of the target mirror, the photoelectric element will output a differential electrical signal. After the signal is amplified, two motors are controlled by the servo control loop to drive the tracking mirror to rotate along the horizontal axis and the vertical axis respectively, so that the direction of the beam irradiated on the target mirror changes. There is a fixed point on the tracking head. At the beginning of measurement, first place the target mirror on this fixed point, and the distance between this point and the rotating center of the rotating mirror is fixed. The computer automatically sets the initial value as this distance value, and then move the target mirror to measure each measured point in the space in turn.

3. Laser Tracking Measurement

The theoretical basis of absolute ranging comes from the decimal repetition method, which is a precise measurement technology that emerged and developed in 1970s. The main idea is the formation of synthetic wavelength chain and its refinement step by step. A large amount of data will be exchanged between the laser tracker and the computer during measurement, and high data transmission speed is required. Therefore, the computer and the laser tracker need to transmit data in the form of LAN through the controller. Laser measurement tracking measurement system can quickly and accurately check whether the size of each finished part is completely consistent with the design size, and it can also quickly transform a part or physical model into a digital file. Place the instrument in the middle of the production line to be measured, and adjust the tripod to set the height of the instrument to ensure that the detected object is within the detection range. Firstly, the installation datum of production line is measured, and the spatial coordinate system meeting the design requirements is established. A cylinder with a small length is fitted by using the measured points, and then the intersection point between the axis of the cylinder and the ideal section is obtained, which is the center of the section circle.

Multi-wavelength absolute ranging interferometry, also known as decimal repetition method, is the theoretical basis of large-scale absolute distance [6]. The measurement formula is

\[ L = (k + \varepsilon) \times \frac{\lambda}{2} \]  

In which:  \( L \) is the measured length;  \( \lambda \) is that synthetic wavelength of light wave;  \( k \) and  \( \varepsilon \) are integers and decimals of interference fringes respectively. The measurement of absolute distance is divided into two steps: to determine the initial value, that is, the value of integral multiple of wavelength; Measure the decimal, that is, determine the numerical value of the decimal part. The value  \( k \) of integral multiple of wavelength can be easily determined by rough measurement.

During the measurement, when the reference pyramid is placed short of the lower end of the guide rail, it will be set to 0. When the measuring pyramid is located in the initial test position, move the
reference mirror and pass through the node. The output pulse of the node discrimination circuit is latched. At this time, the interferometer displacement value $x_1$ is

$$I_{m1} - (l_x + 2x_1) = (2p_1 + 1)\frac{\lambda_b}{4}$$  \hspace{1cm} (2)

In which $p_1$ is a positive integer. When the measuring mirror is put to the end position to be measured, move the reference mirror again. When passing through the node, the node discrimination circuit outputs a pulse to latch the interferometer displacement value $x_2$ at this time, and then

$$I_{m2} - (l_x + 2x_2) = (2p_2 + 1)\frac{\lambda_b}{4}$$  \hspace{1cm} (3)

In which $p_2$ is a positive integer. Therefore, the measured length is calculated as

$$l = \frac{I_{m2} - I_{m1}}{2} = (p_2 - p_1)\frac{\lambda_b}{4} + (x_1 - x_2)$$  \hspace{1cm} (4)

Single-point average measurement takes the average value of the measurement results of the set measurement times as the final result; He~Ne double longitudinal mode laser changes the temperature of the discharge tube by controlling the discharge current. Thereby accurately controlling the length of the laser tube resonant cavity. PSD measures the parallel displacement between incident and reflected light to form a tracking error signal, and the controller minimizes the tracking error by controlling the axis of the rotating drive unit. When the measuring mirror moves along the curve and the reflected light deviates from the incident light, the coincidence degree between the laser beam signal reflected by the measuring mirror and the reference laser beam signal decreases, and the CCD has signal output. The target mirror can move on the constraint plane, and the tracking rotating mirror rotates with it. The laser tracking and measuring system measures the rotation angle and relative displacement of the rotating mirror in real time, and the number of measurement points is larger than all parameters of the corrected system. Hidden point measurement is to calculate the coordinates of hidden points through hidden rod measurement [7]. You can set the time interval for a single measurement, and you can also set whether the sampling interval and spherical radius are known for spherical fitting measurement.

In fig. 1, the origin is the projection of the origin of the measurement coordinate system parallel to the $y$-axis on CCD. the $U$-axis corresponds to the $z$-axis, and the $V$-axis corresponds to the $x$-axis. When the vertex $P'$ of the target mirror moves to $P'(x_{p0} + \Delta x, y_{p0} + \Delta y, z_{p0} + \Delta z)$ the center of light spot on CCD changes $(\Delta V, \Delta U)$.  

![Figure 1 CCD coordinate system](image)

When measuring, firstly, it is necessary to accurately position the positioning ring along the axial direction to determine the position of the section to be measured, then place one side of the probe against the positioning ring, and slide the bottom of the probe along the outer surface of the cylinder to be measured. The measured section circle needs to be offset and corrected along the axial direction.
The reflected light spot position and shape variation are output by CCD, and then processed by microcomputer processing system, which is used to control servo motor, and control two-axis servo system to drive tracking mirror to rotate around horizontal axis and vertical axis. The measuring system measures the same target through multiple tracking and measuring stations. The structure of each tracking station is basically the same as that of single station method. The multi-station method calculates the spatial coordinates of the target by measuring the distance variation from the center of each station to the center of the target, without measuring the azimuth of the target [8]. It can continuously sample in time or distance; Sampling of spatial three-dimensional grid can be carried out; It can be measured in a specified sphere or three-dimensional space; It can also digitize the surface measurement of an object, and the sampling time and distance interval can be freely set.

4. Electrical Control and Programmable Controller based on Laser Tracking Measurement

4.1. Measurement accuracy of laser tracker
The measurement accuracy of laser tracker is mainly determined by its angle and distance measurement accuracy and the influence of measurement environment, but the geometrical features with special requirements can not be obtained directly, and the user's detection requirements can only be met through subsequent software development and simulation of the geodetic horizontal datum plane. Based on the application technology of large-scale integrated circuit, programmable controller improves the anti-interference characteristics of the whole control system. Compared with the traditional relay control mode, programmable controller can realize both sequential and logical control at the same time, and can control in multiple devices at the same time; At the same time, the measurement system has no orthogonal physical reference coordinate system, so it is necessary to establish a virtual reference coordinate system and a virtual measurement standard ruler that meet the design and manufacturing requirements. PLC has intuitive and simple interface, and has various expressions such as graphic symbols and ladder diagram language in programming. It is easy to operate and practical, which can be easily understood by operators and engineers. Only a part of simple operation instructions can be used to program and apply automatic electrical control.

Satisfying the redundancy principle is the premise of realizing self-calibration, establishing virtual coordinate reference system and calculating the spatial position of the target in real time. It is necessary to use more measuring stations, measuring points and measuring data than meeting the basic measurement requirements. Its specific application direction mainly lies in the change of "quantity", such as the change of flow rate, temperature and liquid level, The switch logic control instruction supported by programmable controller can transform complex circuit diagram design into simple programming language, so it is easier to apply; The target position can be determined by extracting the center of gravity of the spot image obtained by CCD. Send the light spot variation to the biaxial servo control system to adjust the tracking mirror, so as to track and rotate. Compared with the traditional wiring logic, it can save the external wiring of the equipment, greatly shorten the design and construction time of the control system, bring great convenience to the post-nursing work, and the written program can be changed at any time. Because the calibration error of reference distance will become the systematic error of interferometric ranging. The accuracy of absolute rangefinders is higher than that of general rangefinders, and the absolute accuracy of measurement can reach ±0.05 mm.

4.2. Data processing
The obtained three-dimensional surface data can not provide intuitive geometric information, and need subsequent data processing software. Then calculate the error and its influence on the total accuracy of the instrument, so that the system design scheme can be correctly selected and the structure and technical parameters can be reasonably determined, and the corresponding communication instructions and tasks can be executed through the data communication bus of the control system under the communication of the upper computer. And these level signals can smoothly enter the circuits at the
input interface or output interface of the programmable controller, so that the level conversion can be effectively realized. As far as electrical control is concerned, the control mode of decentralized control system is mostly the linkage control mode of multiple mechanical production lines (all the above mechanical production lines have interactive relationship of data connection during system operation). The automation of PLC realizes logic control and sequence control at the same time. In addition, it can ensure the independent control of a single device and realize the independence of each component in the automation program.

The ranging accuracy of the system is related to the distance. But there is no obvious proportional relationship. The positioning deviation of tracking nodes is random, and the characteristics of sensors, tracking spindles and servo controllers in the tracking measurement part and the geometric position error among components are the main influencing factors in the system ranging error. Coordinate data can be transmitted to Perceptron online detection equipment through serial connection cable, or input manually. Using the three-coordinate analysis software, develop professional matching molds, create the ground water datum in the system, and cooperate with the reference point provided by the user to establish the coordinate system that meets the user's requirements. CCD camera can get the coordinates of reflector support, and the position of reflector center can be obtained by calculation, so its conversion parameters can be obtained by coordinate conversion. In the configuration of control equipment, the motion module is used for sensing and executing instructions. Its main feature is that it can realize the control of circular motion and linear motion, and has high flexibility. The use of PLC automation control technology can ensure that the conversion of data confidence can be monitored and tracked in time, thus providing a certain degree of solution to the difficult problems in analog quantity analysis and operation.

4.3. Laser adjustment
The laser source is the key component of the measuring sensor, and its power and direction are stable or not, which has a direct impact on the accuracy. In order to adapt to different measured surfaces, the laser power should be adjustable, and it should automatically adapt to the changes of the measured surfaces, so that the received signals reach the best state. The collected spot image will also have some deformation, at which time its positioning accuracy will be questioned. The output shaft has an anti-rotation stop pin, so the spiral sleeve drives the output shaft to move up and down, and the opening signal is detected and transmitted to the precision potentiometer through the gear rack. Another difference between the laser tracking measurement system and the conventional theodolite measurement system is that its measurement result is independent of the operator (it does not need to be aimed by human eyes), and it can automatically track the reflection device, so the measurement data can be collected synchronously with the CCD sensor. Improve the early warning mechanism of the automatic control system, continuously realize the automation and intelligence of the early warning mechanism and alarm facilities, display specific faults in the control headquarters in the form of text data and image network during the early warning and alarm process, and take maintenance measures after analysis by relevant technical personnel. With the help of software, the laser tracker can measure the repeated positioning accuracy of multiple chucks in a very short time (usually only a few seconds), and the accuracy is much higher than that of intersection photography measurement technology based on digital camera.

5. Control Flow of the System
In the light intensity adaptive control of the whole system, by judging the intensity of a frame image collected by CCD, the threshold value is compared, and then the three elements of laser power, gain (CCD amplification factor) and CCD integration time are coordinated and intelligently controlled. Median filtering is used for the original data, but the median filtering here does not replace the value of a pixel with the median value obtained after median filtering for a pixel and its domain. The bottom is provided with a measuring rod with a length of several hundred millimeters, and the optical target is arranged at the top of the measuring head. The sensor integrated inside the intelligent probe can sense
the change of attitude angle of the intelligent probe relative to the laser light. The measurement error of distance measurement is mainly caused by the instability error of beat frequency wavelength, the determination error of field strength distribution node of double longitudinal mode heat stabilized frequency laser space synthesis and the measurement error of less than half beat wavelength length. The action of the precision potentiometer is changed into an electrical signal, which is fed back to the control module as the opening signal. As a result, the deviation between the signals of the computer, regulator or operator and the opening signal is reduced. When the deviation is eliminated, the control part stops the motor at this position.

The system control flow chart is shown in Figure 2. According to the above principles, the initialization parameters are selected: laser driving current 0.7 mA, CCD magnification 15 times, CCD integration time 1.4 ms, sampling frequency 4 MHz.

![System control flow chart](image)

From the point of view of the configuration of the control system mechanism, the special motion control module can finish the control operation performed by the sensor device in the traditional sense more efficiently. Most of that input component connected to the input interface of the program are switches, sensors or buttons, while the output interface is directly connected with controlled objects, which mainly include motors, solenoid valves, indicator lights and contactors. After filtering, the positioning accuracy of various methods has been improved to a certain extent. When the internal temperature of the motor exceeds the allowable temperature, the switching action automatically disconnects the winding power supply, thus protecting the motor from burning. The tracking head will search for the optical target in a spiral track around the theoretical position. After locking the target, the distance between the optical target and the tracking head is measured by absolute ranging technology, and the actual position of the chuck at this time is calculated. Through this process, the response time of the system to the change of light intensity can be obviously shortened, and the adjustment range of light intensity can be greatly increased, and the adaptability of the system to the surface of the measured object can be enhanced.
6. Conclusion
Programmable Logic Controller (PLC) has many outstanding advantages, such as convenient operation, universality, strong adaptability, high stability and reliability, simple programming and strong anti-interference ability. The laser tracking and ranging method adopts dual-mode thermal frequency stabilized laser, which makes the beat frequency stability and laser frequency stability have the same characteristics, which not only solves the problem of wavelength stabilization without external standard frequency, but also has good coaxiality because two longitudinal modes are generated in the same laser resonant cavity. It can intelligently control laser power, gain (CCD amplification factor) and CCD integration time, and greatly adjust the range of light intensity. For the electrical control system, the application of PLC can promote the development of electrical control towards higher efficiency and higher quality, which has far-reaching research and application value in electrical control.

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