Pre-calibration method for concrete distributor based on laser sensor

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Abstract. The initial positioning of concrete distributor in the distributor area is the primary issue that restricts the realization of automatic distribution, in the automation production of precast concrete components. Therefore, the automatic pre-calibration method of concrete distributor based on laser sensor is proposed. The method realizes the locating of the concrete distributor in the moving area by adding encoders on the driving motors of the distribution-big-cart and the distribution-small-cart. The side-mold on the bottom-mold-tray could be positioned through adding a laser sensor and combining the encoders information. Pre-calibration point of concrete distributor is determined by synthesizing the information of sensors. By the designed automatic pre-calibration method, the workload of the operator could be reduced, the automation level of the distributor could be improved, and the foundation for the realization of the subsequent automatic function is laid.

1. Introduction

In the 1950s and 1960s, the concepts of housing industrialization and construction industrialization were introduced from abroad in order to promote the process of industrialization in China [1]. Affected by the above situation, the production industry of the precast concrete components which was abbreviated to PC components, had been developed to some extent in China. However, the advantages of foreign production equipment were not obvious in domestic for various reasons, and the development was felt into a low ebb in the 1990s [2-3]. In recent years, with the improvement of construction system in China, and considering the environment, labor and labor costs, etc. industrialized production of PC components has ushered in new opportunities for development [4-6]. In the development, the improvement of the industrialization level of PC components in the aspects of automation, informatization and intelligence were the main problems faced by the industry. The production technology of PC components in Europe, America, Japan and other countries is relatively perfect [7-9], but due to the differences in technology and standards, it is difficult to give full play to its due performance in China [10-13].
Concrete distributor is the key equipment in the production of PC components [14]. The concrete distributor is driven to the designated location by controlling the distribution-big-cart and the distribution-small-cart, during the distribution process. The concrete in the hopper is pushed out and poured into the range surrounded by the side-mold on the bottom-mold-tray through controlling multiple screws and their corresponding gate to realize the distribution production of PC components. The performance of the concrete distributor directly affects the production level of the whole production line. The higher the automation level of the concrete distributor, the higher the production efficiency of PC components, the shorter the production time of the distributor, and the less the investment of human resources.

At present, the key problem of domestic concrete distributor is the low automation in distribution. The primary reason for the above problem is that the pre-calibration of the concrete distributor could not be achieved, that is, the starting point of distribution could not be found by the concrete distributor. Furtherly, the realization of the automatic control function in subsequent processes is limited by the problem. Therefore, in the distribution production link, a large number of staff needed to conduct auxiliary distribution causing low efficiency in production, high intensity in labor, and more difficulty in the stability of product quality.

In order to realize the automatic pre-calibration of the concrete distributor, a pre-calibration method of concrete distributor based on laser sensor is proposed in this paper. In this method, the running locations of the concrete distributor are measured by the encoders respectively mounted on the motors of the distribution-big-cart and the distribution-small-cart. The location of the side-mold on the bottom-mold-tray is detected by an adding laser sensor. And then, the pre-calibration point of the concrete distributor is determined indirectly.

2. Production technology of concrete distribution

In order to make the distribution production of PC components come true, it is necessary to coordinate the work of multiple mechanical equipment and devices. The production process diagram of the concrete distributor is shown in Fig. 1.

![Figure 1. The production process diagram of the concrete distributor.](image)

Where 1 is the distribution-big-cart. 2 is the distribution-small-cart. 3 is the concrete distributor. 4 is the distribution outlet. 5 is the bottom-mold-tray. 6 is the side-mold. 7 is the guide rail.

As shown in Fig. 1, the distribution-big-cart with concrete distributor could run reciprocally on the guide rail, and the distribution-small-cart with concrete distributor could run reciprocally on the beam of the distribution-big-cart. Point (X0, Y0) is the pre-calibration point of the distributor.

The concrete distributor is located the pre-calibration point \((X_0, Y_0)\) at the corner of the side-mold through carrying out pre-calibration, before distribution production. The pre-calibration point is the vertex of the angle formed by the AA and the BB side-molds as shown in Fig. 1. Then, the distribution...
production begins. The distribution-small-cart with concrete distributor runs from the location of AA side-mold to the location of BB side-mold. At the same time, each screw in the distribution outlet rotates at a certain speed, the concrete in the hopper is pushed out into the distribution area surrounded by the side-molds on the bottom-mold-tray. When the distribution-small-cart runs to the CC side-mold, all the screws stop rotating and the concrete distributor stops distribution. After that, the distribution-big-cart with concrete distributor runs from the location of BB side-mold to the location of DD side-mold. The moving distance is the distribution width completed by the concrete distributor. The concrete distributor moves from the location of CC side-mold to the location of AA side-mold. In the process of moving, the corresponding distribution outlet is opened, and the screws in that rotate to push out the concrete for distribution production. According to the above production process, the concrete distributor driven by the distribution-big-cart and the distribution-small-cart moves reciprocally between AA side-mold and CC side-mold until the distribution is completed for the whole distribution area.

3. Designation of the pre-calibration method for concrete distributor

In order to find the pre-calibration point of the concrete distributor by the pre-calibration method, it is necessary to configure the relevant sensors for the concrete distributor. Then, the pre-calibration point of the concrete distributor is determined by considering the detection information of the configured sensors comprehensively.

3.1 Configuration of Sensors for the Concrete Distributor

According to the section 2, it is the first condition that the location of concrete distributor in the distribution area is known, for making the distributor accurately locate the pre-calibration point. In order to achieve the above goal, the absolute encoders are added to the driving motors of the distribution-big-cart and the distribution-small-cart respectively. The location of the distribution-big-cart is detected with the absolute encoder mounted on its own driving motor, the location of the distribution-small-cart is detected with the absolute encoder mounted on its own driving motor. And then, the position coordinates of the concrete distributor are formed by combining the above two position information

In order to detect the position of the side-mold on the bottom-mold-tray, a laser sensor is added under the No.1 distribution outlet of the concrete distributor. The laser sensor is used to measure to distance between the distributor and bottom-mold-tray. The installation position of laser sensor on the distributor is shown in Fig. 2.

![Figure 2. The installation position of laser sensor on the distributor.](image-url)
Where 1 is the added laser sensor. 2 is the No.1 distribution outlet of the concrete distributor. 3 is the screw in the distribution outlet. Point A is the outer-edge-endpoint of the No.1 distribution outlet. XJ, YJ are respective the distance between the installation position of laser sensor and the outer-edge-endpoint A in X-axis and Y-axis.

When the laser sensor is above the side-mold, its measured distance is the vertical distance between the distributor and the side-mold. The measured distance is shorter than that between the distributor and the bottom-mold-tray. Based on the above feature, the location of the side-mold in the distribution area could be detected indirectly combined with the absolute encoders of the distribution-big-cart and distribution-small-cart.

### 3.2 Determination of the Pre-calibration Point for Concrete Distributor

In order to find the pre-calibration point of the concrete distributor in the distribution area, it is necessary to establish the coordinate system of the running area of the concrete distributor firstly. Secondly, the position of the side-mold need to be detected with the laser sensor. Finally, the pre-calibration point of the concrete distributor is determined. The above three aspects are explained in detail.

#### 3.2.1 Establishing the coordinate system of the running area for the concrete distributor

In order to give full play to the role of the absolute encoders and realize the locating of the concrete distributor in the running area, it is necessary to establish the coordinate system of the running area for the distributor. The intersection point of the guide rail and the beam of the distribution-big-cart beside the PLC control cabinet is defined as the origin of the coordinate system, as shown in Fig. 1. The running route of the distribution-small-cart is specified as X-axis, so the position feedback value of the encoder mount on the driving motor of the distribution-small-cart is the coordinate of the X-axis. The running route of the distribution-big-cart is specified as Y-axis, so the position feedback value of the encoder mount on the driving motor of the distribution-big-cart is the coordinate of the Y-axis. Thus, the coordinate system for the running area of the concrete distributor has been established, and the locations of the distributor in the running area have been achieved through the encoders mounted on the driving motor of the distribution-big-cart and the distribution-small-cart respectively.

#### 3.2.2 Detecting the location of the side-mold based on the laser sensor

As shown in Fig. 1, the coordinate \(X_0\) of the X-axis in the pre-calibration point \((X_0, Y_0)\) is the coordinate of the X-axis of AA side-mold and the coordinate \(Y_0\) of the Y-axis in that is the coordinate of the Y-axis of BB side-mold, in the running area of distributor. The coordinates of pre-calibration point can be determined only by detecting the locations of AA and BB side-mold in the running area of the distributor.

![Figure 3](image)

**Figure 3.** The schematic diagram for detecting the side-mold.

Where 1 is the laser sensor. 2 is the side-mold on the bottom-mold-tray. 3 is the reinforcement-mesh laid on the bottom-mold-tray. 4 is the bottom-mold-tray.
From Fig. 3, it can be seen that when the bottom-mold-tray is under the laser sensor, its detection distance is $X_1$ between the surface of the bottom-mold-tray and the concrete distributor. When the side-mold on the bottom-mold-tray is under the laser sensor, its detection distance is $X_1$ between the side-mold and the concrete distributor. When the reinforcement-mesh laid on the bottom-mold-tray is under the laser sensor, its detection distance is within the range of $[X_1-b, X_1]$ considering the interference of the reinforcement-mesh. During the movement of the concrete distributor, if the detection distance of the laser sensor changes from $X_1$ to $X_1-a$, $[X_1-b, X_1]$ to $X_1-a$ or from $X_1-a$ to $[X_1-b, X_1]$, the detection of the side-mold is realized. When the side-mold is detected, position coordinates of the X-axis or the Y-axis of the concrete distributor are also that of side-mold. In above way, the detection of the position for the side-mold could be realized based on the laser sensor during the movement of the concrete distributor.

### 3.2.3 Determining the pre-calibration point of concrete distributor

On the basis of establishing the coordinates system of the running area for the concrete distributor, the pre-calibration point of the concrete distributor is determined by adopting the following steps with the help of laser sensor:

**Step 1:** The concrete distributor is located at the initial position. The distribution-big-cart and the distribution-small-cart work together to move concrete distributor to the initial position ($X'$, $Y'$). This initial position is located beside the PLC control cabinet and outside the distribution area surrounded by the side-mold.

**Step 2:** The position of the AA side-mold is detected. The distribution-small-cart with the concrete distributor moves along the X-axis from the initial position to the CC side-mold. When the detection distance of laser sensor changes from $X_1$ to $X_1-a$, the edge on the side of nondistribution area of the AA side-mold is detected. Then the distributor continues to move towards the CC side-mold. When the detection distance of laser sensor changes from $X_1-a$ to $[X_1-b, X_1]$, the edge on the side of distribution area of the AA side-mold is detected. At this time, the X-axis coordinate $X_{J0}$ returned by the encoder of the driving motor of the distribution-small-cart is recorded, the distribution-small-cart is stopped, and the detection of the AA side-mold is completed.

**Step 3:** The position of the BB side-mold is detected. Based on the step 2, the distribution-big-cart with the concrete distributor moves along the Y-axis towards the BB side-mold. When the detection distance of laser sensor changes from $[X_1-b, X_1]$ to $X_1-a$, the edge on the side of distribution area of the BB side-mold is detected. At this time, the Y-axis coordinate $Y_{J0}$ returned by the encoder of the driving motor of the distribution-big-cart is recorded, the distribution-big-cart is stopped, and the detection of the BB side-mold is completed.

**Step 4:** The pre-calibration point of the concrete distributor is calculated. The position coordinates of the side-molds detected in step 2 and step 3 are the pre-calibration points ($X_{J0}$, $Y_{J0}$) of the laser sensor relative to the side modes. Based on the above coordinates ($X_{J0}$, $Y_{J0}$) of the pre-calibration point, the pre-calibration point ($X_0$, $Y_0$) of the distributor is calculated combined with the distance ($X_j$, $Y_j$) between the installation position of laser sensor and the outer-edge-endpoint A, as in equation (1) and equation (2).

$$X_0 = X_{J0} - X_j$$

$$Y_0 = Y_{J0} - Y_j$$

Through the above four steps, the pre-calibration point of the concrete distributor could be determined by synthesizing the information of the additional sensor. Then, the pre-calibration method of the concrete distributor is achieved automatically. This method not only improves the efficiency and accuracy of the pre-calibration, but also reduces the manual operation, which lays the foundation for the realization of the automatic distribution subsequently.
4. Conclusion
The pre-calibration function of concrete distributor is the key function to realize automatic distribution. In order to solve the problem that the current concrete distributor lacks automatic pre-calibration method to restrict the input of subsequent automatic distribution function, the pre-calibration method of concrete distributor based on laser sensor is proposed in this paper. This method could automatically complete the pre-calibration, significantly reduce the labor intensity of operators, improve the automation level of the concrete distributor, and lay the foundation for the realization of automatic distribution function subsequently.

5. References
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