

Research on calibration and debugging methods for laser marking device of tire building machine

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Abstract: The tire building machine is a crucial equipment in the tire manufacturing process, and its production performance directly affects the overall quality of the finished tires. As an important component of the building machine, the laser marking device can effectively enhance the precision and efficiency of the building machine during production. This article introduces the debugging principle and application of the laser marking device for tire building machines, elaborates on the steps and considerations for laser lamp calibration and debugging, and verifies its effectiveness through case analysis, providing a reference for improving the tire building process.

Key words: tire building machine; laser marking device; debugging method

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The building quality of tires is crucial to their performance. To ensure the building accuracy of tires, the laser marking device of the building machine plays a vital role. Through precise beam projection, the laser marking device can help operators accurately align the position of the rubber compound, thereby improving the alignment accuracy and process stability during the building process. This article will explore the calibration and debugging methods of the marking device.

With the diversification of market demand for tires, more functional requirements have been put forward for the laser marking device guiding tire building. However, the previous assembly and debugging methods have been difficult to meet the new equipment demands, resulting in many problems during the production debugging process. For example, according to the requirements of the tire building machine, it is necessary to ensure the accuracy of the laser projection position of the laser marking device within the range of 1200~1500 mm. However, in the actual calibration process, due to the large calibration range, there is no suitable mechanism for this task, and it often relies on pasting coordinate paper on walls or floors for calibration. However, this method cannot

visually observe whether the laser line projection positions at 1200 mm and 1500 mm are accurate. The laser marking device needs to be used in conjunction with the building drum of the building machine. According to the requirements of the building process, the operating direction of the internal laser light needs to be parallel to the axis of the building drum to ensure accurate precision. However, in actual debugging, there is no good method to ensure the parallelism between the operating direction of the internal laser light and the axis direction of the building drum. Regarding the debugging process, due to the distortion and stretching of the coordinate paper caused by long-term use, it is necessary to re-paste the coordinate paper and adjust the reference position at regular intervals, leading to issues such as inconsistent accuracy of the calibrated marking device.

To address the aforementioned issues, we analyzed the working principle of the laser marker, produced specialized debugging tooling, and formulated more efficient and

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convenient debugging methods. Now, we will introduce the specific debugging process.

1 Structural design and construction design

1.1 Mechanism design of tooling

Regarding the purpose of debugging the laser marker, it is primarily to provide precise dimensional reference for the laser marker during the operation of the building machine. Therefore, the design of the debugging tooling should strive to replicate the actual working conditions of the laser marker as closely as possible. This debugging tooling mainly consists of an installation frame and a debugging device. The installation frame is used to mount the laser marker, with the installation surface forming a 45° angle with the horizontal plane and parallel to the debugging frame. The calibrated marker is projected obliquely downward at a 45° angle onto the debugging device, simulating the positional relationship between the gantry frame of the building machine and the forming drum, as shown in figure 1.

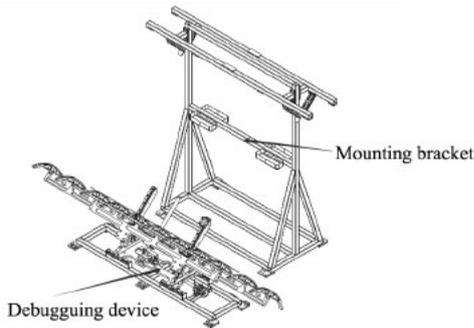


Figure 1 Schematic diagram of tooling

The characteristics of the laser marker debugging tooling are as follows:

(1) The mounting bracket is primarily used for installing the laser marker. Its bottom is equipped with a mechanism for adjusting the levelness, and there are two connecting pieces on it for mounting the laser marker. These two connecting pieces are identical, ensuring consistency in their design and processing. The mounting surface for connecting with the laser marker needs to be coplanar processed. A baffle is set at the bottom of the connecting piece to limit the installation position of the laser marker. During debugging, simply install the marker close to the baffle to control its installation position,

and there is no need to move the marker during subsequent calibration.

(2) The debugging device is primarily designed to simulate the working conditions of a tire building machine. It is equipped with a lateral movement mechanism for horizontal movement, a contraction and expansion mechanism for controlling the calibration distance, and a directly observable drum surface assembly. These three mechanisms are sequentially connected, with the first two primarily responsible for controlling the debugging position. The drum surface tooling can better simulate the shape of the forming drum on the building machine.

(3) The lateral movement mechanism is primarily used for horizontally moving the debugging device. Its base is connected to the ground, and an adjustable mechanism for horizontal and longitudinal movement is set up on it. The moving part uses linear guide rails for guidance and a ladder-type screw rod for transmission. A handwheel is set at the end for manual position adjustment (see Figure 2). Other similar guiding and transmission mechanisms can also be used, or a motor can be selected to provide power instead of the handwheel. When the laser marker is fixed, the lateral movement mechanism can be moved to align the laser light line with the frame's marking scale.

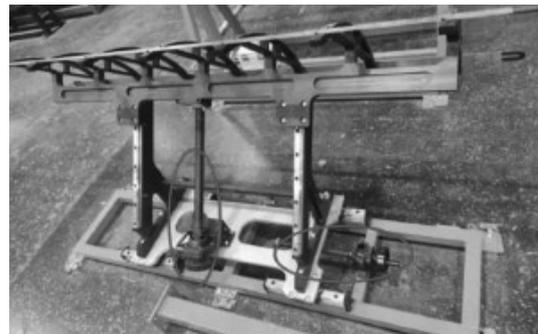


Figure 2 Lateral movement mechanism and expansion/contraction mechanism

(4) The expansion and contraction mechanism is installed on the moving part of the horizontal movement mechanism, primarily used to control the calibration distance. The expansion and contraction direction is parallel to the laser light line, allowing for the simulation of light projection within a certain measurement range. Similar to the horizontal movement mechanism, the expansion and contraction mechanism also

utilizes linear guide rails and trapezoidal lead screws to achieve its expansion and contraction function, with a maximum range of movement being 1100~1600 mm from the distance marker (see Figure 2). The expansion and contraction mechanism enables debugging personnel to visually observe the accuracy of the laser light line within the required range specified in the protocol.

(5) The drum surface assembly is installed on the moving frame of the expansion and contraction mechanism, adjusting its distance from the marking device as the expansion and locking mechanism operates. The drum surface assembly resembles the shape of a drum surface, but it cannot rotate like a drum. It consists of seven identical half-moon-shaped brackets, and the installation position is limited by the processing machinery to ensure consistency in installation location. The surface of the bracket is designed with three recessed platforms, which ensure the consistency of the seven drum surface brackets during processing. The three recessed platforms are respectively equipped with upper, middle, and lower scales, and the scales are aligned using a plumb line so that the projections of their scales on the horizontal plane coincide (see Figure 3). The drum surface tooling simulates the actual drum surface shape, aiming to reduce the difference between the tooling and the actual working conditions, thereby achieving higher debugging accuracy. The three scales installed on the drum surface tooling allow for more intuitive observation of the verticality of the laser light lines and their parallelism to each other.



Figure 3 Drumhead tooling

1.2 Construction design of tooling

The debugging of the laser light marker requires fixing the positions of the mounting frame and the debugging device, and adjusting the relative relationship between the two frames to ensure the convenience and reliability of the subsequent

debugging process.

During the application of the marking device on the tire building machine, it is necessary to ensure that the laser light is vertically irradiated on the drum surface, and the accuracy is always controlled within a certain range throughout the lateral movement of the marking device. This requires that the lateral movement direction of the marking device is always parallel to the axis of the drum. Applying this principle to the debugging tooling means ensuring that the installation surface of the marking device is parallel to the axes of multiple drum surface toolings.

Adjust and verify this parallelism on the currently designed tooling. This can be done by measuring the distance between the two connecting pieces on the left and right of the mounting frame and the two ends of the debugging device. When the distances on both sides are the same, it can be concluded that this parallelism is qualified. The specifics are shown in figure 4 below.

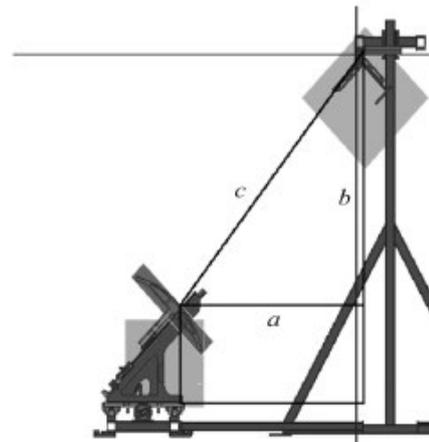


Figure 4 Schematic diagram of construction

To adjust the distance c between the two ends to be equal, that is, $c_1=c_2$, the first step is to adjust the distance a between the reference points of the installation frame and the debugging device to be equal. This process is mainly achieved through equal-length tooling. Use a plumb bob to project the positions of both sides of the installation frame onto the ground, and install equal-length tooling on both ends of the debugging device so that the plumb bob overlaps with the tooling to ensure $a_1=a_2$. Both the installation frame and the debugging device are equipped with horizontal adjustment mechanisms. When both mechanisms are horizontal, it can be determined

that $b_1=b_2$. At this point, it can be determined that $c_1=c_2$, that is, the installation surface of the marking device is parallel to the axes of multiple drum surface tooling. Figure 5 below is an actual site image after debugging.



Figure 5 On-site debugging tooling

2 Calibration scheme

The calibration process of the marking device mainly consists of two parts: adjusting the internal straight-line laser light and adjusting the guiding mechanism of the laser light. The purpose of adjusting the straight-line laser light is to ensure the accuracy of the initial position of the marking device is qualified. Adjusting the guiding mechanism is to ensure the accuracy of the marking device during movement is qualified.

2.1 Adjust the laser light

(1) First, install the marking device onto the mounting frame, position it using the positioning plate designed for the marking device bracket, and secure the marking device with screws.

(2) Adjust the laser lights inside the marking device. Since the laser light path projects in a fan-shaped manner, the projection of the light onto the scale appears as a straight line. Adjust the internal adjustment mechanism of the laser lights so that the light lines of the three laser lights have the same readings on the upper, middle, and lower steel rulers of the scale mechanism (see Figure 6). At this point, it can be determined that the laser light lines inside the marking device are vertical. Then, use the horizontal movement mechanism to translate the debugging bracket so that the central light mark coincides with the central scale of the adjustment device. Check the parallelism of the laser light beams by observing the readings on the upper, middle, and lower scales.

(3) Utilize the expansion and contraction mechanism to move the scale mechanism to positions of 1,200 mm and 1,500

mm respectively (see Figures 7 and 8). Record the light line scale values at these two positions, adjust the laser light so that the values at both positions are the same, and verify whether the emission angle of the laser light path is perpendicular to the drum axis, in order to verify the accuracy of different detection ranges.

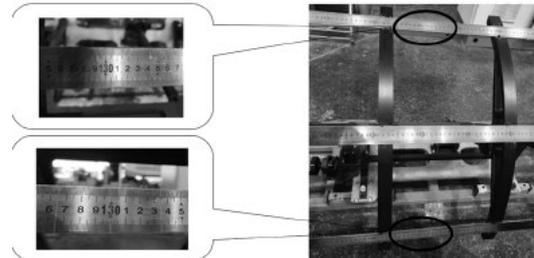


Figure 6 Readings of three scales on the drumhead



Figure 7 Expansion and contraction mechanism at 1200 mm position



Figure 8 Expansion and contraction mechanism at a position of 500 mm

2.2 Adjust the guide mechanism of the marking device

To control the operation of the line marker motor, a standard distance of 50 mm is generally used. Since the length

of each slider in the internal guiding mechanism of the line marker is approximately 60 mm, to ensure accurate positioning of the laser light line, it is recommended that the standard inspection distance be less than the slider size. Move in sections from 50mm to the maximum travel of the light marker to inspect its positioning accuracy.

Since the straight line laser light of the marking device is installed on the guiding module for operation, any directional deviation of the guiding module will affect the direction of the laser light's optical path, resulting in a deviation. This deviation in the optical path direction will be proportionally magnified onto the scale surface, as shown in figure 9 below. The green line indicates the deviation of the guiding module. Through theoretical calculations, when the deviation of the guiding module within a slider range exceeds 0.05 mm, the projection light of the laser light line at a distance of 1200 mm will deviate by more than 1mm, and the projection light at a distance of 1500 mm will deviate by more than 1.25 mm. At this point, it is necessary to adjust the straightness of the guiding module to adjust the marking accuracy of the marking device.

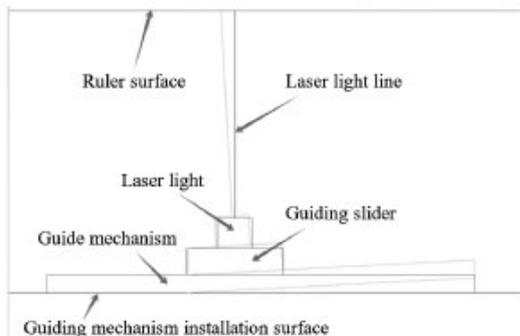


Figure 9 Schematic diagram of accuracy error caused by deviation of the guidance module

If the positioning accuracy exceeds the tolerance (typically ± 0.5 mm), it is necessary to adjust the straightness of the upper busbar on the guide rail using copper shims. If there is a deviation in the dimensions of the upper and lower scales (typically ± 0.5 mm), it is necessary to adjust the straightness of the side busbar on the guide rail using an adjustment tool.

2.3 Data recording and verification

(1) During the debugging process, record the parameter changes for each step to provide a standard for subsequent verification.

(2) The beacon adjusted according to the above steps

needs to operate continuously for more than 24 hours under standard procedures.

(3) After operation, the marking device needs to recheck the previously inspected content. Ensure that the deviation between the recheck results and the initial inspection results does not exceed 50% of the maximum allowable error, and that the recheck results meet the required accuracy for the beacon.

3 Process optimization

(1) During the debugging process, record the parameter changes for each step, the data content of each unit, and develop reasonable solutions for frequently occurring issues to improve product quality. Emphasize the recording of sporadic issues to assist in subsequent design and debugging optimization.

(2) Establish a regular inspection and maintenance system for laser lights to ensure they are in optimal working condition, thereby avoiding accuracy degradation caused by equipment aging or malfunction.

4 Case effect analysis

(1) When our company previously used coordinate paper as a benchmark to debug beacon units, the efficiency was extremely low. The debugging time for each beacon unit was around 12 hours, and when encountering individual beacons that were difficult to debug, it would take even longer to successfully debug them. After adopting new debugging tools and methods, the debugging efficiency was significantly improved, and the current debugging efficiency has reached 8 hours per 2 beacon units.

(2) After adopting new debugging tooling and newly formulated debugging methods, our company applied a total of 87 units of laser light markers on equipment and at customer sites in 2024, and no issues with inaccurate calibration accuracy occurred.

5 Conclusion

Appropriate calibration fixtures and calibration and debugging methods are crucial for enhancing the accuracy and stability of laser light markers. By implementing standardized design and debugging processes, along with necessary regular equipment maintenance, the debugging efficiency and

operational stability of laser light markers can be significantly improved. This, in turn, helps tire building machines maintain their competitiveness in the fierce market competition. By applying the solutions proposed in this paper, our company has achieved a threefold increase in the efficiency of laser light marker debugging, and the stability of delivered products has also been greatly enhanced, resulting in significant economic benefits for the enterprise. Looking ahead, with the continuous advancement of manufacturing technology, laser calibration

technology will play an increasingly important role in the field of tire manufacturing, facilitating more efficient and intelligent production management.

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