# A belt drum deviation correction and lamination structure,control method and control system

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**Abstract:** The existing building machines for heavy-duty three-drum tires come in two structures: a kind of three-drum two-chamber machine and a kind of three-drum three-chamber machine. The former utilizes a shared chamber for the belt drum and the building drum, boasting higher production efficiency due to its in-line bonding without radial movement; however, the significant distance between the building drum and the chamber leads to substantial deflection and makes independent adjustment impossible. This paper presents a belt drum correction structure, along with a bonding control method and control system, to address the aforementioned technical issues.

**Key words:** in-line belt drum machine; alignment; control method; control system

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## 1 Introduction to existing technologies

As shown in Figure 1, the three-drum two-box machine utilizes a single box for both the belt drum and the forming drum, enabling the actuation of both. Although this model boasts high production efficiency, in terms of structural layout, the forming drum is installed at a relatively far distance from the box via its drive shaft, leading to significant deflection during production. Moreover, the coaxial installation of the belt drum and the forming drum makes independent adjustment impossible. On the other hand, as depicted in Figure 2, the three-drum three-box machine employs separate boxes for both the belt drum and the forming drum, which are arranged on two vertically arranged tracks. This model allows for independent adjustment of the installation angles of the two drums through separate boxes, effectively enhancing operational precision. However, in terms of structural layout, the belt drum box is arranged outside the centerline, necessitating radial movement of the belt drum to the outside of the line during production to facilitate the transfer of composite parts, resulting in slow production pace and low efficiency.

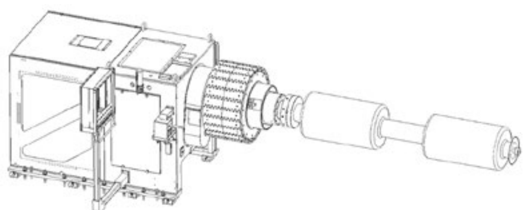

**Figure 1 In-line three-drum and two-chassis structure**

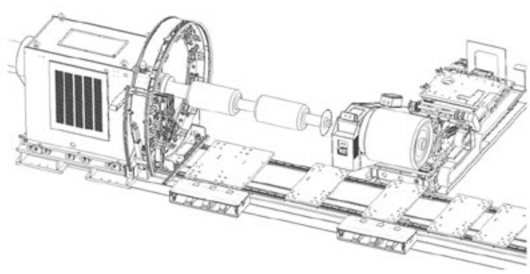

**Figure 2 Out-of-line three-drum and three-box structure**

## 2 New technical solution

Based on existing technology and considering the pros and cons of the two aforementioned machine models, this time

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we adopt the original three-drum, two-box structure layout. The belt drum is independently set up in a box and arranged inline, as shown in Figure 3. This box is coaxially arranged with the forming drum box and can move axially on the base, allowing the main shaft angles of the forming drum and belt drum to be independently adjustable. This achieves further improvement in the operational accuracy of the equipment. Through this optimization adjustment, the impact of the forming drum deflection on accuracy can be reduced by more than 3 mm, and the equipment accuracy adjustment time can be reduced by more than 0.5 days. Additionally, the added movement of the belt drum box enables the function of rubber compound bonding and correction on the belt drum, simplifying the structure of the feeding system and reducing the overall cost of the machine.

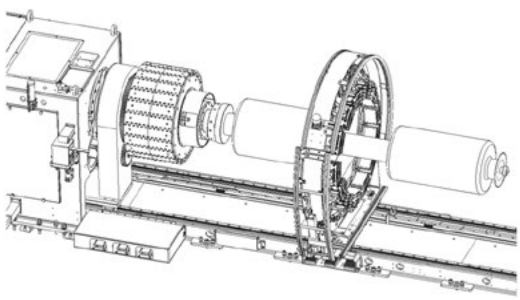
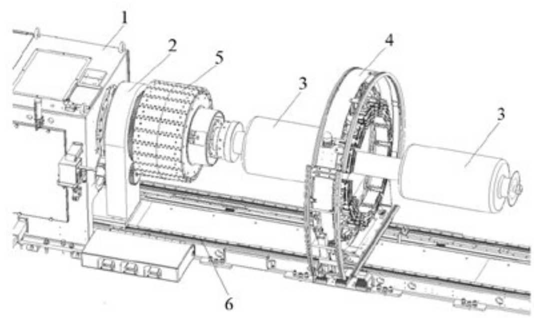


**Figure 3 Stereogram of the three-drum and three-chamber structure within the line**

The belt drum machine adopts two independent servo motors to control the rotation and expansion/contraction of the belt drum, and also incorporates an additional axial movement correction function. However, based on the aforementioned structural improvements, there is still a lack of a corresponding control mechanism to achieve axial movement in accordance with the feeding situation of the belt drum combined feeding system. Therefore, a belt drum correction and fitting control system and its supporting control method are designed based on this mechanism, in order to further enhance the operational accuracy of the equipment.

Next, the control and correction system will be elaborated with reference to Figure 4. The forming drum machine is mounted on the base to control the rotation of the forming drum. The belt drum machine is installed on the guide rail slider of the base and is coaxially arranged with the main shaft of the forming drum through a hollow shaft structure. The belt




1—Forming drum housing; 2—Belt drum housing; 3—Forming drum; 4—Belt ring; 5—Belt drum; 6—Base

**Figure 4 Layout of three drums and three cabinets within the line**

drum machine is equipped with a rotary drive mechanism, a expansion and contraction drive mechanism, and a moving drive mechanism. The rotary drive mechanism controls the rotation direction and speed of the belt drum, the expansion and contraction drive mechanism controls the expansion and contraction state and speed of the belt drum, and the moving drive mechanism controls the axial movement direction and distance of the belt drum on the base.

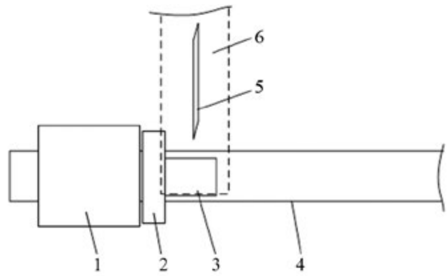
## 3 New technology control methods

In the production operation state, a feeding conveyor belt is installed adjacent to the belt drum. The conveying direction of the feeding conveyor belt is perpendicular to the direction of the slide rail on the base of the building machine, so that while the feeding conveyor belt conveys the rubber compound onto the belt drum, the belt drum rotates synchronously and causes the rubber compound to wrap around the belt drum once, resulting in the rubber compound being finally wrapped around the belt drum and forming an annular belt and tread; in the above process,

(1)Due to the uncertainty of the actual conveying position of the rubber compound on the feeding conveyor belt, in order to achieve the ideal state of the rubber compound being centered and wound around the belt drum, it is necessary for the belt drum to perform axial movement adjustment according to the conveying position of the rubber compound;

(2)During the cutting process of rubber compound before conveying, there is often a cutting length error, resulting in the actual length of the rubber compound being slightly longer or shorter than the circumference of the belt drum. This leads to the inability to form a complete and uniform circular belt and tread on the belt drum, affecting the final tire quality.

Based on this, the belt drum correction and fitting control system achieves correction and fitting control of the belt drum during production operations.




1—Forming drum housing; 2—Belt drum housing; 3—Belt drum; 4—Base; 5— Rubber compound; 6—Conveyor belt

**Figure 5 Layout of three drums and three cabinets within the line**

As shown in Figure 5, the belt drum correction and fitting control system includes:

The image acquisition system is arranged directly above the feeding conveyor belt to capture images of the rubber compound and the feeding conveyor belt beneath it. Specifically, the image acquisition system comprises a camera and a fill light, with the camera being arranged in such a way that the lens is facing vertically downwards;

The image processing system, connected to the image acquisition system, analyzes the images of the rubber compound and the feeding conveyor belt beneath it to obtain the following information: the actual length Lreal of the rubber compound as shown in Figure 6, the length lhead of the head triangle area, the length lmid of the middle area, and the length ltail of the tail triangle area, as well as the center offset value Δd of the rubber compound as shown in Figure 7, which is the vertical distance from the length centerline of the rubber compound to the length centerline of the feeding conveyor belt;

A belt drum displacement controller, which is connected to both the image processing system and the mobile drive mechanism, is designed to output displacement adjustment parameters to the mobile drive mechanism based on the acquisition results from the image processing system;

The belt drum speed controller is connected to both the image processing system and the rotary drive mechanism, and it outputs rotational control parameters to the rotary drive mechanism based on the acquisition results from the image processing system.

Specifically, the specific implementation steps of the belt drum correction and fitting control method based on the aforementioned belt drum correction and fitting control system are described as follows.

S1: Collect images that include the rubber compound and the feed conveyor belt beneath it.

S2: Based on the image obtained in step S1, measure the actual length Lreal of the rubber compound, the length lhead of the head triangle area, the length lmid of the middle area, and the length ltail of the tail triangle area, as well as the center offset value Δd of the rubber compound, as shown in Figures 6 and 7.

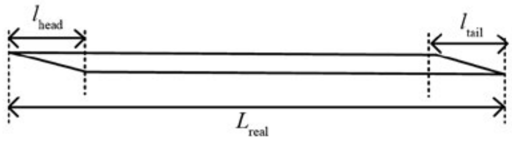



**Figure 6 Schematic diagram of rubber compound shape**

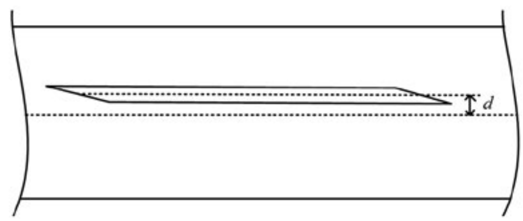



**Figure 7 Schematic diagram of rubber compound conveying and conveyor belt position**

S3: According to the change in the center offset value Δd of the rubber compound from the head to the tail, adjust the axial displacement of the belt drum so that the belt drum always remains centered with the rubber compound. That is, as the rubber compound is conveyed by the feed conveyor belt, it always falls centrally on the outer circumferential centerline of the belt drum and rotates around the belt drum as it rotates.

In practical operations, the position of the feeding conveyor belt is fixed, and the belt drum is generally initially positioned in alignment with the feeding conveyor belt. However, due to various factors, the rubber compound being cut each time often exists in a non-centered state on the feeding conveyor belt, such as being positioned on one side of the feeding conveyor belt or obliquely on it. Therefore, the belt drum needs to adjust its axial displacement during the process of the rubber compound winding around the belt drum according to the change in the spacing between the rubber compound and the feeding conveyor belt, that is, the change in the center offset value Δd, so that the belt drum can always maintain alignment with the rubber compound.

Due to the varying vertical distance between the rubber compound and the centerline position of the feeding conveyor belt in its length direction, that is, the center offset value Δd is variable, the belt drum maintains axial movement throughout the winding process of the rubber compound. Since the distance of the belt drum from the front end of the feeding conveyor belt at the time of image acquisition can also be obtained through image analysis, the starting time of axial displacement adjustment of the belt drum can be determined based on the known distance and the conveying speed of the feeding conveyor belt.

S4: Based on the length Lreal of the rubber compound, the circumference LB of the belt drum, and the conveying speed v0 of the feeding conveyor belt, determine the rotation speed variation method of the belt drum so that the rubber compound can wrap around the belt drum once and, with its head and tail triangular areas joined together, form a complete and uniform circular belt and tread.

In this step S4, the change pattern of the rotational speed vB and the rotation duration t of the belt drum is set as follows:

Stage I: $v_B=v_0, t_1=l_{head}/v_0$;

Phase II: $v_B=\frac{l_{mid}+\Delta l}{l_{mid}}.v_0, t_2=l_{mid}/v_0$;

Stage III: $v_B=v_0, t_3=l_{tail}/v_0$。

In the formula, $v_B$ represents the real-time rotational speed of the belt drum, $v_0$ denotes the conveying speed of the feeding conveyor belt, $t_1$ signifies the duration for the belt drum to maintain the rotational speed in Phase I, lhead stands for the length of the triangular head area of the rubber compound, lmid indicates the length of the middle area, $\Delta l$ represents the difference between the length of the rubber compound and the circumference of the belt drum, where $\Delta l=L_B-L_{real}$, $t_2$ signifies the duration for the belt drum to maintain the rotational speed in Phase II, ltail represents the length of the triangular tail area, and $t_3$ denotes the duration for the belt drum to maintain the rotational speed in Phase III.

In the aforementioned Stage I, the head triangular area of the rubber compound falls onto the belt drum and, as the belt drum rotates, is wound centrally around its outer circumference. During this stage, the rotational speed of the belt drum remains consistent with the conveying speed of the feeding conveyor belt;

In the aforementioned Stage II, the middle region of the rubber compound begins to wrap around the outer circumference of the belt drum. This stage is an adjustment phase where the belt drum adjusts its rotational speed based on the difference between the actual length of the rubber compound and its circumference. Specifically, when the actual length of the rubber compound is less than the circumference of the belt drum, the belt drum appropriately increases its rotational speed to stretch the rubber compound, thereby compensating for the difference and enabling the subsequent alignment and splicing of the tail triangular area with the head triangular area of the rubber compound. Similarly, when the actual length of the rubber compound is greater than the circumference of the belt drum, the belt drum appropriately slows down its rotational speed to allow the rubber compound to lag and loosen its wrapping, thereby reducing the difference and enabling the subsequent alignment and splicing of the tail triangular area with the head triangular area of the rubber compound. When the actual length of the rubber compound equals the circumference of the belt drum, there is no need to adjust the speed of the belt drum, which remains consistent with the conveying speed of the feeding conveyor belt, directly satisfying the subsequent alignment and splicing of the tail triangular area with the head triangular area of the rubber compound.

In the aforementioned Stage III, the tail triangular area of the rubber compound falls onto the belt drum, similar to the head triangular area of the rubber compound. Due to its narrow width and uneven shape, this part is not suitable for length adjustment. Therefore, the rotational speed of the belt drum in this stage also remains consistent with the conveying speed of the feeding conveyor belt.

## 4 Summary

In summary, the belt drum correction and fitting control method and control system are based on the structural characteristics of the belt drum, which has an independently controlled chassis and can move freely in the axial direction on the base. By combining the real-time characteristics of the feeding conveyor belt and the rubber compound conveyed on it, the axial movement mode and rotational speed of the belt drum are controlled to achieve the purpose of correction on the drum. Through actual production application, this control method and control system enable the rubber compound, regardless of the conveying state on the feeding conveyor belt, to be wound centrally on the belt drum, and to form a complete and uniform circular belt and tread by splicing the head and tail triangular areas, ensuring and improving the quality of the subsequent molded tires.