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(54) **ROTOR SPINNING METHOD AND DEVICE FOR FIVE-SLIVER ASYNCHRONOUS INPUTTING AND THREE-LEVEL CARDING**

(57) A multi-level carding rotor spinning method and device. The device comprises a spinning system and a computer control system. The spinning system comprises a feeding and carding mechanism, a collecting and twisting mechanism, and a winding mechanism. The feeding and carding mechanism comprises combined feeding rollers (2-6, 2-7, 2-8, 2-9, 2-10) having five rotational freedom degrees and multiple levels of carding rollers (2-12, 2-13, 2-14). The speed ratio of five rollers of the combined feeding rollers with five rotational freedom degrees can be adjusted, so that the linear density and the blending ratio of rotor spun yarns are randomly adjusted.

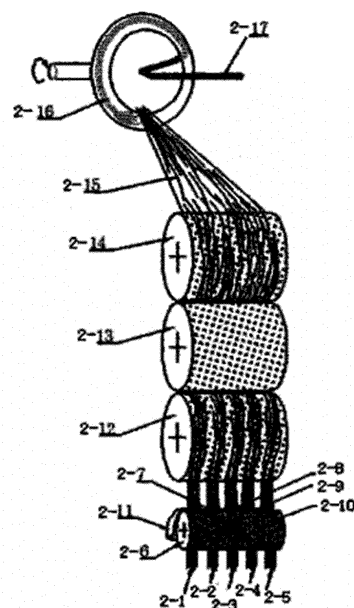


FIG.2

Description**Technical field**

5 [0001] The present invention relates the field of rotor spinning in the textile industry.

Background

10 [0002] The basic principle of the rotor spinning yarn is that the sliver is fed through the trumpet and is held by feeding plate and a feeding roller. The feeding roller rotates to feed the sliver to the carding area. The sliver is opened and stripped, carded separately and mixed by the carding roller, which rotates at a high speed in the carding area, so that the sliver becomes single fibers which are separated and arranged parallel to each other. The single fibers enter into a fiber transport channel. Under the action of air flow, the fiber flows into the rotor through the fiber transport channel. With the centrifugal force of the rapidly rotating rotor, the fibers in the groove are further piled up and mixed, and then the
15 fibers are jointed with the mother-yarn and twisted by a navel to form a yarn.

[0003] In the Patent "Rotor spinning melange yarn forming method and device and product (Application No. CN201410190891.1)" and "Device of spinning rotor spun melange yarn (CN201420229715.X)", the speed of the feeding roller is controlled to keep feeding in an invariable amount, or two or more drafted slivers are fed in segments in different amounts, resulting in that the blending ratio has monochromatic or multi-colored fibers mixture, so as to achieve an effect that the blending ratio can be adjusted while the density of the spun yarn is invariable. However, these two inventions have two problems. First, in those inventions, only the concept of realizing the blending and segment-color spinning process with invariable linear density through the proposed coupling and drafting method, and no indication is given to show how to change the mixing ratio or color blending ratio under the condition that the coupling and drafting achieves an invariable linear density. In the meantime, no specific embodiments and examples are disclosed. Second,
25 a conventional single carding roller is still used in those patent applications. When three slivers are fed at the same time, the original carding and drafting system cannot adequately strip, card, separate and mix a plurality of slivers, which will cause inadequate break down of fiber strands, resulting in blocking the carding roller and rotor, and will be prone to yarn broken and slub, nep and other defects. At the same time, although the total amount of each sliver by coupling and feeding is invariable, there is still a difference in the feeding amount of each sliver, and the short carding area causes
30 little chance of horizontal fiber mixing, resulting in unsatisfactory color blending effect.

[0004] At present, the patent "Method and equipment for rotor spun slub yarn" (patent number CN00137211.4) can achieve invariable blending ratio but the linear density changes during the rotor spinning process. The principle of the patent is that the asynchronous motor and the stepper motor drive feeding roller through the differential, screw and worm wheel. The stepper motor, under the control of the intelligent controller, performs the following operations: reducing from
35 high speed to low speed; continuing to run for a period of time; accelerating to high speed; continuing to run for a period of time, and the rotor spins a segment of slub yarn. The patent can produce a yarn with variable densities but cannot change blending ratios of the yarn.

[0005] The production of the yarn with the linear density and blending ratio both changed, requires not only that the feeding amount of the two or more of the fed roving can be controlled separately on line, but also that the total amount
40 of the fed roving can be controlled when the feeding amount of the roving is changed. There is no prior art that discloses the production of such yarn. The main problem of the existing rotor spinning technology which can produce the yarn having an invariable linear density and blending ratio is that it is impossible to blend two or more fibers in any proportion during the rotor spinning process.

Summary of the Invention

[0006] In order to solve the above problem, the present invention improves the structure of the conventional rotor spinning machine. A device for implementing a rotor spinning method with three-level carding and multi-component feeding, includes a spinning system and a computer control system. The spinning system comprises a feeding and
50 carding mechanism, a collecting and twisting mechanism, and a winding mechanism. The device is characterized in that the feeding and carding mechanism comprises five combined feeding rollers with rotational freedom degrees, and a three-level carding roller. The speed ratio of the five combined feeding rollers with rotational freedom degree can be adjusted. The collecting and twisting mechanism include a fiber transport channel, a rotor, and a yarn guider. The winding mechanism includes a couple of guide rollers and a winding mechanism. The computer control system includes a PLC programmable controller, a servo driver, and a servo motor. The five combined feeding rollers with rotational freedom degrees and the three-level carding roller are driven by the servo motor. The combined feeding rollers with five rotational freedom degrees comprises a shaft, a bearing, a hollow shaft, a first gear, a second gear, a third gear, a fourth gear, a fifth gear, a washer, a first movable roller, a second movable roller, a third movable roller, a fourth movable roller, and

a fifth movable roller. The first to fifth gears and the first to fifth movable rollers rotate around the same axis. The first to fifth gears respectively drive the first to fifth movable rollers. The three-level carding roller comprises the first carding roller, the second carding roller and the third roller that are arranged in parallel. The rotation speed of the three-level carding roller is progressively increased from the first level to the third level. The rotation speed of the first carding roller is 1500-3000 rpm, the rotation speed of the second carding roller is 3000-6000 rpm, and the rotation speed of the third carding roller is 6000-12000 rpm. The density of carding needles of the three-level carding roller progressively increases from the first carding roller to the third carding roller.

[0007] The other objective of the present invention is to provide a rotor spinning method using the above device. The method includes cotton feeding, carding, collecting and twisting, guide and winding. The method is characterized in that combined feeding rollers with five rotational freedom degrees are used in the fiber feeding to feed the fiber into the carding area asynchronously, and three-level carding roller is used in the carding process.

[0008] With the combined rollers and the three-level carding roller configured in the present invention, five slivers (or five different raw material slivers, or five kinds of colored slivers, hereinafter referred to as five components) can be asynchronously fed into the rotor spinning and carding area through the combined feeding rollers. After opening, carding, orienting, separating and mixing by the three-level carding roller, the five slivers are gradually combed into bundle fibers and further combed into single fibers. Under the action of centrifugal force and air flow, a continuous flow comprised by single fibers released and transferred from the carding roller enters into the rotor rotating at a high speed. In the rotor, the fiber flow, under the centrifugal force, is collected together into a sliver again, and then twisted by the navel, and then guided by the guide roller to form the rotor spinning yarn. In the process of spinning, the servo driving system is controlled by a computer program to feed five slivers asynchronously to the carding area by feeding rollers having five freedom degrees. By controlling the feeding amount and feeding ratio of the five feeding rollers, it is possible to dynamically configure the final yarn density of the rotor spinning and the blending ratio of the five components to produce slub yarn, segment-color yarn, segment-color slub yarn, and melange yarn.

[0009] The speed of the first carding roller is low, so that it is ensured that when the plurality of the slivers with great difference are fed, the total number of carding fibers of each sliver carded by the carding roller are within a reasonable range, thereby reducing damage to the fiber. The speed of the second carding roller is higher than that of the first carding roller. After being carded by the second carding roller, the longitudinal orientation of the fiber is optimized, horizontal transfer mixing of the fiber is further optimized. The third carding roller is a high-speed carding roller. The fiber, after being carded by the third carding roller, obtains not only a better carding and transfer, but also the transport speed is improved, thereby meeting the requirement of centrifugal force for entering the fiber transport channel. Therefore, the fiber can smoothly and orderly go into the rotor to form yarns. Through the multi-level stripping, opening, cleaning, carding, separating and transferring, the large-scale drafting function where the slivers are combed into web, which is then combed into bundles of fibers, which are then separated as single fibers is successfully completed, which enhances the function of the carding area of the rotor spinning, providing flexibility, high efficiency, and high yield.

(2) Based on the mechanical innovation design, the present invention constructs the corresponding mathematical model of spinning and the algorithm of the program. Through the mechatronic servo control system, the random control of the linear density and blending ratio of the rotor spinning yarn are achieved. In specific embodiments, the four kinds of spinning yarns are shown as following:

- ① a yarn with invariable linear density and variable blending ratio, such as gradient-color or segment-color yarn with an invariable linear density segment;
- ② a yarn with invariable blending ratio and variable linear density, such as slub yarn, big-belly yarn, dot yarn;
- ③ a yarn with variable linear density and variable blending ratio, such as segment-color slub yarn, segment-color big-belly yarn, segment-color dot yarn;
- ④ a yarn with invariable linear density and invariable blending ratio but mixed with any proportion of blended yarn or color-mixed yarn.

Brief Description of the drawings

[0010]

FIG.1 is a flowchart of the rotor spinning.

FIG.2 is a diagram of the carding and drafting process of the rotor spinning method with three-level carding roller.

FIG.3 is a diagram showing the transmission of the feeding roller, wherein 3b is the right-side view of 3a.

FIG.4 is a structural view of the combined feeding roller.

FIG.5 is a diagram of a spinning control system with five components asynchronous fed and carded.

FIG.6 is a diagram of a control model of a rotor spinning yarn system with five components asynchronous input.

1-1, 1-2, 1-3: carding roller; 1-4, 1-5: trash ejection port; 1-6: feeding roller; 1-7: sliver; 1-8: compression spring; 1-9: feeding plate; 1-10: fiber transport channel; 1-11: navel; 1-12: rotor; 1-13: degassing hole; 1-14, 1-15: guide roller, 1-16: yarn;
 2-6, 2-7, 2-8, 2-9, 2-10: feeding roller; 2-1, 2-2, 2-3, 2-4, 2-5: sliver; 2-11: feeding plate; 2-12, 2-13, 2-14: carding roller; 2-15: fiber flow; 2-16: rotor; 2-17: yarn;
 3a-5, 3a-6, 3a-7, 3a-8, 3a-9: rollers; 3a-1, 3a-2, 3a-14, 3a-15, 3a-16: gears; 3a-3, 3a-4, 3a-10, 3a-11, 3a-12: idler gear; 3a-13: roller shaft; 3a-17, 3a-18, 3a-19: carding roller, 3a-20: spun yarn, 3b-1: gear; 3b-2: roller; 3b-3, 3b-4, 3b-5, 3b-6, 3b-7: gears;
 4-1, 4-2, 4-3, 4-4, 4-5: rollers; 4-6, 4-7, 4-13, 4-14, 4-17: gears; 4-8, 4-12, 4-16: key; 4-9: fixed shaft sleeve; 4-10: screw; 4-11: bearing; 4-15: shaft. Five movable roller (4-1, 4-2, 4-3, 4-4, 4-5) are driven by the gears (4-6, 4-7, 4-13, 4-14, 4-17) respectively.

Detailed Description of the Embodiments

[0011] The meaning of the formula used in the text:

V_{01} : linear velocity of the feeding roller 1; V_{02} : linear velocity of the feeding roller 2; V_{03} : linear velocity of the feeding roller 3; V_{04} : linear velocity of the feeding roller 4; V_{05} : linear velocity of the feeding roller 5; V_1 : the linear velocity of the carding roller 1; V_2 : the linear velocity of the carding roller 2; V_3 : the linear velocity of the carding roller 3; V_4 : the linear speed of the rotor; V_5 : the linear velocity of the guide roller.

ρ_1 : linear density of sliver A (g / m)

ρ_2 : linear density of sliver B (g / m)

ρ_3 : linear density of sliver C (g / m)

ρ_4 : linear density of sliver D (g / m)

ρ_5 : linear density of sliver E (g / m)

p : yarn density (g / m);

ρ_{11} : linear density of the sliver A passing through the carding roller 1 (g / m)

ρ_{12} : linear density of the sliver A passing through the carding roller 2 (g / m)

ρ_{13} : linear density of the sliver A passing through the carding roller 3 (g / m)

ρ_{14} : linear density of the sliver A in the rotor (g / m)

ρ_{21} : linear density of the sliver B passing through the carding roller 1 (g / m)

ρ_{22} : linear density of the sliver B passing through the carding roller 2 (g / m)

ρ_{23} : linear density of the sliver B passing through the carding roller 3 (g / m)

ρ_{24} : linear density of the sliver B in the rotor (g / m)

ρ_{31} : linear density of the sliver C passing through the carding roller 1 (g / m)

ρ_{32} : linear density of the sliver C passing through the carding roller 2 (g / m)

ρ_{33} : linear density of the sliver C passing through the carding roller 3 (g / m)

ρ_{34} : sliver C linear density in the rotor (g / m)

ρ_{41} : linear density of the sliver D passing through the carding roller 1 (g / m)

ρ_{42} : linear density of the sliver D passing through the carding roller 2 (g / m)

ρ_{43} : linear density of the sliver D passing through the carding roller 3 (g / m)

ρ_{44} : linear density of the sliver D in the rotor (g / m)

ρ_{51} : linear density of the sliver E passing through the carding roller 1 (g / m)

ρ_{52} : linear density of the sliver E passing through the carding roller 2 (g / m)

ρ_{53} : linear density of the sliver E passing through the carding roller 3 (g / m)

ρ_{54} : linear density of the sliver D in the rotor (g / m)

E_1 : draft ratio of the carding roller 1 to the feeding roller;

E_2 : draft ratio of the carding roller 2 to the carding roller 1;

E_3 : draft ratio of the carding roller 3 to the carding roller 2;

E_4 : draft ratio of the rotor to the carding roller 3;

E_5 : draft ratio of the guide roller to the rotor;

E : total draft ratio of rotor spinning, which is equal to the draft ratio of guide roller to feeding roller.

[0012] Subscripts 1, 2, 3, 4, 5 represent component A, component B, component C, component D, component E, respectively.

(1) three-level roller carding process design:

[0013] As to feeding a plurality of the slivers, when the feeding speeds of feeding rollers are greatly different, the fiber holding time of each component is also greatly different. In the rotor spinning with single carding roller, due to the need of balancing the stripping /carding fibers, as well as the requirement of the fiber speed when transferring to the fiber transport channel, the rotation speed of the single carding roller is high. Therefore, when there is a significant difference in feeding amount, the number of times that a fiber of the five slivers is carded will be significantly different, and the more the fiber experiences carding, larger will be the damage to this fiber.

[0014] In order to solve the problem of the rotation speed of the carding roller against the damage to fiber and the even mixture of fibers, the present invention adopts the form of three-level carding rollers, that is, the first carding roller, the second carding roller and the third carding roller. The rotation speed of the first carding roller ($\omega = 1500-3000\text{rpm}$) is relatively low, the needle density is also relatively low; the working angle of the needle is relatively small. It is mainly configured for stripping, opening, cleaning and carding and focusing on making the total carding number of fibers of each sliver within a reasonable range, thereby reducing damage to the fiber. The speed of the second carding roller ($\omega = 3000-6000\text{rpm}$) is mainly configured for stripping, carding, and transferring fibers, wherein the needle density is larger than the needle density of the first carding roller, and the working angle of the needle is relatively larger than that of the first carding roller. After being carded by the second carding roller, the longitudinal orientation of the fiber is optimized, and horizontal transfer mixing of the fiber is further optimized. The third carding roller is a high-speed carding roller ($\omega = 6000-12000\text{rpm}$), which is mainly configured for stripping, carding and separating, and transferring fibers, wherein the needle density is larger than the needle density of the second carding roller, and the working angle of the needle is largest. Fibers passing through the third carding roller gets better carding and transfer. Furthermore, due to the high speed of the third carding roller, under the action of centrifugal force and air flow, a highly separated and continuous fiber flow passes through the fiber transport channel and enters orderly into the rotor to form yarns.

[0015] Through the stripping, opening, cleaning, carding, and transfer of the three-level carding roller, the large-scale drafting function, where the slivers are combed into web, which is then combed into fiber bundles, which are separated into single fibers, is successful completed, which enhances the function of the carding area of the rotor spinning, meets the special requirements for the carding of multiple slivers asynchronously feeding into the rotor spun unit. The effects of flexibility, high efficiency, and high yield are realized.

(2) Draft ratio of the rotor spun yarn:

[0016]

$$E_1 = \frac{(\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5) V_1}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}} = \frac{\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5}{\rho_{11} + \rho_{21} + \rho_{31} + \rho_{41} + \rho_{51}}$$

$$E_2 = \frac{V_2}{V_1} = \frac{\rho_{11} + \rho_{21} + \rho_{31} + \rho_{41} + \rho_{51}}{\rho_{12} + \rho_{22} + \rho_{32} + \rho_{42} + \rho_{52}}$$

$$E_3 = \frac{V_3}{V_2} = \frac{\rho_{12} + \rho_{22} + \rho_{32} + \rho_{42} + \rho_{52}}{\rho_{13} + \rho_{23} + \rho_{33} + \rho_{43} + \rho_{53}}$$

$$E_4 = \frac{V_4}{V_3} = \frac{\rho_{13} + \rho_{23} + \rho_{33} + \rho_{43} + \rho_{53}}{\rho_{14} + \rho_{24} + \rho_{34} + \rho_{44} + \rho_{54}}$$

$$E_5 = \frac{V_5}{V_4} = \frac{\rho_{14} + \rho_{24} + \rho_{34} + \rho_{44} + \rho_{54}}{\rho}$$

$$E = E_1 * E_2 * E_3 * E_4 * E_5 = \frac{(\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5) V_5}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}$$

$$= \frac{\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5}{\rho}$$

$$E = \frac{(\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5) V_5}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}} = \frac{\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5}{\rho}$$

(3) Linear density of rotor spun yarn:

[0017]

$$\rho = \frac{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}{V_5}$$

(4) Blending ratio

[0018] The blending ratio of components A, B, C, D, E in the rotor spinning yarn are K_1 , K_2 , K_3 , K_4 , and K_5 , respectively:

$$K_1 = \frac{\rho_1 V_{01}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}$$

$$K_2 = \frac{\rho_2 V_{02}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}$$

$$K_3 = \frac{\rho_3 V_{03}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}$$

$$K_4 = \frac{\rho_4 V_{04}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}$$

$$K_5 = \frac{\rho_5 V_{05}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}$$

(4) Dynamic linear density of rotor spun yarn

[0019] Assuming that the speed V_5 of the guide roller is invariable, the variables of feeding speed V_{01} , V_{02} , V_{03} , V_{04} and V_{05} of the five slivers are as follows:

$$V_{01}' = V_{01} + \Delta V_{01}$$

$$V_{02}' = V_{02} + \Delta V_{02}$$

$$V_{03}' = V_{03} + \Delta V_{03}$$

$$V_{04}' = V_{04} + \Delta V_{04}$$

$$V_{05}' = V_{05} + \Delta V_{05}$$

[0020] So that the new changed linear density of rotor spun yarn is

$$\begin{aligned} \rho' &= \frac{\rho_1 (V_{01} + \Delta V_{01}) + \rho_2 (V_{02} + \Delta V_{02}) + \rho_3 (V_{03} + \Delta V_{03}) + \rho_4 (V_{04} + \Delta V_{04}) + \rho_5 (V_{05} + \Delta V_{05})}{V_5} \\ &= \frac{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}{V_5} \\ &\quad + \frac{\rho_1 \Delta V_{01} + \rho_2 \Delta V_{02} + \rho_3 \Delta V_{03} + \rho_4 \Delta V_{04} + \rho_5 \Delta V_{05}}{V_5} \end{aligned}$$

$$\Delta \rho = \frac{\rho_1 \Delta V_{01} + \rho_2 \Delta V_{02} + \rho_3 \Delta V_{03} + \rho_4 \Delta V_{04} + \rho_5 \Delta V_{05}}{V_5}$$

(5) Dynamic blending ratio of rotor spun yarn is:

[0021] Assuming that: $\rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5 = \rho_0$

$$V_{01} + V_{02} + V_{03} + V_{04} + V_{05} = V_0$$

[0022] Reference blending ratios are shown as below:

$$K_1 = \frac{V_{01}}{V_0}$$

$$K_2 = \frac{V_{02}}{V_0}$$

$$K_3 = \frac{V_{03}}{V_0}$$

$$K_4 = \frac{V_{04}}{V_0}$$

$$K_5 = \frac{V_{05}}{V_0}$$

[0023] When $V_{01}+V_{02}+V_{03}+V_{04}+V_{05} \rightarrow V_{01}+\Delta V_{01}+V_{02}+\Delta V_{02}+V_{03}+\Delta V_{03}+V_{04}+\Delta V_{04}+V_{05}+\Delta V_{05}$, the blending ratio become as below:

$$K_1' = \frac{V_{01} + \Delta V_{01}}{V_0 + \Delta V_0}$$

$$K_2' = \frac{V_{02} + \Delta V_{02}}{V_0 + \Delta V_0}$$

$$K_3' = \frac{V_{03} + \Delta V_{03}}{V_0 + \Delta V_0}$$

$$K_4' = \frac{V_{04} + \Delta V_{04}}{V_0 + \Delta V_0}$$

$$K_5' = \frac{V_{05} + \Delta V_{05}}{V_0 + \Delta V_0}$$

[0024] Mixed configuration is gradient to realize different color scheme.

[0025] By changing V_{01} , V_{02} , V_{03} , V_{04} , and V_{05} , the blending ratio (color mixing ratio) of different fibers (different colors) in the yarn can be changed under the condition that V_0 is kept invariable, so that k_1 , k_2 , k_3 , k_4 , and k_5 are changed between 0 ~ 100%. In various color mixing modes of five primary colors, the minimum increment of the color mixing ratio is 0.1, wherein the color scheme is as follows:

Table 1 color scheme

	Blending Modes	Color number
Monochromatic mode	A, B, C, D, E	5
Double-color mixing mode	AB, AC, AD, AE, BC, BD, BE, CD, CE, DE	9*10=90
Tricolor mixing mode	ABC, BCD, CDE, DEA, EAB	36*5=180
Four-color mixing mode	ABCD, BCDE, CDEA, DEAB, EABC	82*5=410
Five-color mixing mode	ABCDE color mixture	28*3-2=82
	Total	767

[0026] Note: $k_1+k_2+k_3+k_4+k_5 = 100\%$ can have numerous combinations. Based on the five primary colors (five kinds of color slivers) by coupling and drafting, color alternating, gradient color matching, twisting and mixture, numerous color schemes can be formed. In addition, it is possible to form a segment-color yarn having a variety of color distribution in the yarn.

(6) Random dynamic control method of the rotor spun yarn density and blending ratio

[0027] Dynamic change rate of density of rotor spun yarn is shown as below:

$$\epsilon_p = \frac{\Delta \rho}{\rho} = \frac{\frac{\rho_1 \Delta V_{01} + \rho_2 \Delta V_{02} + \rho_3 \Delta V_{03} + \rho_4 \Delta V_{04} + \rho_5 \Delta V_{05}}{V_5}}{\frac{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}{V_5}}$$

$$= \frac{\rho_1 \Delta V_{01} + \rho_2 \Delta V_{02} + \rho_3 \Delta V_{03} + \rho_4 \Delta V_{04} + \rho_5 \Delta V_{05}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}$$

and

$$\rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5 = \rho_0$$

$$V_{01} + V_{02} + V_{03} + V_{04} + V_{05} = V_0$$

then

$$\epsilon_p = \frac{\Delta V_{01} + \Delta V_{02} + \Delta V_{03} + \Delta V_{04} + \Delta V_{05}}{V_0}$$

$$= \frac{\Delta V_0}{V_0}$$

[0028] From the absolute increment of the linear density and relative increment of the linear density, it can be found that the change of yarn linear density, which totally depends on the $V_{01} + \Delta V_{01}$, $V_{02} + \Delta V_{02}$, $V_{03} + \Delta V_{03}$, $V_{04} + \Delta V_{04}$, $V_{05} + \Delta V_{05}$, can have 11 different patterns. Therefore, there can be 11 kinds of yarn in different forms.

1. A yarn with variable linear density, wherein one component of the yarn has variable linear density and other components of the yarn have invariable linear densities.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * (V_{01} + V_{02} + V_{03} + V_{04} + V_{05} + \Delta V_{0i}) \quad (i=1, 2, 3, 4, 5)$$

2. A yarn with two components having variable linear density and other components having invariable linear densities.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\sum_{i=1}^5 V_{0i} + (\Delta V_{0j} + \Delta V_{0k}) \right]$$

($j \neq k$; $j=1, 2, 3, 4, 5$; $k=1, 2, 3, 4, 5$)

3. A yarn with three components having variable linear density and other components having invariable linear densities.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\sum_{i=1}^5 V_{0i} + (\Delta V_{0j} + \Delta V_{0k} + \Delta V_{0m}) \right]$$

($j \neq k \neq m$; $j=1, 2, 3, 4, 5$; $k=1, 2, 3, 4, 5$; $m=1, 2, 3, 4, 5$)

4. A yarn with four components having variable linear density and other components having invariable linear densities.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\sum_{i=1}^5 V_{0i} + (\Delta V_{0j} + \Delta V_{0k} + \Delta V_{0m} + \Delta V_{0n}) \right]$$

($j \neq k \neq m \neq n$; $j=1, 2, 3, 4, 5$; $k=1, 2, 3, 4, 5$; $m=1, 2, 3, 4, 5$; $n=1, 2, 3, 4, 5$)

5. A yarn with variable linear density, wherein all components of the yarn have variable linear densities.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\sum_{i=1}^5 V_{0i} + \sum_{i=1}^5 \Delta V_{0i} \right]$$

6. A yarn with variable linear density, wherein one component of the yarn is continuous and other components of the yarn are discontinuous.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[V_{0r} + \sum_{j=1}^5 \Delta V_{0j} \right]$$

($r=1, 2, 3, 4, 5$)

7. A yarn with variable linear density, wherein two components of the yarn are continuous and other components of the yarn are discontinuous.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\left(V_{0r} + V_{0s} + \sum_{j=1}^5 \Delta V_{0j} \right) \right]$$

($r \neq s$, $r=1, 2, 3, 4, 5$; $s=1, 2, 3, 4, 5$)

8. A yarn with variable linear density, wherein three components of the yarn are continuous and other components of the yarn are discontinuous.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\left(V_{0r} + V_{0s} + V_{0m} + \sum_{j=1}^5 \Delta V_{0j} \right) \right]$$

($r \neq s \neq m$, $r=1, 2, 3, 4, 5$; $s=1, 2, 3, 4, 5$; $m=1, 2, 3, 4, 5$)

9. A yarn with variable linear density, wherein four components of the yarn are continuous and other components of the yarn are discontinuous.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\left(V_{0r} + V_{0s} + V_{0m} + V_{0n} + \sum_{j=1}^5 \Delta V_{0j} \right) \right]$$

($r \neq s \neq m \neq n$, $r=1, 2, 3, 4, 5$; $s=1, 2, 3, 4, 5$; $m=1, 2, 3, 4, 5$; $n=1, 2, 3, 4, 5$)

10. A yarn with variable linear density, wherein five components of the yarn are continuous and have variable linear densities.

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \sum_{i=1}^5 (V_{0i} + \Delta V_{0i})$$

11. The method of dynamic feed speed control of spun yarn

Because

$$\Delta V_0 = \Delta V_{01} + \Delta V_{02} + \Delta V_{03} + \Delta V_{04} + \Delta V_{05}$$

ΔV may come from ΔV_{01} , or come from ΔV_{02} , ΔV_{03} , ΔV_{04} , ΔV_{05} , which can be determined by the blending ratio. Then:

$$\Delta V_{01} = K'_1(V_0 + \Delta V) - V_{01}$$

$$\Delta V_{02} = K'_2(V_0 + \Delta V) - V_{02}$$

$$\Delta V_{03} = K'_3(V_0 + \Delta V) - V_{03}$$

$$\Delta V_{04} = K'_4(V_0 + \Delta V) - V_{04}$$

$$\Delta V_{05} = K'_5(V_0 + \Delta V) - V_{05}$$

Claims

1. A rotor spinning method for five-sliver asynchronous inputting and three-level carding, **characterized in that:**

- 1) feeding fiber by combined feeding rollers with five rotational freedom degrees into carding area where a three-level carding roller is used for carding;
- 2) moving the combined feeding rollers 1, 2, 3, 4, and 5 at linear speeds V_{01} , V_{02} , V_{03} , V_{04} , and V_{05} , respectively; moving a rotor at a linear speed V_4 and moving a guide roller at a linear speed V_5 ; setting linear densities of five slivers drafted by five rollers to be ρ_1 , ρ_2 , ρ_3 , ρ_4 and ρ_5 , respectively, and setting a rotor spun yarn density to be ρ , such that a draft ratio of a rotor spinning yarn is as below:

$$E = \frac{(\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5) V_5}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}} = \frac{\rho_1 + \rho_2 + \rho_3 + \rho_4 + \rho_5}{\rho} \quad (1)$$

a linear density of the rotor spun yarn is formed,

$$\rho = \frac{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}}{V_5} \quad (2)$$

wherein speeds of three carding rollers are as follows: a speed of a first carding roller is 1500-3000 rpm, a speed of a second carding roller is 3000-6000 rpm, a speed of a third carding roller is 6000-12000 rpm,
3) blending ratios of four slivers in the rotor spinning yarn are K_1 , K_2 , K_3 , K_4 , and K_5 , respectively:

$$K_1 = \frac{\rho_1 V_{01}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}} \quad (3)$$

$$K_2 = \frac{\rho_2 V_{02}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}} \quad (4)$$

$$K_3 = \frac{\rho_3 V_{03}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}} \quad (5)$$

$$K_4 = \frac{\rho_4 V_{04}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}} \quad (6)$$

$$K_5 = \frac{\rho_5 V_{05}}{\rho_1 V_{01} + \rho_2 V_{02} + \rho_3 V_{03} + \rho_4 V_{04} + \rho_5 V_{05}} \quad (7)$$

4) assuming that the speed V_5 of the guide roller is invariable, the variables of feeding speeds V_{01} , V_{02} , V_{03} , V_{04} and V_{05} of the feeding rollers of the five slivers are respectively as follows: $V_{01}' = V_{01} + \Delta V_{01}$, $V_{02}' = V_{02} + \Delta V_{02}$, $V_{03}' = V_{03} + \Delta V_{03}$, $V_{04}' = V_{04} + \Delta V_{04}$, $V_{05}' = V_{05} + \Delta V_{05}$, then the dynamic linear density of the rotor spun yarn is obtained according to formula (2)

$$\Delta \rho = \frac{\rho_1 \Delta V_{01} + \rho_2 \Delta V_{02} + \rho_3 \Delta V_{03} + \rho_4 \Delta V_{04} + \rho_5 \Delta V_{05}}{V_5} \quad (8)$$

5) assuming that $\rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5 = \rho_0$, $V_{01} + V_{02} + V_{03} + V_{04} + V_{05} = V_0$, obtaining a reference blending ratio according to the formulas (3), (4), (5), (6), (7) as

$$K_1 = \frac{V_{01}}{V_0}, K_2 = \frac{V_{02}}{V_0}, K_3 = \frac{V_{03}}{V_0}, K_4 = \frac{V_{04}}{V_0}, K_5 = \frac{V_{05}}{V_0}, \quad \text{wherein, when}$$

$V_{01} + V_{02} + V_{03} + V_{04} + V_{05} \rightarrow V_{01} + \Delta V_{01} + V_{02} + \Delta V_{02} + V_{03} + \Delta V_{03} + V_{04} + \Delta V_{04} + V_{05} + \Delta V_{05}$, the blending ratio becomes as below:

$$K_1' = \frac{V_{01} + \Delta V_{01}}{V_0 + \Delta V_0} \quad (8)$$

$$K_2' = \frac{V_{02} + \Delta V_{02}}{V_0 + \Delta V_0} \quad (9)$$

$$K_3' = \frac{V_{03} + \Delta V_{03}}{V_0 + \Delta V_0} \quad (10)$$

$$K_4' = \frac{V_{04} + \Delta V_{04}}{V_0 + \Delta V_0} \quad (11)$$

$$K_5' = \frac{V_{05} + \Delta V_{05}}{V_0 + \Delta V_0} \quad (12)$$

realizing dynamically adjustable spinning of different color blending ratios or color mixing ratios in the yarn with different fibers or colors by controlling of V_{01} , V_{02} , V_{03} , V_{04} , V_{05} .

2. The method according to claim 1, **characterized in that:** assuming $\rho_1 = \rho_2 = \rho_3 = \rho_4 = \rho_5 = \rho_0$, $V_{01} + V_{02} + V_{03} + V_{04} + V_{05} = V_0$, obtaining a dynamic change rate of the rotor spun yarn density according to formulas (2) and (8):

$$\epsilon_{\rho} = \frac{\Delta V_{01} + \Delta V_{02} + \Delta V_{03} + \Delta V_{04} + \Delta V_{05}}{V_0} = \frac{\Delta V_0}{V_0} \quad (13)$$

achieving a random dynamic regulation of the density and the blending ratio of the rotor spun yarn by controlling the speed change of the four rollers.

3. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * (V_{01} + V_{02} + V_{03} + V_{04} + V_{05} + \Delta V_{0i}) \quad (i=1, 2, 3, 4, 5)$$

changing speed of one of the rollers to achieve a yarn with variable linear density, wherein one component of the yarn has variable linear density and other components of the yarn have invariable linear densities.

4. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\sum_{i=1}^5 V_{0i} + (\Delta V_{0j} + \Delta V_{0k}) \right]$$

($j \neq k$; $j=1, 2, 3, 4, 5$; $k=1, 2, 3, 4, 5$),

changing speed of two of the rollers to achieve a yarn with variable linear density, wherein two components of the yarn have variable linear densities and other components of the yarn have invariable linear densities.

5. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\sum_{i=1}^5 V_{0i} + (\Delta V_{0j} + \Delta V_{0k} + \Delta V_{0m}) \right]$$

($j \neq k \neq m$; $j=1, 2, 3, 4, 5$; $k=1, 2, 3, 4, 5$; $m=1, 2, 3, 4, 5$),

changing speed of three of the rollers to achieve yarn with variable linear density, wherein three components of the yarn have variable linear densities and other components of the yarn have invariable linear densities.

6. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\sum_{i=1}^5 V_{0i} + (\Delta V_{0j} + \Delta V_{0k} + \Delta V_{0m} + \Delta V_{0n}) \right]$$

($j \neq k \neq m \neq n$; $j=1, 2, 3, 4, 5$; $k=1, 2, 3, 4, 5$; $m=1, 2, 3, 4, 5$; $n=1, 2, 3, 4, 5$),

changing speed of four of the rollers to achieve a yarn with variable linear density, wherein four components of the yarn have variable linear densities and other components of the yarn have invariable linear densities.

7. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\sum_{i=1}^5 V_{0i} + \sum_{i=1}^5 \Delta V_{0j} \right]$$

changing speed of five of the rollers to achieve a yarn with variable linear density, wherein five components of the yarn have variable linear densities.

8. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[V_{0r} + \sum_{j=1}^5 \Delta V_{0j} \right]$$

($r=1, 2, 3, 4, 5$),

a yarn with variable linear density, wherein one component of the yarn is continuous and other components of the yarn are discontinuous.

9. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\left(V_{0r} + V_{0s} + \sum_{j=1}^5 \Delta V_{0j} \right) \right]$$

($r \neq s, r=1, 2, 3, 4, 5; s=1, 2, 3, 4, 5$)

a yarn with variable linear density, wherein two components of the yarn are continuous and other components of the yarn are discontinuous.

10. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\left(V_{0r} + V_{0s} + V_{0m} + \sum_{j=1}^5 \Delta V_{0j} \right) \right]$$

($r \neq s \neq m, r=1, 2, 3, 4, 5; s=1, 2, 3, 4, 5; m=1, 2, 3, 4, 5$)

a yarn with variable linear density, wherein three components of the yarn are continuous and other components of the yarn are discontinuous.

11. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \left[\left(V_{0r} + V_{0s} + V_{0m} + V_{0n} + \sum_{j=1}^5 \Delta V_{0j} \right) \right]$$

($r \neq s \neq m \neq n, r=1, 2, 3, 4, 5; s=1, 2, 3, 4, 5; m=1, 2, 3, 4, 5; n=1, 2, 3, 4, 5$)

a yarn with variable linear density, wherein four components of the yarn are continuous and other components of the yarn are discontinuous

12. The method according to claim 2, **characterized in that:**

$$\rho' = \rho + \Delta \rho = \frac{\rho}{V_0} * \sum_{i=1}^5 (V_{0i} + \Delta V_{0i})$$

a yarn with variable linear density, wherein five components of the yarn are continuous, and the linear density of the yarn is variable.

5 13. The method according to claim 2, **characterized in that**: in control method of dynamic feeding speed of the yarn, $\Delta V_0 = \Delta V_{01} + \Delta V_{02} + \Delta V_{03} + \Delta V_{04} + \Delta V_{05}$, change of the speed is derived from ΔV_{01} , ΔV_{02} , ΔV_{03} , ΔV_{04} or ΔV_{05} and determined by the blending ratio, and then $\Delta V_{01} = K'_1(V_0 + \Delta V) - V_{01}$, $\Delta V_{02} = K'_2(V_0 + \Delta V) - V_{02}$, $\Delta V_{03} = K'_3(V_0 + \Delta V) - V_{03}$, $\Delta V_{04} = K'_4(V_0 + \Delta V) - V_{04}$, $\Delta V_{05} = K'_5(V_0 + \Delta V) - V_{05}$.

10 14. A device for realizing the method according to any one of the preceding claims, **characterized in that**, the device comprises a spinning system and a computer control system, the spinning system comprises a feeding and carding mechanism, a collecting and twisting mechanism, and a winding mechanism, **characterized in that**, the feeding and carding mechanism comprises combined feeding rollers having five rotational freedom degrees, a three-level carding roller; wherein a speed ratio of fiver rollers of the combined feeding rollers with five rotational freedom degrees can be adjusted, the collecting and twisting mechanism includes a fiber transport channel, a rotor, and a guide device; the winding mechanism includes a guide and winding mechanism; the computer control system includes a PLC programmable controller, a servo driver, a servo motor; wherein the combined feeding rollers with five rotational freedom degrees and the three-level carding roller are driven by the servo motor.

15 20 15. The device according to claim 10, **characterized in that** the combined feeding rollers with five rotational freedom degrees comprises a shaft, a bearing, a hollow shaft, a first gear, a second gear, a third gear, a fourth gear, a fifth gear, a washer, a first movable roller, a second movable roller, a third movable roller, a fourth movable roller, a fifth movable roller, wherein the first to fifth gears and the first to fifth movable rollers are rotated around the same axis, the first to fifth gears drive the first to fifth movable rollers, respectively.

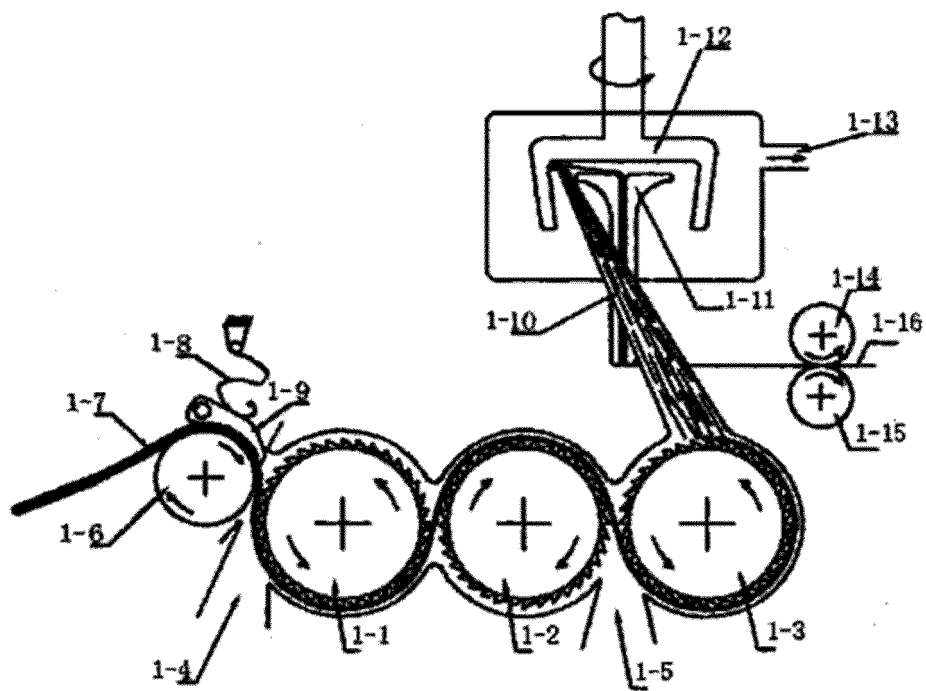


FIG.1

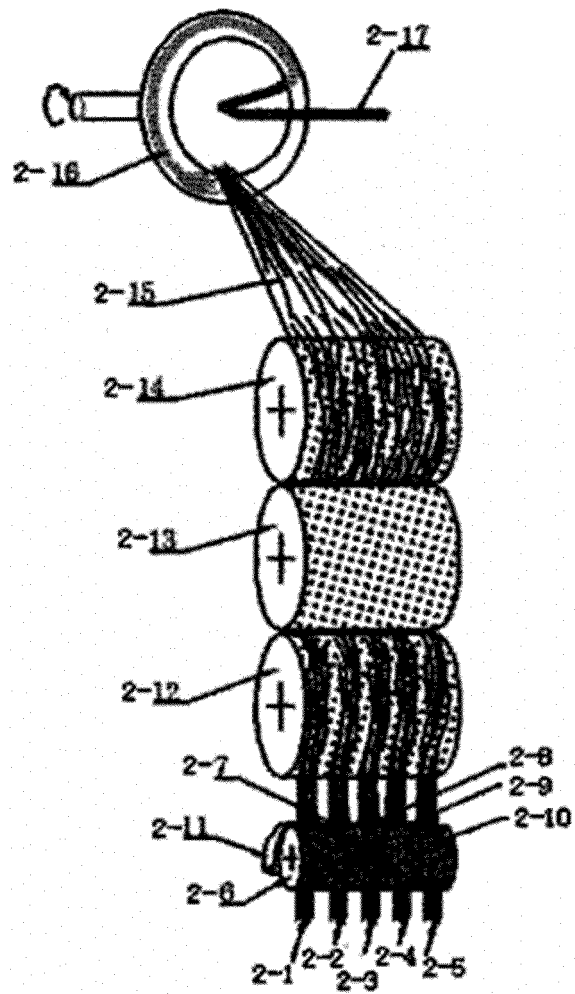
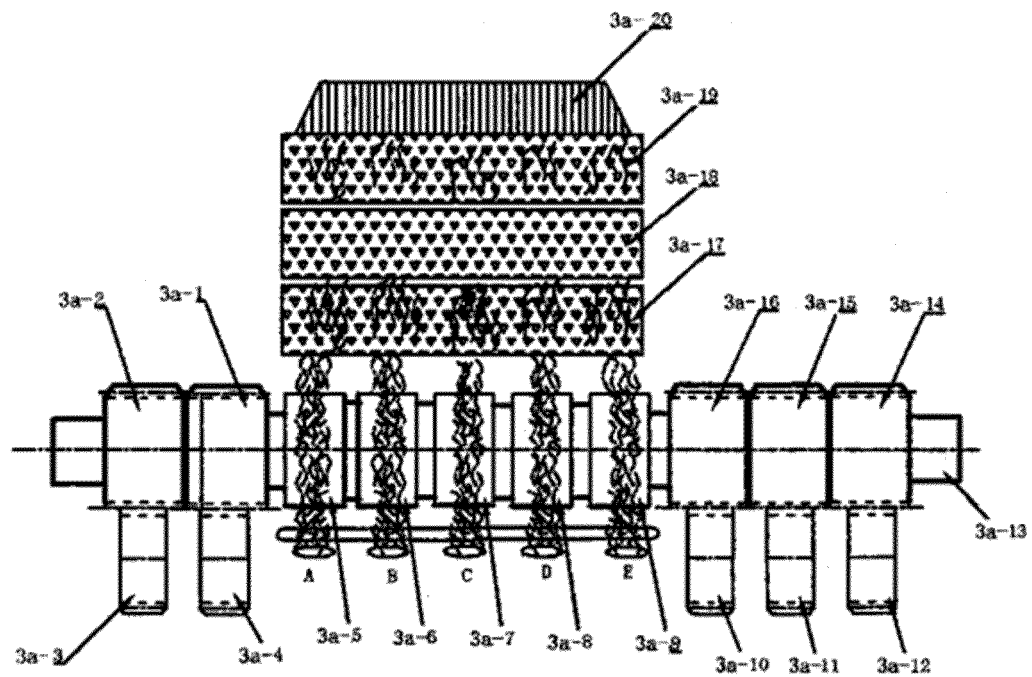
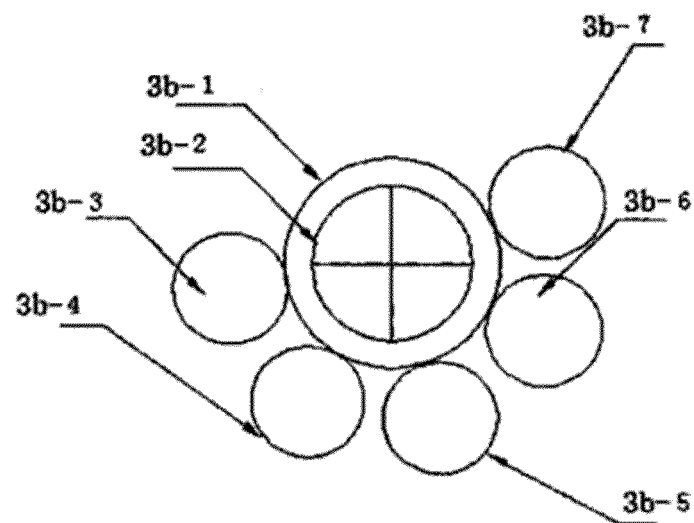


FIG.2



3a



3b

FIG.3

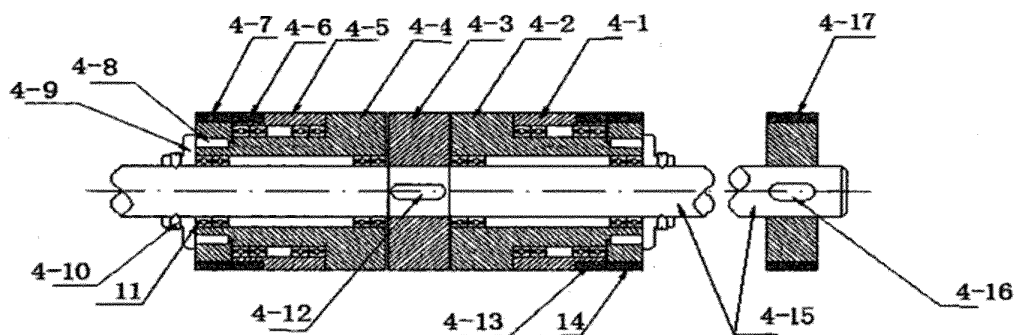


FIG.4

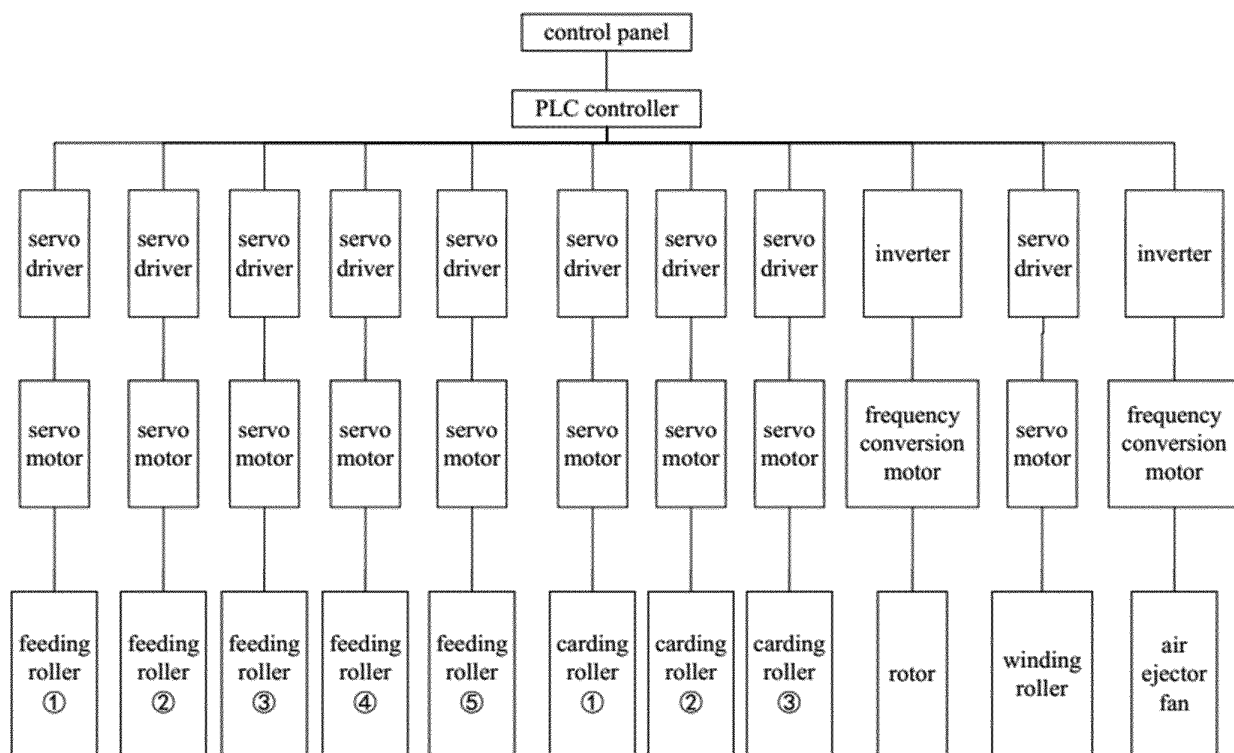


FIG.5

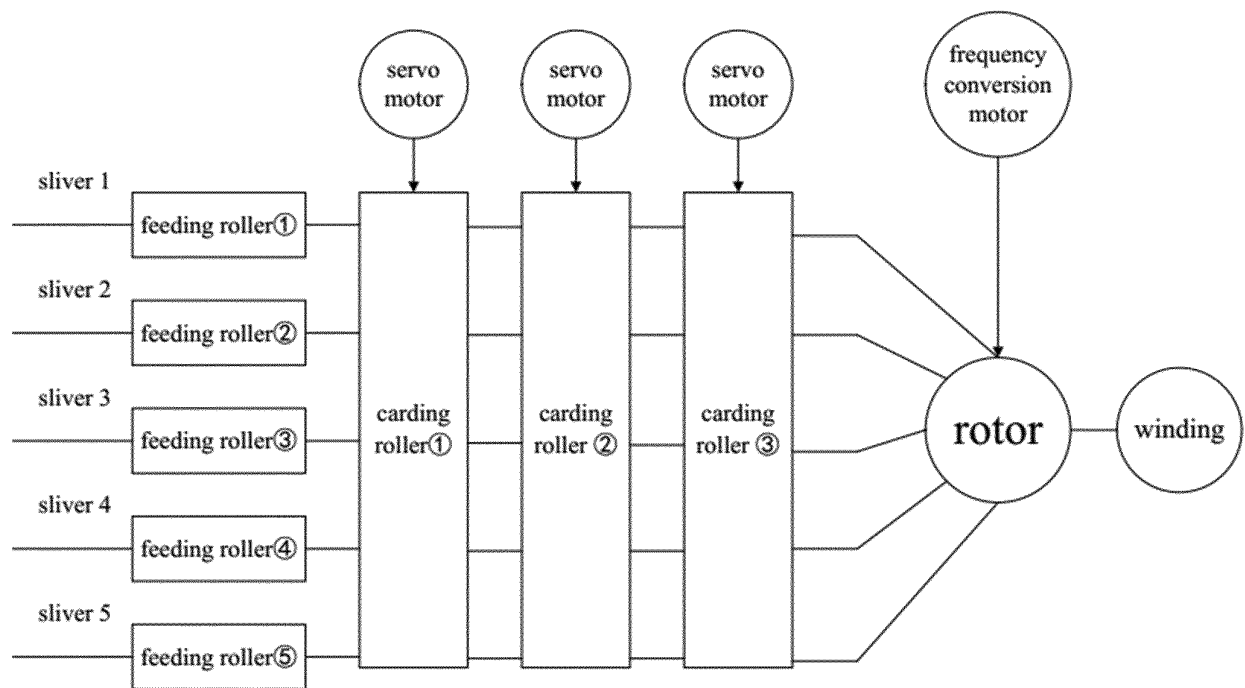


FIG.6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2015/000735

A. CLASSIFICATION OF SUBJECT MATTER

D01H 4/08 (2006.01) i; D01H 4/32 (2006.01) i; D01H 4/44 (2006.01) i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

D01H

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI,EPODOC,CNPAT,CNKI rotor spinning, open-end spinning,mix,blend,ratio,linear,density,roller,speed,adjust,control,online

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	CN 205133852 U (UNIV JIANGNAN) 06 April 2016 (06.04.2016) detailed embodiments, and figures 1-6	1-15
A	CN 103938322 A (UNIV JIAXING) 23 July 2014 (23 July 2014) detailed embodiments, and figures 1-3	1-15
A	CN 203846185 U (UNIV JIAXING) 24 September 2014 (24 September 2014) the whole document	1-15
A	CN 104790074 A (UNIV JIANGNAN) 22 July 2015 (22 July 2015) the whole document	1-15
A	CN 1298969 A (UNIV DONGHUA) 13 June 2001 (13 June 2001) the whole document	1-15

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&"document member of the same patent family

Date of the actual completion of the international search
18 April 2016Date of mailing of the international search report
18 May 2016Name and mailing address of the ISA
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2015/000735

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	WO 2015033811 A1(TOYOTA JIDOSHOKKI KK) 12 March 2015 (12 March 2015) the whole document	1-15

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT
 Information on patent family members

 International application No.
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REFERENCES CITED IN THE DESCRIPTION

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