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Cylindrical coordinate shearing type fruit picking end effector

Abstract

A cylindrical coordinate shearing type fruit picking end effector and a use method therefor are provided. The cylindrical coordinate shearing type fruit picking end effector includes a rack, a fruit clamping mechanism, a rotary motion mechanism, a rotary angle detection mechanism, a linear motion mechanism, a shearing motion mechanism, and a linear distance detection mechanism; where the linear distance detection mechanism is arranged at a front end of the linear motion mechanism; the shearing motion mechanism is arranged at a rear end of the shearing motion mechanism; the linear motion mechanism is arranged at a top end of the rotary motion mechanism; the rotary motion mechanism is arranged at a rear end of the rack; the rotary angle detection mechanism is arranged at a front end of the rotary motion mechanism; and the fruit clamping mechanism is arranged at a front end of the rack.

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Background/Summary

TECHNICAL FIELD

(1) The present invention belongs to the field of agricultural picking equipment, and particularly relates to a cylindrical coordinate shearing type fruit picking end effector and a use method therefor.

BACKGROUND

(2) At present, the cost of manual labor is increasing and becoming unstable, and the supply of agricultural labor is facing a shortage. This has prompted the agricultural industry to seek automated techniques to reduce reliance on human resources and to reduce picking costs. Meanwhile, as the global population grows and the demand for fruits increases, agricultural production needs to improve efficiency and yield to meet market demand. In recent years, the fields of robot technology, visual identification, machine learning, automatic control, and the like are rapidly developed, and more innovation and application possibilities are provided for the research of a fruit picking end effector, so that the automatic picking technology can achieve a faster and more continuous picking process, and production efficiency and yield are improved. At present, the

key problem of automatic fruit picking is how to accurately identify and precisely position fruits and fruit stalks in a complex unstructured environment and achieve automatic undamaged picking.

SUMMARY

(3) An objective of the present invention is to provide a cylindrical coordinate shearing type fruit picking end effector and a use method therefor, thereby solving the defects in the conventional technology.

(4) In order to achieve the foregoing objective, the present invention adopts the following technical solutions.

(5) A cylindrical coordinate shearing type fruit picking end effector includes: a rack, a fruit clamping mechanism, a rotary motion mechanism, a rotary angle detection mechanism, a linear motion mechanism, a shearing motion mechanism, and a linear distance detection mechanism; the linear distance detection mechanism is arranged at a front end of the linear motion mechanism and is configured to detect a position between the shearing motion mechanism and a fruit stalk; the shearing motion mechanism is arranged at a rear end of the shearing motion mechanism and is configured to shear a fruit stalk; the linear motion mechanism is arranged at a top end of the rotary motion mechanism and is configured to adjust a distance between the shearing motion mechanism and a fruit stalk; the rotary motion mechanism is arranged at a rear end of the rack and is configured to adjust an angle of the shearing motion mechanism; the rotary angle detection mechanism is arranged at a front end of the rotary motion mechanism and is configured to detect an angle of a fruit stalk; and the fruit clamping mechanism is arranged at a front end of the rack and is configured to clamp and fix a position of a fruit.

(6) Preferably, fruit protection fingers are further arranged at two sides that are of the rack and that are close to a rear end of the fruit clamping mechanism, and the fruit protection fingers are configured to avoid difficult clamping caused by fruit overlapping.

(7) Preferably, the fruit clamping mechanism includes: a clamping motor, a clamping motor fixing seat, a finger coupler, a finger clamping nut, a bidirectional screw, a clamping bearing seat, a flexible finger, an optical axis fixing seat, a finger guide block, and a guide optical axis; the clamping motor is fixedly connected to the rack by the clamping motor fixing seat, the bidirectional screw is in transmission connection with an output shaft of the clamping motor by the finger coupler, the other end of the bidirectional screw is rotatably connected to the clamping bearing seat, two finger clamping nuts are symmetrically screwed at two ends of the bidirectional screw, the flexible finger is fixed at a front end of the finger clamping nut, the optical axis fixing seat is fixed at a bottom end of the rack, and the finger clamping nut is connected to the guide optical axis in a sliding mode by the finger guide block.

(8) Preferably, the flexible finger is provided with a thin-film pressure sensor, and the thin-film pressure sensor is configured to ensure undamaged fruit picking.

(9) Preferably, the rotary motion mechanism includes: a rotary motion motor, a rotary motor fixing seat, a rotary coupler, a swing rod, a rotary shaft, an arc-shaped guide rail fixing seat, an arc-shaped guide rail, a rotary motion bearing seat, a rolling shaft, a roller bearing, a swing connecting rod, and a rotary platform; the rotary motion motor is connected to the rack by the rotary motor fixing seat, the rotary shaft is connected to an output shaft of the rotary motion motor by the rotary coupler, the other end of the rotary shaft is connected to the rotary motion bearing seat, the swing rod is arranged at one end that is of the rotary shaft and that is close to the rotary coupler, the swing connecting rod is connected to the swing rod in a sliding manner, the rotary platform is fixed on the swing connecting rod, the arc-shaped guide rail is connected to the rack by the arc-shaped guide rail fixing seat, and the rotary platform is movably connected onto the arc-shaped guide rail by the rolling shaft provided with the roller bearing.

(10) Preferably, the rotary angle detection mechanism is installed in front of the rotary motion bearing seat, the rotary angle detection mechanism includes: a rotation detection connecting block, an angle detection rod, and an angle limit switch, the rotation detection connecting block is fixedly

connected to the rotary shaft, the rotation detection connecting block and the angle detection rod are both provided with linear grooves for fixing a torsion spring, and the angle limit switch is installed on the rotation detection connecting block.

(11) Preferably, the linear motion mechanism is installed on a rotary platform, the linear motion mechanism includes: a linear motion motor, a linear motion motor fixing seat, a linear motion guide rail, a linear motion nut, a linear push rod, a linear motion platform, a linear motion sliding block, and a linear motion bearing seat, the linear motion motor is installed on the rotary platform by a linear motion motor fixing seat, a first screw rod is connected to an output shaft of the linear motion motor, the other end of the first screw rod is connected to the linear motion bearing seat, the linear motion nut is in threaded connection with the first screw rod, the linear push rod is connected to the linear motion nut by a bolt, the linear motion guide rail is installed in a middle portion of the rotary platform, and the linear motion platform is slidably installed on the linear motion guide rail by the linear motion sliding block.

(12) Preferably, the shearing motion mechanism is installed at a rear end of the linear motion platform, the shearing motion mechanism includes: a shearing motion motor, a shearing motion guide rod, a shearing motion sliding block, a shearing motion bearing seat, and a boosting shearing mechanism, the shearing motion motor is installed on the linear motion platform, a second screw rod is connected to an output shaft of the shearing motion motor, the shearing motion sliding block is in threaded connection with the second screw rod, the shearing motion bearing seat is connected to the other end of the second screw rod, the shearing motion guide rod is installed on two sides of the second screw rod, and the shearing motion sliding block is connected to the shearing motion guide rods at two sides in a sliding manner; and the boosting shearing mechanism includes: a first connecting rod, a second connecting rod, a third connecting rod, a fixed blade, a movable blade, a movable blade sliding block, a movable blade guide rail, and a connecting rod fixing column, one end of the first connecting rod is hinged to the shearing motion sliding block, the other end of the first connecting rod is hinged to the second connecting rod, the other end of the second connecting rod is hinged to the connecting rod fixing column, the connecting rod fixing column is installed on the linear motion platform, a middle portion of the second connecting rod is hinged to the third connecting rod, the other end of the third connecting rod is hinged to the movable blade, the fixed blade is installed at a position that is at the forefront of the linear motion platform and that is close to a fruit, the movable blade guide rail is transversely installed at a front end of the linear motion platform, and the movable blade is connected to the movable blade guide rail in a sliding manner by the movable blade sliding block.

(13) Preferably, the linear distance detection mechanism is arranged in front of the linear motion platform and close to a direction of a fruit, the linear distance detection mechanism includes: a distance detection push rod, a linear detection fixing seat, and a distance limit switch, the distance detection push rod is arranged below the fixed blade and is connected to the linear detection fixing seat, a cylindrical guide rod and a compression spring are arranged on the distance detection push rod, the distance detection push rod can move linearly along the cylindrical guide rod, the linear detection fixing seat is arranged on the linear motion platform and is positioned between the distance detection push rod and the shearing motion bearing seat, and the distance limit switch is arranged on the linear detection fixing seat and is installed at a position of the cylindrical guide rod on the distance detection push rod.

(14) A use method for the cylindrical coordinate shearing type fruit picking end effector according to any one of the foregoing aspects includes the following steps: S1: the picking end effector is debugged to an initial state; S2: when a position of a fruit is known, a mechanical arm moves to enable the picking end effector to reach a position near a to-be-picked fruit, and the fruit protection finger separates the to-be-picked fruit from other overlapped fruits, so that interference of other fruits and fruit stalks on mechanical detection is avoided; the clamping motor rotates, the flexible finger linearly moves along the guide optical axis along with the finger clamping nut and the finger

guide block, and a rotation direction of the clamping motor should enable a distance of the flexible finger to close; when the flexible finger touches a surface of the fruit, a pressure value is generated on the thin-film pressure sensor on the flexible finger, the pressure value of the thin-film pressure sensor reaches a safety threshold value as the distance of the flexible finger is further shortened, and in this case, the clamping motor stops rotating, and the fruit clamping action is completed; S3: when a position of a fruit stalk cannot be identified visually due to the blocking of fruits and leaves, operations of the rotary angle detection mechanism and the linear distance detection mechanism are required, after the fruit clamping is completed, the rotary motion motor rotates from left to right, the rotary platform and the rotary motion motor coaxially rotate along the arc-shaped guide rail, and when the fruit stalk is touched, and the angle detection rod rotates in a direction opposite to a rotation direction of the rotary motion motor due to the compression of a torsion spring under the action of a contact force, so that the angle limit switch is triggered, the rotary motion motor stops moving, and the angle detection of the fruit stalk is completed; when the angle detection is completed, the linear motion motor rotates to drive the linear push rod to push the linear motion platform to move linearly towards a fruit motion direction along the linear motion guide rail; when the distance detection push rod touches the fruit stalk, the distance detection push rod compresses a compression spring under the action of a contact force, and thus the distance detection push rod moves towards an opposite direction of the fruit along the cylindrical guide rod on the distance detection push rod, so that the distance limit switch is triggered, the linear motion motor stops moving, and the distance detection of the fruit stalk is completed; S4: when the cylindrical coordinate fruit stalk positioning based on the rotary angle and the linear distance detection is completed, the rotary platform and the linear motion platform reach a to-be-sheared position; in this case, the shearing motion motor rotates to drive the shearing motion sliding block to move linearly towards the fruit direction along the shearing motion guide rod; the second connecting rod in the boosting shearing mechanism pushes the movable blade to move linearly towards a closing direction of the blade along the movable blade guide rail, so that the shearing of the fruit stalk is completed; and S5: when the shearing of the fruit stalk is completed, the picking end effector moves to a position of a fruit basket by the mechanical arm, and the clamping motor rotates, so that the flexible finger is opened, a fruit is released, and the undamaged fruit picking is completed.

(15) Compared with the conventional technology, the cylindrical coordinate shearing type fruit picking end effector and the use method therefor provided by the present invention have the following advantages.

(16) By combining machine vision and mechanical detection methods, the present invention can control the end effector based on the actual fruit stalk identification, solves the problem that the fruit stalk is seriously blocked and cannot be identified and positioned, improves the success rate of fruit stalk identification and the success rate of picking; and meanwhile, by using the flexible finger to clamp, the present invention ensures that the fruit is not damaged in the automatic picking process.

(17) Specifically: 1. According to the cylindrical coordinate shearing type fruit picking end effector and the use method therefor of the present invention, a fruit stalk positioning method is provided based on cylindrical coordinates, and can be applied to two positioning modes of machine vision and mechanical detection; especially in a case that the machine vision cannot be used for identifying, the success rate of fruit stalk identification and positioning can be improved by combining mechanical detection and positioning, and the application is flexible. 2. The cylindrical coordinate shearing type fruit picking end effector of the present invention is provided with a design of a boosting shearing mechanism, and can drive the blade to complete the shearing of the fruit stalks by using power with lower power for fruits with serious fruit stalk lignification, so that the shearing stability and success rate are improved, and the volume of the whole shearing mechanism is reduced. 3. The cylindrical coordinate shearing type fruit picking end effector of the present invention is provided with a flexible clamping mechanism, the clamping mechanism is

simple in structure, and the undamaged fruit picking can be implemented through the feedback control of the thin-film pressure sensor.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) In order to more clearly illustrate the technical solutions in the embodiments of the present invention or in the prior art, the drawings required to be used in the description of the embodiments or the prior art are briefly introduced below. It is obvious that the drawings in the description below are merely embodiments of the present invention, and those of ordinary skill in the art can obtain other drawings according to the drawings provided without creative efforts.

(2) FIG. 1 is a schematic diagram of a structure of a rack according to the present invention;

(3) FIG. 2 is a schematic diagram of a structure of a fruit clamping mechanism according to the present invention;

(4) FIG. 3 is a schematic diagram of a structure of a fruit protection finger according to the present invention;

(5) FIG. 4 is a schematic diagram of structures of a rotary motion mechanism and a rotary angle detection mechanism according to the present invention;

(6) FIG. 5 is a schematic diagram of a structure of a rotary platform according to the present invention;

(7) FIG. 6 is a schematic diagram A of structures of a linear motion mechanism, a shearing motion mechanism, and a linear distance detection mechanism according to the present invention;

(8) FIG. 7 is a schematic diagram B of structures of a linear motion mechanism, a shearing motion mechanism, and a linear distance detection mechanism according to the present invention;

(9) FIG. 8 is a schematic diagram of an overall structure according to the present invention;

(10) FIG. 9 is a schematic diagram of a control system according to the present invention; and

(11) FIG. 10 is a schematic diagram of identification and positioning of the present invention.

(12) In the drawings, **1**: rack, **201**: clamping motor, **202**: clamping motor fixing seat, **203**: finger coupler, **204**: finger clamping nut, **205**: bidirectional screw, **206**: clamping bearing seat, **207**: flexible finger, **208**: optical axis fixing seat, **209**: finger guide block, **210**: guide optical axis, **301**: rotary motion motor, **302**: rotary motor fixing seat, **303**: rotary coupler, **304**: swing rod, **305**: rotary shaft, **306**: arc-shaped guide rail fixing seat, **307**: arc-shaped guide rail, **308**: rotary motion bearing seat, **309**: rolling shaft, **310**: roller bearing, **311**: swing connecting rod, **312**: rotary platform, **401**: rotation detection connecting block, **402**: angle detection rod, **403**: angle limit switch, **5**: fruit protection finger, **601**: linear motion motor, **602**: linear motion motor fixing seat, **603**: linear motion guide rail, **604**: linear motion nut, **605**: linear push rod, **606**: linear motion platform, **607**: linear motion sliding block, **608**: linear motion bearing seat, **701**: shearing motion motor, **702**: shearing motion guide rod, **703**: shearing motion sliding block, **704**: first connecting rod, **705**: second connecting rod, **706**: third connecting rod, **707**: shearing motion bearing seat, **708**: fixed blade, **709**: movable blade, **710**: movable blade sliding block, **711**: movable blade guide rail, **712**: connecting rod fixing column, **801**: distance detection push rod, **802**: linear detection fixing seat, and **803**: distance limit switch.

DETAILED DESCRIPTION OF THE EMBODIMENTS

(13) The technical solutions of the present invention are further described below with reference to the accompanying drawings and the embodiments.

Embodiment 1

(14) Referring to FIGS. 1 to 3, the present invention provides a cylindrical coordinate shearing type fruit picking end effector, which includes: a rack **1**, a fruit clamping mechanism, a rotary motion mechanism, a rotary angle detection mechanism, a linear motion mechanism, a shearing motion

mechanism, and a linear distance detection mechanism; the linear distance detection mechanism is arranged at a front end of the linear motion mechanism and is configured to detect a position between the shearing motion mechanism and a fruit stalk; the shearing motion mechanism is arranged at a rear end of the shearing motion mechanism and is configured to shear a fruit stalk; the linear motion mechanism is arranged at a top end of the rotary motion mechanism and is configured to adjust a distance between the shearing motion mechanism and a fruit stalk; the rotary motion mechanism is arranged at a rear end of the rack **1** and is configured to adjust an angle of the shearing motion mechanism; the rotary angle detection mechanism is arranged at a front end of the rotary motion mechanism and is configured to detect an angle of a fruit stalk; and the fruit clamping mechanism is arranged at a front end of the rack **1** and is configured to clamp and fix a position of a fruit.

(15) As a preferred embodiment, fruit protection fingers **5** are further arranged at two sides that are of the rack **1** and that are close to a rear end of the fruit clamping mechanism, and the fruit protection fingers **5** are configured to avoid difficult clamping caused by fruit overlapping.

(16) The fruit clamping mechanism includes: a clamping motor **201**, a clamping motor fixing seat **202**, a finger coupler **203**, a finger clamping nut **204**, a bidirectional screw **205**, a clamping bearing seat **206**, a flexible finger **207**, an optical axis fixing seat **208**, a finger guide block **209**, and a guide optical axis **210**; the clamping motor **201** is fixedly connected to the rack **1** by the clamping motor fixing seat **202**, the bidirectional screw **205** is in transmission connection with an output shaft of the clamping motor **201** by the finger coupler **203**, the other end of the bidirectional screw **205** is rotatably connected to the clamping bearing seat **206**, two finger clamping nuts **204** are symmetrically screwed at two ends of the bidirectional screw **205**, the flexible finger **207** is fixed at a front end of the finger clamping nut **204**, the optical axis fixing seat **208** is fixed at a bottom end of the rack **1**, and the finger clamping nut **204** is connected to the guide optical axis **210** in a sliding mode by the finger guide block **209**. Further, two ends of the bidirectional screw **205** have threads with different rotation directions, one end is left-handed and the other end is right-handed, and the two finger clamping nuts **204** are in a bilateral symmetry structure and are respectively provided with left-handed and right-handed threads in the cylindrical hole, so that the two finger clamping nuts **204** are in opposite motion directions when the bidirectional screw **205** rotates.

(17) In a preferred embodiment, the flexible finger **207** is provided with a thin-film pressure sensor, and the thin-film pressure sensor is configured to ensure undamaged fruit picking.

(18) Referring to FIGS. **4** to **5**, the rotary motion mechanism includes: a rotary motion motor **301**, a rotary motor fixing seat **302**, a rotary coupler **303**, a swing rod **304**, a rotary shaft **305**, an arc-shaped guide rail fixing seat **306**, an arc-shaped guide rail **307**, a rotary motion bearing seat **308**, a rolling shaft **309**, a roller bearing **310**, a swing connecting rod **311**, and a rotary platform **312**; the rotary motion motor **301** is connected to the rack **1** by the rotary motor fixing seat **302**, the rotary shaft **305** is connected to an output shaft of the rotary motion motor **301** by the rotary coupler **303**, the other end of the rotary shaft **305** is connected to the rotary motion bearing seat **308**, the swing rod **304** is arranged at one end that is of the rotary shaft **305** and that is close to the rotary coupler **303**, the swing connecting rod **311** is connected to the swing rod **304** in a sliding manner, the rotary platform **312** is fixed on the swing connecting rod **311**, the arc-shaped guide rail **307** is connected to the rack **1** by the arc-shaped guide rail fixing seat **306**, and the rotary platform **312** is movably connected onto the arc-shaped guide rail **307** by the rolling shaft **309** provided with the roller bearing **310**.

(19) The vertical planes at two ends of the rotary platform **312** are provided with four through holes, the rotary platform is supported on the arc-shaped guide rail **307** by four rolling shafts **309**, when the rotary motion motor **301** rotates, the rotary platform **312** is driven by the swing rod **304** and limited by the arc-shaped guide rail **307**, and the rotary platform **312** can synchronously rotate along with the rotary motion motor **301**; meanwhile, the waist-shaped hole formed by connecting the swing connecting rod **311** and the swing rod **304** can compensate the rotation center

inconsistency and the influence of the processing error of the arc-shaped groove on the arc-shaped guide rail **307** on the rotary motion, and the rotary platform **312** can smoothly complete the left-right rotary motion along the arc-shaped guide rail **307**. In a case that the angle of fruit stalks cannot be obtained through machine vision identification due to severe blocking, the rotary platform **312** needs to cooperate with the rotary angle detection mechanism to reach a specified position; in a case that the angle of fruit stalks can be obtained through machine vision, the controller directly drives the rotary motion motor **301** to rotate the specified angle, so that the rotary platform **312** reaches a specified position.

(20) Referring to FIG. **4**, the rotary angle detection mechanism is installed in front of the rotary motion bearing seat **308**, the rotary angle detection mechanism includes: a rotation detection connecting block **401**, an angle detection rod **402**, and an angle limit switch **403**, the rotation detection connecting block **401** is fixedly connected to the rotary shaft **305**, the rotation detection connecting block **401** and the angle detection rod **402** are both provided with linear grooves for fixing a torsion spring, and the angle limit switch **403** is installed on the rotation detection connecting block **401**. When the rotary angle detection mechanism detects the angle of the fruit stalk, the rotary angle detection mechanism can synchronously rotate along with the rotation shaft **305** of the rotary motion mechanism, and meanwhile, the rotary platform also rotates along with the rotation shaft **305** by the same angle; when the angle detection rod **402** does not touch the fruit stalk in the rotation process, the angle detection rod can rotate along with the rotation detection connecting block **401** under the elastic force action of a torsion spring; when the angle detection rod touches the fruit stalk, the fruit cannot significantly move under certain acting force because the fruit is clamped by the fruit clamping mechanism, and in this case, the fruit stalk can generate a reacting force for the angle detection rod **402** to enable the angle detection rod **402** to rotate in a direction opposite to a rotation direction of the rotation shaft **305**, and then can touch the angle limit switch **403**, so that the rotary motion motor **301** stops rotating, and mechanical detection of the angle value in the cylindrical coordinate of the fruit stalk is completed.

(21) Referring to FIGS. **6** to **8**, the linear motion mechanism is installed on a rotary platform **312**, the linear motion mechanism includes: a linear motion motor **601**, a linear motion motor fixing seat **602**, a linear motion guide rail **603**, a linear motion nut **604**, a linear push rod **605**, a linear motion platform **606**, a linear motion sliding block **607**, and a linear motion bearing seat **608**, the linear motion motor **601** is installed on the rotary platform **312** by a linear motion motor fixing seat **602**, a first screw rod is connected to an output shaft of the linear motion motor **601**, the other end of the first screw rod is connected to the linear motion bearing seat **608**, the linear motion nut **604** is in threaded connection with the first screw rod, the linear push rod **605** is connected to the linear motion nut **604** by a bolt, the linear motion guide rail **603** is installed in a middle portion of the rotary platform **312**, and the linear motion platform **606** is slidably installed on the linear motion guide rail **603** by the linear motion sliding block **607**. The linear motion nut **604** is in threaded connection with the first screw rod, so that the rotary motion of the linear motion motor **601** can be converted into a linear motion. When the angle detection of fruit stalks is completed, the rotary platform **312** reaches a to-be-sheared position, the linear motion motor **601** rotates, the linear push rod **605** moves forwards towards the fruit direction in the rotation direction, the linear push rod **605** pushes the linear motion platform **606**, the shearing motion mechanism and the linear distance detection mechanism are carried on the linear motion platform **606**, in a case that the linear distance of the fruit stalks cannot be obtained through machine vision identification due to serious blocking, the linear motion platform **606** reaches a specified position by cooperating with the linear distance detection mechanism; and in a case that the linear distance of the fruit stalks can be obtained through machine vision, the linear motion motor **601** is driven by the controller, so that the linear motion platform **606** directly reaches a specified position.

(22) As a preferred embodiment, the shearing motion mechanism is installed at a rear end of the linear motion platform **606**, the shearing motion mechanism includes: a shearing motion motor

701, a shearing motion guide rod **702**, a shearing motion sliding block **703**, a shearing motion bearing seat **707**, and a boosting shearing mechanism, the shearing motion motor **701** is installed on the linear motion platform **606**, a second screw rod is connected to an output shaft of the shearing motion motor **701**, the shearing motion sliding block **703** is in threaded connection with the second screw rod, the shearing motion bearing seat **707** is connected to the other end of the second screw rod, the shearing motion guide rod **702** is installed on two sides of the second screw rod, and the shearing motion sliding block **703** is connected to the shearing motion guide rods **702** at two sides in a sliding manner; and the boosting shearing mechanism includes: a first connecting rod **704**, a second connecting rod **705**, a third connecting rod **706**, a fixed blade **708**, a movable blade **709**, a movable blade sliding block **710**, a movable blade guide rail **711**, and a connecting rod fixing column **712**, one end of the first connecting rod **704** is hinged to the shearing motion sliding block **703**, the other end of the first connecting rod is hinged to the second connecting rod **705**, the other end of the second connecting rod **705** is hinged to the connecting rod fixing column **712**, the connecting rod fixing column **712** is installed on the linear motion platform **606**, a middle portion of the second connecting rod **705** is hinged to the third connecting rod **706**, the other end of the third connecting rod **706** is hinged to the movable blade **709**, the fixed blade **708** is installed at a position that is at the forefront of the linear motion platform **606** and that is close to a fruit, the movable blade guide rail **711** is transversely installed at a front end of the linear motion platform **606**, and the movable blade **709** is connected to the movable blade guide rail **711** in a sliding manner by the movable blade sliding block **710**.

(23) The first connecting rod **704**, the second connecting rod **705**, the third connecting rod **706**, and the connecting rod fixing column **712** form a boosting structure, so that the thrust generated by the shearing motion sliding block **703** can be converted into a shearing force with a larger value and generated by the movable blade **709** and the fixed blade **708**, so that the effect of increasing the transmission ratio is achieved, the fruit stalks are sheared more stably, and the input power is reduced; in addition, the overall size of the shearing mechanism is reduced, and the end effector is more flexible and reliable. When the linear distance detection and the rotary angle detection are completed, the rotary platform **312** and the linear moving platform **606** reach the specified positions, the shearing motion mechanism reaches a to-be-sheared position at this time, the shearing motion motor **701** rotates to enable the shearing motion sliding block **703** to push the connecting rod in the boosting shearing mechanism along the shearing motion guide rod **702** towards the fruit direction, the connecting rod is compressed, the movable blade **709** moves along the movable blade guide rail **711** until the fruit shearing is completed, and the shearing motion motor **701** stops moving, so that the fruit stalk shearing action is completed, the picking end effector moves to the fruit basket position by the mechanical arm, and the clamping motion mechanism releases the fruit to complete one-round picking.

(24) In a preferred embodiment, the linear distance detection mechanism is arranged in front of the linear motion platform **606** and close to a direction of a fruit, the linear distance detection mechanism includes: a distance detection push rod **801**, a linear detection fixing seat **802**, and a distance limit switch **803**, the distance detection push rod **801** is arranged below the fixed blade **708** and is connected to the linear detection fixing seat **802**, a cylindrical guide rod and a compression spring are arranged on the distance detection push rod **801**, the distance detection push rod **801** can move linearly along the cylindrical guide rod, the linear detection fixing seat **802** is arranged on the linear motion platform **606** and is positioned between the distance detection push rod **801** and the shearing motion bearing seat **707**, and the distance limit switch **803** is arranged on the linear detection fixing seat **802** and is installed at a position of the cylindrical guide rod on the distance detection push rod **801**. When the linear platform **606** moves towards the fruit direction, the distance detection push rod **801** moves along with the linear platform **606** under the action of the elastic force of the compression spring until the fruit stalk touches the fruit, the fruit stalk can generate a reacting force on the distance detection push rod **801**, the compression spring is

compressed, the distance detection push rod **801** can generate linear motion opposite to the fruit direction until the distance limit switch **803** is touched, the linear motion motor **601** stops moving, and the mechanical detection of the linear distance in the cylindrical coordinate of the fruit stalk is completed.

Embodiment 2

(25) Referring to FIGS. **1** to **10**, the present invention provides a use method for a cylindrical coordinate shearing type fruit picking end effector, which includes the following steps: S1: before picking a fruit, the control system firstly controls the motors on each mechanism to reset by a controller, when a reset switch is touched, the motors are restored to the initial positions, the initial states of the motors are that the clamping motor **201** enables a distance between the flexible fingers **207** to be the largest, the rotary motion motor **301** enables the rotary platform **312** to be at the leftmost position, the linear motion motor **601** enables the linear motion platform **606** to be far away from the direction of the fruit, and the shearing motion motor **701** enables the movable blade **709** to be overlapped with a cutting edge of the fixed blade **708**; further, a visual identification module is used to recognize the fruits and give the position information of the to-be-picked fruit; S2: when a position of a fruit is known, a mechanical arm moves to enable the picking end effector to reach a position near a to-be-picked fruit, and the fruit protection finger **5** separates the to-be-picked fruit from other overlapped fruits, so that interference of other fruits and fruit stalks on mechanical detection is avoided; the clamping motor **201** rotates, the flexible finger **207** linearly moves along the guide optical axis **210** along with the finger clamping nut **204** and the finger guide block **209**, and a rotation direction of the clamping motor **201** should enable a distance of the flexible finger **207** to close; when the flexible finger touches a surface of the fruit, a pressure value is generated on the thin-film pressure sensor on the flexible finger **207**, the pressure value of the thin-film pressure sensor reaches a safety threshold value as the distance of the flexible finger **207** is further shortened, and in this case, the clamping motor **201** stops rotating, and the fruit clamping action is completed; S3: when a position of a fruit stalk cannot be identified visually due to the blocking of fruits and leaves, operations of the rotary angle detection mechanism and the linear distance detection mechanism are required, after the fruit clamping is completed, the rotary motion motor **301** rotates from left to right, the rotary platform **312** and the rotary motion motor **301** coaxially rotate along the arc-shaped guide rail **307**, and when the fruit stalk is touched, and the angle detection rod **402** rotates opposite to a rotation direction of the rotary motion motor **301** due to the compression of a torsion spring under the action of a contact force, so that the angle limit switch **403** is triggered, the rotary motion motor **301** stops moving, and the angle detection of the fruit stalk is completed; when the angle detection is completed, the linear motion motor **601** rotates to drive the linear push rod **605** to push the linear motion platform **606** to move linearly towards a fruit motion direction along the linear motion guide rail **603**; when the distance detection push rod **801** touches the fruit stalk, the distance detection push rod **801** compresses a compression spring under the action of a contact force, and thus the distance detection push rod **801** moves towards an opposite direction of the fruit along the cylindrical guide rod on the distance detection push rod, so that the distance limit switch **803** is triggered, the linear motion motor **601** stops moving, and the distance detection of the fruit stalk is completed; S4: when the cylindrical coordinate fruit stalk positioning based on the rotary angle and the linear distance detection is completed, the rotary platform **312** and the linear motion platform **606** reach a to-be-sheared position; in this case, the shearing motion motor **701** rotates to drive the shearing motion sliding block **703** to move linearly towards the fruit direction along the shearing motion guide rod **702**; the second connecting rod **705** in the boosting shearing mechanism pushes the movable blade **709** to move linearly towards a closing direction of the blade along the movable blade guide rail **711**, so that the shearing of the fruit stalk is completed; and S5: when the shearing of the fruit stalk is completed, the picking end effector moves to a position of a fruit basket by the mechanical arm, and the clamping motor **201** rotates, so that the flexible finger **207** is opened, a fruit is released, and the undamaged fruit picking

is completed.

(26) In the description of the present application, it should be noted that directions or positional relationships indicated by terms such as “upper”, “lower” and the like are those shown based on the accompanying drawings, are merely intended to facilitate and simplify description rather than to indicate or imply that the indicated device or element must have a specific direction and be structured and operated according to the specific direction, and should not be construed as limiting the present application. Unless otherwise clearly specified and defined, the terms “mount”, “interconnect”, and “connect” should be understood in their broad sense. For example, the terms may be “fixedly connect”, “detachably connect” or “integrally connect”; “mechanically connect” and “electrically connect”; or “directly interconnect”, “indirectly interconnect through an intermediate” or “the communication between the interiors of two elements”. Those of ordinary skill in the art may understand specific meanings of the foregoing terms in the present application according to specific cases.

(27) It should be noted that, in the present application, relational terms such as “first” and “second” are merely used to distinguish one entity or operation from another entity or operation without necessarily requiring or implying any actual relationship or order between such entities or operations. Moreover, terms “include”, “comprise”, or any other variants thereof are intended to cover a non-exclusive inclusion, so that a process, a method, an article, or a device that includes a list of elements includes those elements, and also includes other elements which are not expressly listed, or further includes elements inherent to this process, method, article, or device. Without further limitation, an element defined by the phrase “including a/an . . .” does not exclude the presence of another identical elements in the process, method, article or device that includes the element.

(28) The above description is only specific embodiments of the present application to enable those skilled in the art to understand or implement the present application. Various modifications to these embodiments will be apparent to those skilled in the art, and the generic principles defined herein may be implemented in other embodiments without departing from the spirit or scope of the present application. Thus, the present application is limited to these embodiments shown herein, but accords with the broadest scope consistent with the principles and novel features disclosed herein.

Claims

1. A cylindrical coordinate shearing type fruit picking end effector, comprising: a rack, a fruit clamping mechanism, a rotary motion mechanism, a rotary angle detection mechanism, a linear motion mechanism, a shearing motion mechanism, and a linear distance detection mechanism; wherein the linear distance detection mechanism is arranged at a front end of the linear motion mechanism and is configured to detect a position between the shearing motion mechanism and a fruit stalk; the shearing motion mechanism is arranged at a rear end of the linear motion mechanism and is configured to shear the fruit stalk; the linear motion mechanism is arranged at a top end of the rotary motion mechanism and is configured to adjust the distance between the shearing motion mechanism and the fruit stalk; the rotary motion mechanism is arranged at a rear end of the rack and is configured to adjust an angle of the shearing motion mechanism; the rotary angle detection mechanism is arranged at a front end of the rotary motion mechanism and is configured to detect an angle of the fruit stalk; and the fruit clamping mechanism is arranged at a front end of the rack and is configured to clamp and fix a position of a fruit.
2. The cylindrical coordinate shearing type fruit picking end effector according to claim 1, wherein fruit protection fingers are further arranged at two sides of the rack adjacent to a rear end of the fruit clamping mechanism, and the fruit protection fingers are configured to avoid a difficult clamping caused by a fruit overlapping.

3. The cylindrical coordinate shearing type fruit picking end effector according to claim 1, wherein the fruit clamping mechanism comprises: a clamping motor, a clamping motor fixing seat, a finger coupler, two finger clamping nuts, a bidirectional screw, a clamping bearing seat, a flexible finger, an optical axis fixing seat, a finger guide block, and a guide optical axis; the clamping motor is fixedly connected to the rack by the clamping motor fixing seat, a first end of the bidirectional screw is in a transmission connection with an output shaft of the clamping motor by the finger coupler, a second end of the bidirectional screw is rotatably connected to the clamping bearing seat, the two finger clamping nuts are symmetrically screwed at two ends of the bidirectional screw, the flexible finger is fixed at a front end of each of the two finger clamping nuts, the optical axis fixing seat is fixed at a bottom end of the rack, and the two finger clamping nuts are connected to the guide optical axis in a sliding mode by the finger guide block.
4. The cylindrical coordinate shearing type fruit picking end effector according to claim 3, wherein the flexible finger is provided with a thin-film pressure sensor, and the thin-film pressure sensor is configured to ensure an undamaged fruit picking.
5. The cylindrical coordinate shearing type fruit picking end effector according to claim 1, wherein the rotary motion mechanism comprises: a rotary motion motor, a rotary motor fixing seat, a rotary coupler, a swing rod, a rotary shaft, an arc-shaped guide rail fixing seat, an arc-shaped guide rail, a rotary motion bearing seat, a rolling shaft, a roller bearing, a swing connecting rod, and a rotary platform; the rotary motion motor is connected to the rack by the rotary motor fixing seat, a first end of the rotary shaft is connected to an output shaft of the rotary motion motor by the rotary coupler, a second end of the rotary shaft is connected to the rotary motion bearing seat, the swing rod is arranged at the first end of the rotary shaft adjacent to the rotary coupler, the swing connecting rod is connected to the swing rod in a sliding manner, the rotary platform is fixed on the swing connecting rod, the arc-shaped guide rail is connected to the rack by the arc-shaped guide rail fixing seat, and the rotary platform is movably connected onto the arc-shaped guide rail by the rolling shaft provided with the roller bearing.
6. The cylindrical coordinate shearing type fruit picking end effector according to claim 5, wherein the rotary angle detection mechanism is installed in front of the rotary motion bearing seat, the rotary angle detection mechanism comprises: a rotation detection connecting block, an angle detection rod, and an angle limit switch, the rotation detection connecting block is fixedly connected to the rotary shaft, the rotation detection connecting block and the angle detection rod are provided with linear grooves for fixing a torsion spring, and the angle limit switch is installed on the rotation detection connecting block.
7. The cylindrical coordinate shearing type fruit picking end effector according to claim 5, wherein the linear motion mechanism is installed on the rotary platform, the linear motion mechanism comprises: a linear motion motor, a linear motion motor fixing seat, a linear motion guide rail, a linear motion nut, a linear push rod, a linear motion platform, a linear motion sliding block, and a linear motion bearing seat, the linear motion motor is installed on the rotary platform by the linear motion motor fixing seat, a first end of a first screw rod is connected to an output shaft of the linear motion motor, a second end of the first screw rod is connected to the linear motion bearing seat, the linear motion nut is in threaded connection with the first screw rod, the linear push rod is connected to the linear motion nut by a bolt, the linear motion guide rail is installed in a middle portion of the rotary platform, and the linear motion platform is slidably installed on the linear motion guide rail by the linear motion sliding block.
8. The cylindrical coordinate shearing type fruit picking end effector according to claim 7, wherein the shearing motion mechanism is installed at a rear end of the linear motion platform, the shearing motion mechanism comprises: a shearing motion motor, a shearing motion guide rod, a shearing motion sliding block, a shearing motion bearing seat, and a boosting shearing mechanism, the shearing motion motor is installed on the linear motion platform, a first end of a second screw rod is connected to an output shaft of the shearing motion motor, the shearing motion sliding block is in

threaded connection with the second screw rod, the shearing motion bearing seat is connected to a second end of the second screw rod, the shearing motion guide rod is installed on two sides of the second screw rod, and the shearing motion sliding block is connected to the shearing motion guide rods at two sides in a sliding manner; and the boosting shearing mechanism comprises: a first connecting rod, a second connecting rod, a third connecting rod, a fixed blade, a movable blade, a movable blade sliding block, a movable blade guide rail, and a connecting rod fixing column, a first end of the first connecting rod is hinged to the shearing motion sliding block, a second end of the first connecting rod is hinged to a first end of the second connecting rod, a second end of the second connecting rod is hinged to the connecting rod fixing column, the connecting rod fixing column is installed on the linear motion platform, a middle portion of the second connecting rod is hinged to a first end of the third connecting rod, a second end of the third connecting rod is hinged to the movable blade, the fixed blade is installed at a position at a forefront of the linear motion platform and adjacent to the fruit, the movable blade guide rail is transversely installed at a front end of the linear motion platform, and the movable blade is connected to the movable blade guide rail in a sliding manner by the movable blade sliding block.

9. The cylindrical coordinate shearing type fruit picking end effector according to claim 8, wherein the linear distance detection mechanism is arranged in front of the linear motion platform and adjacent to a direction of the fruit, the linear distance detection mechanism comprises: a distance detection push rod, a linear detection fixing seat, and a distance limit switch, the distance detection push rod is arranged below the fixed blade and is connected to the linear detection fixing seat, a cylindrical guide rod and a compression spring are arranged on the distance detection push rod, the distance detection push rod is allowed to move linearly along the cylindrical guide rod, the linear detection fixing seat is arranged on the linear motion platform and is positioned between the distance detection push rod and the shearing motion bearing seat, and the distance limit switch is arranged on the linear detection fixing seat and is installed at a position of the cylindrical guide rod on the distance detection push rod.

10. A use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 1, comprising the following steps: S1: the cylindrical coordinate shearing type fruit picking end effector is debugged to an initial state; S2: when the position of the fruit is known, a mechanical arm moves to allow the cylindrical coordinate shearing type fruit picking end effector to reach a position adjacent to a to-be-picked fruit, and a fruit protection finger separates the to-be-picked fruit from other overlapped fruits to avoid an interference of other fruits and fruit stalks on a mechanical detection; a clamping motor rotates, a flexible finger linearly moves along a guide optical axis along with two finger clamping nuts and a finger guide block, and a rotation direction of the clamping motor is configured to allow a distance of the flexible finger to close; when the flexible finger touches a surface of the fruit, a pressure value is generated on a thin-film pressure sensor on the flexible finger, the pressure value of the thin-film pressure sensor reaches a safety threshold value as the distance of the flexible finger is further shortened, and in this case, the clamping motor stops rotating, and a fruit clamping action is completed; S3: when a position of the fruit stalk is not allowed to be identified visually due to a blocking of fruits and leaves, operations of the rotary angle detection mechanism and the linear distance detection mechanism are required, after the fruit clamping action is completed, a rotary motion motor rotates from a left to a right, a rotary platform and the rotary motion motor coaxially rotate along an arc-shaped guide rail, and when the fruit stalk is touched, and an angle detection rod rotates in a direction opposite to a rotation direction of the rotary motion motor due to a compression of a torsion spring under an action of a contact force, wherein an angle limit switch is triggered, the rotary motion motor stops moving, and an angle detection of the fruit stalk is completed; when the angle detection is completed, a linear motion motor rotates to drive a linear push rod to push a linear motion platform to move linearly towards a fruit motion direction along a linear motion guide rail; when a distance detection push rod touches the fruit stalk, the distance detection push rod compresses a

compression spring under an action of a contact force, and thus the distance detection push rod moves towards an opposite direction of the fruit along a cylindrical guide rod on the distance detection push rod, wherein a distance limit switch is triggered, the linear motion motor stops moving, and a linear distance detection of the fruit stalk is completed; S4: when a cylindrical coordinate fruit stalk positioning based on a rotary angle and the linear distance detection is completed, the rotary platform and the linear motion platform reach a to-be-sheared position; in this case, a shearing motion motor rotates to drive a shearing motion sliding block to move linearly towards a fruit direction along a shearing motion guide rod; a second connecting rod in a boosting shearing mechanism pushes a movable blade to move linearly towards a closing direction of a blade along a movable blade guide rail, and a shearing of the fruit stalk is completed; and S5: when the shearing of the fruit stalk is completed, the cylindrical coordinate shearing type fruit picking end effector moves to a position of a fruit basket by the mechanical arm, and the clamping motor rotates, wherein a flexible finger is opened, the fruit is released, and an undamaged fruit picking is completed.

11. The use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 10, wherein in the cylindrical coordinate shearing type fruit picking end effector, fruit protection fingers are further arranged at two sides of the rack adjacent to a rear end of the fruit clamping mechanism, and the fruit protection fingers are configured to avoid a difficult clamping caused by a fruit overlapping.

12. The use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 10, wherein in the cylindrical coordinate shearing type fruit picking end effector, the fruit clamping mechanism comprises: the clamping motor, a clamping motor fixing seat, a finger coupler, the two finger clamping nuts, a bidirectional screw, a clamping bearing seat, the flexible finger, an optical axis fixing seat, the finger guide block, and the guide optical axis; the clamping motor is fixedly connected to the rack by the clamping motor fixing seat, a first end of the bidirectional screw is in a transmission connection with an output shaft of the clamping motor by the finger coupler, a second end of the bidirectional screw is rotatably connected to the clamping bearing seat, the two finger clamping nuts are symmetrically screwed at two ends of the bidirectional screw, the flexible finger is fixed at a front end of each of the two finger clamping nuts, the optical axis fixing seat is fixed at a bottom end of the rack, and the two finger clamping nuts are connected to the guide optical axis in a sliding mode by the finger guide block.

13. The use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 12, wherein in the cylindrical coordinate shearing type fruit picking end effector, the flexible finger is provided with the thin-film pressure sensor, and the thin-film pressure sensor is configured to ensure the undamaged fruit picking.

14. The use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 10, wherein in the cylindrical coordinate shearing type fruit picking end effector, the rotary motion mechanism comprises: the rotary motion motor, a rotary motor fixing seat, a rotary coupler, a swing rod, a rotary shaft, an arc-shaped guide rail fixing seat, the arc-shaped guide rail, a rotary motion bearing seat, a rolling shaft, a roller bearing, a swing connecting rod, and the rotary platform; the rotary motion motor is connected to the rack by the rotary motor fixing seat, a first end of the rotary shaft is connected to an output shaft of the rotary motion motor by the rotary coupler, a second end of the rotary shaft is connected to the rotary motion bearing seat, the swing rod is arranged at the first end of the rotary shaft adjacent to the rotary coupler, the swing connecting rod is connected to the swing rod in a sliding manner, the rotary platform is fixed on the swing connecting rod, the arc-shaped guide rail is connected to the rack by the arc-shaped guide rail fixing seat, and the rotary platform is movably connected onto the arc-shaped guide rail by the rolling shaft provided with the roller bearing.

15. The use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 14, wherein in the cylindrical coordinate shearing type fruit picking end effector, the rotary

angle detection mechanism is installed in front of the rotary motion bearing seat, the rotary angle detection mechanism comprises: a rotation detection connecting block, the angle detection rod, and the angle limit switch, the rotation detection connecting block is fixedly connected to the rotating shaft, the rotation detection connecting block and the angle detection rod are provided with linear grooves for fixing the torsion spring, and the angle limit switch is installed on the rotation detection connecting block.

16. The use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 14, wherein in the cylindrical coordinate shearing type fruit picking end effector, the linear motion mechanism is installed on the rotary platform, the linear motion mechanism comprises: the linear motion motor, a linear motion motor fixing seat, the linear motion guide rail, a linear motion nut, the linear push rod, the linear motion platform, a linear motion sliding block, and a linear motion bearing seat, the linear motion motor is installed on the rotary platform by the linear motion motor fixing seat, a first end of a first screw rod is connected to an output shaft of the linear motion motor, a second end of the first screw rod is connected to the linear motion bearing seat, the linear motion nut is in threaded connection with the first screw rod, the linear push rod is connected to the linear motion nut by a bolt, the linear motion guide rail is installed in a middle portion of the rotary platform, and the linear motion platform is slidably installed on the linear motion guide rail by the linear motion sliding block.

17. The use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 16, wherein in the cylindrical coordinate shearing type fruit picking end effector, the shearing motion mechanism is installed at a rear end of the linear motion platform, the shearing motion mechanism comprises: the shearing motion motor, the shearing motion guide rod, the shearing motion sliding block, a shearing motion bearing seat, and the boosting shearing mechanism, the shearing motion motor is installed on the linear motion platform, a first end of a second screw rod is connected to an output shaft of the shearing motion motor, the shearing motion sliding block is in threaded connection with the second screw rod, the shearing motion bearing seat is connected to a second end of the second screw rod, the shearing motion guide rod is installed on two sides of the second screw rod, and the shearing motion sliding block is connected to the shearing motion guide rods at two sides in a sliding manner; and the boosting shearing mechanism comprises: a first connecting rod, a second connecting rod, a third connecting rod, a fixed blade, the movable blade, a movable blade sliding block, the movable blade guide rail, and a connecting rod fixing column, a first end of the first connecting rod is hinged to the shearing motion sliding block, a second end of the first connecting rod is hinged to a first end of the second connecting rod, a second end of the second connecting rod is hinged to the connecting rod fixing column, the connecting rod fixing column is installed on the linear motion platform, a middle portion of the second connecting rod is hinged to a first end of the third connecting rod, a second end of the third connecting rod is hinged to the movable blade, the fixed blade is installed at a position at a forefront of the linear motion platform and adjacent to the fruit, the movable blade guide rail is transversely installed at a front end of the linear motion platform, and the movable blade is connected to the movable blade guide rail in a sliding manner by the movable blade sliding block.

18. The use method for the cylindrical coordinate shearing type fruit picking end effector according to claim 17, wherein in the cylindrical coordinate shearing type fruit picking end effector, the linear distance detection mechanism is arranged in front of the linear motion platform and adjacent to a direction of the fruit, the linear distance detection mechanism comprises: the distance detection push rod, a linear detection fixing seat, and the distance limit switch, the distance detection push rod is arranged below the fixed blade and is connected to the linear detection fixing seat, the cylindrical guide rod and the compression spring are arranged on the distance detection push rod, the distance detection push rod is allowed to move linearly along the cylindrical guide rod, the linear detection fixing seat is arranged on the linear motion platform and is positioned between the distance detection push rod and the shearing motion bearing seat, and the distance limit switch is

arranged on the linear detection fixing seat and is installed at a position of the cylindrical guide rod on the distance detection push rod.
