

[0012] A wire bonding apparatus according to another embodiment of the present invention includes: a bonding tool having a capillary detachably held in a holding hole; and a mounting portion that guides the capillary to the holding hole by a guide portion and attaches the capillary to the holding hole. The guide portion includes: a guide body portion capable of being in contact
5 with the capillary held in the holding hole; and a drive portion which arranges the guide body portion at a position capable of being in contact with the capillary by moving the guide body portion along a second direction intersecting a first direction along a central axis of the holding hole. The drive portion includes: a moving body connected to the guide body portion; a drive shaft extending in the second direction and exerting a frictional resistance force with the moving
10 body; and an ultrasonic wave generation body fixed to an end of the drive shaft and supplying an ultrasonic wave to the drive shaft. The wire bonding apparatus includes the guide portion having the same configuration as that of the capillary guide device. Thus, the wire bonding apparatus can reliably perform the automatic replacement work of the capillary.

[Effect]

[0013] According to the present invention, a capillary guide device and a wire bonding apparatus are provided which can reliably perform an automatic replacement work of a capillary.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is a perspective view showing a wire bonding apparatus according to an
20 embodiment.

FIG. 2 is an enlarged perspective view showing a capillary replacement device included in the wire bonding apparatus.

FIG. 3 is a perspective view showing a part of a capillary holding portion in a cross-section view.

[0015] FIG. 4 is a diagram illustrating an operation of the capillary holding portion.

FIG. 5 is a plan view showing a main portion of an actuator included in the capillary

replacement device.

FIG. 6 is a diagram illustrating an operation principle of the actuator.

FIG. 7 is a diagram illustrating specific control of the actuator.

FIG. 8 is a diagram illustrating specific control of the actuator.

5 FIG. 9 is a perspective view showing a part of a capillary guide device in a cross-section view.

FIG. 10 is a function block diagram of the capillary guide device.

FIG. 11 is a diagram showing an operation of the capillary replacement device.

10 FIG. 12 is a diagram showing an operation of the capillary replacement device subsequent to FIG. 11.

FIG. 13 is a diagram showing an operation of the capillary replacement device subsequent to FIG. 12.

FIG. 14 is a diagram showing an operation of the capillary replacement device subsequent to FIG. 13.

15 FIG. 15 is a diagram showing an operation of the capillary replacement device subsequent to FIG. 14.

FIG. 16 is a diagram showing an operation of the capillary replacement device subsequent to FIG. 15.

20 FIG. 17 is a diagram showing a guide function of a capillary fulfilled by the capillary holding portion and the capillary guide device.

FIG. 18 is a diagram showing another guide function of the capillary fulfilled by the capillary holding portion and the capillary guide device.

FIG. 19 is a diagram showing an operation of the capillary replacement device subsequent to FIG. 16.

25 FIG. 20 is a perspective view showing a cross section of a capillary holding portion according to a modification example.

or may be in contact without being fixed. That is, the lower end of the drive shaft 28A is a fixed end. The upper end of the drive shaft 28A is a fixed end or a free end. In addition, a portion 24b of the linear guide 24 is brought into contact with the guide 31.

[0038] The ultrasonic element 29A supplies an ultrasonic wave to the drive shaft 28A.

5 Specifically, the drive shaft 28A to which the ultrasonic wave is supplied slightly reciprocates along the Z-axis. As the ultrasonic element 29A, for example, a piezo element which is a piezoelectric element may be employed. The piezo element deforms according to an applied voltage. Thus, when a high frequency voltage is applied to the piezo element, the piezo element repeatedly deforms according to the frequency of the voltage and the magnitude of the voltage and
10 generates an ultrasonic wave. The ultrasonic element 29A is fixed to a guide 32 protruding from the actuator base 21.

[0039] The control device 27 is electrically connected to the ultrasonic element 29A. The ultrasonic element 29A receives a drive voltage generated by the control device 27. The control device 27 controls a frequency and an amplitude of an AC voltage supplied to the ultrasonic
15 element 29A.

[0040] The configuration of the linear motor 22B is the same as the configuration of the linear motor 22A. The linear motor 22B is arranged apart from the linear motor 22A in the Y-axis direction that intersects the Z-axis. That is, a drive shaft 28B of the linear motor 22B is parallel to the drive shaft 28A of the linear motor 22A. An upper end of the linear motor 22B is arranged
20 at the same height as the upper end of the linear motor 22A. Similarly, a lower end of the linear motor 22B is arranged at the same height as the lower end of the linear motor 22A.

[0041] The carriage 26 is a moving body that is translated and rotated by the linear motors 22A and 22B. The carriage 26 has a disc shape. The carriage 26 is stretched between the linear motors 22A and 22B. The linear guide 24 that guides the carriage 26 in the Z-axis direction is
25 arranged between the actuator base 21 and the carriage 26. The carriage 26 is guided in the Z-axis direction by the linear guide 24. The linear guide 24 regulates a movement direction of the carriage 26. The linear guide 24 does not generate a driving force in the Z-axis direction.

[0042] The carriage 26 has a front disc 33, a pressurizing disc 34, and a rear disc 36. These discs have the same outer diameter with each other and are stacked along a common axis. A shaft body 37 is clamped between the front disc 33 and the pressurizing disc 34. An outer diameter of the shaft body 37 is smaller than an outer diameter of the front disc 33 and an outer diameter of the pressuring disc 34. Thus, a gap is formed between an outer peripheral portion of the front disc 33 and an outer peripheral portion of the pressurizing disc 34. Similarly, a shaft body 38 is also clamped between the rear disc 36 and the pressurizing disc 34. An outer diameter of the shaft body 37 is also smaller than an outer shape of the rear disc 36 and the outer diameter of the pressuring disc 34. Thus, a gap is also formed between an outer peripheral portion of the rear disc 36 and the outer peripheral portion of the pressurizing disc 34. A first surface 33a of front disc 33 is brought into contact with the holder 14.

[0043] A first surface 36b of the rear disc 36 is connected to a table 24a of the linear guide 24. The rear disc 36 is rotatably connected to the table 24a. The pressuring disc 34 and the front disc 33 are mechanically fixed to the rear disc 36. The pressuring disc 34 and the front disc 33 do not rotate with respect to the rear disc 36. Thus, the entire carriage 26 including the front disc 33, the pressurizing disc 34, and the rear disc 36 may rotate with respect to the table 24a of the linear guide 24.

[0044] As shown in FIG. 5, the drive shafts 28A and 28B are clamped in the gap G1 between the pressurizing disc 34 and the rear disc 36. Specifically, the pair of drive shafts 28A and 28B are arranged to clamp the center of gravity of the carriage 26. The drive shafts 28A and 28B are in contact with a back surface 34b of the pressurizing disc 34 and a main surface 36a of the rear disc 36. The drive shafts 28A and 28B are not in contact with an outer peripheral surface 38a of the shaft body 38. The gap G1 is smaller than the outer diameters of the pressurizing disc 34 and the rear disc 36 and larger than the outer diameter of the shaft body 38. A difference between the outer diameter of the shaft body 38 and the outer diameter of the rear disc 36 is larger than the outer diameters of the drive shafts 28A and 28B. A difference between the outer diameter of the shaft body 37 and the outer diameter of the pressurizing disc 34 is larger than the outer diameters

of the drive shafts 28A and 28B.

[0045] The gap G1 is slightly smaller than the outer diameters of the drive shafts 28A and 28B.

A gap G2 is formed between a second surface 33b of the front disc 33 and an opposite surface 34a of the back surface 34b of the pressurizing disc 34. As a result, when the drive shafts 28A and 28B are arranged between the pressurizing disc 34 and the rear disc 36, the pressurizing disc 34 slightly bends toward the front disc 33 side. The bending generates a force that presses the drive shafts 28A and 28B against the rear disc 36.

[0046] An operation principle of the actuator 13 is described below with reference to FIG. 6.

Parts (a), (b) and (c) of FIG. 6 are diagrams for illustrating the operation principle of the actuator

13. For convenience of description, in FIG. 6, the linear motor 22A and the carriage 26 are shown, and illustration of the linear motor 22B and the like is omitted.

[0047] Part (a) of FIG. 6 shows a mode in which a position of the carriage 26 is held. As

described above, in the carriage 26, the drive shaft 28A is clamped between the pressurizing disc

34 and the rear disc 36. The position of the carriage 26 is maintained by the pressure applied by

the clamping. More specifically, the position of the carriage 26 is maintained by the frictional

resistance force which takes the applied pressure as a normal force. At this time, the control

device 27 does not supply a voltage to the ultrasonic element 29A (voltage value zero, see signal

E1). Alternatively, the control device 27 may supply a DC current having a predetermined

voltage value to the ultrasonic element 29A.

[0048] As described above, the position of the carriage 26 is maintained by the frictional

resistance force between the carriage 26 and the drive shaft 28A. Here, when the drive shaft 28A

is moved, a mode in which the carriage 26 is moved along with the drive shaft 28A and a mode in

which the carriage 26 is not moved along with the drive shaft 28A and the position is maintained

by inertia of the carriage 26 may occur. Which of these modes is achieved may be determined

by a speed at which the drive shaft 28A is moved, that is, a frequency of the ultrasonic wave. For

example, when the frequency is relatively low (15 kHz to 30 kHz), the carriage 26 is moved along

with the drive shaft 28A. For example, when the frequency is relatively high (100 kHz to 150

capillary recovery portion 55 accommodates the used capillary 8U.

[0073] A state shown in Part (a) of FIG. 11 is, for example, a state in which a wire bonding work is being performed by the capillary 8U attached to the ultrasonic horn 7. Thus, the capillary replacement device 9 may be retracted to a position that does not hinder the wire bonding work.

5 **[0074]** Part (b) of FIG. 11 shows a state of a first step in the replacement operation. First, the capillary replacement device 9 rotates the carriage 26 in the clockwise direction by the control device 27. This rotation corresponds to the operation shown in Part (a) of FIG. 8. By this rotation, the capillary holding portion 11 retracted to the position where the wire bonding work is not hindered is positioned below the capillary 8U.

10 **[0075]** Part (a) of FIG. 12 and Part (b) of FIG. 12 show a state of a second step in the replacement operation. In the second step, the guide body portion 41 is brought into contact with the capillary 8. First, the control device 27 supplies the signal E14 to the ultrasonic element 47a. This signal E14 moves the table 46 in the positive X-axis direction. The ultrasonic wave includes amplitude toward the positive X-axis direction (hereinafter referred to as “positive amplitude”)
15 and amplitude toward the negative X-axis direction (hereinafter referred to as “negative amplitude”). Modes of the drive shaft 47b and the table 46 differ depending on the frequency of the ultrasonic wave. For example, when the frequency of the ultrasonic wave is relatively low (15 kHz or more and 30 kHz or less), the table 46 is also moved along with the movement of the drive shaft 47b. On the other hand, when the frequency of the ultrasonic wave is relatively high
20 (100 kHz or more and 150 kHz or less), the drive shaft 47b is not moved along with the movement of the table 46. In other words, the drive shaft 47b is moved with respect to the table 46.

[0076] According to the above modes, the control device 27 generates, as shown by the signal E14 in Part (b) of FIG. 12, a control signal which repeats a signal component having a positive amplitude and a relatively low frequency and a signal component having a negative amplitude and
25 a relatively high frequency. As a result, the table 46 is moved in the positive X-axis direction. Then, when the parallel hole portion 41p of the guide body portion 41 comes into contact with the

capillary 8, the control device 27 stops supplying the control signal. When the guide body portion 41 is in contact with the capillary 8, no pressing force acts on the capillary 8 from the guide body portion 41. That is, the guide body portion 41 is merely in contact with the capillary 8.

5 **[0077]** In the second step, an operation of vibrating the guide body portion 41 is also performed in parallel with the operation of moving the guide body portion 41. The control device 27 supplies the control signal to the ultrasonic element 48. As a result, the ultrasonic element 48 supplies the ultrasonic wave to the guide body portion 41 via the connection portion 49. According to this vibration, the capillary 8 can be satisfactorily guided to the parallel hole portion
10 41p.

[0078] Part (a) of FIG. 13 shows a state of a third step in the replacement operation. In the third step, the ultrasonic horn 7 is brought into contact with the guide body portion 41. The control device 27 supplies a control signal to the bonding portion 3. As a result, the ultrasonic horn 7 descends. In other words, the control device 27 moves the ultrasonic horn 7 in the
15 negative Z-axis direction. The control device 27 monitors the output of the ammeter 52 while moving the ultrasonic horn 7. When a predetermined change appears in the output of the ammeter 52, the control device 27 determines that a lower surface 7a of the ultrasonic horn 7 is in contact with the main surface 41a of the guide body portion 41. This predetermined change may be, for example, a case when the output of the ammeter 52 changes from zero (non-contact) to a
20 predetermined value. Then, the control device 27 stops the descent of the ultrasonic horn 7.

[0079] Part (b) of FIG. 13 shows a state of a fourth step in the replacement operation. In the fourth step, the capillary 8U is mounted to the capillary holding portion 11. The capillary replacement device 9 moves the carriage 26 upward by the control device 27. This movement corresponds to the operation shown in Part (b) of FIG. 7. By this movement, the capillary
25 holding portion 11 holds the capillary 8U attached to the ultrasonic horn 7.

[0080] Part (a) of FIG. 14 and Part (b) of FIG. 14 show a state of a fifth step in the replacement