

[DESCRIPTION]

[TITLE OF INVENTION]

WIRE BONDING APPARATUS

[Technical Field]

5 [0001]

The present invention relates to a wire bonding apparatus that corrects a pressing load of a bonding tool.

[Background Art]

[0002]

10 Many wire bonding apparatuses that press a wire onto an electrode of a substrate or an electrode of an electronic component and connect a substrate to an electronic component or between electronic components with a wire using bonding tools have been used. If such a bonding apparatus is allowed to continuously operate for a long period of time, a pressing load may change with time due to influences of the surrounding
15 environment or the like in some cases. The pressing load greatly affects formation of an alloy of the wire and the electrode during bonding, and if the pressing load changes with time, the bonding quality may deteriorate in some cases. Therefore, a wire bonding apparatus is adapted such that the wire bonding apparatus is stopped and the pressing load is corrected after continuous operation for a predetermined period of time, for
20 example, about 1000 hours, to maintain an appropriate pressing load.

[0003]

The correction of the pressing load is performed in the following procedure, for example. First, a load cell is attached to a heat block, and a bonding load is then set in a state in which a tip end of a bonding tool is brought into contact with the load cell. In
25 this manner, the wire bonding apparatus operates such that the bonding tool presses the

load cell with the set load. Meanwhile, an actual pressing load of the bonding tool is detected by the load cell. Then, in a case in which there is a difference between the actual pressing load detected by the load cell and the set pressing load, a current application value of a motor that drives the bonding tool is adjusted such that the actual pressing load becomes consistent with the set pressing load (see Patent Literature 1, for example).

[Citation List]

[Patent Literature]

[0004]

10 [Patent Literature 1]

Japanese Unexamined Patent Application Publication No. 10-284532

[Summary of Invention]

[Technical Problem]

[0005]

15 For the correction of the pressing load as described in Patent Literature 1, it is necessary to attach the load cell to the heat block of the wire bonding apparatus, and it is thus necessary to turn off a heater of the heat block and to wait until the temperature of the heat block drops to a temperature at which the load cell can be used. Also, it is necessary to turn on the heater of the heat block and to wait until the heat block reaches a temperature at which bonding can be performed after the correction of the pressing load ends. In addition, in a case in which a heat plate with a plate shape for adjusting the height in accordance with the models of the substrate, the electronic components, and the like is attached to the heat block, it is necessary to remove the heat plate when the load cell is attached. Therefore, it is necessary to adjust bonding parameters again after the correction of the pressing load ends. There is a problem that producibility may

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deteriorate if it is attempted to maintain the pressing load such that it is as constant as possible by shortening the intervals between correction of the pressing load and to secure bonding quality in this manner.

[0006]

5 Thus, an object of the present invention is to provide a bonding apparatus capable of correcting a pressing load of a bonding tool in succession to a bonding operation with a simple configuration.

[Solution to Problem]

[0007]

10 A wire bonding apparatus according to the present invention is characterized by including: a bonding tool that is driven in a vertical direction by means of a motor and that presses a wire to an electrode; an elastic member in which displacement corresponding to a pressing load of the bonding tool occurs; a displacement detection means for detecting the displacement of the elastic member; and a control unit that
15 adjusts the pressing load of the bonding tool, in which the control unit presses the elastic member with the bonding tool by applying a current of a predetermined value to the motor, detects the displacement of the elastic member by means of the displacement detection means, and corrects the pressing load of the bonding tool on the basis of a detected displacement.

20 [0008]

 According to the wire bonding apparatus of the present invention, in a correction of the pressing load of the bonding tool performed by the control unit, the detected displacement may be compared with a reference displacement being preset, and a value of a current to be applied to the motor may be increased or decreased such that a
25 difference between the detected displacement and the reference displacement becomes

small.

[0009]

According to the wire bonding apparatus of the present invention, the elastic member may have a plurality of pressing points corresponding to a plurality of values of current to be applied to the motor, and the control unit may successively press the respective pressing points of the elastic member with the bonding tool by successively applying the current of a plurality of values to the motor, successively detect each displacement of the respective pressing points by means of the displacement detection means, and correct the pressing load of the bonding tool on the basis of the detected displacement respectively.

[0010]

According to the wire bonding apparatus of the present invention, the plurality of pressing points may be disposed such that each displacement when the respective pressing points of the elastic member corresponding to the respective values of current are successively pressed with the bonding tool by successively applying the current of a plurality of values to the motor falls within a predetermined range.

[0011]

According to the wire bonding apparatus of the present invention, in the correction of the pressing load of the bonding tool performed by the control unit, the detected displacement may be respectively converted into respective loads applied to the respective pressing points, a characteristic curve indicating a relationship between the current of a plurality of values applied to the motor and the load applied to the respective pressing points may be generated, and the value of the current to be applied to the motor may be adjusted on the basis of the generated characteristic curves.

25 [0012]

According to the wire bonding apparatus of the present invention, the elastic member may be a plate spring.

[Advantageous Effects of Invention]

[0013]

5 The bonding apparatus according to the present invention can correct the pressing load of the bonding tool in succession to the bonding operation with a simple configuration.

[Brief Description of Drawings]

[0014]

10 Fig. 1 is a plan view illustrating a wire bonding apparatus according to an embodiment of the present invention.

Fig. 2 is a system diagram illustrating a system configuration of the wire bonding apparatus according to the embodiment of the present invention.

15 Fig. 3 is a perspective view and a plan view illustrating a plate spring assembly of the wire bonding apparatus according to the embodiment of the present invention.

Fig. 4 is an explanatory diagram illustrating pressing points of the plate spring assembly illustrated in Fig. 3, pressing loads, and displacement.

20 Fig. 5 is a flowchart illustrating operations of a first pressing load correction program that a control unit of the wire bonding apparatus executes according to the embodiment of the present invention.

Fig. 6 is a flowchart illustrating operations of a second pressing load correction program that the control unit of the wire bonding apparatus executes according to the embodiment of the present invention.

25 Fig. 7 is a characteristic curve of a motor application current value and a load generated in an operation illustrated in Fig. 6.

Fig. 8 is a perspective view illustrating another plate spring assembly of the wire bonding apparatus according to the embodiment.

Fig. 9 is a perspective view illustrating another plate spring assembly of the wire bonding apparatus according to the embodiment.

5 [Description of Embodiments]

[0015]

Hereinafter, an embodiment of the present invention will be described with reference to the drawings. As illustrated in Fig. 1, a wire bonding apparatus 100 according to the embodiment includes a frame 10, an XY table 11 attached to the frame 10, a bonding head 12 attached to the XY table 11, a bonding arm 13 attached to the bonding head 12, an ultrasonic horn 14 attached to a tip end of the bonding arm 13, a capillary 15 that is a bonding tool attached to a tip end of the ultrasonic horn 14, a substrate 18 to which an electronic component 19 such as a semiconductor die is attached, guide rails 16 that guide the substrate 18 in an X direction, a heat block 17, and a plate spring assembly 20.

[0016]

As illustrated in Fig. 2, a motor 40 that drives the bonding arm 13 in a vertical direction (Z direction) is provided inside the bonding head 12. The motor 40 is configured of a stator 41 fixed to the bonding head 12 and a movable element 42 that rotates about a rotation axis 45. The movable element 42 is integrated with a rear portion of the bonding arm 13, and the tip end of the bonding arm 13 moves in the vertical direction (Z direction) if the movable element 42 moves and rotates. A flange 14b of the ultrasonic horn 14 is secured to the tip end of the bonding arm 13 with a bolt 14c. Also, a recessed portion 13a that accommodates an ultrasonic vibrator 14a of the ultrasonic horn 14 is provided on a lower surface of the tip end portion of the bonding

arm 13. The capillary 15 is attached to the tip end of the ultrasonic horn 14. Also, the heat block 17 is attached to the frame 10 between the two guide rails 16, and the plate spring assembly 20 is attached to the frame 10 between the heat block 17 and the guide rails 16. Also, a heater 17a that heats the heat block 17 is attached to the heat block 17.

5 [0017]

The height of an upper surface of a plate spring 31 of the plate spring assembly 20 is substantially the same as the height of a bonding surface (illustrated by the one-dotted chain line 47 in Fig. 2) that corresponds to the height of an upper surface of the electrode of the electronic component 19 when the substrate 18 is adsorbed to the heat block 17 in a vacuum fashion. Also, the height of a rotation center 43 (illustrated by the intersecting point between the one-dotted chain line 47 and the one-dotted chain line 46 in Fig. 2) of the rotation axis 45 of the movable element 42 is also substantially the same as the height of the bonding surface. Therefore, if the movable element 42 moves and rotates, the tip end of the capillary 15 moves vertically in a substantially perpendicular direction relative to the electrode surface of the electronic component 19 and the upper surface of the plate spring 31.

[0018]

Drive electric power is supplied from a power source 49 to the stator 41 of the motor 40. A value of a current supplied to the stator 41 is detected by a current sensor 51, and the value of the current is adjusted by a motor driver 48. Also, an angle sensor 52 that detects a rotation angle ϕ of the movable element 42 is attached to the rotation axis 45 of the movable element 42. Further, a temperature sensor 53 that detects a representative temperature of the wire bonding apparatus 100 is attached in the vicinity of the bonding head 12.

25 [0019]

The wire bonding apparatus 100 is a computer that includes therein a CPU 61 that performs arithmetic operations and signal processing and a memory 62 that stores programs for causing the wire bonding apparatus 100 to operate and data necessary to execute the programs, and the wire bonding apparatus 100 includes a control unit 60 that controls overall operations of the wire bonding apparatus 100. Signals detected by the angle sensor 52, the current sensor 51, and the temperature sensor 53 are input to the control unit 60. The control unit 60 decides a value of a current to be supplied to the stator 41 of the motor 40 and outputs a command regarding the value of the current to the motor driver 48. The motor driver 48 adjusts the value of the current to be applied to the stator 41 on the basis of a command input from the control unit 60. Also, the control unit 60 is also connected to the XY table 11 illustrated in Fig. 1 and outputs a command for the position of the capillary 15 in an XY direction to the XY table 11. The XY table 11 adjusts the position of the capillary 15 in the XY direction to the position designated by the control unit 60 through the command.

[0020]

The CPU 61 of the control unit 60 executes a bonding program stored in the memory 62, causes the motor 40 to drive, causes the capillary 15 to move in the vertical direction, causes the XY table 11 to move in the XY direction, and causes a bonding operation of connecting the electrode of the electronic component 19 and the electrode of the substrate 18 with a wire to be executed, on the basis of signals detected by the angle sensor 52, the current sensor 51, and the temperature sensor 53, electrode position signals of the electronic component 19 and the substrate 18 input from an imaging apparatus or the like, which is not illustrated in the drawing, and information regarding the type of the electronic component 19, an electrode pitch, and the like stored in advance in the memory 62.

[0021]

Also, the control unit 60 stores a pressing load correction program, which will be described later, in the memory 62. The CPU 61 of the control unit 60 executes the pressing load correction program stored in the memory 62, applies a current of a predetermined value to the motor 40, and presses the plate spring 31 with the tip end of the capillary 15 on the basis of the signals detected by the angle sensor 52, the current sensor 51, and the temperature sensor 53, detects displacement of the plate spring 31, and executes an operation of correcting the pressing load of the capillary 15 on the basis of the detected displacement.

10 [0022]

As illustrated in Fig. 3(a), the plate spring assembly 20 includes a base 21 with a square flat plate shape, a support 22 that projects toward the side above the tip end of the base 21 (a portion on the negative side in the X direction), a flange 26 that is provided in the surface of the base 21 on the lower side (the negative side in the Z direction), and a cantilever plate spring 31 secured to the upper surface of the support 22 (the surface on the upper side in the Z direction) with a bolt 25. The plate spring 31 is a thin metal plate and projects from the upper surface of the support 22 toward the negative side in the X direction. A portion of the support 22 that corresponds to a base side of the plate spring 31 is provided with a notch portion 23 such that the plate spring 31 can be warped and deformed on the lower side. Also, a bolt hole 27 for securing the plate spring assembly 20 to the frame 10 with a bolt is provided in the flange 26.

[0023]

The displacement in the Z direction when the plate spring 31 is pressed with the tip end of the capillary 15 is proportional to the load. Therefore, if a pressing point 32 for 5 g is pressed with a load of 200 g, for example, a displacement of 40 times the

displacement when the pressing point 32 is pressed with a load of 5 g occurs. Also, even if a pressing point for 200 g is pressed with a load of 5 g, the displacement becomes 1/40 the displacement occurring when the pressing point is pressed with a load of 200 g in contrast. Therefore, the plate spring 31 according to the embodiment has a shape in which the entire width becomes narrower toward the tip end by combining a tapered portion with a width narrowing toward the tip end (toward the negative side in the X direction) and a strip-shaped portion with a constant width as illustrated in Fig. 3(b). This leads to a structure in which a larger displacement occurs with a smaller load toward the tip end and a larger load is needed to cause the same displacement toward the base.

10 [0024]

As illustrated in Fig. 3(b), pressing points 32, 33, and 34 against which the tip end of the capillary 15 that is a bonding tool is pressed are marked on the upper surface of the plate spring 31. In regard to the respective pressing points, the pressing point 32 at the tip end is a pressing point used in a case in which the pressing load of the capillary 15 is as small as about 5 g, for example, the central pressing point 33 is a pressing point used in a case in which the pressing load of the capillary 15 is an intermediate load of about 20 g, for example, and the pressing point 34 on the root side is a point used in a case in which the pressing load of the capillary 15 is as large as about 200 g, for example.

[0025]

20 With such a configuration, a displacement $\Delta 1$ when the pressing point 32 at the furthest tip end is pressed with a small load $W1$ (5 g, for example) as illustrated in Fig. 4(a), a displacement $\Delta 2$ when the intermediate pressing point 33 is pressed with an intermediate load $W2$ (20 g, for example) as illustrated in Fig. 4(b), and a displacement $\Delta 3$ when the root pressing point 34 is pressed with a large load $W3$ (200 g, for example) as illustrated in Fig. 4(c) have substantially similar sizes. Therefore, it is possible to

maintain a substantially constant displacement or to cause the displacement to fall within a predetermined range, to inhibit large deviation of the position of the tip end of the capillary 15 from the bonding surface when the pressing points are pressed, and to appropriately ascertain a relationship between the pressing load of the capillary 15 and the displacement by using the pressing point corresponding to the pressing load.

[0026]

<Operations of first pressing load correction program>

Operations of the first pressing load correction program that the CPU 61 of the control unit 60 in the wire bonding apparatus 100 as described above executes will be described with reference to Fig. 5.

[0027]

As illustrated in Step S101 in Fig. 5, the control unit 60 outputs a command for starting the wire bonding apparatus 100. The wire bonding apparatus 100 turns on the heater 17a of the heat block 17 and raises the temperature of the heat block 17 to a predetermined temperature. When the temperature of the heat block 17 reaches the predetermined temperature, the substrate 18 with the electronic component 19 attached to the surface thereof is caused to move to above of the heat block 17 by a feeding mechanism, which is not illustrated in the drawing, along the guide rails 16. If the substrate 18 reaches above of the heat block 17, the substrate 18 is adsorbed to the heat block 17 in a vacuum fashion.

[0028]

Then, the wire bonding apparatus 100 causes the capillary 15 to move in the vertical direction in accordance with the bonding program stored in the memory 62, causes the XY table 11 to move in the XY direction, and connects the electrode of the electronic component 19 and the electrode of the substrate 18 with a wire.

[0029]

If the bonding between all electrodes of the electronic component 19 attached to the substrate 18 and all electrodes of the substrate 18 ends, the wire bonding apparatus 100 breaks the vacuum of the heat block 17 and causes the substrate 18 to move to a storage, which is not illustrated, from the heat block 17 along the guide rails 16. By repeating such operations, a large number of electrodes of the electronic components 19 attached to the substrate 18 and the electrodes of the substrate 18 are bonded.

[0030]

Since heat generated by the heater 17a has not reached the entire wire bonding apparatus 100 when the bonding is started, the representative temperature of the wire bonding apparatus 100 detected by the temperature sensor 53 has not reached a normal operation temperature. As illustrated in Step S102 in Fig. 5, the control unit 60 waits until the representative temperature of the wire bonding apparatus 100 reaches the normal operation temperature. Then, if it is determined that the representative temperature of the wire bonding apparatus 100 has reached the normal operation temperature in Step S102 in Fig. 5, the processing proceeds to Step S103 in Fig. 5, the bonding operation is stopped one side, the XY table 11 is caused to operate, and the position of the capillary 15 is caused to move to above of the pressing point 32 of the plate spring 31 such that the height of the tip end of the capillary 15 conforms to the height of the pressing point 32. Also, a current of a predetermined value is applied to the motor 40. At this time, the heater 17a is maintained in the ON state.

[0031]

The value of the current applied to the motor 40 is a value of a current with which a load of about 5 g is applied to the pressing point 32 of the plate spring 31 as described above with reference to Fig. 4(a), for example. The value of the current may

be a value of a current defined in advance by a test such that a detected load of a load cell against which the capillary 15 is pressed becomes 5 g.

[0032]

As described above with reference to Fig. 4(a), the tip end of the capillary 15
 5 also moves on the negative side in the Z direction by $\Delta 1$ if the plate spring 31 is displaced by $\Delta 1$. At this time, the bonding arm 13 rotates about the rotation axis 45 only by a predetermined angle. The control unit 60 acquires a rotation angle ϕ of the bonding arm 13 from a signal of the angle sensor 52, converts the rotation angle ϕ into the displacement $\Delta 1$ of the tip end of the capillary 15, that is, the displacement $\Delta 1$ of the
 10 plate spring 31, and detects the displacement $\Delta 1$ of the pressing point 32 of the plate spring 31 (Step S104 in Fig. 5). Therefore, the angle sensor 52 configures a displacement detection means for detecting the displacement $\Delta 1$ of the pressing point 32 of the plate spring 31.

[0033]

15 The control unit 60 stores the displacement $\Delta 1$ detected in Step S104 in Fig. 5 as a reference displacement $\Delta 1S$ in the memory 62 as illustrated in Step S105 in Fig. 5.

[0034]

If the reference displacement $\Delta 1S$ is stored in the memory 62, the control unit 60 restarts the bonding operation and moves on to Step S106 in Fig. 5, and the wire bonding
 20 apparatus 100 is operated for a predetermined time such as 1000 hours, for example, and performs bonding operations until the next pressing load correction timing is reached.

[0035]

When the control unit 60 determines that a predetermined time has elapsed and the pressing load correction timing has been reached, the control unit 60 moves on to

Step S107 in Fig. 5, stops the bonding operation one side similarly to the above description for Step S103, maintains the heater 17a in the ON state, causes the XY table 11 to operate, and causes the position of the capillary 15 to move to above of the pressing point 32 of the plate spring 31 such that the height of the tip end of the capillary 15 conforms to the height of the pressing point 32. Then, a current of a predetermined value is applied to the motor 40. Then, similarly to above description, the rotation angle ϕ of the bonding arm 13 is acquired from the signal of the angle sensor 52, the rotation angle ϕ is converted into the displacement $\Delta 1$ of the plate spring 31, and the displacement $\Delta 1$ of the pressing point 32 of the plate spring 31 is detected (Step S108 in Fig. 5).

10 [0036]

Then, the control unit 60 moves on to Step S109 in Fig. 5, calculates an absolute value d of a difference between the previously set reference displacement $\Delta 1S$ and the displacement $\Delta 1$ detected this time = |detected displacement $\Delta 1$ – reference displacement $\Delta 1S$ |, moves on to Step S110, and determines whether or not d exceeds a predetermined threshold value. In a case in which d is equal to or less than the predetermined threshold value, it is determined that there is no need to correct the pressing load, the processing returns to Step S106 in Fig. 5, and the bonding operation is restarted.

[0037]

Meanwhile, in a case in which the absolute value d of the difference exceeds the predetermined threshold value, it is determined that the pressing load has deviated from the initial pressing load and it is necessary to correct the pressing load, and the value of the current to be applied to the motor is increased or decreased such that the absolute value d of the difference becomes small. In a case in which the detected displacement $\Delta 1$ is about 110% of the reference displacement $\Delta 1S$, for example, the value of the

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current to be applied to the motor 40 may be reduced by (100/110). In contrast, in a case in which the detected displacement $\Delta 1$ is about 90% of the reference displacement $\Delta 1S$, the value of the current to be applied to the motor 40 may be caused to increase by (100/90).

5 [0038]

Then, the control unit 60 repeats the operations in Steps S106 to S112 in Fig. 5 when the wire bonding apparatus 100 continues to operate, and if the wire bonding apparatus 100 is stopped, the control unit 60 stops the operations of the program.

[0039]

10 As described above, since the wire bonding apparatus 100 according to the embodiment can correct the pressing load of the capillary 15 without stopping the heater 17a by a simple method of pressing the plate spring 31 with the capillary 15 in succession to the bonding operation and adjusting the value of the current to be applied to the motor 40 on the basis of the displacement of the plate spring 31, it is possible to
15 maintain the pressing load of the capillary 15 such that it is as constant as possible and to secure bonding quality while preventing deterioration of producibility.

[0040]

<Operations of second pressing load correction program>

Next, operations of the second pressing load correction program that the CPU 61
20 of the wire bonding apparatus 100 according to the present invention executes will be described with reference to Fig. 6. The operations are for correcting the pressing load in the wire bonding apparatus 100 such that a characteristic curve representing a relationship between a pressing load W and a value i of the current to be applied to the motor as illustrated in Fig. 7 is stored in the memory 62 of the control unit 60, a
25 command value for the value i of the necessary current to be applied to the motor is

output to the motor driver 48 with reference to the characteristic curve in accordance with a necessary pressing load defined from the bonding position, the type of the electronic component 19, and the like, and the bonding operation of applying the necessary pressing load is performed. Note that operations similar to those described above with reference to Fig. 5 will be briefly described.

[0041]

As illustrated in Step S201 in Fig. 6, if the control unit 60 outputs a command for starting the wire bonding apparatus 100, the wire bonding apparatus 100 turns on the heater 17a of the heat block 17 and raises the temperature of the heat block 17 to a predetermined temperature. Then, if the temperature of the heat block 17 reaches the predetermined temperature, the substrate 18 with the electronic component 19 attached to the surface thereof is caused to move to above of the heat block 17 by a feeding mechanism, which is not illustrated in the drawing, along the guide rails 16. If the substrate 18 reaches above of the heat block 17, the substrate 18 is adsorbed to the heat block 17 in a vacuum manner.

[0042]

Then, the wire bonding apparatus 100 causes the capillary 15 to move in the vertical direction, moves the XY table 11 in the XY direction, and connects the electrode of the electronic component 19 to the electrode of the substrate 18 with a wire in accordance with the bonding program stored in the memory 62. The wire bonding apparatus 100 stores a characteristic curve of the value i of the necessary current to be applied to the motor to cause the pressing load W of the capillary 15 for the bonding as represented by the solid line a in Fig. 7 in the memory 62. The initial characteristic curve represented by the solid line a is a characteristic curve set in advance by a test and the like. Also, information regarding the type of the electronic component 19, the

diameter of the wire, and the like are stored in the memory 62. The control unit 60 decides the pressing load W when the wire is pressed against the electrodes on the basis of such information stored in the memory 62. Then, the control unit 60 outputs a command value for the value i of the current to be applied to the motor 40 to the motor driver 48 when the wire is pressed on the basis of the characteristic curve of the solid line a in Fig. 7. The motor driver 48 performs adjustment such that the value of the current to be applied to the motor 40 conforms to the current value command. In this manner, the pressing load W of the capillary 15 is controlled on the basis of the characteristic curve represented by the solid line a in Fig. 7 for the bonding.

10 [0043]

If the bonding between all electrodes of the electronic component 19 attached to the substrate 18 and all electrodes of the substrate 18 ends, the wire bonding apparatus 100 breaks the vacuum of the heat block 17 and causes the substrate 18 to move from the heat block 17 to the storage, which is not illustrated in the drawing, along the guide rails 16. By repeating such operations, a large number of the electrodes of the electronic component 19 attached to the substrate 18 and the electrodes of the substrate 18 are bonded.

[0044]

As illustrated in Step S202 in Fig. 6, the wire bonding apparatus 100 waits until the representative temperature of the wire bonding apparatus 100 detected by the temperature sensor 53 reaches a predetermined normal operation temperature, and if the representative temperature reaches the predetermined temperature, the processing proceeds to Step S203 in Fig. 6, and the wire bonding apparatus 100 waits until the wire bonding apparatus operates for a predetermined operation time such as 1000 hours, for example, after the representative temperature reaches the normal operation temperature.

Then, if the wire bonding apparatus 100 operates for the predetermined operation time, the processing proceeds to Step S204 in Fig. 6.

[0045]

The control unit 60 moves to Step S204 in Fig. 6 and then resets a counter N to 1.

5 Here, N is the number of the pressing points 32, 33, and 34 disposed on the plate spring 31. The following description will be given on the assumption that the pressing point 32 is a first pressing point 32 corresponding to $N = 1$, the pressing point 33 is a second pressing point 33 corresponding to $N = 2$, and the pressing point 34 is a third pressing point 34 corresponding to $N = 3$. The first pressing point 32 is a pressing point
10 corresponding to pressing with a small pressing load W10 of about 5 g, for example, as illustrated in Fig. 7, the second pressing point 33 is a pressing point corresponding to pressing with an intermediate pressing load W20 of about 20 g, for example, as illustrated in Fig. 7, and the third pressing point 34 is a pressing point corresponding to pressing with a large pressing load W30 of about 200 g, for example, as illustrated in Fig.
15 7. Also, a value i10 of a current to be applied to the motor illustrated in Fig. 7 is a value of a current to be applied to the motor 40 when the pressing load W10 is caused, a value i20 of a current to be applied to the motor is a value of a current to be applied to the motor 40 when the pressing load W20 is caused, and a value i30 of a current to be applied to the motor is a value of a current to be applied to the motor 40 when the
20 pressing load W30 is caused.

[0046]

In a case in which N is set to 1 in Step S204 in Fig. 6, the control unit 60 proceeds to Step S205 in Fig. 6 and applies the value i10 of the current to be applied to the motor as illustrated in Fig. 7 to the motor 40 such that the first pressing point 32
25 corresponding to $N = 1$ is pressed with the pressing load W10 corresponding to the first

pressing point 32. Then, the processing proceeds to Step S207, a rotation angle ϕ of the bonding arm 13 is acquired from a signal of the angle sensor 52, the rotation angle ϕ is converted into displacement $\Delta 11$ of the first pressing point 32, and the displacement $\Delta 11$ of the first pressing point 32 is detected (Step S208 in Fig. 6). Since the displacement $\Delta 11$ of the first pressing point 32 and the pressing load applied to the first pressing point 32 are in a proportional relationship, the control unit 60 multiplies the detected displacement $\Delta 11$ by a constant $K1$ of proportionality indicating the relationship between the displacement of the first pressing point 32 and the pressing load and converts the displacement $\Delta 11$ into the pressing load $W11$ related to the first pressing point 32. The control unit 60 converts the displacement $\Delta 11$ into the pressing load $W11$ and then stores the pressing load $W11$ in the memory 62.

[0047]

The control unit 60 stores the pressing load $W11$ in the memory 62, then moves on to Step S209 in Fig. 6, and determines whether or not N has become N_{end} that is a final value (N_{end} is 3 in the embodiment since the number of the pressing points 32, 33, and 34 is three). Then, in a case in which N has not become 3, N is incremented by 1 (in this case, N becomes 2) in Step S210 in Fig. 6, and the processing returns to Step S205.

[0048]

Then, similarly to the above description, the value $i20$ of the current to be applied to the motor as illustrated in Fig. 7 is applied to the motor 40 such that the second pressing point 33 corresponding to $N = 2$ is pressed with the pressing load $W20$ corresponding to the second pressing point 33. Then, the processing proceeds to Step S207, and displacement $\Delta 21$ of the second pressing point 33 is detected. Then, the

control unit 60 multiplies the detected displacement $\Delta 21$ by a constant $K2$ of proportionality representing a relationship between the displacement of the second pressing point 33 and the pressing load and converts the displacement $\Delta 21$ into the pressing load $W21$ related to the second pressing point 33. The control unit 60 converts
 5 the displacement $\Delta 21$ into the pressing load $W21$ and then stores the pressing load $W21$ in the memory 62. The control unit 60 determines whether or not N has become the final value $Nend$ ($Nend$ is 3 in the embodiment) in the step in Fig. 6. Then, in a case in which N has not become 3, N is incremented by 1 in Step S210 in Fig. 6 (N becomes 3 in this case), and the processing returns to Step S205.

10 [0049]

Then, similarly to the above description, the value $i30$ of the current to be applied to the motor of as illustrated in Fig. 7 is applied to the motor 40 such that the third pressing point 34 corresponding to $N = 3$ is pressed with the pressing load $W30$ corresponding to the second pressing point 34. Then, the processing proceeds to Step
 15 S207, and displacement $\Delta 31$ of the third pressing point 34 is detected. Then, the control unit 60 multiplies the detected displacement $\Delta 31$ by a constant $K3$ of proportionality representing a relationship between the displacement of the third pressing point 34 and the pressing load and converts the displacement $\Delta 31$ into the pressing load $W31$ related to the second pressing point 34. The control unit 60 converts the displacement $\Delta 31$ into
 20 the pressing load $W31$ and then stores the pressing load $W31$ in the memory 62. The control unit 60 determines whether or not N has become the final value $Nend$ ($Nend$ is 3 in the embodiment) in the step in Fig. 6. Now, since $N = 3$ is satisfied, the control unit 60 makes YES determination in Step S209 in Fig. 6 and moves on to Step S211 in Fig. 6.

[0050]

Note that as described above with reference to Figs. 4(a) to 4(c), the respective pressing points 32, 33, and 34 of the plate spring 31 in the embodiment are disposed such that the displacement $\Delta 10$, $\Delta 20$, and $\Delta 30$ in a case in which the pressing loads $W10$ (5 g, for example), $W20$ (20 g, for example), and $W30$ (200 g, for example) corresponding to the respective pressing points 32, 33, and 34 are applied become substantially the same values. Therefore, the constants $K1$, $K2$, and $K3$ of proportionality representing the relationships between the displacement of the respective pressing points 32, 33, and 34 and the pressing loads related to the respective pressing points 32, 33, and 34 are not the same, and $K1 < K2 < K3$ is satisfied. In a case in which $W10$ is 5 g, $W20$ is 20 g, and $W30$ is 200 g as in the aforementioned example, $K2$ is four times as large as $k1$, and $K3$ is forty times as large as $K1$. The values of $K1$ to $K3$ are set in advance depending on the values of $W10$, $W20$, and $W30$ and the positions of the respective pressing points 32 to 34 of the plate spring 31 and are stored in the memory 62.

[0051]

The control unit 60 repeatedly executes Steps S205 to S208 in Fig. 6 N times (three times in the above case), and the pressing loads $W11$, $W21$, and $W31$ in the case in which the values $i10$, $i20$, and $i30$ of the currents to be applied to the motor are applied to the motor 40 are detected. For example, detected $W11$, $W21$, and $W31$ have become larger than initial $W10$, $W20$ and $W30$ as represented by the one-dotted chain line b in Fig. 7 due to a temporal change. Thus, the control unit 60 generates a new characteristic curve for deciding a command value of the value i of the current to be applied to the motor which is applied to the motor 40 when the wire is pressed, as represented by the one-dotted chain line b in Fig. 7 from the result of Steps S205 to S208. The characteristic curve may be generated by linearly complementing three points ($i10$, $W11$), ($i20$, $W21$), and ($i30$, $W31$), or a regression curve may be obtained from the three

points, and a characteristic curve may be set from the regression curve.

[0052]

The control unit 60 generates the new characteristic curve as represented by the one-dotted chain line b in Fig. 7, then moves on to Step S212 in Fig. 6, replaces the characteristic curve for adjusting the pressing load W when the wire is pressed by the capillary 15 with the new characteristic curve generated in Step S212, and restarts the bonding operation. In the restarted bonding operation, the control unit 60 outputs a command for setting the value i of the current to be applied to the motor to i11 that is smaller than i10 to the motor driver 48 when it is attempted to apply the pressing load W10 as illustrated in Fig. 7. The motor driver 48 performs adjustment such that the value i of the current to be applied to the motor becomes i11 on the basis of the command.

[0053]

Then, the control unit 60 repeats the operations in Steps S203 to S213 in Fig. 6 when the wire bonding apparatus 100 continuously operates, and if the wire bonding apparatus 100 is stopped, the control unit 60 stops the operations of the program.

[0054]

As described above, the wire bonding apparatus 100 according to the embodiment successively applies the plurality of values i10, i20, and i30 of the currents to the motor 40 and successively pressing the respective pressing points 32, 33, and 34 of the plate spring 31 with the capillary 15 without stopping the heater 17a in succession to the bonding operation, acquires the respective loads W11, W12, and W13 to be applied to the respective pressing points 32, 33, and 34 from the respective displacement $\Delta 11$, $\Delta 21$, and $\Delta 31$ of the respective pressing points 32, 33, and 34, generates a new characteristic curve for deciding the command value for the value i of the current to be applied to the

motor which is applied to the motor 40 when the wire is pressed, and adjusts the value of the current to be applied to the motor 40 on the basis of the newly generated characteristic curve. In this manner, the wire bonding apparatus 100 according to the embodiment can maintain the pressing load of the capillary 15 to be as constant as possible and secure bonding quality while preventing deterioration of producibility.

[0055]

Although the embodiment has been described on the assumption that the plate spring 31 is a cantilever with such a shape that the entire width becomes narrower toward the tip end by combining the tapered portion with a width narrowed toward the tip end (toward the negative side in the X direction) and a strip-shaped portion with a constant width as described above with reference to Fig. 3(a), the plate spring 31 may be a plate spring 71 with both ends secured to two supports 22 as illustrated in Fig. 8, for example, instead of the aforementioned shape. In this case, a plurality of pressing points 72, 73, and 74 may also be provided in the upper surface of the plate spring 71. Also, a plate spring 75 configured such that the thickness increases toward the root instead of the width that becomes wider toward the root and pressing points 76, 77, and 78 are provided thereon as illustrated in Fig. 9 may also be employed.

[0056]

Advantages that are similar to those described above can be achieved even in a case in which the plate springs 71 and 75 as illustrated in Figs. 8 and 9 are used.

[Reference Signs List]

[0057]

10 Frame

11 Table

25 12 Bonding head

	13 Bonding arm
	13a Recessed portion
	14 Ultrasonic horn
	14a Ultrasonic vibrator
5	14b Flange
	14c Bolt
	15 Capillary
	16 Guide rail
	17 Heat block
10	17a Heater
	18 Substrate
	19 Electronic component
	20 Assembly
	21 Base
15	22 Support
	23 Notch portion
	25 Bolt
	26 Flange
	27 Bolt hole
20	32 to 34, 72 to 74, 76 to 78 Pressing point
	40 Motor
	41 Stator
	42 Movable element
	43 Rotation center
25	45 Rotation axis

	46, 47 One-dotted chain line
	48 Motor driver
	49 Power source
	51 Current sensor
5	52 Angle sensor
	53 Temperature sensor
	60 Control unit
	61 CPU
	62 Memory
10	100 Wire bonding apparatus

[CLAIMS]

[Claim 1]

A wire bonding apparatus comprising:

a bonding tool that is driven in a vertical direction by means of a motor and that

5 presses a wire to an electrode;

an elastic member in which displacement corresponding to a pressing load of the bonding tool occurs;

a displacement detection means for detecting the displacement of the elastic member; and

10 a control unit that adjusts the pressing load of the bonding tool,

wherein the control unit

presses the elastic member with the bonding tool by applying a current of a predetermined value to the motor,

15 detects the displacement of the elastic member by means of the displacement detection means, and

corrects the pressing load of the bonding tool on the basis of a detected displacement.

[Claim 2]

The wire bonding apparatus according to claim 1,

20 wherein in a correction of the pressing load of the bonding tool performed by the control unit,

the detected displacement is compared with a reference displacement being preset, and

25 a value of a current to be applied to the motor is increased or decreased such that a difference between the detected displacement and the reference displacement becomes

small.

[Claim 3]

The wire bonding apparatus according to claim 1,
wherein the elastic member has a plurality of pressing points corresponding to a
5 plurality of values of current to be applied to the motor, and
the control unit
successively presses the respective pressing points of the elastic
member with the bonding tool by successively applying the current of the plurality of
values to the motor,
10 successively detects each displacement of the respective pressing points
by means of the displacement detection means, and
corrects the pressing load of the bonding tool on the basis of the
detected displacement respectively.

[Claim 4]

15 The wire bonding apparatus according to claim 3, wherein the plurality of
pressing points are disposed such that each displacement when the respective pressing
points of the elastic member corresponding to the respective values of current are
successively pressed with the bonding tool by successively applying the current of the
plurality of values to the motor falls within a predetermined range.

20 [Claim 5]

The wire bonding apparatus according to claim 3,
wherein in the correction of the pressing load of the bonding tool performed by
the control unit,
the detected displacement is respectively converted into respective loads applied
25 to the respective pressing points,

a characteristic curve indicating relationships between the current of the plurality of values applied to the motor and the loads applied to the respective pressing points is generated, and

the value of the current to be applied to the motor is adjusted on the basis of the
5 generated characteristic curve.

[Claim 6]

The wire bonding apparatus according to claim 4,

wherein in the correction of the pressing load of the bonding tool performed by the control unit,

10 the detected displacement is respectively converted into respective loads applied to the respective pressing points,

a characteristic curve indicating relationships between the current of the plurality of values applied to the motor and the loads applied to the respective pressing points is generated, and

15 the value of the current to be applied to the motor is adjusted on the basis of the generated characteristic curve.

[Claim 7]

The wire bonding apparatus according to any one of claims 1 to 6, wherein the elastic member is a plate spring.