DESCRIPTION

CALIBRATION METHOD AND ELECTRONIC COMPONENT MANUFACTURING METHOD

Technical Field

[0001] The present invention relates to a calibration method and an electronic component manufacturing method.

Background Art

[0002] JP 2019-201143A (Patent Document 1) discloses an inspection method for measuring the pixel size of an image capturing means included in a processing apparatus. In this inspection method, an inspection jig is used to measure the pixel size. A pattern and a two-dimensional barcode recording the width of the pattern are formed on the surface of the inspection jig. In this inspection method, an image of the pattern formed on the surface of the inspection jig is captured, and the number of pixels that correspond to the width of the pattern is measured. Then, the pixel size is calculated by dividing the width of the pattern read from the two-dimensional barcode by the number of pixels that corresponds to the width of the pattern (see Patent Document 1).

Citation List

Patent Document

[0003] Patent Document 1: JP 2019-201143A

Summary of Invention

Technical Problem

[0004] In a cutting apparatus for manufacturing electronic components by cutting a package substrate, there are cases where the appearance of an electronic component is

inspected. The appearance of an electronic component is inspected by, for example, using a camera to capture an image of the electronic component placed on an inspection table. In order to improve the quality of appearance inspection, it is necessary to improve the accuracy of camera calibration. In one example of camera calibration, the pixel size of the camera is calculated. However, the technique disclosed in Patent Document 1 cannot be said to sufficiently improve the accuracy of camera calibration.

[0005] The present invention has been made to solve such problems, and an object of the present invention is to provide a calibration method for calibrating a camera included in a cutting apparatus with relatively high accuracy, and an electronic component manufacturing method.

Solution to Problem

[0006] A calibration method according to an aspect of the present invention is a calibration method for calibrating a camera included in a cutting apparatus. The cutting apparatus is configured to manufacture an electronic component by cutting a package substrate, and perform appearance inspection on the electronic component based on first image data. The first image data is generated by using the camera to capture an image of the electronic component arranged on a table. The calibration method includes the steps of generating second image data by using the camera to capture an image of a calibration plate arranged on the table, calculating, before calibration of the camera, a relative inclination between the calibration plate and the camera based on the second image data, and calibrating the camera after calculation of the relative inclination.

[0007] An electronic component manufacturing method according to another aspect of the present invention is an electronic component manufacturing method in which the above-described calibration method is used. The electronic component manufacturing method includes the step of manufacturing the electronic component by cutting the package substrate, in a case where a result of the calibrating satisfies a predetermined

condition.

Advantageous Effects of Invention

[0008] According to the present invention, it is possible to provide a calibration method for calibrating a camera included in a cutting apparatus with relatively high accuracy, and an electronic component manufacturing method.

Brief Description of Drawings

[0009] FIG. 1 is a plan view schematically showing a cutting apparatus.

FIG. 2 is a side view schematically showing a spindle unit.

FIG. 3 is a diagram schematically showing a state of inspection performed by a second optical inspection camera.

FIG. 4 is a diagram schematically showing a hardware configuration of a computer.

FIG. 5 is a diagram schematically showing the second optical inspection camera when capturing an image of a calibration plate.

FIG. 6 is a perspective view schematically showing an example of a calibration jig.

FIG. 7 is a diagram schematically showing a surface of the calibration plate.

FIG. 8 is a diagram schematically showing the second optical inspection camera when capturing an image of a reference test piece.

FIG. 9 is a perspective view schematically showing an example of a maintenance jig.

FIG. 10 is a diagram schematically showing an example of a pattern portion.

FIG. 11 is a diagram schematically showing an example of a pattern of a lead surface of a QFN package.

FIG. 12 is a diagram schematically showing an example of a pattern of a ball

surface of a BGA package.

FIG. 13 is a diagram schematically showing an example of a pattern of a mold surface of a package.

FIG. 14 is a flowchart showing an operation procedure performed after assembly of the cutting apparatus.

FIG. 15 is a flowchart showing an operation procedure performed when maintenance is performed on a cutting apparatus.

Description of Embodiments

[0010] An embodiment according to one aspect of the present invention (hereinafter also referred to as “the present embodiment”) will be described in detail below with reference to the drawings. Note that like or corresponding elements in the drawings are denoted by like reference numerals, and descriptions will not be repeated for such elements. Also, the illustrations in the drawings are schematic illustrations with elements omitted or exaggerated as appropriate to facilitate understanding.

[0011] [1. Configuration]

<1-1. Overall configuration of cutting apparatus>

FIG. 1 is a plan view schematically showing a cutting apparatus 1 used in a calibration method according to the present embodiment. The cutting apparatus 1 is configured to cut a package substrate (cutting target) in order to divide the package substrate into a plurality of electronic components (package components). In the package substrate, substrates or lead frames, each of which has a semiconductor chip mounted thereon, are sealed with resin.

[0012] Examples of package substrates include a BGA (Ball Grid Array) package substrate, an LGA (Land Grid Array) package substrate, a CSP (Chip Size Package) package substrate, an LED (Light Emitting Diode) package substrate, and a QFN (Quad Flat No-leaded) package substrate.

[0013] The cutting apparatus 1 is also configured to inspect each of the separated electronic components. In the cutting apparatus 1, an image is captured for each electronic component, and each electronic component is inspected based on the image thereof. Inspection data is generated through the inspection, and each electronic component is classified as a “good component” or a “defective component”.

[0014] In this example, a package substrate P1 is the cutting target, and the cutting apparatus 1 divides the package substrate P1 into a plurality of electronic components S1. Hereinafter, out of the two main surfaces of the package substrate P1, the resin-sealed surface will be referred to as the mold surface, and the surface opposite to the mold surface will be referred to as the ball/lead surface.

[0015] As shown in FIG. 1, the cutting apparatus 1 includes a cutting module A1 and an inspection/storage module B1 as constituent elements. The cutting module A1 is configured to manufacture a plurality of electronic components S1 by cutting the package substrate P1. The inspection/storage module B1 is configured to inspect each of the manufactured electronic components S1, and then store the electronic components S1 in trays. Various constituent elements of the cutting apparatus 1 can be removed from the other constituent elements and replaced.

[0016] The cutting module A1 mainly includes a substrate supply unit 3, a positioning unit 4, cutting tables 5, spindle units 6, and a transport unit 7.

[0017] A magazine M1 stores a plurality of package substrates P1, and the substrate supply unit 3 supplies the package substrates P1 one by one to the positioning unit 4 by pushing out the package substrates P1 one by one from the magazine M1. At this time, the package substrates P1 are each arranged such that the ball/lead surface faces upward.

[0018] The positioning unit 4 positions the package substrate P1 pushed out from the substrate supply unit 3 by arranging the package substrate P1 on a rail unit 4a. After that, the positioning unit 4 transports the positioned package substrate P1 to the cutting tables 5.

[0019] The cutting tables 5 each hold the package substrate P that is to be cut. In this example, the illustrated cutting apparatus 1 has a twin cut table configuration including two cutting tables 5. Each of the cutting tables 5 includes a holding member 5a, a rotating mechanism 5b, and a moving mechanism 5c. The holding member 5a holds the package substrate P1 transported by the positioning unit 4 by suctioning the package substrate P1 from below. The rotating mechanism 5b can rotate the holding member 5a in a θ1 direction shown in the figure. The moving mechanism 5c can move the holding member 5a along the Y axis shown in the figure.

[0020] The spindle units 6 each divide the package substrate P1 into a plurality of electronic components S1 by cutting the package substrate P1. In this example, the illustrated cutting apparatus 1 has a twin spindle configuration including two spindle portions 6. The spindle units 6 can be moved along the X axis and the Z axis shown in the figure. Note that the cutting apparatus 1 may have a single spindle configuration including only one spindle unit 6.

[0021] FIG. 2 is a side view schematically showing one spindle unit 6. As shown in FIG. 2, the spindle unit 6 includes a blade 6a, a rotation shaft 6c, a first flange 6d, a second flange 6e, and a fastening member 6f.

[0022] The blade 6a cuts the package substrate P1 by rotating at high speed, and thus divides the package substrate P1 into a plurality of electronic components S1. The blade 6a is mounted on the rotation shaft 6c in a state of being held between one flange (first flange) 6d and the other flange (second flange) 6e. The first flange 6d and the second flange 6e are fixed to the rotation shaft 6c by the fastening member 6f, which is a nut or the like. The first flange 6d is also called an inner flange, and the second flange 6e is also called an outer flange.

[0023] The spindle unit 6 includes a cutting water nozzle that sprays cutting water toward the blade 6a rotating at high speed, a cooling water nozzle that sprays cooling water, and a cleaning water nozzle that sprays cleaning water to wash cutting debris or

the like away, for example (none of which is shown).

[0024] Referring again to FIG. 1, after the cutting table 5 suctions the package substrate P1, an image of the package substrate P1 is captured by a first position checking camera 5d, and the position of the package substrate P1 is checked. The checking performed using the first position checking camera 5d is, for example, checking of the position of a mark provided on the package substrate P1. The mark indicates a cutting position of the package substrate P1, for example.

[0025] After that, the cutting table 5 moves along the Y axis in the figure toward a corresponding one of the spindle units 6. After the cutting table 5 moves to a position below the spindle unit 6, the package substrate P1 is cut by moving the cutting table 5 and the spindle unit 6 relative to each other. After that, if necessary, an image of the package substrate P1 is captured by a second position checking camera 6b, and the position or the like of the package substrate P1 is checked. The checking performed using the second position checking camera 6b is, for example, the checking of a cutting position and a cutting width of the package substrate P1.

[0026] After the cutting of the package substrate P1 is complete, the cutting table 5 moves away from the spindle unit 6 along the Y axis in the figure while suctioning the separated electronic components S1. During this moving process, a first cleaner 5e cleans and dries the upper surfaces (ball/lead surfaces) of the electronic components S1.

[0027] The transport unit 7 suctions the electronic components S1 held on the cutting table 5 from above and transports the electronic components S1 to the inspection table 11 of the inspection/storage module B1. During this transportation process, a second cleaner 7a cleans and dries the lower surfaces (mold surfaces) of the electronic components S1.

[0028] The inspection/storage module B1 mainly includes the inspection table 11, a first optical inspection camera 12, a second optical inspection camera 13, an arrangement unit 14, and an extraction unit 15. Note that the first optical inspection camera 12 may

be provided in the cutting module A1.

[0029] The inspection table 11 holds the electronic components S1 for optical inspection of the electronic components S1. The inspection table 11 can be moved along the X axis in the figure. Furthermore, the inspection table 11 can be vertically inverted. The inspection table 11 includes a holding member that holds an electronic component S1 by suctioning the electronic component S1.

[0030] The first optical inspection camera 12 and the second optical inspection camera 13 capture images of the two surfaces (ball/lead surface and mold surface) of the electronic component S1. Based on the image data generated by the first optical inspection camera 12 and the second optical inspection camera 13, various aspects of the electronic component S1 are inspected. The first optical inspection camera 12 and the second optical inspection camera 13 are each arranged in the vicinity of the inspection table 11 so as to capture an image of the upper portion of the image capturing target.

[0031] The first optical inspection camera 12 is provided with an illumination device 12a, and the second optical inspection camera 13 is provided with an illumination device 13a. The illumination device 12a is configured to irradiate the inspection table 11 with light during inspection performed by the first optical inspection camera 12. The illumination device 13a is configured to irradiate the inspection table 11 with light during inspection performed by the second optical inspection camera 13.

[0032] The first optical inspection camera 12 captures an image of the mold surface of the electronic component S1 that has been transported to the inspection table 11 by the transport unit 7. After that, the transport unit 7 places the electronic component S1 on the holding member of the inspection table 11. After the holding member suctions the electronic component S1, the inspection table 11 is vertically inverted. The inspection table 11 moves to a position above the second optical inspection camera 13, and an image of the ball/lead surface of the electronic component S1 is captured by the second optical inspection camera 13. As one example, inspection performed by the second optical

inspection camera 13 will be described below.

[0033] FIG. 3 is a diagram schematically showing a state of inspection performed by the second optical inspection camera 13. As shown in FIG. 3, inspection is performed by the second optical inspection camera 13 in the state where the electronic component S1 is held on the lower surface the inspection table 11, and the inspection table 11 is positioned above the second optical inspection camera 13. Specifically, the second optical inspection camera 13 captures an image of the electronic component S1 held on the inspection table 11 and generates image data, and inspects the appearance of the ball/lead surface of the electronic component S1 based on the generated image data. As described above, the appearance of the mold surface of the electronic component S1 is inspected by the first optical inspection camera 12.

[0034] Referring again to FIG. 1, the inspected electronic component S1 is then disposed on the arrangement unit 14. The arrangement unit 14 can be moved along the Y axis in the figure. The inspection table 11 disposes the inspected electronic component S1 on the arrangement unit 14.

[0035] The electronic component S1 that was disposed on the arrangement unit 14 is transferred to a tray by the extraction unit 15. The electronic components S1 are classified as a “good component” or a “defective component” based on the results of the inspections performed using the first optical inspection camera 12 and the second optical inspection camera 13. The extraction unit 15 transfers each of the electronic components S1 to a good component tray 15a or a defective component tray 15b based on the classification results. In other words, good components are stored in the good component tray 15a, and defective components are stored in the defective component tray 15b. When the good component tray 15a or the defective component tray 15b is completely full with electronic components S1, it is replaced with a new tray.

[0036] The cutting apparatus 1 further includes a computer 50 and a monitor 20. The monitor 20 is configured to display images. The monitor 20 is constituted by a

display device such as a liquid crystal monitor or an organic EL (Electro Luminescence) monitor.

[0037] The computer 50 controls the operations of various units of the cutting module A1 and the inspection/storage module B1, for example. For example, the computer 50 controls the operations of the substrate supply unit 3, the positioning unit 4, the cutting tables 5, the spindle units 6, the transport unit 7, the inspection table 11, the first optical inspection camera 12, the second optical inspection camera 13, the arrangement unit 14, the extraction unit 15, and the monitor 20.

[0038] Also, the computer 50 performs various types of inspection on the electronic components S1 based on image data generated by the first optical inspection camera 12 and the second optical inspection camera 13, for example. Next, the computer 50 will be described in detail.

[0039] <1-2. Hardware configuration of computer>

FIG. 4 is a diagram schematically showing the hardware configuration of the computer 50. As shown in FIG. 4, the computer 50 includes a computation unit 70, an input/output I/F (interface) 90, and a storage unit 80, and these elements are electrically connected to each other via a bus.

[0040] The computation unit 70 includes a CPU (Central Processing Unit) 72, a RAM (Random Access Memory) 74, a ROM (Read Only Memory) 76, and the like. The computation unit 70 is configured to control constituent elements of the computer 50 and constituent elements of the cutting apparatus 1 according to information processing.

[0041] The input/output I/F 90 is configured to communicate with various constituent elements included in the cutting apparatus 1 via signal lines. The input/output I/F 90 is used in the transmission of data from the computer 50 to various constituent elements of the cutting apparatus 1 and in the reception of data transmitted from various constituent elements of the cutting apparatus 1 to the computer 50.

[0042] The storage unit 80 is an auxiliary storage device such as a hard disk drive or

a solid state drive, for example. The storage unit 80 is configured to store a control program 81, for example. The storage unit 80 may store inspection data generated through inspection performed using the first optical inspection camera 12 and the second optical inspection camera 13.

[0043] [2. Ensuring quality of appearance inspection]

As described above, in the cutting apparatus 1, the appearance of the mold surface of an electronic component S1 is inspected based on an image captured by the first optical inspection camera 12 (hereinafter, also referred to as “first appearance inspection”), and the appearance of the ball/lead surface of an electronic component S1 is inspected based on an image captured by the second optical inspection camera 13 (hereinafter, also referred to as “second appearance inspection”). In both the first appearance inspection and the second appearance inspection, information on the pixel size of the corresponding camera (hereinafter also referred to as “pixel size information”) is used, for example. Here, “pixel size” (image resolution) refers to the actual length of the imaged object corresponding to one side of one pixel of the camera. For example, if the length of one side of the object in the portion of the image captured by one pixel of the camera is 1 mm, the pixel size is 1 mm.

[0044] The pixel size of each camera is calculated when the camera is calibrated. Each camera is calibrated after installation of the cutting apparatus 1, for example. Calibration of the first optical inspection camera 12 is performed by using the first optical inspection camera 12 to capture an image of a calibration plate 130 (described later) held on the transport unit 7. Also, calibration of the second optical inspection camera 13 is performed by using the second optical inspection camera 13 to capture an image of the calibration plate 130 held on the inspection table 11. Camera calibration will be described in detail later.

[0045] The quality of the first appearance inspection is influenced by the accuracy of the pixel size information of the first optical inspection camera 12. The higher the

accuracy of the pixel size information of the first optical inspection camera 12 is, the higher the quality of the first appearance inspection is. Furthermore, the quality of the second appearance inspection is influenced by the accuracy of the pixel size information of the second optical inspection camera 13. The higher the accuracy of the pixel size information of the second optical inspection camera 13 is, the higher the quality of the second appearance inspection is.

[0046] The accuracy of the pixel size information of the first optical inspection camera 12 is influenced by relative inclination between the first optical inspection camera 12 and the calibration plate 130 (transport unit 7) during calibration of the first optical inspection camera 12. During calibration of the first optical inspection camera 12, the closer the optical axis of the first optical inspection camera 12 is to being perpendicular to the calibration plate 130, the higher the accuracy of the pixel size information of the first optical inspection camera 12 is.

[0047] Furthermore, the accuracy of the pixel size information of the second optical inspection camera 13 is influenced by relative inclination between the second optical inspection camera 13 and the calibration plate 130 (inspection table 11) during calibration of the second optical inspection camera 13. During calibration of the second optical inspection camera 13, the closer the optical axis of the second optical inspection camera 13 is to being perpendicular to the calibration plate 130, the higher the accuracy of the pixel size information of the second optical inspection camera 13 is.

[0048] Furthermore, the quality of the first appearance inspection is influenced by, for example, relative inclination between the first optical inspection camera 12 and an electronic component S1 (transport unit 7) during the first appearance inspection of the electronic component S1. During the first appearance inspection, the closer the optical axis of the first optical inspection camera 12 is to being perpendicular to the electronic component S1, the higher the quality of the first appearance inspection is. Furthermore, the quality of the second appearance inspection is influenced by, for example, relative

inclination between the second optical inspection camera 13 and an electronic component S1 (inspection table 11) during the second appearance inspection of the electronic component S1. During the second appearance inspection, the closer the optical axis of the second optical inspection camera 13 is to being perpendicular to the electronic component S1, the higher the quality of the second appearance inspection is.

[0049] In this way, in order to ensure the quality of the first appearance inspection, it is necessary to manage the relative inclination between the first optical inspection camera 12 and the transport unit 7. Furthermore, in order to ensure the quality of the second appearance inspection, it is necessary to manage the relative inclination between the second optical inspection camera 13 and the inspection table 11.

[0050] In the cutting apparatus 1, before calibration of the first optical inspection camera 12 is performed, the relative inclination between the first optical inspection camera 12 and the calibration plate 130 (transport unit 7) is calculated. Furthermore, before calibration of the second optical inspection camera 13 is performed, the relative inclination between the second optical inspection camera 13 and the calibration plate 130 (inspection table 11) is calculated. Both the calculation of the relative inclination between the first optical inspection camera 12 and the calibration plate 130 and the calculation of the relative inclination between the second optical inspection camera 13 and the calibration plate 130 are performed using substantially the same method. The following describes a representative example of a method for calculating the relative inclination between the second optical inspection camera 13 and the calibration plate 130.

[0051] FIG. 5 is a diagram schematically showing the second optical inspection camera 13 when capturing an image of the calibration plate 130. As shown in FIG. 5, when the second optical inspection camera 13 captures an image of the calibration plate 130, the inspection table 11 is located above the second optical inspection camera 13. A jig 100 is arranged on the lower surface of the inspection table 11. The jig 100 is fixed at a predetermined position on the lower surface of the inspection table 11 with fixing

members such as screws. Since the jig 100 is fixed to the inspection table 11 by the fixing members, the jig 100 is located at a predetermined position on the inspection table 11. For example, at the predetermined position, the center position of the jig 100 and the center position of the inspection table 11 match each other.

[0052] FIG. 6 is a perspective view schematically showing an example of the calibration jig 100. As shown in FIG. 6, the jig 100 includes a base 110, a holding plate 120, and the calibration plate 130. The base 110, the holding plate 120, and the calibration plate 130 are each a plate-like member that is rectangular in plan view. The calibration plate 130 is disposed in a recess 124 formed in the holding plate 120, and is fixed to the holding plate 120 by using head bearing surfaces of screws 122 to press portions near the four corners of the calibration plate 130.

[0053] FIG. 7 is a diagram schematically showing the surface of the calibration plate 130. As shown in FIG. 7, a predetermined pattern is formed on the calibration plate 130. The predetermined pattern is formed on the calibration plate 130 by printing or cutting, for example. In this example, a plurality of dots D1 are printed on the calibration plate 130. Information regarding the predetermined pattern is stored in advance in the storage unit 80 (FIG. 4), for example. Examples of information regarding the predetermined pattern include the diameter of each of the dots D1 and the distance between the dots D1.

[0054] Referring again to FIG. 6, the holding plate 120 is fixed to the base 110 by using pressing members 114 to press portions near the four corners of the holding plate 120. The pressing members 114 each include a first surface portion 114a, a bent portion 114b, and a second surface portion 114c. The bent portion 114b is bent relative to both the first surface portion 114a and the second surface portion 114c. In a plan view of the pressing member 114, the first surface portion 114a and the second surface portion 114c extend in opposite directions from the bent portion 114b. The second surface portion 114c is fixed to the base 110 by a screw 116, and the first surface portion 114a presses the holding plate 120 toward the base 110. The holding plate 120 is thus fixed to the

base 110. A plurality of screw holes 112 are formed in the base 110. By inserting screws into the screw holes 112, the jig 100 is fixed at the predetermined position on the inspection table 11. While the jig 100 is fixed at the predetermined position on the inspection table 11, the center position of the calibration plate 130 is the same as the center position of the electronic component S1 during, for example, the second appearance inspection.

[0055] Referring again to FIG. 5, the second optical inspection camera 13 captures an image of the calibration plate 130 of the jig 100 and generates image data. In the cutting apparatus 1, the relative inclination between the second optical inspection camera 13 and the calibration plate 130 is calculated based on the generated image data. In the cutting apparatus 1, a relative inclination is calculated for a θ1 direction, a θ2 direction, and a θ3 direction shown in the figure, for example. The relative inclination between the second optical inspection camera 13 and the calibration plate 130 is calculated based on the extent of distortion of the pattern (e.g., the dots D1) on the calibration plate 130 in the captured image, for example.

[0056] In this way, in the cutting apparatus 1, before calibration of the first optical inspection camera 12 is performed, the relative inclination between the first optical inspection camera 12 and the calibration plate 130 (transport unit 7) is calculated. Furthermore, before calibration of the second optical inspection camera 13 is performed, the relative inclination between the second optical inspection camera 13 and the calibration plate 130 (inspection table 11) is calculated. According to the cutting apparatus 1, for each camera, it is first confirmed that there is no problem with the relative inclination between the camera and the calibration plate 130 before calibration is performed for the camera, thus making it possible to ensure the accuracy of the calibration for each camera. As a result, according to the cutting apparatus 1, it is possible to ensure the quality of appearance inspection.

[0057] If a long period of time has passed since the cutting apparatus 1 has been used,

for example, the relative inclination between a camera and the transport unit 7 or the inspection table 11 may change. In such a case, the quality of appearance inspection deteriorates. The quality of appearance inspection may deteriorate due to various other factors as well. In the cutting apparatus 1, maintenance is performed to suppress deterioration of the quality of appearance inspection. If it is determined through maintenance that any of various adjustments need to be made for appearance inspection, the necessary adjustments are made. Maintenance is performed by capturing an image of a reference test piece 210 (described later) with each camera. Since the maintenance method is substantially the same when using the first optical inspection camera 12 and the second optical inspection camera 13, the following describes the maintenance method performed when using the second optical inspection camera 13, as a representative example.

[0058] FIG. 8 is a diagram schematically showing the second optical inspection camera 13 when capturing an image of the reference test piece 210. As shown in FIG. 8, when the second optical inspection camera 13 captures an image of the reference test piece 210, the inspection table 11 is located above the second optical inspection camera 13. A jig 200 is arranged on the lower surface of the inspection table 11. The jig 200 is fixed at a predetermined position on the lower surface of the inspection table 11 with fixing members such as screws. Since the jig 200 is fixed to the inspection table 11 by the fixing members, the jig 200 is located at a predetermined position on the inspection table 11. For example, at the predetermined position, the center position of the jig 200 and the center position of the inspection table 11 match each other.

[0059] FIG. 9 is a perspective view schematically showing an example of the calibration jig 200 for maintenance. As shown in FIG. 9, the jig 200 includes a base 110 and a reference test piece 210. The reference test piece 210 is a plate-like member that is rectangular in plan view. A pattern portion 220 is formed on the reference test piece 210. The pattern portion 220 is formed on the reference test piece 210 by printing or

cutting, for example.

[0060] Portions of the reference test piece 210 at two locations on each long side (four places in total) are pressed by pressing members 114, and portions of the reference test piece 210 at three locations on each long side (six places in total) are fixed to the base 110 by being screwed thereto with screws 212. As described above, a plurality of screw holes 112 are formed in the base 110. By inserting screws into the screw holes 112, the jig 200 is fixed at a predetermined position on the inspection table 11.

[0061] FIG. 10 is a diagram schematically showing an example of the pattern portion 220. As shown in FIG. 10, the pattern portion 220 includes QFN pattern groups 221 to 225, BGA pattern groups 231 to 235, and mark pattern groups 241 to 244. The QFN pattern groups 221 to 225, the BGA pattern groups 231 to 235, and the mark pattern groups 241 to 244 each include patterns of a plurality of packages of the same type. Each of the package patterns indicate a package not having a defective appearance, for example. Also, the QFN pattern groups 221 to 225, the BGA pattern groups 231 to 235, and the mark pattern groups 241 to 244 each have a size greater than or equal to the image capturing range of the first optical inspection camera 12 and the second optical inspection camera 13.

[0062] The QFN pattern groups 221 to 225 each include patterns of a plurality of QFN packages. The QFN package patterns included in each of the QFN pattern groups 221 to 225 show the lead surfaces of QFN packages.

[0063] FIG. 11 is a diagram schematically showing an example of a pattern of a lead surface of a QFN package. As shown in FIG. 11, a pattern 229 shows the lead surface of a QFN package.

[0064] Referring again to FIG. 10, the QFN pattern groups 221 to 225 each include patterns of a plurality of QFN packages of the same size. The QFN pattern groups 221, 222, 223, 224, and 225 respectively include patterns of QFN packages of 2 mm square, 3 mm square, 5 mm square, 7 mm square, and 9 mm square, for example. Information

regarding the length of each side for each pattern is stored in advance in the storage unit 80 (FIG. 4), for example.

[0065] The BGA pattern groups 231 to 235 each include patterns of a plurality of BGA packages. The BGA package patterns included in each of the BGA pattern groups 231 to 235 show the ball surfaces of BGA packages.

[0066] FIG. 12 is a diagram schematically showing an example of a pattern of a ball surface of a BGA package. As shown in FIG. 12, a pattern 239 shows the ball surface of a BGA package.

[0067] Referring again to FIG. 10, the BGA pattern groups 231 to 235 each include patterns of a plurality of BGA packages of the same size. The BGA pattern groups 231, 232, 233, 234, and 235 respectively include patterns of BGA packages of 2 mm square, 4 mm square, 8 mm square, 10 mm square, and 12 mm square, for example. Information regarding the length of each side for each pattern is stored in advance in the storage unit 80, for example.

[0068] The mark pattern groups 241 to 244 each include patterns of a plurality of packages. The package patterns included in each of mark pattern groups 241 to 244 show the mold surfaces of packages. The pattern of each package includes marks including letters or the like.

[0069] FIG. 13 is a diagram schematically showing an example of a pattern on a mold surface of a package. As shown in FIG. 13, a pattern 249 shows the mold surface of a package. For example, a mark including the letters “ABC” is formed on the mold surface.

[0070] Referring again to FIG. 10, each of the mark pattern groups 241 to 244 includes patterns of a plurality of packages of the same size. The mark pattern groups 241, 242, 243, and 244 respectively include patterns of packages of 3 mm square, 4 mm square, 7 mm square, and 12 mm square, for example. Information regarding the length of each side for each pattern is stored in advance in the storage unit 80, for example.

[0071] Referring again to FIG. 8, the second optical inspection camera 13 is located below the image capturing target pattern among the patterns on the reference test piece 210. If the electronic component manufactured by the cutting apparatus 1 is a 2 mm square QFN package, the second optical inspection camera 13 is located below the QFN pattern group 221 of the reference test piece 210. In this state, the second optical inspection camera 13 captures an image of the reference test piece 210 and generates image data.

[0072] In the cutting apparatus 1, the length of one side of the QFN package pattern in the captured image, for example, is calculated based on the generated image data. Specifically, the length of one side of the QFN package pattern is calculated by integrating the number of pixels corresponding to one side of the QFN package pattern in the captured image and the pixel size calculated during calibration of the second optical inspection camera 13. Based on the difference between the calculated length of one side and the length of one side (reference value) stored in the storage unit 80, it is determined whether or not any of various types of adjustments need to be made for appearance inspection.

[0073] In this way, in the cutting apparatus 1, the accuracy of the pixel size information is checked during maintenance. According to the cutting apparatus 1, before appearance inspection is performed on the electronic component S1, it is first confirmed that there is no problem with the accuracy of the pixel size information during maintenance, thus making it possible to continuously ensure the quality of the appearance inspection performed on the electronic component S1. Hereinafter, operations of the cutting apparatus 1 will be described in detail.

[0074] [3. Operations for manufacturing electronic component]

<3-1. Operations after assembly of cutting apparatus>

FIG. 14 is a flowchart showing an operation procedure performed after assembly of the cutting apparatus 1. As shown in FIG. 14, a worker attaches the calibration plate 130 (jig 100) at a predetermined position on the inspection table 11 (step S100). The

computer 50 controls the second optical inspection camera 13 to capture an image of the calibration plate 130 fixed to the inspection table 11 (step S105). The computer 50 calculates the relative inclination between the second optical inspection camera 13 and the calibration plate 130 based on the image data generated by the second optical inspection camera 13 (step S110).

[0075] The computer 50 controls the monitor 20 to display the calculated inclination information (step S115). After that, it is determined whether or not the relative inclination between the second optical inspection camera 13 and the calibration plate 130 is in a predetermined range. This determination is made by the worker, for example.

[0076] If it is determined that the relative inclination is not in the predetermined range (NO in step S120), the inclination of at least either the second optical inspection camera 13 or the calibration plate 130 (inspection table 11) is adjusted (step S125). This inclination adjustment is performed manually by the worker, for example.

[0077] On the other hand, if it is determined that the relative inclination is in the predetermined range (YES in step S120), the computer 50 controls the second optical inspection camera 13 to capture an image of the calibration plate 130 fixed to the inspection table 11 (step S130). The computer 50 performs calibration processing on the second optical inspection camera 13 based on the image data generated by the second optical inspection camera 13 (step S135). For example, the computer 50 calculates the pixel size of the second optical inspection camera 13 based on the image data generated by the second optical inspection camera 13 and information regarding the predetermined pattern of the calibration plate 130 stored in the storage unit 80. The second optical inspection camera 13 is thus calibrated.

[0078] The computer 50 controls the monitor 20 to display the calibration result (e.g., the pixel size of the second optical inspection camera 13) (step S140). After that, it is determined whether or not the second optical inspection camera 13 needs to be recalibrated (step S145). For example, if the calculated pixel size does not meet a certain

standard, it is determined that recalibration is necessary, whereas if the calculated pixel size meets a certain standard, it is determined that recalibration is not necessary. This determination is made by the worker, for example.

[0079] If it is determined that the second optical inspection camera 13 needs to be recalibrated (YES in step S145), the cause may be a problem in the assembly of the cutting apparatus 1, and thus the cutting apparatus 1 is reassembled (step S150). Reassembly of the cutting apparatus 1 is performed by the worker, for example.

[0080] If it is determined that the second optical inspection camera 13 does not need to be recalibrated (NO in step S145), and the calibration of the first optical inspection camera 12 is also complete, manufacturing of the electronic components S1 in the cutting apparatus 1 is started (step S155). Note that, similarly to the second optical inspection camera 13, operations corresponding to steps S100 to S150 are performed for the first optical inspection camera 12 as well.

[0081] In this way, in the cutting apparatus 1, before calibration of the first optical inspection camera 12 is performed, the relative inclination between the first optical inspection camera 12 and the calibration plate 130 (transport unit 7) is calculated. Furthermore, before calibration of the second optical inspection camera 13 is performed, the relative inclination between the second optical inspection camera 13 and the calibration plate 130 (inspection table 11) is calculated. According to the cutting apparatus 1, for each camera, it is first confirmed that there is no problem with the relative inclination between the camera and the calibration plate 130 before calibration is performed for the camera, thus making it possible to ensure the accuracy of the calibration for each camera. As a result, according to the cutting apparatus 1, it is possible to ensure the quality of appearance inspection.

[0082] <3-2. Operations during maintenance >

FIG. 15 is a flowchart showing an operation procedure performed during maintenance of the cutting apparatus 1. As shown in FIG. 15, the worker attaches the

reference test piece 210 (jig 200) at a predetermined position on the inspection table 11 (step S200). The computer 50 controls the second optical inspection camera 13 to capture an image of the reference test piece 210 fixed to the inspection table 11 (step S205).

[0083] The computer 50 calculates the length of a target region of the reference test piece 210 based on the image data generated by the second optical inspection camera 13 (step S210). The computer 50 calculates the length of one side of the pattern (package pattern) that is the imaging target, for example. The computer 50 compares the calculated length of one side with the length of one side of the target pattern (reference value), which is stored in advance in the storage unit 80 (step S215).

[0084] The computer 50 determines, based on the comparison result, whether or not adjustment for appearance inspection needs to be performed (step S220). For example, if the difference between the calculated length of one side and the reference value is greater than or equal to a first predetermined value, it is determined that adjustment for appearance inspection needs to be performed, whereas if the difference between the calculated length of one side and the reference value is less than the first predetermined value, it is determined that adjustment for appearance inspection does not need to be performed.

[0085] If it is determined that the adjustment for appearance inspection does not need to be performed (NO in step S220), and adjustment and the like regarding the first optical inspection camera 12 is complete, the manufacturing of the electronic components S1 in the cutting apparatus 1 is started (step S250). Note that, similarly to the second optical inspection camera 13, operations corresponding to steps S200 to S240 are performed for the first optical inspection camera 12 as well.

[0086] On the other hand, if it is determined that adjustment for appearance inspection needs to be performed (YES in step S220), the computer 50 determines whether or not the second optical inspection camera 13 needs to be calibrated (step S225).

For example, if the difference between the calculated length of one side and the reference value is greater than or equal to a second predetermined value (second predetermined value > first predetermined value), it is determined that the second optical inspection camera 13 needs to be calibrated, whereas if the difference between the calculated length of one side and the reference value is less than the second predetermined value, it is determined that the second optical inspection camera 13 does not need to be calibrated.

[0087] If it is determined that the second optical inspection camera 13 needs to be calibrated (YES in step S225), the operations shown in the flowchart of FIG. 14 (calibration flow) are performed (step S230), for example. On the other hand, if it is determined that the second optical inspection camera 13 does not need to be calibrated (NO in step S225), various parameters that influence appearance inspection are adjusted. One example of such parameters is a parameter related to the illuminance of the illumination device 13a. The adjustment of various parameters is performed by the worker, for example.

[0088] After that, it is determined whether or not adjustment for appearance inspection needs to be performed again (step S240). This determination is made by the worker, for example. If it is determined that adjustment needs to be performed again (YES in step S240), the operation of step S200 is performed again. On the other hand, if it is determined that adjustment does not need to be performed again (NO in step S240), and adjustment and the like regarding the first optical inspection camera 12 is complete, the manufacturing of the electronic components S1 in the cutting apparatus 1 is started (step S250).

[0089] In this way, in the cutting apparatus 1, the accuracy of the pixel size information is checked during maintenance, and whether or not recalibration or the like needs to be performed is determined for each camera. According to the cutting apparatus 1, before appearance inspection is performed on the electronic component S1, it is first confirmed that there is no problem with the accuracy of the pixel size information

during maintenance, thus making it possible to continuously ensure the quality of the appearance inspection performed on the electronic component S1.

[4. Features]

[0090] As described above, in the cutting apparatus 1, before calibration of the first optical inspection camera 12 is performed, the relative inclination between the first optical inspection camera 12 and the calibration plate 130 (transport unit 7) is calculated. Furthermore, before calibration of the second optical inspection camera 13 is performed, the relative inclination between the second optical inspection camera 13 and the calibration plate 130 (inspection table 11) is calculated. According to the cutting apparatus 1, for each camera, it is first confirmed that there is no problem with the relative inclination between the camera and the calibration plate 130 before calibration is performed for the camera, thus making it possible to ensure the accuracy of the calibration for each camera. As a result, according to the cutting apparatus 1, it is possible to ensure the quality of appearance inspection.

[0091] Note that the cutting apparatus 1 is an example of a “cutting apparatus” of the present invention. The first optical inspection camera 12 and the second optical inspection camera 13 are each an example of a “camera” of the present invention. The package substrate P1 is an example of a “package substrate” of the present invention. The electronic component S1 is an example of an “electronic component” of the present invention. The transport unit 7 and the inspection table 11 are each an example of a “table” of the present invention. The calibration plate 130 is an example of a “calibration plate” of the present invention.

[0092] [5. Other embodiments]

The idea of the above embodiment is not limited to the embodiment described above. Hereinafter, examples of other embodiments to which the idea of the above embodiment is applicable will be described.

[0093] <5-1>

In the above embodiment, whether or not adjustment for appearance inspection needs to be performed is determined during maintenance of the cutting apparatus 1. However, this determination does not necessarily need to be made. It is sufficient that the relative inclination between the calibration plate 130 and the cameras is calculated based on a captured image at least at a time that is after installation of the cutting apparatus 1 and before the calibration of the cameras.

[0094] <5-2>

Furthermore, in the above embodiment, the relative inclination between the calibration plate 130 and the first optical inspection camera 12 is calculated before the calibration of the first optical inspection camera 12, and the relative inclination between the calibration plate 130 and the second optical inspection camera 13 is calculated before the calibration of the second optical inspection camera 13. However, for each of the cameras, the relative inclination between the camera and the calibration plate 130 does not necessarily need to be calculated before the calibration of the camera. It is sufficient that for at least one of the cameras, the relative inclination between the camera and the calibration plate 130 is calculated before the calibration of the camera.

[0095] <5-3>

Furthermore, in the above embodiment, during maintenance of the cutting apparatus 1, the accuracy of the pixel size information is checked for both the first optical inspection camera 12 and the second optical inspection camera 13. However, the accuracy of the pixel size information does not necessarily need to be checked for both the first optical inspection camera 12 and the second optical inspection camera 13. For example, a configuration is possible in which the accuracy of the pixel size information is checked for either the first optical inspection camera 12 or the second optical inspection camera 13.

[0096] <5-4>

Also, the calibration of the cameras may include calculating the size of the image

capturing range (field of view size) of the cameras.

[0097] <5-5>

Also, in the appearance inspection of an electronic component S1, a corner portion of the electronic component S1 may be detected. In this case, the corner portion of the electronic component S1 may be detected based on an amount of change in brightness in the captured image. The parameters adjusted in step S235 in FIG. 15 may include a threshold regarding the amount of change in brightness for detecting the corner portion of the electronic component S1.

[0098] <5-6>

Also, some of the operations in the flowcharts of FIGS. 14 and 15 are performed by a worker (person). However, such operations may also be performed automatically by the cutting apparatus 1. For example, determinations may be made by the computer 50 rather than by a worker.

[0099] <5-7>

Also, the reference test piece 210 has a rectangular package pattern formed thereon. However, the shape of the pattern formed on the reference test piece 210 is not limited to being a rectangle. A pattern having a special shape, such as a micro SD (registered trademark) pattern, may be formed on the reference test piece 210. Also, a pattern of a package other than a QFN package or a BGA package (e.g., an LGA package or a CSP package) may be formed on the reference test piece 210.

[0100] The embodiments of the present invention described above are illustrative. In other words, the detailed description and accompanying drawings have been disclosed for the purpose of illustration. Therefore, some of the components described in the detailed description and the attached drawings may not be essential for solving the problem. Accordingly, simply because non-essential components are described in the detailed description and accompanying drawings, such non-essential components are not intended to be immediately identified as essential.

[0101] Furthermore, the above embodiments are merely illustrative of the present invention in all respects. Various improvements and changes can be made to the above embodiments within the scope of the present invention. In other words, when implementing the present invention, specific configurations can be adopted as appropriate depending on the embodiment.

List of Reference Numerals

[0102]

1	Cutting apparatus
3	Substrate supply unit
4	Positioning unit
4a	Rail unit
5	Cutting table
5a	Holding member
5b	Rotating mechanism
5c	Moving mechanism
5d	First position checking camera
5e	First cleaner
6	Spindle unit
6a	Blade
6b	Second position checking camera
6c	Rotation shaft
6d	First flange
6e	Second flange
6f	Fastening member
7	Transport unit
7a	Second cleaner
11	Inspection table

12 First optical inspection camera

12a, 13a Illumination device

13 Second optical inspection camera

14 Arrangement unit

15 Extraction unit

15a Good component tray

15b Defective component tray

20 Monitor

50 Computer

70 Computation unit

72 CPU

74 RAM

76 ROM

80 Storage unit

81 Control program

90 Input/output I/F

100, 200 Jig

110 Base

120 Holding plate

124 Recess

130 Calibration plate

112 Screw hole

114 Pressing member

114a First surface portion

114b Bent portion

114c Second surface portion

116, 122, 212 Screw

210 Reference test piece

220 Pattern portion

221, 222, 223, 224, 225 QFN pattern group

231, 232, 233, 234, 235 BGA pattern group

241, 242, 243, 244 Mark pattern group

229, 239, 249 Pattern

A1 Cutting module

B1 Inspection/storage module

D1 Dot

M1 Magazine

P1 Package substrate

S1 Electronic component

CLAIMS

1. A calibration method for calibrating a camera included in a cutting apparatus,

the cutting apparatus being configured to manufacture an electronic component by cutting a package substrate, and perform appearance inspection on the electronic component based on first image data,

the first image data being generated by using the camera to capture an image of the electronic component arranged on a table,

the calibration method comprising the steps of:

generating second image data by using the camera to capture an image of a calibration plate arranged on the table;

calculating, before calibration of the camera, a relative inclination between the calibration plate and the camera based on the second image data; and

calibrating the camera after calculation of the relative inclination.

2. The calibration method according to claim 1, further comprising the step of:

adjusting an inclination of at least either the calibration plate or the camera, in a case where the relative inclination is not in a predetermined range.

3. The calibration method according to claim 2,

wherein in the calibrating step, in a case where the relative inclination is in the predetermined range, third image data is generated by using the camera to capture an image of the calibration plate, and the camera is calibrated based on the third image data.

4. The calibration method according to any one of claims 1 to 3,

wherein the calibrating includes calculating a pixel size of the camera.

5. An electronic component manufacturing method in which the calibration method according to claim 3 or 4 is used, the electronic component manufacturing method comprising the step of:

manufacturing the electronic component by cutting the package substrate, in a case where a result of the calibrating satisfies a predetermined condition.

6. The electronic component manufacturing method according to claim 5, further comprising the step of:

reassembling the cutting apparatus in a case where the result of the calibrating does not satisfy the predetermined condition.