

TITLE OF THE INVENTION

Workpiece Inspection Apparatus And Inspection Method

BACKGROUND OF THE INVENTION**FIELD OF THE INVENTION**

The present invention relates to a workpiece inspection apparatus and inspection method for inspecting the faces of polyhedral workpieces.

DESCRIPTION OF THE PRIOR ART

As one example of a prior art workpiece inspection apparatus, Japanese Laid-Open Patent Publication No. HEI 9-315566 discloses an apparatus for inspecting the faces of hexahedral workpieces. To accomplish such inspection, the inspection apparatus is equipped with a first disk which has a plurality of first concave portions formed in the outer periphery thereof to hold workpieces, and a second disk which is arranged orthogonal to the first disk and which has a plurality of second concave portions formed in the outer periphery thereof to hold workpieces received from the first concave portions. Further, a first face inspection camera is provided outside the first disk to inspect three faces of the workpiece, and a second face inspection camera is

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provided outside the second disk to inspect the remaining three faces of the workpiece.

Unfortunately, because this workpiece inspection apparatus uses the outer circumferential portions of disks to hold workpieces while carrying out inspection, the workpieces are crowded together and there is only a narrow space available for arranging the inspection cameras and the like. Consequently, the selection of components and the number of possible design configurations for such inspection apparatus are extremely limited.

SUMMARY OF THE INVENTION

In view of the problems of the prior art described above, it is an object of the present invention to provide a workpiece inspection apparatus and inspection method which make it possible to expand the selection of components and the number of possible design configurations.

In order to achieve the object of the present invention stated above, the workpiece inspection apparatus for inspecting the faces of polyhedral workpieces according to the present invention includes at least one endless conveyor belt having a plurality of cutaway portions formed therein for holding the workpieces, and inspection devices for inspecting the exposed faces of the workpieces held in the cutaway portions of the conveyor belt.

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Further, the workpiece inspection apparatus is provided with at least one guide plate arranged on at least one side of the conveyor belt to prevent the workpieces from falling out of the cutaway portions of the conveyor belt.

Furthermore, in the method of inspecting the faces of polyhedral workpieces according to the present invention, the workpieces are inserted into cutaway portions of an endless conveying belt, and the exposed faces of the workpieces held in the cutaway portions of the conveyor belt are inspected while the conveyor belt is moved to convey the workpieces.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a perspective view of a first embodiment of a workpiece inspection apparatus according to the present invention.

Fig. 2 is a perspective view of an example workpiece that is inspected by the workpiece inspection apparatus of the present invention.

Fig. 3 is a partial enlarged view used in describing the transfer of workpieces from the disk to the conveyor belt.

Fig. 4 is a perspective view showing the structure of the guide plates arranged on either side of the conveyor belt.

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Fig. 5 is an enlarged top view showing the vicinity of the third inspection camera.

Fig. 6 is a perspective view of a second embodiment of a workpiece inspection apparatus according to the present invention.

Fig. 7 is an enlarged view of the workpiece supplying portion.

Fig. 8 is an enlarged view of the transfer portion.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

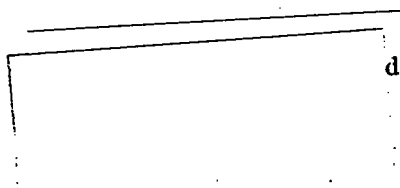
A detailed description of the preferred embodiments of the present invention will now be given with reference to the appended drawings.

First, Fig. 1 shows a workpiece inspection apparatus 3 according to a first embodiment of the present invention for inspecting four faces of a workpiece, and Fig. 2 shows an example hexahedral workpiece (ceramic capacitor) 1 with faces 1a - 1f having example dimensions $1\text{mm} \times 0.5\text{mm} \times 0.5\text{mm}$, in which the two opposing faces 1a and 1b are electrodes and the remaining four faces 1c - 1f form inspection faces. In this arrangement, inspection of the workpiece 1 is carried out by taking video images of the four inspection faces 1c - 1f with cameras to measure such quantities as the dimensions of the electrodes and dielectric portions and to determine whether or not the dielectric portions are damaged.

As shown in Fig. 1, the workpiece inspection apparatus 3 is equipped with a workpiece supplying portion 100 for supplying the workpieces 1, a first stage 200 for inspecting two inspection faces of the workpieces 1, a second stage 300 for inspecting the other two inspection faces of the workpieces 1, and an endless conveyor belt 400 for conveying the workpieces 1 from the first stage 200 to the second stage 300.

The workpiece supplying portion 100 is provided with an apparatus known as a "ball feeder" or "parts feeder." In such apparatus, a plurality of workpieces 1 placed inside ball portions are conveyed in an ordered manner by a spiral-shaped groove to cause the workpieces 1 to be supplied one at a time from the tip of the feeder. In this connection, the workpiece supplying portion 100 may use, for example, the feeding apparatus disclosed in Japanese Laid-Open Patent Publication No. HEI 5-286549.

The first stage 200 is equipped with a disk 201, a first inspection camera 203 and a second inspection camera 205. In this regard, each of the inspection cameras may be constructed, for example from CCD cameras or the like. Further, a plurality of concave portions 207 are formed in the outer periphery of the disk 201, and as shown in Fig. 3, a suction hole 209 is formed in the bottom portion of each concave portion 207. In this arrangement, the workpieces 1 that are supplied one at a time from the workpiece supplying portion 100 are inserted into the concave portions 207 and held in place by suction from the suction holes 209 to prevent the workpieces 1 from falling out of the concave portions 207. In the case of the example workpiece 1



shown in Fig. 2, the electrode face 1a or 1b is held by suction against the bottom of the concave portion 207. Further, the disk 201 is rotated by a prescribed angular amount in the clockwise direction to convey each workpiece 1.

The first inspection camera 203 is arranged at a position near the highest point of the concave portions 207 of the disk 201 to take video images of a first inspection face of the workpieces 1, and the second inspection camera 205 is arranged on the other side of the disk 201 at a position roughly 90 degrees from the first camera 203 with respect to the angular movement of the disk 201 to take video images of a second inspection face which lies opposite the first inspection face. Namely, two opposing faces (e.g., 1c and 1d in Fig. 2) of the workpieces 1 are inspected in the first stage 200.

The conveyor belt 400 is made of steel and has a plurality of sprocket holes 400a formed therein, and the conveyor belt 400 is stretched between two sprocket wheels 401, 401, with the sprockets thereof engaging with the sprocket holes 400a to enable the conveyor belt 400 to be moved by the rotation of the sprocket wheels 401. Further, a plurality of cutaway portions 400b for holding the workpieces 1 are formed in the upper portion of the conveyor belt 400.

In this connection, Fig. 3 is an enlarged view taken along the arrow A in Fig. 1 showing the state in which the workpieces 1 are transferred from the disk 201 to the conveyor belt 400. Namely, with the upper portion of the conveyor belt 400 inserted into a concave portion 207 of the disk 201, the



conveyor belt 400 is moved forward until a cutaway portion 400b reaches the position of the empty concave portion 207, at which time the movement of the conveyor belt 400 is temporarily suspended. In this state, the disk 201 is rotated until the next concave portion 207 which holds a workpiece 1 is positioned inside the cutaway portion 400b, at which time the rotation of the disk 201 is suspended (see Fig. 3). Next, after the workpiece 1 is transferred from the concave portion 207 to the cutaway portion 400b, the conveyor belt 400 is driven again until the next cutaway portion 400b is positioned inside the newly emptied concave portion 207, at which time the movement of the conveyor belt 400 is once again suspended. Accordingly, by repeating these steps, the workpieces 1 are transferred one at a time from the disk 201 to the conveyor belt 400 in a manner that enables the two inspection faces (e.g., 1e and 1f in Fig. 2) that were not exposed while being held in the concave portions 207 to become exposed while being held in the cutaway portions 400b.

As shown in Fig. 4, guide plates 403, 405 are provided on either side of the conveyor belt 400 (or on only one side depending on the location) along a workpiece conveyance interval from the disk 201 to a conforming article box 409 (described below) to cover the sides of the cutaway portions 400b in order to prevent the workpieces 1 from falling out of the cutaway portions 400b.

The second stage 300 is equipped with a third inspection camera 301 and a fourth inspection camera 303 for taking video images of the remaining two inspection faces 1e and 1f of the workpieces 1. In this connection, Fig. 5 is an enlarged top view showing the state in which the third inspection camera

301 takes video images of the workpieces 1, and as shown in this drawing, a workpiece positioning suction nozzle 305 is arranged on the opposite side of the conveyor belt 400 from the third inspection camera. The workpiece positioning suction nozzle 305 is equipped with a chamber 305a and a suction opening 305b, and in accordance with the timing of the suspension of the movement of the conveyor belt 400, a negative pressure is created in the chamber 305a to generate suction at the suction opening 305b in order to hold the workpiece 1 in place. As is further shown in Fig. 5, an opening 405a is formed in the guide plate 405 to expose the inspection face of the workpiece 1 opposite the inspection face held by the suction opening 305b. Namely, images of the inspection face opposite the inspection face held by the suction opening 305b are taken by the third inspection camera 301 through the opening 405a. In this way, by taking video images while the workpiece 1 is held in place by suction, it becomes possible to obtain stable images and improve the inspection accuracy. Similarly, a workpiece positioning suction nozzle 307 is arranged on the opposite side of the conveyor belt 400 from the fourth inspection camera 303, and an opening is provided in the guide plate 403 to enable the fourth inspection camera to take video images of the exposed inspection face of the workpiece 1 opposite the inspection face held by the workpiece positioning suction nozzle 307.

Arranged downstream from the second stage 300 are a nonconforming article box 407 for collecting workpieces judged to be nonconforming articles in the first stage 200 or second stage 300, and a conforming article box 409 for collecting workpieces judged to be conforming articles in the first stage 200 and second stage 300. Further, each of air jet nozzles 411, 413 are arranged

on the opposite side of the conveyor belt 400 from the boxes 407, 409. Accordingly, in the case where a workpiece 1 is judged to be a nonconforming article in the first stage 200 or second stage 300, the air jet nozzle 411 blasts out a jet of air when the workpiece 1 reaches the position of the nonconforming article box 407 to force the workpiece 1 to fall into the nonconforming article box 407, and in the case where a workpiece 1 is judged to be a conforming article in the first stage 200 and second stage 300, the air jet nozzle 413 blasts out a jet of air when the workpiece 1 reaches the position of the conforming article box 409 to force the workpiece 1 to fall into the conforming article box 409. In this embodiment, another nonconforming article box may be arranged downstream from the first stage 200 to collect workpieces judged to be nonconforming articles in the first stage 200. In other words, nonconforming article boxes can be arranged after each stage to collect workpieces judged to be nonconforming articles in such stage.

Next, the operation of the workpiece inspection apparatus 3 will be described.

First, the basic operations of the conveyor belt 400 and the disk 201 will be described. Namely, the conveyor belt 400 is driven in a stepwise manner by the sprocket wheels 401, wherein during each step the conveyor belt 400 is moved only by an amount equal to the spacing of the cutaway portions 400b and then stopped. During the time the conveyor belt 400 is stopped, the inspection cameras 301 and 303 are operated. Now, even though the upper portion of the conveyor belt 400 lies inside one of the concave portions 207, during the time that the conveyor belt 400 is stopped, one of the cutaway

portions 400b of the conveyor belt 400 is positioned to match the position of such concave portion 207 of the disk 201. Further, the disk 201 is also rotated in a stepwise manner, wherein during each step the disk 201 is rotated only by an amount equal to the spacing of the concave portions 207 and then stopped. During the time that the disk 201 is stopped, the inspection cameras 203 and 205 are operated.

Now, in accordance with the timing of the suspension of the disk 201, the workpiece supplying portion 100 supplies one workpiece 1 into one of the concave portions 207, and then after this supplying step has been completed, the disk 201 is rotated in the clockwise direction. In the first stage 200, images of two of the inspection faces of the workpieces 1 are taken by the inspection cameras 203 and 205, and then after such images have been taken, these workpieces 1 are transferred in turn to the cutaway portions 400b of the conveyor belt 400. Next, the workpieces 1 transferred to the cutaway portions 400b are conveyed by the conveyor belt 400 to the second stage 300 where images of the remaining two inspection faces are taken by the inspection cameras 301 and 303. Then, based on the results of such inspections carried out in the first stage 200 and the second stage 300, the workpieces 1 judged to be nonconforming articles are collected in the nonconforming article box 407, and the workpieces 1 judged to be conforming articles are collected in the conforming article box 409, whereupon the conforming workpieces 1 can be packaged and carried away.

At this point, it should be noted that the size of the concave portions 207 and the cutaway portions 400b were exaggerated in Figs. 1 ~ 5 for the

purpose of description, and in actuality their sizes are extremely small to match the size of the workpieces 1.

Now, in contrast with the extremely limited selection of components and number of possible design configurations of the prior art workpiece apparatus which uses the outer circumferential portions of disks to hold workpieces, by inspecting the inspection faces of the workpieces 1 while the workpieces 1 are being conveyed by the conveyor belt 400, the workpiece inspection apparatus 3 of the present embodiment enables appropriate space to be secured along the conveyance route of the workpieces 1, and this makes it possible to expand the selection of components and the number of possible design configurations. For example, in view of space, it is possible to arrange a set of two cameras on each side, with each camera taking video images of one inspection face of the workpieces (in which two workpieces are conveyed at a time and images are taken of inspection faces of the two workpieces at once). In this way, because images of the inspection faces can be taken while carrying out high speed conveyance of the workpieces, the processing capacity of the workpiece inspection apparatus can be improved.

Next, a workpiece inspection apparatus 5 according to a second embodiment of the present invention will be described with reference to Fig. 6. In this embodiment, the disk 201 shown in Fig. 1 is replaced by a conveyance belt. Namely, the workpiece inspection apparatus 5 is equipped with a workpiece supplying portion 100 for supplying workpieces 1, a first stage 500 for inspecting two inspection faces of the workpieces 1, a second stage 600 for inspecting the two remaining inspection faces of the workpieces

1, a transfer portion 700 for transferring the workpieces 1 from the first stage 500 to the second stage 600, a first endless conveyor belt 415 for conveying the workpieces 1 in order from the workpiece supplying portion 100 through the first stage 500 to the transfer portion 700, and a second endless conveyor belt 417 for conveying the workpieces 1 from the transfer portion 700 to the second stage 600. Further, the conveyor belts 415 and 417 have the same structure as the conveyor belt 400 shown in Fig. 1 (but in Fig. 6 the cutaway portions are not shown).

Further, the workpieces 1 from the workpiece supplying portion 100 are supplied one at a time to a disk 101. In this regard, the disk 101 of the present embodiment has the same structure as the disk 201 of the first embodiment, and as shown in Fig. 7, a guide plate 103 is provided along the upper half of the disk 101. In this arrangement, the workpieces 1 are placed inside the concave portions of the disk 101, and when a workpiece 1 reaches the highest position of the disk 101, an air jet nozzle 105 arranged at such position blasts a jet of air at such workpiece 1 to force the workpiece 1 to move from the concave portion of the disk 101 into a cutaway portion 415a of the first conveyor belt 415. Further, the first conveyor belt 415 is interposed between guide plates 107 and 109, and a suction nozzle 111 having the same structure as the workpiece positioning suction nozzle 305 shown in Fig. 5 is arranged on the guide plate 109 to provide suction so as to make sure the workpieces 1 are reliably placed inside the cutaway portions 415a of the first conveyor belt 415.

The first stage 500 is equipped with a first inspection camera 501 and a second inspection camera 503 to inspect two inspection faces of the workpieces 1. Further, suction nozzles 505, 507 having the same structure as the workpiece positioning suction nozzle 305 shown in Fig. 5 are arranged respectively on the sides opposite the inspection cameras 501, 503.

The transfer portion 700 is equipped with a disk 701 and air jet nozzles 703 and 705, and a suction nozzle 707 having the same structure as the suction nozzle 111 shown in Fig. 7 is arranged on the opposite side of the second conveyor belt 417 from the disk 701. In this connection, Fig. 8 is an enlarged view of the transfer portion 700 taken along the arrow B in Fig. 6. As shown in Fig. 8, workpieces 1 conveyed by the first conveyor belt 415 to the transfer portion 700 are first transferred to the disk 701 by a jet of air blasted out from the air jet nozzle 703, and then after the disk 701 has been rotated 90 degrees, the workpieces 1 held in the concave portions of the disk 701 are transferred to the second conveyor belt 417 by a jet of air blasted out from the air jet nozzle 705.

The second stage 600 is equipped with a third inspection camera 601 and a fourth inspection camera 603 to inspect the remaining two inspection faces of the workpieces 1. Further, suction nozzles 605, 607 having the same structure as the workpiece positioning suction nozzle 305 shown in Fig. 5 are arranged respectively on the sides opposite the inspection cameras 601, 603.

Arranged downstream from the second stage 600 on one side of the second conveyor belt 417 are a nonconforming article box 609 for collecting

nonconforming articles and a conforming article box 611 for collecting conforming articles, and air jet nozzles 613, 615 are respectively arranged on the opposite side of the second conveyor belt 417 to interpose the second conveyor belt 417 between the boxes 609, 611 and the air jet nozzles 613, 615. Further, a nonconforming article box 709 is arranged below the disk 701 to collect workpieces 1 judged to be nonconforming articles by the inspection carried out in the first stage 500.

In this embodiment, because two conveyor belts are used, more space is made available than in the first embodiment, and this makes it possible to further expand the number of design configurations.

In the embodiments described above, inspection of the workpiece faces were carried out using CCD cameras. However, the present invention is not limited to such arrangement, and it is possible to use any appropriate inspection means (e.g., devices that measure the electrical resistance or capacitance) to inspect the exposed faces of the workpieces. Further, even though the cutaway portions (400b, 415a, 417a) were described in the embodiments above as being formed in the upper portion of the conveyor belts (400, 415 and 417), the present invention is not limited to such arrangement, and it is possible to form the cutaway portions in any desired portion of the conveyor belt (e.g., at the position 400c indicated by dashed lines in Fig. 4).

Furthermore, the present invention is not limited to the use of air jet nozzles, and it is possible to use any appropriate means (e.g., a cylinder which mechanically pushes against the workpieces) to transfer workpieces between

stages and to force workpieces into conforming article and nonconforming article boxes.

In the case where all six faces of the workpieces need to be inspected, the workpiece inspection apparatus of the present invention may be equipped with three conveyor belts, one disk and two conveyor belts, or two disks and one conveyor belt.

As described above, in contrast with the prior art inspection apparatus which uses only disks, the workpiece inspection apparatus of the present invention uses one or more conveyor belts to hold the workpieces for inspection. As a result, the present invention makes it possible to expand the available space and the number of possible design configurations.

CLAIMS



1. A workpiece inspection apparatus for inspecting the faces of polyhedral workpieces, comprising:
 - at least one endless conveyor belt having a plurality of cutaway portions formed therein for holding the workpieces;
 - means for inspecting the exposed faces of the workpieces held in the cutaway portions of the conveyor belt.
2. The workpiece inspection apparatus of Claim 1, further comprising at least one guide plate arranged on at least one side of the conveyor belt to prevent the workpieces from falling out of the cutaway portions of the conveyor belt.
3. A method of inspecting the faces of polyhedral workpieces, comprising the steps of:
 - inserting the workpieces into cutaway portions of an endless conveyor belt;
 - moving the conveyor belt to convey the workpieces; and
 - inspecting the exposed faces of the workpieces held in the cutaway portions of the conveyor belt.

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