

AUTOMATIC BLADE CHANGER

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an automatic blade changer to be coupled to a cutting apparatus.

Description of the Related Art

Wafers where a plurality of devices such as integrated circuits (ICs) and large scale integration (LSI) circuits are constructed in respective areas on a face side thereof that are demarcated by a grid of projected dicing lines are cut into individual device chips by a cutting apparatus. The device chips will be used in electric appliances including cellular phones, personal computers, etc.

The cutting apparatus includes a chuck table having a holding surface for holding a wafer thereon, a cutting means having a cutting blade, mounted in place by a fastening nut, for cutting the wafer held on the holding surface of the chuck table, an X-axis feeding means for processing-feeding the chuck table along an X-axis, a Y-axis feeding means for indexing-feeding the cutting means along a Y-axis perpendicular to the X-axis, and a Z-axis feeding means for incising-feeding the

cutting means along a Z-axis perpendicular to the X-axis and the Y-axis. The holding surface is defined by, i.e., lies along, the X-axis and the Y-axis. The cutting apparatus is able to divide the wafer into individual device chips to a nicety.

The present applicant has proposed an automatic blade changer that is capable of automatically changing a cutting blade mounted on a cutting means (see, for example, Japanese Patent Laid-open No. 2022-103852).

SUMMARY OF THE INVENTION

The automatic blade changer incorporates a cutting blade storing means for storing a plurality of cutting blades that have been classified into different kinds. There is an instance where the kind of the cutting blade unloaded from the cutting blade storing means by an unloading and loading means is different from a desired kind to be used by the cutting means. In such a case, the cutting means is unable to perform an adequate cutting process on the wafer on the chuck table.

It is therefore an object of the present invention to provide an automatic blade changer that is capable of reliably replacing a cutting blade mounted on a cutting apparatus with a desired cutting blade.

In accordance with an aspect of the present invention, there is provided an automatic blade changer adapted to be coupled to a cutting apparatus including a chuck table having a holding surface for holding a workpiece thereon, a cutting means having a cutting blade mounted thereon with a mounting nut, for cutting the workpiece held on the chuck table, an X-axis feeding means for processing-feeding the chuck table along an X-axis, a Y-axis feeding means for indexing-feeding the cutting means along a Y-axis perpendicular to the X-axis, and a Z-axis feeding means for incising-feeding the cutting means along a Z-axis perpendicular to the X-axis and the Y-axis, the holding surface being defined by the X-axis and the Y-axis, the automatic blade changer including a cutting blade storing means for storing a plurality of cutting blades therein, an unloading and loading means for unloading cutting blades from the cutting blade storing means, delivering the unloaded cutting blades to the cutting means, and loading the cutting blades removed from the cutting means to the cutting blade storing means, and a reading means disposed adjacent to a working position in which the unloading and loading means works on the cutting blade storing means, for reading an indicator marked on a side surface of each

of the cutting blades stored in the cutting blade storing means and indicating the kind of each of the cutting blades.

Preferably, the reading means includes a camera, a mirror having a reflecting surface inclined 45° to an optical axis of the camera, a rotating unit for rotating the mirror about the optical axis of the camera, and a positioning unit for positioning the mirror selectively in a working position and a retracted position, the reflecting surface of the mirror faces at an angle of 45° a first side surface of one of the cutting blades stored in the cutting blade storing means and a second side surface, opposite the first side surface, of one of the cutting blades unloaded from the cutting blade storing means by the unloading and loading means, and the reading means reads the indicator marked on the first side surface or the second side surface of each of the cutting blades and indicating the kind of each of the cutting blades from an image of the first side surface or the second side surface captured by the camera via the mirror positioned in the working position.

Preferably, the cutting blade storing means includes a drive gear having a rotational shaft extending along the Y-axis, a driven gear that is spaced from the

drive gear along the Z-axis and that has a rotational shaft extending along the Y-axis, an endless track trained around the drive gear and the driven gear, and a plurality of blade support shafts disposed on the endless track at predetermined spaced intervals and supporting the respective cutting blades thereon by being inserted in respective central openings defined in the cutting blades, the blade support shafts extending along the Y-axis.

Preferably, the automatic blade changer further includes a Y-axis moving means for selectively bringing the unloading and loading means into the working position and a retracted position along the Y-axis with respect to the cutting blade storing means, a Z-axis moving means for moving the unloading and loading means along the Z-axis, and an X-axis moving means for moving the unloading and loading means along the X-axis and positioning the unloading and loading means in the working position in which the unloading and loading means works on the cutting blade mounted on a spindle of the cutting means, and the unloading and loading means includes a Z-axis rotational shaft extending along the Z-axis, a blade holder coupled radially to the Z-axis rotational shaft for holding a cutting blade under suction thereon, and a

mounting nut holder for threading a mounting nut over or off an externally threaded distal end portion of the spindle.

Preferably, each of the cutting blades stored in the cutting blade storing means is a hub blade including a base and an annular cutting blade disposed on an outer circumferential portion of the base, each of the blade support shafts has a diameter commensurate with a diameter of the central openings of the hub blades, and the blade holder supports at least one of the hub blades.

Preferably, each of the cutting blades stored in the cutting blade storing means is a washer blade including an annular cutting edge, each of the blade support shafts has a diameter commensurate with a diameter of the central openings of the hub blades, and the blade holder supports at least one of the washer blades and a mounting flange for mounting the washer blade on the spindle of the cutting means.

Preferably, the unloading and loading means is disposed in a frame by a bendable arm of the X-axis moving means, and the frame is slidably supported on a guide rail disposed on a vertically movable table and extending along the Y-axis and is able to selectively be positioned in the working position and the retracted

position along the Y-axis with respect to the cutting blade storing means by the Y-axis moving means.

The automatic blade changer according to the present invention is capable of reliably replacing a cutting blade mounted on a cutting apparatus with a desired cutting blade.

The above and other objects, features and advantages of the present invention and the manner of realizing them will become more apparent, and the invention itself will best be understood from a study of the following description and appended claims with reference to the attached drawings showing a preferred embodiment of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an automatic blade changer according to an embodiment of the present invention;

FIG. 2 is an exploded perspective view of a cutting blade storing means of the automatic blade changer illustrated in FIG. 1;

FIG. 3 is a perspective view of a blade support shaft of the automatic blade changer illustrated in FIG. 2;

FIG. 4 is a cross-sectional view of the blade support shaft illustrated in FIG. 3;

FIG. 5 is a perspective view of the blade support shaft that supports washer blades;

FIG. 6 is a perspective view of an unloading and loading means of the automatic blade changer illustrated in FIG. 1, with a blade holder and a mounting nut holder illustrated at an enlarged scale;

FIG. 7 is an exploded perspective view of a frame, a vertically movable table, and a base mount of the automatic blade changer illustrated in FIG. 1;

FIG. 8 is an exploded perspective view of the frame of the automatic blade changer illustrated in FIG. 1;

FIG. 9 is a perspective view of the automatic blade changer and a reading means illustrated in FIG. 1;

FIG. 10 is a side elevational view of a mirror and a camera of the reading means illustrated in FIG. 9;

FIG. 11 is a perspective view of a cutting apparatus with which the automatic blade changer illustrated in FIG. 1 is to be coupled;

FIG. 12 is a perspective view of a chuck table of the cutting apparatus illustrated in FIG. 11;

FIG. 13 is a perspective view of a cutting means

of the cutting apparatus illustrated in FIG. 11;

FIG. 14 is a perspective view of the cutting means with a blade cover illustrated in FIG. 13 being open;

FIG. 15 is an exploded perspective view of the cutting means illustrated in FIG. 11;

FIG. 16 is an exploded perspective view of the cutting means that supports a washer blade;

FIG. 17 is a perspective view of the cutting apparatus illustrated in FIG. 11 with which the automatic blade changer illustrated in FIG. 1 is coupled;

FIG. 18 is a perspective view of the automatic blade changer illustrated in FIG. 1 where the cutting blade storing means and the unloading and loading means face each other;

FIG. 19 is a perspective view of the automatic blade changer illustrated in FIG. 1 where the frame has advanced from its position illustrated in FIG. 18 toward the cutting blade storing means;

FIG. 20 is a perspective view of the automatic blade changer illustrated in FIG. 1 where the frame has been retracted from its position illustrated in FIG. 19 and the vertically movable table has been lifted;

FIG. 21 is a perspective view of the automatic

blade changer illustrated in FIG. 1 where the unloading and loading means has advanced from its position illustrated in FIG. 20 toward the cutting apparatus; and

FIG. 22 is a side elevational view illustrating the manner in which the reading means is reading a second side surface of a washer blade.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

An automatic blade changer according to a preferred embodiment of the present invention will hereinafter be described with reference to the drawings. (Automatic blade changer 2)

As illustrated in FIG. 1, the automatic blade changer, generally denoted by the reference numeral 2, includes a cutting blade storing means 4 that stores a plurality of cutting blades therein and an unloading and loading means 6 for unloading a cutting blade from the cutting blade storing means 4 and loading a cutting blade into the cutting blade storing means 4.

The automatic blade changer 2 also includes a Y-axis moving means 8 for positioning the unloading and loading means 6 selectively in a working position and a retracted position along a Y-axis with respect to the cutting blade storing means 4, a Z-axis moving means 10

for moving the unloading and loading means 6 along a Z-axis, and an X-axis moving means 12 for moving the unloading and loading means 6 along an X-axis and positioning the unloading and loading means 6 in a working position in which the unloading and loading means 6 works on a cutting blade mounted on a spindle of a cutting means of a cutting apparatus.

The X-axis refers to an axis indicated by an arrow X in FIG. 1, and the Y-axis refers to an axis indicated by an arrow Y in FIG. 1 and is perpendicular to the X-axis. X-axis directions refer to horizontal directions along the X-axis, and Y-axis directions refer to horizontal directions along the Y-axis. The Z-axis refers to an axis indicated by an arrow Z in FIG. 1 and is perpendicular to the X-axis and the Y-axis. Z-axis directions refer to vertical directions along the Z-axis. A plane defined by and extending along the X-axis and the Y-axis lies substantially horizontally. The X-axis, the Y-axis, and the Z-axis and their definitions also apply to FIGS. 2 through 9 and 11 through 21 to be described later.

(Cutting blade storing means 4)

As illustrated in FIG. 2, the cutting blade storing means 4 includes a drive gear 16 having a

rotational shaft 14 extending along the Y-axis, a driven gear 20 that is spaced from the drive gear 16 along the Z-axis and that has a rotational shaft 18 extending along the Y-axis, an endless track 22 trained around the drive gear 16 and the driven gear 20, and a plurality of blade support shafts 24 mounted at predetermined spaced intervals on the endless track 22 and extending along the Y-axis for being inserted in the central openings of respective cutting blades to support the cutting blades thereon.

(Drive gear 16)

As illustrated in FIGS. 1 and 2, the cutting blade storing means 4 according to the present embodiment includes a base plate 26 (see FIG. 1) lying horizontally, a support wall 28 extending upwardly along the Z-axis from an upper surface of the base plate 26, and an electric motor 30 fixedly mounted on a vertical surface of the support wall 28. As illustrated in FIG. 2, the rotational shaft 14 of the drive gear 16 is coupled to the output shaft of the electric motor 30, so that, when the electric motor 30 is energized, it rotates the drive gear 16 about the Y-axis.

(Driven gear 20)

As illustrated in FIG. 2, the driven gear 20 is

disposed above the drive gear 16, and the rotational shaft 18 of the driven gear 20 is supported on the support wall 28 such that the rotational shaft 18 is rotatable about the Y-axis and vertically movable along the Z-axis. The support wall 28 houses therein an unillustrated vertically moving means for vertically moving, i.e., lifting and lowering, the driven gear 20 along the Z-axis. The vertically moving means may be of a structure having a ball screw coupled to the rotational shaft 18 of the driven gear 20 and extending along the Z-axis and an electric motor for rotating the ball screw about its central axis extending along the Z-axis.

(Endless track 22)

The endless track 22 includes a number of interconnected links, not denoted by reference characters, and is trained around the drive gear 16 and the driven gear 20, as described above. The endless track 22 is rotated around the drive gear 16 and the driven gear 20 when the drive gear 16 is rotated by the electric motor 30.

In the cutting blade storing means 4 according to the present embodiment, the distance along the Z-axis between the drive gear 16 and the driven gear 20 can be adjusted by changing the position of the driven gear 20

along the Z-axis with the vertically moving means.

Furthermore, the length of the endless track 22 can be adjusted by increasing or reducing the number of links of the endless track 22.

(Blade support shaft 24)

As illustrated in FIG. 2, the blade support shafts 24 are mounted at predetermined spaced intervals on the endless track 22, as described above. As illustrated in FIGS. 2 and 3, each of the blade support shafts 24 has a cylindrical base 32 coupled to the endless track 22 and a cylindrical shank 34 extending along the Y-axis from an end face of the cylindrical base 32. The shank 34 is smaller in diameter than the base 32.

(Cutting blade)

FIG. 3 also illustrates hub blades 36 as cutting blades that can be stored in the cutting blade storing means 4. Each of the hub blades 36 has an annular base 38 and an annular cutting edge 40 disposed on an outer circumferential portion of the base 38. The base 38 is made of a suitable metal material such as aluminum alloy. A side surface of the base 38 is marked with an indicator T ("A005" in FIG. 3) indicating the kind of the hub blade 36. The indicator T may be in the form of letters,

numerals, a barcode, or the like. The base 38 has a circular central opening 38a defined in a central portion thereof. The cutting edge 40 is made of abrasive grains such as diamond and a binding material such as metal or resin. The cutting edge 40 has a predetermined thickness ranging from approximately 10 to 30 μm , for example, and protrudes radially outwardly from the outer circumferential portion of the base 38.

The shank 34 of each of the blade support shafts 24 according to the present embodiment is commensurate in diameter with the central opening 38a of the hub blade 36. Each of the blade support shafts 24 supports a plurality of, e.g., five, hub blades 36 on the shank 34 that is inserted in the central openings 38a of the hub blades 36. Though each of the blade support shafts 24 supports a plurality of cutting blades of one kind, the cutting blade storing means 4 as a whole stores a plurality of kinds of cutting blades that are made of different materials and have different shapes.

According to the present embodiment, as illustrated in FIG. 2, the hub blades 36 are supported on half of the blade support shafts 24 on the endless track 22. As illustrated in FIG. 3, a plurality of ball plungers 42 are mounted at circumferentially spaced

intervals on a distal end portion of each of the shanks 34 for retaining the hub blades 36 on the shank 34 to safeguard against dislodgement.

As illustrated in FIG. 4, the base 32 of each of the blade support shafts 24 has a fluid channel 32a defined therein. The endless track 22 has a plurality of fluid channels 22a held in fluid communication with respective ends of the fluid channels 32a in the blade support shafts 24. As illustrated in FIG. 3, the other end of the fluid channel 32a is open at respective portions of the end face of the base 32 that are positioned radially outwardly of the shank 34.

As illustrated in FIG. 2, the support wall 28 supports thereon an air nozzle 44 that protrudes along the Y-axis below the drive gear 16. The air nozzle 44 is fluidly connected to an unillustrated high-pressure air supply means. According to the present embodiment, the air nozzle 44 has its tip end facing one of the blade support shafts 24 that is positioned at the lowermost end of the path followed by the endless track 22 as it is rotated.

When a hub blade 36 positioned on the distal end portion of the shank 34 of the blade support shaft 24 at the lowermost end of the path followed by the endless

track 22 is unloaded from the cutting blade storing means 4, the air nozzle 44 ejects high-pressure air from the high-pressure air supply means through the fluid channel 22a in the endless track 22 into the fluid channel 32a in the base 32 of the blade support shaft 24, pushing the remaining hub blades 36 on the shank 34 toward the distal end portion of the shank 34. These remaining hub blades 36 are prevented from being dislodged from the shank 34 by the ball plungers 42.

(Washer blade 45)

The cutting blades stored in the cutting blade storing means 4 are not limited to the hub blades 36, and may be washer blades 45 illustrated in FIG. 5, each having an annular cutting edge and free of a base unlike the hub blades 36. Both side surfaces of each of washer blades 45 are marked with an indicator T ("B006" in FIG. 3) indicating the kind of the washer blade 45.

In a case where washer blades 45 are stored in the cutting blade storing means 4, the shank 34 of each of the blade support shafts 24 has a diameter D commensurate with the diameter of a central opening 45a defined in each of the washer blades 45. A plurality of, e.g., 10, washer blades 45 are supported on the shank 34 of each of the blade support shafts 24 that is inserted

in each of the central openings 45a of the washer blades 45.

The cutting blade storing means 4 may store either hub blades 36 or washer blades 45. Alternatively, the cutting blade storing means 4 may store both hub blades 36 and washer blades 45. The kind or kinds of the cutting blades stored in the cutting blade storing means 4 are registered in advance in an unillustrated memory of the automatic blade changer 2 in association with the blade support shafts 24.

(Unloading and loading means 6)

The unloading and loading means 6 will be described below with reference to FIG. 6. As illustrated in FIG. 6, the unloading and loading means 6 includes at least a Z-axis rotational shaft 46 extending along the Z-axis, a plurality of blade holders 48 coupled radially to the Z-axis rotational shaft 46 for holding cutting blades under suction thereon, and a plurality of mounting nut holders 50 coupled radially to the Z-axis rotational shaft 46 for threading a mounting nut over or off an externally threaded distal end portion of a spindle of a cutting apparatus, to be described later.

As illustrated in FIG. 6, the unloading and loading means 6 also includes a casing 52 having a

hexagonal top plate 54 and six side walls 56 each shaped as a rectangular plate extending downwardly from a peripheral edge of the top plate 54. The Z-axis rotational shaft 46 protrudes upwardly from an upper surface of the top plate 54. The casing 52 houses therein an unillustrated electric motor coupled to the Z-axis rotational shaft 46.

According to the present embodiment, the blade holders 48 are mounted respectively on four of the six side walls 56 of the casing 52, and the mounting nut holders 50 are mounted respectively on the remaining two of the six side walls 56. The two of the six side walls 56 on which the mounting nut holders 50 are mounted are positioned diametrically opposite each other.

(Blade holder 48)

Each of the blade holders 48 is of a hollow cylindrical shape and includes an end face 58 having a circular central opening 60 that is capable of receiving therein the shank 34 of the blade support shaft 24 and the distal end portion of the spindle of the cutting apparatus and a plurality of first suction holes 61 defined therein at circumferentially equally spaced intervals around the central opening 60.

An annular ridge 62 is disposed on an outer

circumferential portion of the end face 58. The annular ridge 62 has a plurality of second suction holes 63 defined therein at circumferentially equally spaced intervals. The first and second suction holes 61 and 63 are fluidly connected to an unillustrated suction means.

The annular ridge 62 has an inside diameter slightly larger than the diameter D of the shanks 34 that support the washer blades 45. The annular ridge 62 can receive each of the shanks 34 that support the washer blades 45.

When each of the blade holders 48 is positioned to keep the end face 58 in contact with the base 38 of a hub blade 36 stored in the cutting blade storing means 4, the suction means generates and transmits suction forces to the first suction holes 61, holding the hub blade 36 under suction on the blade holder 48.

For holding a washer blade 45, each of the blade holders 48 is positioned in a position where the annular ridge 62 of the blade holder 48 is in contact with a side surface of the washer blade 45 that is stored in the cutting blade storing means 4. Then, the suction means generates and transmits suction forces to the second suction holes 63 to hold the washer blade 45 under suction on the blade holder 48.

(Mounting nut holder 50)

As illustrated in FIG. 6, each of the mounting nut holders 50 includes a hollow cylindrical housing 64 fixed to one of the side walls 56 of the casing 52, an annular rotor 66 rotatably housed in the housing 64, and an unillustrated electric motor for rotating the annular rotor 66 about its central axis.

The rotor 66 has a central opening 68 that is capable of receiving therein the distal end portion of the spindle of the cutting apparatus. The rotor 66 has an end face 66a in which a plurality of suction holes 70 are defined and on which a plurality of pins 72 are axially movably disposed, the suction holes 70 and the pins 72 being alternately arrayed at circumferentially spaced intervals.

The suction holes 70 are fluidly connected to an unillustrated suction means. The pins 72 are normally biased by unillustrated springs housed in the rotor 66, to be placed in the position illustrated in FIG. 6 where the pins 72 protrude from the end face 66a of the rotor 66. When the pins 72 are pushed into the rotor 66, the pins 72 are accommodated within the rotor 66 while compressing the springs. The pins 72 are positioned in alignment with respective unillustrated pin holes defined

in the mounting nut.

Each of the mounting nut holders 50 operates as follows: The suction means generates and transmits suction forces to the suction holes 70 to hold the mounting nut under suction on the mounting nut holder 50. While the pins 72 are being inserted in the respective pin holes defined in the mounting nut, the electric motor is energized to rotate the rotor 66 and thread the mounting nut over or off the externally threaded distal end portion of the spindle of the cutting apparatus, thereby mounting or dismounting a hub blade 36 or a washer blade 45 on or from the spindle.

Even if the pins 72 of the mounting nut holder 50 and the pin holes in the mounting nut are out of alignment with each other at the time when the mounting nut is to be threaded off, i.e., removed from, the spindle, the end face 66a of the rotor 66 is brought against an end face of the mounting nut mounted on the spindle, pushing the pins 72 into the rotor 66, after which the electric motor is energized to rotate the rotor 66 until the pins 72 are aligned with the pin holes, whereupon the pins 72 are pushed out of the rotor 66 and inserted into the pin holes under the bias of the springs.

The unloading and loading means 6 thus constructed is disposed in a frame 74 as illustrated in FIG. 1. As illustrated in FIG. 1, the frame 74 is movably supported on a vertically movable table 76 for movement along the Y-axis. The vertically movable table 76 is vertically movably supported on a base mount 78 for vertical movement along the Z-axis.

(Frame 74)

As illustrated in FIGS. 7 and 8, the frame 74 includes a bottom panel 80 shaped as a rectangular plate, four support posts 82 extending upwardly from respective four corners of an upper surface of the bottom panel 80, and a top panel 84 (see FIG. 8) shaped as a rectangular plate fixed to upper ends of the support posts 82. A pair of guided members 86 each having a groove 86a that extends along the Y-axis are mounted on a lower surface of the bottom panel 80. The guided members 86 are spaced from each other along the X-axis.

(Vertically movable table 76)

As illustrated in FIG. 7, the vertically movable table 76 includes a top panel 88 shaped as a rectangular plate and four cylindrical legs 90 extending downwardly from respective four corners of a lower surface of the top panel 88. A pair of parallel guide rails 92 spaced

from each other along the X-axis and extending along the Y-axis are mounted on an upper surface of the top panel 88. The guide rails 92 are slidably fitted in the respective grooves 86a in the guided members 86 of the frame 74.

(Y-axis moving means 8)

The Y-axis moving means 8 is mounted on the upper surface of the top panel 88 of the vertically movable table 76. The Y-axis moving means 8 has a ball screw 94 disposed between the guide rails 92 and extending along the Y-axis and an electric motor 96 for rotating the ball screw 94 about its central axis. The ball screw 94 is operatively threaded through an unillustrated nut fixedly mounted on the lower surface of the bottom panel 80.

The Y-axis moving means 8 operates as follows: When the electric motor 96 is energized, the ball screw 94 converts rotary motion of the electric motor 96 into linear motion and transmits the linear motion to the frame 74, moving the frame 74 along the Y-axis along the guide rails 92. The frame 74 where the unloading and loading means 6 is disposed is slidably supported on the guide rails 92 that are disposed on the vertically movable table 76 and extending along the Y-axis. The frame 74 can be positioned selectively in the working

position and the retracted position along the Y-axis with respect to the cutting blade storing means 4 by the Y-axis moving means 8.

The working position refers to a position where the blade holders 48 of the unloading and loading means 6 are close to the cutting blade storing means 4 and are capable of holding under suction the cutting blades supported by the cutting blade storing means 4. The retracted position refers to a position where the blade holders 48 of the unloading and loading means 6 are spaced from the cutting blade storing means 4 farther than they are in the working position.

(Base mount 78)

As illustrated in FIG. 7, the base mount 78 includes a frame 98 and a rectangular base plate 100 fixed to an upper portion of the frame 98. The base plate 100 has four circular holes 102 defined in respective four corners thereof for receiving the respective legs 90 of the vertically movable table 76 that are slidably inserted therein. The base plate 100 also has an internally threaded hole 104 defined centrally therein.

(Z-axis moving means 10)

Continuously described with reference to FIG. 7,

the Z-axis moving means 10 is coupled to the vertically movable table 76 and the base mount 78. The Z-axis moving means 10 includes a ball screw 106 extending along the Z-axis, an electric motor 108 coupled to an end of the ball screw 106 for rotating the ball screw 106 about its central axis, and a joint plate 110 fixed to an upper end of the electric motor 108. The ball screw 106 is threaded through the internally threaded hole 104 in the base plate 100. The joint plate 110 is fastened to the lower surface of the top panel 88 of the vertically movable table 76 by a suitable, unillustrated fastening means such as bolts.

The Z-axis moving means 10 operates as follows: When the electric motor 108 is energized, the ball screw 106 converts rotary motion of the electric motor 108 into linear motion, vertically moving the vertically movable table 76 with respect to the base mount 78 to thereby move the frame 74 where the unloading and loading means 6 is disposed along the Z-axis.

(X-axis moving means 12)

As illustrated in FIG. 8, the X-axis moving means 12 includes a bendable arm 112 mounted on the frame 74 and first and second electric motors 114 and 115 for actuating the bendable arm 112. The bendable arm 112 has

a first arm member 118 swingably coupled to a lower surface of the top panel 84 of the frame 74 with a spacer 116 interposed therebetween and a second arm member 120 swingably coupled to a lower surface of the first arm member 118.

The spacer 116 is disposed on an end of the first arm member 118. The first arm member 118 is swingably coupled to the top panel 84 for swinging movement about an axis on the spacer 116. Another spacer 122 is disposed on an opposite end of the first arm member 118. The second arm member 120 is swingably coupled to the first arm member 118 for swinging movement about an axis on the spacer 122.

The second arm member 120 has a distal end that is positioned remotely from the spacer 122 and that has an unillustrated circular hole defined therein. The Z-axis rotational shaft 46 of the unloading and loading means 6 is inserted in the circular hole in the distal end of the second arm member 120 and fixed to the second arm member 120 in a non-rotatable manner. When the electric motor coupled to the Z-axis rotational shaft 46 of the unloading and loading means 6 is energized, the casing 52 of the unloading and loading means 6 is turned with respect to the second arm member 120 to direct the

blade holders 48 and the mounting nut holders 50 in desired orientations. The unloading and loading means 6 is thus coupled to the distal end of the bendable arm 112 through the Z-axis rotational shaft 46 and disposed in the frame 74 by the bendable arm 112.

The X-axis moving means 12 operates as follows: When the first electric motor 114 is energized, it swings the first arm member 118 about the axis on the spacer 116. When the second electric motor 115 is energized, it swings the second arm member 120 about the axis on the spacer 122. The bendable arm 112 is thus bent or extended, moving the unloading and loading means 6 along the X-axis.

(Reading means 126)

As illustrated in FIG. 9, a reading means 126 for reading the indicator T marked on a side surface of a cutting blade stored in the cutting blade storing means 4 and indicating the kind of the cutting blade is disposed adjacent to the working position in which the unloading and loading means 6 works on the cutting blade storing means 4, i.e., the position where a cutting blade stored in the cutting blade storing means 4 can be unloaded by the unloading and loading means 6.

The reading means 126 includes a camera 128, a

mirror 130 having a reflecting surface 130a (see FIG. 10) inclined 45° to the optical axis, denoted by A in FIG. 10, of the camera 128, a rotating unit 132 for rotating the mirror 130 about the optical axis A of the camera 128, and a positioning unit 134 for positioning the mirror 130 selectively in an upper working position and a lower retracted position to be described later.

(Positioning unit 134)

According to the present embodiment, the positioning unit 134 includes a housing 136 mounted on the upper surface of the base plate 26, a vertically movable base 138 vertically movably supported in the housing 136, and an unillustrated lifting and lowering means for lifting and lowering the vertically movable base 138. The lifting and lowering means may be a combination of an air actuator or a ball screw and an electric motor.

(Rotating unit 132)

The rotating unit 132 has a rotary table 140 rotatably attached to an upper surface of the vertically movable base 138 and an unillustrated electric motor for rotating the rotary table 140 about the Z-axis. The camera 128 and the mirror 130 are fixedly mounted on the rotary table 140. When energized, the electric motor of

the rotating unit 132 rotates the camera 128 and the mirror 130 in unison with the rotary table 140 about the Z-axis.

(Camera 128, mirror 130)

The optical axis A of the camera 128 is aligned with the center of rotation of the rotary table 140 that extends parallel to the Z-axis. The camera 128 is directed upwardly toward the reflecting surface 130a of the mirror 130 that is disposed above the camera 128. As described above, the reflecting surface 130a of the mirror 130 is inclined 45° to the optical axis A of the camera 128.

As illustrated in FIG. 10, the reflecting surface 130a of the mirror 130 is positioned such that it faces a first surface of a cutting blade stored in the cutting blade storing means 4 obliquely at an angle of 45° . The reflecting surface 130a of the mirror 130 is also positioned such that it faces a second surface (opposite the first surface) of a cutting blade unloaded from the cutting blade storing means 4 by the unloading and loading means 6 obliquely at an angle of 45° . The first surface of a cutting blade stored in the cutting blade storing means 4 faces the unloading and loading means 6, and is to be held by one of the blade holders 48 under

suction.

The reading means 126 thus constructed operates as follows: When the lifting and lowering means of the positioning unit 134 lifts the vertically movable base 138, the mirror 130 is brought into the upper working position where the camera 128 can capture an image of a cutting blade via the mirror 130. When the lifting and lowering means of the positioning unit 134 lowers the vertically movable base 138, the mirror 130 is brought into the lower retracted position where the mirror 130 stays out of the way in which the unloading and loading means 6 unloads a cutting blade from the cutting blade storing means 4 and loads a cutting blade into the cutting blade storing means 4.

When the mirror 130 is in the upper working position, the camera 128 captures an image of the first or second surface of a cutting blade via the reflecting surface 130a of the mirror 130, thereby reading the indicator T marked on a side surface of the cutting blade and indicating the kind of the cutting blade. The image captured by the camera 128 may be displayed on a monitor M (see FIG. 10) and saved in the memory of the automatic blade changer 2.

A cutting apparatus 170 with which the automatic

blade changer 2 described above is to be coupled will be described below with reference to FIGS. 11 through 15.

(Cutting apparatus 170)

As illustrated in FIG. 11, the cutting apparatus 170 includes a chuck table 172 having a holding surface for holding a workpiece thereon, a pair of cutting means 174 each having a cutting blade (see FIGS. 13 through 15) mounted in position by a mounting nut for cutting the workpiece held on the chuck table 172, an X-axis feeding means 176 for processing-feeding the chuck table 172 along the X-axis, a pair of Y-axis feeding means 178 for indexing-feeding the pair of cutting means 174 along the Y-axis perpendicular to the X-axis, and a pair of Z-axis feeding means 180 for incising-feeding the pair of cutting means 174 along the Z-axis perpendicular to the X-axis and the Y-axis.

(Chuck table 172)

As illustrated in FIGS. 11 and 12, the cutting apparatus 170 also includes a base 182 (see FIG. 11), an X-axis movable plate 184 movable along a pair of guide rails 182a disposed on an upper surface of the base 182 and extending along the X-axis, a support column 186 fixedly mounted on an upper surface of the X-axis movable plate 184, and a cover plate 188 fixedly mounted on an

upper end of the support column 186. The cover plate 188 has a circular opening 188a defined therein. The chuck table 172 is rotatably mounted on the upper end of the support column 186 and extends upwardly through the circular opening 188a in the cover plate 188. The chuck table 172 is rotatable about its central axis along the Z-axis by an unillustrated electric motor housed in the support column 186.

As illustrated in FIG. 12, a circular porous suction chuck 190 that is fluidly connected to an unillustrated suction means is disposed on an upper end of the chuck table 172. When the suction means generates and transmits suction forces to an upper surface of the suction chuck 190, the suction chuck 190 attracts and holds a workpiece under suction on the upper surface thereof.

Thus, the upper surface of the suction chuck 190 functions as a holding surface for holding the workpiece under suction thereon. The holding surface lies in an XY plane defined along the X-axis and the Y-axis. A plurality of clamps 192 that are positioned at circumferentially spaced intervals are disposed on an outer circumferential surface of the chuck table 172. (X-axis feeding means 176)

As illustrated in FIG. 12, the X-axis feeding means 176 includes a ball screw 198 threadedly coupled to the X-axis movable plate 184 and extending along the X-axis and an electric motor 200 connected to an end of the ball screw 198 for rotating the ball screw 198 about its central axis. The X-axis feeding means 176 operates as follows: When the electric motor 200 is energized, the ball screw 198 converts rotary motion of the electric motor 200 into linear motion and transmits the linear motion to the X-axis movable plate 184, moving the X-axis movable plate 184 along the guide rails 182a on the base 182 to thereby processing-feed the chuck table 172 along the X-axis.

As illustrated in FIG. 11, the cutting apparatus 170 includes a portal-shaped frame 202 disposed on the upper surface of the base 182 and straddling the chuck table 172. The frame 202 includes a pair of support posts 204 spaced from each other along the Y-axis and extending upwardly from the upper surface of the base 182 and a beam 206 extending along the Y-axis between respective upper ends of the support posts 204.

(Cutting means 174)

The pair of cutting means 174 are disposed on a side surface of the beam 206, i.e., a rear side surface

of the beam 206 that faces away from the viewer of FIG. 11, and are spaced from each other along the Y-axis. In the cutting apparatus 170 according to the present embodiment, the pair of cutting means 174 have respective cutting blades facing each other along the Y-axis and are capable of simultaneously cutting the workpiece held on the chuck table 172 with the cutting blades. According to the present invention, however, the cutting apparatus 170 may have only one cutting means.

As illustrated in FIG. 13, each of pair of the cutting means 174 includes a rectangular Y-axis movable member 208 movably supported on a side surface of the beam 206 for movement along the Y-axis, a Z-axis movable member 210 having an L-shaped cross section that is vertically movably supported on the Y-axis movable member 208 for vertical movement along the Z-axis, and a spindle housing 212 fixed to a lower end of the Z-axis movable member 210.

The Y-axis movable member 208 has a pair of guided grooves 208a defined in a side surface thereof that faces the viewer of FIG. 13 and vertically spaced from each other along the Z-axis, the guided grooves 208a extending along the Y-axis. The guided grooves 208a are slidably fitted over respective unillustrated guide rails

extending on the rear side surface of the beam 206 along the Y-axis and vertically spaced from each other along the Z-axis.

(Y-axis feeding means 178)

Each of the pair of Y-axis feeding means 178 includes a ball screw 214 extending over the rear side surface of the beam 206 along the Y-axis and an electric motor 216 coupled to an end of the ball screw 214 for rotating the ball screw 214 about its central axis. The ball screw 214 is threadedly coupled to the Y-axis movable member 208. The Y-axis feeding means 178 operates as follows: When the electric motor 216 is energized, the ball screw 214 converts rotary motion of the electric motor 216 into linear motion and transmits the linear motion to the Y-axis movable member 208, indexing-feeding the Y-axis movable member 208 along the guide rails on the rear side surface of the beam 206 along the Y-axis.

The Y-axis movable member 208 has a pair of unillustrated vertical guide rails spaced from each other along the Y-axis and extending along the Z-axis on another side surface of the Y-axis movable member 208, i.e., a rear side surface of the Y-axis movable member 208 that faces away from the viewer of FIG. 13. The Z-

axis movable member 210 has a pair of unillustrated vertical guided grooves defined in a side surface thereof that faces the viewer of FIG. 13 and spaced from each other along the Y-axis. The guided grooves are slidably fitted respectively over the vertical guide rails of the Y-axis movable member 208.

(Z-axis feeding means 180)

Each of the pair of Z-axis feeding means 180 includes an unillustrated ball screw threadedly coupled to the Z-axis movable member 210 and extending along the Z-axis and an electric motor 218 coupled to an end of the ball screw for rotating the ball screw about its central axis. The Z-axis feeding means 180 operates as follows: When the electric motor 218 is energized, the ball screw converts rotary motion of the electric motor 218 into linear motion and transmits the linear motion to the Z-axis movable member 210, incising-feeding the Z-axis movable member 210 along the guide rails of the Y-axis movable member 208 along the Z-axis.

As illustrated in FIG. 14, the spindle housing 212 supports thereon a cylindrical spindle 220 that is rotatable about its central axis along the Y-axis, and houses therein an unillustrated electric motor for rotating the spindle 220 about its central axis. A

cutting blade for cutting a workpiece is detachably fixed to a distal end of the spindle 220 by a mounting nut 222. FIG. 14 illustrates by way of example a hub blade 36 fixed as the cutting blade to the spindle 220.

The cutting blade is covered with a blade cover 224 mounted on a distal end of the spindle housing 212. The blade cover 224 has a first cover member 224a fixed to the distal end of the spindle housing 212 and a second cover member 224b movably mounted on a distal end of the first cover member 224a. The second cover member 224b is movable along the X-axis by an unillustrated actuator such as an air cylinder. When the cutting blade is to be replaced, the second cover member 224b is moved to and positioned in an open position illustrated in FIG. 14. When the cutting blade is to cut a workpiece, the second cover member 224b is moved to and positioned in a closed position illustrated in FIG. 13.

As illustrated in FIG. 15, an annular mount flange 226 that protrudes radially outwardly is mounted on the outer circumferential surface of a distal end portion of the spindle 220. The mount flange 226 has an annular recess 226a defined in a radially inward portion of a distal end face thereof. The distal end face of the mount flange 226 also includes a radially outward portion

acting as an annular bearing portion 226b that protrudes axially. The spindle 220 includes a distal end portion extending axially beyond the mount flange 226 and having an externally threaded surface 228.

When a hub blade 36 is mounted as a cutting blade on the spindle 220, the central opening 38a of the hub blade 36 is fitted over the distal end portion of the spindle 220, and the mounting nut 222 is threaded over, i.e., tightened on, the externally threaded surface 228 of the spindle 220, sandwiching the hub blade 36 between the bearing portion 226b of the mount flange 226 and the mounting nut 222. In this manner, the hub blade 36 is detachably secured to the distal end portion of the spindle 220. The mounting nut 222 has a plurality of pin holes 222a defined in a side surface of the mounting nut 222 at circumferentially equal spaced intervals for receiving the respective pins 72 of each of the mounting nut holders 50.

When a washer blade 45 is mounted as a cutting blade on the spindle 220, as illustrated in FIG. 16, the mounting nut 222 is threaded over, i.e., tightened on, the externally threaded surface 228 of the spindle 220, sandwiching the washer blade 45 between the bearing portion 226b of the mount flange 226 and an annular

mounting flange 229. In this manner, the washer blade 45 is detachably secured to the distal end portion of the spindle 220.

The mounting flange 229 includes an annular land 229a disposed on a reverse surface thereof. The annular land 229a has an outside diameter D, which is the same as the diameter D of the shanks 34 of the cutting blade storing means 4, commensurate with the diameter of the central opening 45a of the washer blade 45. For securing the washer blade 45 to the spindle 220, the central opening 45a of the washer blade 45 is fitted over the annular land 229a.

As illustrated in FIG. 11, a pair of image capturing means 230 for capturing images of a workpiece held on the chuck table 172 are movably mounted on another side surface, i.e., a front side surface facing the viewer of FIG. 11, of the beam 206 of the frame 202. The pair of image capturing means 230 are movable along the Y-axis by a pair of respective moving means 232 mounted on the front side surface of the beam 206.

Each of the pair of moving means 232 has a ball screw 234 extending over the front side surface of the beam 206 along the Y-axis and an electric motor 236 coupled to an end of the ball screw 234 for rotating the

ball screw 234 about its central axis. The ball screw 234 is coupled to the respective one of the pair of image capturing means 230. The moving means 232 operates as follows: When the electric motor 236 is energized, the ball screw 234 converts rotary motion of the electric motor 236 into linear motion and transmits the linear motion to the image capturing means 230, moving the image capturing means 230 along the Y-axis along guide rails 206a mounted on the front side surface of the beam 206. Although the cutting apparatus 170 according to the present embodiment includes two image capturing means 230, the cutting apparatus may have only one image capturing means.

(Cutting process)

For cutting a workpiece such as a wafer on the cutting apparatus 170, the workpiece is held under suction on the chuck table 172. Next, the X-axis feeding means 176 moves the chuck table 172 to a position below the pair of image capturing means 230, and the pair of moving means 232 adjust the positions of the pair of image capturing means 230 along the Y-axis. Then, the pair of image capturing means 230 capture images of the workpiece from above and detect regions to be cut of the workpiece in the captured images.

According to the regions to be cut of the workpiece that have been detected by the pair of image capturing means 230, the chuck table 172 is rotated about its central axis to adjust the orientation of the regions to be cut of the workpiece with respect to the cutting blades 35 of the pair of cutting means 174. Then, the X-axis feeding means 176 moves the chuck table 172 along the X-axis, and the pair of Y-axis feeding means 178 move the spindle housings 212 along the Y-axis, positioning the cutting blades above the regions to be cut of the workpiece.

Subsequently, the pair of Z-axis feeding means 180 lower the spindle housings 212 to cause the cutting edges of the cutting blades that are rotating at a high speed to cut into the regions to be cut of the workpiece. At the same time, while cutting water is being supplied to the regions of the workpiece into which the cutting edges of the cutting blades are cutting, the X-axis feeding means 176 incising-feeds the chuck table 172 along the X-axis to cause the cutting blades to cut the regions to be cut of the workpiece. Then, the pair of Y-axis feeding means 178 indexing-feed the spindle housings 212 along the Y-axis, after which the above cutting process is repeated to fully cut the regions to be cut of

the workpiece. The workpiece that has been cut in the cutting process is delivered to the next processing step.
(Replacement of cutting blades)

When the cutting process is repeated, the cutting blades are progressively worn. When the cutting blades are worn to a certain threshold level, their cutting accuracy drops below a required accuracy level. Hence, those unduly worn cutting blades mounted on the spindles 220 need to be replaced with fresh cutting blades. Even if the cutting blades mounted on the spindles 220 have not been worn to the threshold level, when the cutting apparatus 170 is required to cut workpieces of a material different from the material of the workpieces that have been cut previously, the cutting blades mounted on the spindles 220 need to be replaced with cutting blades that match the different material of the workpieces to be cut.

According to the present embodiment, as illustrated in FIG. 17, the automatic blade changer 2 that is capable of automatically replacing the cutting blades of the cutting apparatus 170 is coupled to the cutting apparatus 170. A process of replacing hub blades 36 on the spindles 220 with use of the automatic blade changer 2 will be described below by way of example.

As illustrated in FIG. 17, the automatic blade

changer 2 is disposed behind the cutting apparatus 170 along the X-axis. The automatic blade changer 2 can subsequently be added to the cutting apparatus 170 that has already been delivered to the user.

The hub blades 36 on the cutting apparatus 170 are replaced with fresh hub blades 36 by the automatic blade changer 2, as follows: First, the endless track 22 of the cutting blade storing means 4 is rotated to bring the blade support shaft 24 that is supporting a fresh hub blade 36 to be loaded into the cutting apparatus 170 to a predetermined position, e.g., a position at the lowermost end of the path followed by the endless track 22.

Then, it is confirmed with the reading means 126 whether the kind of the hub blade 36 positioned in the above predetermined position agrees with the kind of the hub blade 36 to be loaded into the cutting apparatus 170 or not. Specifically, the positioning unit 134 lifts the vertically movable base 138 to position the mirror 130 in the upper working position in which the camera 128 can capture an image of the hub blade 36 via the mirror 130.

If the reflecting surface 130a of the mirror 130 is not facing the cutting blade storing means 4, then the rotating unit 132 rotates the mirror 130 with the rotary table 140 until the reflecting surface 130a of the mirror

130 faces the cutting blade storing means 4.

Then, the camera 128 captures an image of a first side surface of the hub blade 36, i.e., the surface facing the unloading and loading means 6, via the reflecting surface 130a of the mirror 130. Subsequently, as illustrated in FIG. 10, the reading means 126 reads the indicator T, e.g., "A005," marked on the side surface of hub blade 36 and indicating the kind of the hub blade 36 from the captured image of the first side surface of the hub blade 36.

If it is found from the indicator T thus read that the kind of the hub blade 36 positioned in the above predetermined position does not agree with the kind of the hub blade 36 to be loaded into the cutting apparatus 170, then an unillustrated alarm of the automatic blade changer 2 or an unillustrated illuminating means such as a revolving light, of the automatic blade changer 2 is energized to indicate the discrepancy to the operator of the automatic blade changer 2.

On the other hand, if it is found from the indicator T thus read that the kind of the hub blade 36 positioned in the above predetermined position agrees with the kind of the hub blade 36 to be loaded into the cutting apparatus 170, then the positioning unit 134

lowers the vertically movable base 138 to position the mirror 130 in the lower retracted position where the mirror 130 stays out of the way in which the unloading and loading means 6 unloads a cutting blade from the cutting blade storing means 4 and loads a cutting blade into the cutting blade storing means 4.

After the reading means 126 has read the kind of the hub blade 36 and completed the confirmation of the kind of the hub blade 36, as illustrated in FIG. 18, the electric motor coupled to the Z-axis rotational shaft 46 of the unloading and loading means 6 is energized to rotate the casing 52 until one of the side walls 56 of the casing 52 on which a blade holder 48 is mounted extends along the X-axis, thereby causing the blade holder 48 to face the cutting blade storing means 4.

The X-axis moving means 12 and the Z-axis moving means 10 are actuated to adjust the position of the blade holder 48 along the X-axis and the position of the blade holder 48 along the Z-axis in order to allow the shank 34 of the blade support shaft 24 in the predetermined position described above to be inserted into the central opening 60 (see FIG. 6) of the blade holder 48.

Then, as illustrated in FIG. 19, the Y-axis moving means 8 is actuated to move the frame 74 along the

Y-axis and position the unloading and loading means 6 in the working position where the blade holder 48 can hold the hub blade 36 supported on the blade support shaft 24. The shank 34 of the blade support shaft 24 in the predetermined position is now inserted into the central opening 60 of the blade holder 48, and the end face 58 of the blade holder 48 is brought into contact with the end face of the hub blade 36 that is positioned on the distal end portion of the shank 34. Then, suction forces are generated and transmitted to act in the first suction holes 61 of the blade holder 48, enabling the blade holder 48 to hold under suction the hub blade 36 positioned on the distal end portion of the shank 34.

Next, the Y-axis moving means 8 is actuated to space the unloading and loading means 6 away from the cutting blade storing means 4 along the Y-axis and position the unloading and loading means 6 in the retracted position. Then, the casing 52 of the unloading and loading means 6 is turned 180° to cause the blade holder 48 that is diametrically opposite the blade holder 48 that is holding the hub blade 36 under suction to face the cutting blade storing means 4.

Subsequently, the Y-axis moving means 8 is actuated to position the unloading and loading means 6 in

the working position where the opposite blade holder 48 can hold a hub blade 36 supported on a blade support shaft 24. Then, suction forces are generated and transmitted to act in the first suction holes 61 of the opposite blade holder 48, enabling the opposite blade holder 48 to hold under suction the hub blade 36 positioned on the distal end portion of the shank 34. Now, the two diametrically opposite blade holders 48 of the four blade holders 48 have held fresh hub blades 36 under suction.

Since the same blade support shafts 24 support the hub blades 36 of the same kind, the confirmation of the kind of the hub blades 36 may be omitted. However, the reading means 126 may confirm the kind of hub blades 36 before the diametrically opposite blade holders 48 hold hub blades 36 under suction.

After the two diametrically opposite blade holders 48 have held the fresh hub blades 36 under suction, as illustrated in FIG. 20, the Y-axis moving means 8 is actuated to move the frame 74 away from the cutting blade storing means 4 along the Y-axis, and the Z-axis moving means 10 is actuated to move the vertically movable table 76 along the Z-axis. As a result, the unloading and loading means 6 is spaced from the cutting

blade storing means 4 and placed in the retracted position, and the positions of the unloading and loading means 6 along the Y-axis and the Z-axis with respect to the cutting apparatus 170 are adjusted. The adjusted position of the unloading and loading means 6 along the Y-axis lies between the pair of cutting means 174 of the cutting apparatus 170, and the adjusted position of the unloading and loading means 6 along the Z-axis lies above the holding surface of the chuck table 172.

Then, as illustrated in FIG. 21, the X-axis moving means 12 is actuated to move the unloading and loading means 6 along the X-axis to adjust the position of the unloading and loading means 6 along the X-axis with respect to the pair of cutting means 174. Specifically, the positions along the X-axis of the centers of the fresh hub blades 36 held under suction by the two blade holders 48 of the unloading and loading means 6 and the positions along the X-axis of the centers of the hub blades 36 mounted on the pair of cutting means 174 are aligned with each other.

The Z-axis moving means 10 of the automatic blade changer 2 or the Z-axis feeding means 180 of the cutting apparatus 170 is actuated to align the positions along the Z-axis of the centers of the hub blades 36 on the

blade holders 48 and the positions along the Z-axis of the centers of the hub blades 36 on the pair of cutting means 174 with each other.

Next, the casing 52 of the unloading and loading means 6 is turned 60° to cause the two mounting nut holders 50 to face the hub blades 36 on the pair of cutting means 174. The casing 52 may be turned 60° before the unloading and loading means 6 is advanced.

Subsequently, the second cover members 224b of the respective blade covers 224 of the pair of cutting means 174 are brought into the open position (see FIG. 14). Then, the pair of Y-axis feeding means 178 of the cutting apparatus 170 are actuated to move the pair of cutting means 174 along the Y-axis until the mounting nuts 222 by which the hub blades 36 are mounted on the spindles 220 are brought into contact with the end faces 66a of the rotors 66 of the mounting nut holders 50. The pins 72 of the mounting nut holders 50 are pushed into the rotors 66 by the mounting nuts 222, and the distal end portions of the spindles 220 are placed in the central openings 68 of the rotors 66.

Then, the electric motors of the mounting nut holders 50 are energized to rotate the rotors 66 until the pins 72 are aligned with the respective pin holes

222a in the mounting nuts 222 whereupon the pins 72 are fitted respectively into the pin holes 222a. The rotary motion of the rotors 66 is transmitted through the pins 72 to the mounting nuts 222, loosening the mounting nuts 222. The mounting nuts 222 are now threaded off, i.e., removed from, the externally threaded surfaces 228 of the spindles 220 of the pair of cutting means 174. Then, suction forces are generated and transmitted to act in the suction holes 70 of the mounting nut holders 50, enabling the mounting nut holders 50 to hold under suction the mounting nuts 222 that have been removed from the spindles 220.

Subsequently, the pair of Y-axis feeding means 178 are actuated to space the pair of cutting means 174 away from the unloading and loading means 6, and the casing 52 of the unloading and loading means 6 is turned 60° to cause empty blade holders 48 that are not holding hub blades 36 under suction to face the hub blades 36 on the pair of cutting means 174.

Then, the pair of Y-axis feeding means 178 are actuated to move the pair of cutting means 174 closer to the unloading and loading means 6 until the spindles 220 of the pair of cutting means 174 are inserted into the central openings 60 of the empty blade holders 48 and the

end faces 58 of the empty blade holders 48 are brought into contact with the end faces of the hub blades 36 on the pair of cutting means 174. Subsequently, suction forces are generated and transmitted to act in the first suction holes 61 of the empty blade holders 48, enabling the empty blade holders 48 to hold the hub blades 36 on the pair of cutting means 174 under suction.

Then, the pair of Y-axis feeding means 178 are actuated to space the pair of cutting means 174 away from the unloading and loading means 6, and the casing 52 of the unloading and loading means 6 is turned 60° to cause the blade holders 48 that are holding the fresh hub blades 36 under suction to face the spindles 220 of the pair of cutting means 174.

Subsequently, the pair of Y-axis feeding means 178 are actuated to move the pair of cutting means 174 closer to the unloading and loading means 6 until the spindles 220 are inserted into the central openings 38a of the fresh hub blades 36 and the end faces of the fresh hub blades 36 are brought into contact with the bearing portions 226b of the mount flanges 226 of the spindles 220. Then, the blade holders 48 are released of the suction forces, transferring the fresh hub blades 36 to the spindles 220.

Next, the pair of Y-axis feeding means 178 are actuated to space the pair of cutting means 174 away from the unloading and loading means 6, and the casing 52 of the unloading and loading means 6 is turned 60° to cause the mounting nut holders 50 that are holding the removed mounting nuts 222 under suction to face the spindles 220 of the pair of cutting means 174.

Then, the pair of Y-axis feeding means 178 are actuated to move the pair of cutting means 174 closer to the unloading and loading means 6 until the mounting nuts 222 held under suction by the mounting nut holders 50 are fitted over the distal end portions of the spindles 220. Subsequently, the electric motors of the mounting nut holders 50 are reversed to rotate the mounting nuts 222 in a direction opposite the direction in which the mounting nuts 222 have been rotated for removal from the spindles 220, threading the mounting nuts 222 over, i.e., tightening the mounting nuts 222 on, the externally threaded surfaces 228 of the spindles 220.

In this manner, the fresh hub blades 36 to be mounted on the pair of cutting means 174 are fixedly mounted on the spindles 220 by being sandwiched between the bearing portions 226b of the mount flanges 226 of the spindles 220 and the mounting nuts 222.

Then, after the mounting nut holders 50 have been released of the suction forces, the second cover members 224b of the blade covers 224 of the pair of cutting means 174 are brought into the closed position. The mounting nuts 222 and the hub blades 36 may be mounted on or removed from the pair of cutting means 174 simultaneously or separately.

Then, the unloading and loading means 6 is retracted and the casing 52 of the unloading and loading means 6 is turned 60° to cause one of the pair of removed hub blades 36 to face the cutting blade storing means 4. The endless track 22 of the cutting blade storing means 4 is rotated to place an empty blade support shaft 24 that is not supporting a hub blade 36 into a predetermined position, e.g., a position at the lowermost end of the path followed by the endless track 22.

Then, the X-axis moving means 12 and the Z-axis moving means 10 are actuated to adjust the position of the blade holder 48 along the X-axis and the position of the blade holder 48 along the Z-axis in order to allow the shank 34 of the blade support shaft 24 in the predetermined position described above to be inserted into the central opening 38a of one of the hub blades 36 that is held under suction by the blade holder 48.

Subsequently, the Y-axis moving means 8 is actuated to move the frame 74 along the Y-axis to insert the shank 34 of the blade support shaft 24 in the predetermined position described above into the central opening 38a of one of the hub blades 36 held under suction by the blade holders 48 and to bring the end face of the one of the hub blades 36 into contact with the end face of the base 32 of the blade support shaft 24. Then, the blade holder 48 is released of the suction forces, transferring the removed one of the hub blades 36 to the blade support shaft 24.

The Y-axis moving means 8 is actuated to space the unloading and loading means 6 away from the cutting blade storing means 4 along the Y-axis, and the casing 52 of the unloading and loading means 6 is turned 180° to cause the blade holder 48 that is diametrically opposite the blade holder 48 that is holding the removed other hub blade 36 under suction to face the cutting blade storing means 4.

Next, the Y-axis moving means 8 is actuated to move the frame 74 along the Y-axis and thereby insert the shank 34 of the blade support shaft 24 in the predetermined position referred to above into the central opening 38a of the other hub blade 36 held under suction

by the diametrically opposite blade holder 48 and bring the end face of the other hub blade 36 into contact with the end face of the hub blade 36 supported on the blade support shaft 24. Then, the blade holder 48 is released of the suction forces, transferring the removed other hub blade 36 to the blade support shaft 24.

As described above, the automatic blade changer 2 according to the present embodiment can subsequently be added to the cutting apparatus 170 that has already been delivered to the user for replacing the hub blades 36 mounted on the cutting means 174 of the cutting apparatus 170.

The automatic blade changer 2 is able to replace not only hub blades 36, but also washer blades 45. For replacing a washer blade 45, the unloading and loading means 6 is positioned between the pair of cutting means 174 of the cutting apparatus 170 while a fresh replacement washer blade 45 is not being held under suction on a blade holder 48. Then, a mounting nut holder 50 is brought into facing relation to one of the pair of cutting means 174, and removes the mounting nut 222 from the spindle 220 of the cutting means 174.

After the blade holder 48 has faced the pair of cutting means 174, suction forces are developed in the

first suction holes 61 of the blade holder 48, holding the mounting flange 229 under suction, and suction forces are developed in the second suction holes 63 of the blade holder 48, causing the blade holder 48 to hold a washer blade 45 mounted on the spindle 220 under suction. The blade holder 48 removes the washer blade 45 and the mounting flange 229 that are held under suction from the spindle 220.

Then, the unloading and loading means 6 is moved to bring the blade holder 48 that is holding the washer blade 45 and the mounting flange 229 under suction into facing relation to the cutting blade storing means 4. The endless track 22 of the cutting blade storing means 4 is rotated to bring an empty blade support shaft 24 that is capable of supporting a washer blade 45 into a predetermined position.

The washer blade 45 is fitted over the shank 34 of the empty blade support shaft 24, and the second suction holes 63 are released of the suction forces, transferring the washer blade 45 to the blade support shaft 24. At this time, the first suction holes 61 are not released of the suction forces, continuously causing the blade holder 48 to hold the mounting flange 229 under suction.

Then, the endless track 22 of the cutting blade storing means 4 is rotated to place the blade support shaft 24 that is supporting a fresh washer blade 45 to be loaded into the cutting apparatus 170 into a predetermined position, e.g., a position at the lowermost end of the path followed by the endless track 22. The unloading and loading means 6 is moved away from the cutting blade storing means 4 to the extent that the mirror 130 of the reading means 126 will not be prevented from being positioned in the upper working position.

Subsequently, in order for the reading means 126 to confirm whether the kind of the washer blade 45 positioned in the predetermined position agrees with the kind of the washer blade 45 to be loaded into the cutting apparatus 170 or not, the positioning unit 134 lifts the vertically movable base 138, bringing the mirror 130 into the upper working position where the camera 128 can capture an image of the washer blade 45 via the mirror 130.

At this time, if the reflecting surface 130a of the mirror 130 is not facing the cutting blade storing means 4, then the rotating unit 132 rotates the mirror 130 in unison with the rotary table 140 about the Z-axis, causing the reflecting surface 130a of the mirror 130 to

face the cutting blade storing means 4.

Then, the camera 128 captures an image of a first side surface, i.e., the surface facing the unloading and loading means 6, of the washer blade 45 via the reflecting surface 130a of the mirror 130. The reading means 126 reads the indicator T, e.g., "B006," marked on the first side surface of the washer blade 45 and indicating the kind of the washer blade 45 from the captured image of the first side surface of the washer blade 45.

If it is found from the indicator T thus read that the kind of the washer blade 45 positioned in the predetermined position does not agree with the kind of the washer blade 45 to be loaded into the cutting apparatus 170, then the unillustrated alarm of the automatic blade changer 2 or the unillustrated illuminating means such as the revolving light, of the automatic blade changer 2 is energized to indicate the discrepancy to the operator of the automatic blade changer 2.

On the other hand, if it is found from the indicator T thus read that the kind of the washer blade 45 positioned in the predetermined position agrees with the kind of the washer blade 45 to be loaded into the

cutting apparatus 170, then the positioning unit 134 lowers the vertically movable base 138 to position the mirror 130 in the lower retracted position where the mirror 130 stays out of the way in which the unloading and loading means 6 unloads a cutting blade from the cutting blade storing means 4 and loads a cutting blade into the cutting blade storing means 4.

Subsequently, suction forces are developed in the second suction holes 63 of the blade holder 48 that is holding the mounting flange 229 under suction, holding a fresh replacement washer blade 45 under suction on the blade holder 48. In other words, the same blade holder 48 holds the fresh replacement washer blade 45 together with the mounting flange 229 under suction.

Hub blades 36 are easy to tell their face side from their reverse side because they have the base 38 and the cutting edge 40. Hence, it is less likely to make a mistake in placing a hub blade 36 with its face and reverse sides oriented properly, i.e., with the side surface marked with the indicator T facing the unloading and loading means 6, on a blade support shaft 24 of the cutting blade storing means 4.

In contrast, washer blades 45 are difficult to tell their face side from their reverse side because they

do not have a base and have only a cutting edge. Hence, it is more likely to place a washer blade 45 in a wrong orientation on a blade support shaft 24 of the cutting blade storing means 4. If a washer blade 45 is wrongly oriented on the blade support shaft 24, then the side surface of the washer blade 45 that is marked with the indicator T does not face the unloading and loading means 6, and the reading means 126 is unable to read the indicator T of the washer blade 45 stored in the cutting blade storing means 4.

According to the present embodiment, the blade holder 48 of the unloading and loading means 6 holds the fresh replacement washer blade 45 together with the mounting flange 229 under suction. After the unloading and loading means 6 has been retracted into the frame 74, the reading means 126 reads the indicator T.

Specifically, after the unloading and loading means 6 has been retracted into the frame 74, the positioning unit 134 of the reading means 126 lifts the vertically movable base 138, and the rotating unit 132 turns the rotary table 140 through 180°. As illustrated in FIG. 22, the mirror 130 is positioned in the upper working position, and the reflecting surface 130a of the mirror 130 faces the washer blade 45 held under suction

on the blade holder 48.

Then, the camera 128 captures an image of a second side surface of the washer blade 45, i.e., the surface opposite the first side surface thereof, via the reflecting surface 130a of the mirror 130. The reading means 126 reads an indicator T, e.g., "B006," marked on the second side surface of the washer blade 45 and indicating the kind of the washer blade 45 from the captured image of the first side surface of the washer blade 45.

If it is found from the indicator T thus read that the kind of the washer blade 45 positioned in the predetermined position does not agree with the kind of the washer blade 45 to be loaded into the cutting apparatus 170, then the alarm or the illuminating means of the automatic blade changer 2 is energized to indicate the discrepancy to the operator of the automatic blade changer 2.

On the other hand, if it is found from the indicator T thus read that the kind of the washer blade 45 positioned in the predetermined position agrees with the kind of the washer blade 45 to be loaded into the cutting apparatus 170, then the unloading and loading means 6 is moved to bring the blade holder 48 that is

holding the mounting flange 229 and the fresh washer blade 45 into facing relation to one of the pair of cutting means 174. Then, the unloading and loading means 6 transfers the mounting flange 229 and the fresh washer blade 45 to the spindle 220. After one of the mounting nut holders 50 has faced the cutting means 174, the mounting nut 222 is threaded over the externally threaded surface 228 of the spindle 220.

As described above, the automatic blade changer 2 according to the present embodiment can subsequently be added to the cutting apparatus 170 that has already been delivered to the user, for replacing the washer blades 45 mounted on the cutting means 174 of the cutting apparatus 170.

Since the reading means 126 of the automatic blade changer 2 can read and confirm the kinds of cutting blades to be loaded into the cutting apparatus 170, cutting blades in the cutting apparatus 170 can reliably be replaced with desired cutting blades.

Furthermore, even if cutting blades, particularly, washer blades 45, are stored with their face and reverse sides in wrong orientations in the cutting blade storing means 4, the indicators T marked on the cutting blades can be read from captured images of

the side surfaces of the cutting blades to identify the kinds of the cutting blades. This similarly applies to the hub blades 36.

The present invention is not limited to the details of the above described preferred embodiment. The scope of the invention is defined by the appended claims and all changes and modifications as fall within the equivalence of the scope of the claims are therefore to be embraced by the invention.

WHAT IS CLAIMED IS:

1. An automatic blade changer adapted to be coupled to a cutting apparatus including a chuck table having a holding surface for holding a workpiece thereon, a cutting means having a cutting blade mounted thereon with a mounting nut, for cutting the workpiece held on the chuck table, an X-axis feeding means for processing-feeding the chuck table along an X-axis, a Y-axis feeding means for indexing-feeding the cutting means along a Y-axis perpendicular to the X-axis, and a Z-axis feeding means for incising-feeding the cutting means along a Z-axis perpendicular to the X-axis and the Y-axis, the holding surface being defined by the X-axis and the Y-axis, the automatic blade changer comprising:

a cutting blade storing means for storing a plurality of cutting blades therein;

an unloading and loading means for unloading cutting blades from the cutting blade storing means, delivering the unloaded cutting blades to the cutting means, and loading the cutting blades removed from the cutting means to the cutting blade storing means; and

a reading means disposed adjacent to a working position in which the unloading and loading means works on the cutting blade storing means, for reading an

indicator marked on a side surface of each of the cutting blades stored in the cutting blade storing means and indicating the kind of each of the cutting blades.

2. The automatic blade changer according to claim 1, wherein the reading means includes

a camera,

a mirror having a reflecting surface inclined 45° to an optical axis of the camera,

a rotating unit for rotating the mirror about the optical axis of the camera, and

a positioning unit for positioning the mirror selectively in a working position and a retracted position,

the reflecting surface of the mirror faces at an angle of 45° a first side surface of one of the cutting blades stored in the cutting blade storing means and a second side surface, opposite the first side surface, of one of the cutting blades unloaded from the cutting blade storing means by the unloading and loading means, and

the reading means reads the indicator marked on the first side surface or the second side surface of each of the cutting blades and indicating the kind of each of the cutting blades from an image of the first side surface or the second side surface captured by the camera

via the mirror positioned in the working position.

3. The automatic blade changer according to claim 1, wherein the cutting blade storing means includes

a drive gear having a rotational shaft extending along the Y-axis,

a driven gear that is spaced from the drive gear along the Z-axis and that has a rotational shaft extending along the Y-axis,

an endless track trained around the drive gear and the driven gear, and

a plurality of blade support shafts disposed on the endless track at predetermined spaced intervals and supporting the respective cutting blades thereon by being inserted in respective central openings defined in the cutting blades, the blade support shafts extending along the Y-axis.

4. The automatic blade changer according to claim 1, further comprising:

a Y-axis moving means for selectively bringing the unloading and loading means into the working position and a retracted position along the Y-axis with respect to the cutting blade storing means;

a Z-axis moving means for moving the unloading and loading means along the Z-axis; and

an X-axis moving means for moving the unloading and loading means along the X-axis and positioning the unloading and loading means in the working position in which the unloading and loading means works on the cutting blade mounted on a spindle of the cutting means,

wherein the unloading and loading means includes a Z-axis rotational shaft extending along the Z-axis,

a blade holder coupled radially to the Z-axis rotational shaft for holding a cutting blade under suction thereon, and

a mounting nut holder for threading a mounting nut over or off an externally threaded distal end portion of the spindle.

5. The automatic blade changer according to claim 4, wherein each of the cutting blades stored in the cutting blade storing means is a hub blade including a base and an annular cutting blade disposed on an outer circumferential portion of the base,

each of the blade support shafts has a diameter commensurate with a diameter of the central openings of the hub blades, and

the blade holder supports at least one of the hub blades.

6. The automatic blade changer according to claim 4, wherein each of the cutting blades stored in the cutting blade storing means is a washer blade including an annular cutting edge,

each of the blade support shafts has a diameter commensurate with a diameter of the central openings of the hub blades, and

the blade holder supports at least one of the washer blades and also a mounting flange for mounting the washer blade on the spindle of the cutting means.

7. The automatic blade changer according to claim 4, wherein the unloading and loading means is disposed in a frame by a bendable arm of the X-axis moving means, and the frame is slidably supported on a guide rail disposed on a vertically movable table and extending along the Y-axis and is able to selectively be positioned in the working position and the retracted position along the Y-axis with respect to the cutting blade storing means by the Y-axis moving means.