DESCRIPTION

SHAFT DISTORTION CORRECTING APPARATUS

TECHNICAL FIELD

[0001] The present invention relates to a shaft distortion correcting apparatus.

BACKGROUND ART

[0002] Conventional shaft distortion correcting apparatuses require manual setup operations.

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0003] In conventional shaft distortion correcting apparatuses, there has been a problem that the amount of work required for setup operations is large and productivity is low.

MEANS FOR SOLVING THE PROBLEM

[0004] According to an aspect of the present invention, there is provided a shaft distortion correcting apparatus including an anvil that supports a workpiece, a linear guide that supports the anvil so as to be movable in an axial direction of the workpiece, and an anvil moving unit that moves the anvil in the axial direction of the workpiece.

EFFECT OF THE INVENTION

[0005] According to an embodiment of the present invention, it becomes possible to improve the efficiency of the setup operations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006]

[FIG. 1] FIG. 1 is a front view of a shaft distortion correcting apparatus (during long-length setting) according to an embodiment of the present invention.

[FIG. 2] FIG. 2 is a plan view of the shaft distortion correcting apparatus (during long-length setting) according to the embodiment of the present invention.

[FIG. 3] FIG. 3 is a right side view of the shaft distortion correcting apparatus according to the embodiment of the present invention.

[FIG. 4] FIG. 4 is a front view of a workpiece driving unit.

[FIG. 5] FIG. 5 is a front view of a roller anvil.

[FIG. 6] FIG. 6 is a right side view of the roller anvil.

[FIG. 7] FIG. 7 is a front view of an encoder unit.

[FIG. 8] FIG. 8 is a view taken along arrow A of FIG. 2.

[FIG. 9] FIG. 9 is a block diagram showing a schematic configuration of a control system of the shaft distortion correcting apparatus.

[FIG. 10] FIG. 10 is a front view of the shaft distortion correcting apparatus (during short-length setting) according to the embodiment of the present invention.

[FIG. 11] FIG. 11 is a flowchart showing a procedure of a shaft distortion correction process according to an embodiment of the present invention.

[FIG. 12] FIG. 12 is a flowchart showing a procedure of a setup process according to an embodiment of the present invention.

[FIG. 13] FIG. 13 is a plan view of a comparative example (during long-length setting).

[FIG. 14] FIG. 14 is a plan view of a comparative example (during short-length setting).

EMBODIMENTS FOR CARRYING OUT THE INVENTION

[0007] Hereinafter, embodiments of the present invention will be described with reference to the drawings. In the following description, the same or corresponding elements are denoted by the same or corresponding reference numerals, and redundant description is omitted. Further, in each drawing, when a plurality of elements having common reference numerals are shown, the reference numerals are not necessarily indicated for all of the plurality of elements, and the indication of the reference numerals to some of the plurality of elements may be appropriately omitted.

[0008] FIGS. 1, 2, and 3 are a front view, a plan view, and a right side view, respectively, of a shaft distortion correcting apparatus 1 according to an embodiment of the present invention.

[0009] In the following description, the direction from left to right in FIG. 1 (front view) is defined as an X direction (first direction), the direction perpendicular to the paper from the front side to the back side in FIG. 1 (front view) is defined as a Y direction (second direction), and the direction from bottom to top in FIG. 1 (front view) is defined as a Z direction (third direction). The X, Y, and Z directions are three directions orthogonal to each other. The X and Y directions are horizontal directions, and the Z direction is a vertical direction. Unless otherwise specified, the X direction is referred to as “right,” the direction opposite to the X

direction is referred to as “left,” the Y direction is referred to as “rear,” the direction opposite to the Y direction is referred to as “front,” the Z direction is referred to as “up,” and the direction opposite to the Z direction is referred to as “down.”

[0010] The shaft distortion correcting apparatus 1 includes a base 2, a measurement unit M that measures runout of a workpiece W, and a correction unit P that supports the workpiece W and bends the workpiece W so that the runout of the workpiece W is eliminated (more precisely, so that the runout of the workpiece W falls within a predetermined range). The shaft distortion correcting apparatus of the present embodiment measures the runout of the workpiece W at a plurality of positions in the longitudinal direction of the workpiece W and corrects the workpiece W based on the measurement results.

[0011] The base 2 includes a top plate 2a and a top plate 2b (lower base plate). In the present embodiment, the top plate of the base 2 is divided into two parts, namely a front-side top plate 2a and a rear-side top plate 2b, and the front-side top plate 2a is disposed at a position one step higher than the rear-side top plate 2b, thereby forming a step. Main parts of the correction unit P are installed on the front-side top plate 2a, and main parts of the measurement unit M are installed on the rear-side top plate 2b. It should be noted that the present invention is not limited to this configuration, and the top plates 2a and 2b may be arranged at the same height and integrated (that is, the top plate of the base 2 may be formed as a single plate member without a step).

[0012] An upper base plate 3a is attached to an upper surface of the top plate 2a, and the upper base plate 3b is attached to an upper surface of the top plate 2b.

[0013] The correction unit P includes a workpiece driving unit 30, an encoder unit 40, a pair of left and right movable anvils 20 (20L, 20R) [second anvils], an anvil moving unit 50 (FIGS. 4 and 7), and a press unit 6 (FIG. 1). The anvil moving unit 50 is means for moving the workpiece driving unit 30, the encoder unit 40, and the movable anvils 20 to predetermined positions in the X direction. The anvil moving unit 50 includes a pair of linear guides 51 (51f, 51b) extending in the X direction, a pair of left and right first driving units 50D (50DL, 50DR), and a pair of left and right second driving units 60D (60DL, 60DR) (FIG. 2).

[0014] Correction of the workpiece W is performed by supporting both sides of a correction portion from below by a pair of movable anvils 20 (20L, 20R), and pressing the correction portion downward from above by a press head 6a of the press unit 6. The press unit 6 includes a not-shown moving device capable of moving and positioning the press head 6a in the X direction. The moving device of the press unit 6 is, for example, an electric linear actuator

formed by combining a rotary motor of which angular position (rotational position) can be controlled, such as a servo motor or a stepping motor, and a ball screw.

[0015] The linear guide 51 is a ball circulation linear bearing (linear guideway), but a linear guide of another mechanism (for example, sliding guide type or hydrostatic guide type) may be used. The linear guide 51 supports the workpiece driving unit 30, the encoder unit 40, and the movable anvils 20 so as to be movable in the X direction with low friction.

[0016] The linear guide 51 includes a rail 511 and a plurality of (for example, six) carriages 512 capable of traveling on the rail 511. The rail 511 of each linear guide 51 is mounted on the upper surface of the upper base plate 3a with its longitudinal direction oriented in the X direction (FIG. 3). One or more carriages 512 of each linear guide 51 are attached to bottom surfaces of the workpiece driving unit 30, the encoder unit 40, and the movable anvils 20L, 20R, respectively. For example, two carriages 512 of each linear guide 51 are attached to each of the workpiece driving unit 30 and the encoder unit 40, and one carriage 512 is attached to each of the movable anvils 20L, 20R. Thus, the workpiece driving unit 30, the encoder unit 40, and the movable anvils 20L, 20R are supported so as to be slidable in the X direction.

[0017] The workpiece driving unit 30 is a unit that supports one end portion of the workpiece W (left end portion in FIG. 1) and rotates the workpiece W to hold it at a predetermined angular position (rotational position). The encoder unit 40 is a unit that supports the other end portion of the workpiece W (right end portion in FIG. 1) and detects the angular position (more precisely, the rotational angle) of the workpiece W. The movable anvils 20L and 20R are members that support both sides of a position of the workpiece W where correction is to be performed.

[0018] The left first driving unit 50DL is a unit that drives the workpiece driving unit 30 in the X direction, and the right first driving unit 50DR is a unit that drives the encoder unit 40 in the X direction. The left second driving unit 60DL is a unit that drives the left movable anvil 20L in the X direction, and the right second driving unit 60DR is a unit that drives the right movable anvil 20R in the X direction.

[0019] FIG. 4 is a front view of the workpiece driving unit 30. The workpiece driving unit 30 includes a base plate 30b, a roller anvil 10 [first anvil], and a driving module 30A. The roller anvil 10 and the driving module 30A are respectively mounted on an upper surface of the base plate 30b. A nut 532L that engages with a screw shaft 531L of a ball screw 53L described later is mounted on the upper surface of the base plate 30b. On a lower surface of the base plate 30b, one or more (for example, two) carriages 512 of each linear guide 51 are attached.

[0020] The roller anvil 10 is a unit that supports an end portion of the workpiece W from below, and the driving module 30A is a unit that rotationally drives the workpiece W supported by the roller anvil 10.

[0021] FIGS. 5 and 6 are a front view and a right side view of the roller anvil 10, respectively. The roller anvil 10 includes a fixed part 10f fixed to the base plate 30b, a movable part 10m movable up and down with respect to the fixed part 10f, and an air cylinder 12 [elevating means] that moves the movable part 10m up and down. The air cylinder 12 is arranged with its operating direction oriented vertically, a cylinder tube 121 is attached to the fixed part 10f, and a piston rod 122 is attached to the movable part 10m. By operating the air cylinder 12 to advance and retract the piston rod 122, the movable part 10m moves up and down relative to the fixed part 10f. The movable part 10m is configured to be movable up and down between a lock position L (lower position) and an unlock position U (upper position), which will be described later. FIG. 6 shows a state in which the movable part 10m is at the unlock position U.

[0022] As shown in FIG. 6, an anvil unit 13 is replaceably provided on an upper portion of the fixed part 10f. On an upper surface of the anvil unit 13, a support surface 131 is formed which is a concave curved surface extending in the X direction formed by cutting into a cylindrical surface having substantially the same curvature as the outer peripheral surface of the workpiece W. Depending on an outer diameter of the workpiece W, the anvil unit 13 having the support surface 131 of an appropriate curvature is selected and used.

[0023] The movable part 10m includes a positioning pin 18 shown in FIG. 5, an arm 17 supporting the positioning pin 18, and a pair of roller units16 shown in FIG. 6. The positioning pin 18 is arranged at substantially the same height as the workpiece W and oriented in the X direction, and its tip abuts against one end surface of the workpiece W (the left end surface in FIG. 5).

[0024] As shown in FIG. 6, the pair of roller units 16 are arranged side by side in the Y direction with the anvil unit 13 interposed therebetween.

[0025] the roller unit 16 includes a frame 161, a shaft 162 supported by the frame 161, and a roller 163 supported by the shaft 162. In the present embodiment, the shaft 162 is fixed to the frame 161, and the roller 163 is supported so as to be rotatable with respect to the shaft 162 via a not-shown rolling bearing. However, the configuration is not limited thereto, and it is sufficient that at least one of the shaft 162 and the roller 163 is rotatably supported with respect to the frame 161 or the shaft 162. The frame 161 is fixed to the piston rod 122 of the air cylinder 12 shown in FIG. 5, and the roller unit 16 moves up and down in accordance with the advance

and retract of the piston rod 122.

[0026] When the movable part 10m is at the lock position L, the roller 163 is arranged at a position lower than a cylindrical surface C (that is, an outer peripheral surface of the workpiece W placed on the support surface 131). Therefore, the workpiece W does not contact the roller 163 (movable part 10m) and is placed on the support surface 131 of the anvil unit 13 (fixed part 10f). At this time, the rotation of the workpiece W is hindered by friction between the workpiece W and the support surface 131, and the angular position of the workpiece W is fixed.

[0027] When the piston rod 122 of the air cylinder 12 protrudes and the movable part 10m rises to the unlock position U, a portion of the roller 163 is arranged at a position higher than the cylindrical surface C. Therefore, the workpiece W is separated from the support surface 131 of the anvil unit 13 (fixed part 10f) and is rotatably supported by the rollers 163 of the pair of roller units 16.

[0028] As shown in FIG. 4, the driving module 30A includes a frame 31, an air cylinder 32, a motor 33, a shaft 35, and a roller 36. As the motor 33, for example, a rotary motor of which angular position (rotational position) can be controlled, such as a servo motor or a stepping motor, is used. As will be described later, the roller 36 contacts the workpiece W and constitutes a friction wheel together with the workpiece W. In order to ensure that rotation of the roller 36 is transmitted to the workpiece W accurately (that is, with a low slip rate), the roller 36 made of a material having a high friction coefficient, such as silicone rubber, is used.

[0029] The frame 31 includes a fixed frame 31f, a movable frame 31m, and a hinge pin 31p. A lower end portion of the columnar fixed frame 31f is fixed to the upper surface of the base plate 30b, and an upper end portion of the fixed frame 31f and a lower end portion of the movable frame 31m are connected via the hinge pin 31p extending in the Y direction so as to be pivotable about the hinge pin 31p (pivot axis).

[0030] The movable frame 31m has a cylindrical part 311. Bearings 312 are provided at both axial ends of an inner periphery of the cylindrical part 311. The shaft 35 is inserted into a hollow portion of the cylindrical part 311 and is rotatably supported by the pair of bearings 312.

[0031] The motor 33 is attached to the movable frame 31m. A shaft 331 of the motor 33 is connected to the shaft 35 by a coupling 34.

[0032] The roller 36 is attached to a distal end portion (right end portion in FIG. 4) of the shaft 35 protruding from the cylindrical part 311. Rotational motion output from the motor 33 is transmitted to the roller 36 via the coupling 34 and the shaft 35, thereby rotating the roller 36 to a predetermined angular position.

[0033] The air cylinder 32 is disposed on the left side of the fixed frame 31f in a substantially vertical orientation (that is, substantially parallel to the fixed frame 31f). A cylinder tube 321 is pivotably connected at its lower end portion to the base plate 30b via a hinge pin 323 extending in the Y direction. A piston rod 322 is pivotably connected at its upper end portion to the movable frame 31m via a hinge pin 324 extending in the Y direction. Thus, as the air cylinder 32 operates (as the piston rod 322 advances and retract), the driving module 30A pivots about the hinge pin 31p (pivot axis).

[0034] The piston rod 322 of the air cylinder 32 is configured to be movable up and down between an operating position A (upper position) where it protrudes upward and a retracted position S (lower position) where it retracts downward. As the piston rod 322 rises from the retracted position S to the operating position A, the driving module 30A pivots clockwise in FIG. 4, and the roller 36 descends to contact one end portion (left end portion in FIG. 4) of the workpiece W. At this time, the one end portion of the workpiece W is held by the pair of rollers 163 of the roller anvil 10 and the roller 36 of the driving module 30A. Thus, the roller 36 and the workpiece W constitute a friction wheel. In this state, when the motor 33 is rotationally driven, rotation of the roller 36 is transmitted to the workpiece W by rolling contact, and the workpiece W rotates by an angle corresponding to the rotation angle of the roller 36. That is, when the piston rod 322 is at the operating position A, the workpiece driving unit 30 is in an operating mode in which the workpiece W can be driven.

[0035] As the piston rod 322 descends from the operating position A to the retracted position S, the driving module 30A pivots counterclockwise in FIG. 4, and the roller 36 rises and separates from the workpiece W. As the piston rod 322 descends up to the retracted position S, the roller 36 moves further to the left side beyond the left end of the workpiece W. Therefore, the workpiece W can be lifted vertically upward and removed from the roller anvil 10 (or placed onto the roller anvil 10 from above) without interference from the roller 36. That is, when the piston rod 322 is at the retracted position S, the workpiece driving unit 30 is in a standby mode that allows attachment and detachment of the workpiece W.

[0036] FIG. 7 is a front view of the encoder unit 40. The encoder unit 40 includes a base plate 40b, the roller anvil 10, and an encoder module 40A. The roller anvil 10 and the encoder module 40A are respectively mounted on an upper surface of the base plate 40b. A nut 532R that engages with a screw shaft 531R of a ball screw 53R described later is mounted on the upper surface of the base plate 40b. The encoder unit 40 has the same configuration as the workpiece driving unit 30 except that the encoder module 40A is provided instead of the driving module

30A and that the nut 532R is provided instead of the nut 532L. Therefore, redundant description is herein omitted.

[0037] The encoder unit 40 has the same configuration as the driving module 30A except that a rotary encoder 43 is provided instead of the motor 33 and that a coupling 44 that connects a shaft 432 of the rotary encoder 43 and the shaft 35 is provided instead of the coupling 34. Therefore, redundant description is herein omitted.

[0038] When the piston rod 322 is at the operating position A, the encoder unit 40 is in an operating mode in which rotation of the workpiece W is transmitted to the roller 36 by rolling contact, and further transmitted to the shaft 432 of the rotary encoder 43 via the shaft 35 and the coupling 44 connected to the roller 36, thereby enabling detection of the angular position of the workpiece W by the rotary encoder 43.

[0039] As shown in FIGS. 1 and 2, the first driving unit 50D (50DL, 50DR) includes driving modules 52 (52L, 52R), couplings 522 (522L, 522R), bearing units 54 (54L, 54R), a bearing unit 55, and ball screws 53 (53L, 53R). As shown in FIGS. 4 and 7, each ball screw 53 (53L, 53R) includes the screw shaft 531 (531L, 531R) that is rotationally driven by the driving module 52 (52L, 52R), and the nut 532 (532L, 532R) that engages with the screw shaft 531 (531L, 531R).

[0040] The driving module 52L and the bearing unit 54L that move the workpiece driving unit 30 are installed on the left end portion of the top plate 2a of the base 2. The driving module 52R and the bearing unit 54R that move the encoder unit 40 are installed on the right end portion of the top plate 2a. The bearing unit 55 is installed on the central portion in the X direction of the top plate 2a. The bearing unit 55 has a bearing 551L provided on its left side surface and a bearing 551R provided on its right side surface.

[0041] The screw shaft 531L of the ball screw 53L and the screw shaft 531R of the ball screw 53R are arranged on the same straight line extending in the X direction. Specifically, the screw shaft 531L is arranged on the left side of the bearing unit 55, and the screw shaft 531R is arranged on the right side of the bearing unit 55. The screw shaft 531L of the ball screw 53L is rotatably supported at its distal end portion (right end portion) by the bearing 551L of the bearing unit 55 and at its proximal end portion (left end portion) by the bearing unit 54L. The screw shaft 531R of the ball screw 53R is rotatably supported at its distal end portion (left end portion) by the bearing 551R of the bearing unit 55 and at its proximal end portion (right end portion) by the bearing unit 54R.

[0042] Each driving module 52 (52L, 52R) includes a motor 521 (521L, 521R) and a coupling

522 (522L, 522R). As the motor 521, for example, a rotary motor of which angular position (rotational position) can be controlled, such as a servo motor or a stepping motor, is used.

[0043] Each coupling 522 (522L, 522R) connects a shaft 521a of the motor 521 (521L, 521R) and the screw shaft 531 (531L, 531R) of the ball screw 53 (53L, 53R). In this specification, one end of the screw shaft 531 connected to the shaft 521a of the motor 521 is referred to as a "proximal end" or "base end," and the other end is referred to as a "distal end."

[0044] As shown in FIG. 4, the nut 532L of the ball screw 53L is attached to the workpiece driving unit 30. Rotational motion output from the motor 521L is converted into linear motion in the X direction by the ball screw 53L and transmitted to the workpiece driving unit 30. The workpiece driving unit 30 moves to a position in the X direction corresponding to an angular position of the motor 521L.

[0045] As shown in FIG. 7, the nut 532R of the ball screw 53R is attached to the encoder unit 40. Rotational motion output from the motor 521R is converted into linear motion in the X direction by the ball screw 53R and transmitted to the encoder unit 40. The encoder unit 40 moves to a position in the X direction corresponding to an angular position of the motor 521R.

[0046] FIG. 8 is a view taken along arrow A of FIG. 2. The movable anvil 20 has a height changing function capable of changing its height in two stages, namely an upper stage and a lower stage, and a height of a support unit 212c (an upper portion 212U of a movable frame 212 described later) that supports the workpiece W can be changed according to the workpiece W.

[0047] A frame 21 of the movable anvil 20 includes a base plate 210, a fixed frame 211, and the movable frame 212. The fixed frame 211 is fixed on the base plate 210. On the lower surface of the base plate 210, at least one carriage 512 of each of the linear guides 51f and 51b is attached.

[0048] The fixed frame 211 is formed in a substantially box shape having a hollow portion 211a inside. An opening 211b is formed on an upper surface of the fixed frame 211. Openings 211c are formed at lower portions of the front and rear surfaces of the fixed frame 211, respectively. The fixed frame 211 has a pair of plate-shaped projections 211p that project horizontally inward (toward the opening) from upper end portions of left and right side walls.

[0049] The movable frame 212 has a lower portion 212L housed in the hollow portion 211a of the fixed frame 211, and the upper portion 212U protruding upward from the hollow portion 211a of the fixed frame 211. On an upper surface of the upper portion 212U, a support surface 212d is formed which is a concave curved surface extending in the X direction and cut into a

cylindrical surface having substantially the same curvature as the outer peripheral surface of the workpiece W. The upper portion 212U is replaceably attached to the lower portion 212L. According to the outer diameter of the workpiece W to be corrected, the upper portion 212U having the support surface 212d of an appropriate curvature is selected and used.

[0050] At an upper portion of the lower portion 212L of the movable frame 212, cutout portions 212n are formed at both ends in the Y direction, respectively. Compression springs 214 are housed in spaces surrounded by the cutout portions 212n of the movable frame 212 and the projections 211p of the fixed frame 211.

[0051] At a lower end portion of the lower portion 212L of the movable frame 212, a bottom surface 212a, which is a horizontal plane at a central portion in the Y direction, is formed. On both sides in the Y direction of the bottom surface 212a, inclined surfaces 212b connected to the bottom surface 212a are formed. The inclined surfaces 212b are inclined with respect to the bottom surface 212a and are planes perpendicular to the plane of FIG. 8 (that is, the YZ plane).

[0052] The movable anvil 20 includes an elevation driving unit 22 that drives the movable frame 212 up and down. The elevation driving unit 22 includes an air cylinder 221 and a wedge 222. A cylinder tube 221a of the air cylinder 221 is fixed to the fixed frame 211. A distal end portion of a piston rod 221b is inserted into the hollow portion 211a through the opening 211c of the fixed frame 211. The wedge 222 is detachably attached to a distal end of the piston rod 221b. The air cylinder 221 is mounted such that its operating direction is oriented in the Y direction, and the wedge 222 is moved in the Y direction by advancing and retracting the piston rod 221b.

[0053] On an upper surface of the wedge 222, a lower-stage plane 222a, an inclined surface 222b, and an upper-stage plane 222c are formed. The lower-stage plane 222a and the upper-stage plane 222c are both horizontal planes, and the upper-stage plane 222c is formed at a higher position than the lower-stage plane 222a. The inclined surface 222b is a plane parallel to the inclined surface 212b of the movable frame 212 and connects the lower-stage plane 222a and the upper-stage plane 222c.

[0054] When the piston rod 221b is retracted, the bottom surface 212a of the movable frame 212 is placed on the lower-stage plane 222a of the wedge 222. At this time, the movable frame 212 is positioned at a low position (lower stage).

[0055] When the piston rod 221b is pushed out, the inclined surface 222b of the wedge 222 comes into contact with the inclined surface 212b of the movable frame 212. When the piston rod 221b is further pushed out, the movable frame 212 is guided by the inclined surface 222b

and rises. When a lower end of the inclined surface 212b of the movable frame 212 passes over an upper end of the inclined surface 222b of the wedge 222, the bottom surface 212a of the movable frame 212 is placed on the upper-stage plane 222c of the wedge 222. At this time, the movable frame 212 is positioned at a high position (upper stage).

[0056] The movable frame 212 is pressed against the wedge 222 with an appropriate load by the compression springs 214. Thus, the movable frame 212 can be accurately positioned at a predetermined height.

[0057] As shown in FIGS. 1 and 2, each second driving unit 60D (60DL, 60DR) includes a driving module 62 (62L, 62R), a bearing unit 64 (64L, 64R), a bearing unit 65 (65L, 65R), and a ball screw 63 (63L, 63R). Each ball screw 63 (63L, 63R) includes a screw shaft 631 (631L, 631R) driven to rotate by the driving module 62 (62L, 62R), and a nut 632 (632L, 632R) that engages with the screw shaft 631 (631L, 631R).

[0058] The driving module 62L that moves the left movable anvil 20L is installed at a position near the left end on the top plate 2a of the base 2. The driving module 62R that moves the right movable anvil 20R is installed at a position near the right end on the top plate 2a.

[0059] Each driving module 62 (62L, 62R) includes a motor 621 (621L, 621R) and a coupling 622 (622L, 622R). As the motor 621, for example, a rotary motor of which angular position (rotational position) can be controlled, such as a servo motor or a stepping motor, is used.

[0060] Each coupling 622 (622L, 622R) connects a shaft 621a of the motor 621 (621L, 621R) and the screw shaft 631 (631L, 631R) of the ball screw 63 (63L, 63R). In this specification, one end of the screw shaft 631 connected to the shaft 621a of the motor 621 is referred to as a "proximal end" or "base end," and the other end is referred to as a "distal end."

[0061] The screw shaft 631L and the screw shaft 631R are arranged parallel to the X direction with their distal ends oriented in opposite directions. In the present embodiment, the screw shaft 631R is arranged directly above the screw shaft 631L. The screw shafts 631 (631L, 631R) are rotatably supported at their proximal ends by the bearing units 64 (64L, 64R) and at their distal ends by the bearing units 65 (65L, 65R), respectively. A through hole through which the screw shaft 631L passes is formed at a lower portion of the bearing unit 65R that supports the distal end of the screw shaft 631R.

[0062] The nut 632L of the ball screw 63L is attached to the left movable anvil 20L. The nut 632R of the ball screw 63R is attached to the right movable anvil 20R. Rotational motion output from each motor 621 (621L, 621R) is converted into linear motion in the X direction by the ball screw 63 (63L, 63R) and transmitted to the movable anvil 20 (20L, 20R). Each movable anvil

20 (20L, 20R) moves to a position in the X direction corresponding to an angular position of the shaft 621a of the motor 621 (621L, 621R).

[0063] As shown in FIGS. 2 and 3, the measurement unit M includes a plurality of pairs (for example, nine pairs) of measurement modules 70 (70A to 70I) and first measurement module moving units 80, and a pair of second measurement module moving units 90 (90L, 90R). The measurement modules 70 are units that measure runout of the workpiece W. The first measurement module moving unit 80 is a unit that guides movement of the measurement modules 70 in the X direction and moves the measurement modules 70 in the front-rear direction (Y direction) between a measurement position MP and a retracted position SP, which will be described later. The measurement modules 70 are installed on the corresponding first measurement module moving units 80. The second measurement module moving unit 90 is a unit that moves the measurement modules 70A to 70I to predetermined positions in the X direction.

[0064] As shown in FIG. 8, the first measurement module moving unit 80 includes a base 80b, a pair of linear guides 81, an electric linear actuator 82, and a stopper 83. The pair of linear guides 81 constitute a measurement module guide unit that guides movement of the measurement modules 70 in the X direction.

[0065] Each linear guide 81 is, for example, a ball circulation linear bearing. Each linear guide 81 includes a rail 811 extending in the X direction and mounted on the upper base plate 3b, and a plurality of carriages 812 capable of traveling on the rail 811. The rail 811 is shared by all (or some) of the first measurement module moving units 80. The pair of linear guides 81 are arranged side by side in the Y direction. Carriages 812 of the pair of linear guides 81 are attached to a lower surface of the base 80b. The base 80b is supported by the pair of linear guides 81 so as to be movable in the X direction with low friction.

[0066] The electric linear actuator 82 is mounted on the base 80b with its operating direction oriented in the Y direction. The measurement module 70 is mounted on a movable part 821 of the electric linear actuator 82. The electric linear actuator 82 moves the measurement module 70 in the Y direction between the measurement position MP where measurement of the workpiece W is possible and the retracted position SP where it is separated rearward from the workpiece W. FIG. 8 shows the measurement module 70 at the retracted position SP. At the measurement position MP, a distal end portion of a probe 74, which will be described later, is positioned below the workpiece W.

[0067] The stopper 83 is provided on the base 80b. The stopper 83 includes an air cylinder 831

and a shoe 832. The air cylinder 831 is arranged with a piston rod 831b oriented downward, and a cylinder tube 831a is attached to the base 80b. The shoe 832 is attached to a distal end portion of the piston rod 831b. By operation of the air cylinder 831, the shoe 832 moves up and down together with the piston rod 831b.

[0068] A movable part 83m of the stopper 83 (that is, the piston rod 831b and the shoe 832) moves up and down between an operating position AQ (lower position) where the shoe 832 is lowered and contacts the upper base plate 3b, and a retracted position SQ (upper position) where the shoe 832 is raised and separated from the upper base plate 3b. When the movable part 83m is at the operating position AQ, movement of the measurement module 70 is hindered by frictional force generated between the shoe 832 and the upper base plate 3b, and the position of the measurement module 70 is fixed. When the movable part 83m is at the retracted position SQ, fixing of the position of the measurement module 70 is released.

[0069] When the movable part 83m is at the retracted position SQ, no frictional force acts between the shoe 832 and the upper base plate 3b, and since the measurement module 70 is supported so as to be movable in the X direction with low friction by the linear guides 81, the position of the measurement module 70 becomes unstable.

[0070] When measuring runout of the workpiece W using the measurement module 70, the movable part 83m of the stopper 83 is moved to the operating position AQ in order to prevent the measurement module 70 from moving during measurement. Thus, measurement accuracy is improved.

[0071] The measurement module 70 includes a main frame 71, a lever 72, an arm 73, a probe 74, a contact-type displacement sensor 75, an air cylinder 76, and a tension coil spring 77.

[0072] The main frame 71 is installed on the movable part 821 of the electric linear actuator 82. The main frame 71 includes a base 71b and a bearing module 71s. The base 71b is provided at a lower end portion of the main frame 71 and is fixed to the movable part 821 of the electric linear actuator 82. The bearing module 71s is replaceably provided on an upper portion of the main frame 71. A pivot shaft 722 of the lever 72, which will be described later, is rotatably supported by the bearing module 71s.

[0073] The bearing module 71s includes a support block 711, a pair of holding plates 713, and two pairs of pressing units 714. A groove-shaped recess 711c penetrating in the Y direction is provided at a central portion in the X direction on an upper portion of the support block 711. A portion of the lever 72 (specifically, a shaft support portion that supports the pivot shaft 722) is accommodated in the recess 711c. A pair of bearing units 711b are provided on both sides in

the X direction of the recess.

[0074] On an upper surface of the support block 711 in each bearing unit 711b, a V-groove 711a extending in the X direction is formed. The pivot shaft 722 of the lever 72 is supported by the V-groove 711a. The pivot shaft 722 is held between the V-groove 711a and the holding plate 713 so that the pivot shaft 722 does not come out of the V-groove 711a. The holding plate 713 is pressed against the pivot shaft 722 on the V-groove 711a by the pair of pressing units 714.

[0075] Each pressing unit 714 includes a stud bolt 714a, a compression coil spring 714b, and a nut 714c. The nut 714c is, for example, a hexagonal nut with a flange. Screw holes (not shown) are provided at both ends in the Y direction on the upper surface of the support block 711 in the bearing unit 711b. Through holes (not shown) are provided at both ends in the Y direction of the holding plate 713. The stud bolt 714a is inserted into a hollow portion of the compression coil spring 714b, and a lower end portion of the stud bolt 714a is inserted into the screw hole. An upper end portion of the stud bolt 714a passes through the through hole of the holding plate 713, and the nut 714c is fitted to the upper end portion of the stud bolt 714a. By screwing the nut 714c onto the stud bolt 714a, the compression coil spring 714b is compressed, and a restoring force of the compression coil spring 714b is applied to the pivot shaft 722 via the holding plate 713. Thus, the pivot shaft 722 is pressed against the V-groove 711a, and separation of the pivot shaft 722 from the V-groove 711a is prevented.

[0076] The lever 72 includes a frame 721, and the pivot shaft 722 fixed to the frame 721. A center line of the pivot shaft 722 is oriented in the X direction and the pivot shaft 722 vertically penetrates a central portion of the frame 721 extending substantially in the Y direction. The lever 72 is supported by the bearing unit 711b of the main frame 71 so as to be pivotable about the pivot shaft 722. The lever 72 is pivotable between a substantially horizontal measurement position MR and a retracted position SR (shown by dashed lines in FIG. 8) in which a front side (left side in FIG. 8) is inclined downward.

[0077] Behind the bearing module 71s, the tension coil spring 77 is arranged with its axis oriented vertically. A lower end portion of the tension coil spring 77 is fixed to the main frame 71, and an upper end portion of the tension coil spring 77 is fixed to a rear portion of the lever 72. The tension coil spring 77 applies a clockwise torque in FIG. 8 to the lever 72.

[0078] Behind the bearing module 71s, the air cylinder 76 is arranged with a piston rod 762 oriented upward. A cylinder tube 761 of the air cylinder 76 is fixed to the main frame 71. A distal end of the piston rod 762 contacts a lower surface of the lever 72, and the rear portion of

the lever 72 is supported from below by the piston rod 762. The lever 72 pivots in accordance with operation of the air cylinder 76. Specifically, when the piston rod 762 is retracted, the rear portion of the lever 72 is pulled downward by tension of the tension coil spring 77 (that is, the lever 72 pivots clockwise in FIG. 8), and the lever 72 moves to the measurement position MR. When the piston rod 762 is pushed out, the rear portion of the lever 72 is pushed upward by the piston rod 762 (that is, the lever 72 pivots counterclockwise in FIG. 8), and the lever 72 moves to the retracted position SR.

[0079] Behind the bearing module 71s, the displacement sensor 75 is arranged with a contactor 752 oriented upward. The displacement sensor 75 is, for example, a contact-type displacement sensor of a differential transformer type. A sensor head body 751 of the displacement sensor 75 is fixed to the main frame 71. A distal end of the contactor 752 contacts a lower surface of a rear end portion of the lever 72. Vertical displacement of the rear end portion of the lever 72 is detected by the displacement sensor 75. Based on detection results of the displacement sensor 75, runout of the workpiece W is calculated by a controller 9a.

[0080] The arm 73 extending substantially in the Z direction is attached to a front end portion of the lever 72. A vertically extending elongated hole 732 is formed to the arm 73. By fitting a knob screw 733 inserted through the elongated hole 732 into a screw hole provided at the front end portion of the lever 72, the arm 73 is fixed to the lever 72. The elongated hole 732 and the knob screw 733 constitute a height adjustment mechanism 73a, and when the knob screw 733 is loosened, the height of the arm 73 can be changed.

[0081] As shown in FIGS. 2 and 3, each second measurement module moving unit 90 (90L, 90R) includes an electric linear actuator 91, an air cylinder 92, and a catcher 93. The catcher 93 is composed of a convex part 931 and a concave part 932 (FIG. 8) that are engageable with each other.

[0082] The electric linear actuator 91 is arranged with its operating direction oriented in the X direction, and a base 911 (fixed part) is attached to a rear surface of the base 2. The second measurement module moving unit 90L is attached to a left side of the base 2 and can move four measurement modules 70A to 70D on the left side in the X direction. The second measurement module moving unit 90R is attached to a right side of the base 2 and can move four measurement modules 70F to 70I on the right side in the X direction. It should be noted that all the measurement modules 70 may be moved by one second measurement module moving unit having a wide movable range.

[0083] The air cylinder 92 is arranged with a piston rod 922 oriented forward, and a cylinder

tube 921 is attached to a slider 912 (movable part) of the electric linear actuator 91. As shown in FIG. 8, one of the convex part 931 and the concave part 932 of the catcher 93 is attached to a distal end of the piston rod 922 of the air cylinder 92. The other of the convex part 931 and the concave part 932 of the catcher 93 is attached to a rear surface of the base 80b of each first measurement module moving unit 80.

[0084] For example, moving of the measurement module 70B with the second measurement module moving unit 90L is performed in the following procedure. First, the stopper 83 of the first measurement module moving unit 80 is set to the retracted position SQ so that the measurement module 70B can move in the X direction. Then, the electric linear actuator 91 is driven to move the slider 912 (movable part) to behind the measurement module 70B. Then, when the air cylinder 92 is driven to push the piston rod 922 forward, the convex part 931 (or the concave part 932) attached to the distal end of the piston rod 922 engages with the concave part 932 (or the convex part 931) attached to the rear surface of the first measurement module moving unit 80. By the engagement between the convex part 931 and the concave part 932 of the catcher 93, the first measurement module moving unit 80 is positioned in the X direction relative to the second measurement module moving unit 90L. Then, in a state in which the convex part 931 and the concave part 932 are engaged, the electric linear actuator 91 is driven to move the slider 912 to a destination of the measurement module 70B, whereby the measurement module 70B and the first measurement module moving unit 80 move together with the slider 912 to the destination of the measurement module 70B. Then, the stopper 83 of the first measurement module moving unit 80 is set to the operating position AQ to fix the position of the measurement module 70. Then, when the air cylinder 92 is driven to retract the piston rod 922 rearward, the engagement between the convex part 931 and the concave part 932 of the catcher 93 is released. In this manner, the measurement module 70 can be moved to a predetermined position in the X direction by the second measurement module moving unit 90.

[0085] FIG. 9 is a block diagram showing a schematic configuration of a control system 9 of the shaft distortion correcting apparatus 1. The control system 9 includes the controller 9a that integrally controls the entire shaft distortion correcting apparatus 1, and a pneumatic controller 9b that controls operation of each air cylinder. The controller 9a is constituted by, for example, an industrial PC (Personal Computer), a PLC (Programmable Logic Controller), or a composite control device formed by combining these.

[0086] The controller 9a is communicably connected to the press unit 6, the electric linear actuators 82 and 91, the rotary encoder 43, the displacement sensor 75, the pneumatic controller

9b, and amplifiers 33a, 521La, 521Ra, 621La, and 621Ra. The amplifiers 33a, 521La, 521Ra, 621La, and 621Ra are respectively connected to the motors 33, 521L, 521R, 621L, and 621R, and supply driving power to the respective motors.

[0087] The controller 9a includes an interface unit 9c that performs input and output with the outside. The interface unit 9c includes, for example, one or more of a user interface for performing input/output with a user, a network interface for connection to various networks such as a LAN (Local Area Network), and various communication interfaces such as USB (Universal Serial Bus) and GPIB (General Purpose Interface Bus) for connection with external devices. The user interface also includes various input/output devices such as, for example, one or more of various operation switches, indicators, various display devices such as LCDs (liquid crystal displays), various pointing devices such as a mouse and a touch pad, a touch screen, a video camera, a printer, a scanner, a buzzer, a speaker, a microphone, and a memory card reader/writer.

[0088] The shaft distortion correcting apparatus 1 of the present embodiment is configured to be able to perform distortion correction of workpieces W having various lengths. FIGS. 1 and 2 show the shaft distortion correcting apparatus 1 during long-length setting applied when processing a relatively long workpiece W. FIG. 10 is a plan view showing the shaft distortion correcting apparatus 1 during short-length setting applied when processing a relatively short workpiece W.

[0089] In the long-length setting, as shown in FIG. 2, the workpiece driving unit 30 is arranged near the left end portion of the rail 511 (specifically, to the left of the leftmost measurement module 70A), and the encoder unit 40 is arranged near the right end portion of the rail 511 (specifically, to the right of the rightmost measurement module 70I). In the long-length setting, distortion of the workpiece W is measured using all the measurement modules 70 from the leftmost measurement module 70A to the rightmost measurement module 70I.

[0090] In the short-length setting, the workpiece driving unit 30 is arranged substantially in front of the measurement module 70C, and the encoder unit 40 is arranged substantially in front of the measurement module 70G. In the short-length setting, runout of the workpiece W is measured using only three central measurement modules 70D to 70F.

[0091] The positions of the workpiece driving unit 30 and the encoder unit 40 can be automatically changed by the anvil moving unit 50. According to the shaft distortion correcting apparatus 1 of the embodiment of the present invention, it is possible to automatically perform setup changeover between the long-length setting and the short-length setting.

[0092] The arrangement of the workpiece driving unit 30 and the encoder unit 40 is changed according to the length of the workpiece W. For example, the workpiece driving unit 30 may be arranged substantially in front of the measurement module 70A, and the encoder unit 40 may be arranged substantially in front of the measurement module 70I. In this case, runout of the workpiece W is measured using seven central measurement modules 70B to 70H. The workpiece driving unit 30 may be arranged substantially in front of the measurement module 70B, and the encoder unit 40 may be arranged substantially in front of the measurement module 70H. In this case, runout of the workpiece W is measured using five central measurement modules 70C to 70G.

[0093] FIG. 11 is a flowchart showing a procedure of a shaft distortion correction process according to an embodiment of the present invention in which distortion of the workpiece W is corrected using the shaft distortion correcting apparatus 1. The shaft distortion correction process is performed under control of the controller 9a.

[0094] When the shaft distortion correcting apparatus 1 is switched on, an initialization process is performed, and after each part of the shaft distortion correcting apparatus 1 is arranged at a predetermined initial position, the shaft distortion correction process (FIG. 11) is started. In the shaft distortion correction process, first, a setup process S1 is performed.

[0095] FIG. 12 is a flowchart showing a procedure of the setup process S1 according to an embodiment of the present invention. In the setup process S1, first, a model type of the workpiece W to be subjected to shaft distortion correction is input (S11). The input of the model type is performed, for example, by a user touching a registered model displayed on a touch screen with a finger.

[0096] A dimension table is stored in storage of the controller 9a. In the dimension table, dimensional information including the length of the workpiece W is registered in advance for each model type. The controller 9a acquires the dimensional information corresponding to the input model type of the workpiece W from the dimension table (S12).

[0097] Then, the controller 9a determines a setting of the shaft distortion correcting apparatus 1 based on the dimensional information of the workpiece W (S13). The determination of the setting is performed, for example, based on a determination table that defines a correspondence relationship between the dimensional information and settings to be applied, which is set in advance. The determination table is stored in the storage of the controller 9a. Hereinafter, a case where the setting is determined to be the long-length setting shown in FIG. 1 will be described as an example.

[0098] A setting table is stored in the storage of the controller 9a. In the setting table, specific setting information for each setting is recorded in advance. The controller 9a acquires the setting information of the determined setting from the setting table (S14).

[0099] Then, the controller 9a drives the second measurement module moving unit 90 to sequentially move the measurement modules 70A to 70I to predetermined positions in the X direction (setting positions defined by the setting information) (S15). After moving the measurement modules 70A to 70I, the controller 9a drives the air cylinder 831 of the stopper 83 to move the shoe 832 to the operating position AQ, thereby fixing the measurement modules 70.

[0100] Then, the controller 9a drives the first driving unit 50DL to move the workpiece driving unit 30 to a predetermined position in the X direction (setting position defined by the setting information) (S16).

[0101] Then, the controller 9a drives the first driving unit 50DR to move the encoder unit 40 to a predetermined position in the X direction (setting position defined by the setting information) (S17). Thus, the setup process S1 is completed. The processes S15 to S17 may be performed simultaneously or in any order.

[0102] Then, the workpiece W is conveyed into the shaft distortion correcting apparatus 1 by a not-shown conveying device, and both end portions of the workpiece W are placed on the respective roller anvils 10 (S2).

[0103] Then, initial runout of the workpiece W is measured (S3). In S3, first, the controller 9a drives each first measurement module moving unit 80 to move all the measurement modules 70A to 70I forward from the retracted position SP to the measurement position MP.

[0104] Then, the controller 9a drives the air cylinder 32 of the workpiece driving unit 30 and the encoder unit 40 to switch the workpiece driving unit 30 and the encoder unit 40 from the standby mode to the operating mode. Thus, the end portions of the workpiece W are gripped by the pair of rollers 163 of the roller anvil 10 and the roller 36 of the driving module 30A (or encoder module 40A).

[0105] Then, the controller 9a drives the motor 33 of the workpiece driving unit 30 to rotate the workpiece W at a predetermined speed, and measures runout at each portion in the longitudinal direction of the workpiece W using the measurement modules 70A to 70I. When measurement is completed, driving of the motor 33 is stopped, and the workpiece W is stopped. The controller 9a stores the measurement results in the storage.

[0106] Then, it is determined whether or not the measurement result of the initial runout of the

workpiece W satisfies a predetermined criterion (pass criterion) (S4). The pass criterion defined for each model type of the workpiece W is stored in advance in, for example, a criterion table stored in the storage of the controller 9a. The controller 9a acquires the pass criterion corresponding to the model type of the workpiece W from the criterion table, compares the measurement result with the pass criterion, and determines whether the workpiece W passes or fails.

[0107] When the workpiece W is determined to pass (S4: YES), the process proceeds to S6.

[0108] When the workpiece W is determined to fail (S4: NO), then a correction process S5 is performed. In the correction process S5, first, the controller 9a determines correction contents necessary for distortion correction the workpiece W (specifically, correction portions and correction amounts). The determination of the correction contents is performed, for example, using a calculation formula set for each model type of the workpiece W. This calculation formula is stored, for example, in the storage of the controller 9a.

[0109] Then, the controller 9a drives each first measurement module moving unit 80 to retract all the measurement modules 70A to 70I from the measurement position MP to the retracted position SP.

[0110] Then, the controller 9a drives the second driving units 60DL and 60DR to move the left and right movable anvils 20L and 20R to predetermined positions on both sides in the X direction of the correction portion. For example, when correcting a measurement location of the measurement module 70B, as shown in FIGS. 1 and 2, the left movable anvil 20L is moved to a position between the measurement module 70A and the measurement module 70B in the X direction, and the right movable anvil 20R is moved to a position between the measurement module 70B and the measurement module 70C in the X direction.

[0111] Then, the controller 9a drives the motor 33 of the workpiece driving unit 30 to rotate the workpiece W to a predetermined angular position. Specifically, the workpiece W is rotated to a position rotated by 180° from an angular position at which a maximum displacement toward the outer peripheral side was measured in the runout measurement S3, and the workpiece W is held at that position.

[0112] Then, the controller 9a operates the moving device of the press unit 6 to move the press head 6a in the X direction to the correction portion. Then, the press head 6a is lowered, and the correction portion of the workpiece W is pressed downward by the press head 6a to correct the workpiece. Then, the press head 6a is raised until it separates from the workpiece W. If a displacement amount of the surface of the workpiece W from before to after the correction

detected by the measurement module 70B is approximately equal to a predetermined correction amount, the correction process S5 is ended, and the runout measurement S3 is performed again. If the displacement amount of the surface of the workpiece W from before to after the correction is smaller than the predetermined correction amount, correction by the press unit 6 is repeated until the displacement amount of the surface of the workpiece W from before to after the correction becomes approximately equal to the predetermined correction amount.

[0113] Until the workpiece W is determined to pass in the process S4, the processes S3 to S5 are repeated. When the workpiece W is determined to pass (S4: YES), the controller 9a then drives the air cylinders 32 of the workpiece driving unit 30 and the encoder unit 40 to switch the workpiece driving unit 30 and the encoder unit 40 from the operating mode to the standby mode. Thus, gripping of the end portions of the workpiece W by the pair of rollers 163 of the roller anvil 10 and the roller 36 of the driving module 30A (or encoder module 40A) is released. Then, the workpiece W is conveyed out of the shaft distortion correcting apparatus 1 by the conveying device (S6).

[0114] Then, it is confirmed whether or not to end the shaft distortion correction process (S7). When continuing the shaft distortion correction process (S7: NO), it is next confirmed whether or not to change the model type of the workpiece W to be subjected to shaft distortion correction (S8). When changing the model type of the workpiece W (S8: YES), the process proceeds to the setup process S1. When not changing the model type (S8: NO), the process proceeds to the workpiece conveyance process S2. The processes S1 to S8 are repeated until the shaft distortion correction process is ended.

[0115] FIGS. 13 and 14 are plan views of a shaft distortion correcting apparatus 1000 as a comparative example that does not include an automatic setup system. FIG. 13 shows a state of long-length setting, and FIG. 14 shows a state of short-length setting.

[0116] The shaft distortion correcting apparatus 1000 includes a movable anvil measurement unit 1020, a workpiece driving unit 1030, and an encoder unit 1040 (hereinafter, these three types of units are referred to as functional units). The movable anvil measurement unit 1020 is a functional unit obtained by combining the movable anvil 20 and the measurement module 70 of the above embodiment. Each functional unit is configured to be manually attachable to and detachable from a pair of rails 1511. The functional units 1020, 1030, and 1040 include lock levers 1029, 1039, and 1049, respectively. When the lock levers 1029, 1039, and 1049 are rotated clockwise in a state in which the functional units 1020, 1030, and 1040 are mounted at predetermined positions on the pair of rails 1511, the functional units 1020, 1030, and 1040 are

fixed to the rails 1511.

[0117] When changing setup of the shaft distortion correcting apparatus 1000 from the long-length setting (FIG. 13) to the short-length setting (FIG. 14), first, all of a plurality of cable connectors (not shown) and air couplers (not shown) connected to respective functional units are removed. In this comparative example, since two cable connectors and air couplers are connected to each functional unit, it is necessary to remove a total of 18 cable connectors and a total of 18 air couplers.

[0118] Then, all the functional units except the movable anvil measurement unit 1020 at the center are removed. When removing the functional units, the lock levers 1029, 1039, and 1049 are rotated counterclockwise to release fixation of the functional units 1020, 1030, and 1040. Then, the workpiece driving unit 1030 and the encoder unit 1040 are manually moved to predetermined positions, and then the lock levers 1039 and 1049 are rotated clockwise to fix the workpiece driving unit 1030 and the encoder unit 1040 to the rails 1511. Further, various settings of a controller (not shown) are manually changed from settings for long workpieces to settings for short workpieces.

[0119] Thus, in the shaft distortion correcting apparatus 1000 of the comparative example, since the number of functional units and the number of cables and pipes connected thereto are large, many manual operations are required for setup change, and the burden on the operator is large. In particular, moving and attachment/detachment work of the movable anvil measurement units 1020, which are heavy, impose a large burden on the operator. Further, there are many setting items of the controller that need to be changed during setup change, and setting errors are likely to occur. Therefore, time required for setup change is long, and the operating rate of the shaft distortion correcting apparatus 1000 is low. Further, since each functional unit is manually moved, wear of the functional units is large.

[0120] In the shaft distortion correcting apparatus 1 according to the embodiment of the present invention, since the setup process is fully automated, all of the above-described problems of the comparative example are solved. In particular, the time required for the setup process is reduced to one minute or less in the present embodiment, compared to an average of about 15 minutes in the comparative example, thereby greatly improving productivity and working environment of operators. Further, since electric motors are used as driving means except for air cylinders, compared to, for example, a case of using hydraulic devices, operation noise is small and energy utilization efficiency is high. In the comparative example, the movable anvil measurement unit 1020 obtained by combining the movable anvil and the measurement unit is used. In other

words, in the comparative example, a movable anvil is provided for each of nine measurement units. In contrast, in the shaft distortion correcting apparatus 1 of the present embodiment, by configuring the movable anvils independently from the measurement units so that each movable anvil can automatically move to a correction portion, the number of movable anvils is reduced to two, and a significant reduction in the number of components is achieved.

[0121] The above is a description of exemplary embodiments of the present invention. The embodiments of the present invention are not limited to those described above, and various modifications are possible within the scope of the technical idea of the present invention. For example, combinations of embodiments exemplarily disclosed in the specification and/or obvious embodiments are also included in the embodiments of the present invention.

[0122] In the above embodiment, the first driving unit 50DL that moves the workpiece driving unit 30 in the X direction, the first driving unit 50DR that moves the encoder unit 40 in the X direction, the second driving units 60 that move the movable anvils 20 in the X direction, the first measurement module moving units 80 that move the measurement modules 70 in the Y direction, and the second measurement module moving units 90 that move the measurement modules 70 in the X direction are provided, thereby realizing full automation of the setup process. However, the present invention is not limited to this configuration, and configurations including one or more of the first driving units 50DL, 50DR, the second driving units 60, the first measurement module moving units 80, and the second measurement module moving units 90 are also included in the present invention.

[0123] In the above embodiment, since the measurement and correction reference of the workpiece W is the outer peripheral surface, a configuration is adopted in which the workpiece W is supported and driven by a plurality of rollers that contact the outer peripheral surface of the workpiece W (specifically, the pair of rollers 163 of the roller anvil 10 and the roller 36 of the driving module 30A/encoder module 40A). However, the present invention is not limited to this configuration. For example, when an inner peripheral surface of a tubular workpiece W is used as the measurement and correction reference, a configuration may be adopted in which a pair of rotating centers each having a conical tip portion are inserted into a center hole of the workpiece W from both ends, and the workpiece W is supported and driven by the pair of rotating centers.

[0124] Hereinafter, the above-described embodiments of the present invention will be summarized.

[0125] According to an aspect of the present invention, there is provided a shaft distortion

correcting apparatus including an anvil that supports a workpiece, a linear guide that supports the anvil so as to be movable in an axial direction of the workpiece, and an anvil moving unit that moves the anvil in the axial direction of the workpiece.

[0126] In the above shaft distortion correcting apparatus, the anvil moving unit may include a servo motor, and a ball screw that converts rotational motion output from the servo motor into linear motion.

[0127] In the above shaft distortion correcting apparatus, the anvil may include a first anvil that supports an end portion of the workpiece, and the anvil moving unit may include a first anvil moving unit that moves the first anvil.

[0128] In the above shaft distortion correcting apparatus, the first anvil may be a roller anvil including a pair of rollers arranged parallel to the workpiece and supporting the end portion of the workpiece rotatably from below.

[0129] In the above shaft distortion correcting apparatus, the first anvil may include an anvil unit formed with a support surface that statically supports the workpiece, a pair of roller units including rollers and arranged side by side in a horizontal direction perpendicular to the axis with the anvil unit interposed therebetween, and an elevating means capable of raising and lowering the pair of roller units. The elevating means may raise and lower the roller units between a lock position lower than a height at which the workpiece contacts both the support surface and the rollers of the anvil unit and an unlock position higher than the height at which the workpiece contacts both the support surface and the rollers of the anvil unit.

[0130] In the above shaft distortion correcting apparatus, the anvil may include a second anvil that supports a correction portion of the workpiece, and the anvil moving unit may include a second anvil moving unit that moves the second anvil in the axial direction of the workpiece.

[0131] In the above shaft distortion correcting apparatus, the second anvil may include a fixed frame, a movable frame movable up and down relative to the fixed frame, and an elevation driving unit that drives the movable frame up and down. A second support surface that statically supports the workpiece may be formed on an upper surface of the movable frame, and the elevation driving unit may raise and lower the movable frame between a first height suitable for supporting a workpiece having a first outer diameter and a second height suitable for supporting a workpiece having a second outer diameter.

[0132] The above shaft distortion correcting apparatus may include a workpiece driving unit that rotationally drives the workpiece. The workpiece driving unit may include a second fixed frame, a second movable frame connected to the second fixed frame pivotably about a pivot

axis perpendicular to the axial direction of the workpiece, a pivot drive unit that pivotally drives the second movable frame, a shaft rotatably supported by the second movable frame, a drive means that rotationally drives the shaft, and a second roller attached to a distal end portion of the shaft. The pivot drive unit may pivot the second roller between an operating position where the second roller contacts an end portion of the workpiece such that the second roller and the workpiece constitute a friction wheel and a retracted position where the second roller is separated from the workpiece.

[0133] The above shaft distortion correcting apparatus may include a measurement module that measures runout of the workpiece, a second linear guide that supports the measurement module so as to be movable in the axial direction of the workpiece, and a first measurement module moving unit that moves the measurement module in the axial direction of the workpiece.

[0134] In the above shaft distortion correcting apparatus, the measurement module may include a probe extending in a first horizontal direction perpendicular to the axial direction of the workpiece, and the above shaft distortion correcting apparatus may include a measurement module moving unit that moves the measurement module in an extending direction of the probe, and the measurement module moving unit may move the measurement module between a measurement position where the probe contacts the workpiece and can measure runout of the workpiece and a retracted position where the probe is separated from the workpiece.

[0135] The above shaft distortion correcting apparatus may include a second pivot drive unit that pivotally drives the probe about a second pivot axis parallel to the workpiece.

[0136] The above shaft distortion correcting apparatus may be configured to include a measurement module that measures runout of the workpiece, a second linear guide that supports the measurement module so as to be movable in the axial direction of the workpiece, and a first measurement module moving unit that moves the measurement module in the axial direction of the workpiece.

DESCRIPTION OF REFERENCE NUMERALS

[0137] 1 Shaft distortion correcting apparatus

10 Roller anvil

20 Movable anvil

30 Workpiece driving unit

40 Encoder unit

50 Anvil moving unit

70 Measurement module

80 First measurement module moving unit

90 Second measurement module moving unit

CLAIMS

1. A shaft distortion correcting apparatus comprising:

an anvil that supports a workpiece;

a linear guide that supports the anvil so as to be movable in an axial direction of the workpiece; and

an anvil moving unit that moves the anvil in the axial direction of the workpiece.

2. The shaft distortion correcting apparatus according to claim 1,

wherein the anvil moving unit includes:

a servo motor; and

a ball screw that converts rotational motion output from the servo motor into linear motion.

3. The shaft distortion correcting apparatus according to claim 1,

wherein the anvil includes a first anvil that supports an end portion of the workpiece, and

the anvil moving unit includes a first anvil moving unit that moves the first anvil.

4. The shaft distortion correcting apparatus according to claim 3,

wherein the first anvil is a roller anvil including a pair of rollers arranged parallel to the workpiece and supporting the end portion of the workpiece rotatably from below.

5. The shaft distortion correcting apparatus according to claim 4,

wherein the first anvil includes:

an anvil unit formed with a support surface that statically supports the workpiece;

a pair of roller units including rollers and arranged side by side in a horizontal direction perpendicular to the axis with the anvil unit interposed therebetween; and

an elevating means capable of raising and lowering the pair of roller units,

wherein the elevating means raises and lowers the roller units between

a lock position lower than a height at which the workpiece contacts both the support surface and the rollers of the anvil unit and

an unlock position higher than the height at which the workpiece contacts both the support surface and the rollers of the anvil unit.

6. The shaft distortion correcting apparatus according to claim 1,

wherein the anvil includes a second anvil that supports a correction portion of the workpiece, and

the anvil moving unit includes a second anvil moving unit that moves the second anvil in the axial direction of the workpiece.

7. The shaft distortion correcting apparatus according to claim 6,

wherein the second anvil includes:

a fixed frame;

a movable frame movable up and down relative to the fixed frame; and

an elevation driving unit that drives the movable frame up and down,

wherein a second support surface that statically supports the workpiece is formed on an upper surface of the movable frame, and

the elevation driving unit raises and lowers the movable frame between

a first height suitable for supporting a workpiece having a first outer diameter and

a second height suitable for supporting a workpiece having a second outer diameter.

8. The shaft distortion correcting apparatus according to claim 1,

comprising a work driving unit that rotationally drives the workpiece,

wherein the work driving unit includes:

a second fixed frame;

a second movable frame connected to the second fixed frame pivotably about a pivot axis perpendicular to the axial direction of the workpiece;

a pivot drive unit that pivotally drives the second movable frame;

a shaft rotatably supported by the second movable frame;

a drive means that rotationally drives the shaft; and

a second roller attached to a distal end portion of the shaft,

wherein the pivot drive unit pivots the second roller between:

an operating position where the second roller contacts an end portion of the workpiece such that the second roller and the workpiece constitute a friction wheel; and

a retracted position where the second roller is separated from the workpiece.

9. The shaft distortion correcting apparatus according to claim 1, comprising:

a measurement module that measures runout of the workpiece;

a second linear guide that supports the measurement module so as to be movable in the axial direction of the workpiece; and

a first measurement module moving unit that moves the measurement module in the axial direction of the workpiece.

10. The shaft distortion correcting apparatus according to claim 9,

wherein the measurement module includes a probe extending in a first horizontal direction perpendicular to the axial direction of the workpiece,

the shaft distortion correcting apparatus comprises a measurement module moving unit that moves the measurement module in an extending direction of the probe, and

the measurement module moving unit moves the measurement module between:

a measurement position where the probe contacts the workpiece and can measure runout of the workpiece; and

a retracted position where the probe is separated from the workpiece.

11. The shaft distortion correcting apparatus according to claim 10,

comprising a second pivot drive unit that pivotally drives the probe about a second pivot axis parallel to the workpiece.

12. A shaft distortion correcting apparatus comprising:

a measurement module that measures runout of a workpiece;

a second linear guide that supports the measurement module so as to be movable in an axial direction of the workpiece; and

a first measurement module moving unit that moves the measurement module in the axial direction of the workpiece.