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(54) POSITIONING METHOD, PRESS-FITTING APPARATUS, PIN PROCESSING METHOD, EXPOSURE APPARATUS, AND ARTICLE MANUFACTURING METHOD

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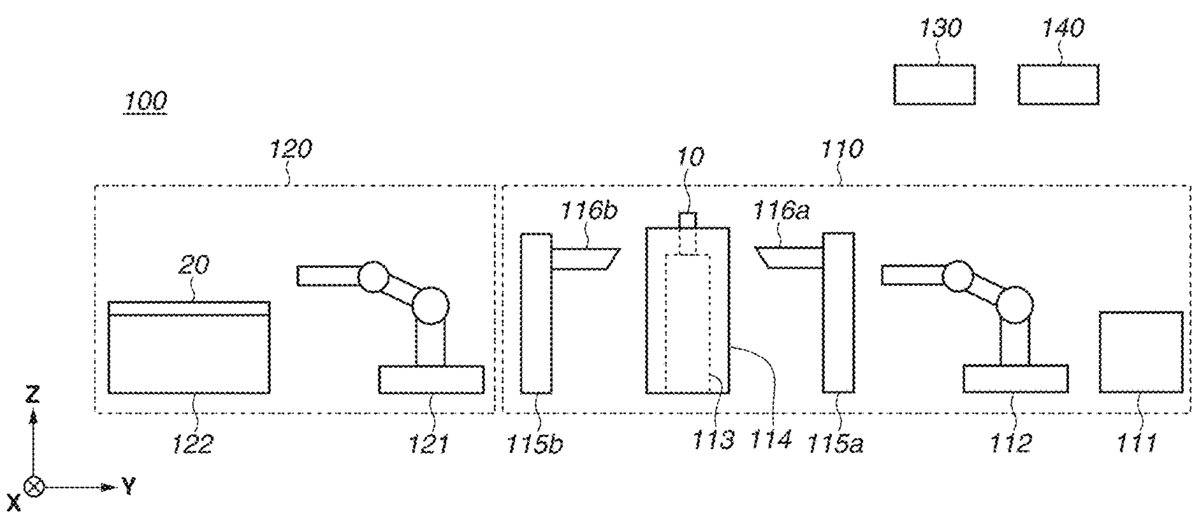
(57) **ABSTRACT**

Disclosed is a method for positioning a second member with respect to a first member, including deforming a pin to form an indentation, press-fitting the deformed pin into a hole in the first member; and abutting the second member against the pin, wherein, when abutting the second member, a center position of a deformed area of the pin is closer to the second member than to a central axis of the pin.



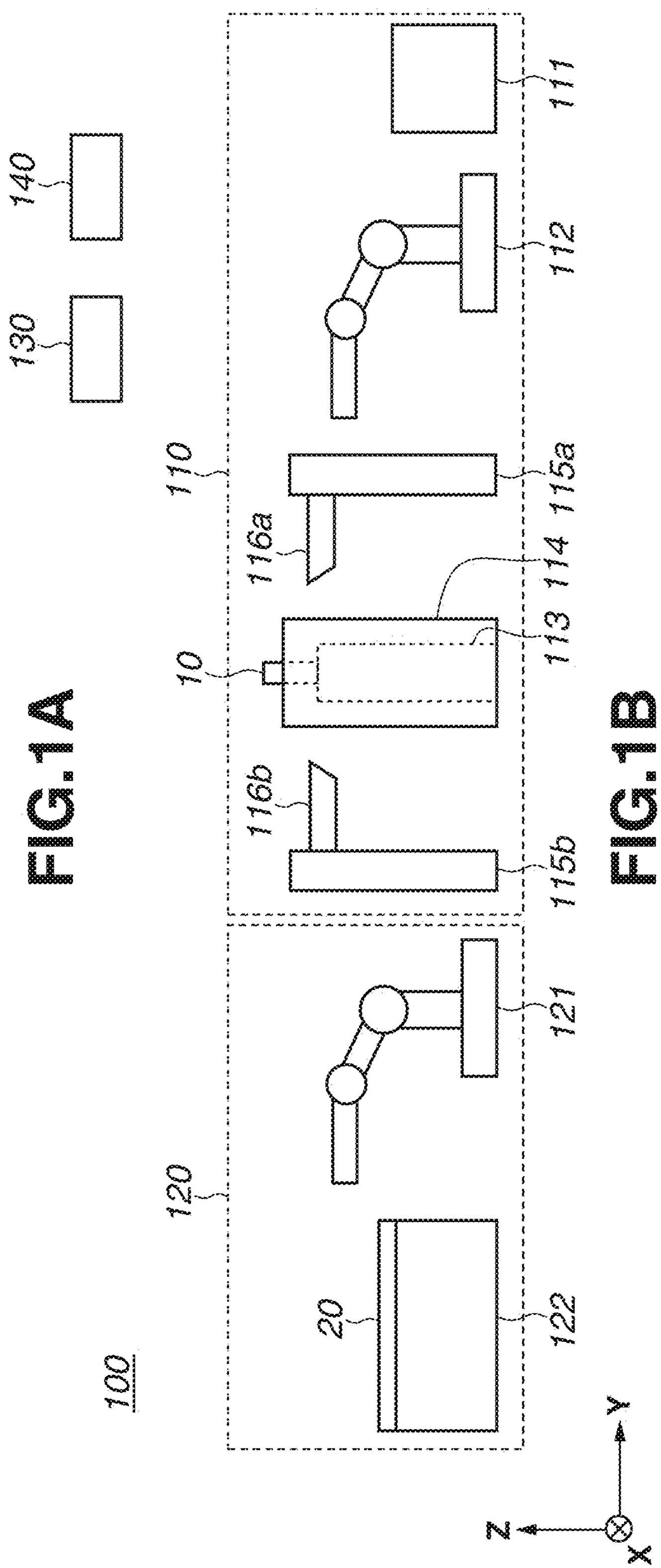

100
110
111
112
113
114
115a
115b
116a
116b
10
120
121
122
20
130
140
X
Y
Z

FIG.1A

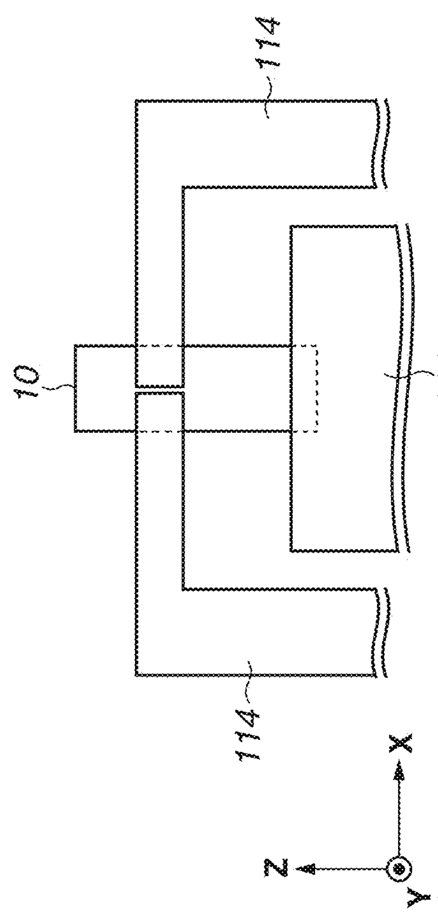

10
113
114
114
114
X
Y
Z

FIG.1B

FIG.2A

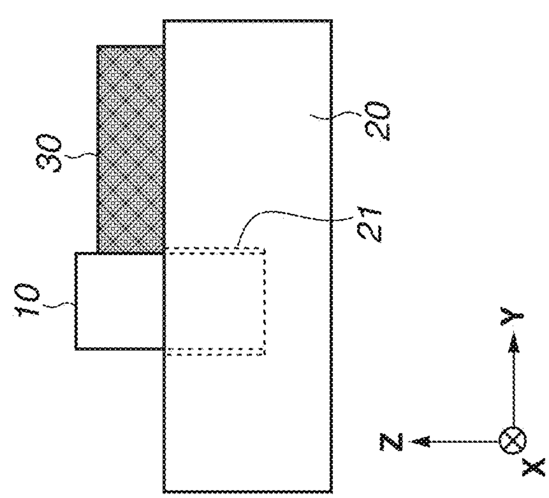


FIG.2B

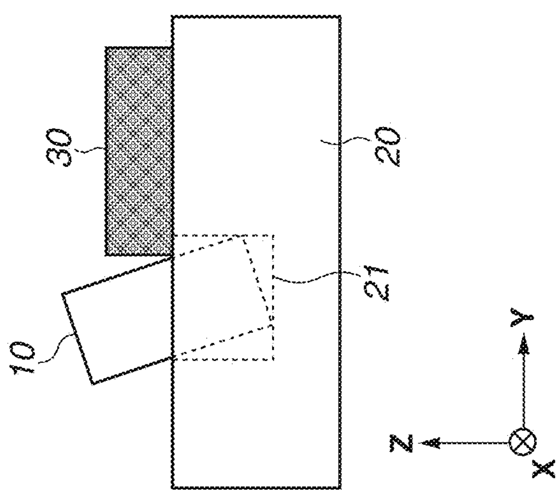


FIG.2C

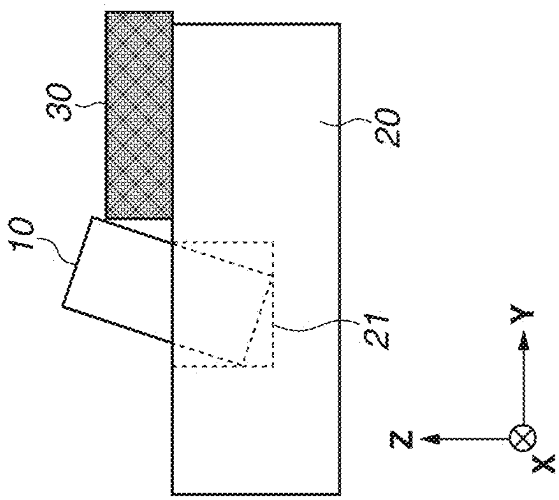


FIG.3A

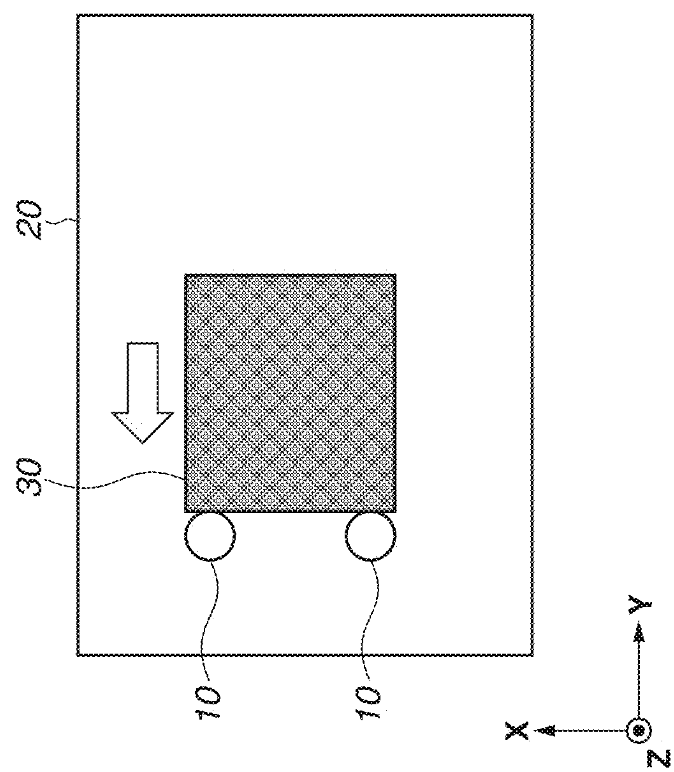


FIG.3B

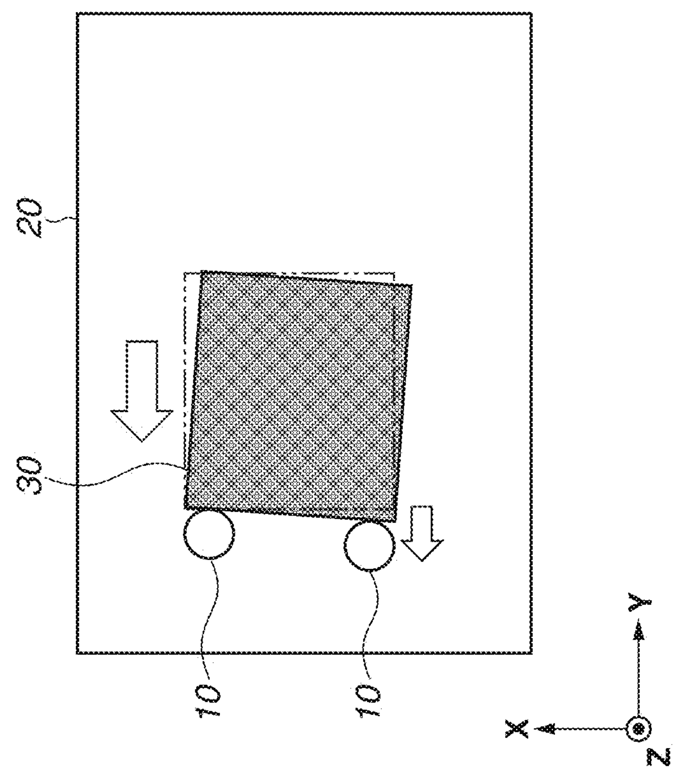


FIG.4A

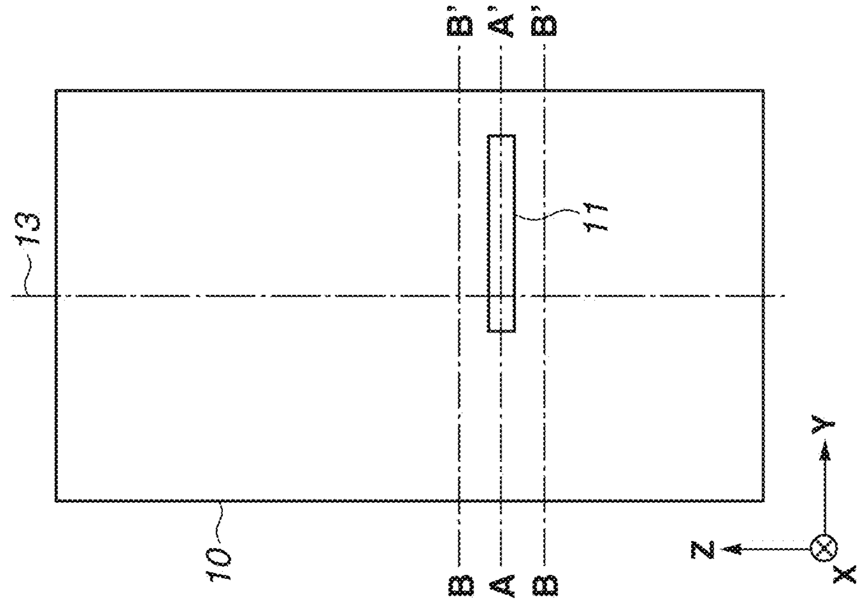


FIG.4B

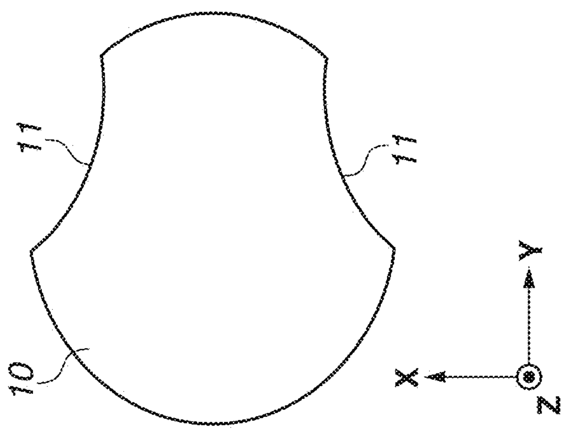


FIG.4C

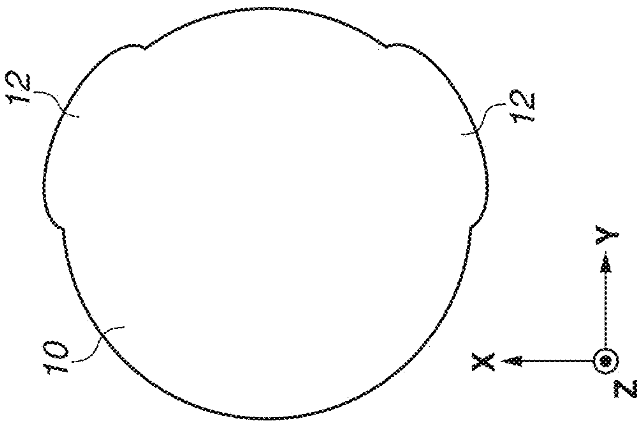


FIG.5C

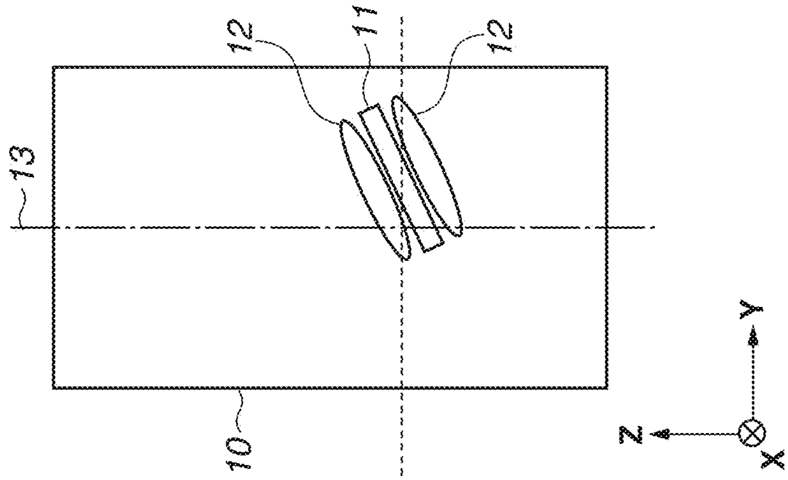


FIG.5B

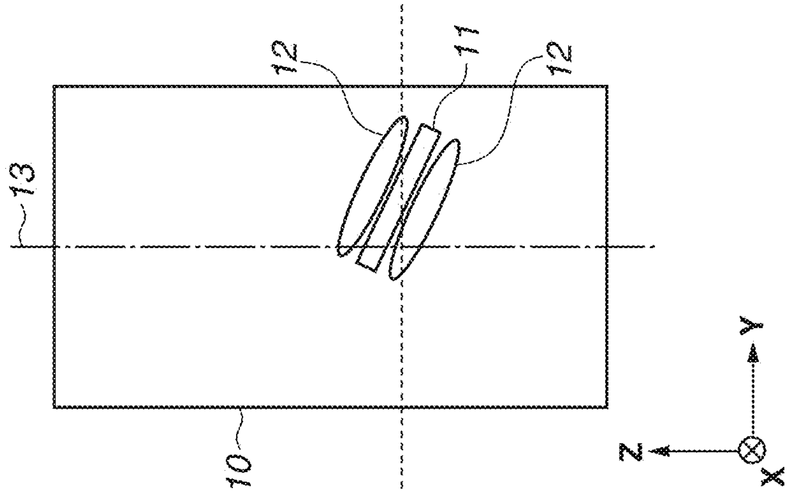


FIG.5A

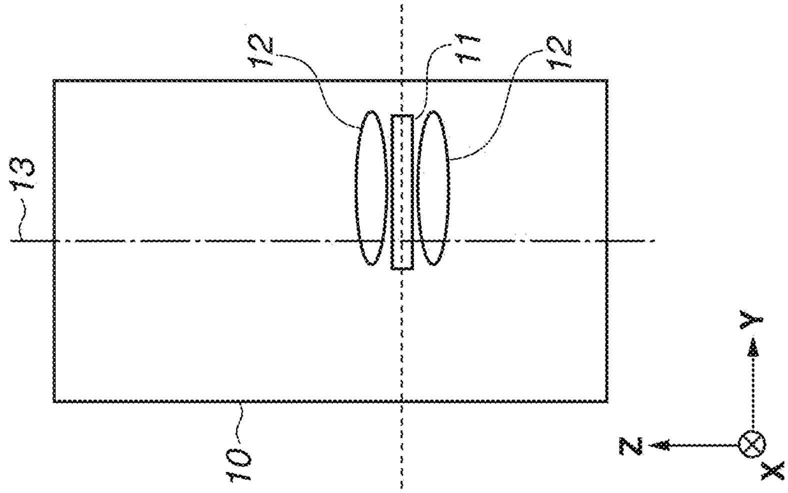


FIG.6A

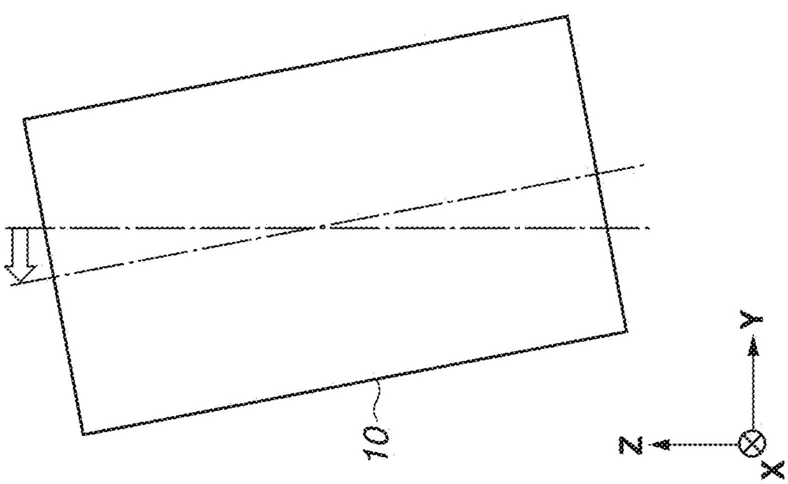


FIG.6B

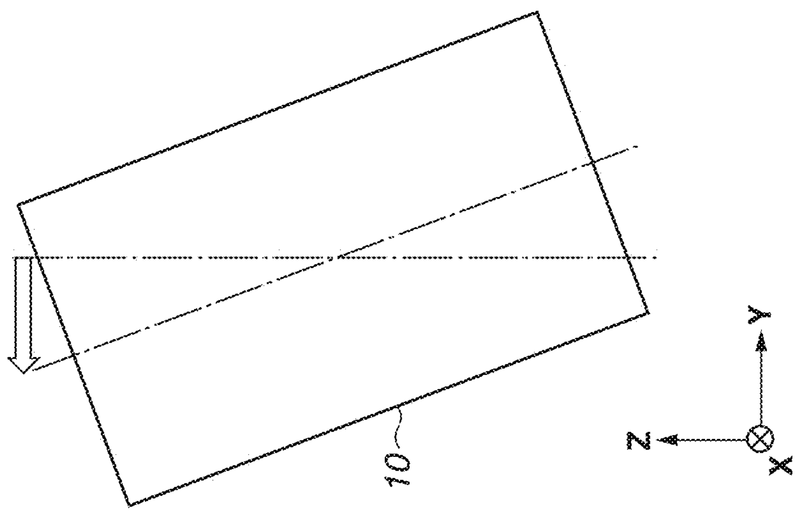
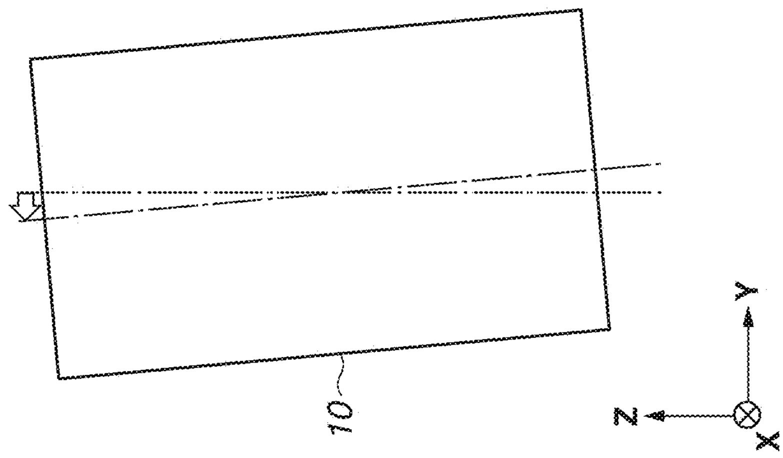


FIG.6C



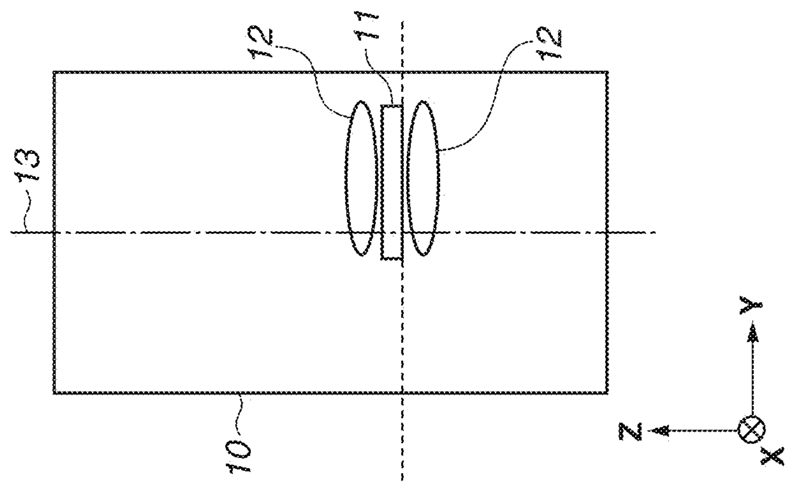


FIG.7C

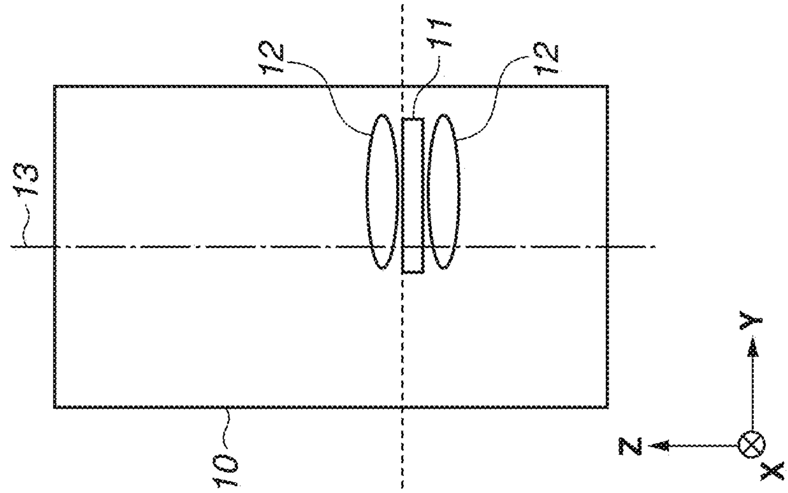


FIG.7B

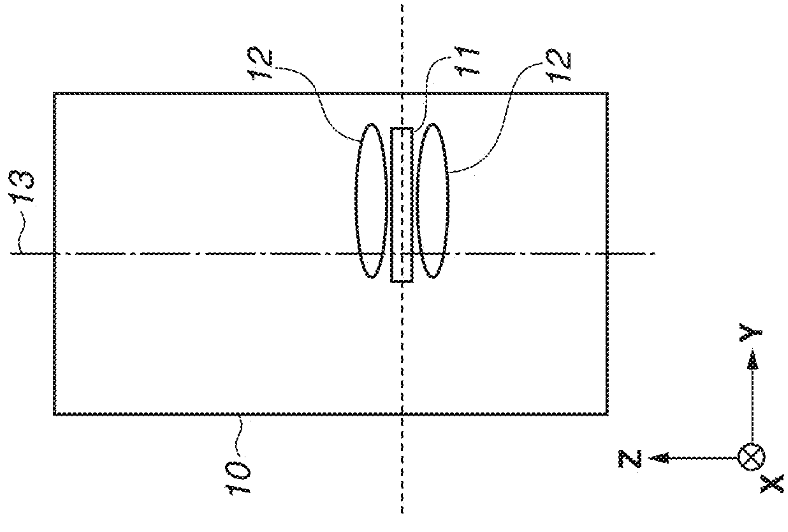


FIG.7A

FIG.8

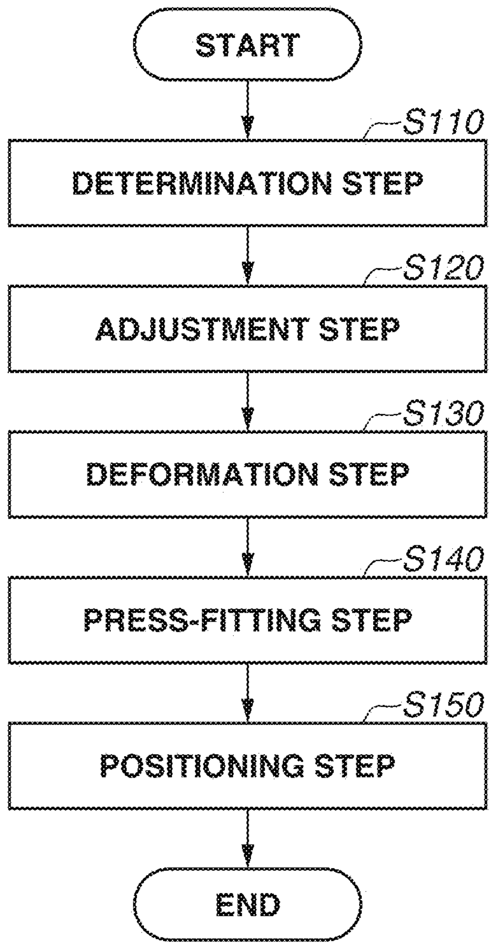

START
S110
DETERMINATION STEP
S120
ADJUSTMENT STEP
S130
DEFORMATION STEP
S140
PRESS-FITTING STEP
S150
POSITIONING STEP
END

FIG.9

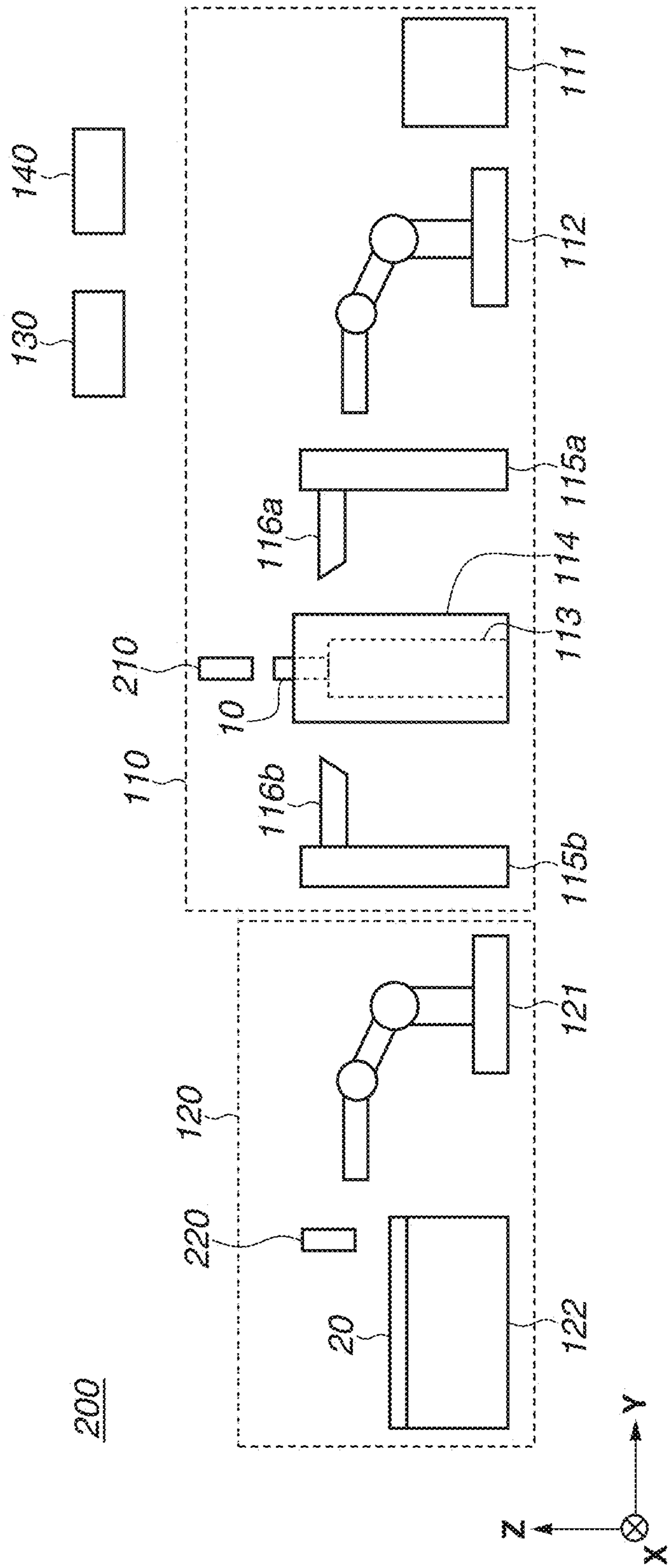

140
130
111
112
115a
116a
114
113
210
10
110
116b
115b
121
120
220
20
122
200
Z
Y
X

FIG.10

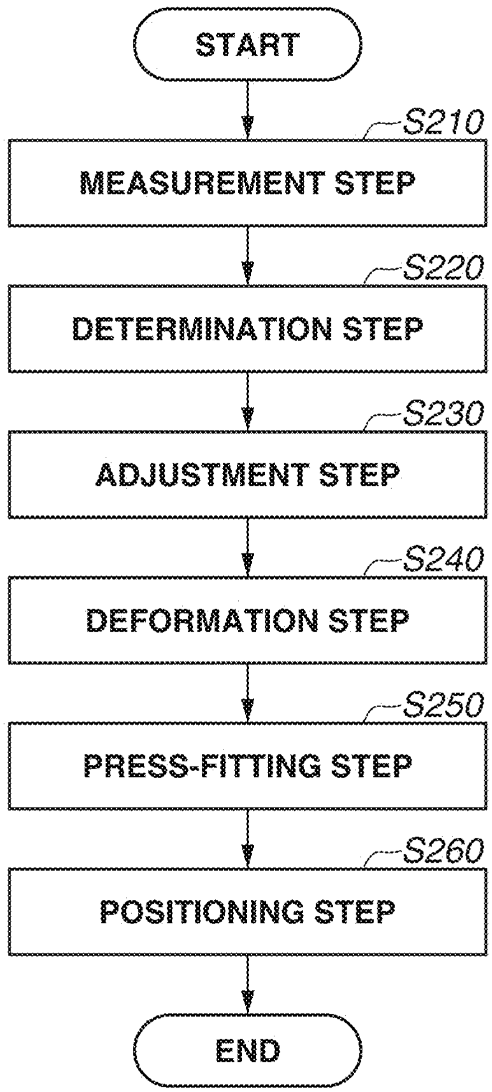

START
S210
MEASUREMENT STEP
S220
DETERMINATION STEP
S230
ADJUSTMENT STEP
S240
DEFORMATION STEP
S250
PRESS-FITTING STEP
S260
POSITIONING STEP
END

FIG.11C

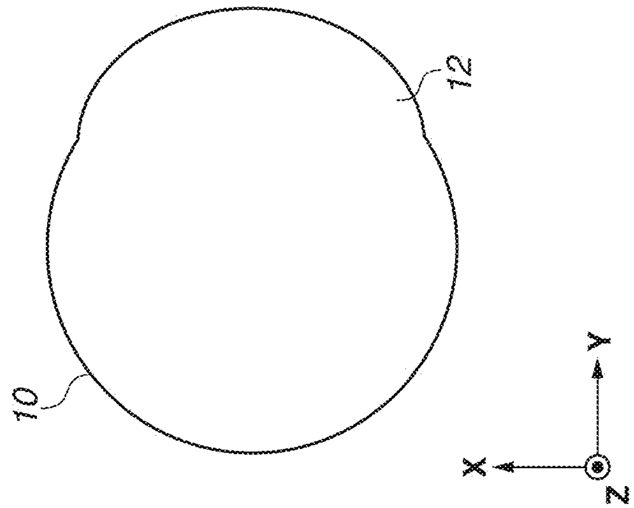


FIG.11B

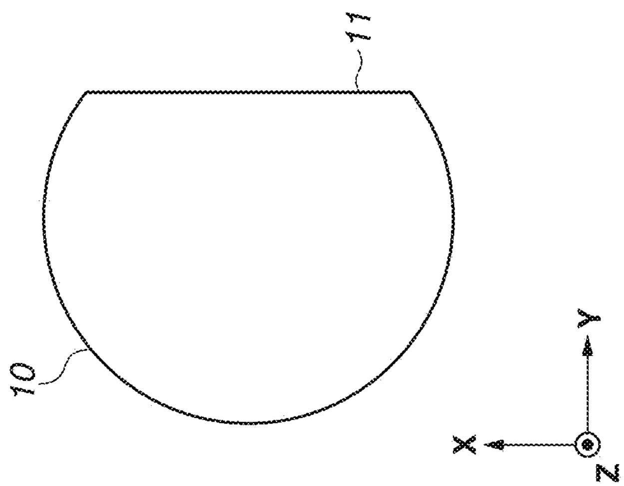


FIG.11A

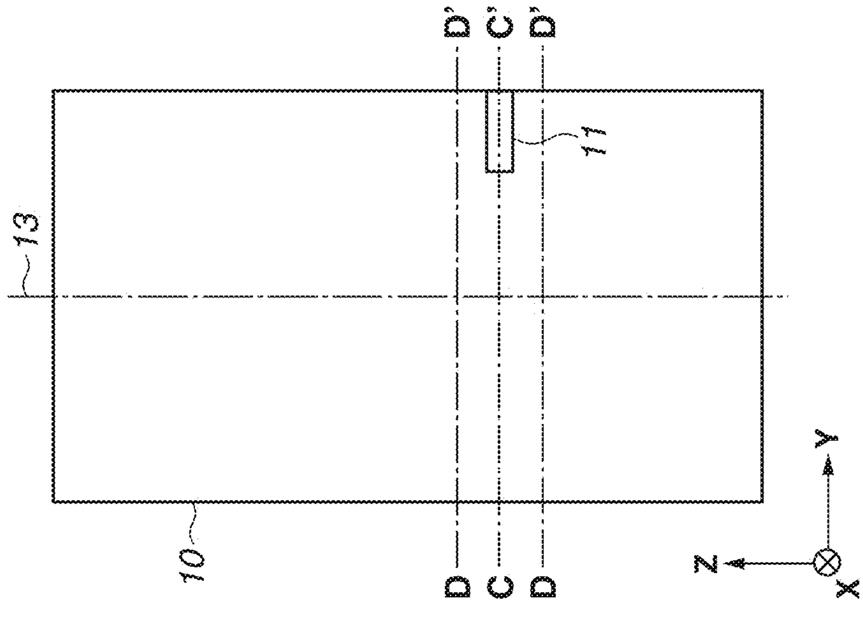


FIG.12

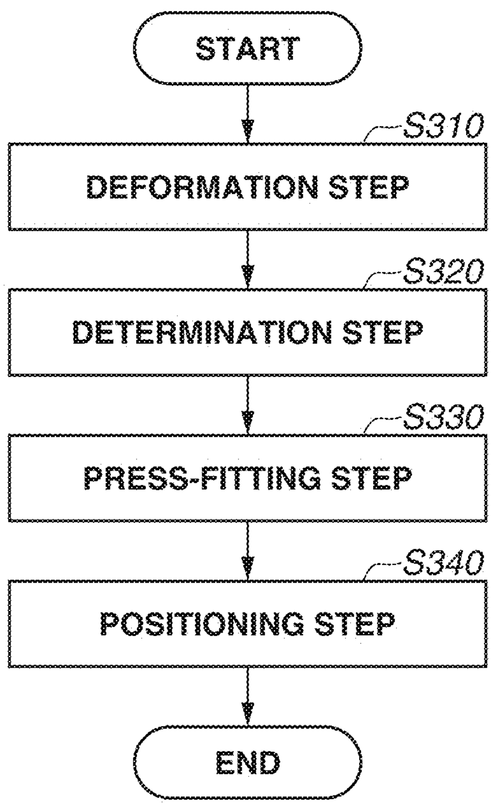
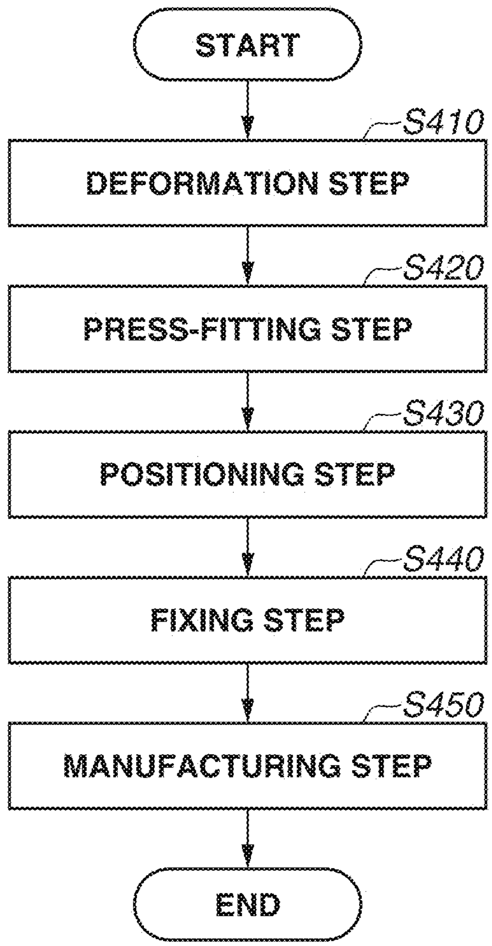

START
S310
DEFORMATION STEP
S320
DETERMINATION STEP
S330
PRESS-FITTING STEP
S340
POSITIONING STEP
END

FIG.13


START
S410
DEFORMATION STEP
S420
PRESS-FITTING STEP
S430
POSITIONING STEP
S440
FIXING STEP
S450
MANUFACTURING STEP
END

POSITIONING METHOD, PRESS-FITTING APPARATUS, PIN PROCESSING METHOD, EXPOSURE APPARATUS, AND ARTICLE MANUFACTURING METHOD

BACKGROUND

Field

[0001] The present disclosure relates to a positioning method, a press-fitting apparatus, a pin processing method, an exposure apparatus, and an article manufacturing method.

Description of the Related Art

[0002] For a manufacturing step in which an article is manufactured by combining a plurality of members, there is a method in which a pin is used to position a second member with respect to a first member, and to fix the relative positions of the first and second members. Japanese Patent Application Laid-Open No. 2007-54937 discusses a pin driving device that automatically press-fits positioning pins into holes.

[0003] When a positioning pin is press-fitted into a hole, a pin that has been deformed by being crimped can be used to reduce the possibility of the pin coming out of the hole. This crimping is performed by applying force from the outer periphery of the pin to the center of the pin by using a tool or the like to deform the pin. Here, when the crimped pin is press-fitted into the hole, the pin may tilt. This tilt of the pin changes depending on the conditions under which the pin is crimped. If the tilt direction of the pin is not the desired direction, the second member may not be positioned correctly with respect to the first member.

SUMMARY

[0004] The present disclosure is directed to a positioning method capable of improving the positioning accuracy of a second member with respect to a first member by tilting a pin in a desired direction.

[0005] According to an aspect of the present disclosure, a method for positioning a second member with respect to a first member is provided that includes deforming a pin to form an indentation, press-fitting the deformed pin into a hole in the first member; and abutting the second member against the pin, wherein, when abutting the second member, a center position of a deformed area of the pin is closer to the second member than to a central axis of the pin.

[0006] Further features of the present disclosure will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIGS. **1**A and **1**B are schematic diagrams of a pin press-fitting apparatus according to a first exemplary embodiment.

[0008] FIGS. **2**A to **2**C are schematic diagrams illustrating a state where a second member is positioned with respect to a first member by using a pin.

[0009] FIGS. **3**A and **3**B are schematic diagrams illustrating states where the second member abuts on the first member.

[0010] FIGS. **4**A to **4**C are schematic diagrams of a crimped pin according to the first exemplary embodiment.

[0011] FIGS. **5**A to **5**C illustrate examples of an angle of an indentation (scratch) of a pin.

[0012] FIGS. **6**A to **6**C illustrate examples of tilt of a pin.

[0013] FIGS. **7**A to **7**C illustrate examples of the position of a scratch of a pin in the Z-axis direction.

[0014] FIG. **8** is a flowchart of positioning the second member with respect to the first member by using the pin according to the first exemplary embodiment.

[0015] FIG. **9** is a schematic diagram of a pin press-fitting apparatus according to a second exemplary embodiment.

[0016] FIG. **10** is a flowchart of positioning a second member with respect to a first member by using a pin according to the second exemplary embodiment.

[0017] FIGS. **11**A to **11**C illustrate an example of a crimped pin according to a third exemplary embodiment.

[0018] FIG. **12** is a flowchart of positioning a second member with respect to a first member by using a pin according to a fourth exemplary embodiment.

[0019] FIG. **13** is a flowchart of an article manufacturing method according to a fifth exemplary embodiment.

DESCRIPTION OF THE EMBODIMENTS

[0020] Embodiments of the present disclosure will be described below with reference to the drawings. The following exemplary embodiments do not limit the recited claims. Although the exemplary embodiments describe a plurality of features, not all of these features are essential to the disclosure, and the exemplary embodiments may be combined in any desired manner. In the drawings, the same reference numbers are used for the same or similar components, and duplicate description may not be repeated, for conciseness.

[0021] In the present specification and drawings, directions are indicated utilizing an XYZ coordinate system in which the vertical direction is the Z axis and a horizontal plane perpendicular to the vertical direction is the XY plane, with the axes being orthogonal to each other. When an XYZ coordinate system is indicated in each drawing, that coordinate system shall take precedence.

[0022] A specific configuration will be described below for each exemplary embodiment.

[0023] FIG. **1**A is a schematic diagram of a pin press-fitting apparatus **100** according to a first exemplary embodiment. As illustrated in FIG. **1**A, the pin press-fitting apparatus **100** includes a crimping device **110**, a press-fitting device **120**, a control unit **130**, and a storage unit **140**. The control unit **130** controls the components of the crimping device **110** and the press-fitting device **120**.

[0024] The crimping device **110** includes a supply unit **111**, a first transport unit **112**, a pin holding unit **113**, a pin fixing unit **114**, a first drive unit **115*a***, a first tool **116*a***, a second drive unit **115*b***, and a second tool **116*b***. The first transport unit **112** is, for example, an articulated robot, and is provided at its tip portion with a gripper unit (robot hand) capable of gripping a pin **10** and a rotator unit capable of rotating the pin **10**. The supply unit **111** stores a plurality of the pins **10**. The plurality of pins **10** may include a plurality of types of pins having different diameters, for example. In a case where the supply unit **111** is to supply the plurality of types of pins, the plurality of types of pins is managed by type. The first transport unit **112** transports, to the pin holding unit **113**, a desired pin **10**, which has been supplied from the supply unit **111**, to be press-fitted into a predetermined hole provided in a first member **20**. The desired pin

10 is, for example, a pin having a diameter corresponding to the diameter of the hole into which the pin **10** is to be press-fitted, or a pin of a desired length.

[0025] FIG. **1**B illustrates a method for holding the pin **10**. The pin holding unit **113** holds one end of the pin **10**. This holding may be performed, for example, by pinching the pin **10** or by suctioning gas and vacuum-suctioning the pin **10**; the holding method is not particularly limited. The height of the pin holding unit **113** can be changed according to the length of the pin **10** to be held, and by changing the height of the pin **10**, the position at which the pin **10** is crimped (deformed) can be adjusted. The pin **10** held by the pin holding unit **113** is fixed at its upper portion by the pin fixing unit **114**. The pin fixing unit **114** sandwiches the pin **10** to be fixed. In the present exemplary embodiment, applying force to a predetermined region of the pin **10** to deform the pin **10** may be referred to as crimping.

[0026] Then, the pin **10**, the position of which has been fixed by the pin holding unit **113** and the pin fixing unit **114**, is deformed by being crimped at the position between the portion held by the pin holding unit **113** and the portion fixed by the pin fixing unit **114**. This crimping is performed by the first tool **116***a* and the second tool **116***b* applying force from respective points on the outer periphery of the pin **10** to the center of the pin **10**, to deform the pin. Specifically, the crimping is performed by sandwiching the pin **10** between the first tool **116***a* and the second tool **116***b*. For the crimping, the first tool **116***a* is driven by the first drive unit **115***a*, and the second tool **116***b* is driven by the second drive unit **115***b*.

[0027] The first tool **116***a* and the second tool **116***b* are made of a hard material (e.g., tool steel) capable of crimping the pin **10**, and applying force to the pin **10** at their tip portions to create scratches (indentations) as the pin **10** is crimped and deformed. The first tool **116***a* and the second tool **116***b* are, for example, cylindrical members cut obliquely with sharpened tips. The first drive unit **115***a* and the second drive unit **115***b* each include, for example, an air cylinder. The pin **10** is sandwiched between the first tool **116***a* and the second tool **116***b* by the force of the air cylinders, thereby crimping the pin **10**. One of the first tool **116***a* and the second tool **116***b* may be fixed in position, and only the other may be driven to crimp the pin **10**.

[0028] The pin **10** that has been deformed by being crimped is press-fitted into the hole provided in the first member **20** by the press-fitting device **120**. The press-fitting device **120** includes a second transport unit (press-fitting unit) **121** and a member holding unit **122**. The second transport unit **121** transports the pin **10**, which has been deformed by being crimped by the crimping device **110**, from the crimping device **110**, and press-fits the pin **10** by a predetermined amount into the hole provided in the first member **20** held by the member holding unit **122**. The member holding unit **122** includes, for example, abutment portions (such as pins or steps) for positioning the first member **20** and fixing portions (such as taps or clamps) for fixing the position of the first member **20**. The second transport unit **121** is, for example, an articulated robot, and is provided at its tip portion with a gripper unit capable of gripping the pin **10** and a rotator unit capable of rotating the pin **10**. The press-fitting device **120** includes an imaging unit or a sensor, which detects the position of the hole into which the pin **10** is to be press-fitted, and the second transport unit **121** press-fits the pin **10** according to the detected position of the hole. This imaging unit or sensor may be included in the second transport unit **121**. In this manner, the pin **10** is press-fitted into the first member **20**. The gripper unit may have an elongated shape so that the pin **10** can be press-fitted in a narrow space, for example. Further, the gripper unit may include a structure that acts as a stopper for the pin **10** so that the position at which the pin **10** is gripped does not deviate when the pin **10** is press-fitted. The gripper unit is fixed to an arm of the second transport unit **121** by a fixing unit using an electromagnet, vacuum suction, a screw, or the like.

[0029] FIGS. **2**A, **2**B, and **2**C are schematic diagrams illustrating states where a second member **30** is positioned with respect to the first member **20** by using the pin **10**. The pin **10** is press-fitted into the first member **20**, and the second member **30** can be positioned with respect to the first member **20** by the second member **30** abutting on the press-fitted pin **10**.

[0030] Then, by fixing the relative positions of the first member **20** and the positioned second member **30**, the second member **30** can be fixed at a desired position.

[0031] FIG. **2**A is a diagram illustrating a state where the pin **10** press-fitted into a hole **21** provided in the first member **20** does not tilt. A tolerance is set for each of the pin **10** and the hole **21**. The pin **10** has a shape error within a tolerance range, and the hole **21** also has a shape error within the tolerance range. When the difference between the diameter of the pin **10** and the diameter of the hole **21** is small, the pin **10** press-fitted into the hole **21** does not tilt. In such a case, the second member **30** is correctly positioned with respect to the first member **20**.

[0032] FIG. **2**B is a diagram illustrating a state where the pin **10** press-fitted into the hole **21** provided in the first member **20** tilts toward the side opposite to the side on which the second member **30** abuts (the −Y direction side). As illustrated in FIG. **2**B, the pin **10** press-fitted into the hole **21** may tilt due to a shape error within the tolerance range of the pin **10** and a shape error within the tolerance range of the hole **21**. In the example of FIG. **2**B, the pin **10** tilts toward the side opposite to the side on which the second member **30** abuts, and therefore the pin **10** does not tilt toward the side on which the pin **10** abuts (the +Y direction side) after abutting. Therefore, in such a case, the positioning of the second member **30** with respect to the first member **20** will result in a deviation from the desired position, more than when the first member **10** and the second member **30** do not tilt, as in FIG. **2**A, but the relative positions of the first member **20** and the second member **30** do not change after the second member **30** abuts. Thus, the positioning is relatively accurate.

[0033] FIG. **2**C is a diagram illustrating a state where the pin **10** press-fitted into the hole **21** provided in the first member **20** tilts towards the side on which the second member **30** abuts (the +Y direction side). In FIG. **2**C, as in FIG. **2**B, the pin **10** press-fitted into the hole **21** tilts due to a shape error within the tolerance range of the pin **10** and a shape error within the tolerance range of the hole **21**. In the example of FIG. **2**C, the pin **10** tilts toward the side on which the second member **30** abuts, and therefore the pin **10** may tilt toward the side opposite to the side on which the pin **10** abuts (the −Y direction side) after abutting. Therefore, after the second member **30** abuts on the first member **20**, the relative positions of the first member **20** and the second member **30** change, and the positioning is not accurate.

[0034] FIGS. **3**A and **3**B are schematic diagrams illustrating states where the second member **30** abuts on the first member **20**. As illustrated in FIG. **3**, a plurality of the pins **10** may be press-fitted into the first member **20**, and the second member **30** may abut, i.e. butt on, each of the plurality of press-fitted pins **10**, thereby positioning the second member **30** with respect to the first member **20**. For example, when the plurality of pins **10** are in the state illustrated in FIG. **2**A, the positions of the plurality of pins **10** do not move after abutting, so that the second member **30** is correctly positioned at a desired position. When the plurality of pins **10** is in the state illustrated in FIG. **2**B and has the similar amount and direction of tilt, the tilt of the pins **10** may cause the position of the second member **30** to deviate from the desired position. However, since the positions of the plurality of pins **10** do not move after abutting, the second member **30** is correctly positioned as illustrated in FIG. **3**A.

[0035] Here, when the plurality of pins **10** are in the state illustrated in FIG. **2**C, the positions of the plurality of pins **10** may move after the second member **30** abuts. Since this movement of the pins **10** does not always occur, one pin **10** may not move, while the other pin **10** may move and tilt in the opposite direction to the abutting side. In such a case, the second member **30** is positioned at an angle with respect to the first member **20** as illustrated in FIG. **3**B, and therefore the second member **30** is not positioned correctly.

[0036] Accordingly, to correctly position the second member **30** with respect to the first member **20**, the pin **10** should not tilt in a desired direction (toward the side opposite to the side on which the pin **10** abuts). However, as described above, the pin **10** may tilt due to the tolerance between the pin **10** and the hole **21**.

[0037] Therefore, to correctly position the second member **30** with respect to the first member **20**, the pin **10** tilts in a desired direction (toward the side opposite to the side on which the second member **30** abuts).

[0038] The tilt of the pin **10** changes depending on the conditions when the pin **10** is crimped. However, in conventional pin processing methods (crimping methods), the pin **10** is not crimped under conditions that takes into account the direction in which the pin **10** would tilt after being press-fitted, so that the pin **10** could sometimes tilt in a direction other than a desired direction. For example, conventionally, the pin **10** is crimped at positions near where its diameter is greatest. In that case, a worker needs to adjust the position of the second member **30** by adjusting the tilt of the pin **10** with a tool or the like. A plurality of the positioning pins **10** may be press-fitted into one first member **20**. In such a case, the worker needs to adjust the tilt of the plurality of pins **10** as appropriate, which takes time for the adjustment.

[0039] Therefore, in the present exemplary embodiment, the pin **10** is crimped under conditions that allow the pin **10** to tilt in a desired direction. Since the direction in which the pin **10** tilts depends on the crimping position at which the pin **10** is crimped, in the present exemplary embodiment, the pin **10** is crimped at the position on the side of the pin **10** on which the second member **30** abuts so that the pin **10** tilts in the desired direction (toward the side opposite to the side on which the second member **30** abuts).

[0040] FIGS. **4**A, **4**B, and **4**C are schematic diagrams of a crimped pin **10** according to the present exemplary embodiment. In the present exemplary embodiment, as illustrated in FIG. **4**A, the first tool **116***a* and the second tool **116***b* crimp the pin **10** while making a scratch **11** on the pin **10**, centered at a position deviating from a central axis **13** of the pin **10**, with the central axis being formed along the longitudinal direction of the pin **10**. Then, the pin **10** is press-fitted so that the center positions in the longitudinal direction of the deformed regions (scratches **11**, dents) of the pin **10** are closer to the side on which the second member **30** abuts than the central axis **13** is. In this case, in a cross section A-A', which corresponds to a position in the Z-axis direction coincides with the positions of the scratches **11**, the places of the scratches **11** are recessed, as illustrated in FIG. **4**B. Then, in a cross section B-B', which corresponds to a position in the Z-axis direction deviating from the positions of the scratches **11**, regions **12** located on the +Z and −Z direction sides of the scratches **11** extend, i.e. bulge, as illustrated in FIG. **4**C. The deformation (bulge) of the regions **12** increases the resistance between the pin **10** and an object (hole **21**) into which the pin **10** is press-fitted, making it difficult for the pin **10** to be removed from the hole **21**. The central axis **13** of the pin **10** is, for example, the central axis of the pin **10** before the pin **10** is deformed (before being crimped).

[0041] In the example of FIGS. **4**A to **4**C, the scratches **11** are made on the +Y direction side of the central axis **13**. Therefore, when the pin **10** is press-fitted into the first member **20**, the extension/bulge of the regions **12** causes greater resistance between the pin **10** and the first member **20** (hole **21**) on the +Y direction side of the pin **10** than on the −Y direction side. Therefore, the +Y direction side of the pin **10** is less likely to be press-fitted into the first member **20**, and the −Y direction side of the pin **10** is more likely to be press-fitted into the first member **20**. As a result, the length of the pin **10** to be press-fitted on the −Y direction side is longer than that on the +Y direction side, and the pin **10** tilts toward the −Y direction side, resulting in the state illustrated in FIG. **2**B. In this manner, in the present exemplary embodiment, the crimping position is set to a position on the side of the pin **10** on which the second member **30** abuts, so that the pin **10** can tilt toward the opposite side to the direction in which the second member **30** abuts, and the pin **10** can correctly position the second member **30** with respect to the first member **20**.

[0042] The position(s) (position(s) in the Y-axis direction) at which the pin **10** is crimped may be adjusted by adjusting the positions of the first tool **116***a* and the second tool **116***b* in the Y-axis direction, by using the first drive unit **115***a* and the second drive unit **115***b*. Alternatively, the position may be adjusted by adjusting the position of the pin **10** in the Y-axis direction when the pin **10** is crimped by a drive mechanism included in the pin holding unit **113**.

[0043] The tilt direction of the pin **10** may be set to a desired direction, and/or the tilt amount of the pin **10** may set to a desired amount. For example, even when a plurality of the pins **10** tilt in a desired direction as illustrated in FIG. **2**B, if the plurality of pins **10** have different amounts of tilt, the second member **30** may be positioned at an angle with respect to the first member **20**, as illustrated in FIG. **3**B. As a result, the second member **30** is not positioned correctly. The amount of tilt of the pin **10** depends on the angle between the first tool **116***a* and the second tool **116***b*, the crimping position (crimping height) of the pin **10** in the Z-axis direction, and the strength of the crimping force (the size of the scratch **11**).

[0044] The relationship between the amount of tilt of the pin **10** and the angle between the first tool **116***a* and the second tool **116***b* is described with reference to FIGS. **5**A, **5**B, **5**C, **6**A, **6**B, and **6**C. FIGS. **5**A, **5**B, and **5**C illustrate examples of the angle of the scratch **11** of the pin **10**. FIGS. **6**A, **6**B, and **6**C illustrate examples of the amount of tilt of the pin **10**.

[0045] FIG. **5**A illustrates an example in which the pin **10** is crimped without inclining the first tool **116***a* and the second tool **116***b*, and the scratch **11** does not tilt with respect to the Y axis. FIG. **5**B illustrates an example in which the pin **10** is crimped by inclining the first tool **116***a* and the second tool **116***b*, and the +Y direction side of the scratch **11** is closer to the −Z direction side than the −Y direction side of the scratch **11** is. FIG. **5**C illustrates an example in which the pin **10** is crimped by inclining the first tool **116***a* and the second tool **116***b*, and the −Y direction side of the scratch **11** is closer to the −Z direction side than the +Y direction side of the scratch **11** is.

[0046] When the pin **10** is crimped as illustrated in FIG. **5**A, the pin **10** tilts toward the −Y direction side, as illustrated in FIG. **6**A, due to the bulge of the regions **12**. When the pin **10** is crimped as illustrated in FIG. **5**B, the +Y direction ends of the regions **12** are closer to the −Z direction side than when the pin **10** is crimped as illustrated in FIG. **5**A, and therefore resistance caused by the regions **12** when the pin **10** is press-fitted into the first member **20** occurs at an early stage of the press-fitting. As a result, as illustrated in FIG. **6**B, the pin **10** tilts toward the −Y direction side, further than in FIG. **6**A. When the pin **10** is crimped as illustrated in FIG. **5**C, the +Y direction ends of the regions **12** are closer to the +Z direction side than when the pin **10** is crimped as illustrated in FIG. **5**A, and therefore resistance caused by the regions **12** when the pin **10** is press-fitted into the first member **20** occurs at a later stage of the press-fitting. As a result, as illustrated in FIG. **6**C, the pin **10** is tilted less than in FIG. **6**A. In this manner, by adjusting the angle of the scratches **11**, that is, the angle between the first tool **116***a* and the second tool **116***b*, the amount of tilt of the pin **10** can be adjusted. The angles of the first tool **116***a* and the second tool **116***b* are adjusted, for example, by the first drive unit **115***a* and the second drive unit **115***b* rotating the tools about the central axes (axes in the longitudinal direction) of the first tool **116***a* and the second tool **116***b*, respectively. The tilt of the pin **10** is adjusted so that the central axis **13** tilts by, for example, about 30 μm or less.

[0047] The relationship between the amount of tilt of the pin **10** and the crimping position (crimping height) of the pin **10** in the Z-axis direction will be described with reference to FIGS. **7**A, **7**B, and **7**C. FIGS. **7**A, **7**B, and **7**C illustrate examples of the position of the scratch **11** of the pin **10** in the Z-axis direction.

[0048] FIG. **7**A illustrates an example in which the pin **10** is crimped without adjusting the positions of the first tool **116***a* and the second tool **116***b* in the Z-axis direction. FIG. **7**B illustrates an example in which the positions of the first tool **116***a* and the second tool **116***b* in the Z-axis direction are adjusted toward the −Z direction side further than in the case of FIG. **7**A to crimp the pin **10**, and the scratch **11** is on the −Z direction side. FIG. **7**C illustrates an example in which the positions of the first tool **116***a* and the second tool **116***b* in the Z-axis direction are adjusted toward the +Z direction side further than in the case of FIG. **7**A to crimp the pin **10**, and the scratch **11** is on the +Z direction side.

[0049] When the pin **10** is crimped as illustrated in FIG. **7**A, the pin **10** tilts toward the −Y direction side as illustrated in FIG. **6**A due to the bulge of the regions **12**. When the pin **10** is crimped as illustrated in FIG. **7**B, the regions **12** are closer to the −Z direction side than when the pin **10** is crimped as illustrated in FIG. **7**A, and therefore resistance caused by the regions **12** when the pin **10** is press-fitted into the first member **20** occurs at an early stage of the press-fitting.

[0050] As a result, as illustrated in FIG. **6**B, the pin **10** tilts toward the −Y direction side, further than in FIG. **6**A. When the pin **10** is crimped as illustrated in FIG. **7**C, the regions **12** are closer to the +Z direction side than when the pin **10** is crimped as illustrated in FIG. **7**A, and therefore resistance caused by the regions **12** when the pin **10** is press-fitted into the first member **20** occurs at a later stage of the press-fitting. As a result, as illustrated in FIG. **6**C, the pin **10** is less tilted than in FIG. **6**A. In this manner, by adjusting the position of the scratches **11** in the Z-axis direction, that is, the crimping position (crimping height) of the pin **10** in the Z-axis direction, the amount of tilt of the pin **10** can be adjusted. The crimping position (crimping height) may be adjusted by adjusting the height position of the pin holding unit **113**, for example. Alternatively, the position may be adjusted by adjusting the positions of the first tool **116***a* and the second tool **116***b* in the Z-axis direction by using the first drive unit **115***a* and the second drive unit **115***b*.

[0051] The relationship between the amount of tilt of the pin **10** and the strength of the crimping force (the size of the scratch **11**) will be described. If a large crimping force is applied, the scratch **11** becomes correspondingly large and the/bulge of the regions **12** also becomes large. This increases the resistance caused by the regions **12** when the pin **10** is press-fitted into the first member **20**. Therefore, by enhancing (increasing) the strength of the crimping force, the size of the scratch **11** and the amount of tilt of the pin **10** increases. When each tool is driven by an air cylinder, the strength of the crimping force can be adjusted by adjusting the air pressure.

[0052] FIG. **8** is a flowchart of positioning the second member **30** with respect to the first member **20** by using the pin **10** according to the present exemplary embodiment. In step **S110**, the control unit **130** determines conditions for crimping the pin **10**. This determination is made by determining, based on the direction in which the second member **30** abuts, conditions for achieving a desired tilt direction and a desired amount of tilt after the pin **10** is press-fitted into the first member **20**. The conditions include, for example, at least one of a position at which the pin **10** is crimped (Y-axis direction, Z-axis direction), an angle of the tool for crimping, and a strength of force for crimping. For example, if pins have the same shape but differ in hardness due to differences in materials, different strengths of force for crimping each of the pins is to be applied. The condition of the position (Y-axis direction, Z-axis direction) at which the pin **10** is crimped corresponds to a condition of a position of the tool (Y-axis direction, Z-axis direction) when the pin **10** is crimped or a condition of a position of the pin **10**, i.e., a position of a predetermined region to which force is applied from the tool. Further, the angle of the tool for crimping is synonymous with an angle of a predetermined region to which force is applied from the tool. The determination in the determination step may be made by the control unit **130** based on design information (including, for example, information on a direction in which the second member **30** abuts) stored in the storage unit **140**. Alternatively, the control unit **130** may make the determination based on condition information input in advance by a user and stored in the storage unit **140**.

[0053] Such information may be input by the user using, for example, an input device and a display device.

[0054] The input device is a device for inputting characters and data, and includes various types of keyboards, mice, and touch panels. The display device is a device for displaying information necessary for operations, processing results, and the like, and corresponds to a cathode ray tube (CRT) or liquid crystal monitor. Alternatively, the information may be input from the user through communication from another information processing apparatus.

[0055] Based on the conditions determined in the determination step, the control unit **130** controls to adjust at least one of the position of the pin **10** and the tool settings (angle, position, strength of crimping force) in step S**120**. After the position and the settings have been made, the pin **10** is crimped, i.e. deformed, in step S**130**. Then, the pin **10** that has been crimped in such deformation step is press-fitted into the first member **20** in step S**140**. In this press-fitting step, due to a difference in shape between the pin **10** and the hole **21** into which the pin **10** is to be press-fitted, the pin **10** may not be press-fitted normally, since torque detected in the second transport unit **121** may indicate an abnormal value. In this case, the control unit **130** may cancel the press-fitting, and perform the determination step, the adjustment step, and the deformation step again for another pin, and then perform the press-fitting step. The abnormal pin **10** for which the press-fitting has been canceled is transported, for example, to a box for disposal. Further, if the press-fitting of the pin **10** repeatedly fails, deformation or wear may have occurred in the second transport unit **121**. In this case, a replacement unit may replace the gripper unit of the second transport unit **121**.

[0056] In the press-fitting step, the control unit **130** controls the rotation of the pin **10** about the central axis **13** when the second transport unit **121** transports the pin **10** so that the pin **10** tilts in a desired direction. This control is performed based on the design information (including, for example, information on a direction in which the second member **30** abuts) stored in the storage unit **140**. Specifically, this control is performed according to the direction in which the second member **30** abuts and the positions of regions in which the pin **10** is deformed by the tools. In the press-fitting step, the position and angle at which the pin **10** is press-fitted are also controlled.

[0057] The second member **30** abuts on the pin **10** that is press-fitted into the hole of the first member **20** in the press-fitting step, thereby positioning the second member **30** with respect to the first member **20** (positioning step, step S**150**). This positioning step may be performed after the press-fitting of a predetermined number of pins **10** is completed.

[0058] Here, if a program relating to the crimping conditions and adjustment for each pin has been provided in advance by the user, the determination step may not be performed, and the adjustment step and the deformation step may be performed in accordance with the program. In addition, after the press-fitting step, a determination step may be performed in which the pin **10** is pulled in a direction to be pulled out from the first member **20** with a predetermined force to check whether the press-fitting has been performed correctly, and if the pin is pulled out, it is determined that the press-fitting has not been performed correctly, and otherwise, that the press-fitting has been performed correctly.

[0059] The determination step and the adjustment step may not be performed individually for all of the pins **10**. For example, if the pins **10** are of the same type, they may be adjusted in the adjustment step to the conditions determined in the determination step initially, and the determination step and adjustment step may not be performed while the same type of the pins **10** are crimped.

[0060] Further, all of the conditions may not be changed, and a configuration may be adopted in which the angle of the tool (the angle of the scratch **11**) is set to a constant value and other parameters are determined and adjusted.

[0061] In this manner, in the present exemplary embodiment, the tilt of the pin **10** used to position the second member **30** with respect to the first member **20** when the pin **10** is press-fitted into the first member **20** is adjusted by adjusting the conditions for crimping the pin **10**. Therefore, the tilt direction and amount of tilt of the pin **10** can be set to a desired direction and amount, respectively, and the accuracy of positioning the second member **30** with respect to the first member **20** by using the pin **10** can be improved.

[0062] Further, the moving speeds of the first tool **116***a* and the second tool **116***b* when the first tool **116***a* and the second tool **116***b* crimp (sandwich) the pin **10** may also be adjusted as conditions for crimping the pin **10**.

[0063] The control unit **130** includes a processing unit, a bus, a read only memory (ROM), a random access memory (RAM), and a storage device, and each of the components functions according to a program. The processing unit is a processing device that performs calculations for control according to a program and controls each of the components connected to the bus. This processing unit can be configured by a central processing unit (CPU), a programmable logic device (PLD) such as a field programmable gate array (FPGA), an application specific integrated circuit (ASIC), a computer with an embedded program, or a combination of all or some of these. The ROM is a memory dedicated to reading data, and stores programs and data. The RAM is a memory for reading and writing data, and is used for storing programs and data. The RAM is used for temporarily storing data such as the results of calculations by the CPU. The storage device is also used to store programs and data. The storage device is also used as a temporary storage area for data and programs of an operating system (OS) of the control unit **130**. Although the data input/output of the storage device is slower than that of the RAM, the storage device is capable of storing a large amount of data. The storage device is desirably a non-volatile storage device capable of storing data as permanent data to allow the stored data to be referred to for a long period of time. The storage device mainly includes a magnetic storage device (HDD) or a solid state drive (SSD), but may also be a device that reads and writes data by loading an external medium such as a compact disc (CD), a digital versatile disc (DVD), and a memory card. The control unit **130** may be configured separately from the other parts of the pin press-fitting apparatus **100** (in a separate housing).

[0064] Here, in the present exemplary embodiment, an example has been described in which the first transport unit **112** and the second transport unit **121** are different from each other. However, they may be provided in a single transport unit. Further, in the present exemplary embodiment, an example has been described in which the control unit **130** controls both the crimping device **110** and the press-fitting device **120**. However, each of them may include a control unit. The determination step may be performed by another information processing apparatus instead of the control unit **130**. In addition, in the present exemplary embodiment, an example has been described in which the first drive unit **115***a* and the second drive unit **115***b* are separate from each other. However, they may be a single drive unit. Further, in the present exemplary embodiment, an example has been described in which the pin **10** is crimped while the pin holding unit **113** holds the pin **10**. However, the pin **10** may be crimped while being gripped by the first transport unit **112**. Further, the pin **10** may be held (gripped) by a same holding unit (transport unit) from the deformation step to the press-fitting step to deform and press-fit the pin **10**.

[0065] In this manner, the pin **10** may be grasped at a desired rotation angle about the central axis **13**, for grasping at positions of the regions to be deformed in the deformation step.

[0066] The positioning of the second member **30** with respect to the first member **20** by using the pin **10** according to the present exemplary embodiment is used for positioning between members in a device for processing substrates such as semiconductor wafers and glass plates, for example. Examples of such a device include a projection exposure apparatus, a drawing apparatus, an imprint apparatus, a planarization apparatus, an ion implantation apparatus, a development apparatus, an etching apparatus, a film formation apparatus, an annealing apparatus, a sputtering apparatus, and a deposition apparatus. In particular, the accuracy of positioning is important for apparatuses including an optical system. For example, an exposure apparatus uses a plurality of the positioning pins **10** for positioning members. In a case where a plurality of the pins **10** are used, the time to correct the tilt directions of the pins **10** can be significantly reduced by using the pins **10** according to the present exemplary embodiment. For example, the exposure apparatus includes a first member **20** and a second member **30**, the second member **30** is in contact with the pin **10** press-fitted into a hole provided in the first member **20**, and the pin **10** has a scratch (indentation) **11**. As a result of the scratch **11** being made, regions of the pin **10** near the extension/bulges of the scratch **11**. The center positions in the longitudinal direction of the extending/bulging regions of the pin **10** are closer to the side where the second member **30** is in contact than the central axis **13** of the pin **10** is.

[0067] A second exemplary embodiment differs from the first exemplary embodiment in method of determining conditions for crimping the pin **10**. FIG. **9** is a schematic diagram of a pin press-fitting apparatus **200** according to the present exemplary embodiment. The pin press-fitting apparatus **200** includes a pin measurement unit **210** configured to measure the shape of the pin **10**, and a hole measurement unit **220** configured to measure the shape of a hole into which the pin **10** is to be press-fitted. As the pin measurement unit **210** and the hole measurement unit **220**, for example, a sensor configured to measure the shape of an object by image capture, or a sensor configured to measure the shape of an object by using a laser may be used. Further, the pin measurement unit **210** may be an optical micrometer. In this case, the pin **10** is inserted into the pin measurement unit **210** by the first transport unit **112** to measure the shape of the pin **10**. Information on the shape of the pin **10** or hole to be measured is, for example, information on the diameter and roundness. The information on the roundness also includes information on the flexure of the pin **10** and the curvature of the hole.

[0068] FIG. **10** is a flowchart of positioning the second member **30** with respect to the first member **20** by using the pin **10** according to the present exemplary embodiment. The shape of the pin **10** and the shape of the hole into which the pin **10** is to be press-fitted are measured by the pin measurement unit **210** and the hole measurement unit **220** in step S**210**. The control unit **130** then determines conditions for crimping the pin **10** in step S**220**. This determination is made by determining, based on the results of the measurement in the measurement step and the direction in which the second member **30** abuts, conditions for achieving a desired tilt direction and a desired amount of tilt after the pin **10** is press-fitted into the first member **20**.

[0069] In the measurement of step **210**, for example, when the diameter of the pin **10** is small and the diameter of the hole is large, the conditions for crimping are determined to increase the resistance between the pin **10** and the first member **20**, specifically to increase the extension/bulge of the regions **12**. For example, the strength of force for crimping is enhanced to increase the extension/bulge of the regions **12**. In such a case, the pin **10** may significantly tilt, and accordingly, adjustment is made to reduce the amount of tilt based on the measurement results. For example, the pin **10** is crimped so that resistance caused by the extension/bulge of the regions **12** increases at a later stage of the press-fitting. Additionally, the rotation of the pin **10** about the central axis **13** may be adjusted depending on the roundness. Further, in the measurement step, in a case where the pin **10** is bent or the hole is curved, the pin **10** will tilt due to these shapes, and therefore, the conditions for crimping are determined taking into account the tilt direction and amount of tilt of the pin **10** tilting due to the shapes of the pin **10** and the hole. The control unit **130** determines the conditions for crimping based on, for example, a table or a formula that indicates the relationship between the measurement results of the pin **10**, the measurement results of the hole, and the amount of tilt when the pin **10** is press-fitted.

[0070] The conditions include, for example, at least one of the position where the pin **10** is crimped (Y-axis direction, Z-axis direction), the angle of the tool for crimping, and the strength of force for crimping. The condition of the position (Y-axis direction, Z-axis direction) at which the pin **10** is crimped is synonymous with a condition of a position of the tool (Y-axis direction, Z-axis direction) when the pin **10** is crimped or a condition of a position of the pin **10**, in other words, a position of a predetermined region to which force is applied from the tool. Further, the angle of the tool for crimping is synonymous with an angle of a predetermined region to which force is applied from the tool. The determination in the determination step may be made by the control unit **130** based on design information (including, for example, information on a direction in which the second member **30** abuts) stored in the storage unit **140**. Alternatively, the control unit **130** may make the determination based on condition information input in advance by a user and stored in the storage unit **140**.

[0071] Based on the conditions determined in the determination step, the control unit **130** controls to adjust at least one of the position of the pin **10** and the tool settings (angle, position, strength of force for crimping) in step S**230**. In the state where the position and the settings have been made in the adjustment of step S**230**, the pin **10** is crimped in step S**240**. Then, the pin **10** that has been crimped in the deformation of step S**240** is press-fitted into the first member **20** in step S**250**. In the press-fitting of step S**250**, the control unit **130** controls the rotation of the pin **10** about the central axis **13** when the second transport unit **121** transports the pin **10** so that the pin **10** tilts in a desired direction. This control is performed based on the design information (including, for example, information on a direction in which the second member **30** abuts) stored in the storage unit **140**.

[0072] The second member **30** abuts on the pin **10** that is press-fitted into the hole of the first member **20** in the press-fitting step, thereby positioning the second member **30** with respect to the first member **20** in step S**260**. This positioning of step S**260** may be performed after the press-fitting of a predetermined number of pins **10** is completed.

[0073] According to the present exemplary embodiment, the conditions for crimping are determined based on the measurement results, and therefore, it is possible to improve the possibility of press-fitting the pin **10** in a desired direction with a desired amount of tilt.

[0074] In the present exemplary embodiment, an example has been described in which the pin measurement unit **210** is placed at a position where the pin measurement unit **210** can detect the pin **10** held by the pin holding unit **113**, and the hole measurement unit **220** is placed at a position where the hole measurement unit **220** can detect the hole provided in the first member **20** held by the member holding unit **122**. However, the arrangement of the pin measurement unit **210** and the hole measurement unit **220** is not limited to this example. By detecting the pin **10** held in the pin holding unit **113** by the pin measurement unit **210**, even when the pin **10** is not held correctly in the pin holding unit **113** but is held at an angle, for example, conditions for crimping can be determined according to the holding state.

[0075] Further, the shapes of the pin **10** and the hole may be measured externally to the pin press-fitting apparatus **200**. In that case, information on the shapes of the pin **10** and the hole measured externally is stored in the storage unit **140**, and the control unit **130** determines conditions for crimping based on the information stored in the storage unit **140**.

[0076] In the present exemplary embodiment, an example has been described in which the conditions for crimping are determined using the measurement results of both the pin measurement unit **210** and the hole measurement unit **220**. However, the measurement results of at least one of the pin measurement unit **210** and the hole measurement unit **220** (information on the shape of at least one pin) may be used.

[0077] A third exemplary embodiment differs from the first exemplary embodiment in position where the pin **10** is crimped. FIGS. **11**A, **11**B, and **11**C illustrate examples of a crimped pin **10** according to the present exemplary embodiment. In the present exemplary embodiment, the pin **10** is crimped using one tool instead of two tools, and the scratch **11** is made as illustrated in FIG. **11**A. In this case, in a cross section C-C', whose position in the Z-axis direction coincides with the position of the scratch **11**, the place of the scratch **11** is recessed as illustrated in FIG. **11**B. Then, in a cross section D-D', where a position in the Z-axis direction deviates from the position of the scratch **11**, regions **12** located on the +Z and −Z direction sides of the scratch **11** extension/bulge, as illustrated in FIG. **11**C.

[0078] As described above, the regions **12** cause resistance when the pin **10** is press-fitted into the first member **20**. In the present exemplary embodiment, as in the first exemplary embodiment, the tilt direction and amount of tilt of the pin **10** can be set to a desired state by adjusting conditions including the position at which the pin **10** is crimped (Y-axis direction, Z-axis direction), the angle of the tool for crimping, and the strength of force for crimping.

[0079] A fourth exemplary embodiment differs from the first exemplary embodiment in method of determining conditions for crimping. In the present exemplary embodiment, a determination step for determining conditions for crimping is not performed, and instead, the pin **10** is crimped under fixed conditions. At this time, as illustrated in FIG. **4**A, the first tool **116***a* and the second tool **116***b* crimp the pin **10** while making scratches **11** on the pin **10**, centered at a position deviating from the central axis **13** of the pin **10**. That is, the pin **10** is crimped so that the center positions in the longitudinal direction of the regions where the pin **10** is to be deformed deviate from the positions where the diameter of the pin **10** is maximum before the pin **10** is deformed. In other words, the pin **10** is crimped so that the center positions in the longitudinal direction of the regions where the pin **10** is to be deformed are closer to the side on which the second member **30** abuts than the central axis **13** of the pin **10** is.

[0080] Then, the control unit **130** controls the second transport unit (press-fitting unit) **121** to adjust the position and angle of the pin **10** when the pin **10** is press-fitted into the first member **20** so that the pin **10** tilts in a desired direction. That is, the second transport unit (press-fitting unit) **121** is controlled (adjusted) so that the center positions in the longitudinal direction of the deformed regions of the pin **10** are closer to the side on which the second member **30** abuts than the central axis **13** of the pin **10** is. That is, when abutting the second member, a center position of the deformed region is closer to the second member than to a central axis of the pin. More preferably, the control unit **130** controls the second transport unit (press-fitting unit) **121** to adjust the position and angle of the pin **10** when the pin **10** is press-fitted into the first member **20** so that the pin **10** tilts at a desired amount of tilt. This adjustment may be made based on design information stored in the storage unit **140** (including, for example, information on a direction in which the second member **30** abuts) or based on condition information input in advance by the user and stored in the storage unit **140**.

[0081] FIG. **12** is a flowchart of positioning the second member **30** with respect to the first member **20** by using the pin **10** according to the present exemplary embodiment. The pin **10** is crimped (deformed) in step S310. The control unit **130** determines conditions for press-fitting the pin **10** in step S320. This determination is made by determining, based on the direction in which the second member **30** abuts, conditions for achieving a desired tilt direction and a desired amount of tilt after the pin **10** is press-fitted into the first member **20**. Examples of the conditions include the position and angle of the pin **10** when the pin **10** is press-fitted, in other words, the position and angle of the second transport unit **121**. Such information is input by the user using, for example, an input device or a display device. The input device is a device for inputting characters and data, and includes various types of keyboards, mice, and touch panels.

[0082] The display device is a device for displaying information necessary for operations, processing results, and the like, and corresponds to a CRT or liquid crystal monitor. Alternatively, the information may be input from the user through communication from another information processing apparatus.

[0083] In step S**330**, the pin **10** is press-fitted into the first member **20** under the conditions determined in the determining of step S**320**). The second member **30** abuts on the pin **10** press-fitted into the hole of the first member **20** in the press-fitting of step S**320**, thereby positioning the second member **30** with respect to the first member **20** during positioning in step S**340**.

[0084] In the present exemplary embodiment, since the pin **10** is crimped under fixed conditions, there is no need to perform an adjustment step, and the time for crimping the pin **10** can be reduced.

[0085] A fifth exemplary embodiment relates to a method for manufacturing an article, in which the article is manufactured by using the above-described method for processing the pin **10**.

[0086] FIG. **13** is a flowchart of a method for manufacturing an article according to the present exemplary embodiment. Deformation is performed to deform the pin **10** in step S**410**. In step S**420**, a press-fitting is performed in which the pin **10** deformed in the deformation step is press-fitted into a hole provided in the first member **20**. In step S**430**, positioning is performed in which the second member **30** abuts on the pin **10** press-fitted in the press-fitting of step S**420**, thereby positioning the second member **30** with respect to the first member **20**.

[0087] In step S**440**, fixing is performed in which the first member **20** and the second member **30** are fixed together to form a third member including the first member **20** and the second member **30**. In step S**450**, manufacturing is performed to manufacture an article including the third member processed in the fixing in step S**440**).

[0088] Here, the center positions in the longitudinal direction of the regions where the pin **10** are deformed in the deformation step are closer to the side on which the second member **30** abuts than the central axis **13** of the pin **10** is. According to the present manufacturing method, an article can be manufactured with higher accuracy of positioning the second member **30** with respect to the first member **20** than in the conventional techniques.

[0089] The present disclosure is not limited to the above-described exemplary embodiments, and various changes and modifications can be made without departing from the spirit and scope of the disclosure. Accordingly, the following claims are appended to apprise the public of the scope of the disclosure.

[0090] According to the present disclosure, it is possible to provide a positioning method capable of improving the positioning accuracy of a second member with respect to a first member by tilting a pin in a desired direction.

[0091] While the present disclosure has been described with reference to exemplary embodiments, it is to be understood that the disclosure is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

[0092] This application claims the benefit of Japanese Patent Application No. 2024-018442, filed Feb. 9, 2024, which is hereby incorporated by reference herein in its entirety.

What is claimed is:

1. A method for positioning a second member with respect to a first member, the method comprising:

deforming a pin to form an indentation;

press-fitting the deformed pin into a hole in the first member; and

abutting the second member against the pin,

wherein, when abutting the second member, a center position of a deformed area of the pin is closer to the second member than to a central axis of the pin.

2. The method according to claim **1**, wherein the press-fitting corresponds to a direction in which the second member is to abut the pin.

3. The method according to claim **1**, further comprising determining conditions for deforming the pin.

4. The method according to claim **3**,

wherein the determining is performed based on at least one of design information, information input by a user, a shape of the pin, and a shape of the hole.

5. The method according to claim **3**,

wherein the conditions include at least one of a position of the pin while deforming, a position of a tool utilized to deform the pin, an angle of the tool relative to the pin, and an amount of force used to deform the pin.

6. The method according to claim **3**,

adjusting the conditions for deforming the pin,

wherein the adjusting includes adjusting at least one of a position of the pin, a position of a tool utilized to deform the pin, an angle of the tool relative to the pin, and a setting of the tool.

7. The method according to claim **1**, wherein in the deforming and the press-fitting, the pin is held by a same holding unit.

8. An apparatus for press-fitting a pin configured to abut a second member, the press-fitting apparatus comprising:

a holding unit configured to hold the pin;

a tool configured to deform the pin held by the holding unit; and

a press-fitting unit configured to press-fit the deformed pin into a hole provided in a first member,

wherein the hole is provided in the first member for positioning the second member with respect to the first member, and

wherein, when abutting the second member, a center position of a deformed area of the pin by force applied by the tool is closer to the second member than to a central axis of the pin.

9. The apparatus according to claim **8**, further comprising:

a control unit configured to control at least one of a position of the pin, a position of the tool, and a force for driving the tool; and

a pin measurement unit configured to measure a shape of the pin,

wherein the tool is configured to deform the pin based on a measurement result of the pin measurement unit.

10. The apparatus according to claim **8**, further comprising:

a control unit configured to control at least one of a position of the pin, a position of the tool, and a force to drive the tool; and a hole measurement unit configured to measure a shape of the hole,

wherein the tool is configured to deform the pin based on a measurement result of the hole measurement unit.

11. The apparatus according to claim **8**, further comprising:

a control unit configured to control at least one of a position of the pin, a position of the tool, and a force to drive the tool; and

a storage unit configured to store shape information of at least one of the pin and the hole,

wherein the control unit is configured to control deformation of the pin using the tool based on the shape information stored in the storage unit.

12. The apparatus according to claim **8**, wherein, to press-fit the pin, the press-fitting unit adjusts a position of the pin according to a direction in which the second member abuts the first member and a position of a region where the pin is deformed.

13. An apparatus for press-fitting a pin configured to abut a second member, the press-fitting apparatus comprising:

a press-fitting unit configured to press-fit a region of the pin into a hole provided in a first member for positioning the second member with respect to the first member, with the region being deformed before the press-fitting; and

a control unit configured to control the press-fitting unit,

wherein, when abutting the second member, a diameter of the pin at a center position of the region is less than a diameter of the pin at the center position before the pin is deformed, and

wherein the control unit is further configured to control the press-fitting unit to align the center position of the region closer to the second member than a central axis of the pin.

14. A method for processing a pin configured to abut a second member, the pin being configured to be press-fitted into a hole provided in a first member to position the second member with respect to the first member, the method comprising:

deforming the pin,

wherein, when the second member abuts the first member, a center position of a deformed area of the pin is closer to the second member than to a central axis of the pin.

15. An exposure apparatus comprising:

a first member; and

a second member,

wherein the second member is configured to contact a pin press-fitted into a hole provided in the first member,

wherein the pin includes a bulged region, and

wherein, when the second member abuts the first member, a center position of the bulged region is closer to the second member than to a central axis of the pin.

16. An article manufacturing method comprising:

deforming a pin;

press-fitting the deformed pin into a hole provided in a first member;

positioning a second member with respect to the first member by abutting the second member against the press-fitted pin; and

forming a third member by fixing the first member and the second member,

wherein the manufactured article includes the third member,

wherein, when abutting the second member, a center position of a deformed area of the pin is closer to the second member than to a central axis of the pin.

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