(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 626 360 A1

(12) EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:
25.03.2020 Bulletin 2020/13

(21) Application number: **18802620.7**

(22) Date of filing: **22.03.2018**

(51) Int Cl.:
B21D 7/16 *(2006.01)*

(86) International application number:
PCT/JP2018/011246

(87) International publication number:
WO 2018/211814 (22.11.2018 Gazette 2018/47)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

(30) Priority: **19.05.2017 JP 2017099835**

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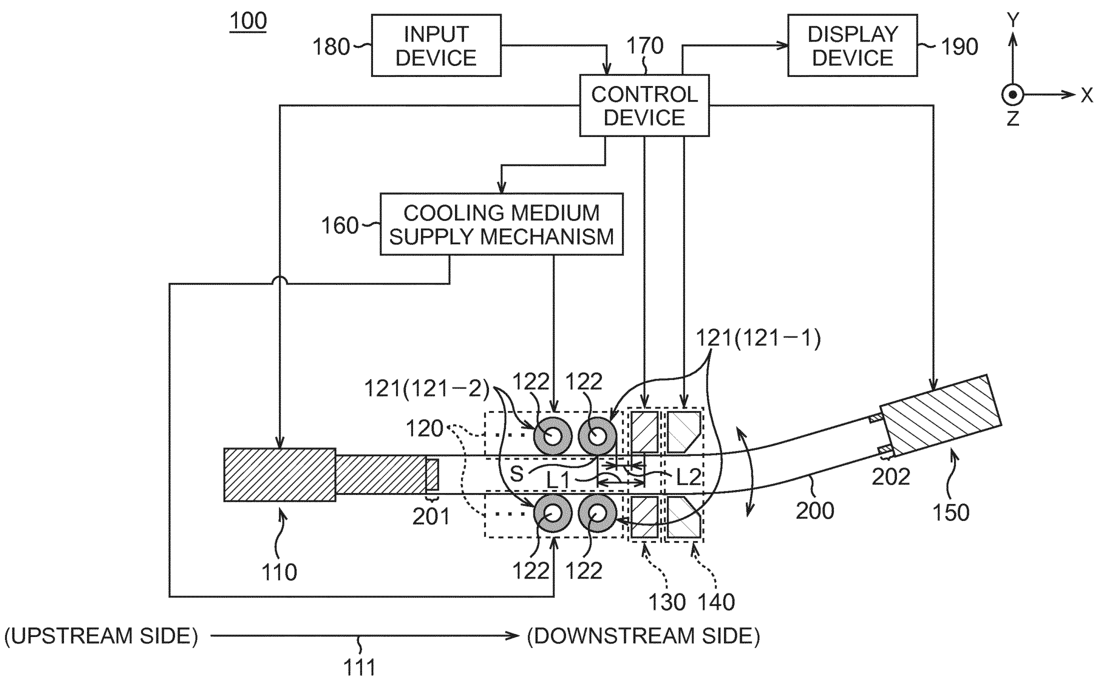
(54) QUENCHING TREATMENT APPARATUS

(57) The present invention includes: a conveying mechanism (110) that conveys a workpiece (200) in the longitudinal direction; a supporting mechanism (120) that is arranged on the downstream side in the conveyance direction of the workpiece (200) from the conveying mechanism (110); and a heating mechanism (130) that is arranged on the downstream side in the conveyance direction of the workpiece (200) from the supporting mechanism (120) and heats the workpiece (200), in which the supporting mechanism (120) is formed to include support rolls (121) that abut on an outer surface of the workpiece (200) and each include a hollow structure (122) allowing a cooling medium to pass therethrough therein.

FIG. 1



EP 3 626 360 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a quenching processing apparatus that processes a workpiece.

BACKGROUND ART

[0002] Conventionally, for example, Patent Literature 1 has proposed a processing apparatus in which a first support mechanism configured by including rolls feeds a steel tube being a workpiece fed from a feed mechanism to the downstream side in a feeding direction while supporting it, a heating mechanism arranged on the downstream side of the support mechanism heats the fed steel tube, and a second support mechanism arranged on the downstream side of the heating mechanism moves the fed steel tube in a predetermined direction while supporting it, thereby imparting a bending load to a portion of the workpiece heated by the heating mechanism and bending the steel tube to a desired shape.

CITATION LIST

PATENT LITERATURE

[0003]

Patent Literature 1: Japanese Patent No. 5304893
Patent Literature 2: Japanese Patent No. 4825019

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0004] In the above-described processing apparatus described in Patent Literature 1, the distance between a support position of the first support mechanism where the rolls support the steel tube being a workpiece and the heating mechanism is preferred to be short from the viewpoint of yield of a processed product because the distance is an extra length portion from an end portion of the processed product. However, when the rolls are brought too close to the heating mechanism in order to shorten the distance between the support position where the rolls support the workpiece and the heating mechanism, the rolls become high in temperature by heating of the heating mechanism. As a result, the rolls are damaged. The above-described processing apparatus described in Patent Literature 1 does not consider this point at all. Therefore, there has been a problem that it is difficult to achieve an improvement in yield of the processed product by arranging the rolls closer to the heating mechanism without causing the damage of the rolls by the heat from the heating mechanism.

[0005] The present invention has been made in consideration of such a problem, and an object thereof is to provide a quenching processing apparatus capable of improving the yield of a processed product by arranging rolls closer to a heating mechanism without causing damage of the rolls by heat from the heating mechanism.

SOLUTION TO PROBLEM

[0006] The quenching processing apparatus of the present invention is a quenching processing apparatus that processes a workpiece and is configured by including: a conveying mechanism that conveys the workpiece in the longitudinal direction; a supporting mechanism that is arranged on the downstream side in the conveyance direction of the workpiece from the conveying mechanism and supports the workpiece; and a heating mechanism that heats the workpiece. The supporting mechanism is formed by including rolls that abut on an outer surface of the workpiece and each include a hollow structure allowing a cooling medium to pass therethrough therein. The roll is formed by including: an outer ring portion that abuts on the outer surface of the workpiece; a shaft that is arranged at an inner side of the outer ring portion, supports the outer ring portion rotatably, and includes the hollow structure therein; and a sliding bearing arranged between the outer ring portion and the shaft.

ADVANTAGEOUS EFFECTS OF INVENTION

[0007] According to the present invention, since rolls are not damaged by the heat from a heating mechanism, the rolls can be arranged closer to the heating mechanism, resulting in that it is possible to improve the yield of a processed product.

BRIEF DESCRIPTION OF DRAWINGS

[0008]

[Fig. 1] Fig. 1 is a view illustrating one example of a schematic configuration of a quenching processing apparatus according to an embodiment of the present invention.
[Fig. 2] Fig. 2 is a view illustrating the embodiment of the present invention and illustrating one example of a schematic configuration of a support roll illustrated in Fig. 1.
[Fig. 3A] Fig. 3A is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of a sliding bearing illustrated in Fig. 2.
[Fig. 3B] Fig. 3B is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the sliding bearing illustrated in Fig. 2.
[Fig. 3C] Fig. 3C is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the sliding bearing illustrated in Fig. 2.

[Fig. 4A] Fig. 4A is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the sliding bearing illustrated in Fig. 2.

[Fig. 4B] Fig. 4B is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the sliding bearing illustrated in Fig. 2.

[Fig. 4C] Fig. 4C is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the sliding bearing illustrated in Fig. 2.

[Fig. 5A] Fig. 5A is a view illustrating the embodiment of the present invention and illustrating one example of a method of assembling the sliding bearing illustrated in Fig. 2.

[Fig. 5B] Fig. 5B is a view illustrating the embodiment of the present invention and illustrating the sliding bearing illustrated in Fig. 5A in an enlarged manner.

[Fig. 5C] Fig. 5C is a cross-sectional view in the method of assembling the sliding bearing illustrated in Fig. 5A, which illustrates the embodiment of the present invention.

[Fig. 5D] Fig. 5D is a cross-sectional view in a method of disassembling the sliding bearing illustrated in Fig. 5C, which illustrates the embodiment of the present invention.

[Fig. 6A] Fig. 6A is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the shape of an outer ring portion illustrated in Fig. 2.

[Fig. 6B] Fig. 6B is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the shape of the outer ring portion illustrated in Fig. 2.

[Fig. 6C] Fig. 6C is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the shape of the outer ring portion illustrated in Fig. 2.

[Fig. 7A] Fig. 7A is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the arrangement of the outer ring portion illustrated in Fig. 2.

[Fig. 7B] Fiq. 7B is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the arrangement of the outer ring portion illustrated in Fig. 2.

[Fig. 7C] Fig. 7C is a view illustrating the embodiment of the present invention and illustrating a concrete aspect example of the arrangement of the outer ring portion illustrated in Fig. 2.

[Fig. 8A] Fig. 8A is a view illustrating a comparative example and illustrating an example of the case where rolling bearings are provided between an outer ring portion and a shaft.

[Fig. 8B] Fig. 8B is a view illustrating the comparative example and illustrating a stress to occur in an inner side of the outer ring portion illustrated in Fig. 8A.

[Fig. 8C] Fig. 8C is a view illustrating the embodiment of the present invention and illustrating an example of the case where the sliding bearing is provided between the outer ring portion and a shaft.

[Fig. 8D] Fig. 8D is a view illustrating the embodiment of the present invention and illustrating a stress to occur in an inner side of the outer ring portion illustrated in Fig. 8C.

[Fig. 9A] Fig. 9A is a view illustrating a support roll according to a comparative example and illustrating one example of the case where a rolling bearing is provided between a shaft and a roll holder.

[Fig. 9B] Fig. 9B is a view illustrating the support roll according to the embodiment of the present invention and illustrating one example of the case where the sliding bearing is provided between the shaft and the outer ring portion.

[Fig. 9C] Fig. 9C is a table illustrating one example of respective factors in the case of the support roll according to the comparative example illustrated in Fig. 9A and the case of the support roll according to the embodiment of the present invention illustrated in Fig. 9B.

[Fig. 10A] Fig. 10A is a chart illustrating the embodiment of the present invention and illustrating one example where the temperature of a support roll in the case of using an austenitic stainless steel as a material of the outer ring portion of the support roll illustrated in Fig. 2 changes as the time elapses.

[Fig. 10B] Fig. 10B is a chart illustrating the embodiment of the present invention and illustrating one example where the temperature of a support roll in the case of using non-magnetic ceramic as a material of the outer ring portion of the support roll illustrated in Fig. 2 changes as the time elapses.

[Fig. 10C] Fig. 10C is a table illustrating one example of temperature characteristics according to a test processing condition in the case of the support roll according to the comparative example, the case of the support roll according to the embodiment of the present invention illustrated in Fig. 10A, and the case of the support roll according to the embodiment of the present invention illustrated in Fig. 10B.

[Fig. 11A] Fig 11A is a view illustrating the embodiment of the present invention and illustrating one example of the relationship between the outer ring portion and the sliding bearing.

[Fig. 11B] Fig. 11B is a view illustrating a comparative example and illustrating one example of the relationship between the outer ring portion and the sliding bearing.

DESCRIPTION OF EMBODIMENTS

[0009] There will be explained an embodiment of the present invention with reference to the drawings below.

[0010] Fig. 1 is a view illustrating one example of a schematic configuration of a quenching processing apparatus 100 according to the embodiment of the present invention. The quenching processing apparatus 100 is configured by including a conveying mechanism 110, a supporting mechanism 120, a heating mechanism 130, a cooling mechanism 140, a holding mechanism 150, a cooling medium supply mechanism 160, a control device 170, an input device 180, and a display device 190.

[0011] There will be explained an example assuming a 3 Dimensional Hot Bending and Quenching (3DQ) processing apparatus that three-dimensionally bends a workpiece 200 as the quenching processing apparatus 100 in this embodiment. However, the present invention is not limited to this 3 dimensional hot bending and quenching processing apparatus, and another quenching processing apparatus other than the 3 dimensional hot bending and quenching processing apparatus (for example, a 2 dimensional bending and quenching processing apparatus) is also applicable to the present invention. Further, the present invention is not limited to a bending apparatus that bends the workpiece 200, and an apparatus that quenches the workpiece 200 is also applicable.

[0012] Further, in this embodiment, there will be explained an example assuming a steel pipe having a circular transverse section as the workpiece 200. On this occasion, as the steel pipe being the workpiece 200, it is preferred to use one having an outside diameter of about 10 [mm] to 200 [mm] and having a thickness of about 1 [mm] to 8 [mm], for example. In this embodiment as above, the example assuming a steel pipe as the workpiece 200 is explained, but in the present invention, the workpiece 200 is not limited to this steel pipe and other workpieces are also applicable to the present invention as long as they are made of a metal material. Further, the shape of a transverse section of the workpiece 200 is not limited to the above-described circular shape, and may be a polygon such as a rectangle or another shape such as an oval, for example. Further, the workpiece 200 may be a solid bar-shaped member. Further, the material of the workpiece 200 may be various metals such as aluminum, aluminum alloy, and titanium, in addition to steel and special steel, for example.

(Conveying mechanism 110)

[0013] The conveying mechanism 110 is provided on the upstream side in the quenching processing apparatus 100 and is a mechanism to convey the workpiece 200 in the longitudinal direction of this workpiece 200. Concretely, the conveying mechanism 110 performs conveyance by holding an upstream-side end portion 201 of the workpiece and additionally, continuously or intermittently moving the workpiece 200 in the longitudinal direction based on control from the control device 170, for example. Fig. 1 is a view illustrating one example of a conveyance direction 111 relating to the longitudinal direction of the workpiece 200 by this conveying mechanism 110. In the example illustrated in Fig. 1, the conveyance direction 111 of the workpiece 200 is set to the X-axis direction. Further, Fig. 1 illustrates two directions perpendicular to the X-axis direction relating to the conveyance direction 111 of the workpiece 200 each other as the Y-axis direction and the Z-axis direction respectively. On this occasion, in Fig. 1, the Y-axis direction is a direction corresponding to the width direction of the workpiece 200, for example. Further, the Z-axis direction is a direction corresponding to the vertical direction.

(Supporting mechanism 120)

[0014] The supporting mechanism 120 is arranged parallel to the direction in which the conveying mechanism 110 moves at the position on the downstream side in the conveyance direction 111 of the workpiece 200 from the conveying mechanism 110 and is arranged at the position on the upstream side of the conveyance direction 111 from the heating mechanism 130 that heats the workpiece 200, and is a mechanism that guides a portion of the workpiece 200. This supporting mechanism 120 is configured by including support rolls 121 arranged to cover the outer periphery of the workpiece 200 in a place of the longitudinal direction (the conveyance direction 111) of the workpiece 200 and a support member that supports these support rolls 121 to make them abut on an outer surface of the workpiece 200, for example. Incidentally, the arrangement of the supporting mechanism 120 is not limited to this. That is, the supporting mechanism 120 may be arranged on the downstream side in the conveyance direction 111 from the heating mechanism 130 that heats the workpiece 200.

[0015] Further, in the example illustrated in Fig. 1, a plurality of the support rolls 121 are arranged at different positions in the conveyance direction 111 of the workpiece 200. Incidentally, in this embodiment, the outside diameter of the support roll 121 is about 10 [mm] to 100 [mm], for example. In the following explanation, in the case where the support rolls 121 are explained by paying attention to the position of the conveyance direction 111 where the support roll 121 is arranged, for example, the explanation is made by setting the support roll 121 closest to the heating mechanism 130 to a "first support roll 121-1" and setting the support roll 121 second closest to the heating mechanism 130 to a "second support roll 121-2" as necessary. Further, for example, in the case where the respective support rolls 121-1 and 121-2 are explained representatively without paying attention to the position of the conveyance direction 111 where the support roll 121 is arranged in particular, they are explained as the "support roll 121" simply.

[0016] Further, as illustrated in Fig. 1, the first support roll 121-1 and the second support roll 121-2 are arranged in pairs across the workpiece 200 at different positions in the X-axis direction. Incidentally, in the above-described embodiment, the case where the first support roll 121-1 and the second support roll 121-2 are arranged at different positions in the conveyance direction 111 of the workpiece 200 has been explained. However, the present invention is not limited to this, and an aspect in which three or more support rolls 121 are provided at different positions on the X axis is also included.

[0017] The supporting mechanism 120 can support a portion of the workpiece 200 in the longitudinal direction (the conveyance direction 111) in the radial direction of the workpiece 200 mainly by the support rolls 121 arranged so as to cover the outer periphery of the workpiece 200. In the quenching processing apparatus 100, the holding mechanism 150 adds a bending load to a high-temperature portion of the workpiece 200 heated by the heating mechanism 130, and thereby bending is performed. The bending load to be added to the workpiece 200 has a component in the radial direction of the workpiece 200 mainly. Therefore, in this bending, a bending reaction force, which is a machining reaction force in the bending direction, acts on the support rolls 121 of the supporting mechanism 120 by the bending load added to the workpiece 200.

[0018] Further, in the supporting mechanism 120 in this embodiment, a hollow structure 122 allowing a cooling medium intended to cool the support roll 121 to pass therethrough is provided inside each of the support rolls 121. The cooling medium passes through the hollow structure 122 inside the support roll 121, thereby making it possible to obtain a cooling effect resulting from heat removal and suppress a temperature rise of the support roll 121 caused by heating of the heating mechanism 130, and so on. Therefore, in this embodiment, it becomes possible to arrange the support rolls 121 closer to the heating mechanism 130 while reducing the damage of the support rolls 121 (the first support roll 121-1, in particular) caused by high temperature, (which is, for example, about 200°C), as compared to the case where these hollow structures 122 are provided. This makes it possible to shorten a distance L1 between a supporting position S where the first support roll 121-1 supports the workpiece 200 and the heating mechanism 130 as illustrated in Fig. 1. Shortening the distance L1 between the supporting position S and the heating mechanism 130 makes it possible to shorten a portion that can be an extra length from an end portion of a bent product obtained by bending the workpiece 200. As a result, this embodiment enables a yield of the bent product to improve. Incidentally, the explanation has been made based on the case where the support rolls 121 are arranged at the position on the upstream side of the heating mechanism 130 and bending is performed, but the present invention is not limited to this. That is, the similar effect can be obtained as long as the distance L1 between the supporting position S where the first support roll 121-1 supports the workpiece 200 and the heating mechanism 130 and the support rolls 121 is shortened. The similar effect can be obtained even in the case where the support rolls 121 are arranged at the position on the upstream side of the heating mechanism 130 and direct pipe quenching is performed, for example. Further, the similar effect can be obtained even in the case where the support rolls 121 are arranged at the position on the downstream side of the heating mechanism 130 and bending or direct pipe quenching is performed.

[0019] Further, the supporting mechanism 120 is formed in which a plurality of the support rolls 121 (at least the first support roll 121-1 and the second support roll 121-2 in the example illustrated in Fig. 1) are arranged side by side at different positions in the conveyance direction 111 of the workpiece 200. This is more likely to be achieved as a result that the distance L1 can be shortened by providing the hollow structure 122 allowing a cooling medium to pass therethrough inside each of the above-described support rolls 121. According to such a configuration, during bending of the workpiece 200, at least the first support roll 121-1 or the second support roll 121-2 can support the workpiece 200. Therefore, in this embodiment, at least the first support roll 121-1 or the second support roll 121-2 can receive the above-described bending reaction force.

[0020] Then, there will be explained one example of a schematic configuration of the support roll 121.

[0021] Fig. 2 is a view illustrating the embodiment of the present invention and illustrating one example of the schematic configuration of the support roll 121 illustrated in Fig. 1. Concretely, Fig. 2 illustrates a cross-sectional view of the support roll 121 in the Z-axis direction.

[0022] As illustrated in Fig. 2, the support roll 121 is formed by including an outer ring portion 1211, a sliding bearing 1212, and a shaft 1213. Further, Fig. 2 illustrates an example where as the sliding bearing 1212, two sliding bearings 1212-1 and 1212-2 are provided in the Z-axis direction. In the following explanation, when the sliding bearings 1212-1 and 1212-2 are explained representatively, they are explained as the "sliding bearing 1212" simply. Further, Fig. 2 illustrates the example where the two sliding bearings 1212-1 and 1212-2 are provided in the Z-axis direction, but the present invention is not limited to this and an aspect in which three or more sliding bearings 1212 are provided is also included.

[0023] The outer ring portion 1211 is a member to abut on the outer surface of the workpiece 200. The sliding bearing 1212 is a member provided between the outer ring portion 1211 and the shaft 1213. The shaft 1213 is arranged at the inner side of the outer ring portion 1211 and is a member that rotatably supports the outer ring portion 1211 and includes the hollow structure 122 therein. On this occasion, cores of the outer ring portion 1211, the sliding bearing 1212, and the shaft 1213 are positioned concentrically. An outer surface of the shaft 1213 comes in contact with an inner surface of the sliding bearing 1212 to slide. Concretely, the outer ring portion 1211 that abuts on the workpiece 200 rotates, and the sliding bearing 1212 also rotates in the same manner. The shaft 1213 that supports a load is incapable of rotating and is fixed to roll holders (roll holders 902 in Fig. 9B to be described later) of the supporting mechanism 120. At the inner side of the outer ring portion 1211, a mechanism that rotatably supports the outer ring portion 1211 is internally provided.

[0024] Further, in this embodiment, as described above, the sliding bearing 1212 is provided as a bearing to be provided between the outer ring portion 1211 and the shaft 1213, so that it becomes possible to increase a structural strength and additionally, reduce the thickness of the bearing as compared to the case where a rolling bearing is provided as this sliding bearing, for example. When it is possible to increase the structural strength, it is possible to increase the bending load to be imparted by the holding mechanism 150, for example, which is more suitable as the quenching processing apparatus 100. Further, when it is possible to reduce the thickness of the bearing, the outside diameter of the support roll 121 can be made small. Therefore, it is possible to set the supporting position S on the more downstream side in the conveyance direction 111 even when the shortest distance L2 between the outer surface of the first support roll 121-1 and an end portion of the heating mechanism 130, which is illustrated in Fig. 1, is the same distance. That is, the distance L1 can be further shortened, so that this embodiment can further improve the yield of the bent product.

(Heating mechanism 130)

[0025] Here, Fig. 1 is explained again.

[0026] The heating mechanism 130 is arranged on the downstream side in the conveyance direction 111 of the workpiece 200 from the supporting mechanism 120 and is a mechanism to heat the workpiece 200. For example, the heating mechanism 130 is configured by including a heating coil arranged to cover the outer periphery of the workpiece 200 in a portion in the longitudinal direction (the conveyance direction 111) of the workpiece 200. Concretely, for example, the heating mechanism 130 is configured to heat the workpiece 200 by a high-frequency current being applied to the heating coil by the control of the control device 170. In this heating mechanism 130, a communication part that carries the high-frequency current from the upstream side to the downstream side in the conveyance direction 111, for example, is provided, and the workpiece 200 passes through this communication part. Concretely, for example, the heating coil of the heating mechanism 130 is provided to wind around this communication part, so that the space on the inner peripheral side of the heating mechanism 130, which corresponds to this communication part, is equivalent to a region of an object to be heated by the heating mechanism 130.

(Cooling mechanism 140)

[0027] The cooling mechanism 140 is arranged on the downstream side in the conveyance direction 111 of the workpiece 200 from the heating mechanism 130 (arranged between the heating mechanism 130 and the holding mechanism 150 in the conveyance direction 111 of the workpiece 200) and is a mechanism to cool a high-temperature portion of the workpiece 200 heated by the heating mechanism 130. For example, the cooling mechanism 140 jets a cooling medium to a high-temperature portion of the workpiece 200 heated by the heating mechanism 130 based on the control of the control device 170, to thereby cool this high-temperature portion. Concretely, in the cooling mechanism 140, a jetting port for jetting the cooling medium is provided and the cooling medium is jetted through this jetting port. Further, the cooling mechanism 140 is configured so that the control device 170 controls a jetting amount of the cooling medium to be jetted. Incidentally, as one example of the cooling medium to be jetted from the cooling mechanism 140, water is applicable.

[0028] For example, the cooling mechanism 140 is configured by including a jetting member arranged so as to cover the outer periphery of the workpiece 200 in a portion in the longitudinal direction (the conveyance direction 111) of the workpiece 200 and a supply mechanism for supplying the cooling medium to this jetting member. On this occasion, the supply mechanism is configured by, for example, a flow path through which the cooling medium circulates, a pump to circulate the cooling medium, and so on. Concretely, in the jetting member, a jetting port is provided, and the cooling mechanism 140 is configured so that the cooling medium supplied to the jetting member by the supply mechanism is jetted through this jetting port. Further, the control device 170 is configured to control a jetting amount of the cooling medium to be jetted by the cooling mechanism 140 by controlling the amount of the cooling medium to be supplied to the jetting member from the supply mechanism.

(Holding mechanism 150)

[0029] The holding mechanism 150 is arranged on the downstream side in the conveyance direction 111 of the workpiece 200 from the heating mechanism 130 and is a mechanism capable of holding the workpiece 200 and additionally, adding a bending load to the workpiece 200. Concretely, in the example illustrated in Fig. 1, the holding mechanism 150 is capable of holding a downstream-side end portion 202 of the workpiece located on the side opposite to the upstream-side end portion 201 of the workpiece held by the conveying mechanism 110 and additionally, adding a bending load to the workpiece 200. Further, the holding mechanism 150 is configured so that the direction and the size of the bending load to be added to the workpiece 200 are controlled by the control device 170.

(Cooling medium supply mechanism 160)

[0030] The cooling medium supply mechanism 160 is a mechanism to supply a cooling medium for cooling the support roll 121 (more specifically, the shaft 1213, the sliding bearing 1212, and the outer ring portion 1211 illustrated in Fig. 2) to the hollow structure 122 of the support roll 121 (more specifically, the hollow structure 122 included in the shaft 1213). Concretely, the cooling medium supply mechanism 160 is configured so that the control device 170 controls a supply amount of the cooling medium to be supplied to the hollow structure 122. Incidentally, as one example of the cooling medium to be supplied from the cooling medium supply mechanism 160, liquid can be used, and similarly to the cooling mechanism 140, water is applicable. On this occasion, the cooling medium supply mechanism 160 may supply a cooling water being one example of the cooling medium with circulation or without circulation.

(Control device 170)

[0031] The control device 170 is a device to bend the workpiece 200 to a desired shape by controlling divings of the conveying mechanism 110, the heating mechanism 130, the cooling mechanism 140, the holding mechanism 150, and the cooling medium supply mechanism 160 in conjunction with one another based on input information from the input device 180, for example. Concretely, the control device 170, in accordance with processing condition information according to a product shape input from the input device 180, for example, makes the heating mechanism 130 partially heat the workpiece 200, makes the holding mechanism 150 add a bending load to a heated portion heated of the workpiece 200, and immediately after it, makes the cooling mechanism 140 cool this heated portion of the workpiece 200 while making the conveying mechanism 110 convey the workpiece 200 in the longitudinal direction at a predetermined conveying speed. Thereby, bending of the workpiece 200 in accordance with a desired product shape is implemented. Further, the control device 170 performs a control to display, for example, input information from the input device 180, operation information relating to a bending process of the workpiece 200, and so on on the display device 190 as necessary.

(Input device 180)

[0032] The input device 180 is a device to input various pieces of information to the control device 170. Concretely, for example, the input device 180 inputs the above-described processing condition information according to a product shape to the control device 170.

(Display device 190)

[0033] The display device 190 is a device to display various pieces of information based on the control of the control device 170. Concretely, for example, the display device 190 displays input information from the input device 180, operation information relating to a bending process of the workpiece 200, and so on. Incidentally, it is also possible for this display device 190 not to be configured as one component in the quenching processing apparatus 100 but to be configured separately from the quenching processing apparatus 100, or this display device 190 can also be omitted as necessary.

[0034] As explained above, the quenching processing apparatus 100 is formed to include the supporting mechanism 120 abutting on the outer surface of the workpiece 200 and the support rolls 121 each including the hollow structure 122 allowing the cooling medium to pass therethrough therein. Such a configuration makes it possible to suppress a temperature rise of the support roll 121 caused by heating of the heating mechanism 130, and the like. Furthermore, providing the hollow structure 122 as in this embodiment makes it possible to reduce the damage of the support roll 121 caused by heat and arrange the support roll 121 closer to the heating mechanism 130 as compared to the case where this hollow structure 122 is not provided. This makes it possible to shorten the distance L1 illustrated in Fig. 1, so that it is possible to shorten an extra length portion of the end portion of the bent product obtained by bending the workpiece 200. As a result, it is possible to improve the yield of the bent product. Further, as a result that it is possible to suppress a temperature rise of the support roll 121 caused by heating of the heating mechanism 130, the damage of the support roll 121 can be reduced, so that it is possible to maintain good operation of the bent product.

[0035] Here, the improvement in yield means that the length allowing bending is lengthened with respect to the entire length of the workpiece 200. When the yield improves, an extra length incapable of being utilized as the material decreases in the workpiece 200, so that cutting of the extra length often becomes no longer necessary. That is, when the yield improves, the cutting work is not performed any more, so that it is possible to omit a cutting process when producing a product. Therefore, it is possible to enjoy a large production merit. Furthermore, it is possible to drive down a material cost.

[0036] Here, good operation means that a high-quality processed product can be produced accurately by using a treatment appears including long-life consumable parts. The long-life processing apparatus means a processing apparatus including consumable parts each having low exchange frequency. In the quenching processing apparatus 100 in this embodiment, when the exchange frequency of the support roll 121 decreases, the operation life of the quenching processing apparatus 100 lengthens. When the operation life of the quenching processing apparatus 100 lengthens, it is possible to improve productivity, resulting in good operation.

[0037] The high-quality processed product means a product processed to have a long range where bending is allowed with respect to the entire length of the workpiece 200 and have good shape accuracy. The length of a range where bending is not allowed (to be referred to as a bending limit, hereinafter) is substantially equivalent to the distance L1 between the supporting position S of the support roll 121 and the heating mechanism 130. This is because the bending moment imparted to the downstream side of the workpiece 200 when bending is transmitted to the heated region of the workpiece 200 and further, the bending moment transmitted to the upstream side of the workpiece 200 is transmitted to the supporting position S of the support roll 121. Such a configuration makes it possible to stably impart the bending moment to the high-temperature region of the workpiece 200 with a decrease in deformation resistance in a range where the distance from the upstream end portion in the workpiece 200 is longer than the bending limit. As a result, it is possible to accurately bend the workpiece 200. Further, when the range where bending is allowed is lengthened with respect to the entire length of the workpiece 200, it is possible to increase flexibility of a bent shape with respect to a product shape, resulting in that the processed product is more preferred.

[0038] Further, the support roll 121 in the quenching processing apparatus 100 includes the outer ring portion 1211 abutting on the outer surface of the workpiece 200 and the shaft 1213 including the hollow structure 122 therein. The shaft 1213 rotatably supports the outer ring portion 1211 and is arranged at the inner side of the outer ring portion 1211. Incidentally, the strength of the shaft 1213 only needs to be maintained, and the material of the shaft 1213 may be metal, ceramic, or resin.

[0039] Further, in the quenching processing apparatus 100 according to this embodiment, even in the case where the workpiece 200 has been conveyed to the most downstream side in the conveyance direction 111 by the conveying mechanism 110, a plurality of the support rolls 121 (in the example illustrated in Fig. 1, the first support roll 121-1 and the second support roll 121-2) are arranged at different positions in the conveyance direction 111 of the workpiece 200 between the conveying mechanism 110 and the heating mechanism 130. According to such a configuration, during bending of the workpiece 200, at least the first support roll 121-1 or the second support roll 121-2 can support the workpiece 200, so that at least the first support roll 121-1 or the second support roll 121-2 can receive the bending reaction force to act by the bending load added to the workpiece 200. Thereby, this embodiment can more stably support the workpiece 200 as compared to the case where only a pair of the support rolls 121 supports the workpiece 200. As a result, this embodiment can stably add the bending load by the holding mechanism 150 to the high-temperature portion of the workpiece 200 heated by the heating mechanism 130, and thus it also becomes possible to improve bending accuracy.

<<Concrete aspect examples of the supporting mechanism 120>>

[0040] Next, there will be explained concrete aspect examples of the supporting mechanism 120.

[0041] Fig. 3A to Fig. 3C are views each illustrating the embodiment of the present invention and illustrating a concrete aspect example of the sliding bearings 1212-1 and 1212-2 illustrated in Fig. 2. In Fig. 3A to Fig. 3C, the same reference numerals are added to the same components as those illustrated in Fig. 2. Concretely, Fig. 3A illustrates an example where the axial-direction (Z-axis direction) length of sliding bearings 1212-1 and 1212-2 is shorter than the axial-direction (Z-axis direction) length of an outer ring portion 1211. Fig. 3B illustrates an example where the Z-axis direction length of sliding bearings 1212-1 and 1212-2 is substantially the same as the Z-axis direction length of an outer ring portion 1211, which is the same as the case illustrated in Fig. 2. Fig. 3C illustrates an example where the Z-axis direction length of sliding bearings 1212-1 and 1212-2 is longer than the Z-axis direction length of an outer ring portion 1211. Incidentally, Fig. 2 and Fig. 3A to Fig. 3C each illustrate an example where the sliding bearing 1212 is divided into two in the Z-axis direction, but the present invention is not limited to this aspect.

[0042] Fig. 4A to Fig. 4C are views each illustrating the embodiment of the present invention and illustrating a concrete aspect example of the sliding bearing 1212 illustrated in Fig. 2. In Fig. 4A to Fig. 4C, the same reference numerals are added to the same components as those illustrated in Fig. 2 and Fig. 3A to Fig. 3C. Concretely, Fig. 4A illustrates an example where a single sliding bearing 1212 is formed in the Z-axis direction without dividing the sliding bearing 1212 in the axial direction (the Z-axis direction). Fig. 4B illustrates an example where a sliding bearing 1212 is divided into two in the Z-axis direction to form two sliding bearings 1212-1 and 1212-2 in the Z-axis direction, which is the same as the case illustrated in Fig. 2. Fig. 4C illustrates an example where a sliding bearing 1212 is divided into three in the Z-axis direction to form three sliding bearings 1212-1 to 1212-3 in the Z-axis direction.

[0043] Further, the material of the sliding bearing 1212 is not limited to a metal material, and may be resin. The hardness of the sliding bearing 1212 is preferred to be smaller than the hardness of the shaft 1213. The sliding bearing 1212 is characterized in that the sliding bearing 1212 has a shape in which the axis-direction (Z-axis direction) entire surface receives a machining reaction force with respect to the outer ring portion 1211.

[0044] Next, there will be explained one example of a method of assembling the sliding bearing 1212 illustrated in Fig. 2. Fig. 5A is a view illustrating the embodiment of the present invention and illustrating one example of the method of assembling the sliding bearing 1212 illustrated in Fig. 2. Concretely, Fig. 5A illustrates that the outer ring portion 1211 is placed on a lower jig 301, the sliding bearing 1212 is placed on the outer ring portion 1211, and additionally, an upper jig 302 is placed on the sliding bearing 1212 to be moved downward, and thereby the sliding bearing 1212 is assembled to the outer ring portion 1211.

[0045] Further, Fig. 5B is a view illustrating the embodiment of the present invention and illustrating the sliding bearing 1212 illustrated in Fig. 5A in an enlarged manner. As illustrated in Fig. 5A and Fig. 5B, a slit 12121 is formed in the sliding bearing 1212 in this embodiment. The slit 12121 can prevent the outer ring portion 1211 formed of non-magnetic ceramic, for example, from being damaged when the sliding bearing 1212 is assembled to the outer ring portion 1211 explained in Fig. 5A, to thus have an effect of facilitating this assembling. Since the slit 12121 is formed in the sliding bearing 1212, it is possible to prevent the outer ring portion 1211 from being damaged when the sliding bearing 1212 is assembled to the outer ring portion 1211 explained in Fig. 5A. Therefore, the sliding bearing 1212 is easily assembled to the outer ring portion 1211.

[0046] Further, the slit 12121 can absorb thermal expansion caused by heating of the heating mechanism 130. As a result, it is possible to reduce a load of the sliding bearing 1212 on the outer ring portion 1211 due to the thermal expansion and reduce the outside diameter of the outer ring portion 1211. In this embodiment, the sliding bearing 1212 is provided between the outer ring portion 1211 and the shaft 1213, and thus the slit 12121 can be formed. However, the rolling bearing is covered with an outer frame and an inner frame in the 360° circumferential direction generally, and thus it is difficult to form the slit 12121 in the rolling bearing. Therefore, the rolling bearing fails to exhibit the above-described effect obtained by forming the slit 12121.

[0047] Fig. 5C is a cross-sectional view in the method of assembling the sliding bearing 1212 illustrated in Fig. 5A, which illustrates the embodiment of the present invention. Further, Fig. 5D is a cross-sectional view in a method of disassembling the sliding bearing illustrated in Fig. 5C, which illustrates the embodiment of the present invention. In Fig. 5C and Fig. 5D, the same reference numerals are added to the same components as those in Fig. 5A and Fig. 5B. Fig. 5D illustrates a state where the sliding bearing 1212 has been disassembled from the outer ring portion 1211 by assembling the outer ring portion 1211 with the sliding bearing 1212 assembled thereto to a lower jig 311, placing an upper jig 312 on the sliding bearing 1212, and moving it downward.

[0048] Concretely, by the method illustrated in Fig. 5C, a projecting portion at a lower end of the upper jig 302 abuts on an upper end portion of the sliding bearing 1212 in the circumferential direction at substantially 360° , and thus the circumferential load by abutting on the upper end portion of the sliding bearing 1212 becomes uniform. Then, the lower end of the upper jig 302 is inserted into the inner side of the upper end portion of the sliding bearing 1212 so that the both become concentric. Therefore, the direction of a downward load in the axial direction, which is necessary for the insertion, is stabilized. Then, the circumferential load on the upper end portion of the sliding bearing 1212 becomes uniform and the direction of the downward load in the axial direction, which is necessary for the insertion, is stabilized, thus making it possible to reduce occurrence of loads on the outer ring portion 1211 other than the load in the axial direction. As above, using the upper jig 302 and the lower jig 301 facilitates the concentric arrangement of the outer ring portion 1211 and the sliding bearing 1212, and further makes it possible to stabilize the direction of the load necessary when the sliding bearing 1212 is inserted. Therefore, it is possible to reduce a pressing force to the outer ring portion 1211, which is caused by misalignment between the sliding bearing 1212 and the outer ring portion 1211 that are provided internally, so that cracking or damage of, for example, non-magnetic ceramic forming the outer ring portion 1211 can be avoided. Further, the upper jig 302 is placed on the sliding bearing 1212 and the upper jig 302 is moved downward, thereby making it possible to easily assemble the sliding bearing 1212 to the outer ring portion 1211.

[0049] Further, when the sliding bearing 1212 is disassembled from the outer ring portion 1211 by the method illustrated in Fig. 5D, the upper jig 312 is placed on the sliding bearing 1212 to press the sliding bearing 1212 downward in the axial direction. How the load is applied downward by pressing is the same as that at the previously described insertion time. Then, as illustrated in Fig. 5D, the lower jig 311 has a column-shaped hollow that guides the sliding bearing 1212, and thus the direction in which the sliding bearing 1212 moves downward agrees with the outer ring portion 1211, resulting in that the sliding bearing 1212 and the outer ring portion 1211 become concentric. As a result, it is possible to reduce occurrence of loads other than the load in the axial direction on the outer ring portion 1211 caused by disassembling of the sliding bearing 1212.

[0050] Further, as described above while using Fig. 5B, the slit 12121 is formed in the sliding bearing 1212 in this embodiment in the axial direction. Then, as explained while using Fig. 5A and Fig. 5C, even when a pressing state is made between the shaft 1213 and the outer ring portion 1211 by the insertion and disassembling works on the occasion of assembling the sliding bearing 1212 to the outer ring portion 1211, the gap of the slit 12121 decreases, thereby making it possible to avoid the pressing state. Performing such procedures makes it possible to prevent cracking or damage of the outer ring portion 1211 formed of non-magnetic ceramic, for example. Accordingly, it is possible to easily assemble the sliding bearing 1212 in this embodiment.

[0051] Further, in this embodiment, as illustrated in Fig. 2, the two sliding bearings 1212-1 and 1212-2 are provided in a divided manner in the axial direction of the support roll 121. This is because when the outer ring portion 1211 is long in the axial direction, a positional displacement between cores of the sliding bearing 1212 and the outer ring portion 1211 is sometimes likely to occur when the sliding bearing 1212 is inserted and disassembled. As a result, there is sometimes a case that the upper jig 302 and the slit 12121 are not enough to avoid the pressing state, and thus in order to cope with the case, the sliding bearing 1212 is divided. When the sliding bearing 1212 is divided, the axial-direction length of the sliding bearing 1212 per one part becomes short. This makes it possible to reduce a misalignment amount of the sliding bearing 1212 per one part, and thus the pressing state can be avoided. That is, it is possible to easily assemble the sliding bearing in this embodiment.

[0052] Further, this embodiment can also be designed to provide a slight gap between the inner surface of the sliding bearing 1212 and the outer surface of the shaft 1213 as illustrated in Fig. 2. Providing a slight gap in this manner makes it possible to absorb the thermal expansion caused by heating of the heating mechanism 130 and facilitate the assembling explained using Fig. 5A.

[0053] Fig. 6A to Fig. 6C are views illustrating the embodiment of the present invention and illustrating concrete aspect examples of the shape of the outer ring portion 1211 illustrated in Fig. 2. In Fig. 6A to Fig. 6C, the same reference numerals are added to the same components as those illustrated in Fig. 1 and Fig. 2. Further, Fig. 6A to Fig. 6C each illustrate a cross-sectional view viewed from the X-axis direction illustrated in Fig. 1. Concretely, Fig. 6A illustrates an example where the shape of the outer ring portion 1211 is a cylindrical shape. Fig. 6B illustrates an example where the shape of the outer ring portion 1211 is a bobbin shape. Fig. 6C illustrates an example where the shape of the outer ring portion 1211 is a bowl shape.

[0054] Fig. 7A to Fig. 7C are views illustrating the embodiment of the present invention and illustrating concrete aspect examples of the arrangement of the outer ring portion 1211 illustrated in Fig. 2. In Fig. 7A to Fig. 7C, the same reference numerals are added to the same components as those illustrated in Fig. 1 and Fig. 2. Further, Fig. 7A to Fig. 7C each illustrate a view of a section view viewed from the X-axis direction illustrated in Fig. 1. Concretely, Fig. 7A illustrates, in the case of guiding a quadrangular-shaped workpiece 200, an example where outer ring portions 1211 (namely, support rolls 121) are arranged right and left in the sheet (namely, the support rolls 121 are arranged on the Y axis across the workpiece 200). Fig. 7B illustrates, in the case of guiding the quadrangular-shaped workpiece 200, an example where outer ring portions 1211 (namely support rolls 121) are arranged above and below in the paper (namely, the support rolls 121 are arranged on the Z axis across the workpiece 200). Fig. 7C illustrates, in the case of guiding the quadrangular-shaped workpiece 200, an example where outer ring portions 1211 (namely, support rolls 121) are arranged above and below and right and left in the sheet (namely, the two support rolls 121 out of the support rolls 121 are arranged on the Z axis across the workpiece 200 and the other two support rolls 121 are arranged on the Y axis across the workpiece 200).

[0055] Subsequently, there will be explained details of the support roll 121 illustrated in Fig. 2, and so on. Even if it is a mechanism to rotatably support the shaft 1213 at the substantially outer side of the outer ring portion 1211, the bending moment is generated in the bearing by a load perpendicularly applied to the shaft 1213. The bending moment generated in the bearing located at the substantially outer side of the shaft 1213 is added to the load perpendicularly applied to the shaft 1213, and thus stress to be applied to the shaft 1213 increases. Therefore, it is necessary to increase the diameter of the shaft 1213. However, in this embodiment, the sliding bearing 1212 is internally provided between the outer ring portion 1211 and the shaft 1213. Therefore, the shaft 1213 can rotatably support the outer ring portion 1211 at the inner side of the outer ring portion 1211. As a result, it is only necessary to geometrically receive a compressed surface pressure by the load perpendicularly applied to the shaft 1213, and the bending moment is not nearly added to the sliding bearing 1212. Then, it is possible to reduce the stress to be added to the sliding bearing 1212 and the shaft 1213. It is possible to reduce the outside diameter of the shaft 1213 and reduce the outside diameter of the outer ring portion 1211. In this embodiment, when the outside diameter of the outer ring portion 122 is reduced, the effect by heating from the heating mechanism 130 on the outer ring portion 1211 decreases, so that it is possible to arrange the support roll 121 close to the heating mechanism 130.

[0056] Hereinafter, there will be explained the case where the heating mechanism 130 inductively heats the workpiece 200 and the temperature of the workpiece 200 reaches about 850°C to 1000°C. In such a case, due to the effect of heat transfer and radiant heat, the temperature of the supporting mechanism 120 rises. Particularly, the support rolls 121 in the supporting mechanism 120 increase in temperature. Further, in the case of the material of the outer ring portion 1211 being a magnetic material, the outer ring portion 1211 is directly affected by the induction heating by the heating mechanism 130, and thus the temperature of the support rolls 121 becomes likely to rise. When the distance between the heating mechanism 130 and the support rolls 121 is short, the temperature rise of the support rolls 121 becomes prominent. When the temperatures of the shaft 1213 and the outer ring portion 1211 in the support roll 121 exceed permissible values (for example, 200°C), serious problems are caused in terms of a rotation function and a structural strength. In order to solve the problems, the embodiment of the present invention more preferably employs an embodiment in which the outer ring portion 1211 is formed of a non-magnetic material. Incidentally, Patent Literature 2 described above describes that the support guide illustrated in paragraph 0051 and Fig. 3 is manufactured of a non-magnetic material. In terms of this point, the support guide illustrated in Fig. 3 of Patent Literature 2 is to achieve support by sliding (fixing) and is not to achieve support by rotation like the outer ring portion 1211 in the embodiment of the present invention, so that the support guide is different from the art assumed in the embodiment of the present invention.

[0057] Generally, a lubricating oil is used for the shaft

1213 in order to prevent seizing of a sliding portion. When the temperature of the shaft 1213 exceeds a heatproof temperature of the lubricating oil, deterioration in the lubricating oil is caused to fail to exhibit lubricating performance, resulting in that seizing is caused on a sliding surface of the shaft 1213. Further, when the temperature of the support roll 121 exceeds the permissible value, the strength of the support roll 121 decreases, the surface of the support roll 121 is thermally deformed, and cracking is caused in the surface of the support roll 121 (namely, the outer ring portion 1211) in some cases. When deformation or cracking of the support roll 121 is caused, a mechanical backlash between the outer ring portion 1211 and the shaft 1213 occurs, and thus spacing in the Y-axis direction between a pair of the support rolls 121 changes from a desired set value. Therefore, when the supporting mechanism 120 can no longer support the workpiece 200 stably, shapes of processing dimensions vary and dimension errors increase, leading to a decrease in the quality of the processed product. Furthermore, a use environment where the support roll 121 is likely to deteriorate is made, and thus the operating life of the quenching processing apparatus 100 shortens. Additionally, the frequency of exchanging the support roll 121 increases and the operating rate decreases, thus adversely affecting the production.

[0058] However, in the support roll 121 in this embodiment, the hollow structure 122 allowing the cooling medium for cooling this support roll 121 to pass therethrough is provided, and thus even when the support roll 121 is arranged near the heating mechanism 130, a temperature rise of the support roll 121 can be suppressed. Therefore, deterioration in a sliding portion of the support roll 121, for example, is prevented, leading to a decrease in the thermal deformation of the outer ring portion 1211. As a result, the operating life of the quenching processing apparatus 100 in this embodiment is extended.

[0059] Here, there will be explained a stress to occur in the outer ring portion 1211 when the support roll 121 receives the machining reaction force by the workpiece. Fig. 8A is a view illustrating a comparative example and illustrating an example of the case where rolling bearings 801 are provided between an outer ring portion 1211 and a shaft 1213. Fig. 8B is a view illustrating the comparative example and illustrating the stress to occur in the inner side of the outer ring portion 1211 on which the workpiece 200 illustrated in Fig. 8A abuts. Incidentally, in Fig. 8A, waterproof rings 802 for providing the rolling bearings 801 are also illustrated.

[0060] As illustrated in Fig. 8A, when a plurality of the rolling bearings 801 are arranged in the axial direction between the outer ring portion 1211 and the shaft 1213, a gap is made between the plural rolling bearings 801. When a lubricating oil is used for the rolling bearings 801, the waterproof rings need to be provided adjacently to the rolling bearing 802 in order to prevent water penetration. Under such circumstances, when the rolling bearings 801 are employed, it becomes difficult to flatten the inner side of the outer ring portion 1211 when viewed in section. Then, a gap occurs between a plurality of the rolling bearings. As a result, a distribution of the stress to occur in the inner side of the outer ring portion 1211 does not become uniform. In Fig. 8B, the horizontal axis indicates a stress to occur in the inner side of the outer ring portion 1211 and the vertical axis indicates an axial-direction position of the roll. The outer ring has an uneven inner side shape when viewed in section and further, a contact surface between the rolling bearings and the outer ring is not continuous, and thus the stress generated in the inner side of the outer ring portion does not become uniform. Therefore, a portion with an increasing stress concentration coefficient of the load by bending is generated and the outer ring portion 1211 is likely to be damaged.

[0061] Fig. 8C is a view illustrating the embodiment of the present invention and illustrating an example where the sliding bearing 1212 is provided between the outer ring portion 1211 and the shaft 1213. Further, Fig. 8D is a view illustrating the embodiment of the present invention and illustrating the stress to occur in the inner side of the outer ring portion 1211 illustrated in Fig. 8C.

[0062] In the example illustrated in Fig. 8C, the sliding bearing 1212 is internally provided continuously with respect to the axial direction of the outer ring portion 1211. The sliding bearing 1212 is internally provided continuously in this manner, and thus the sliding bearing 1212 can continuously receive the load from the workpiece 200 in the longitudinal direction via the outer ring portion 1211. Further, the shape of the inner side of the outer ring portion 1211 is flat when viewed in section. As above, the shape of the inner side of the outer ring portion 1211 is flat, thus making it possible to receive the load continuously, and thus distribution of the stress to occur in the inner side of the outer ring becomes uniform. That is, the present invention has an effect capable of alleviating the stress concentration to substantially uniformize the stress.

[0063] This effect capable of alleviating the stress concentration to substantially uniformize the stress can be obtained by internally providing the sliding bearing 1212 between the outer ring portion 1211 and the shaft 1213 and making the inner side of the outer ring portion 1211 flat when viewed in section as in this embodiment. The sliding bearing 1212 is internally provided between the outer ring portion 1211 and the shaft 1213 and the outer ring portion 1211 has a flat inner side shape when viewed in section as in this embodiment, thereby making it possible to substantially uniformize the stress. The following effects can be obtained as compared to the case where the rolling bearings 801 are provided between the outer ring portion 1211 and the shaft 1213.

[0064] As the first effect, it becomes possible to increase the structural strength of the shape of the support roll 121, thus making it possible to increase a use range of the bending load by the holding mechanism 150. Therefore, in this embodiment, the sliding bearing 1212 is internally provided as a bearing, thereby making it possible to increase the degree of freedom of the size of the processing load in the quenching processing apparatus 100.

[0065] As the second effect, it becomes possible to reduce the thickness of the bearing. Thereby, the outside diameter of the support roll 121 can be made small, and therefore, it is possible to set the supporting position S on the more downstream side in the conveyance direction 111 even in the case where the distance L2 between the first support roll 121-1 and the heating mechanism 130 illustrated in Fig. 1 is the same. That is, the distance L1 can be further shortened. As a result, it becomes possible to improve the yield of the processed product.

[0066] Generally, ceramic is inferior in toughness to metal materials and is weak against impact, and thus has a problem in terms of strength. Then, in order to achieve a small diameter of the outer ring portion 1211, the outer ring portion 1211 often tends to have a thin shape. Further, the outer ring portion 1211 often has an axial-direction length substantially equal to that of the sliding bearing 1212 due to space restriction. Therefore, the outer ring portion 1211 receives a pressing force from the sliding bearing 1212 to be likely to crack due to the toughness of ceramic of the outer ring portion 1211 and geometrical conditions of a thin cylindrical shape. However, this configuration makes it possible to prevent damage and the like of the outer ring portion 1211 when the sliding bearing 1212 is inserted into and disassembled from the outer ring portion 1211 as explained using Fig. 5C and Fig. 5D because the slit 12121 is provided in the sliding bearing 1212 as illustrated in Fig. 5B, for example.

[0067] Next, the supporting mechanism 120 will be explained from different viewpoints.

[0068] A rotation supporting mechanism is internally provided in the outer ring portion 1211 like the supporting mechanism 120 in this embodiment, thereby making it possible to simplify a configuration of both ends to fix the shaft 1213, and thus it is effective for space saving regarding a layout. As illustrated in a comparative example in Fig. 9A, when a bearing is provided at both ends of the shaft 1213, a space for providing each bearing is required additionally. In Fig. 9B, which is this embodiment, the rotation supporting mechanism is internally provided in the outer ring portion 1211, and thus space saving can be achieved geometrically. In Fig. 9B, the shaft 1213 is fixed to the roll holders 902 configuring a portion of the supporting mechanism 120 to be incapable of rotation, and thus the rotation supporting mechanism can be internally provided in the outer ring portion 1211. Generally, on the periphery of the heating mechanism of quenching, there are a busbar to supply electric power to the heating mechanism 130 and a cooling pipe to cool the heating mechanism of quenching. Therefore, it is impossible to say that bringing the supporting mechanism 120 close to the heating mechanism 130 as a result of providing a rolling bearing 903 separately from an abutting portion of the outer ring portion 1211 in the Z-axis direction of the support roll 121 in order to reduce the effect of heating by the heating mechanism 130 on a bearing portion as illustrated in the comparative example in Fig. 9A is a proper method also from the viewpoint of space. On the other hand, in the supporting mechanism 120 in this embodiment, the space saving can be achieved by the bearing configuration, and thus even when the supporting mechanism 120 is arranged near the heating mechanism 130, no interference with the above-described peripheral devices is caused. That is, in this embodiment, the supporting mechanism 120 can be arranged near the heating mechanism 130 also from the point of space.

[0069] Incidentally, the supporting mechanism 120 only needs to be one to support the workpiece, and the above-described effects can be obtained even when the supporting mechanism 120 is arranged in any direction. That is, the supporting mechanism 120 may be arranged so as to make the axial direction of the support roll 121 in the supporting mechanism 120 vertical to the XY plane illustrated in Fig. 1 or make the axial direction of the support roll 121 in the supporting mechanism 120 vertical to the YZ plane illustrated in Fig. 1.

[0070] Fig. 9A is a view illustrating a support roll according to the comparative example and illustrating one example of the case where the rolling bearing 903 is provided between the shaft 1213 and the roll holder 902. Fig. 9A illustrates a rolling element 901 configuring the rolling bearing. Fig. 9B is a view illustrating the support roll 121 according to the embodiment of the present invention and illustrating one example of the case where the sliding bearing 1212 is provided between the shaft 1213 and the outer ring portion 1211. Fig. 9B illustrates a sliding portion 904 in the case of the support roll 121 in this embodiment. Further, Fig. 9C is a table illustrating one example of respective factors in the case of the support roll according to the comparative example illustrated in Fig. 9A and the case of the support roll 121 according to this embodiment illustrated in Fig. 9B. Here, Fig. 9C illustrates the case where a machine structural steel (SCM material) is used as the material of the shaft 1213 of the support roll according to the comparative example illustrated in Fig. 9A and the material of the shaft 1213 of the support roll 121 according to this embodiment illustrated in Fig. 9B.

[0071] As illustrated in Fig. 9B, in this embodiment, the sliding bearing 1212 is present between the outer ring portion 1211 and the shaft 1213, and thus, as illustrated in Fig. 9C, the length of the shaft 1213 can be made short, and thus the moment decreases, and the shaft diameter can be made small, and thus the support roll 121 can be arranged close to the heating mechanism 130. As illustrated in Fig. 9C, when the length of the shaft 1213 according to this embodiment is set to 50 mm and the length of the shaft 1213 in the comparative example is set to 100 mm, the outside diameter of the shaft 1213 according to this embodiment can be made 80% (17.5 mm/22 mm = 80%). The shaft 1213 is fixed to the roll holders 902 configuring a portion of the supporting mechanism 120 to be incapable of rotation, thereby making it possible to provide the sliding bearing 1212 between the outer ring portion 1211 and the shaft 1213. The shaft 1213 is fixed to the roll holders 902 configuring a portion of the supporting mechanism 120 to be incapable of rotation, and thus the outside diameter of the shaft 1213 can be made as small as 80%. The support roll 121 according to this embodiment has a function of abutting on the workpiece 200 and further has a function of supporting rotation therein in an axial-direction range of the abutting portion.

[0072] The support roll 121 in the supporting mechanism 120 in the case of direct pipe quenching only needs to have a structural strength capable of enduring the weight and the conveyance resistance of the workpiece 200. However, the load to be added to the support roll 121 to be used for bending increases excessively as compared to the load to be added to the support roll 121 to be used for the direct pipe quenching in many cases. This is because the support roll 121 to be used for bending is required to have not only the structural strength capable of enduring the weight and the conveyance resistance of the workpiece 200 but also a structural strength capable of enduring the bending load to be added to the workpiece 200. When the load on the shaft 1213 that supports the support roll 121 increases, it is necessary to increase the shaft diameter in order to reduce the stress. However, when the shaft diameter of the shaft 1213 is increased, the outside diameter of the outer ring portion 1211 increases. As a result, as illustrated in Fig. 1, as long as the distance L1 between the position where the support roll 121 supports the workpiece 200 (the position S of the portion abutting on the workpiece illustrated in Fig. 1) and the position of the heating mechanism 130 is the same in the conveyance direction of the workpiece, the shortest distance L2 between the outer ring portion 1211 and the heating mechanism 130 becomes short when the outside diameter of the support roll 121 is larger.

[0073] Further, the outer ring portion 1211 in this embodiment is formed of non-magnetic ceramic, for example, and thus is not affected by electromagnetic induction generated from the heating mechanism 130. As above, this embodiment can reduce the effect of the temperature rise by heating of the heating mechanism 130 because the outer ring portion 1211 is formed of non-magnetic ceramic as compared to the case where this outer ring portion is formed of a magnetic material, for example. As a result, it is possible to further shorten the distance L1 illustrated in Fig. 1. Incidentally, the outer ring portion 1211 only needs to be a non-magnetic material, for example, and therefore, is not limited to the non-magnetic ceramic in the present invention. An embodiment in which, for example, a non-magnetic resin is used as the non-magnetic material forming the outer ring portion 1211 is also applicable to the present invention. Here, in the case of the outer ring portion 1211 being formed of the non-magnetic ceramic, silicon nitride (Si_3N_4) ceramic can be cited as one example of the concrete material. Further, in the case of the outer ring portion 1211 being formed of the non-magnetic resin, a polyetheretherketone (PEEK) resin can be cited as one example of the concrete material. Further, an embodiment in which, for example, an austenitic stainless steel being non-magnetic stainless steel is used as the non-magnetic material forming the outer ring portion 1211 is also applicable to the present invention.

[0074] In this embodiment, the hardness of the sliding bearing 1212 is set to be smaller than that of the shaft 1213. Therefore, the sliding bearing 1212 between the outer ring portion 1211 and the shaft 1213 wears out. On this occasion, the sliding bearing 1212 rotates, to thus abrade uniformly in the circumferential direction. Therefore, variations in thickness of the sliding bearing 1212 in the circumferential direction decrease. As a result, it is possible to prevent local wear of the shaft 1213 in the circumferential direction caused by the outer ring portion 1211 and reduce uneven abrasion, and thus the supporting position S where the support roll 121 abuts on the workpiece 200 is stabilized. That is, employing the sliding bearing in this embodiment makes it possible to fabricate the supporting mechanism 120 that is capable of stably keeping the supporting position S. Incidentally, when the sliding bearing 1212 has worn out only by a predetermined amount, the sliding bearing 1212 only needs to be exchanged, and the exchange is simple as has been explained using Fig. 5C and Fig. 5D above, to thus be advantageous in terms of production.

[0075] Fig. 10A is a chart illustrating the embodiment of the present invention and illustrating one example of, in the case of using an austenitic stainless steel as the material of the outer ring portion 1211 in the support roll 121 illustrated in Fig. 2, a temperature change of the support roll as the time elapses. Further, Fig. 10B is a chart illustrating the embodiment of the present invention and illustrating one example of, in the case of using non-magnetic ceramic as the material of the outer ring portion 1211 in the support roll 121 illustrated in Fig. 2, a temperature change of the support roll as the time elapses. Each graph in Fig. 10A and Fig. 10B indicates the temperature change of the support roll 121 when the quenching processing apparatus processes five materials to be processed continuously, and the horizontal axis indicates the elapsed time and the vertical axis indicates the temperature of the support roll 121. The case of Fig. 10A using the austenitic stainless steel as the material of the outer ring portion 1211 is not suitable from the viewpoint of implementing the present invention but is a level applicable to implementation of the present invention even though the temperature rises as the processing advances to then reach about 200°C or so. Further, it is possible to say that the case of Fig. 10B using the non-magnetic ceramic as the material of the outer ring portion 1211 is a more suitable material of the outer ring portion 1211 from the viewpoint of implementing the present invention as compared to the case of Fig. 10A using the austenitic stainless steel as the material of the outer ring portion

1211 because the maximum temperature is fixed substantially at about 100°C. The reason why both the graphs in Fig. 10A and Fig. 10B rise and fall repeatedly in waves as the time elapses is because there are time zones for carrying-out and carrying-in of the workpiece during processing and heating is not performed during these time zones, and thus the temperature of the support roll 121 falls temporarily. The point that the case of using the non-magnetic ceramic as the material of the outer ring portion 1211 is more excellent than the case of using the austenitic stainless steel is that the maximum temperature is fixed substantially in a relatively low-temperature zone (at about 100°C in the example illustrated in Fig. 10B) and the temperature rise is suppressed.

[0076] Fig. 10C is a table illustrating one example of temperature characteristics according to the test processing condition in the case of the support roll according to the comparative example, the case of the support roll 121 according to the embodiment of the present invention illustrated in Fig. 10A, and the case of the support roll 121 according to the embodiment of the present invention illustrated in Fig. 10B. Here, in Fig. 10C, as the support roll according to the comparative example, a support roll with the outer ring portion 1211 whose material is a machine structural steel (SCM material) is illustrated, and as the support roll 121 according to the embodiment of the present invention, the support roll 121 with the outer ring portion 1211 whose material is an austenitic stainless steel (SUS304), which is illustrated in Fig. 10A, and the support roll 121 with the outer ring portion 1211 whose material is non-magnetic ceramic, which is illustrated in Fig. 10B, are illustrated. When the temperature change within a processing time period per unit product is seen in Fig. 10C, the temperature change is about 20°C in the support roll according to the comparative example with the outer ring portion 1211 whose material is a machine structural steel, while the temperature change is about 10°C in the support roll 121 according to the embodiment of the present invention with the outer ring portion 1211 whose material is an austenitic stainless steel. The results of the temperature change within the processing time period per unit product reveal that the support roll 121 according to the embodiment of the present invention with the outer ring portion 1211 whose material is an austenitic stainless steel is more excellent than the support roll according to the comparative example with the outer ring portion 1211 whose material is a machine structural steel in the viewpoint of suppressing the temperature rise. Further, when the temperature change within a predetermined processing time period of a plurality of products is seen in Fig. 10C, in the support roll according to the comparative example with the outer ring portion 1211 whose material is a machine structural steel, the temperature change is about 300°C with a significant temperature rise, while in the support roll 121 according to the embodiment of the present invention with the outer ring portion 1211 whose material is an austenitic stainless steel, the temperature change remains at about 200°C with a temperature rise and further, in the support roll 121 according to the embodiment of the present invention with the outer ring portion 1211 whose material is non-magnetic ceramic, the temperature change is substantially fixed at about 100°C due to temperature saturation. The results of the temperature change within the predetermined processing time period of a plurality of products reveal that the support roll 121 according to the embodiment of the present invention with the outer ring portion 1211 whose material is an austenitic stainless steel or non-magnetic ceramic is more excellent than the support roll according to the comparative example with the outer ring portion 1211 whose material is a machine structural steel in the viewpoint of suppressing the temperature rise. Further, the comparison between the materials of the outer ring portion 1211 according to the embodiment of the present invention reveals that as described above in Fig. 10A and Fig. 10B, the support roll 121 according to the embodiment of the present invention with the outer ring portion 1211 whose material is non-magnetic ceramic is more excellent than the support roll 121 according to the embodiment of the present invention with the outer ring portion 1211 whose material is an austenitic stainless steel in the viewpoint of suppressing the temperature rise.

[0077] Next, the structure of the support roll 121 will be mentioned again.

[0078] In the support roll according to the comparative example in Fig. 8A, the rolling bearings 801 are provided between the outer ring portion 1211 and the shaft 1213, and thus a gap for absorbing thermal expansion of the rolling bearings 801 is required between an inner surface of the outer ring portion 1211 and an outer surface of the rolling bearings 801. With this gap, a contact area between the outer ring portion 1211 and the rolling bearings 801 becomes small. Generally, the contact area is determined from factors such as the inside diameter of the outer ring portion 1211, the outside diameter of the rolling bearing 801, a load, and an elastic modulus by a Hertz stress equation. When the contact area is found by the Hertz stress equation, the contact area becomes small due to the gap being present at the inner side of the outer ring portion 1211, and thus the stress in the inner side of the outer ring portion 1211, which is generated by contact, increases. When this stress increases, a required thickness of the outer ring portion 1211 thickens, leading to an increase in the outside diameter, and the distance L1 illustrated in Fig. 1 increases, resulting in that the yield becomes worse.

[0079] Fig. 11A is a view illustrating this embodiment of the present invention and illustrating one example of the relationship between the outer ring portion 1211 and the sliding bearing 1212. In Fig. 11A, the shaft 1213 is omitted. As illustrated in Fig. 11A, in this embodiment, the sliding bearing 1212 is inserted into the outer ring portion 1211 by interference fit 1101, and thus the sliding bearing 1212 and the outer ring portion 1211 are brought into a contact state, and thus it is possible to increase a contact area of the abutting portion with the workpiece. When the contact area increases, it is possible to reduce the stress generated by abutting on the workpiece. That is, the sliding bearing 1212 in this embodiment can reduce the stress generated in the inner side of the outer ring portion 1211, thereby making it possible to reduce the thickness of the outer ring portion. On the other hand, a comparative example is illustrated in Fig. 11B. Fig. 11B is a view illustrating the comparative example and illustrating one example of the relationship between the outer ring portion 1211 and the sliding bearing 1212. The shaft 1213 is omitted also in Fig. 11B. As illustrated in Fig. 11B, a void 1102 is present between the outer ring portion 1211 and the sliding bearing 1212 in order to absorb thermal expansion of the sliding bearing 1212. As a result, the contact area between the outer ring portion 1211 and the sliding bearing 1212 at the abutting portion with the workpiece 200 becomes small in the circumferential direction of the sliding bearing 1212, and thus the stress generated in the inner side of the outer ring portion 1211 increases. As a result of a comparison between Fig. 11A in this embodiment and Fig. 11B in the comparative example, the contact area between the outer ring portion 1211 and the sliding bearing 1212 in this embodiment becomes larger than the contact area between the outer ring portion 1211 and the sliding bearing 1212 in the comparative example, and thus, the stress generated in the inner side of the outer ring portion 1211 in this embodiment becomes smaller than the stress generated in the inner side of the outer ring portion 1211 in the comparative example. Therefore, as long as this embodiment and the comparative example are the same in the load to be applied to the abutting portion, this embodiment can make the stress generated in the inner side of the outer ring portion 1211 smaller as compared to the comparative example, and thus it is possible to reduce the thickness of the outer ring portion 1211 in this embodiment. As a result, this embodiment can make the outside diameter of the outer ring portion 1211 small. Further, as illustrated in Fig. 11A, the reason why the insertion is enabled by the interference fit 1101 is due to the effect of having the slit 12121 in the axial direction of the sliding bearing 1212.

[0080] Since the slit 12121 is formed in the sliding bearing 1212 in this embodiment, the thermal expansion by heating of the heating mechanism 130 can be absorbed by the gap of the slit 12121. That is, this embodiment can reduce a tensile load on the outer ring portion 1211 caused by the thermal expansion. From such reasons, applying the sliding bearing 1212 makes it possible to fabricate the support roll 121 with high durability even when the outer ring portion 1211 formed of the non-magnetic ceramic, for example, is used.

[0081] In the support roll according to the comparative example in Fig. 8A, the rolling bearings 801 are provided between the outer ring portion 1211 and the shaft 1213, and in the example illustrated in Fig. 8A, it is assumed that the rolling bearing 801 has a 360° cylindrical shape. The rolling bearing 801 needs to be covered with an outer frame and an inner frame in the 360° circumferential direction because rolling elements inserted in the rolling bearing 801 rotate smoothly. Therefore, it is difficult to form the slit 12121 in the rolling bearing 801 as in this embodiment. That is, it is impossible to form a slit for thermal expansion in the rolling bearing 801, and thus it is difficult to use ceramic as the material of the outer ring. On the other hand, in this embodiment, the sliding bearing 1212 is provided between the outer ring portion 1211 and the shaft 1213 as described above, thus making it possible to form the slit 12121. As a result, this embodiment can alleviate concentration of stress to be applied to the sliding bearing 1212, and thus using the non-magnetic ceramic as the material of the outer ring portion 1211 can be achieved.

[0082] Further, in this embodiment, what is called an oilless bearing may be used as the sliding bearing 1212. When the oilless bearing is used as the sliding bearing 1212 as above, the lubricating oil is no longer required, and thus the oilless bearing is advantageous as compared to the rolling bearing that requires the lubricating oil generally also from the viewpoint of maintenance.

(Other embodiments)

[0083] The above-described embodiment of the present invention is an embodiment in which the conveying mechanism 110 holds the upstream-side end portion 201 of the workpiece when holding the workpiece 200 and the holding mechanism 150 holds the downstream-side end portion 202 of the workpiece when holding the workpiece 200. However, the present invention is not limited to this embodiment, and for example, an embodiment in which the conveying mechanism 110 holds not the upstream-side end portion 201 of the workpiece but a middle portion of the workpiece 200 and an embodiment in which the holding mechanism 150 holds not the downstream-side end portion 202 but a middle portion of the workpiece 200 are also applicable to the present invention.

[0084] It should be noted that the above embodiments of the present invention merely illustrate concrete examples of implementing the present invention, and the technical scope of the present invention is not to be construed in a restrictive manner by these embodiments. That is, the present invention may be implemented in various forms without departing from the technical spirit or main features thereof.

Claims

1. A quenching processing apparatus that processes a workpiece, the quenching processing apparatus comprising:

   a conveying mechanism that conveys the work-

piece in the longitudinal direction;
a supporting mechanism that is arranged on the downstream side in the conveyance direction of the workpiece from the conveying mechanism and supports the workpiece; and
a heating mechanism that heats the workpiece, wherein
the supporting mechanism includes rolls that abut on an outer surface of the workpiece and each include a hollow structure allowing a cooling medium to pass therethrough therein, and
the roll is formed by including an outer ring portion that abuts on the outer surface of the workpiece;
a shaft that is arranged at an inner side of the outer ring portion, supports the outer ring portion rotatably, and includes the hollow structure therein; and
a sliding bearing arranged between the outer ring portion and the shaft.

2. The quenching processing apparatus according to claim 1, further comprising:
a holding mechanism that is arranged on the downstream side in the conveyance direction of the workpiece from the heating mechanism and is capable of holding the workpiece and additionally, adding a bending load to the workpiece.

3. The quenching processing apparatus according to claim 1 or 2, wherein
the outer ring portion is formed of a non-magnetic material.

4. The quenching processing apparatus according to claim 3, wherein
the non-magnetic material is ceramic or resin.

5. The quenching processing apparatus according to any one of claims 1 to 4, wherein
the shaft is fixed to roll holders to be incapable of rotation.

6. The quenching processing apparatus according to any one of claims 1 to 5, wherein
the inner side of the outer ring portion is a cylindrical shape and is flat in section view.

7. The quenching processing apparatus according to any one of claims 1 to 6, wherein
a slit is formed in the sliding bearing over an entire region in the axial direction of the sliding bearing.

8. The quenching processing apparatus according to any one of claims 1 to 7, wherein
a plurality of the sliding bearings are provided continuously in the axial direction of the roll.

9. The quenching processing apparatus according to any one of claims 1 to 8, wherein
a hardness of the sliding bearing is smaller than a hardness of the shaft.

10. The quenching processing apparatus according to any one of claims 1 to 9, wherein
the sliding bearing is inserted into the outer ring portion by interference fit.

11. The quenching processing apparatus according to any one of claims 1 to 10, wherein
the supporting mechanism is formed in which a plurality of the rolls are arranged side by side at different positions in the conveyance direction of the workpiece.

12. The quenching processing apparatus according to any one of claims 1 to 11, further comprising:
a cooling mechanism that is arranged on the downstream side in the conveyance direction of the workpiece from the heating mechanism and cools a heated portion of the workpiece heated by the heating mechanism.

FIG. 1

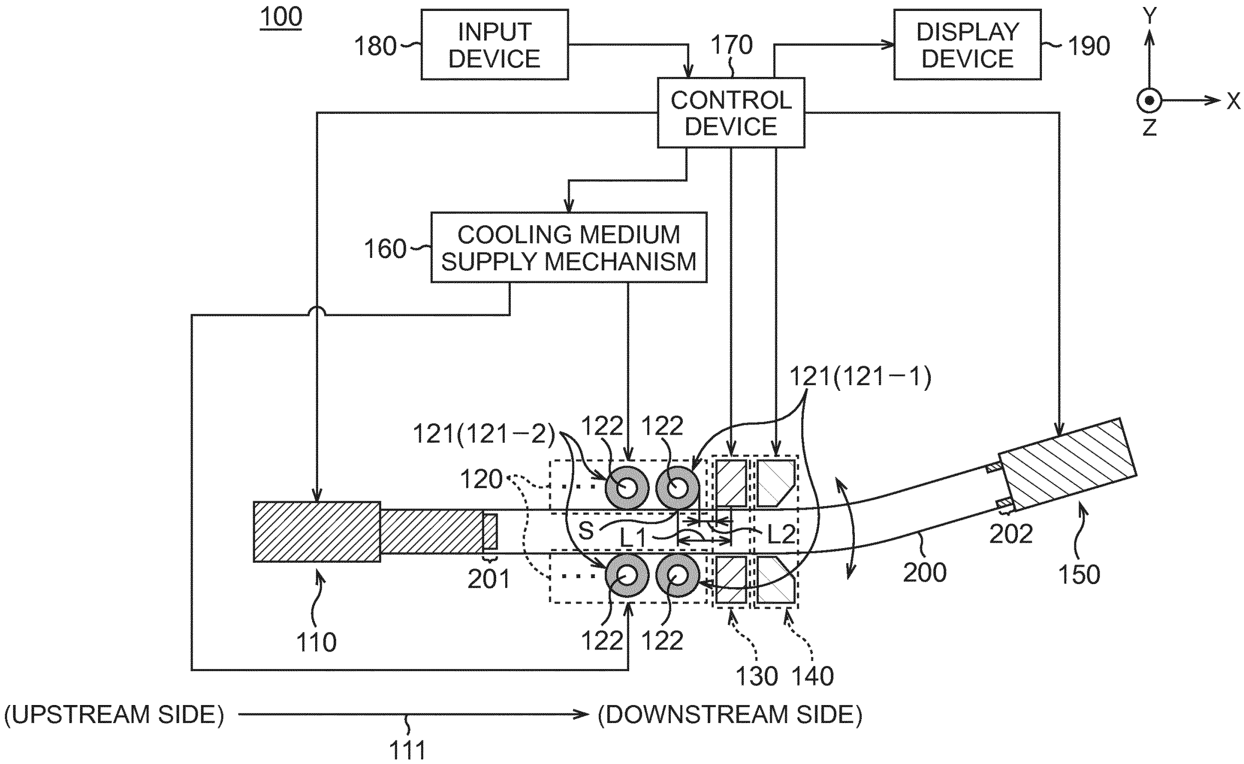

100
180
INPUT DEVICE
170
DISPLAY DEVICE
190
CONTROL DEVICE
Y
X
Z
160
COOLING MEDIUM SUPPLY MECHANISM
121(121−1)
121(121−2)
122
122
120
S
L1
L2
201
200
202
150
110
122
122
130
140
(UPSTREAM SIDE)
(DOWNSTREAM SIDE)
111

FIG. 2

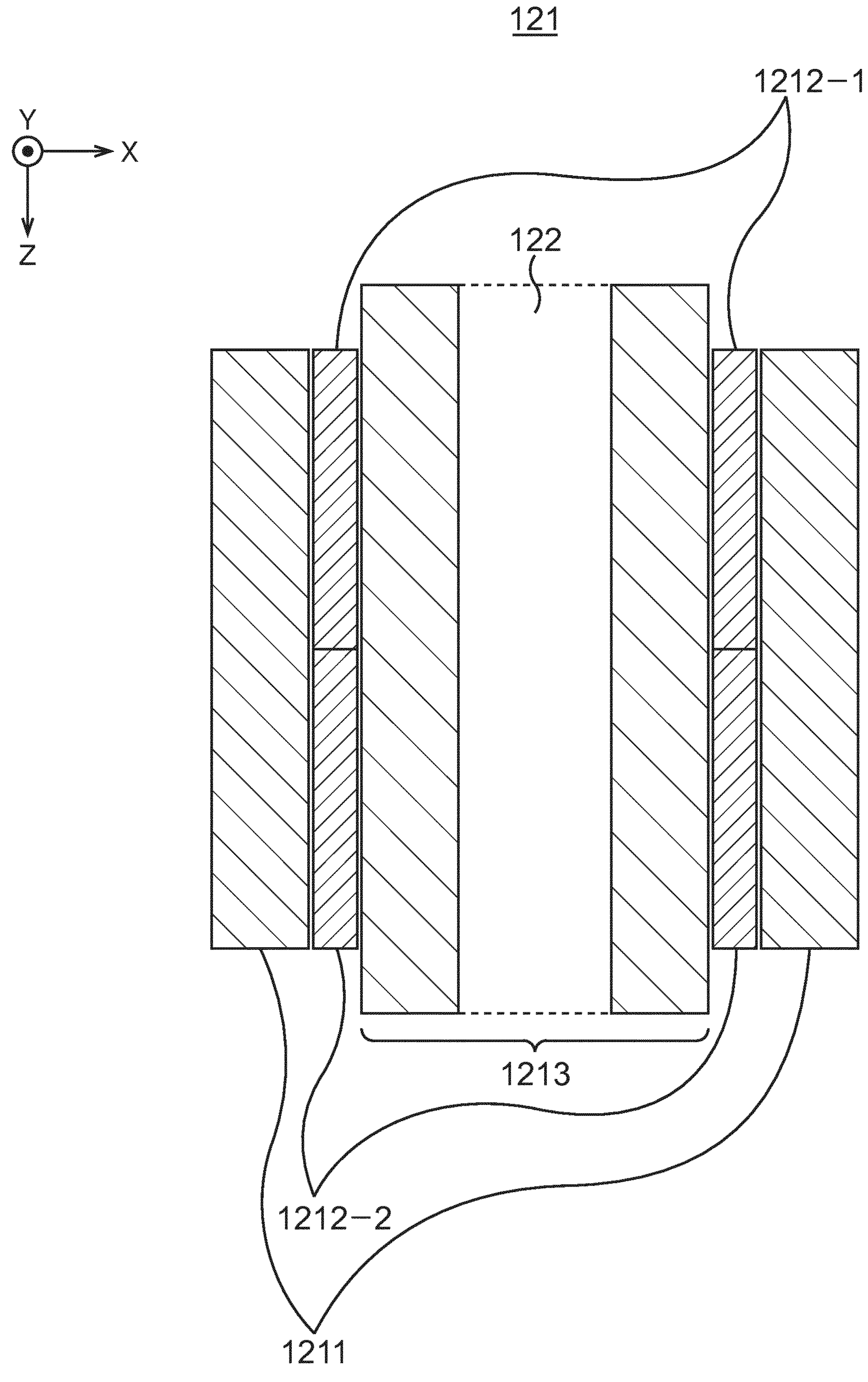


FIG. 3A

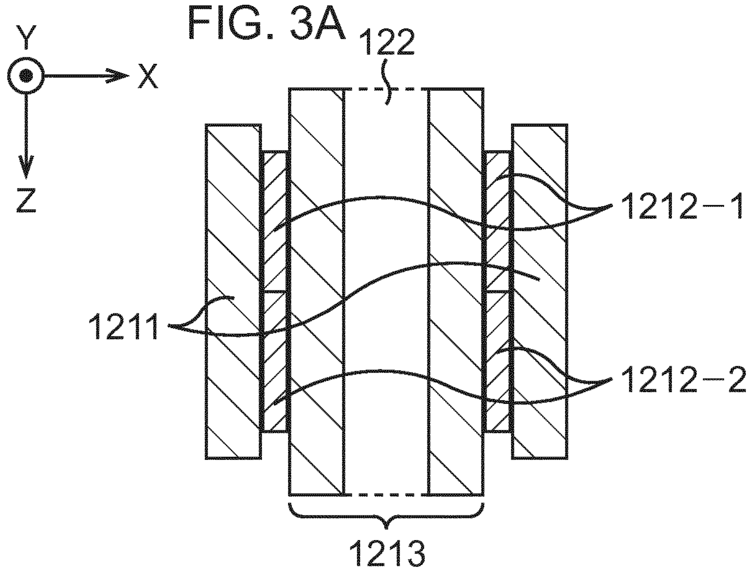


FIG. 3B

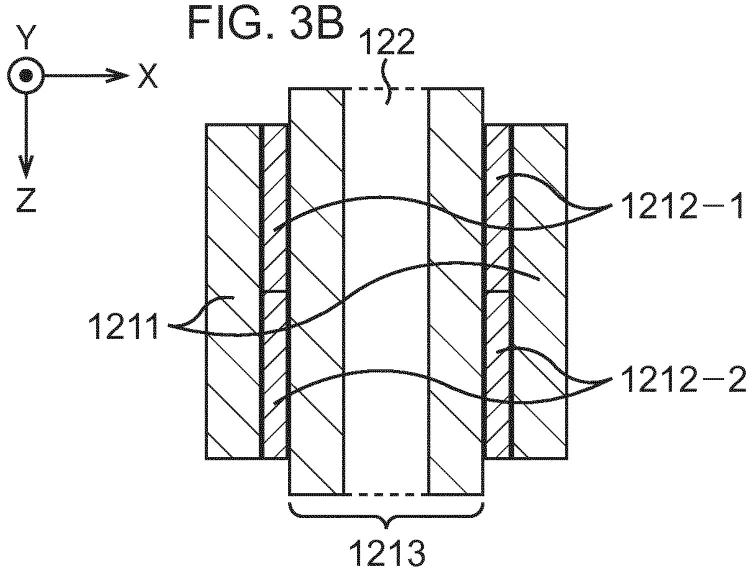


FIG. 3C

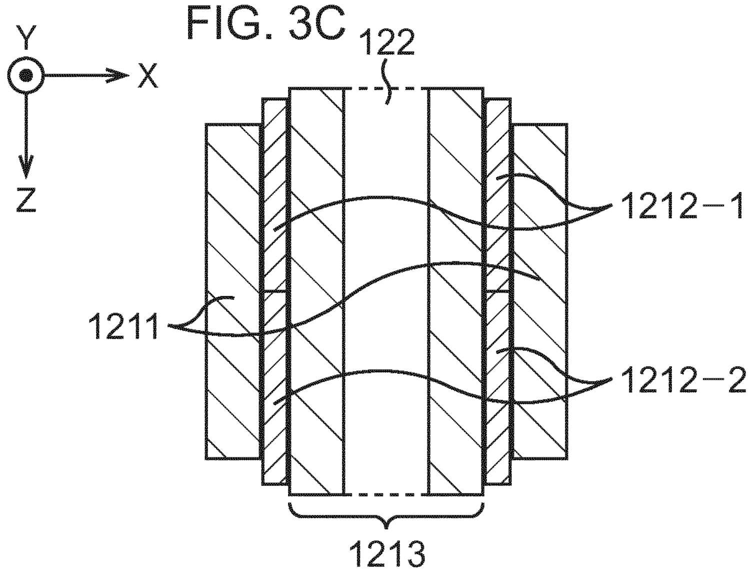


FIG. 4A

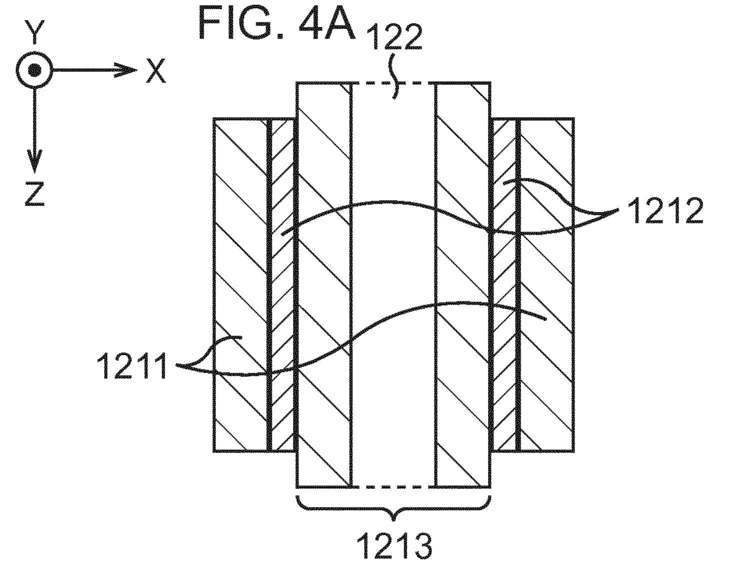


FIG. 4B

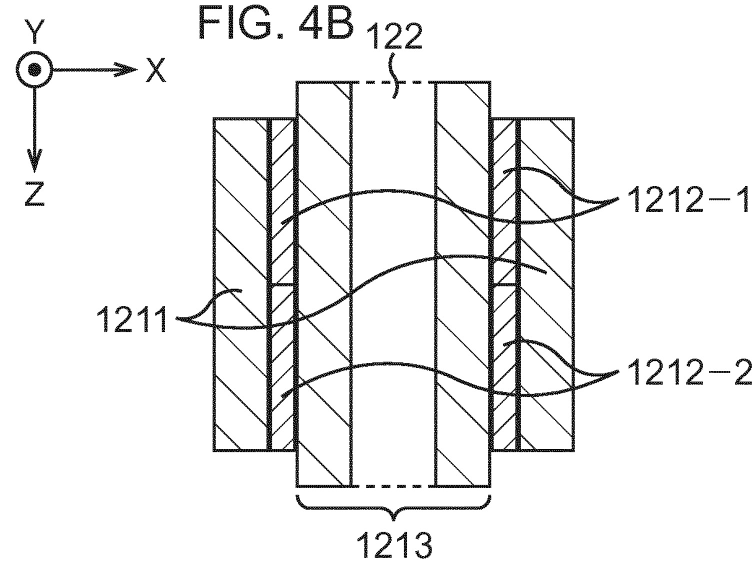


FIG. 4C

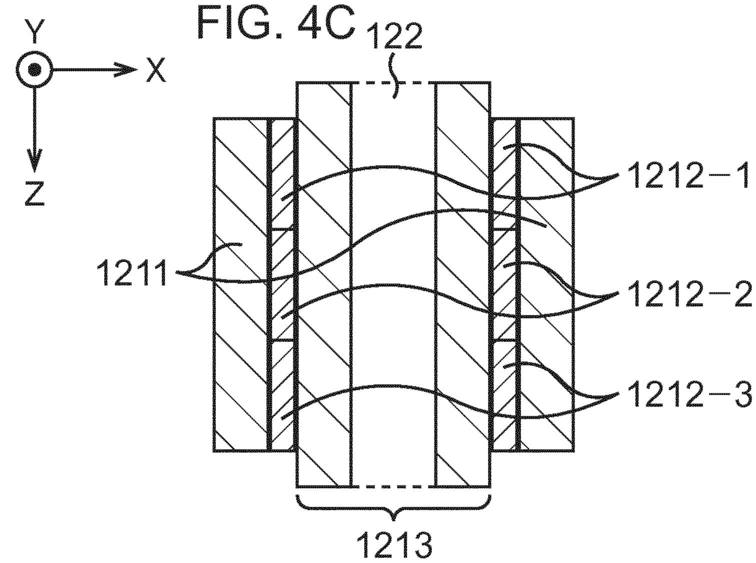


FIG. 5A

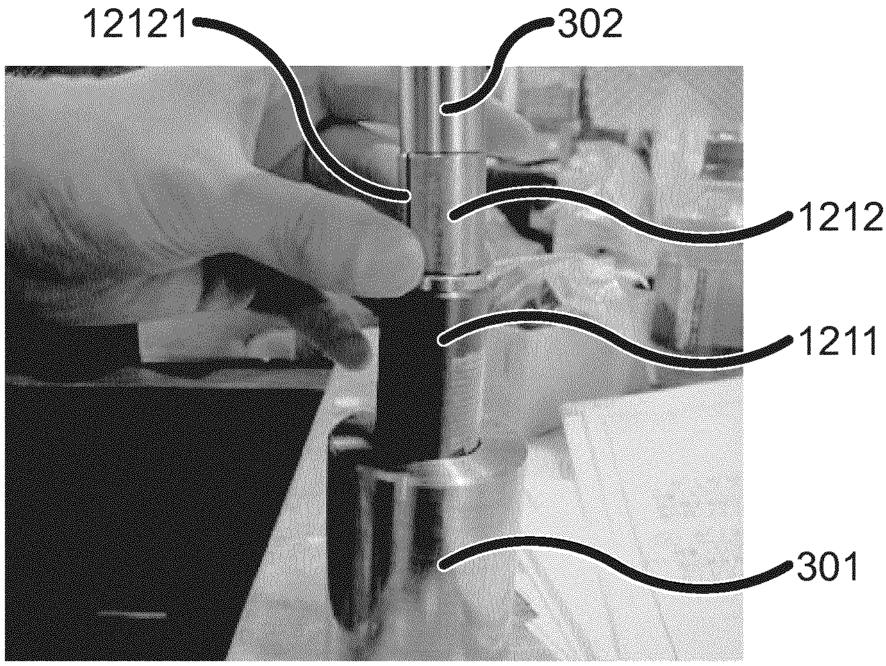


FIG. 5B

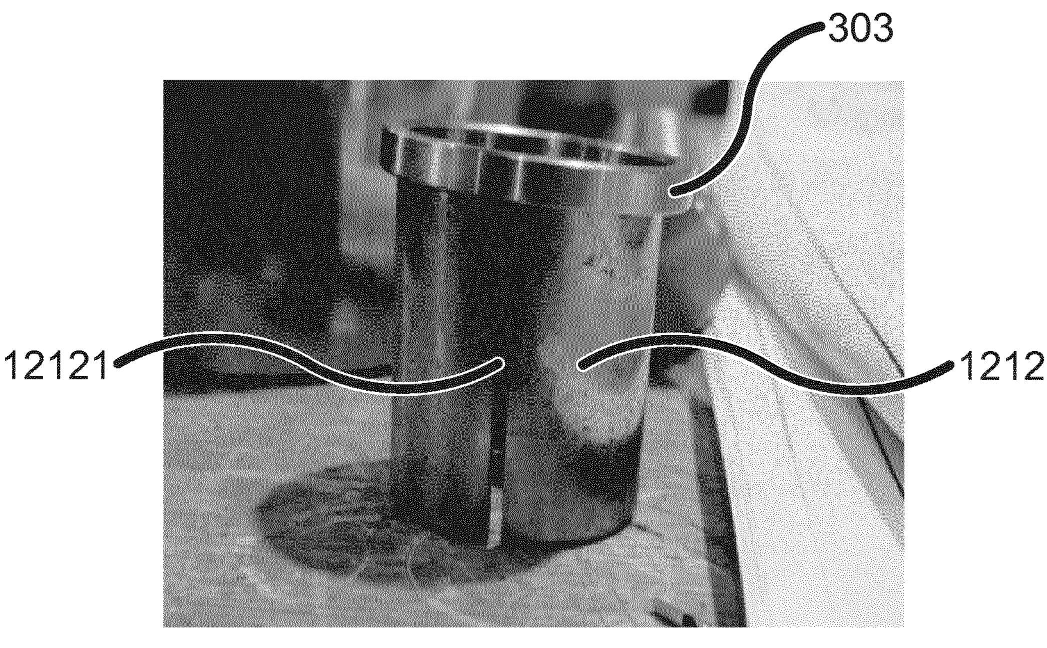


FIG. 5C

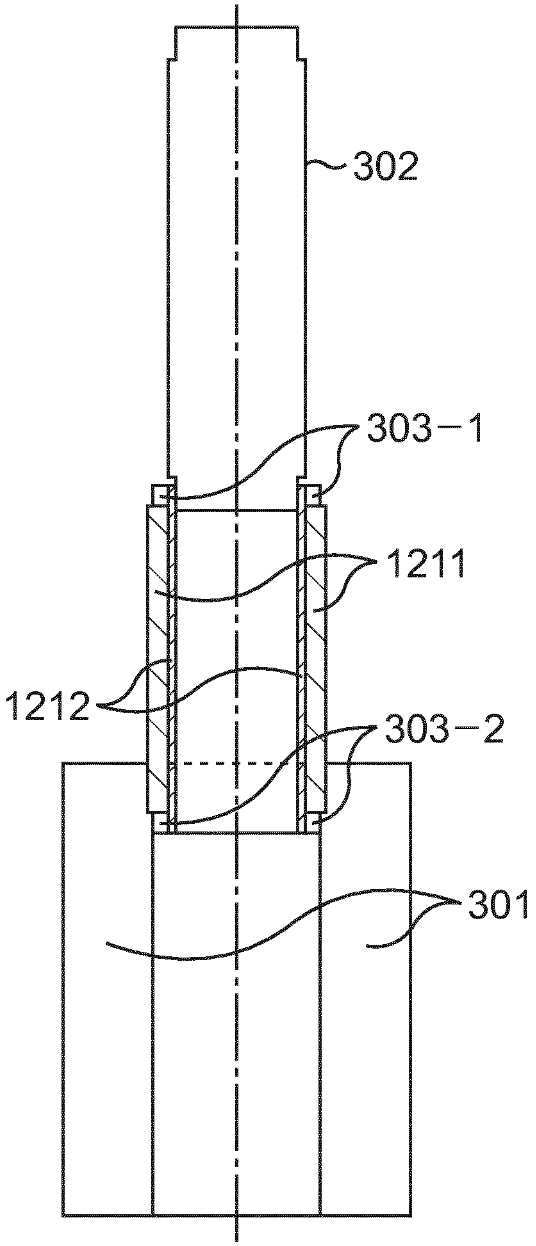


FIG. 5D

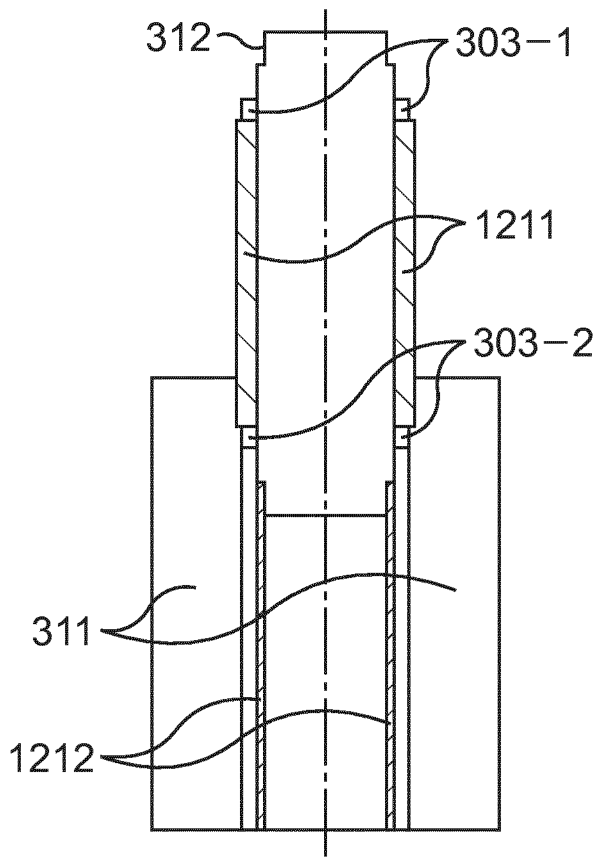


FIG. 6A

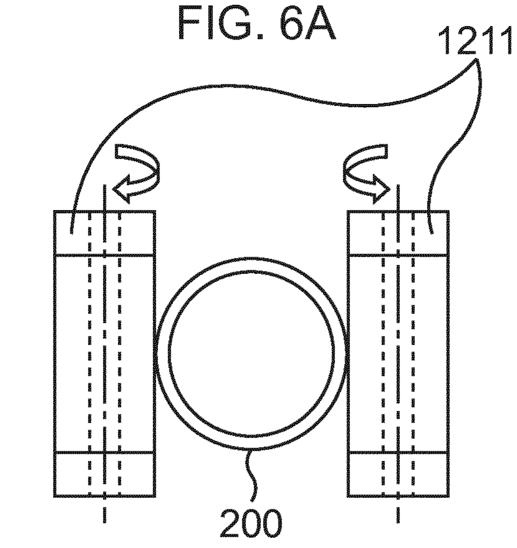


FIG. 6B

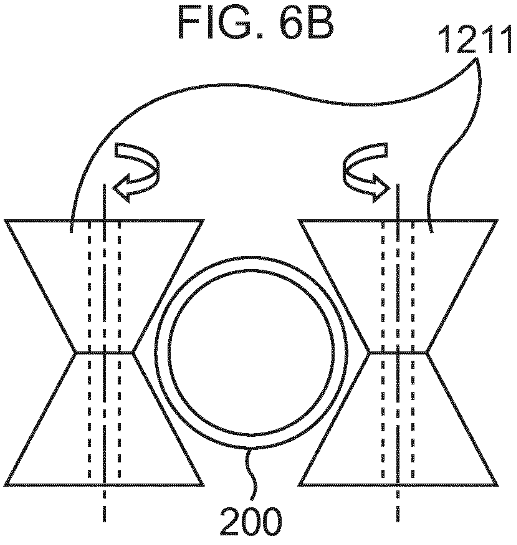


FIG. 6C

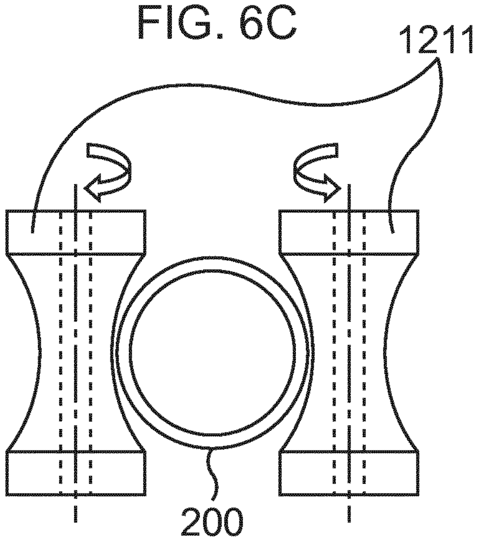


FIG. 7A

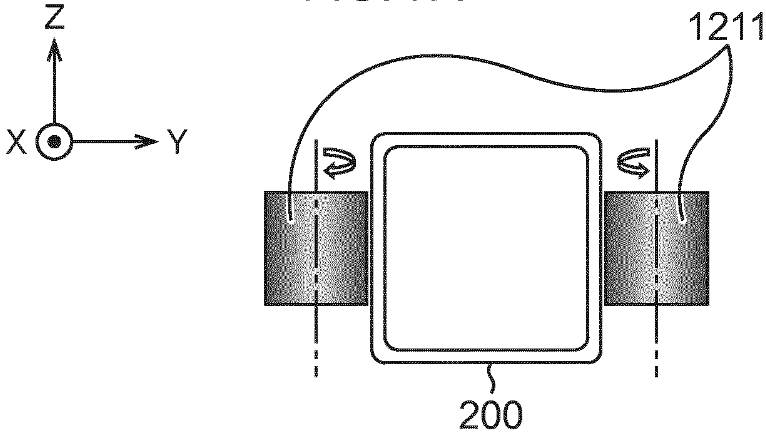


FIG. 7B

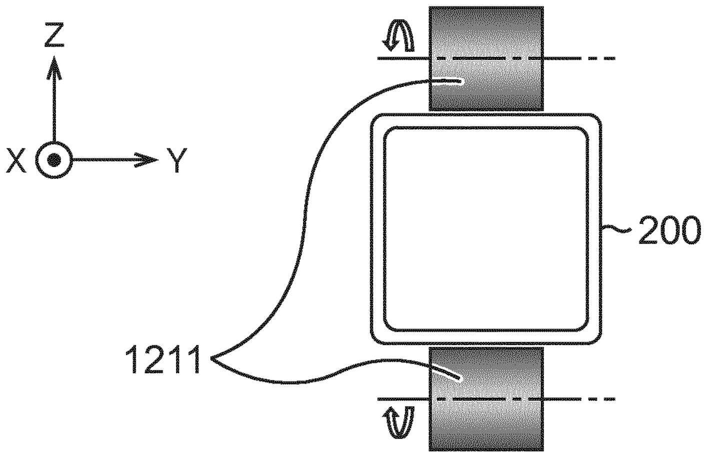


FIG. 7C

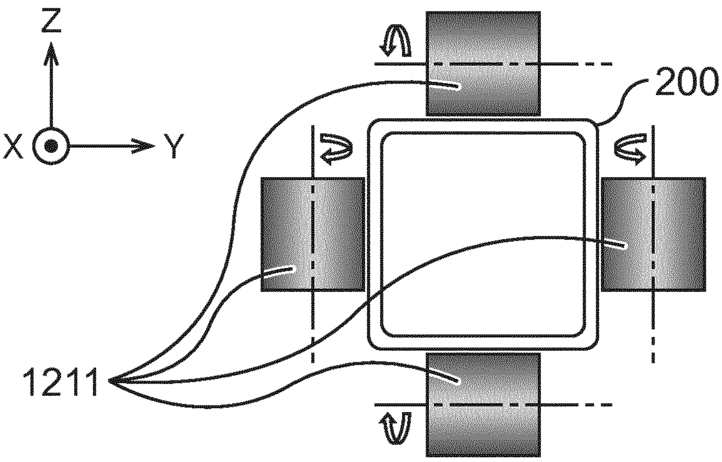


FIG. 8A

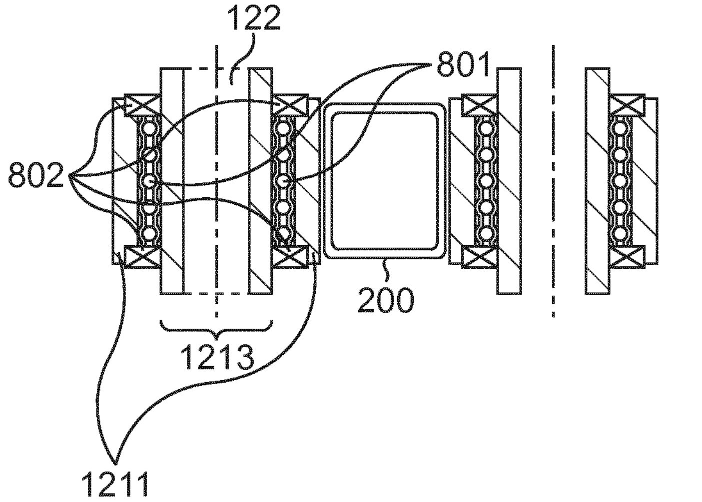

122
801
802
200
1213
1211

FIG. 8B

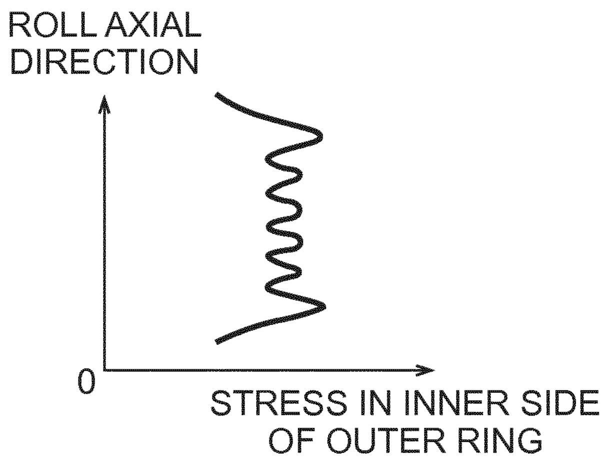

ROLL AXIAL DIRECTION
0
STRESS IN INNER SIDE OF OUTER RING

FIG. 8C

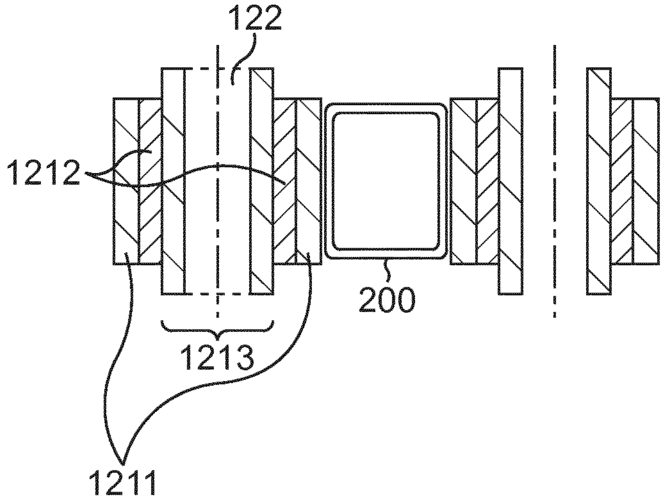

122
1212
200
1213
1211

FIG. 8D

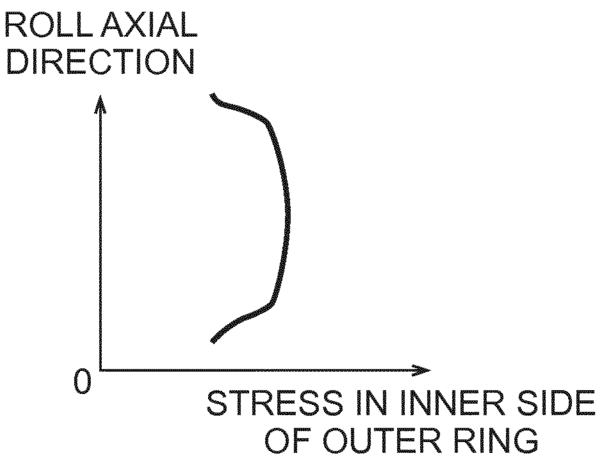

ROLL AXIAL DIRECTION
0
STRESS IN INNER SIDE OF OUTER RING

FIG. 9A

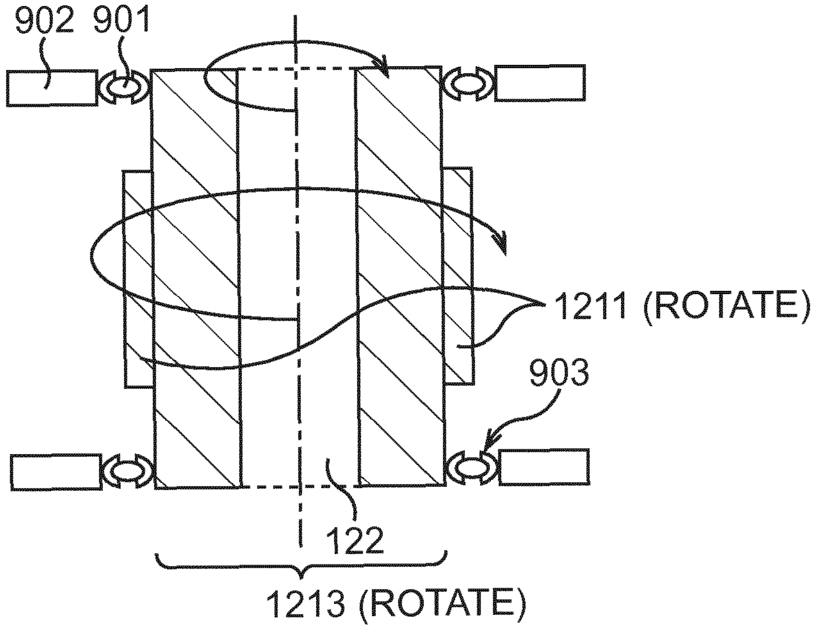

902
901
1211 (ROTATE)
903
122
1213 (ROTATE)

FIG. 9B

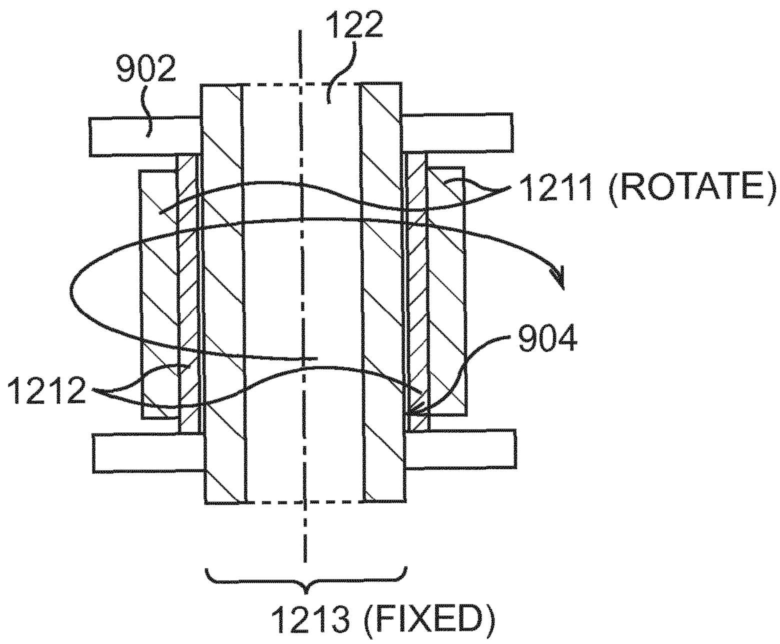

122
902
1211 (ROTATE)
904
1212
1213 (FIXED)

FIG. 9C

	SHAFT MATERIAL	BEARING POSITION	SHAFT LENGTH	SHAFT OUTSIDE DIAMETER	SHAFT INSIDE DIAMETER
COMPARATIVE EXAMPLE	MACHINE STRUCTURAL STEEL	OUTSIDE OUTER RING	ϕ100mm	22mm	5mm
EMBODIMENT	MACHINE STRUCTURAL STEEL	INTERNALLY PROVIDED IN OUTER RING	ϕ50mm	17.5mm	5mm

※CASE OF SHAFT ENDURING 550-kg LOAD

FIG. 10A

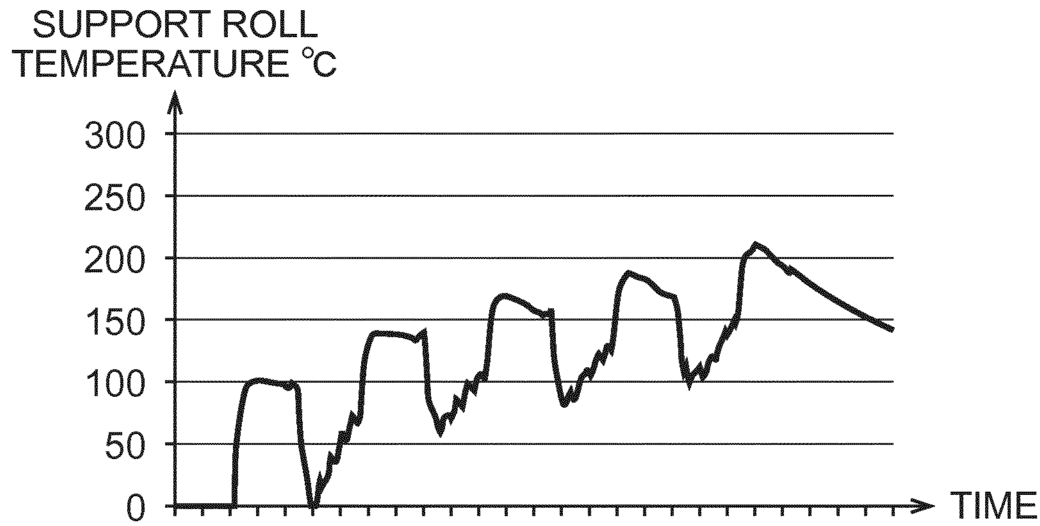


FIG. 10B

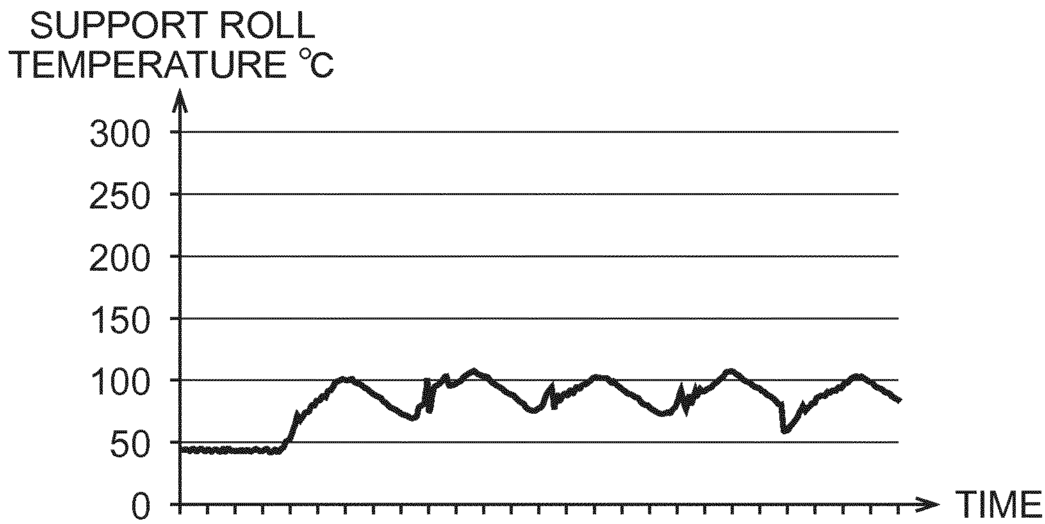


FIG. 10C

TEST PROCESSING CONDITION \ OUTER RING MATERIAL	COMPARATIVE EXAMPLE	EMBODIMENT	EMBODIMENT
	MACHINE STRUCTURAL STEEL	AUSTENITIC STAINLESS STEEL	NON−MAGNETIC CERAMIC
TEMPERATURE CHANGE WITHIN PROCESSING TIME PERIOD PER UNIT PRODUCT	ABOUT 20℃	ABOUT 10℃	——
TEMPERATURE CHANGE WITHIN PREDETERMINED PROCESSING TIME PERIOD OF PLURAL PRODUCTS	SIGNIFICANT TEMPERATURE RISE ABOUT 300℃(NOTE)	TEMPERATURE RISE ABOUT 200℃	TEMPERATURE SATURATION SUBSTANTIALLY FIXED AT ABOUT 100℃

(NOTE) IT WAS IMPOSSIBLE TO PERFORM TEST DUE TO LARGE TEMPERATURE RISE, BUT IT BECAME ABOUT 300℃BY PREDICTION WITH CALCULATED VALUE

FIG. 11A

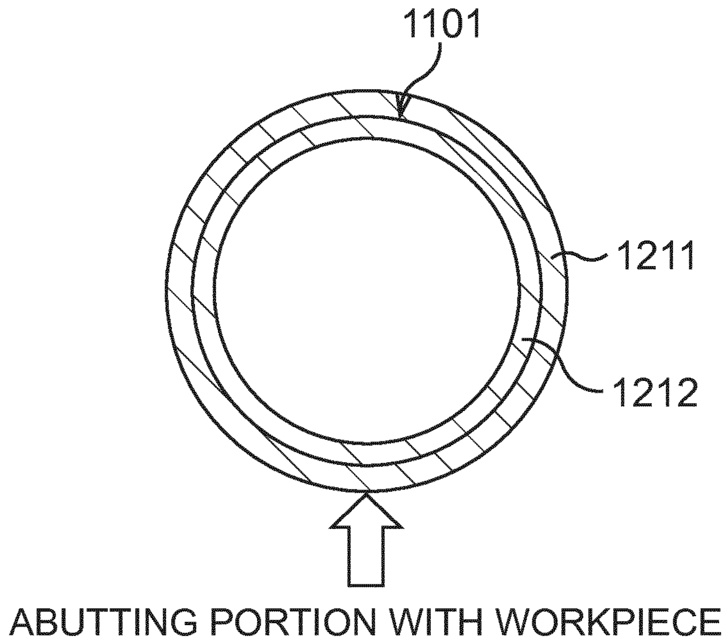
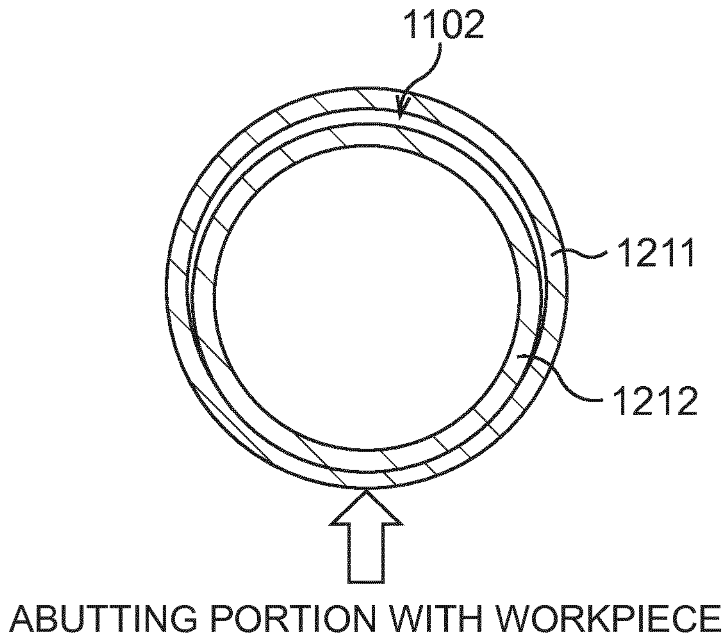


FIG. 11B



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2018/011246

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. B21D7/16(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl. B21D7/16, B21C37/08, F16C37/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2017-60996 A (AISIN KEIKINZOKU CO., LTD.) 30 March 2017, paragraphs [0005]-[0015], fig. 1 (Family: none)	1-11
A	JP 10-85952 A (NKK CORP.) 07 April 1998, paragraphs [0002]-[0017], fig. 1-2 (Family: none)	1-11
A	JP 6-339779 A (TOSHIBA KOKAN KK, TOSHIBA CORP.) 13 December 1994, paragraphs [0011]-[0025], fig. 1 (Family: none)	1-11

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 June 2018 (14.06.2018)	26 June 2018 (26.06.2018)

Name and mailing address of the ISA/	Authorized officer
Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2018/011246

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 5304893 B2 (NIPPON STEEL & SUMITOMO METAL CORPORATION, SUMITOMO PIPE & TUBE CO., LTD.) 02 October 2013, entire text, all drawings & US 2012/0085138 A1, entire text, all drawings & WO 2010/134495 A1 & EP 2433722 A1 & AU 2010250498 A1 & CA 2762532 A1 & MX 2011012244 A & CN 102481612 A & KR 10-2012-0023803 A & ES 2498729 T3 & EA 201301342 A1	1-11
A	JP 4825019 B2 (SUMITOMO METAL INDUSTRIES, LTD., SUMITOMO PIPE & TUBE CO., LTD., SUMIKIN PLANT LTD.) 30 November 2011, entire text, all drawings & US 2008/0066517 A1, entire text, all drawings & WO 2006/093006 A1 & EP 1857195 A1 & KR 10-2007-0102594 A & CN 101132869 A	1-11

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5304893 B **[0003]**
- JP 4825019 B **[0003]**