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(54) **Method for bending metal material and bent product**

Verfahren zum Biegen von Metallmaterial und gebogenes Produkt

Procédé de traitement de cintrage d’un matériau métallique et produit cintré

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Description

TECHNICAL FIELD

[0001] The present invention relates to a method for bending a metal material, and more particularly, to a method for effectively bending a metal material through a two-dimensional continuous bending operation in which the metal material is two-dimensionally bent in different directions (for example ending in a S shape) or a three-dimensional continuous bending operation in which the metal material is three-dimensionally bent in different directions, and to a bent product made by the bending method.

BACKGROUND ART

[0002] In recent years, demands for structural metal materials having high strength and light weight have increased in consideration of global environment. For example, in an automobile industry, there are growing demands for a safe car body and high-strength and light-weight parts of an automobile, and parts of an automobile have been developed in order to improve fuel efficiency and collision safety.

[0003] In order to meet these demands, a steel sheet having a much higher tensile strength than that in the related art, for example, a material having high strength with a tensile strength of 780 MPa or more, preferably, 900 MPa or more, has come into widespread use.

[0004] Meanwhile, while improving the strength of the steel sheet, the conventional structures of parts of an automobile have been reexamined. Following the above, there is a strong demand for the development of an art for accurately bending a metal material in any of various shapes, such as an art for two-dimensionally or three-dimensionally bending a metal material in different directions, in order to apply to various types of parts of an automobile.

[0005] In order to meet the demands for the development of the bending technology, various processing techniques have been proposed. For example, Japanese Patent Application Publication No. 50-59263 and Japanese Patent No. 2816000 disclose a method for bending a metal tube or the like while performing a thermal treatment on the metal tube or the like. Specifically, the following methods are disclosed: a bending method for clamping a leading end of a metal tube or the like with a rotatable arm, heating the metal tube or the like by using a heating unit, appropriately moving the heated portion of the metal tube or the like to bend the heated portion, and cooling down the bent portion (Japanese Patent Application Publication No. 50-59263); and a method for applying torsion and bending force to the heated portion of the metal tube or the like to bend the metal tube or the like while twisting the metal tube or the like (Japanese Patent No. 2816000).

[0006] However, the disclosed bending methods are so-called grab bending methods requiring a rotatable arm for clamping the leading end of a metal tube or the like, which makes it difficult to feed the metal tube or the like to be bent at high speed. In addition, the arm needs to make a return movement in order to repeatedly clamp the metal tube or the like, resulting in a remarkable variation in the feeding speed of the metal tube or the like. Therefore, a complicated control is required for a heating or cooling speed, which makes it difficult to ensure predetermined quenching accuracy.

[0007] In order to solve the above-mentioned problems of the grab bending method, Japanese Patent Application Publication No. 2000-158048 discloses a high-frequency heating bender based on push bending that supports a push bending roller so as to be movable in a three-dimensional direction. According to the high-frequency heating bender disclosed in Japanese Patent Application Publication No. 2000-158048, the push bending roller is moved over a workpiece to be bent to reach the opposite side of the workpiece, and comes into contact with the opposite side of the workpiece, thereby bending the workpiece. Therefore, in a two-dimensional continuous bending operation in which a workpiece is two-dimensionally bent in different directions in, for example, an S shape, a process of turning the workpiece by 180 degrees is not needed.

[0008] However, in the high-frequency heating bender disclosed in Japanese Patent Application Publication No. 2000-158048, since a unit for clamping both side-faces of a workpiece to be bent is not provided, the workpiece is likely to be deviated from the intended shape due to the residual stress caused by a cooling operation after the high-frequency heating. Therefore, it is difficult to ensure predetermined numerical accuracy, and the processing speed of the workpiece is restricted, which makes it difficult to improve the accuracy of bending.

[0009] Further, Japanese Patent No. 3195083 discloses a push-through bending machine that includes a fixed die, a movable gyro die that is movable in a three-dimensional direction, and a heating unit that heats a metal member at a temperature corresponding to the curvature of the metal member bent by the movable gyro die, instead of the push bending roller of the high-frequency heating bender or the grab bending method.

[0010] In the bending machine disclosed in Japanese Patent No. 3195083, since the movable gyro die, which is the fixed die, do not rotatably support a metal member to be bent, the metal material is likely to be adhered to the surfaces of the movable gyro die. In the bending machine disclosed in Japanese Patent No. 3195083, a cooling fluid is supplied to the movable gyro die to prevent the decrease of the strength of the dies and the lowering of bending accuracy due to thermal expansion. However, Japanese Patent No. 3195083 does not disclose a method for performing a thermal treatment, such as quenching, on the bent metal member, and thus it is difficult to obtain a metal member having high strength.

DISCLOSURE OF THE INVENTION

[0011] As described above, a technique for bending a metal material in various bending shapes to be applied to various parts of an automobile is demanded with re-examining the structures of the parts of an automobile. Meanwhile, it is desirable that the metal material have a tensile strength of 900 MPa or more, preferably, 1300 MPa or more, in order to reduce the weight of the metal material. In this case, a metal tube having a tensile strength of about 500 to 700 MPa is bent as a starting material and a thermal treatment is performed on the bent metal tube to improve the strength of the metal tube, thereby obtaining a metal material having high strength.

[0012] However, in the grab bending method disclosed in Japanese Patent Application Publication No. 50-59263 and Japanese Patent No. 2816000, since the feeding speed of the metal tube varies significantly, the cooling speed cannot be accurately controlled, and a high degree of quenching accuracy cannot be ensured, which makes it difficult to prevent the occurrence of non-uniform distortion. As a result, variations occur in the shape of the bent metal material, and delayed fracture occurs in the metal material having high strength due to the residual stress. Thus, products made by the grab bending method are not suitable for parts of an automobile.

[0013] Further, the bending machine disclosed in Japanese Patent No. 3195083 is based on push-through bending, but does not disclose a technique for performing hot working on a metal tube having low strength as a starting material and then performing quenching on the heated metal tube to increase the strength of the metal tube so as to obtain a metal material having high strength. In addition, the metal material is likely to have seizure defects on the surface of the movable gyro die due to heating. Therefore, the hot bending machine needs to be further improved.

JP 5-302119 discloses a cold worked pipe which is heated to 850°C - 1050°C for 0.5 to 30 min to form a fine austenitic structure and then air cooled.

[0014] US 2003/0038489 discloses cold working a bumper.

[0015] US 4,061,005 discloses a method in which the metal material is clamped with a movable die that is provided at the downstream side of the supporting unit, the position of the movable die and the moving speed of the metal material are controlled, and the metal material is heated by using a heating unit that is provided around the outer circumference of the metal material at an entrance side of the movable die, to apply a bending moment to the heated portion: and the heated portion is cooled down by using a cooling unit that is provided around the outer circumference of the metal material at the entrance side of the movable die.

[0016] The invention is designed to solve the above-mentioned problems, and it is an object of the present invention to provide a method for bending a metal material with a high degree of operation efficiency, while the method allowing a high degree of bending accuracy to be ensured even when a metal material is bent in various shapes and further even when a metal material having high strength is bent in association with diversification of structures of automoblie parts.

[0017] In order to achieve the object, according to an aspect of the present invention, there is provided a method for bending a metal material in which, in a bending process, while successively or continuously feeding a metal material held by a supporting unit from an upstream side of the supporting unit, the bending is performed for the metal material at a downstream side of the supporting unit, characterized in that: the metal material is clamped with a movable roller die that is provided at the downstream side of the supporting unit; the position of the movable roller die and/or the moving speed of the metal material is controlled; the metal material is heated in a temperature range in which quenching can be performed at or above the A3 transformation point and up to a temperature at which coarse grains are not generated, by using a heating unit that is provided around the outer circumference of the metal material at an entrance side of the movable roller die, to apply a bending moment to the heated portion; and the heated portion is rapidly cooled down at a rate of 100°C/sec or more by using a cooling unit that is provided around the outer circumference of the metal material at the entrance side of the movable roller die.

[0018] That is, during the bending of a metal material, the downstream side of the metal material is supported, and a thermal treatment is performed on the metal material while moving the metal material at a predetermined speed, which makes it possible to ensure a predetermined cooling speed. In addition, since the bent metal material is uniformly cooled down, it is possible to obtain a metal material having excellent shape fixability despite high strength, and uniform hardness.

[0019] For example, specifically, a blank tube as a work piece is successively and continuously heated by a high-frequency heating coil at an A_3 transformation point or more and up to a temperature at which coarse grains are not generated, and the locally heated portion of the metal material is plastically deformed by the movable roller die. Then, a cooling medium having water or oil as the main ingredient or other coolants, gas, or mist is injected onto the outside surface or both the outside and inside surface of the in-process tube, thereby enabling to ensure a cooling speed of 100°C/sec or more.

[0020] In addition, the movable roller die functioned to apply a bending moment supports the metal material in a rolling manner to prevent seizure defects on the surface of the die, which makes it possible to effectively bend the metal material. Similarly, since the supporting unit rotatably supports the metal material, it is possible to prevent seizure defects on the surface of the supporting unit.

[0021] According to a second aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the movable roller die includes at least one of a shift mechanism for moving the movable roller die in a vertical direction, a shift mechanism for moving the movable roller die in a horizontal direction, a tilt mechanism for inclining the movable roller die in the verticals direction, and a tilt mechanism for inclining the movable roller die in the horizontal direction. According to this structure, even when the metal material is bent in various shapes, such as in a two-dimensional continuous bending operation (for example, an S-shaped bending operation) in which the metal material is two-dimensionally bent in different directions or a three-dimensional continuous bending operation in which the metal material is three-dimensionally bent in different directions, it is possible to effectively perform bending.

[0022] According to a third aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the movable roller die further includes a moving mechanism for moving the movable roller die in a forward or backward direction in an axial direction of the metal material relative to the supporting unit. According to this structure, even when the bending radius of a metal material is small, it is possible to ensure an appropriate arm length L, which makes it possible to prevent an increase in scale of a bending machine and ensure a high degree of bending accuracy.

[0023] According to a fourth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the heating unit and/or the cooling unit include at least one of a shift mechanism for moving the unit in the vertical direction, a shift mechanism for moving the unit in the horizontal direction, a tilt mechanism for inclining the unit in the vertical direction, and a tilt mechanism for inclining the unit in the horizontal direction. According to this structure, it is possible to synchronize the operation of the movable roller die with the operations of the heating unit and the cooling unit, which makes it possible to perform much more accurate and uniform bending.

[0024] According to a fifth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the heating unit and/or the cooling unit further include a moving mechanism for moving the unit in a forward or backward direction in an axial direction of the metal material relative to the supporting unit. According to this structure, it is possible to heat the leading end of a metal tube at the beginning of a bending operation, in addition to synchronization between the operation of the movable roller die and the operations of the heating and the cooling unit. Therefore, it is possible to improve workability and operability when mounting or dismounting a metal tube.

[0025] According to a sixth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the movable roller die includes a rotational mechanism for rotating the movable roller die in the circumferential direction. According to this structure, it is possible to twist the metal material, in addition to two-dimensionally or three-dimensionally bending the metal material in different directions.

[0026] According to a seventh aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, a pushing apparatus provided at the upstream side of the metal material may include a mechanism that holds and rotates a workpiece in a circumferential direction. According to this structure, it is possible to twist the metal material, in addition to two-dimensionally or three-dimensionally bending the metal material in different directions, without using the rotational mechanism of the movable roller die.

[0027] According to an eighth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the supporting unit includes a rotational mechanism for rotating the supporting unit in a circumferential direction, and rotates in the circumferential direction in synchronization with the rotation of the pushing apparatus. According to this structure, during torsional deformation of a metal material, the rotational mechanism of the feeding apparatus twists a rear end of the metal material, while synchronizing with the operation of the supporting unit, without rotating the movable roller die in the circumferential direction, which makes it possible to accurately twist the metal material. Alternatively, the rotational mechanism of the feeding apparatus may twist the rear end of the metal material in synchronization with the operation of the supporting unit, while rotating the movable roller die in the circumferential direction. In this case, it is also possible to accurately twist the metal material.

[0028] According to a ninth aspect of the present invention, in the method of bending a metal material according to the above-mentioned aspect, preferably, the movable roller die includes a driving mechanism that drives rollers, such as a driving motor that drives and rotates the rollers according to the amount of the metal material extruded by the pushing apparatus. That is, when the movable roller die does not include the driving and rolling mechanism, the rollers are driven by only frictional resistance, and compressive stress is applied to the bent portion of the metal material. As a result, the inner radius side of the bent portion is thickened, resulting in buckling. In particular, when a thin metal material is used, the buckling makes it difficult to bend the thin metal material, or may otherwise cause the accuracy of bending to be lowered.

[0029] In contrast, the driving and rolling mechanism provided in the movable roller die reduces the compressive stress applied to the bent portion. In addition, when the rotational speed of the rollers of the movable roller die is controlled so as to be synchronized with the feed amount of the metal material fed through by the feeding apparatus, it is possible to apply tensile stress to the bent portion and thus widen the available range for bending.

As a result, it is possible to improve the bending accuracy of a metal material.

[0030] According to a tenth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the movable roller die may comprise two rollers, three rollers, or four rollers. According to an eleventh aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the metal material subjected to a bending operation is a closed cross-section member, an open cross-section member, an irregular cross-section member, or a rod member, wherein the cross-section thereof is formed in various shapes. According to this structure, it is possible to design the roll caliber of the movable roller die according to the cross-section of a metal material to be bent.

[0031] According to a twelfth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, one or more preheating units are provided at the upstream side of the heating unit to perform two-stage heating or preferential heating on the metal material. According to this aspect, when a preheating unit for plural-stage heating is used, it is possible to disperse the heating load of a metal material, and thus enabling to improve bending efficiency.

[0032] Meanwhile, when a preheating unit for preferential heating is used, the temperature of the heated portion of the metal material intended to be an inner radius side of the bend is controlled to be lower than that of the heated portion intended to be an outer radius side of the bend, taking into account the bending direction of the metal material determined by the movable roller die. When the heated portion of the metal material is configured in this way, it is possible to prevent wrinkles from being generated on the inner radius surface of the bent portion and cracks from being generated in the outer radius surface of the bent portion.

[0033] According to a thirteenth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, a mandrel, serving as the cooling unit, is inserted into the inside of the metal material, and a cooling medium is supplied by the mandrel alone and/or in combination with the cooling unit provided around the outer circumference of the metal material. According to this structure, it is possible to ensure the cooling rate for, particularly, a thick-wall metal material.

[0034] According to a fourteenth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, the cooling medium supplied from the cooling unit contains water as a primary component, and a rust-preventative agent. When a sliding portion is wet by cooling water without the rust preventative agent that is supplied from the cooling unit, rust occurs in the sliding portion. Therefore, it is preferable that the cooling water contains a rust-preventative agent in order to protect the bending machine.

[0035] Further, preferably, the cooling medium supplied from the cooling unit includes water as a primary component, and a quenching agent. For example, a quenching agent mixed with an organic polymer agent has been known. When the quenching agent is mixed at a predetermined concentration, it is possible to appropriately control the cooling rate and thus ensure a stable quenching performance.

[0036] According to a fifteenth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, a lubricant and/or a cooling fluid are supplied to the movable roller die. According to this structure in which the lubricant is supplied to the movable roller die, even when scales generated from the heated portion of the metal material are inadvertently migrated into the movable roller die, the lubricant can prevent the scales from causing seizure defects on the surface of the movable roller die.

[0037] In addition, when the cooling fluid is supplied to the movable roller die, the movable roller die is cooled by the cooling fluid. Therefore, it is possible to prevent the decrease of the strength of the movable roller die, the lowering of bending accuracy due to the thermal expansion of the movable roller die, and the seizure defects on the surface of the movable roller die.

[0038] According to a sixteenth aspect of the present invention, in the method for bending a metal material according to the above-mentioned aspect, preferably, a robot having one or more joints is provided, the joint being able to rotate on its axis respectively, and the articulated robot performs the operation of at least one of the shift mechanism, the tilt mechanism, and the moving mechanism of the movable roller die, and the heating unit and/or the cooling unit.

[0039] According to this structure, during the bending of a metal material, the articulated robot can perform a series of operations each of which is performed by a manipulator as a shift operation in the vertical or horizontal direction, as a tilt operation in the vertical or horizontal direction, and as a moving operation in the forward or backward direction which the movable roller die, the heating unit, and the cooling unit entail respectively, on the basis of control signals. Therefore, it is possible to improve the efficiency of a bending operation and reduce the size of a bending machine.

[0040] Further, a bent product of the invention is characterized in that the product having a tensile strength of 900 MPa or more is made by the above bending method for a metal material.

[0041] According to the method for bending a metal material in accordance with the above-described aspects of the present invention, even when a metal material is bent in various shapes, such as in a two-dimensional continuous bending operation in which the metal material is two-dimensionally bent in different directions (for example, an S shape) or in a three-dimensional continuous bending operation in which the metal material is three-dimensionally bent in different directions, and even when a metal material having high strength is bent, the metal material is uniformly cooled down, whereby it is possible to effectively obtain a metal material having excellent shape fixability despite having high strength, and uniform hardness distribution at a low cost.

[0042] Further, since the movable roller die rotatably supports a metal material, it is possible to retard the generation of seizure defects on the surface of the movable roller die. Therefore, the accuracy of a bending operation can be ensured, and a push-through bending operation can be performed with a high degree of operation efficiency. In this way, the bending method according to the present invention can be widely applied as an art of accurately bending automobile parts.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043]

Fig. 1 is a diagram illustrating the overall structure of a bending machine for performing a bending operation according to the present invention.

Figs. 2A and 2B are diagrams illustrating the cross-sectional shapes of a workpiece that can be used as a metal material according to the present invention. Specifically, Fig. 2A shows a channel with an open cross section that is made by roll forming, and Fig. 2B shows a channel with an irregular cross-section that is made by the bending.

Figs. 3A and 3B are diagrams illustrating examples of the structure of a supporting guide that can be used as a supporting unit according to the present invention. Specifically, Fig. 3A shows the cross-sectional structure of the supporting guide and a rotational mechanism provided in the supporting guide, and Fig. 3B is a perspective view illustrating the general appearance of the supporting guide.

Fig. 4 is a diagram illustrating the structure of a main part of the bending machine.

Fig. 5 is a diagram schematically illustrating the structure of a heating unit and a cooling unit provided in the bending machine.

Fig. 6 is a diagram illustrating the structure of a mandrel that is inserted into a metal material having a closed cross section (a metal tube) in order to ensure the cooling rate of a heavy-wall material.

Fig. 7 is a diagram illustrating a shift mechanism for movement in the vertical and horizontal directions and a rotational mechanism for rotation in the circumferential direction of a movable roller die that is provided in the bending machine.

Fig. 8 is a diagram illustrating the operation of a moving mechanism for movement in the forward or backward direction of the movable roller die that is provided in the bending machine.

Figs. 9A to 9C are diagrams illustrating examples of the configuration of the movable roller die that is provided in the bending machine. Specifically, Fig. 9A shows the movable roller die having two rollers when a metal material is a member with a closed cross section, such as a circular tube, Fig. 9B shows the movable roller die having two rollers when a metal material is a member with a closed cross section, such as a rectangular tube, or a member with an open cross section, such as a channel, and Fig. 9C shows the movable roller die having four rollers when a metal material is a member with a closed cross section, such as a rectangular tube, or a member with an irregular cross section, such as a channel.

Fig. 10 is a diagram illustrating the operation of a preheating unit for performing preferential heating on a metal material.

Fig. 11 is a diagram illustrating the overall structure and arrangement of an articulated robot that can be applied to the bending machine.

Fig. 12 is a diagram illustrating another structural example of the articulated robot that can be applied to the bending machine.

Fig. 13 is a diagram illustrating the overall structure of an electric resistance welded steel tube manufacturing line that can be used to manufacture a workpiece.

Fig. 14 is a diagram illustrating the overall structure of a roll forming line that can be used to manufacture a workpiece.

BEST MODE FOR CARRYING OUT THE INVENTION

[0044] Hereinafter, the overall structure of a bending machine, the structure of a supporting unit, the structure of a machining unit, the structures of heating and cooling units, the structure of a movable roller die, the operation of a preheating unit, the structure and layout of an articulated robot, and the characteristics of a bending equipment line according to exemplary embodiments of the present invention will be described with reference to the accompanying drawings.

1. Overall structure of bending machine and structure of supporting unit

[0045] Fig. 1 is a diagram illustrating the overall structure of a bending machine for performing a bending operation according to the present invention. In the bending method, a metal material 1 as a workpiece that is rotatably supported by a supporting unit 2, is successively or continuously fed from an upstream side, and is then bent at a downstream side of the supporting unit 2.

[0046] The metal material 1 shown in Fig. 1 has a circular shape (circular tube) in a sectional view, but the present invention is not limited thereto. Workpieces having various shapes in sectional view may be used. For example, the following materials may be used as the metal material 1: materials with a closed cross section that have various shapes in sectional view including the circular shape (circular tube) shown in Fig. 1, a rectangular shape, a trapezoidal shape, and other complicated shapes; materials (channels) with an open cross section that are manufactured by, for example, roll forming; materials (channels) with an irregular cross section that are manufactured by an extrusion process; and rod-shaped materials having various shapes in sectional view (a circular rod, a rectangular rod, and an irregular-shape rod).

[0047] Figs. 2A and 2B are diagrams illustrating the cross-sectional shapes of workpieces that can be used as the metal materials according to the present invention. Specifically, Fig. 2A shows a channel with an open cross section that is manufactured by, for example, roll forming, and Fig. 2B shows channels with an irregular cross section that are manufactured by extrusion. In the bending machine according to the present invention, it is necessary to design the shape of the movable roller die or the supporting unit according to the cross-sectional shape of the metal material used.

[0048] The structure of the bending machine shown in Fig. 1 includes: two pairs of supporting units 2 for rotatably supporting the metal material 1; an feeding apparatus 3 that is provided at the upstream side of the supporting units 2 and successively or continuously feeds the metal material 1; and a movable roller die 4 that is provided at the downstream side of the two pairs of supporting units 2, clamps the metal material 1, and controls the supporting position of the metal material 1 and/or the moving speed thereof. The structure of the bending machine further includes: a high-frequency heating coil 5 that is provided around the outer circumference of the metal material 1 on the entrance side of the movable roller die 4, and locally heats the metal material 1; and a cooling unit 6 that rapidly cools down the heated portion of the metal material 1 to which bending moment is applied.

[0049] In the bending machine shown in Fig. 1, since the metal material having a circular shape (circular tube) in sectional view is used, supporting rollers are used as the supporting unit 2, but the present invention is not limited thereto. For example, a supporting guide may be used according to the cross-sectional shape of a metal material used. In addition, as shown in Fig. 1, two pairs of supporting rollers are used, but the number of supporting rollers is not limited to two. For example, a pair of supporting rollers, or three or more pairs of supporting rollers may be used.

[0050] Figs. 3A and 3B are diagrams illustrating examples of the structure of a supporting guide that can be used as the supporting unit according to the present invention. Specifically, Fig. 3A shows the cross-sectional structure of the supporting guide and a rotating mechanism provided in the supporting guide, and Fig. 3B is a perspective view illustrating the general appearance of the supporting guide 2. The supporting guide 2 shown in Fig. 3 rotatably supports a rectangular tube 1, which is a workpiece, and includes means for preventing the heating of the supporting guide that is disposed close to the heating unit (the high-frequency heating coil 5 shown in Fig. 1). The means for preventing the heating of the supporting guide is preferably made of a non-magnetic material. In addition, as shown in Fig. 3B, the means for preventing the heating of the supporting guide may be divided into two or more segments, and an insulating material, such as Teflon, may be attached to the divided segments, in order to effectively prevent the supporting guide from being heated.

[0051] A rotating mechanism including a driving motor 10 and a rotational gear 10a is directly connected to the supporting guide 2 such that the supporting guide 2 can be rotated in the circumferential direction in synchronization with the rotation of the pushing apparatus, which will be described in detail below. Therefore, when the metal material 1 is twisted, it is possible to accurately deform the metal material 1.

[0052] In the bending machine, the supporting rollers shown in Fig. 1 or the supporting guide shown in Fig. 3 can be used as the supporting unit for the metal material 1. However, for the purpose of the consistency of explanation, in the following a mode and an effect will be shown in the case where a circular tube is used as the metal material, and the supporting rollers are used as the supporting unit. In the present invention, it goes without saying that, even when a rod-shaped material or a material with a closed cross section, an open cross section, or an irregular cross section is used instead of the circular tube, or even when the supporting guide is used as the metal material instead of the supporting roller, the exactly same effect as described above can be obtained.

2. Structure of processing section and structure of each of heating and cooling units.

[0053] Fig. 4 is a diagram illustrating the structure of a core processing section of the bending machine. The two pairs of supporting rollers 2 for supporting the metal material 1 are provided, and the movable roller die 4 is arranged at the downstream side of the supporting rollers 2. In addition, the high-frequency heating coil 5 and the cooling unit 6 are arranged on the entrance side of the movable roller die 4. Further, a preheating unit 5a is provided between the two pairs of supporting rollers 2, and a lubrication unit 8 for supplying a lubricant is provided at the entrance of the movable roller die 4 so as to be close to the movable roller die.

[0054] In the structure of the bending machine shown in Fig. 4, the movable roller die 4 clamps the metal material 1 passing through the two pairs of supporting rollers 2, and controls the supporting position and/or the moving speed thereof. Then, the high-frequency heating coil 5 provided around the outer circumference of the metal material 1 locally heats the metal material 1 to bend the metal material 1, and the cooling unit 6 provided around the outer circumference of the metal material 1 rapidly cools down the bent portion. During the bending operation, since the high-frequency heating coil 5 heats the metal material 1 passing through the supporting rollers 2, the yield point of a portion of the metal material 1 bent by the movable roller die 4 is dropped, and deformation resistance is lowered, which makes it easy to bend the metal material 1.

[0055] Furthermore, since the movable roller die 4 clamps the metal material 1 using movable rolls, it is possible to retard the generation of seizure defects on the surfaces of the die despite clamping the heated metal material 1. In addition, the lubricant is supplied to the movable roller die. Therefore, even when scales generated from the heated portion of the metal material 1 are migrated into the movable roller die, the lubricant can prevent the generation of seizure defects on the surface of the movable roller die.

[0056] In the bending machine according to the present invention, since a cooling fluid is supplied to the movable roller die 4 to cool down the movable roller die 4, it is possible to prevent decrease of the strength of the movable roller die 4, the deterioration of the machining accuracy of the movable roller die due to thermal expansion, and the generation of seizure defects on the surface of the movable roller die.

[0057] Fig. 5 is a diagram schematically illustrating the structure of each of the heating unit and the cooling unit provided in the bending machine according to the present invention. The ring-shaped high-frequency heating coil 5 is provided around the outer circumference of a metal material to be heated, and heats the metal material at a temperature at which the heated portion of the metal material can be plastically deformed concentrically. Then, bending moment is applied to the heated portion of the metal material by the action of the movable roller die, and the cooling unit 6 injects the cooling fluid to quench the heated portion of the metal material. Before high frequency heating, the metal material is held by the two pairs of supporting rollers. In this embodiment, the heating unit and the cooling unit are integrated into one-piece, but the present invention is not limited thereto. The heating coil may be separated from the cooling unit.

[0058] According to this bending method, it is possible to successively and continuously heat the metal material at a temperature at which coarse grains are not generated and at an A_3 transformation point or more. In addition, the locally heated portion of the metal material is plastically deformed by the movable roller die, and immediately the cooling fluid is injected to the deformed portion, which makes it possible to ensure a cooling rate of 100°C/sec or more.

[0059] The metal material subjected to bending can have excellent shape fixability and stable equality. For example, even when a metal material having low strength is bent as a starting material, it is possible to increase the strength of the metal material by uniform quenching, and thus obtain a metal material having a tensile strength of 900 MPa or more, preferably, 1300 MPa or more.

[0060] When the metal material is thick in wall thickness, in some cases, it is difficult to ensure a cooling rate of 100°C/sec or more. When the metal material is a circular tube, a rectangular tube, or a trapezoidal tube with a closed cross section (metal tube), a mandrel as a cooling unit can be inserted into the metal material having the closed cross section.

[0061] Fig. 6 is a diagram illustrating the structure of the mandrel that is inserted into the metal material having the closed cross section (metal tube) in order to ensure the cooling rate of the heavy-wall metal material. When the metal material with the closed cross section is thick in wall thickness, a mandrel 6a can be inserted into the metal material as a cooling unit. It is possible to ensure the cooling rate by supplying a cooling medium into the mandrel 6a in synchronization with the cooling unit 6 provided around the outer circumference of the metal material 1. In this case, a fluid or mist may be supplied into the metal material 1 to cool down the metal material 1, and the mandrel 6a is desirably made of a non-magnetic material or a refractory material.

[0062] In the bending machine according to the present invention, the cooling medium supplied from the cooling unit 6 desirably includes water as a primary component and a rust-preventative agent. When a sliding portion of the bending machine is wet by cooling water without the rust-preventative agent, rust occurs, which may cause serious machine malfunctions. Therefore, it is effective that the rust-preventative agent be contained in the cooling water in order to protect the machine.

[0063] Further, it is desirable that the cooling medium supplied from the cooling unit contains water as a primary componenet, and a quenching agent. For example, a quenching agent mixed with an organic polymer agent has been known. When the quenching agent having a predetermined concentration is mixed with water, it is possible to adjust the cooling rate and thus ensure a stable quenching performance.

3. Structure of movable roller die

[0064] Fig. 7 is a diagram illustrating the structural examples of shift mechanisms for moving the movable roller die in the vertical and horizontal directions and a rotational mechanism for rotating the movable roller die in the circumferential direction in the movable roller die provided in the bending machine according to the present invention. The metal material (circular tube) 1, which is a workpiece, is supported by the movable roller die 4 having four rollers. The shift mechanism for moving the movable roller die in the vertical direction is operated by a driving motor 8, and the shift mechanism for moving the movable roller die in the horizontal direction is operated by a driving motor 9. The rotational mechanism for rotating the movable roller die in the circumferential direction is operated by a driving motor 10.

[0065] In Fig. 7, although the structure of a tilt mechanism for inclining the movable roller die 4 in the horizontal and vertical directions is not shown, the tilt mechanism used in the present invention is not limited to a specifically limited structure, but any tilt mechanism may be used.

[0066] Fig. 8 is a diagram illustrating the operation of a moving mechanism for moving the movable roller die provided in the bending machine according to the present invention in the forward or backward direction. As shown in Fig. 8, when the length of an arm (processed length of the metal material) is L, a bending moment M required for bending is represented by Expression A given below:

[Expression A]

$$M = P \times L = P \times R \sin\theta.$$

[0067] Therefore, as the length L of the arm increases, force P exerted on a pinch roll (movable roller die) 4 becomes smaller. That is, in the processing range from a small bending radius to a large bending radius, when the movable roller die 4 is not moved in the forward or backward direction, the force P required to process the metal material 1 to have a small bending radius restricts bending equipment. Therefore, when the length L of the arm is set to be large so as to process the metal material 1 to have a small bending radius, the shift mechanisms and the tilt mechanism of the movable roller die require a large stroke for processing the metal material to have a large bending radius, which results in an increase in scale of the bending machine.

[0068] Meanwhile, considering the stoppage accuracy or allowable play (movement runout) of the bending machine, when the length L of the arm is small, processing accuracy is lowered. Therefore, it is possible to select the optimum length L of the arm by moving the movable roller die 4 in the forward or backward direction according to the bending radius of the metal material 1, and thus to widen the available processing range. In this case, it is also possible to ensure sufficient processing accuracy without increasing the scale of the bending machine.

[0069] Furthermore, in the bending machine according to the present invention, the high-frequency heating unit and/or the cooling unit can have, independently or in common, a moving mechanism for moving the unit in the forward or backward direction. This structure makes it possible to ensure synchronization with the movable roller die and to heat the leading end of a metal tube at the beginning of bending. As a result, it is possible to improve workability and operability when the metal tube is mounted or demounted.

[0070] Figs. 9A to 9C are diagrams illustrating examples of the configuration of the movable roller die provided in the bending machine. Specifically, Fig. 9A shows a movable roller die including two rollers when a metal material is a member with a closed cross section such as a circular tube, Fig. 9B shows a movable roller die including two rollers when a metal material is a member with a closed cross section such as a rectangular tube or a material with an open cross section, such as a channel, and Fig. 9C shows a movable roller die including four rollers when a metal material is a member with a closed cross section such as a rectangular tube or a member with an irregular cross section, such as a channel.

[0071] The roll caliber type of the movable roller die 4 can be designed according to the cross section of the metal material 1. The number of rollers is not limited to 2 or 4, as shown in Figs. 9A to 9C, but the movable roller die may include three rollers. In general, the metal material used for bending can have a closed cross section with a circular shape, a rectangular shape, a trapezoidal shape, or a complex shape, an open cross section formed by a roll forming operation, or an irregular cross section formed by an extrusion operation. However, when the metal material 1 has a substantially rectangular cross section, as shown in Fig. 9C, it is desirable that the movable roller die be composed of four rollers.

[0072] In the bending machine according to the present invention, as shown in Fig. 7, a rotational mechanism for rotating in a circumferential direction can be provided in the movable roller die 4 in order to twist the metal material. At the same time, although not shown in Fig. 1, the feeding apparatus 3 can be provided with a chuck mechanism 7 capable of holding and rotating the metal material 1 in the circumferential direction, which serves as a rotational mechanism.

[0073] Therefore, in order to twist the metal material in the bending machine according to the present invention, the following methods can be used: a method of twisting the leading end of the metal material using the rotational mechanism of the movable roller die; and a method for twisting the rear end of the metal material using the rotational mechanism of the pushing apparatus. In general, when the method of twisting the rear end of the metal material using the rotational mechanism of the feeding apparatus is employed, a compact machine structure is obtained. On the other hand, in the method of twisting the leading end of the metal material using the rotational mechanism of the movable roller die, as shown in Fig. 7, there is a fear that the scale of the bending machine will increase. However, both the methods can be used to twist the metal material.

[0074] In the bending machine according to the present invention, a rotational mechanism for rotating in the circumferential direction may be provided in the supporting unit (the supporting roller or the supporting guide), which makes it possible to rotate the metal material in the circumferential direction in synchronization with the rotation of the feeding apparatus. Either the method of twisting the leading end of the metal material using the rotational mechanism of the movable roller die or the method of twisting the rear end of the metal material using the rotational mechanism of the feeding apparatus can be used to accurately twist the metal material in synchronization with the supporting unit.

[0075] In the bending machine according to the present invention, a roller driving and rotating mechanism may be provided in the movable roller die. In this case, the roller can be driven and rotated by, for example, a driving motor according to the feed amount of the metal material pushed by the feeding apparatus. That is, when compressive stress exerted on a bent portion is reduced and the rotational speed of the rollers of the movable roller die is controlled so as to be synchronized with the feed amount of the metal material fed by the feeding apparatus, it is possible to apply tensile stress to the bent portion, and the avialble bending range is widened. In addition, it is possible to improve the bending accuracy of a metal material.

4. Preheating unit and operation of preheating unit

[0076] The bending machine according to the present invention includes a preheating unit at the upstream side of the heating unit. The preheating unit can perform preferential heating or plural-stage heating on the metal material. When the preheating unit performs plural-stage heating, it is possible to disperse heating load of the metal material, and thus improve bending efficiency.

[0077] Fig. 10 is a diagram illustrating the operation of the preheating unit that performs prefrential heating on the metal material. When the high-frequency preheating coil 5a is used as the preheating unit to perform preferential heating on the metal material 1, the metal material 1 is disposed so as to off-set from the center of the high-frequency preheating coil 5a in a direction in which the metal material is bent by the movable roller die. Thus, the temperature of the heated portion of the metal material 1 to be the inner radius side of the bend can be controlled to be lower than that of the outer radius side of the bend.

[0078] Specifically, in Fig. 10, the metal material 1 is disposed such that a portion A is close to the high-frequency preheating coil 5a, so that the temperature of the outer surface of the portion A corresponding to the outer radius side of the bent portion is higher than the temperature of the outer surface of a portion B corresponding to theinner radius side of the bent portion. The structure of the heated portion of the metal material 1 can effectively prevent the wrinkles on the inner radius side of the bent portion and cracking on the outer radius side of the bent portion.

[0079] In the bending machine according to the present invention, a lubricant can be supplied to the movable roller die. Therefore, even when scales generated from the heated portion of the metal material are migrated in the movable roller die, the lubricant can retard the generation of seizure defects on the surface of the movable roller die.

[0080] Similarly, in the bending machine according to the present invention, a cooling fluid can be supplied to the movable roller die. A cooling pipe is provided in the movable roller die in the vicinity of a portion for supporting the metal material, and the cooling fluid is supplied to the movable roller die through the cooling pipe. In this way, the movable roller die is cooled down by the cooling fluid. As a result, it is possible to prevent decrease of the strength of the movable roller die, the lowering of bending accuracy due to thermal expansion of the movable roller die, and seizure defects on the surface of the movable roller die.

5. Structure and arrangement of articulated robot

[0081] Fig. 11 is a diagram illustrating the overall structure and arrangement of an articulated robot that is applicable to the bending machine according to the present invention. As shown in Fig. 11, an articulated robot 11 for the movable roller die 4 can be provided at the downstream side of the bending machine.

[0082] The articulated robot 11 for the movable roller die includes a fixed surface 12 that is fixed to an operating surface, three arms 13, 14, and 15, and three joints 16, 17, and 18 that connect the arms 13, 14, and 15, respectively, and each of these can rotate on its shaft thereof. The movable roller die 4 is attached to the leading arm 15 of the articulated robot 11.

[0083] Fig. 12 is a diagram illustrating another example of the structure of the articulated robot that is applicable to the bending machine according to the present invention. In the bending machine shown in Fig. 11, only the articulated robot for the movable roller die is provided. However, both the articulated robot 11 for the heating unit and the cooling unit, and the articulated robot 11 for the movable roller die can be concurrently provided. The use of the two articulated robots makes it possible to further improve bending efficiency.

[0084] In the bending machine according to the present invention, at least one articulated robot having three joints that each can rotate on its axis is provided. During the bending of the metal material, the articulated robots can perform a series of operations, such as forward and backward movement, rotation, and translation, performed by the shift mechanism, the tilt mechanism, and the moving mechanism of the movable roller die 4, on the basis of control signals. That is, during the bending of the metal material, the articulated robots can perform a total of six types of operations performed by manipulators, on the basis of the control signals. As a result, it is possible to improve bending efficiency and reduce the scale of a bending machine.

6. Bending-equipment line

[0085] As described above, a workpiece with a closed cross section having a circular shape or the like or an open cross section is provided to the bending machine according to the present invention. An electric resistance welded steel tube has been generally used as the material with a circular closed cross section of a circular tube, and a steel material made by roll forming has been generally used as the material with the open cross section.

[0086] Fig. 13 is a diagram illustrating the overall structure of an electric resistance welded steel tube manufacturing line that is used to manufacture a workpiece. An electric resistance welded steel tube manufacturing line 19 is used to manufacture steel tube from a strip-shaped steel sheet 20. The electric resistance welded steel tube manufacturing line 19 includes an uncoiler 21 for continuously unrolling into the strip-shaped steel sheet 20 from a strip-shaped steel sheet roll, a forming apparatus 22 having a plurality of roll forming devices that form the unrolled strip-shaped steel sheet 20 into tube having a predetermined cross-sectional shape, a welding apparatus 23 having a welding machine that welds the opposite edges of the strip-shaped steel sheet to each other to form continuous steel tube, a weld bead cutter, a post-annealing apparatus, a post-processing apparatus 24 that adjusts the size of the continuous tube to a predetermined dimension, and a cutting apparatus 25 having a flying cutter for cutting the steel tube having the predetermined dimension to a necessary length, which are sequentially arranged in the order as above.

[0087] Fig. 14 is a diagram illustrating the overall structure of a roll forming line used to manufacture a workpiece. A roll forming line 26 is used to form the strip-shaped steel sheet 20 into a predetermined shape. The roll forming line 26 includes the uncoiler 21 that the strip-shaped steel sheet 20 as a metal material is unwound and unrolled from the coil, a forming apparatus 27 having roll forming devices that form the strip-shaped steel sheet 20 unrolled by the uncoiler 21 into a predetermined shape, and a cutting apparatus 28 having a flying cutter that continuously cuts the strip-shaped steel sheet 20 that has been formed into a predetermined shape by the roller forming machines to a predetermined length.

[0088] A workpiece manufactured by the electric resistance welded steel tube manufacturing line 19 shown in Fig. 13 or the roll forming line 26 shown in Fig. 14 is provided into a bending machine as a metal material to be bent. When the manufacturing lines and the bending machine are separated from each other, it is necessary to ensure a place for stocking workpiece since the processing speeds between the manufacturing line and the bending machine are different from each other. In addition, an auxiliary transfer equipment and means for transporting workpiece between the manufacturing line and the bending machine, such as a crane and a truck, are needed.

[0089] The bending machine is sequentially provided at the exit side of the electric resistance welded steel tube manufacturing line 19 or the roll forming line 26. Therefore, a bending-equipment line from the supply side of workpiece to the overall bending machine becomes compact, and it is possible to appropriately adjust operation conditions of the bending equipment. As a result, it is possible to effectively perform a bending operation to manufacture accurate and inexpensive bent products.

INDUSTRIAL APPLICABILITY

[0090] According to a method of bending a metal material, according to the present invention, even when there is a need for bending a metal material in various shapes, such as in a two-dimensional continuous bending operation in which the metal material is two-dimensionally bent in different directions (for example, an S shape) or in a three-dimensional continuous bending operation in which the metal material is three-dimensionally bent in different directions, and even when there is a need for bending a metal material having high strength, the metal material is uniformly cooled down. Therefore, it is possible to effectively obtain a metal material having excellent shape fixability despite having high strength, and uniform hardness distribution at a low cost.

[0091] Further, since the movable roller die rotatably clamps a metal material, it is possible to retard the generation of seizure defects on the surface of the movable roller die. Therefore, the accuracy of a bending operation can be ensured, and a bending operation can be performed with a high degree of operation efficiency. In this way, the bending method according to the present invention can be widely applied as an art of bending sophisticated and diversified automobile parts.

Claims

1. A method for bending a metal material (1) in which, in a bending process, while successively or continuously feeding a metal material (1) held by a supporting unit (2) from an upstream side of the supporting unit (2), the bending is performed for the metal material (1) at a downstream side of the supporting unit (2), whereby:

   the metal material (1) is clamped with a movable roller die (4) that is provided at the downstream side of the supporting unit (2);
   the position of the movable roller die (4) and/or the moving speed of the metal material (1) is controlled;
   the metal material (1) is heated in a temperature range in which quenching can be performed at or above the A3 transformation point and up to a temperature at which coarse grains are not generated, by using a heating unit (5) that is provided around the outer circumference of the metal material (1) at an entrance side of the movable roller die (4), to apply a bending moment to the heated portion; and
   the heated portion is rapidly cooled down at a rate of 100°C/sec or more by using a cooling unit (6) that is provided around the outer circumference of the metal material (1) at the entrance side of the movable roller die (4).

2. The method for bending a metal material according to claim 1, **characterized in that** the movable roller die (4) includes at least one of a shift mechanism (8) for moving the movable roller die (4) in a vertical

direction, a shift mechanism (8) for moving the movable roller die (4) in a horizontal direction, a tilt mechanism for inclining the movable roller die (4) in a vertical direction, and a tilt mechanism for inclining the movable roller die (4) in a horizontal direction.

3. The method for bending a metal material according to claim 2, **characterized in that** the movable roller die (4) further includes a moving mechanism for moving the movable roller die (4) in a forward or backward direction in an axial direction of the metal material relative to the supporting unit.

4. The method for bending a metal material according to claim 2, **characterized in that** the heating unit (5) and/or the cooling unit (6) include at least one of a shift mechanism for moving the unit in a vertical direction, a shift mechanism for moving the unit in a horizontal direction, a tilt mechanism for inclining the unit in a vertical direction, and a tilt mechanism for inclining the unit in a horizontal direction.

5. The method for bending a metal material according to claim 4, **characterized in that** the heating unit (5) and/or the cooling unit (6) further include a moving mechanism for moving the unit in a forward or backward direction in an axial direction of the metal material relative to the supporting unit.

6. The method for bending a metal material according to any one of claims 1 to 5, **characterized in that** the movable roller die (4) includes a rotational mechanism (10) for rotating the movable roller die (4) in a circumferential direction.

7. The method for bending a metal material according to any one of claims 1 to 6, **characterized in that** a feeding apparatus is provided at the upstream side of the metal material (1), and includes a mechanism that holds and rotates a workpiece in a circumferential direction.

8. The method for bending a metal material according to claim 7, **characterized in that** the supporting unit (2) includes a rotational mechanism for rotating the supporting unit in a circumferential direction, and rotates in the circumferential direction in synchronization with the rotation by the feeding apparatus.

9. The method for bending a metal material according to any one of claims 1 to 8, **characterized in that** the movable roller die (4) includes a driving mechanism that drives rollers, and drives and rotates the rollers according to the feed amount of the metal material fed by the feeding apparatus.

10. The method for bending a metal material according to any one of claims 1 to 9, **characterized in that** the movable roller die (4) includes two rollers, three rollers, or four rollers.

11. The method for bending a metal material according to any one of claims 1 to 10, **characterized in that** the metal material (1) subjected to bending is a closed cross-section member, an open cross-section member, an irregular cross-section member that has any of various shapes in sectional view.

12. The method for bending a metal material according to any one of claims 1 to 11, **characterized in that** one or more preheating units (5a) are provided at the upstream side of the heating unit (5) to perform plural-stage heating or preferential heating on the metal material (1).

13. The method for bending a metal material according to any one of claims 1 to 12, **characterized in that** a mandrel, serving as the cooling unit, is inserted into the metal material, and a cooling medium is supplied into the mandrel.

14. The method for bending a metal material according to any one of claims 1-10 or 12, **characterized in that** the metal material subjected to bending is a rod-shaped member that has any of various shapes in sectional view.

15. The method for bending a metal material according to any one of claims 1 to 14, **characterized in that** the cooling medium supplied from the cooling unit contains water as a primary component and a rust-preventative agent and/or a quenching agent.

16. The method for bending a metal material according to any one of claims 1 to 15, **characterized in that** a lubricant and/or a cooling fluid are supplied to the movable roller die.

17. The method for bending a metal material according to any one of claims 1 to 16, **characterized in that** an articulated robot having one or more joints that each can rotate on its axis is provided, and
the articulated robot (11) performs the operation of at least one of the shift mechanism, the tilt mechanism, and the moving mechanism for the movable roller die, and the heating unit (5) and/or the cooling unit (6).

18. The method for bending metal material according to any one of claims 1 to 17, wherein the metal material (1) is clamped and moved at a predetermined speed.

19. A bent product, that has a tensile strength of 900 MPa or more **characterized in that** it has been subjected to a thermomechanical treatment by virtue of the method for bending the metal material according

to any one of claims 1 to 18.

Patentansprüche

1. Verfahren zum Biegen eines Metallmaterials (1), bei dem in einem Biegeprozess während des sukzessiven oder kontinuierlichen Zuführens eines von einer Trägereinrichtung (2) gehaltenen Metallmaterials (1) von einer stromaufwärts liegenden Seite der Trägereinrichtung (2) das Biegen für das Metallmaterial (1) an einer stromabwärts liegenden Seite der Trägereinrichtung (2) erfolgt, wodurch:

   das Metallmaterial (1) mit einem beweglichen Walzstempel (4), der an der stromabwärts liegenden Seite der Trägereinrichtung (2) vorgesehen ist, eingespannt wird;
   die Position des beweglichen Walzstempels (4) und/oder die Bewegungsgeschwindigkeit des Metallmaterials (1) gesteuert wird;
   das Metallmaterial (1) in einem Temperaturbereich, in dem ein Abschrecken bei oder über dem A3-Umwandlungspunkt durchgeführt werden kann, und bis zu einer Temperatur, bei der keine grobe Körner erzeugt werden, durch Verwenden einer Heizeinrichtung (5) erwärmt wird, die um den Außenumfang des Metallmaterials (1) an einer Eintrittseite des beweglichen Walzstempels (4) vorgesehen ist, um an dem erwärmten Abschnitt ein Biegemoment auszuüben; und
   der erwärmte Abschnitt durch Verwenden einer Kühleinrichtung (6), die um den Außenumfang des Metallmaterials (1) an der Eintrittseite des beweglichen Walzstempels (4) vorgesehen ist, bei einer Rate von 100°C/s oder mehr schnell abgekühlt wird.

2. Verfahren zum Biegen eines Metallmaterials nach Anspruch 1, **dadurch gekennzeichnet, dass** der bewegliche Walzstempel (4) mindestens eines von einem Verschiebemechanismus (8) zum Bewegen des beweglichen Walzstempels (4) in einer vertikalen Richtung, einem Verschiebemechanismus (8) zum Bewegen des beweglichen Walzstempels (4) in einer horizontalen Richtung, einem Kippmechanismus zum Neigen des beweglichen Walzstempels (4) in einer vertikalen Richtung und einem Kippmechanismus zum Neigen des beweglichen Walzstempels (4) in einer horizontalen Richtung umfasst.

3. Verfahren zum Biegen eines Metallmaterials nach Anspruch 2, **dadurch gekennzeichnet, dass** der bewegliche Walzstempel (4) weiterhin einen Bewegungsmechanismus zum Bewegen des beweglichen Walzstempels (4) in einer Vorwärts- oder Rückwärtsrichtung in einer axialen Richtung des Metallmaterials relativ zu der Trägereinrichtung umfasst.

4. Verfahren zum Biegen eines Metallmaterials nach Anspruch 2, **dadurch gekennzeichnet, dass** die Heizeinrichtung (5) und/oder die Kühleinrichtung (6) mindestens eines von einem Verschiebemechanismus zum Bewegen der Einrichtung in einer vertikalen Richtung, einem Verschiebemechanismus zum Bewegen der Einrichtung in einer horizontalen Richtung, einem Kippmechanismus zum Neigen der Einrichtung in einer vertikalen Richtung und einem Kippmechanismus zum Neigen der Einrichtung in einer horizontalen Richtung umfassen.

5. Verfahren zum Biegen eines Metallmaterials nach Anspruch 4, **dadurch gekennzeichnet, dass** die Heizeinrichtung (5) und/oder die Kühleinrichtung (6) weiterhin einen Bewegungsmechanismus zum Bewegen der Einrichtung in einer Vorwärts- oder Rückwärtsrichtung in einer axialen Richtung des Metallmaterials relativ zu der Trägereinrichtung umfassen.

6. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 5, **dadurch gekennzeichnet, dass** der bewegliche Walzstempel (4) einen Drehmechanismus (10) zum Drehen des beweglichen Walzstempels (4) in einer Umfangsrichtung umfasst.

7. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 6, **dadurch gekennzeichnet, dass** an der stromaufwärts liegenden Seite des Metallmaterials (1) eine Zufuhrvorrichtung vorgesehen ist und einen Mechanismus umfasst, der ein Werkstück hält und in einer Umfangsrichtung dreht.

8. Verfahren zum Biegen eines Metallmaterials nach Anspruch 7, **dadurch gekennzeichnet, dass** die Trägereinrichtung (2) einen Drehmechanismus zum Drehen der Trägereinrichtung in einer Umfangsrichtung umfasst und in der Umfangsrichtung synchron mit der Drehung durch die Zufuhrvorrichtung dreht.

9. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 8, **dadurch gekennzeichnet, dass** der bewegliche Walzstempel (4) einen Antriebsmechanismus umfasst, der Walzen antreibt, und die Walzen entsprechend dem Zufuhrbetrag des Metallmaterials antreibt und dreht, das von der Zufuhrvorrichtung zugeführt wird.

10. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 9, **dadurch gekennzeichnet, dass** der bewegliche Walzenstempel (4) zwei Walzen, drei Walzen oder vier Walzen umfasst.

11. Verfahren zum Biegen eines Metallmaterials nach

einem der Ansprüche 1 bis 10, **dadurch gekennzeichnet, dass** das einem Biegen unterzogene Metallmaterial (1) ein Element geschlossenen Querschnitts, ein Element offenen Querschnitts, ein Element unregelmäßigen Querschnitts ist, das in Schnittansicht beliebige von verschiedenen Formen aufweist.

12. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 11, **dadurch gekennzeichnet, dass** eine oder mehrere Vorheizeinrichtungen (5a) an der stromaufwärts liegenden Seite der Heizeinrichtung (5) vorgesehen sind, um an dem Metallmaterial (1) mehrstufiges Erwärmen oder bevorzugtes Erwärmen durchzuführen.

13. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 12, **dadurch gekennzeichnet, dass** ein Dorn, der als Kühleinrichtung dient, in das Metallmaterial eingeführt wird und in den Dorn ein Kühlmedium geliefert wird.

14. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1-10 oder 12, **dadurch gekennzeichnet, dass** das einem Biegen unterzogene Metallmaterial ein stabförmiges Element ist, das in Schnittansicht eine beliebige von verschiedenen Formen aufweist.

15. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 14, **dadurch gekennzeichnet, dass** das von der Kühleinrichtung gelieferte Kühlmedium als Hauptbestandteil Wasser und ein Rostschutzmittel und/oder ein Abschreckmittel enthält.

16. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 15, **dadurch gekennzeichnet, dass** dem beweglichen Walzstempel ein Schmiermittel und/oder ein Kühlfluid geliefert werden.

17. Verfahren zum Biegen eines Metallmaterials nach einem der Ansprüche 1 bis 16, **dadurch gekennzeichnet, dass** ein Knickarmroboter mit einem oder mehreren Gelenken, die jeweils an ihrer Achse drehen können, vorgesehen ist und
der Knickarmroboter (11) den Betrieb mindestens eines von Verschiebemechanismus, Kippmechanismus und Bewegungsmechanismus für den beweglichen Walzstempel und der Heizeinrichtung (5) und/oder der Kühleinrichtung (6) vornimmt.

18. Verfahren zum Biegen von Metallmaterial nach einem der Ansprüche 1 bis 17, wobei das Metallmaterial (1) eingespannt und bei einer vorbestimmten Geschwindigkeit bewegt wird.

19. Gebogenes Erzeugnis, das eine Zugfestigkeit von 900 MPa oder mehr aufweist, **dadurch gekennzeichnet, dass** es dank des Verfahrens zum Biegen des Metallmaterials nach einem der Ansprüche 1 bis 18 einer thermomechanischen Behandlung unterzogen wurde.

Revendications

1. Procédé pour cintrer un matériau métallique (1) dans lequel, lors d'un processus de cintrage, tout en alimentant successivement ou en continu un matériau métallique (1) maintenu par une unité de support (2) depuis un côté en amont de l'unité de support (2), le cintrage est réalisé pour le matériau métallique (1) au niveau d'un côté en aval de l'unité de support (2), moyennant qui :

le matériau métallique (1) est bloqué avec une matrice à rouleaux mobiles (4) qui est prévue au niveau du côté en aval de l'unité de support (2) ;
la position de la matrice à rouleaux mobiles (4) et/ou la vitesse de déplacement du matériau métallique (1) sont contrôlées ;
le matériau métallique (1) est chauffé dans une plage de températures dans laquelle la trempe peut être réalisée au niveau de ou au-dessus du point de transformation A3 et jusqu'à une température à laquelle des grains grossiers ne sont pas générés, en utilisant une unité de chauffage (5) qui et prévue autour de la circonférence externe du matériau métallique (1) d'un côté d'entrée de la matrice à rouleaux mobiles (4), pour appliquer un moment de cintrage sur la partie chauffée ; et
la partie chauffée est rapidement refroidie à une vitesse de 100 °C/s ou plus en utilisant une unité de refroidissement (6) qui est prévue au bout de la circonférence externe du matériau métallique (1) du côté d'entrée de la matrice à rouleaux mobiles (4).

2. Procédé pour cintrer un matériau métallique selon la revendication 1, **caractérisé en ce que** la matrice à rouleaux mobiles (4) comprend au moins l'un parmi un mécanisme de changement de position (8) pour déplacer la matrice à rouleaux mobiles (4) dans une direction verticale, un mécanisme de changement de position (8) pour déplacer la matrice à rouleaux mobiles (4) dans une direction horizontale, un mécanisme d'inclinaison pour incliner la matrice à rouleaux mobiles (4) dans une direction verticale, et un mécanisme d'inclinaison pour incliner la matrice à rouleaux mobiles (4) dans une direction horizontale.

3. Procédé pour cintrer un matériau métallique selon la revendication 2, **caractérisé en ce que** la matrice à rouleaux mobiles (4) comprend en outre un mécanisme de déplacement pour déplacer la matrice à rouleaux mobiles (4) dans une direction vers l'avant ou vers l'arrière dans une direction axiale du matériau métallique par rapport à l'unité de support.

4. Procédé pour cintrer un matériau métallique selon la revendication 2, **caractérisé en ce que** l'unité de chauffage (5) et/ou l'unité de refroidissement (6) comprennent au moins l'un parmi un mécanisme de changement de position pour déplacer l'unité dans une direction verticale, un mécanisme de changement de position pour déplacer l'unité dans une direction horizontale, un mécanisme d'inclinaison pour incliner l'unité dans une direction verticale et un mécanisme d'inclinaison pour incliner l'unité dans une direction horizontale.

5. Procédé pour cintrer un matériau métallique selon la revendication 4, **caractérisé en ce que** l'unité de chauffage (5) et/ou l'unité de refroidissement (6) comprennent en outre un mécanisme de déplacement pour déplacer l'unité dans une direction vers l'avant ou vers l'arrière dans une direction axiale du matériau métallique par rapport à l'unité de support.

6. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 5, **caractérisé en ce que** la matrice à rouleaux mobiles (4) comprend un mécanisme de rotation (10) pour faire tourner la matrice à rouleaux mobiles (4) dans une direction circonférentielle.

7. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 6, **caractérisé en ce qu'**un appareil d'alimentation est prévu du côté en amont du matériau métallique (1), et comprend un mécanisme qui maintient et fait tourner une pièce dans une direction circonférentielle.

8. Procédé pour cintrer un matériau métallique selon la revendication 7, **caractérisé en ce que** l'unité de support (2) comprend un mécanisme de rotation pour faire tourner l'unité de support dans une direction circonférentielle, et tourne dans la direction circonférentielle en synchronisation avec la rotation de l'appareil d'alimentation.

9. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 8, **caractérisé en ce que** la matrice à rouleaux mobiles (4) comprend un mécanisme d'entraînement qui entraîne des rouleaux, et entraîne et fait tourner les rouleaux selon la quantité d'alimentation du matériau métallique alimenté par l'appareil d'alimentation.

10. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 9, **caractérisé en ce que** la matrice à rouleaux mobiles (4) comprend deux rouleaux, trois rouleaux ou quatre rouleaux.

11. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 10, **caractérisé en ce que** le matériau métallique (1) soumis au cintrage est un élément à section transversale fermée, un élément à section transversale ouverte, un élément à section transversale irrégulière qui a l'une quelconque des différentes formes en vue en coupe.

12. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 11, **caractérisé en ce qu'**une ou plusieurs unités de préchauffage (5a) sont prévues du côté en amont de l'unité de chauffage (5) pour réaliser un chauffage en plusieurs phases ou le chauffage préférentiel sur le matériau métallique (1).

13. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 12, **caractérisé en ce qu'**un mandrin, servant d'unité de refroidissement, est inséré dans le matériau métallique, et un milieu de refroidissement est alimenté dans le mandrin.

14. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 10 ou 12, **caractérisé en ce que** le matériau métallique soumis au cintrage est un élément en forme de tige qui a l'une quelconque des différentes formes en vue en coupe.

15. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 14, **caractérisé en ce que** le milieu de refroidissement alimenté à partir de l'unité de refroidissement contient de l'eau en tant que composant principal et un agent antirouille et/ou un agent de trempe.

16. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 15, **caractérisé en ce qu'**un lubrifiant et/ou un fluide de refroidissement sont alimentés à la matrice à rouleaux mobiles.

17. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 16, **caractérisé en ce qu'**un robot articulé ayant un ou plusieurs joints qui peuvent chacun tourner sur leur axe, est prévu, et

le robot articulé (11) réalise l'opération de l'un parmi le mécanisme de changement de position, le mécanisme d'inclinaison et le mécanisme de déplacement pour la matrice à rouleaux mobiles, et l'unité de chauffage (5) et/ou l'unité de refroidissement (6).

18. Procédé pour cintrer un matériau métallique selon l'une quelconque des revendications 1 à 17, dans lequel ledit matériau métallique (1) est bloqué et déplacé à une vitesse prédéterminée.

19. Produit cintré qui a une résistance à la traction de 900 MPa ou plus, **caractérisé en ce qu'**il a été soumis à un traitement thermomécanique en vertu du procédé pour cintrer le matériau métallique selon l'une quelconque des revendications 1 à 18.

FIG. 1

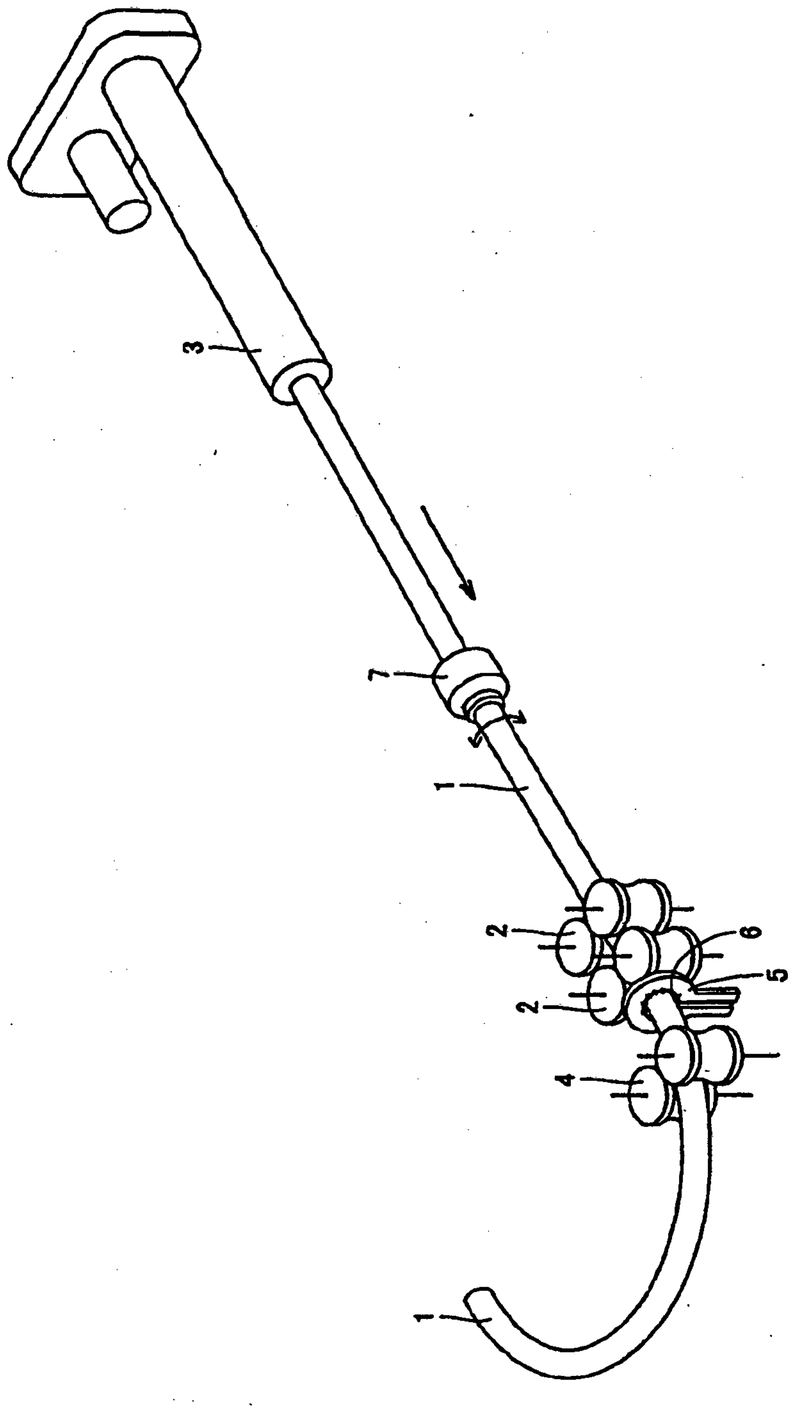
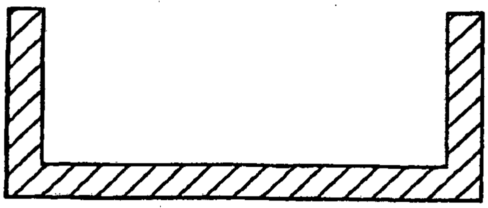


FIG. 2

(a)



(b)

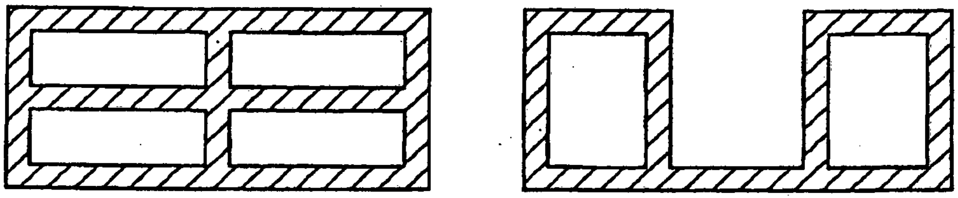
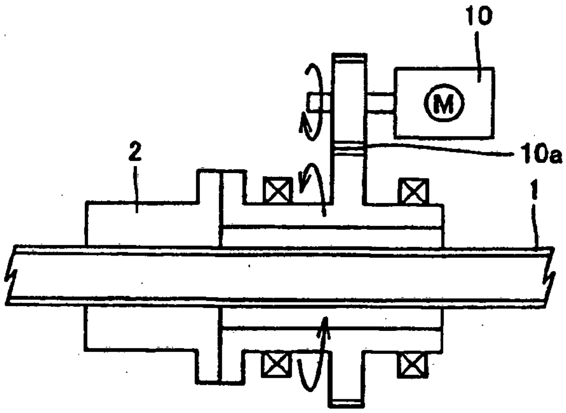


FIG. 3

(a)



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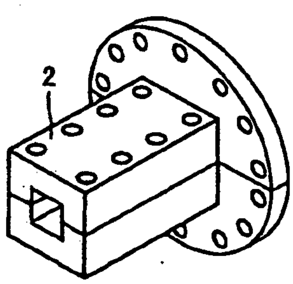


FIG. 4

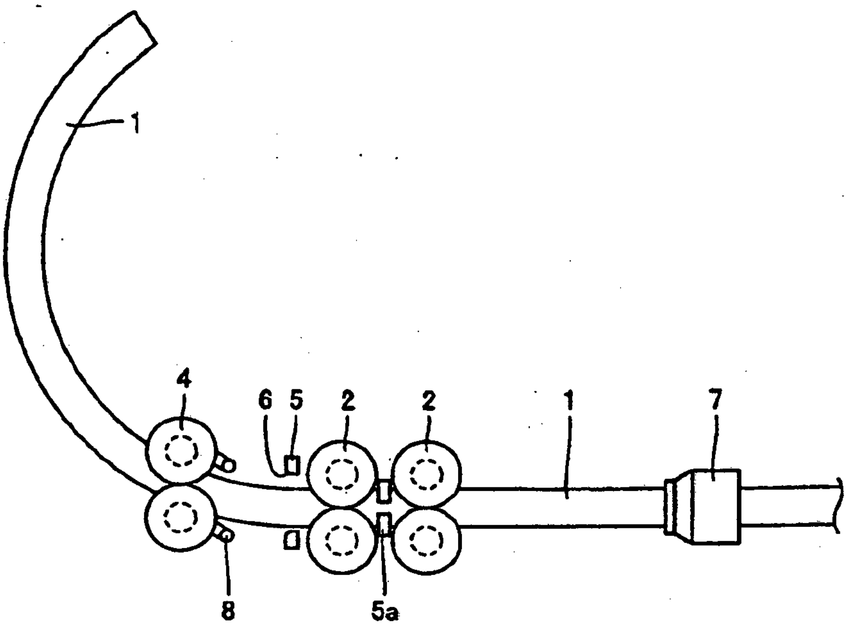


FIG. 5

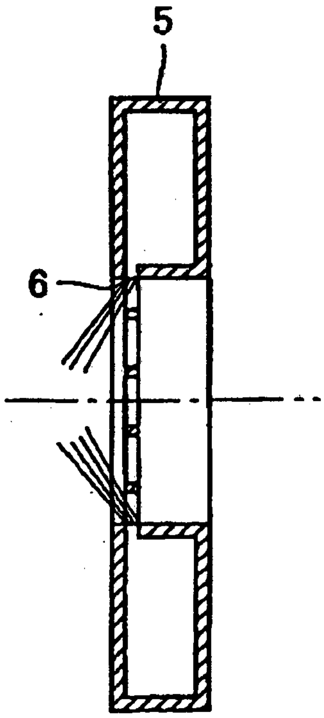


FIG. 6

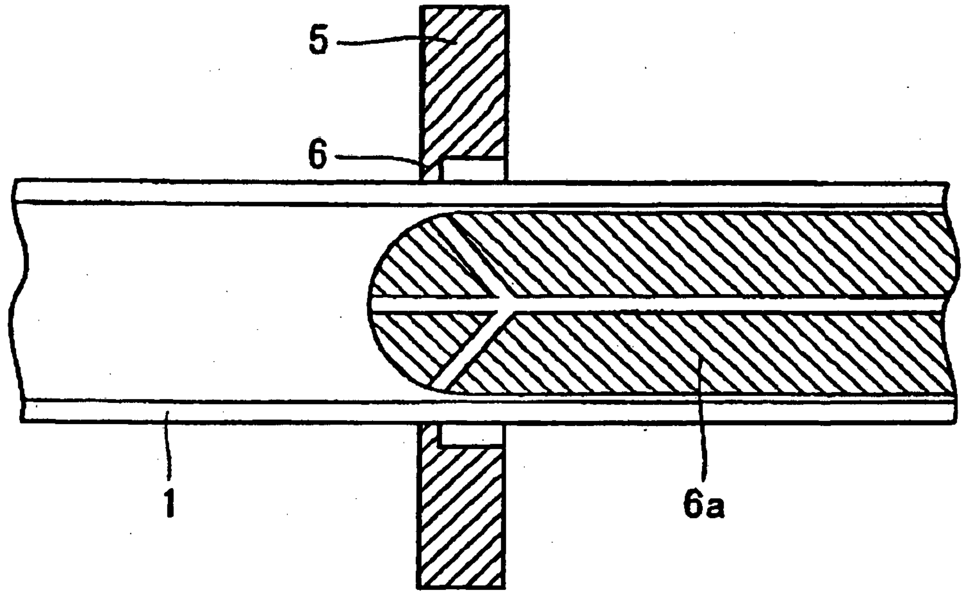


FIG. 7

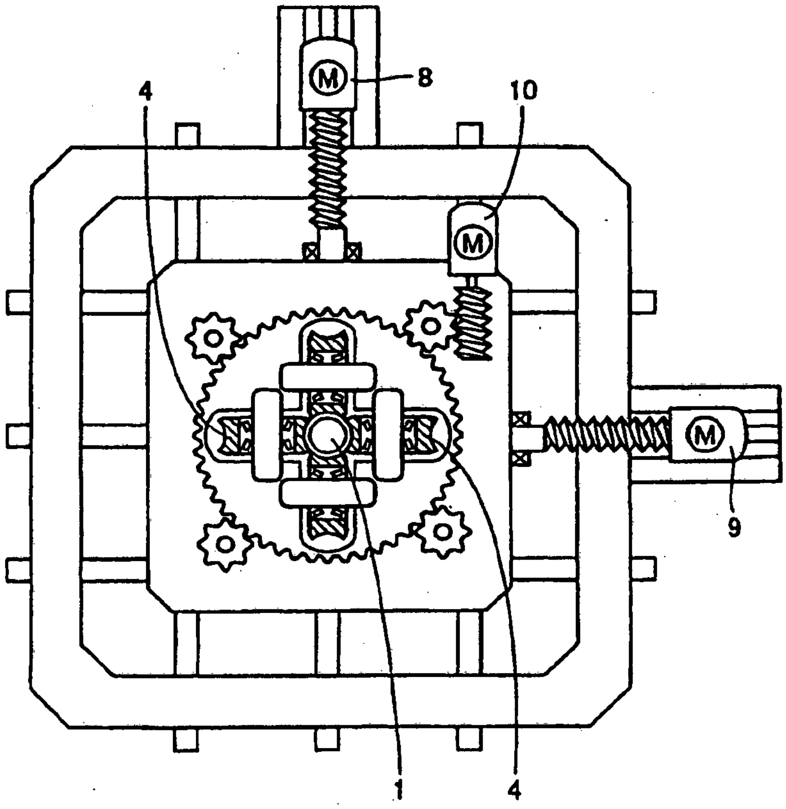


FIG. 8

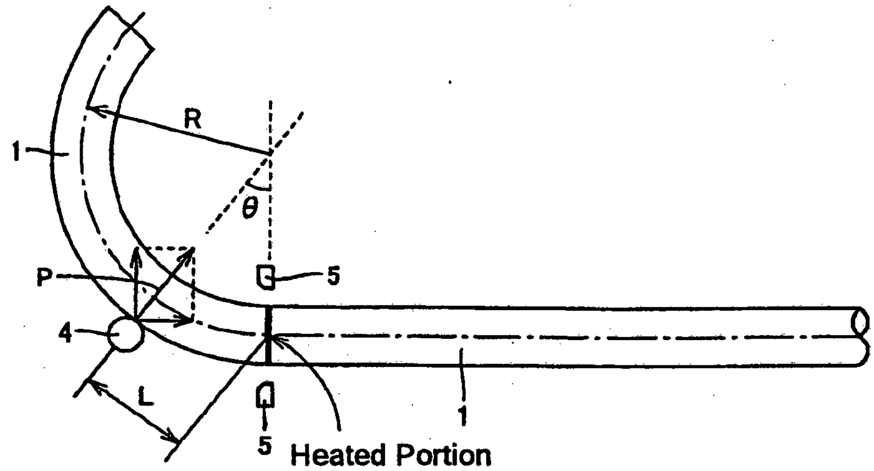


FIG. 9

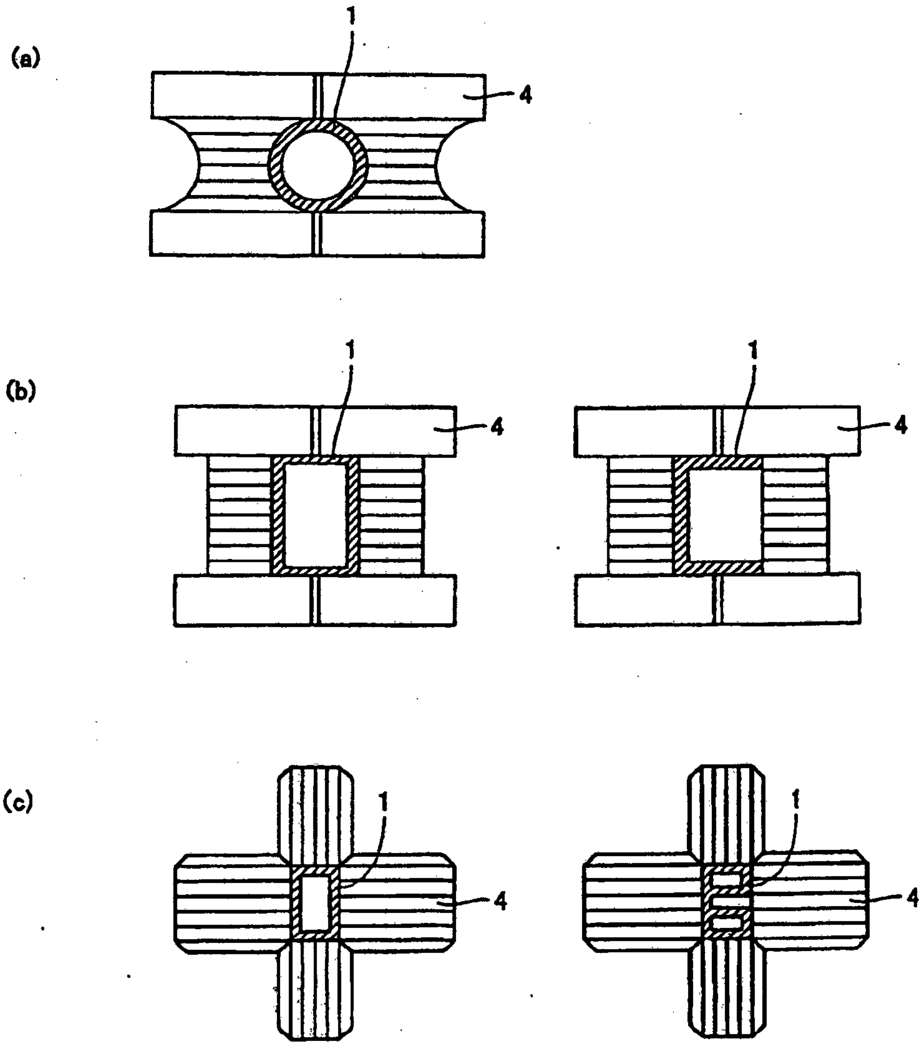


FIG. 10

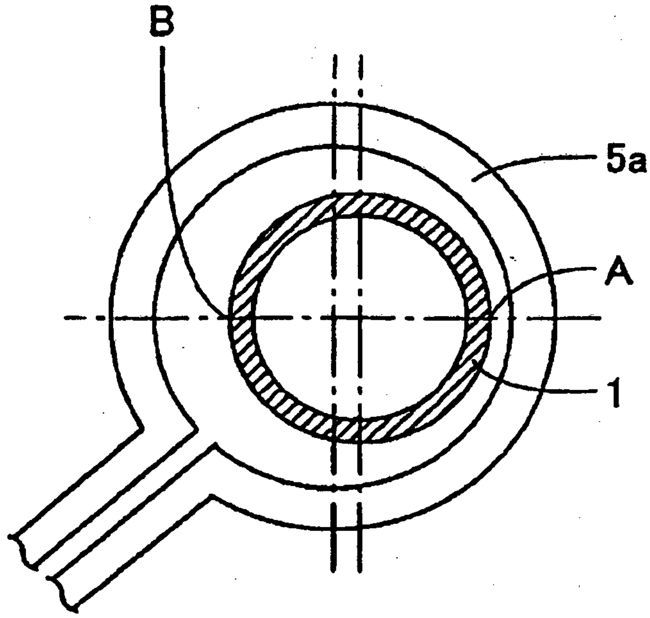


FIG. 11

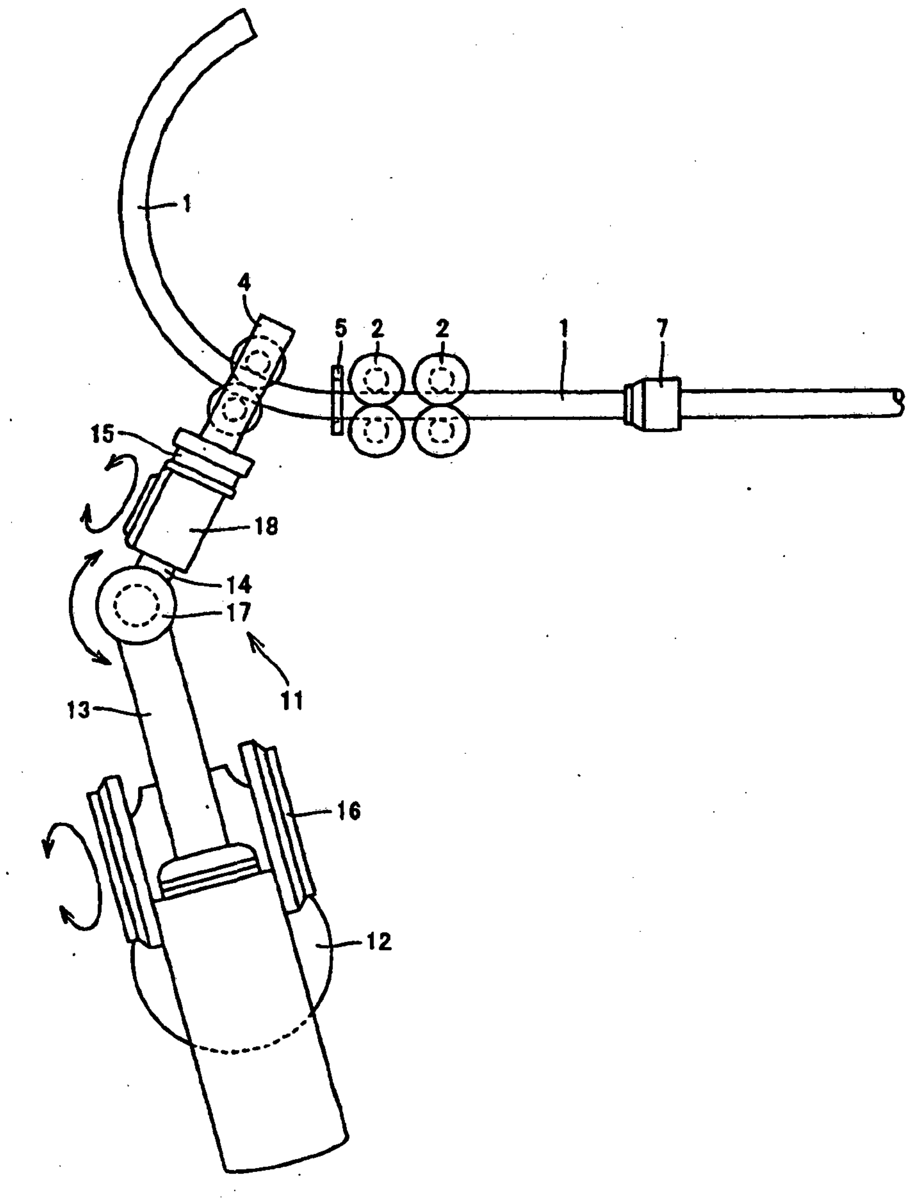


FIG. 12

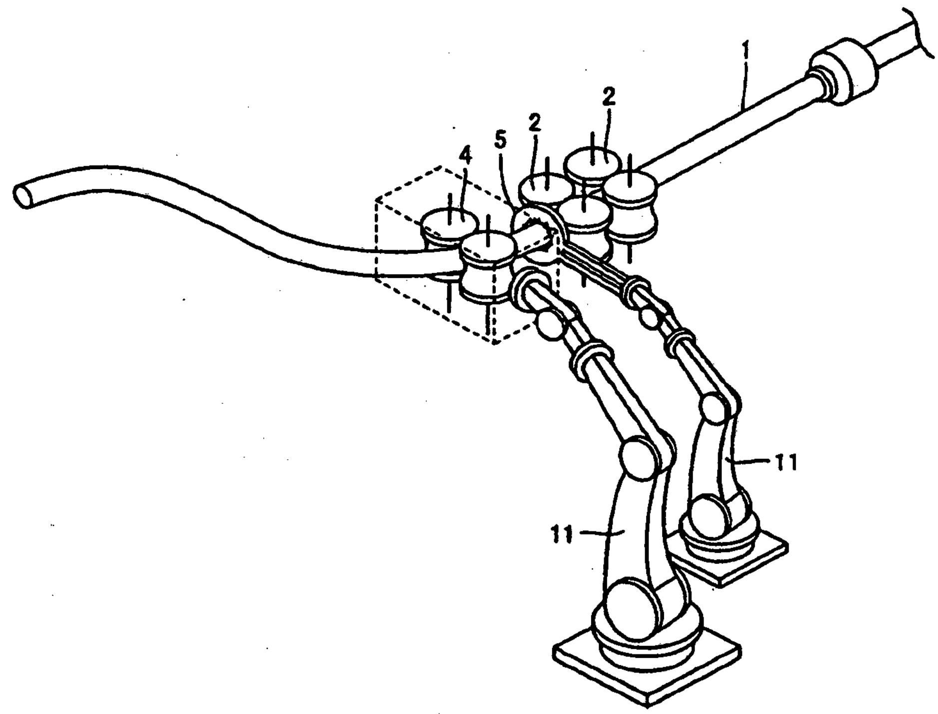


FIG. 13

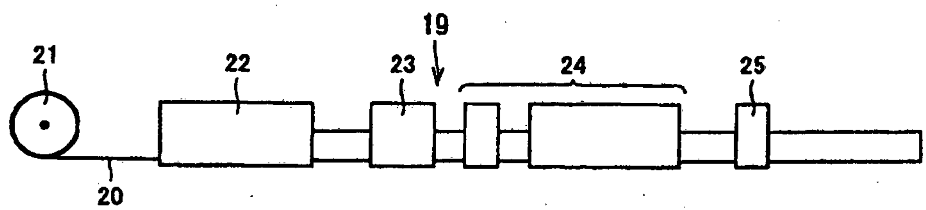
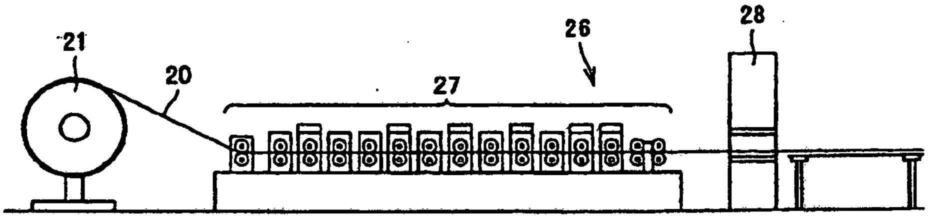


FIG. 14



REFERENCES CITED IN THE DESCRIPTION

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