tubes. In such a case, the surface defects must be treated with surface polishing after manufacturing the metal tubes. In other words, the die draw forming method results in lower productivity and higher production cost.

[0009] Not only in the roll forming method but also in the die draw forming method, laser welding have been adopted as a method to butt and weld the edge parts of the metal bands cylindrically formed. Laser welding is preferred in view of productivity and workability of welded metal tubes.

[0010] (Prior Art Documents)

(Patent Documents)

Patent Document 1: Japanese Patent Application Publication No. H6-134525

Patent Document 2: Japanese Patent Application Publication No. H8-267150

[0011] (Problems to be Solved)

As mentioned above, a problem of the roll forming method has been not only that increased workload due to roll exchange and dimension adjustment are required but also that tiny adjustment errors made in the roll forming stands when manufacturing small-diameter metal tubes, in particular, are likely to cause problems such as meandering and twisting of the metal bands during butting of the edge parts of the metal bands.

[0012] Furthermore, another problem of the die draw forming method has been that a large amount of grease is used to reduce friction between the metal band and the forming die, and therefore degreasing of the metal band is required after it is formed into a cylindrical shape for laser welding.

SUMMARY OF THE INVENTION

[0013] The present invention is proposed for solving the above problems. Specifically, the object of the present invention is to provide a method and device for manufacturing small-diameter metal tubes in which only one stage of a roll clearly larger in outside diameter than a metal tube to be manufactured, i.e., a single stand of a roll having large diameter is used, and in which a metal band is formed into a cylindrical shape with high accuracy without greasing, and thereafter, the edge parts of the metal band are butted and welded each other.

[0014] (Means for Solving Problems)

In order to achieve the above object, the method for manufacturing small-diameter metal tubes according to the present invention is characterized by comprising: feeding a metal band to a large-diameter side roll so that the metal band is formed into a cylindrical shape, the large-diameter side roll having an outside diameter ratio, φ_2/φ_1, of 10 or more between an outside diameter φ_1 of the metal tube to be manufactured and an outside diameter φ_2 of the large-diameter side roll including at least a first large-diameter side roll and a second large-diameter side roll; and thereafter, welding edge parts of the metal band.

[0015] It is preferable that the outside diameter ratio, φ_2/φ_1, is 25 or more. As will be described later, for improvement of the forms of the abutting edge parts in welding, it is also preferable that the metal band is fed to an edge bending roll to bend its edge parts in advance before the metal band is fed to the large-diameter side roll.

[0016] It is preferable that the stand for roll having large diameter used in the present invention has two large-diameter side rolls and one bottom roll arranged therein on the

basis of a three-sided roll system (see FIG. 8 (A)). As will be described later, FIG. 8 (A) is a cross-sectional view showing the structure of such a three-sided roll system having a bottom roll placed therein. A pair of large-diameter side rolls are arranged side by side in such a fashion that their rotation axes are parallel to each other and that their outer peripheries face each other. Then, the bottom roll is arranged in such a fashion that its outer periphery is positioned in the vicinity of a facing portion at which the outer peripheries of the two large-diameter side rolls face each other. In the above facing portion, the edge parts of the metal band are butted each other during the process of forming a metal tube. The rotation axis of the bottom roll is substantially perpendicular to those of the two large-diameter side rolls. It is preferable that the bottom roll is offset-positioned on the upstream side in the moving direction of the metal band (that is, on the entrance side of the manufacturing line) with respect to a line connecting between the rotation axes of a pair of large-diameter side rolls (see FIG. 10). As will be described later, FIG. 10 is a top view showing a more preferable installation position of the bottom roll used in the large-diameter side roll based on the three-sided roll system according to the present invention. The offset-layout of the bottom roll on the upstream side in the moving direction of the metal band allows further reduction of strain caused in the process of forming metal tubes.

[0017] The three-sided roll system may be changed into a four-sided roll system by adding a fin roll (see FIG. 11). The fin roll is placed in the above facing portion in such a fashion that its outer periphery faces the outer periphery of the bottom roll, and that its rotation axis is parallel to the rotation axis of the bottom roll. The layout of the fin roll allows a position at which the edge parts of the metal band are butted each other to be maintained with high accuracy.

[0018] Furthermore, a fin roll may be placed above the squeeze roll immediately before the edge parts of the metal band are welded at the position of the squeeze roll. The fin roll can prohibit an abutting position of the edge parts of the metal band from twisting at the position of the fin roll (see FIG. 13). It is preferable that the fin roll used here has a fin and a concave face having a curvature larger in radius than the metal tube to be manufactured, because the fin enables accurate positioning of the abutting part preferable for subsequent welding, and the concave face enables correction of the forms of the abutting edge parts of the metal band by pressing the edge parts, which results in the obtainment of small-diameter metal tubes with excellent forming accuracy.

[0019] (Advantageous Effects of the Invention)

According to the present invention, by using large-diameter side rolls whose outside diameter is clearly larger than an outside diameter of a metal tube to be manufactured, metal bands can be formed into a cylindrical shape through a single stand, and small-diameter metal tubes each having excellent surface property can be manufactured in a highly efficient fashion. Further, by forming metal bands into a cylindrical shape through a single stand, the total number of stands required for manufacturing metal tubes can be drastically reduced, and the workload required for roll exchange and dimension adjustment by workers can be reduced as well. Still further, by appropriate use of fin rolls, small-diameter metal tubes can be stably manufactured.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] For more thorough understanding of the present invention and advantages thereof, the following descriptions should be read in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective view (A) showing the outline structure of large-diameter side roll and the spatial relationship between the large-diameter side roll and a welding machine configured to weld abutting part of edges, which are used in the present invention, and is also an enlarged view (B) showing groove part of the large-diameter side roll.

FIG. 2 is a view showing a relation between outside diameter ratio, φ_2/φ_1, and equivalent plastic strain caused in the edge parts of a metal band.

FIG. 3 is a schematic view of a manufacturing line used for manufacturing small-diameter metal tubes according to the present invention.

FIG. 4 is a cross-sectional view showing the outline structure of edge bending roll.

FIG. 5 is a cross-sectional view showing the outline structure of large-diameter side roll.

FIG. 6 is a view showing the state where the edge parts of a metal band is bent by using two large-diameter side rolls.

FIG. 7 is a view showing the state where a problem stems from a part of a metal band under transformation between two large-diameter side rolls.

FIG. 8 is a cross-sectional view (A) showing the structure of a large-diameter side roll based on three-sided roll system having a bottom roll placed therein, and is also an enlarged view (B) showing the spatial relationship between the two large-diameter side rolls and the bottom roll.

FIG. 9 is a top view showing an installation position of the bottom roll used in the large-diameter side roll based on three-sided roll system according to the present invention.

FIG. 10 is a top view showing a more preferable installation position of the bottom roll used in the large-diameter side roll based on three-sided roll system according to the present invention.

FIG. 11 is a cross-sectional view showing the structure of the large-diameter side roll based on four-sided roll system obtained by arranging a first fin roll in the three-sided roll system according to the present invention.

FIG. 12 is an explanatory view showing the state of a metal band when one stage of fin roll is placed.

FIG. 13 is an explanatory view showing the state of a metal band when two stages of fin rolls are placed.

FIG. 14 is an explanatory view showing the form of the edge parts in the abutting part of a large-diameter metal tube.

FIG. 15 is an explanatory view showing the form of the edge parts in the abutting part of a small-diameter metal tube.

FIG. 16 is a view showing a preferable form of a second fin roll placed immediately in front of the squeeze roll.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0021] In general, under the roll forming method, metal tubes are formed gradually by means of multistage forming through 10 or more roll forming stands arranged in a tandem fashion. Therefore, in order to alter the diameter of the metal tube to be manufactured, all the rolls placed in the forming stands are required to be replaced with rolls corresponding to the altered outside diameter of the metal tube to be manufactured. Furthermore, a considerable amount of labor and time required for roll exchange leads to lower productivity.

[0022] Therefore, the present invention provides a means to form metal bands into a cylindrical shape gradually through a single stand and reduce strain on metal bands caused in roll forming. A detailed description will be provided hereinafter.

[0023] FIG. 1 is given to describe the large-diameter side rolls used in the present invention. The large-diameter side rolls (42, 44) in the present invention (see FIG. 1 (A)) are designed so that the ratio, φ_2/φ_1, of the outside diameter φ_2 of the forming roll relative to the outside diameter φ_1 of the metal tube to be manufactured is considerably large, that is, the outside diameter ratio, φ_2/φ_1, is 10 or more, and preferably 25 or more.

[0024] The large-diameter side rolls (42, 44) designed to have a great outside diameter ratio, φ_2/φ_1, can be regarded as being a forming die used in the die draw forming method. In other words, the present invention can form a metal band (100) into a cylindrical shape not through a multistage stands but through a single stand. However, the present invention does not need grease used in the die draw forming method.

[0025] The method for manufacturing metal tubes according to the present invention is suitable for manufacturing small-diameter metal tubes having an outside diameter less than 20 mm. This is because the method requires large-diameter side rolls having a considerably large outside diameter ratio corresponding to the outside diameter of the metal tube to be manufactured. This means that the required diameter of large-diameter side rolls would be realistic if manufacturing small-diameter metal tubes each having an outside diameter less than 20 mm, but too large diameter of large-diameter side rolls would be required if manufacturing metal tubes each having an outside diameter more than 20 mm, which would be unrealistic and disadvantageous for increase in cost.

[0026] A preferable relationship of the outside diameter ratio, φ_2/φ_1, between the outside diameter φ_1 of the metal tube to be manufactured and the outside diameter φ_2 of the forming rolls will be described here. The use of side rolls having a great outside diameter ratio, φ_2/φ_1, allows a gradual roll forming of metal bands, more specifically, allows roll forming while reducing strain caused in roll forming.

[0027] FIG. 2 shows a relation between the outside diameter ratio, φ_2/φ_1, and equivalent plastic strain caused in the edge parts of the metal band (see FIG. 2). By setting the outside diameter ratio, φ_2/φ_1, at 10 or more, metal bands can be formed into a cylindrical shape while much less strain occurring 0.25-mm inside the edge parts of the metal band being maintained (see FIG. 2). Further, by setting the outside diameter ratio, φ_2/φ_1, at 10 or more, the edge parts of the metal band can be bent while a good cross-sectional shape thereof being maintained, and the edge parts of the metal band can be formed without warpage. Still further, equivalent plastic strain caused in the

lateral parts of the metal band (see FIG. 2) becomes constant at a low level when the outside diameter ratio, φ_2/φ_1, is set at approximately 25.

[0028] Therefore, it is preferable that the outside diameter ratio, φ_2/φ_1, is set at 25 or more. Although there is no particular need to set an upper limit on the outside diameter ratio, the upper limit at approximately 80 would be practical. Such an upper limit is considered on the basis of the saturation of reducing effect of strain caused in the edge parts of metal bands at the outside diameter ratio, φ_2/φ_1, of around 80 as well as on the roll cost.

[0029] It is preferable that the metal band (100) is fed to edge bending rolls before it is formed into a cylindrical shape by the large-diameter side rolls (42, 44) on the single stand. Accordingly, bending can be provided preliminarily to the edge parts of the metal band (100), which enables the subsequent smooth bending of the edge parts by the rolls having large diameter.

[0030] FIG. 3 is given to describe the manufacturing method according to the present invention. FIG. 3 is a schematic view showing the outline of a practical manufacturing line used for manufacturing small-diameter metal tubes according to the present invention.

[0031] The metal band (100) is fed to an edge bending roll stand (30) while the metal band (100) being pressed against by a plate presser (10) with both edges thereof aligned by a guide (20). The metal band (100) has both edges bent by edge bending rolls (32, 34) according to the lateral ends R of the edge bending rolls before the band is formed into a cylindrical shape by large-diameter side rolls (42, 44) on a large-diameter side roll stand (40). Subsequently, a fin roll (80) enhances accuracy of the abutting position of the edge parts of the metal band (100) before the band is fed to a squeeze roll stand (50) for welding the abutting part by a welding machine (120). Through such processes, the metal band (100) is made into a metal tube (70). Reference numeral 60 indicates drawing equipment.

[0032] As shown in FIG. 4, the edge bending roll stand (30) consists of a pair of rolls arranged in a vertical direction, of which: the first edge bending roll (32) has a concave portion with lateral ends R; and the second edge bending roll (34) has a convex portion with lateral ends R.

[0033] The metal band (100) is fed to the edge bending roll stand (30), and both edge parts of the metal band (100) are bent according to the lateral ends R of the edge bending rolls. Furthermore, the metal band (100) is fed to the large-diameter side roll stand (40) (see FIGS. 1 and 5), and is formed into a cylindrical shape.

[0034] After having passed through the edge bending rolls, the metal band (100) is formed into a cylindrical shape under a pressing force provided inwardly from a pair of large-diameter side rolls (42, 44) in a lateral direction (see FIG. 6). A gap is formed between the first and second large-diameter side rolls (42, 44) (see P in FIG. 7). When the metal band (100) receives the pressing force of the large-diameter side rolls (42, 44), the metal band (100) can partly escape into the above gap P, which results in occurrence of defects in a cylindrical shape (see FIG. 7).

[0035] It is preferable that the so-called "supporting member" is placed in the gap P formed between the first and second large-diameter side rolls (42, 44) to prevent the metal band (100) from partly escaping into the gap P.

[0036] FIG. 8 is given to describe the "supporting member" mentioned above. The first and second large-diameter side rolls (42, 44) are cut at either one of both end parts

in an axial direction so that said either one is inclined by approximately 30 degree with respect to a direction from the outermost part to the inner part in a radial direction. More specifically, the first and second large-diameter side rolls (42, 44) on a bottom-surface side of metal band (i.e. in a lower side of FIG. 8) are cut in such a fashion that they are inclined by approximately 30 degree with respect to a direction from the outermost part to the inner part in a radial direction as shown in FIG. 8. A bottom roll (90) is placed between the inclined parts of the large-diameter side rolls (42, 44) (see FIG. 8 (A)) so as to serve as the "supporting member." It is preferable that a three-sided roll system is adopted by placing the bottom roll (90) in the large-diameter side roll stand (40).

[0037] FIGS. 9 and 10 are given to describe the layout of the bottom roll (90). If the bottom roll (90) is arranged in such a fashion that its center line O' coincides with the line O substantially perpendicular to rotation axes of the first and second large-diameter side rolls (42, 44) (hereinafter referred to as "perpendicular line O") (see FIG. 9), there is a probability that defects would occur when the metal band (100) is formed into a cylindrical shape. It is assumedly because the metal band (100) is subjected to excessive strain caused by the constraints of the entire circumference of the band in a circumferential direction thereof, when the perpendicular line O coincides with the center line O' of the bottom roll (90).

[0038] When the perpendicular line O of the large-diameter side rolls (42, 44) coincides with the center line O' of the bottom roll (90), there is a probability that, as mentioned above, before the metal band (100) having been fed to the large-diameter side rolls (42, 44) is supported by the bottom roll (90), the bottom of the metal band (100) slips downward and is folded. Subsequently, the folded bottom of the metal band (100) is supported and lifted by the bottom roll (90) thereby being refolded or folded back. It is assumed, therefore, that excessive strain would occur on the metal band (100), which leads to defects.

[0039] In the present invention, therefore, the bottom roll is offset-positioned on a side (i.e. on an upstream side of the manufacturing line) opposite to a moving direction (i.e. a moving direction X of the manufacturing line) of the metal band (100) with respect to the perpendicular line O of the large-diameter side rolls (42, 44) (see Q in FIG. 10). Accordingly, the entire circumference of the metal band (100) is not restrained as a whole, an escape route is generated, unnecessary deformation due to folding and folding back is diminished, and strain is significantly reduced. Therefore, the formed metal band (100) is drastically improved in shape and quality.

[0040] The edge parts of the metal band (100) cylindrically formed are butted and welded thereby manufacturing a metal tube. As shown in FIG. 3, under the sate where the metal band (100) cylindrically formed is held on the squeeze roll stand (50), its edge parts are butted and welded by the welding machine (120). Laser welding is preferred in view of productivity and workability of welded metal tubes.

[0041] Laser welding is not the only method for welding. Other examples of possible methods are arc welding, such as tungsten inert gas (TIG) welding and plasma welding, high-frequency welding, and the like.

[0042] Not only in laser welding but also in other welding methods, it is preferable that, when the edge parts of the metal band (100) are butted and welded, the abutting position is determined with high accuracy and the abutting part extends in a straight fashion along the moving direction X of the manufacturing line. In order to enhance

the positioning accuracy of the abutting position in the present invention, it is preferable that roll forming is carried out by the large-diameter side roll stand (40) based on a four-sided roll system including a first fin roll (80) on a side of the abutting part in addition to the bottom roll (90) (see FIG. 11).

[0043] Even when roll forming of metal tube is carried out by installing a fin roll (80) on the large-diameter side rolls (42, 44) on a top-surface side of metal band (i.e. immediately above the large-diameter side rolls (42, 44) in FIG. 11) (see FIG. 17), there is a probability that the metal band (100) would twist in a circumferential direction before the band is conveyed to the squeeze roll stand (50) after having been formed at the large-diameter side rolls (42, 44), which results in defects of welding (see e.g. FIG. 12). This is probably due to deviation in a centering position of the metal band (100) when it is fed to the manufacturing line, or deviation of the centers of the large-diameter side rolls and the squeeze roll. However, manual correction of such deviations is difficult and unrealistic due to increase in cost.

[0044] In the present invention, therefore, not only the first fin roll (80) is placed at the large-diameter side rolls (42, 44) on a top-surface side of the metal band, as shown in FIG. 11, but also a second fin roll (82) is placed immediately in front of a position where the band (100) is fed to the squeeze roll stand (50) on a side opposite to a side of the metal band (100) with respect to the squeeze roll (i.e. above the squeeze roll), as shown in FIG. 3.

[0045] In other words, such concurrent use of the two fin rolls (80, 82) ensures that the abutting position of the edge parts is accurately determined at two points along the moving direction X of the manufacturing line, and the abutting part extends in a straight fashion, thereby enabling stable and continuous welding.

[0046] Furthermore, in continuous roll forming of the metal band (100), the metal band receives non-uniform strain to each part in a biased fashion, depending on various factors. Therefore, the edge parts of the metal band (100) are likely to have unstable forms due to level differences in the abutting position of the edge parts. Even if there are no such level differences, there is a probability that the abutting of the edge parts would be poor as shown in FIG. 13, which results in difficulties in subsequent welding.

[0047] The smaller the diameter of the metal tube to be manufactured is, the more remarkable the above-mentioned phenomenon becomes. As shown in FIG. 14, if the diameter of the metal tube to be manufactured is relatively large (see FIG. 14 (A)), the abutting part of the edge parts (110a, 110b) has an I-shape (see FIG. 14 (B)) and can be butted and welded without problem. However, if the diameter of the metal tube to be manufactured is small (see FIG. 15 (A)), the abutting position of the edge parts (110c, 110d) is in a V-shape as shown in FIG. 15 (B), which leads to defective welding.

[0048] In the present invention, therefore, a second fin roll (82) is placed immediately in front of a position where the steel band is fed to the squeeze roll stand (50) on a side opposite to a side of the metal band (100) with respect to the squeeze roll (i.e. above the squeeze roll) (see FIG. 16). The second fin roll (82) has a fin (82a) and a pressing face (88) having a curvature larger in radius than the metal tube to be manufactured. The fin enables an accurate positioning of the abutting part preferable for the subsequent welding by using the second fin roll (82), and the concave face enables correction of the forms of the abutting position of the edge parts by pressing the edge parts of the metal band (100).

[0049] (Examples)

Example 1: A case of manufacturing metal tubes each having an outside diameter of 6.5 mm (φ_1) from raw material of 0.5 mm thick ferritic stainless steel bands each having a composition of 18Cr-1Mo-Ti-low C, N will be described below.

[0050] The manufacturing line is shown in FIG. 3. The edge bending rolls are shown in FIG. 4. The large-diameter side rolls (42, 44) are shown in FIGS. 5 and 7 (φ_2 = 300 mm, outside diameter ratio, φ_2/φ_1, = 46). The bottom roll had an outside diameter of 62 mm, and offset Q of the large-diameter side rolls was 0 mm, 12 mm, 14 mm, 15 mm, 16 mm, 18 mm, and 20 mm on the upstream side of the manufacturing line with respect to the center line. The first fin roll (80) was placed at the large-diameter side rolls (42, 44) on a top-surface side of the metal band (i.e. above the large-diameter side rolls (42, 44)) without placing a second fin roll (82) at a position immediately in front of the squeeze roll stand (50).

[0051] Plate leading of the above raw material was performed at a line velocity of 4 m/min, and the raw material was subjected to fiber laser welding with a power output of approximately 900 W and a beam diameter of 0.6 mm on the squeeze roll to manufacture metal tubes. No grease was used. The result was that, when the offset Q was 0 mm, the obtained metal tubes had outer surface defects, and their roundness was poor. When the offset Q was set at other values, the obtained metal tubes had no outer surface defects at any offset value, and their roundness was good.

[0052]

Example 2: A case of manufacturing metal tubes each having an outside diameter of 3.7 mm (φ_1) from raw material of 0.3 mm thick ferritic stainless steel bands each having a composition of 16.5Cr-Ti-low C, N will be described below.

[0053] The manufacturing line is shown in FIG. 3. The edge bending rolls had a diameter φ of 100 mm. The large-diameter side rolls (42, 44) had an outside diameter φ_2 of 100 mm or 300 mm, with an outside diameter ratio, φ_2/φ_1, of 27 or 81, respectively. The bottom roll had an outside diameter of 62 mm, and its offset Q was 0 mm, 10 mm, 12 mm, 14 mm, 15 mm, 16 mm, 18 mm, and 20 mm on the upstream side in the moving direction of the metal band (100) with respect to the perpendicular line O connecting the large-diameter side rolls (42, 44). The metal tubes were manufactured under the conditions of the line velocity of 4 m/min, fiber laser output of approximately 500 W, and a beam diameter of 0.6 mm. No grease was used.

[0054] The first fin roll (80) was placed above the large-diameter side rolls (42, 44), and a second fin roll (82) was not placed at the position immediately in front of the squeeze roll stand (50). As a result, when the offset Q was 0 mm, the obtained metal tubes had outer surface defects, and their roundness was poor irrespective of whether the outside diameter ratio, φ_2/φ_1, was 27 or 81. When the offset Q was set at any other values, the obtained metal tubes had no outer surface defects, and their roundness was good at any offset value.

[0055]

Example 3: A case of manufacturing metal tubes each having an outside diameter of 6.5 mm (φ_1) from raw material of 0.3 mm thick ferritic stainless steel bands each having a composition of 16.5Cr-Ti-low C, N will be described below.

[0056] The manufacturing line, the edge bending rolls, the large-diameter side rolls (42, 44), and the bottom roll were the same as those used in example 1. In other words, the outside diameter ratio, φ_2/φ_1, was 46.

[0057] In example 3, the offset Q of the bottom roll was 0 mm, 5 mm, 7 mm, 10 mm,

12 mm, 15 mm, 18 mm, and 20 mm on the upstream side in the moving direction of the metal band (100) with respect to the perpendicular line O connecting the large-diameter side rolls (42, 44). In all the cases, the first fin roll (80) was placed above the large-diameter side rolls (42, 44), and a second fin roll (82) was placed at a position immediately in front of the squeeze roll stand (50) on a side opposite to a side of the metal band (100) (i.e. above the squeeze roll) with respect to the squeeze roll. Two types of the second fin roll (82) having a pressing face with a curvature radius of 5 or 10 mm placed at the upper side position immediately in front of the squeeze roll stand (50) were used. Thus, 16 types of metal tubes were manufactured. No grease was used.

[0058] Plate leading of the steel band made from the above raw material was performed at the line velocity of 10 m/min, and the steel band was subjected to fiber laser welding with a power output at approximately 1500 W and a beam diameter of 0.6 mm.

[0059] When the offset Q was 0 mm, the obtained metal tubes had outer surface defects, and their roundness was poor under the respective manufacturing conditions mentioned above. When the offset Q was set at any other values, the obtained metal tubes had no outer surface defects, and their roundness was good at any offset value.

[0060]

Example 4: Metal tubes each having an outside diameter of 6.5 mm (φ_1) were manufactured from the raw material of 0.5 mm thick ferritic stainless steel bands each having a composition of 16.5Cr-Ti-low C, N plated on both surfaces thereof with aluminum.

[0061] The manufacturing line, the edge bending rolls, the large-diameter side rolls, and the bottom roll were the same as those used in example 1. In other words, the outside diameter ratio, φ_2/φ_1, was 46.

[0062] In example 4, the offset Q of the bottom roll was set to 3 mm, 5 mm, 7 mm, 10 mm, and 15 mm on the upstream side of the metal band (100) with respect to the perpendicular line O connecting the large-diameter side rolls (42, 44). The fin roll was placed only above the large-diameter side rolls (42, 44), and no fin roll was placed at a position immediately in front of and above the squeeze roll stand (50).

[0063] Plate leading of the above-mentioned raw material was performed at the line velocity of 2 m/min, and the raw material was subjected to fiber laser welding with a power output of approximately 580 W and a beam diameter of 0.6 mm on the squeeze roll.

[0064] The result was that metal tubes with good roundness and no outer surface defects could be manufactured from the raw material of stainless steel bands with aluminum plating as mentioned above at any offset value.

[0065] (Reference Numerals)

10 plate presser
20 guide
30 edge bending roll stand
32 first edge bending roll
34 second edge bending roll
40 large-diameter side roll stand
42 first large-diameter side roll
42a groove part of first large-diameter side roll

44	second large-diameter side roll
44a	groove part of second large-diameter side roll
50	squeeze roll stand
60	drawing equipment
70	metal tube
70a	large-diameter metal tube
70b	small-diameter metal tube
80	first fin roll
82	second fin roll
82a	fin
88	pressing face
90	bottom roll
100	metal band
110a	edge part
110b	edge part
110c	edge part
110d	edge part
120	welding machine
O	perpendicular line
O'	center line of bottom roll
P	gap between two large-diameter side rolls
Q	offset
X	moving direction of manufacturing line

WHAT IS CLAIMED IS:

1. A method for manufacturing metal tubes comprising:

feeding a metal band to a large-diameter side roll so that the metal band is formed into a cylindrical shape, the large-diameter side roll having an outside diameter ratio, φ_2/φ_1, of 10 or more between an outside diameter φ_1 of the metal tube to be manufactured and an outside diameter φ_2 of the large-diameter side roll including at least a first large-diameter side roll and a second large-diameter side roll; and

thereafter, welding edge parts of the metal band.

2. The method for manufacturing metal tubes according to claim 1, wherein the large-diameter side roll having an outside diameter ratio, φ_2/φ_1, of 25 or more is used.

3. The method for manufacturing metal tubes according to claim 1 or 2 further comprising

bending edge parts of the metal band in advance by an edge bending roll before feeding the metal band to the large-diameter side roll.

4. The method for manufacturing metal tubes according to claim 1, wherein the first and second large-diameter side rolls and a bottom roll are arranged on the basis of a three-sided roll system.

5. The method for manufacturing metal tubes according to claim 4, wherein the bottom roll is offset-positioned directly below an underside of the metal band at the first and second large-diameter side rolls as well as on a side opposite to a feeding-direction side of the metal band with respect to a line connecting between a rotation axis of the first large-diameter side roll and a rotation axis of the second large-diameter side roll.

6. The method for manufacturing metal tubes according to claim 1, 4, or 5, wherein at least one fin roll is placed on a top-surface side of the metal band at the first and second large-diameter side rolls.

7. The method for manufacturing metal tubes according to claim 1, 4, or 5, wherein at least one fin roll is placed on a side opposite to a side of the metal band with respect to a squeeze roll for welding the edge parts of the metal band after the metal band is formed into a cylindrical shape.

8. The method for manufacturing metal tubes according to claim 7, wherein the fin roll placed on a side opposite to the side of the metal band with respect to the squeeze roll includes a fin and a pressing face having a curvature radius larger than a radius of the metal tube to be manufactured, the pressing face configured to correct forms of the edge parts by pressing the edge parts of the metal band.

9. A device for manufacturing metal tubes comprising:

a large-diameter side roll having an outside diameter ratio, φ_2/φ_1, of 10 or more between an outside diameter φ_1 of a metal tube to be manufactured and an

outside diameter φ_2 of the large-diameter side roll, the large-diameter side roll including at least a first large-diameter side roll and a second large-diameter side roll; and

a squeeze roll and a welding machine are placed on a downstream side of the large-diameter side roll.

10. The device for manufacturing metal tubes according to claim 9, wherein the large-diameter side roll having an outside diameter ratio, φ_2/φ_1, of 25 or more is used.

11. The device for manufacturing metal tubes according to claim 9 or 10 further comprising

an edge bending roll arranged so as to bend edges of a metal band before the metal band is fed to the large-diameter side roll.

12. The device for manufacturing metal tubes according to claim 9, wherein the first and second large-diameter side rolls and a bottom roll are arranged on the basis of a three-sided roll system.

13. The device for manufacturing metal tubes according to claim 12, wherein the bottom roll is offset-positioned on a side opposite to a feeding direction side of a metal band fed to the large-diameter side roll with respect to a line connecting between a rotation axis of the first large-diameter side roll and a rotation axis of the second large-diameter side rolls.

14. The device for manufacturing metal tubes according to claim 9, 12, or 13, wherein at least one fin roll is placed on a top-surface side of a metal band at the first and second large-diameter side rolls.

15. The device for manufacturing metal tubes according to claim 9, 12, or 13, wherein at least one fin roll is placed on a side opposite to a side of a metal band fed to the large-diameter side roll with respect to a squeeze roll for welding the edge parts of the metal band after the metal band is formed into a cylindrical shape.

16. The device for manufacturing metal tubes according to claim 15, wherein the fin roll placed on a side opposite to the side of the metal band with respect to the squeeze roll includes a fin and a pressing face having a curvature radius larger than a radius of the metal tube to be manufactured, the pressing face configured to correct forms of the edge parts by pressing the edge parts of the metal band.

tubes. In such a case, the surface defects must be treated with surface polishing after manufacturing the metal tubes. In other words, the die draw forming method results in lower productivity and higher production cost.

[0009] Not only in the roll forming method but also in the die draw forming method, laser welding have been adopted as a method to butt and weld the edge parts of the metal bands cylindrically formed. Laser welding is preferred in view of productivity and workability of welded metal tubes.

[0010] (Prior Art Documents)

(Patent Documents)

Patent Document 1: Japanese Patent Application Publication No. H6-134525

Patent Document 2: Japanese Patent Application Publication No. H8-267150

[0011] (Problems to be Solved)

As mentioned above, a problem of the roll forming method has been not only that increased workload due to roll exchange and dimension adjustment are required but also that tiny adjustment errors made in the roll forming stands when manufacturing small-diameter metal tubes, in particular, are likely to cause problems such as meandering and twisting of the metal bands during butting of the edge parts of the metal bands.

[0012] Furthermore, another problem of the die draw forming method has been that a large amount of grease is used to reduce friction between the metal band and the forming die, and therefore degreasing of the metal band is required after it is formed into a cylindrical shape for laser welding.

SUMMARY OF THE INVENTION

[0013] The present invention is proposed for solving the above problems. Specifically, the object of the present invention is to provide a method and device for manufacturing small-diameter metal tubes in which only one stage of a roll clearly larger in outside diameter than a metal tube to be manufactured, i.e., a single stand of a roll having large diameter is used, and in which a metal band is formed into a cylindrical shape with high accuracy without greasing, and thereafter, the edge parts of the metal band are butted and welded each other.

[0014] (Means for Solving Problems)

In order to achieve the above object, the method for manufacturing small-diameter metal tubes by using a roll stand according to the present invention is characterized by comprising: feeding a metal band to the roll stand so that the metal band is formed into a cylindrical shape, the roll stand having a pair of large-diameter side rolls and a bottom roll arranged in a three-sided roll system, the pair of large-diameter side rolls each having an outside diameter ratio, φ_2/φ_1, of 10 or more defined as an outside diameter φ_2 thereof relative to an outside diameter φ_1 of the metal tube to be manufactured, the pair of large-diameter side rolls including at least a first large-diameter side roll and a second large-diameter side roll arranged so as to face the first large-diameter side roll, the bottom roll being offset-positioned on an entrance side with respect to a line connecting between a rotation axis of the first large-diameter side roll and a rotation axis of the second large-diameter side roll; and thereafter, welding edge parts of the metal band.

[0015] It is preferable that the outside diameter ratio, φ_2/φ_1, is 25 or more. As will

be described later, for improvement of the forms of the abutting edge parts in welding, it is also preferable that the metal band is fed to an edge bending roll to bend its edge parts in advance before the metal band is fed to the large-diameter side roll.

[0016] It is preferable that the stand for roll having large diameter used in the present invention has two large-diameter side rolls and one bottom roll arranged therein on the basis of a three-sided roll system (see FIG. 8 (A)). As will be described later, FIG. 8 (A) is a cross-sectional view showing the structure of such a three-sided roll system having a bottom roll placed therein. A pair of large-diameter side rolls are arranged side by side in such a fashion that their rotation axes are parallel to each other and that their outer peripheries face each other. Then, the bottom roll is arranged in such a fashion that its outer periphery is positioned in the vicinity of a facing portion at which the outer peripheries of the two large-diameter side rolls face each other. In the above facing portion, the edge parts of the metal band are butted each other during the process of forming a metal tube. The rotation axis of the bottom roll is substantially perpendicular to those of the two large-diameter side rolls. It is preferable that the bottom roll is offset-positioned on the upstream side in the moving direction of the metal band (that is, on the entrance side of the manufacturing line) with respect to a line connecting between the rotation axes of a pair of large-diameter side rolls (see FIG. 10). As will be described later, FIG. 10 is a top view showing a more preferable installation position of the bottom roll used in the large-diameter side roll based on the three-sided roll system according to the present invention. The offset-layout of the bottom roll on the upstream side in the moving direction of the metal band allows further reduction of strain caused in the process of forming metal tubes.

[0017] The three-sided roll system may be changed into a four-sided roll system by adding a fin roll (see FIG. 11). The fin roll is placed in the above facing portion in such a fashion that its outer periphery faces the outer periphery of the bottom roll, and that its rotation axis is parallel to the rotation axis of the bottom roll. The layout of the fin roll allows a position at which the edge parts of the metal band are butted each other to be maintained with high accuracy.

[0018] Furthermore, a fin roll may be placed above the squeeze roll immediately before the edge parts of the metal band are welded at the position of the squeeze roll. The fin roll can prohibit an abutting position of the edge parts of the metal band from twisting at the position of the fin roll (see FIG. 13). It is preferable that the fin roll used here has a fin and a concave face having a curvature larger in radius than the metal tube to be manufactured, because the fin enables accurate positioning of the abutting part preferable for subsequent welding, and the concave face enables correction of the forms of the abutting edge parts of the metal band by pressing the edge parts, which results in the obtainment of small-diameter metal tubes with excellent forming accuracy.

[0019] (Advantageous Effects of the Invention)

According to the present invention, by using large-diameter side rolls whose outside diameter is clearly larger than an outside diameter of a metal tube to be manufactured, metal bands can be formed into a cylindrical shape through a single stand, and small-diameter metal tubes each having excellent surface property can be manufactured in a highly efficient fashion. Further, by forming metal bands into a cylindrical shape through a single stand, the total number of stands required for manufacturing metal tubes can be drastically reduced, and the workload required for

roll exchange and dimension adjustment by workers can be reduced as well. Still further, by appropriate use of fin rolls, small-diameter metal tubes can be stably manufactured.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] For more thorough understanding of the present invention and advantages thereof, the following descriptions should be read in conjunction with the accompanying drawings, in which:

FIG. 1 is a perspective view (A) showing the outline structure of large-diameter side roll and the spatial relationship between the large-diameter side roll and a welding machine configured to weld abutting part of edges, which are used in the present invention, and is also an enlarged view (B) showing groove part of the large-diameter side roll.

FIG. 2 is a view showing a relation between outside diameter ratio, φ_2/φ_1, and equivalent plastic strain caused in the edge parts of a metal band.

FIG. 3 is a schematic view of a manufacturing line used for manufacturing small-diameter metal tubes according to the present invention.

FIG. 4 is a cross-sectional view showing the outline structure of edge bending roll.

FIG. 5 is a cross-sectional view showing the outline structure of large-diameter side roll.

FIG. 6 is a view showing the state where the edge parts of a metal band is bent by using two large-diameter side rolls.

FIG. 7 is a view showing the state where a problem stems from a part of a metal band under transformation between two large-diameter side rolls.

FIG. 8 is a cross-sectional view (A) showing the structure of a large-diameter side roll based on three-sided roll system having a bottom roll placed therein, and is also an enlarged view (B) showing the spatial relationship between the two large-diameter side rolls and the bottom roll.

FIG. 9 is a top view showing an installation position of the bottom roll used in the large-diameter side roll based on three-sided roll system according to the present invention.

FIG. 10 is a top view showing a more preferable installation position of the bottom roll used in the large-diameter side roll based on three-sided roll system according to the present invention.

FIG. 11 is a cross-sectional view showing the structure of the large-diameter side roll based on four-sided roll system obtained by arranging a first fin roll in the three-sided roll system according to the present invention.

FIG. 12 is an explanatory view showing the state of a metal band when one stage of fin roll is placed.

FIG. 13 is an explanatory view showing the state of a metal band when two stages of fin rolls are placed.

FIG. 14 is an explanatory view showing the form of the edge parts in the abutting part of a large-diameter metal tube.

FIG. 15 is an explanatory view showing the form of the edge parts in the abutting part of a small-diameter metal tube.

FIG. 16 is a view showing a preferable form of a second fin roll placed immediately in front of the squeeze roll.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0021] In general, under the roll forming method, metal tubes are formed gradually by means of multistage forming through 10 or more roll forming stands arranged in a tandem fashion. Therefore, in order to alter the diameter of the metal tube to be manufactured, all the rolls placed in the forming stands are required to be replaced with rolls corresponding to the altered outside diameter of the metal tube to be manufactured. Furthermore, a considerable amount of labor and time required for roll exchange leads to lower productivity.

[0022] Therefore, the present invention provides a means to form metal bands into a cylindrical shape gradually through a single stand and reduce strain on metal bands caused in roll forming. A detailed description will be provided hereinafter.

[0023] FIG. 1 is given to describe the large-diameter side rolls used in the present invention. The large-diameter side rolls (42, 44) in the present invention (see FIG. 1 (A)) are designed so that the ratio, φ_2/φ_1, of the outside diameter φ_2 of the forming roll relative to the outside diameter φ_1 of the metal tube to be manufactured is considerably large, that is, the outside diameter ratio, φ_2/φ_1, is 10 or more, and preferably 25 or more.

[0024] The large-diameter side rolls (42, 44) designed to have a great outside diameter ratio, φ_2/φ_1, can be regarded as being a forming die used in the die draw forming method. In other words, the present invention can form a metal band (100) into a cylindrical shape not through a multistage stands but through a single stand. However, the present invention does not need grease used in the die draw forming method.

[0025] The method for manufacturing metal tubes according to the present invention is suitable for manufacturing small-diameter metal tubes having an outside diameter less than 20 mm. This is because the method requires large-diameter side rolls having a considerably large outside diameter ratio corresponding to the outside diameter of the metal tube to be manufactured. This means that the required diameter of large-diameter side rolls would be realistic if manufacturing small-diameter metal tubes each having an outside diameter less than 20 mm, but too large diameter of large-diameter side rolls would be required if manufacturing metal tubes each having an outside diameter more than 20 mm, which would be unrealistic and disadvantageous for increase in cost.

[0026] A preferable relationship of the outside diameter ratio, φ_2/φ_1, between the outside diameter φ_1 of the metal tube to be manufactured and the outside diameter φ_2 of the forming rolls will be described here. The use of side rolls having a great outside diameter ratio, φ_2/φ_1, allows a gradual roll forming of metal bands, more specifically, allows roll forming while reducing strain caused in roll forming.

[0027] FIG. 2 shows a relation between the outside diameter ratio, φ_2/φ_1, and equivalent plastic strain caused in the edge parts of the metal band (see FIG. 2). By setting the outside diameter ratio, φ_2/φ_1, at 10 or more, metal bands can be formed into a cylindrical shape while much less strain occurring 0.25-mm inside the edge parts of the metal band being maintained (see FIG. 2). Further, by setting the outside diameter

ratio, φ_2/φ_1, at 10 or more, the edge parts of the metal band can be bent while a good cross-sectional shape thereof being maintained, and the edge parts of the metal band can be formed without warpage. Still further, equivalent plastic strain caused in the lateral parts of the metal band (see FIG. 2) becomes constant at a low level when the outside diameter ratio, φ_2/φ_1, is set at approximately 25.

[0028] Therefore, it is preferable that the outside diameter ratio, φ_2/φ_1, is set at 25 or more. Although there is no particular need to set an upper limit on the outside diameter ratio, the upper limit at approximately 80 would be practical. Such an upper limit is considered on the basis of the saturation of reducing effect of strain caused in the edge parts of metal bands at the outside diameter ratio, φ_2/φ_1, of around 80 as well as on the roll cost.

[0029] It is preferable that the metal band (100) is fed to edge bending rolls before it is formed into a cylindrical shape by the large-diameter side rolls (42, 44) on the single stand. Accordingly, bending can be provided preliminarily to the edge parts of the metal band (100), which enables the subsequent smooth bending of the edge parts by the rolls having large diameter.

[0030] FIG. 3 is given to describe the manufacturing method according to the present invention. FIG. 3 is a schematic view showing the outline of a practical manufacturing line used for manufacturing small-diameter metal tubes according to the present invention.

[0031] The metal band (100) is fed to an edge bending roll stand (30) while the metal band (100) being pressed against by a plate presser (10) with both edges thereof aligned by a guide (20). The metal band (100) has both edges bent by edge bending rolls (32, 34) according to the lateral ends R of the edge bending rolls before the band is formed into a cylindrical shape by large-diameter side rolls (42, 44) on a large-diameter side roll stand (40). Subsequently, a fin roll (80) enhances accuracy of the abutting position of the edge parts of the metal band (100) before the band is fed to a squeeze roll stand (50) for welding the abutting part by a welding machine (120). Through such processes, the metal band (100) is made into a metal tube (70). Reference numeral 60 indicates drawing equipment.

[0032] As shown in FIG. 4, the edge bending roll stand (30) consists of a pair of rolls arranged in a vertical direction, of which: the first edge bending roll (32) has a concave portion with lateral ends R; and the second edge bending roll (34) has a convex portion with lateral ends R.

[0033] The metal band (100) is fed to the edge bending roll stand (30), and both edge parts of the metal band (100) are bent according to the lateral ends R of the edge bending rolls. Furthermore, the metal band (100) is fed to the large-diameter side roll stand (40) (see FIGS. 1 and 5), and is formed into a cylindrical shape.

[0034] After having passed through the edge bending rolls, the metal band (100) is formed into a cylindrical shape under a pressing force provided inwardly from a pair of large-diameter side rolls (42, 44) in a lateral direction (see FIG. 6). A gap is formed between the first and second large-diameter side rolls (42, 44) (see P in FIG. 7). When the metal band (100) receives the pressing force of the large-diameter side rolls (42, 44), the metal band (100) can partly escape into the above gap P, which results in occurrence of defects in a cylindrical shape (see FIG. 7).

[0035] It is preferable that the so-called "supporting member" is placed in the gap P formed between the first and second large-diameter side rolls (42, 44) to prevent the

metal band (100) from partly escaping into the gap P.

[0036] FIG. 8 is given to describe the "supporting member" mentioned above. The first and second large-diameter side rolls (42, 44) are cut at either one of both end parts in an axial direction so that said either one is inclined by approximately 30 degree with respect to a direction from the outermost part to the inner part in a radial direction. More specifically, the first and second large-diameter side rolls (42, 44) on a bottom-surface side of metal band (i.e. in a lower side of FIG. 8) are cut in such a fashion that they are inclined by approximately 30 degree with respect to a direction from the outermost part to the inner part in a radial direction as shown in FIG. 8. A bottom roll (90) is placed between the inclined parts of the large-diameter side rolls (42, 44) (see FIG. 8 (A)) so as to serve as the "supporting member." It is preferable that a three-sided roll system is adopted by placing the bottom roll (90) in the large-diameter side roll stand (40).

[0037] FIGS. 9 and 10 are given to describe the layout of the bottom roll (90). If the bottom roll (90) is arranged in such a fashion that its center line O' coincides with the line O substantially perpendicular to rotation axes of the first and second large-diameter side rolls (42, 44) (hereinafter referred to as "perpendicular line O") (see FIG. 9), there is a probability that defects would occur when the metal band (100) is formed into a cylindrical shape. It is assumedly because the metal band (100) is subjected to excessive strain caused by the constraints of the entire circumference of the band in a circumferential direction thereof, when the perpendicular line O coincides with the center line O' of the bottom roll (90).

[0038] When the perpendicular line O of the large-diameter side rolls (42, 44) coincides with the center line O' of the bottom roll (90), there is a probability that, as mentioned above, before the metal band (100) having been fed to the large-diameter side rolls (42, 44) is supported by the bottom roll (90), the bottom of the metal band (100) slips downward and is folded. Subsequently, the folded bottom of the metal band (100) is supported and lifted by the bottom roll (90) thereby being refolded or folded back. It is assumed, therefore, that excessive strain would occur on the metal band (100), which leads to defects.

[0039] In the present invention, therefore, the bottom roll is offset-positioned on a side (i.e. on an upstream side of the manufacturing line) opposite to a moving direction (i.e. a moving direction X of the manufacturing line) of the metal band (100) with respect to the perpendicular line O of the large-diameter side rolls (42, 44) (see Q in FIG. 10). Accordingly, the entire circumference of the metal band (100) is not restrained as a whole, an escape route is generated, unnecessary deformation due to folding and folding back is diminished, and strain is significantly reduced. Therefore, the formed metal band (100) is drastically improved in shape and quality.

[0040] The edge parts of the metal band (100) cylindrically formed are butted and welded thereby manufacturing a metal tube. As shown in FIG. 3, under the sate where the metal band (100) cylindrically formed is held on the squeeze roll stand (50), its edge parts are butted and welded by the welding machine (120). Laser welding is preferred in view of productivity and workability of welded metal tubes.

[0041] Laser welding is not the only method for welding. Other examples of possible methods are arc welding, such as tungsten inert gas (TIG) welding and plasma welding, high-frequency welding, and the like.

[0042] Not only in laser welding but also in other welding methods, it is preferable

that, when the edge parts of the metal band (100) are butted and welded, the abutting position is determined with high accuracy and the abutting part extends in a straight fashion along the moving direction X of the manufacturing line. In order to enhance the positioning accuracy of the abutting position in the present invention, it is preferable that roll forming is carried out by the large-diameter side roll stand (40) based on a four-sided roll system including a first fin roll (80) on a side of the abutting part in addition to the bottom roll (90) (see FIG. 11).

[0043] Even when roll forming of metal tube is carried out by installing a fin roll (80) on the large-diameter side rolls (42, 44) on a top-surface side of metal band (i.e. immediately above the large-diameter side rolls (42, 44) in FIG. 11) (see FIG. 11), there is a probability that the metal band (100) would twist in a circumferential direction before the band is conveyed to the squeeze roll stand (50) after having been formed at the large-diameter side rolls (42, 44), which results in defects of welding (see e.g. FIG. 12). This is probably due to deviation in a centering position of the metal band (100) when it is fed to the manufacturing line, or deviation of the centers of the large-diameter side rolls and the squeeze roll. However, manual correction of such deviations is difficult and unrealistic due to increase in cost.

[0044] In the present invention, therefore, not only the first fin roll (80) is placed at the large-diameter side rolls (42, 44) on a top-surface side of the metal band, as shown in FIG. 11, but also a second fin roll (82) is placed immediately in front of a position where the band (100) is fed to the squeeze roll stand (50) on a side opposite to a side of the metal band (100) with respect to the squeeze roll (i.e. above the squeeze roll), as shown in FIG. 3.

[0045] In other words, such concurrent use of the two fin rolls (80, 82) ensures that the abutting position of the edge parts is accurately determined at two points along the moving direction X of the manufacturing line, and the abutting part extends in a straight fashion, thereby enabling stable and continuous welding.

[0046] Furthermore, in continuous roll forming of the metal band (100), the metal band receives non-uniform strain to each part in a biased fashion, depending on various factors. Therefore, the edge parts of the metal band (100) are likely to have unstable forms due to level differences in the abutting position of the edge parts. Even if there are no such level differences, there is a probability that the abutting of the edge parts would be poor as shown in FIG. 15, which results in difficulties in subsequent welding.

[0047] The smaller the diameter of the metal tube to be manufactured is, the more remarkable the above-mentioned phenomenon becomes. As shown in FIG. 14, if the diameter of the metal tube to be manufactured is relatively large (see FIG. 14 (A)), the abutting part of the edge parts (110a, 110b) has an I-shape (see FIG. 14 (B)) and can be butted and welded without problem. However, if the diameter of the metal tube to be manufactured is small (see FIG. 15 (A)), the abutting position of the edge parts (110c, 110d) is in a V-shape as shown in FIG. 15 (B), which leads to defective welding.

[0048] In the present invention, therefore, a second fin roll (82) is placed immediately in front of a position where the steel band is fed to the squeeze roll stand (50) on a side opposite to a side of the metal band (100) with respect to the squeeze roll (i.e. above the squeeze roll) (see FIG. 16). The second fin roll (82) has a fin (82a) and a pressing face (88) having a curvature larger in radius than the metal tube to be manufactured. The fin enables an accurate positioning of the abutting part preferable for the subsequent welding by using the second fin roll (82), and the concave face enables

correction of the forms of the abutting position of the edge parts by pressing the edge parts of the metal band (100).

[0049] (Examples)

Example 1: A case of manufacturing metal tubes each having an outside diameter of 6.5 mm (φ_1) from raw material of 0.5 mm thick ferritic stainless steel bands each having a composition of 18Cr-1Mo-Ti-low C, N will be described below.

[0050] The manufacturing line is shown in FIG. 3. The edge bending rolls are shown in FIG. 4. The large-diameter side rolls (42, 44) are shown in FIGS. 5 and 7 (φ_2 = 300 mm, outside diameter ratio, φ_2/φ_1, = 46). The bottom roll had an outside diameter of 62 mm, and offset Q of the large-diameter side rolls was 0 mm, 12 mm, 14 mm, 15 mm, 16 mm, 18 mm, and 20 mm on the upstream side of the manufacturing line with respect to the center line. The first fin roll (80) was placed at the large-diameter side rolls (42, 44) on a top-surface side of the metal band (i.e. above the large-diameter side rolls (42, 44)) without placing a second fin roll (82) at a position immediately in front of the squeeze roll stand (50).

[0051] Plate leading of the above raw material was performed at a line velocity of 4 m/min, and the raw material was subjected to fiber laser welding with a power output of approximately 900 W and a beam diameter of 0.6 mm on the squeeze roll to manufacture metal tubes. No grease was used. The result was that, when the offset Q was 0 mm, the obtained metal tubes had outer surface defects, and their roundness was poor. When the offset Q was set at other values, the obtained metal tubes had no outer surface defects at any offset value, and their roundness was good.

[0052]

Example 2: A case of manufacturing metal tubes each having an outside diameter of 3.7 mm (φ_1) from raw material of 0.3 mm thick ferritic stainless steel bands each having a composition of 16.5Cr-Ti-low C, N will be described below.

[0053] The manufacturing line is shown in FIG. 3. The edge bending rolls had a diameter φ of 100 mm. The large-diameter side rolls (42, 44) had an outside diameter φ_2 of 100 mm or 300 mm, with an outside diameter ratio, φ_2/φ_1, of 27 or 81, respectively. The bottom roll had an outside diameter of 62 mm, and its offset Q was 0 mm, 10 mm, 12 mm, 14 mm, 15 mm, 16 mm, 18 mm, and 20 mm on the upstream side in the moving direction of the metal band (100) with respect to the perpendicular line O connecting the large-diameter side rolls (42, 44). The metal tubes were manufactured under the conditions of the line velocity of 4 m/min, fiber laser output of approximately 500 W, and a beam diameter of 0.6 mm. No grease was used.

[0054] The first fin roll (80) was placed above the large-diameter side rolls (42, 44), and a second fin roll (82) was not placed at the position immediately in front of the squeeze roll stand (50). As a result, when the offset Q was 0 mm, the obtained metal tubes had outer surface defects, and their roundness was poor irrespective of whether the outside diameter ratio, φ_2/φ_1, was 27 or 81. When the offset Q was set at any other values, the obtained metal tubes had no outer surface defects, and their roundness was good at any offset value.

[0055]

Example 3: A case of manufacturing metal tubes each having an outside diameter of 6.5 mm (φ_1) from raw material of 0.3 mm thick ferritic stainless steel bands each having a composition of 16.5Cr-Ti-low C, N will be described below.

[0056] The manufacturing line, the edge bending rolls, the large-diameter side rolls

(42, 44), and the bottom roll were the same as those used in example 1. In other words, the outside diameter ratio, φ_2/φ_1, was 46.

[0057] In example 3, the offset Q of the bottom roll was 0 mm, 5 mm, 7 mm, 10 mm, 12 mm, 15 mm, 18 mm, and 20 mm on the upstream side in the moving direction of the metal band (100) with respect to the perpendicular line O connecting the large-diameter side rolls (42, 44). In all the cases, the first fin roll (80) was placed above the large-diameter side rolls (42, 44), and a second fin roll (82) was placed at a position immediately in front of the squeeze roll stand (50) on a side opposite to a side of the metal band (100) (i.e. above the squeeze roll) with respect to the squeeze roll. Two types of the second fin roll (82) having a pressing face with a curvature radius of 5 or 10 mm placed at the upper side position immediately in front of the squeeze roll stand (50) were used. Thus, 16 types of metal tubes were manufactured. No grease was used.

[0058] Plate leading of the steel band made from the above raw material was performed at the line velocity of 10 m/min, and the steel band was subjected to fiber laser welding with a power output at approximately 1500 W and a beam diameter of 0.6 mm.

[0059] When the offset Q was 0 mm, the obtained metal tubes had outer surface defects, and their roundness was poor under the respective manufacturing conditions mentioned above. When the offset Q was set at any other values, the obtained metal tubes had no outer surface defects, and their roundness was good at any offset value.

[0060]

Example 4: Metal tubes each having an outside diameter of 6.5 mm (φ_1) were manufactured from the raw material of 0.5 mm thick ferritic stainless steel bands each having a composition of 16.5Cr-Ti-low C, N plated on both surfaces thereof with aluminum.

[0061] The manufacturing line, the edge bending rolls, the large-diameter side rolls, and the bottom roll were the same as those used in example 1. In other words, the outside diameter ratio, φ_2/φ_1, was 46.

[0062] In example 4, the offset Q of the bottom roll was set to 3 mm, 5 mm, 7 mm, 10 mm, and 15 mm on the upstream side of the metal band (100) with respect to the perpendicular line O connecting the large-diameter side rolls (42, 44). The fin roll was placed only above the large-diameter side rolls (42, 44), and no fin roll was placed at a position immediately in front of and above the squeeze roll stand (50).

[0063] Plate leading of the above-mentioned raw material was performed at the line velocity of 2 m/min, and the raw material was subjected to fiber laser welding with a power output of approximately 580 W and a beam diameter of 0.6 mm on the squeeze roll.

[0064] The result was that metal tubes with good roundness and no outer surface defects could be manufactured from the raw material of stainless steel bands with aluminum plating as mentioned above at any offset value.

[0065] (Reference Numerals)

10 plate presser
20 guide
30 edge bending roll stand
32 first edge bending roll
34 second edge bending roll

40	large-diameter side roll stand
42	first large-diameter side roll
42a	groove part of first large-diameter side roll
44	second large-diameter side roll
44a	groove part of second large-diameter side roll
50	squeeze roll stand
60	drawing equipment
70	metal tube
70a	large-diameter metal tube
70b	small-diameter metal tube
80	first fin roll
82	second fin roll
82a	fin
88	pressing face
90	bottom roll
100	metal band
110a	edge part
110b	edge part
110c	edge part
110d	edge part
120	welding machine
O	perpendicular line
O'	center line of bottom roll
P	gap between two large-diameter side rolls
Q	offset
X	moving direction of manufacturing line

WHAT IS CLAIMED IS:

1. A method for manufacturing metal tubes by using a roll stand comprising:

feeding a metal band to the roll stand so that the metal band is formed into a cylindrical shape, the roll stand having a pair of large-diameter side rolls and a bottom roll arranged in a three-sided roll system, the pair of large-diameter side rolls each having an outside diameter ratio, φ_2/φ_1, of 10 or more defined as an outside diameter φ_2 thereof relative to an outside diameter φ_1 of the metal tube to be manufactured, the pair of large-diameter side rolls including at least a first large-diameter side roll and a second large-diameter side roll arranged so as to face the first large-diameter side roll, the bottom roll being offset-positioned on an entrance side with respect to a line connecting between a rotation axis of the first large-diameter side roll and a rotation axis of the second large-diameter side roll; and

thereafter, welding edge parts of the metal band.

2. A device for manufacturing metal tubes by using a roll stand comprising:

a pair of large-diameter side rolls each having an outside diameter ratio, φ_2/φ_1, of 10 or more defined as an outside diameter φ_2 thereof relative to an outside diameter φ_1 of a metal tube to be manufactured, the pair of large-diameter side rolls including at least a first large-diameter side roll and a second large-diameter side roll arranged so as to face the first large-diameter side roll, the roll stand having the pair of large-diameter side rolls and a bottom roll arranged in a three-sided roll system, the bottom roll being offset-positioned on an entrance side with respect to a line connecting between a rotation axis of the first large-diameter side roll and a rotation axis of the second large-diameter side roll; and

a squeeze roll and a welding machine placed on a downstream side of the large-diameter side roll.