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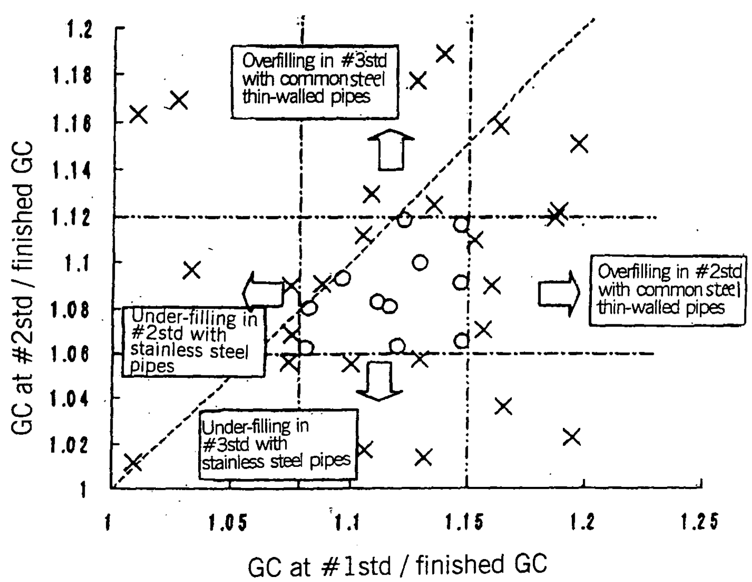
(54) **DRAWING ROLLING METHOD BY MANDREL MILL**

(57) An elongation rolling method of a mother tube from a hollow shell using a mandrel mill can prevent overfilling and under-filling using a single combination of grooved roll. The outer diameter of the hollow shell is set such that the ratio of outer circumference of the hollow shell to outer circumference of the mother tube on the exit side of the finishing stand is at least 1.1 when the mother tube contains at least 10% Cr or the ratio is less than 1.1 when the mother tube contains less than 10% Cr. The groove profile of grooved rolls provided in a first stand and a second stand of the mandrel mill is set such that the groove circumference determined by a plurality of grooved rolls provided in the first stand satisfies Equation 1, the groove circumference determined by a plurality of grooved rolls provided in the second stand satisfies Equation 2, and the groove circumferences in the first stand and the second stand satisfy Equation 3. Under these conditions, elongation rolling of a mother tube is carried out using a mandrel mill.

Fig. 4



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Description

Technical Field

[0001] This invention relates to an elongation rolling method using a mandrel mill. Specifically, the present invention relates to an elongation rolling method using a mandrel mill in which the occurrence of so-called overfilling and underfilling can be effectively prevented during elongation rolling using a mandrel mill.

Background Art

[0002] In the manufacture of seamless tube (including seamless pipe) by the Mannesmann mandrel mill method, a round billet or a square billet is charged into a rotary hearth heating furnace and heated therein to 1200 - 1260°C, and it is then subjected to piercing rolling in a piercer using a plug and rolls to produce a hollow shell. The hollow shell is then used as a material being rolled (mother tube) and subjected to elongation rolling using a mandrel mill to reduce its wall thickness to a predetermined value. The mother tube is then subjected to sizing by a sizing mill (sizer) so as to have a predetermined outer diameter, and thus a product in the form of a seamless tube is manufactured.

[0003] Hitherto, a 2-roll type mandrel mill having a pair of grooved rolls which are disposed such that the direction of reduction differs by 90° between adjoining stands has been much used as such a mandrel mill. In recent years, a 4-roll type mandrel mill having four grooved rolls with the angle of reduction of two adjoining stands differing by an angle of 90° has also come to be used. In addition, a 3-roll type mandrel mill equipped with three grooved rolls having rolling directions which form an angle of 120° and which has the angle of reduction of adjoining stands differing by 60° has also been proposed.

[0004] In order to increase the operating efficiency in any of a 2-roll, 4-roll, or 3-roll mandrel mill, in general, one type of grooved rolls are used with adjustment for elongation rolling of mother tubes made of various types of steels from common steels to alloy steel such as stainless steel having various wall thicknesses.

[0005] However, if the elongation rolling conditions of a mandrel mill are not suitably set, the outer circumference of a mother tube formed by elongation rolling may not become sufficiently small or rather increase; leading to the formation of overfilled scars or other rolling troubles caused by overfilling, which is a phenomenon in which a mother tube is protruded into a gap between the flange portions of grooved rolls. In other cases, the outer circumference of a mother tube formed by elongation rolling becomes too small, resulting in the occurrence of mandrel bar withdrawal defects or the formation of holes in the mother tube caused by under-filling, which is a phenomenon in which the inner surface of a mother tube adheres to a mandrel bar. Various inventions have been proposed in the past in order to solve these problems.

[0006] For example, Patent Document 1 discloses an invention in which elongation rolling in a mandrel mill of a mother tube made primarily of an alloy steel such as stainless steel is performed such that the ratio of groove circumference to circumference of a hot finished mother tube on the exit side of the mill is made at least 1.12 for the first stand, at least 1.06 for the second stand, and at least 1.02 for the third stand whereby an appropriate outer circumference of the mother tube on the exit side of the mandrel mill is ensured and in the end portion of the mother tube where under-filling most easily occurs, a suitable gap can be formed between the mandrel bar and the mother tube so as to prevent the occurrence of under-filling.

[0007] Patent Document 2 discloses an invention in which elongation rolling in a mandrel mill of a mother tube made primarily of an alloy steel such as 13% Cr steel (in this description, unless otherwise specified, percent means mass percent) is performed such that the ratio of groove circumference determined by the grooved rolls in each of the first stand and the second stand to the outer circumference of the mother tube undergoing elongation rolling in the mandrel mill is made to be in a certain range, whereby the occurrence of under-filling in the end portion of a mother tube is prevented.
Patent Document 1: JP 2582705 B
Patent Document 2: JP 2003-10907 A1

Disclosure of Invention

[0008] As a result of diligent investigation by the present inventors, it was found that the invention disclosed by Patent Document 1 prescribes suitable conditions with respect to a mother tube made of an alloy steel such as stainless steel having specific dimensions. Namely, overfilling occurs if elongation rolling is carried out to form a thin-walled mother tube for which the ratio of the wall thickness to the outer diameter (wall thickness/outer diameter ratio) is at most 3% and which is made of common steel with a Cr content of less than 1% according to the dimensions of groove circumference, outer diameter of the mother tube, and other parameters disclosed by Patent Document 1. In order to suppress this overfilling, elongation rolling is generally carried out while applying tension between each stand, but in the case of a thin-walled mother tube for which the wall thickness/outer diameter ratio is at most 3%, if the tension becomes too large, holes easily form, and it is not possible to prevent both overfilling and hole formation in a stable manner.

[0009] Accordingly, with the invention disclosed by Patent Document 1, it is necessary to change the grooved rolls when elongation rolling is performed to form a mother tube made of an alloy steel or to form a thin-walled mother tube made of common steel with a thickness/outer diameter ratio of at most 3%. Normally, in elongation rolling of seamless tube, the grooved rolls of a sizing mill are changed each time the outer diameter to be finished is changed, but in order to carry out the invention disclosed by Patent Document 1, in addition to replacing the grooved rolls in a sizing mill, it is necessary to stop the mandrel mill for elongation rolling and change the grooved rolls of the mill each time there is a change in the type of steel or dimension to be finished in elongation rolling. In order to reduce the number of times that the grooved rolls in a mandrel mill are changed to just one time, it is necessary to separately manufacture seamless steel tubes for common steel and alloy steel even when the outer diameter is the same, and the time required for changing the grooved rolls in a sizing mill is doubled. In order to prevent the time for changing the grooved rolls in a sizing mill from increasing, it is necessary to change the grooved rolls of a mandrel mill for elongation rolling each time the diameter to be finished changes. In either case, it is necessary to stop the entire manufacturing process for a long time, which greatly decreases productivity.

[0010] The invention disclosed by Patent Document 2 discloses suitable rolling conditions specified for a mother tube made of an alloy steel such as 13% Cr steel having specific dimensions, so it has problems like those of the invention disclosed by Patent Document 1.

[0011] The present invention was made in light of the problems of the prior art. Its object is to provide an elongation rolling method using a mandrel mill which can effectively prevent the occurrence of overfilling and under-filling using a combination of the same grooved rolls for mother tubes of different steel types such as common steel and alloy steel and having different wall thicknesses.

[0012] The present invention is a method of carrying out elongation rolling of a mother tube from a hollow shell using a mandrel mill having a plurality of stands each equipped with a plurality of grooved rolls, characterized by setting the outer diameter of the hollow shell such that the ratio of outer circumference of the hollow shell to finished circumference, which is the circumference of the mother tube on the exit side of the finishing stand, is at least 1.1 when the Cr content of the mother tube is at least 10%, or less than 1.1 when the Cr content of the mother tube is less than 10%, and setting the groove profile of grooved rolls provided in a first stand and a second stand of the mandrel mill such that the groove circumference in the first stand determined by the plurality of grooved rolls provided in the first stand satisfies the following Equation 1, the groove circumference in the second stand determined by the plurality of grooved rolls provided in the second stand satisfies the following Equation 2, and the groove circumferences in the first stand and the second stand satisfy the following Equation 3:

$$1.06 \leq \text{the ratio of groove circumference in the 1st stand to finished circumference} \leq 1.12 \quad \ldots\ldots \quad (1)$$

$$1.05 \leq \text{the ratio of groove circumference in the 2nd stand to finished circumference} \leq 1.10 \quad \ldots\ldots \quad (2)$$

$$\text{groove circumference in the 1st stand} > \text{groove circumference in the 2nd stand} \quad \ldots\ldots \quad (3)$$

[0013] According to the present invention, both overfilling and under-filling can be effectively prevented for mother tubes made of various types of steel including common steel and alloy steels and having various wall thicknesses using one type of combination of grooved rolls without changing the combination of grooved rolls in accordance with the type of steel and other factors. As a result, it is ensured that the occurrence of overfilled scars caused by overfilling and withdrawal defects and scars caused by under-filling can be effectively and inexpensively prevented.

Brief Description of the Drawings

[0014]

Figure 1(a) is a graph showing a model of behavior when a mother tube made an alloy steel is formed by elongation rolling, Figure 1(b) is a graph showing a model of behavior when a mother tube made of an alloy steel is formed by elongation rolling when the groove circumference of grooved rolls is set to a large value based on the prior art, and Figure 1(c) is a graph showing a model of behavior when a mother tube made of common steel is formed by elongation rolling. The axial strain on the abscissa of the graph shown in each of Figures 1(a) - 1(c) is the value expressed by [In (length of mother tube after elongation rolling/length of mother tube before elongation rolling)].

Figure 2 is a graph showing the variation in the outer diameter and axial strain of a mother tube from the entrance side to the exit side of a stand when elongation rolling was carried out under the same conditions as for Figure 1 (a) except that the outer diameter of the mother tube was set to a larger value of 102 mm.

Figure 3 shows explanatory views for explaining the definition of groove circumference, in which Figure 3(a) is a vertical cross-sectional view schematically showing a portion of a grooved roll provided in a 2-roll mandrel mill, and Figure 3(b) is a vertical cross-sectional view schematically showing a portion of a grooved roll provided in a 3-roll mandrel mill.

Figure 4 is a graph showing one example of the results of an elongation rolling test.

Figure 5 is a graph showing one example of the results of an elongation rolling test.

Figure 6 is a table showing results of examples of an elongation rolling method using a mandrel mill according to the present invention and comparative

examples.

Best Mode for Carrying Out the Invention

[0015] Below, the best mode for carrying out an elongation rolling method using a mandrel mill according to the present invention will be explained while referring to the attached drawings.

[0016] First, the principle of the present invention will be explained.

[0017] Figure 1(a) is a graph showing a model of the behavior when a mother tube made of an alloy steel underwent elongation rolling, Figure 1(b) is a graph showing a model of the behavior when a mother tube made of an alloy steel underwent elongation rolling when the groove circumference of grooved rolls was set to a large value based on the prior art, and Figure 1(c) is a graph showing a model of the behavior when a mother tube made of common steel underwent elongation rolling. The axial strain on the abscissa of the graphs shown in Figures 1(a) - 1(c) is the value expressed by [In (length of mother tube after elongation rolling/length of mother tube before elongation rolling)].

[0018] The mechanism whereby overfilling occurs with a mother tube made of common steel in spite of it being possible to prevent under-filling with a mother tube made of a specific alloy steel based on the prior art of Patent Document 1 and the like will be explained using the models shown in Figure 1.

[0019] The graph shown in Figure 1(a) shows the variation in the outer diameter and the axial strain of a mother tube from the entrance side to the exit side of a stand having grooved rolls with a groove circumference corresponding to an inner diameter of 98 mm (shown by the dashed line in the figure) when elongation rolling was carried out on a hollow shell made of an alloy steel with an outer diameter of 100 mm until the axial strain on the exit side of the stand reached 0.3. If the sum of the outer diameter of the mandrel bar and two times the wall thickness of the mother tube on the exit side of the stand is made 96 mm, the outer diameter of the mother tube on the exit side of the stand (where the axial strain = 0.3) becomes approximately 96 mm, which is approximately equal to the above-described sum, so under-filling occurs.

[0020] The graph shown in Figure 1(b) shows the variation in the outer diameter and axial strain of a mother tube from the entrance side to the exit side of a stand when elongation rolling was carried out under the same conditions as for Figure 1(a) except that the groove circumference of the grooved rolls was set to a large value corresponding to an inner diameter of 99 mm shown by the dashed line in the figure in accordance with the prior art. In this case, the graph shown in Figure 1(a) moves in the direction shown by arrows in the figure, and the outer diameter of the mother tube on the exit side of the stand (where the axial strain = 0.3) becomes approximately 97 mm. As a result, there is sufficient margin with respect to the above-described sum (96 mm), and under-filling can be prevented.

[0021] The graph shown in Figure 1(c) shows the variation in the outer diameter and the axial strain of a mother tube from the entrance side to the exit side of a stand when elongation rolling was carried out under the same conditions as for Figure 1(a) except that the mother tube was made of common steel. In this case, the outer diameter of the mother tube on the exit side of the stand (where the axial strain = 0.3) becomes approximately 97.5 mm. Accordingly, there is sufficient margin with respect to the above-described sum (96 mm), and under-filling does not develop.

[0022] For a mother tube made of common steel exhibiting behavior like that shown in Figure 1(c), if the groove circumference of grooved rolls is set to a large value corresponding to an inner diameter of 99 mm in the same manner as in Figure 1(b), the graph showing the behavior moves upwards in the same manner as in Figure 1(b) so that the outer diameter of the mother tube on the exit side of the stand (where the axial strain = 0.3) becomes too large, and there is a possibility of overfilling occurring.

[0023] Thus, if a mother tube made of an alloy steel and a mother tube made of common steel each undergo elongation rolling using grooved rolls having a roll circumference corresponding to an inner diameter of 98 mm, under-filling develops for the mother tube made of an alloy steel. If the groove circumference of the grooved rolls is set to a large value corresponding to an inner diameter of 99 mm in order to prevent this under-filling, overfilling develops for the mother tube made of common steel.

[0024] In this manner, the mechanism whereby under-filling of a mother tube made of an alloy steel can be prevented by setting the groove circumference of grooved rolls to a large value is explained by the model of behavior which was explained while referring to Figure 1(a) and Figure 1(b). The mechanism whereby overfilling develops with a mother tube made of common steel when the groove circumference of grooved rolls is set to a large value in the above-described manner is explained by the model showing the behavior explained while referring to Figure 1(c).

[0025] Figure 2 is a graph showing the variation in the outer diameter and the axial strain of a mother tube from the entrance side to the exit side of a stand when elongation rolling was carried out under the same conditions as for Figure 1(a) except that the outer diameter of the mother tube was set to a large value of 102 mm.

[0026] In the same manner as described above, in the model of behavior for an alloy steel shown in Figure 1(a), under-filling can be prevented by setting the outer diameter of a mother tube to a large value as in the model shown in Figure 2 instead of by setting the groove circumference of grooved rolls for a mother tube to a large value as shown in Figure 1(b).

[0027] As shown in Figure 2, if the outer diameter of a mother tube is set to a large value, the same behavior is exhibited as if the graph shown in Figure 1(a) were moved upwards, and the outer diameter of a mother tube on the exit side of the stand (where the axial strain = 0.3) becomes approximately 97 mm. Accordingly, there is sufficient margin with respect to the above-described sum (96 mm), and under-filling is prevented.

[0028] The present invention was achieved based on the fact that under-filling can be prevented by setting the outer diameter of a hollow shell to a large value as shown by the graph in Figure 2. In the model shown in Figure 2, it is not necessary to vary the groove circumference of a grooved roll, and overfilling can be prevented with grooved rolls having the same groove circumference corresponding to an inner diameter of 98 mm even for a mother tube made of common steel which exhibits the behavior shown in Figure 1(c). In other words, if the outer diameter of a hollow shell which undergoes elongation rolling in a mandrel mill is suitably varied depending on the particular steel type and size using known methods such as by varying the setting of a piercer or using a shell sizer, a single combination of grooved rolls can be employed without producing under-filling of a mother tube made of an alloy steel or overfilling of a mother tube made of common steel.

[0029] The graphs showing the models of rolling behavior in Figure 1 and Figure 2 were plotted based on the concept described below. The process of deformation of a mother tube can be divided into an "outer diameter working step" from when the outer peripheral surface of the mother tube first contacts the grooved rolls until it is reduced between the grooved rolls and the mandrel bar (until the outer diameter of the mother tube becomes equal to the inner diameter of the grooved rolls) and a "wall thickness working step" in which the mother tube is reduced between the grooved rolls and the mandrel bar.

[0030] The graph shown by line segment A1B1 in Figure 1(a) corresponds to the behavior in the outer diameter working step. Regardless of the type of steel, the outer diameter of the mother tube, i.e., the outer circumference is decreased as the mother tube is inwardly forced by the groove profile of the grooved rolls. Similarly, the graph shown by line segment A2B2 in Figure 1 (b), the graph shown by line segment A3B3 in Figure 1(c), and the graph shown by line segment A4B4 in Figure 2 correspond to the behavior in the outer diameter working step. As described above, the behavior in the outer diameter working step does not depend upon the steel type, so each of the graphs has the same slope.

[0031] The graph shown by line segment B1C1 in Figure 1 (a) corresponds to the behavior in the wall thickness working step. The mother tube is not inwardly forced by the groove profile of the grooved rolls, but in the portion of the mother tube in which direct reduction does not take place between the grooved rolls and the mandrel bar, as the amount of elongation increases and the mother tube lengthens, tensile deformation develops resulting in a decrease in the outer diameter, i.e., the outer circumference. Similarly, the graph shown by line segment B2C2 in Figure 1(b), the graph shown by line segment B3C3 in Figure 1 (c), and the graph shown by line segment B4C4 in Figure 2 correspond to the behavior in the wall thickness working step. The change in the outer diameter relative to the change in the amount of elongation, i.e., the change in the axial strain in the wall thickness working step, namely, the absolute value of the slope of each graph depends upon the type of steel. As a result, there is a tendency for the amount of deformation to be larger for a mother tube made of an alloy steel. Accordingly, the graph shown by line segment B1C1 in Figure 1(a), the graph shown by line segment B2C2 in Figure 1(b), and the graph shown by line segment B4C4 in Figure 2 are all plotted with the same slope, but the graph shown by line segment B3C3 in Figure 1(c) is plotted with a slope having a smaller absolute value than the other graphs.

[0032] The graphs of Figure 1 and Figure 2 showing models of behavior are plotted based on this principle. As stated above, they match the results of actual rolling tests carried out by the present inventors.

[0033] The present invention was completed by utilizing these principles and specifying various parameters in elongation rolling conditions by above-described Equations 1-3. The present invention is not limited to application to a 2-roll mandrel mill, and it can be applied in the same manner to a 3-roll or 4-roll mandrel mill. In the present invention, the "finished circumference" means the outer circumference of a mother tube on the exit side of a finishing stand.

[0034] Next, the meaning of "groove circumference" in the present invention will be explained while referring to Figure 3.

[0035] Figure 3 shows explanatory views for explaining the definition of the groove circumference. Figure 3(a) is a vertical cross-sectional view schematically showing a portion of a grooved roll provided in a 2-roll mandrel mill, and Figure 3(b) is a vertical cross-sectional view schematically showing a portion of a grooved roll provided in a 3-roll mandrel mill.

[0036] As shown in Figure 3(a), the groove profile P of a grooved roll 1 provided in a mandrel mill generally has a shape which is a combination of three arcs. It is a curve with left and right symmetry having a straight line connecting the groove bottom B and the groove center O as an axis of symmetry. The profile on one side has a shape formed by continuously combining an arc with a radius R1 and a central angle $\alpha 1$, an arc with a radius R2 and a central angle $\alpha 2$ (referred to below as arc R2), and an arc with a radius R3 and a central angle $\alpha 3$ (referred to below as arc R3). Taking an arc with a radius R4 and a central angle $\alpha 4$ which is tangent to the joining point of arc R2 and arc R3 at one end and which, at the other end is, perpendicular to straight line L, which forms an angle of 90° with respect to the straight line connecting the groove bottom B and the groove center O, the groove circumference is defined as $4(R1\alpha 1 + R2\alpha 2 + R4\alpha 4)$.

[0037] As shown in Figure 3(b), in the same manner as for the above-described 2-roll mandrel mill, the groove profile P of a grooved roll 1 provided in a 3-roll mandrel mill generally has a shape formed by combining three arcs R1, R2, and R3. Taking an arc with a radius R4 and a central angle $\alpha 4$ which is tangent to the joining point of arc R2 and arc R3 at one end and which, at the other end, is perpendicular to straight line L, which forms an angle of 60° with respect to a straight line connecting the groove bottom B and the groove center O, the groove circumference is defined as $6(R1\alpha 1 + R2\alpha 2 + R4\alpha 4)$.

[0038] The definition of the groove circumference for any number of grooved rolls can be generalized as follows. If the number of grooved rolls provided in each stand of a mandrel mill is n (n = 2 in the case of a 2-roll mandrel mill, n = 3 in the case of a 3-roll mandrel mill, and n = 4 in the case of a 4-roll mandrel mill), then the groove circumference is defined as $2n(R1\alpha 1 + R2\alpha 2 + R4\alpha 4)$, wherein R4 and $\alpha 4$ are the radius and central angle, respectively, of an arc which is tangent to the joining point of arc R2 and arc R3 at one end and, at the other end, is perpendicular to a straight line L which forms an angle of 180/n (°) with respect to a straight line connecting the groove bottom B and the groove center O.

[0039] In the above explanation, an example was given of the case in which the groove profile P of a grooved roll 1 has a shape formed by continuously combining two outwardly-facing convex arcs R1 and R2 (which face away from the groove center O) and an inwardly-facing convex arc R3 (which faces towards the groove center O). However, the present invention is not limited to this shape of groove profile, and the groove profile may have a shape formed by continuously combining one outwardly-facing convex arc or three or more outwardly-facing convex arcs of different radius with one inwardly-facing convex arc. In addition, the inwardly-facing convex arc may be formed by continuously combining a plurality of arcs of different radius. Furthermore, a straight line shape may be used instead of an inwardly-facing convex arc. Generalizing the definition of the groove circumference of any shape of grooved roll 1, if the circumferential length of the portion of one or more outwardly-facing convex arcs from the groove bottom B to the joining point with the inwardly-facing convex arc (or straight line) is made LO, when the outwardly-facing convex arcs have the above-described two arcs R1 and R2, then $LO = R1\alpha 1 + R2\alpha 2$. In this case, the groove circumference is defined as $2n(LO + R4\alpha 4)$, wherein R4 and $\alpha 4$ are the radius and central angle, respectively, of an arc which is tangent to the joining point of arc R2 and arc R3 at one end and, at the other end, is perpendicular to a straight line L which forms an angle of 180/n (°) with respect to a straight line connecting the groove bottom B and the groove center O.

[0040] Furthermore, in an elongation rolling method using a mandrel mill according to the present invention, the groove profile of grooved rolls provided in the third stand of the mandrel mill is preferably set so that the groove circumference in the third stand determined by the plurality of grooved rolls provided in the third stand satisfies the following Equation 4 and the groove circumferences in the second stand and the third stand satisfy the following Equation 5. Here, the finished circumference means the circumference of a mother tube at the completion of elongation rolling:

$$1.02 \leq \text{the ratio of groove circumference in the 3rd stand to finished circumference} \leq 1.07 \quad \ldots\ldots \quad (4)$$

$$\text{groove circumference in the 2nd stand} > \text{groove circumference in the 3rd stand} \quad \ldots\ldots \quad (5)$$

[0041] Next, the best mode for carrying out an elongation rolling method using a mandrel mill according to the present invention will be explained while referring to the attached figures.

[0042] An elongation rolling test was carried out in order to determine one type of combination of grooved rolls which can be used both for a mother tube of an alloy steel without causing under-filling and for a mother tube of common steel without causing overfilling by adjusting the outer diameter of a hollow shell. In this elongation rolling test, stainless steel was used as an alloy steel having a Cr content of at least 10%. For this steel, the outer circumference of the hollow shell was set such that the ratio of outer circumference of the hollow shell to finished circumference, which is the outer circumference of the mother tube on the exit side of the finishing stand, was at least 1.1. A thin-walled mother tube with a wall thickness/outer diameter ratio of at most 3% was used as a mother tube of common steel with a Cr content of less than 10%. For this steel, the ratio of outer circumference of the hollow shell to finished circumference was set to less than 1.1. For each steel, the value of the ratio of groove circumference to finished circumference for the first stand and the ratio of groove circumference to finished circumference for the second stand were varied.

[0043] Figure 4 is a graph showing an example of the results of this elongation rolling test. In the graph shown in Figure 4, X indicates a mother tube with which under-filling or overfilling developed, and O (circle) indicates a mother tube which did not develop either under-filling or overfilling.

[0044] As shown in the graph of Figure 4, for a mother tube made of stainless steel, if the ratio of groove circumference (abbreviated as G.C. in the figure) to finished circumference (finished G.C.) for the first stand (#1std) is less than 1.06, under-filling develops in the second stand, and when the ratio of groove circumference to finished circumference for the second stand (#2std) is less than 1.05, under-filling develops in the third stand. On the other hand, for a thin-walled mother tube made from the common steel, if the ratio of groove circumference to finished circumference for the first stand is larger than 1.12, overfilling develops in the second stand, and if the ratio of groove circumference to finished circumference for the second stand is larger than 1.10, overfilling develops in the third stand.

[0045] When the groove circumference in the first stand is less than or equal to the groove circumference in the second stand, the outer circumference of the mother tube cannot be adjusted in the second stand, and it becomes easy for under-filling or overfilling to develop. There are also cases in which overfilling occurs in the third stand.

[0046] Based on the test results shown in the graph of Figure 4, it can be seen that by setting the outer diameter of a hollow shell such that the ratio of outer circumference of the hollow shell to finished circumference, which is the outer circumference of the mother tube on the exit side of the finishing stand, is at least 1.1 when the mother tube has a Cr content of at least 10% and setting the outer diameter of a hollow shell so that the ratio of outer circumference of the hollow shell to finished circumference, which is the outer circumference of the mother tube on the exit side of the finishing stand, is less than 1.1 when the Cr content of the mother tube is less than 10%, rolling can be performed with a single combination of grooved rolls without changing the combination in accordance with the Cr content of a mother tube as long as prescribed conditions are satisfied.

[0047] The outer diameter of a hollow shell can be suitably adjusted by known methods such as those disclosed in JP H08-71615 A1, JP 2002-11507 A1, and the like.

[0048] In a mandrel mill rolling method according to this embodiment, particularly in the second stand and the third stand where under-filling and overfilling can easily occur, under-filling and overfilling can be effectively prevented with a single combination of grooved rolls. However, as a more preferred mode, in order to prevent the occurrence of under-filling and overfilling with certainty in the fourth stand as well, a rolling test was carried out on each mother tube with which the test results shown in Figure 4 were obtained while varying the ratio of groove circumference to finished circumference for the third stand.

[0049] Figure 5 is a graph showing one example of the results of this rolling test. In Figure 5, X indicates mother tubes with which under-filling or overfilling developed, Δ (triangle) indicates mother tubes which had a tendency for under-filling or overfilling, and O (circle) indicates mother tubes with which neither under-filling nor overfilling developed.

[0050] As shown in the graph of Figure 5, mother tubes made from stainless steel had somewhat of a tendency to develop under-filling in the fourth stand if the ratio of groove circumference to finished circumference in the third stand (#3std) was less than 1.02, and the thin-walled mother tubes made from common steel had somewhat of a tendency towards overfilling in the fourth stand if the ratio of groove circumference to finished circumference in the third stand was greater than 1.07. When the groove circumference in the second stand (#2std) was less than or equal to the groove circumference in the third stand, the outer circumference of the mother tube in the third stand cannot be adjusted, and it becomes easy for under-filling or overfilling to develop. There are also cases in which overfilling occurs in the fourth stand.

[0051] From the graph shown in Figure 5, it can be seen that the groove profile of the grooved rolls provided in the third stand is preferably set such that the groove circumference in the third stand which is determined by the plurality of grooved rolls provided in the third stand satisfies Equation 4 ($1.02 \leq$ groove circumference in the 3rd stand/finished circumference ≤ 1.07) and such that the groove circumferences in the second stand and the third stand satisfy Equation 5 (groove circumference in the 2nd stand > groove circumference in the 3rd stand).

[0052] By satisfying Equation 4 and Equation 5, the occurrence of under-filling and overfilling in the fourth stand can be prevented with certainty.

EXAMPLES

[0053] A more detailed explanation will be given while referring to examples of the present invention and comparative examples.

Examples

[0054] As shown in the table in Figure 6, an elongation rolling test was performed using hollow shells made from 13% Cr steel having an outer diameter of 300 mm, a wall thickness of 20 mm, and a length of 6,000 mm (only the value of the outer diameter is shown in the table), which were subjected to elongation rolling in a 2-roll mandrel mill having 5 stands to produce mother tubes having the size on the exit side of the mandrel mill of an outer diameter of 270 mm (finished circumference = 270 x π mm) and a thickness of 10 mm (Examples 1-1, 2-1, and 3-1). In addition, also as shown in the table of Figure 6, another elongation rolling test was performed using hollow shells made of carbon steel, 9% Cr steel, or 5% Cr steel with an outer diameter of 295 mm, a wall thickness of 19 mm, and a length of 6,000 mm (only the value of the outer diameter is shown in the table), which were subjected to elongation rolling in a 2-roll mandrel mill having 5 stands to produce mother tubes having the size on the exit side of the mandrel mill of an outer diameter of 270 mm (finished circumference = 270 x π mm) and a thickness of 7 mm (Examples 1-2, 1-3, 1-4, 2-2, and 3-2).

[0055] The groove circumferences S 1 to S3 in the first stand through the third stand set for each condition were as shown in the table of Figure 6. Examples 1-1 through 1-4, Examples 2-1 and 2-2, and Examples 3-1 and 3-2 had the same groove circumference (they used the same combination of grooved rolls). In the table shown in Figure 6, the numbers shown in the column for "shell/finished" are the values of the outer circumference of the hollow shell divided by the finished circumference.

Comparative Example

[0056] A rolling test was carried out under the same conditions as for the examples except that the value (ratio) of (outer circumference of the hollow shell/finished circumference) and the set values of the groove circumferences S 1 to S3 in the first stand through the third stand were varied. Namely, for a hollow shell with an outer diameter of 300 mm, a thickness of 20 mm, and a length of 6,000 mm, rolling was carried out using a 2-roll mandrel mill having 5 stands to produce a mother tube with an outer diameter of 270 mm (finished circumference = 270 x π mm) and a wall thickness of 10 mm on the exit side of the mandrel mill (Comparative Examples 1-1, 1-4, 2-1, 2-4, 3-2, 3-3, 3-4, 4-2, and 5-2). For a hollow shell with an outer diameter of 295 mm, a thickness of 19 mm, and a length of 6,000 mm, rolling was carried out with a 2-roll mandrel mill having 5 stands to produce a mother tube with an outer diameter of 270 mm (finished circumference = 270 x π mm) and a wall thickness of 7 mm on the exit side of the mandrel mill (Comparative Examples 1-2, 1-3, 2-2, 2-3, 3-1, 4-1, and 5-1). The groove circumferences S1 to S3 in the first stand through the third stand for each condition were as shown in the table in Figure 6. Comparative Examples 1-1 through 1-4, Comparative Examples 2-1 through 2-4, Comparative Examples 3-1 through 3-4, Comparative Examples 4-1 and 4-2, and Comparative Examples 5-1 and 5-2 employed the same groove circumference and used the same combination of grooved rolls.

Test Results

[0057] In the comparative examples, at least one of either the mother tubes with a Cr content of at least 10% (13% Cr steel) or the mother tubes with a Cr content of less than 10% (9% Cr steel, 5% Cr steel, and carbon steel) had scars occurring at a rate exceeding 4%. In contrast, in the examples of the present invention, both the mother tubes with a Cr content of at least 10% (13% Cr steel) and the mother tubes with a Cr content of less than 10% (9% Cr steel, 5% Cr steel, and carbon steel) had almost no occurrence of scars in spite of being rolled using the same combination of grooved rolls.

Claims

1. An elongation rolling method of a mother tube from a hollow shell using a mandrel mill having a plurality of stands each provided with a plurality of grooved rolls, **characterized by**
setting the outer diameter of the hollow shell such that the ratio of outer circumference of the hollow shell to finished circumference, which is the outer circumference of the mother tube on the exit side of a finishing stand, is at least 1.1 when the mother tube has a Cr content of at least 10 mass % or it is less than 1.1 when the Cr content of the mother tube is less than 10 mass %, and
setting the groove profile of grooved rolls provided in a first stand and a second stand of the mandrel mill such that

the groove circumference in the first stand which is determined by a plurality of grooved rolls provided in the first stand satisfies the following Equation 1, the groove circumference in the second stand which is determined by a plurality of grooved rolls provided in the second stand satisfies the following Equation 2, and the groove circumferences in the first stand and the second stand satisfy the following Equation 3.

$$1.06 \leq \text{the ratio of groove circumference in the 1st stand to finished circumference} \leq 1.12 \quad \ldots\ldots \quad (1)$$

$$1.05 \leq \text{the ratio of groove circumference in the 2nd stand to finished circumference} \leq 1.10 \quad \ldots\ldots \quad (2)$$

$$\text{groove circumference in the 1st stand} > \text{groove circumference in the 2nd stand} \quad \ldots\ldots \quad (3)$$

2. An elongation rolling method as set forth in claim 1 using a mandrel mill, **characterized in that** the groove profile of grooved rolls provided in a third stand of the mandrel mill is set so that the groove circumference in the third stand which is determined by a plurality of grooved rolls provided in the third stand satisfies the following Equation 4, and the groove circumferences in the second stand and the third stand satisfy the following Equation 5.

$$1.02 \leq \text{the ratio of groove circumference in the 3rd stand to finished circumference} \leq 1.07 \quad \ldots\ldots \quad (4)$$

$$\text{groove circumference in the 2nd stand} > \text{groove circumference in the 3rd stand} \quad \ldots\ldots \quad (5)$$

Fig. 1

(a)

(b)

(c)

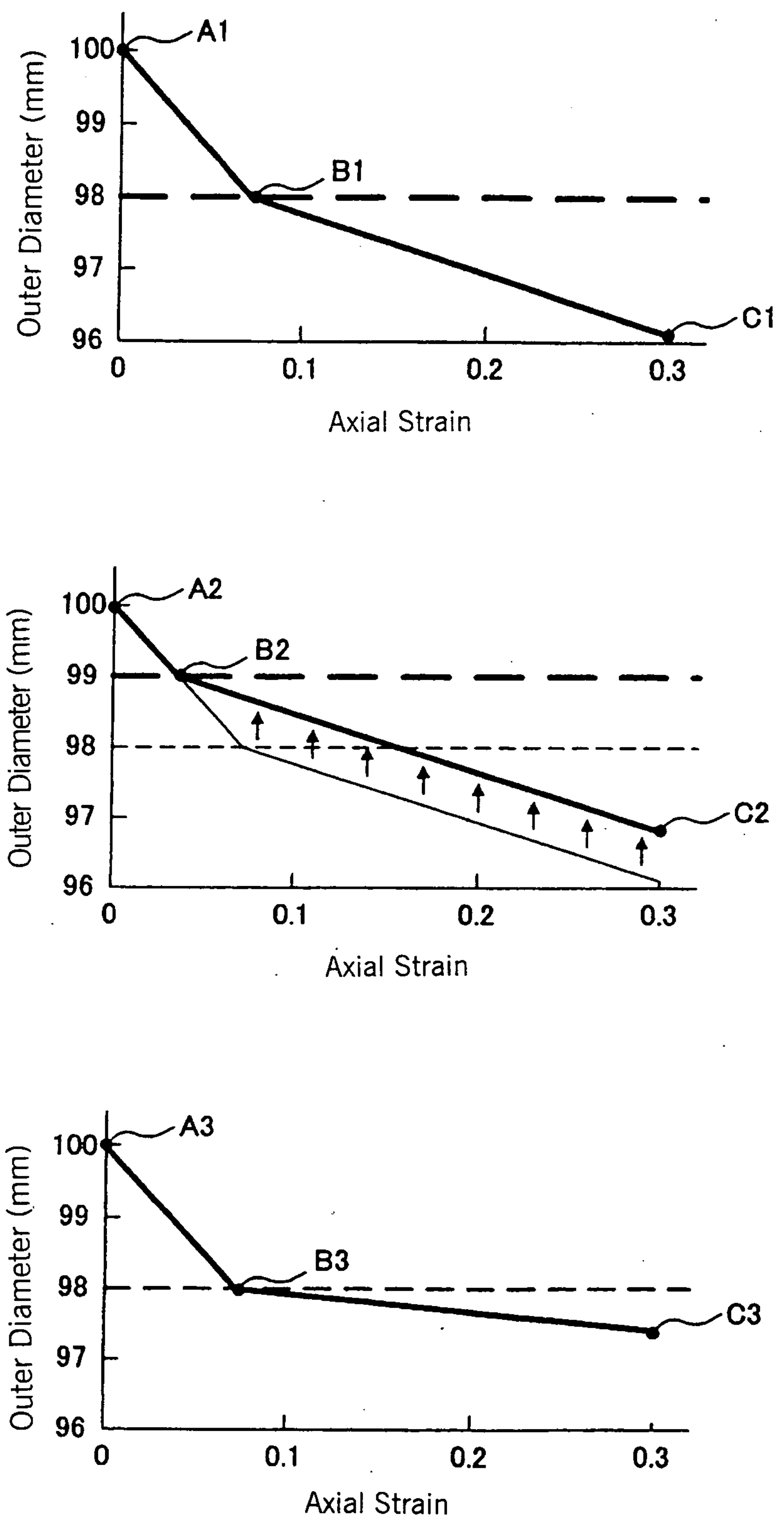

A1
B1
C1
A2
B2
C2
A3
B3
C3
100
99
98
97
96
0
0.1
0.2
0.3
Outer Diameter (mm)
Axial Strain

Fig. 2

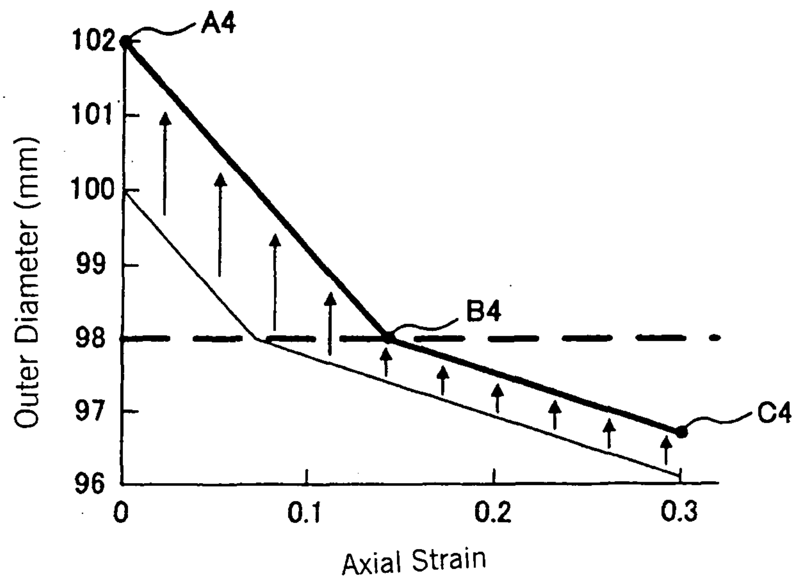
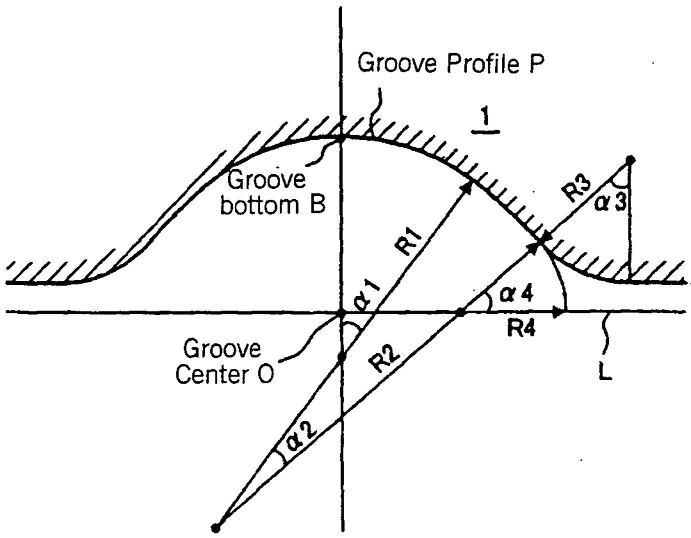

A4
B4
C4
102
101
100
99
98
97
96
0
0.1
0.2
0.3
Outer Diameter (mm)
Axial Strain

Fig. 3

(a)


Groove Profile P
1
Groove bottom B
R1
R3
α3
α1
α4
R4
Groove Center O
R2
L
α2

(b)

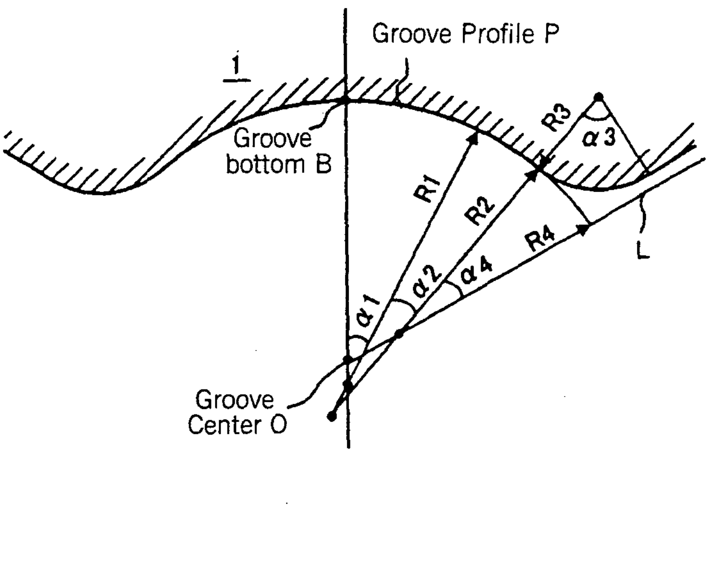

Groove Profile P
1
Groove bottom B
R3
α3
R1
R2
R4
L
α1
α2
α4
Groove Center O

Fig. 4

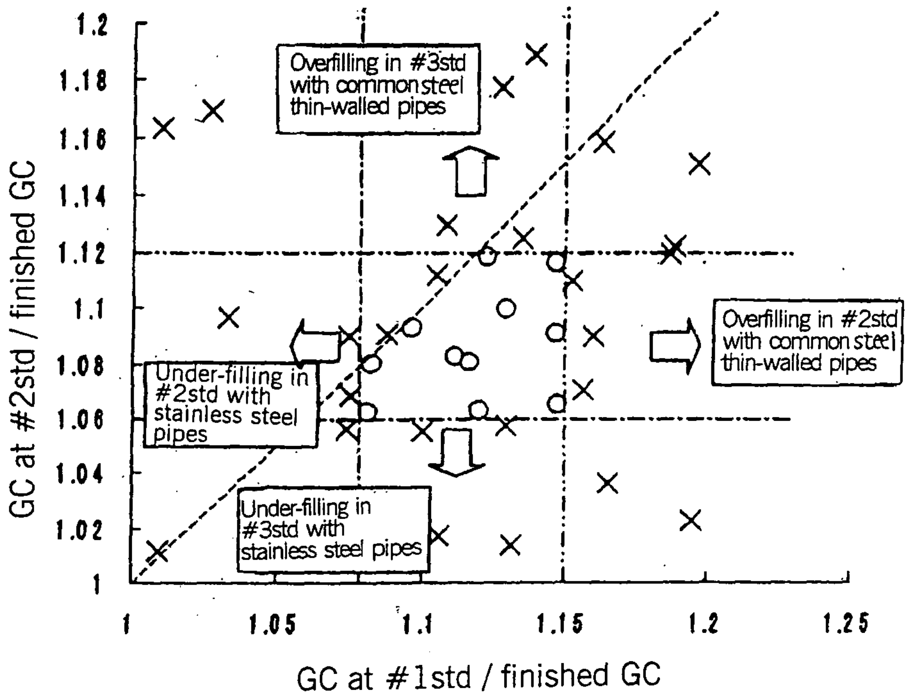

Overfilling in #3std with common steel thin-walled pipes
Overfilling in #2std with common steel thin-walled pipes
Under-filling in #2std with stainless steel pipes
Under-filling in #3std with stainless steel pipes
1.2
1.18
1.16
1.14
1.12
1.1
1.08
1.06
1.04
1.02
1
1.05
1.1
1.15
1.2
1.25
GC at #2std / finished GC
GC at #1std / finished GC

Fig. 5

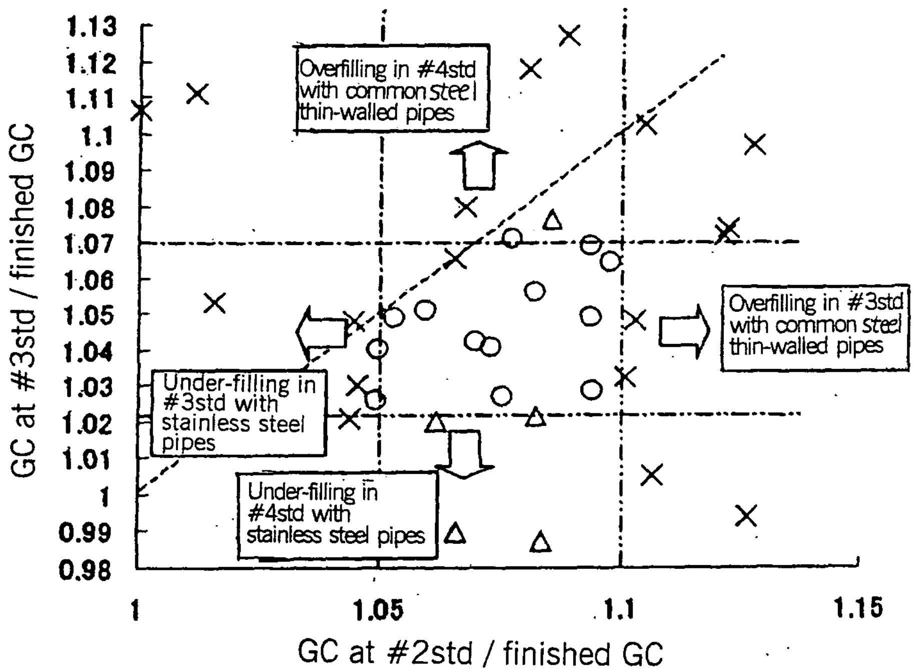

Overfilling in #4std with common steel thin-walled pipes
Overfilling in #3std with common steel thin-walled pipes
Under-filling in #3std with stainless steel pipes
Under-filling in #4std with stainless steel pipes
1.13
1.12
1.11
1.1
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1
0.99
0.98
1.05
1.1
1.15
GC at #3std / finished GC
GC at #2std / finished GC

Fig. 6

	Steel material	O.D. of hollow shell	G.C. ratio shell/finished	G.C. at #1std (S1)	G.C. ratio S1/finished	G.C. at #2std (S2)	G.C. ratio S2/finished	G.C. at #3std (S3)	G.C. ratio S3/finished	Occurrence of scars
Example 1-1	13Cr	300 (mm)	1.11	917 (mm)	1.08	902 (mm)	1.06	885 (mm)	1.04	0.0%
Example 1-2	common	295 (mm)	1.09	917 (mm)	1.08	902 (mm)	1.06	885 (mm)	1.04	0.0%
Example 1-3	9Cr	295 (mm)	1.09	917 (mm)	1.08	902 (mm)	1.06	885 (mm)	1.04	0.0%
Example 1-4	5Cr	295 (mm)	1.09	917 (mm)	1.08	902 (mm)	1.06	885 (mm)	1.04	0.0%
Example 2-1	13Cr	300 (mm)	1.11	952 (mm)	1.12	926 (mm)	1.09	903 (mm)	1.06	0.0%
Example 2-2	common	295 (mm)	1.09	952 (mm)	1.12	926 (mm)	1.09	903 (mm)	1.06	0.0%
Example 3-1	13Cr	300 (mm)	1.11	917 (mm)	1.08	889 (mm)	1.05	856 (mm)	1.01	0.2%
Example 3-2	common	295 (mm)	1.09	917 (mm)	1.08	889 (mm)	1.05	856 (mm)	1.01	0.0%
Comp. Ex. 1-1	13Cr	300 (mm)	1.11	890 (mm)	1.05	880 (mm)	1.04	858 (mm)	1.01	5.8%
Comp. Ex. 1-2	common	295 (mm)	1.09	890 (mm)	1.05	880 (mm)	1.04	858 (mm)	1.01	0.4%
Comp. Ex. 1-3	13Cr	295 (mm)	1.09	890 (mm)	1.05	880 (mm)	1.04	858 (mm)	1.01	7.1%
Comp. Ex. 1-4	common	300 (mm)	1.11	890 (mm)	1.05	880 (mm)	1.04	858 (mm)	1.01	0.9%
Comp. Ex. 2-1	13Cr	300 (mm)	1.11	967 (mm)	1.14	948 (mm)	1.12	914 (mm)	1.08	0.0%
Comp. Ex. 2-2	common	295 (mm)	1.09	967 (mm)	1.14	948 (mm)	1.12	914 (mm)	1.08	6.9%
Comp. Ex. 2-3	13Cr	295 (mm)	1.09	967 (mm)	1.14	948 (mm)	1.12	914 (mm)	1.08	0.2%
Comp. Ex. 2-4	common	300 (mm)	1.11	967 (mm)	1.14	948 (mm)	1.12	914 (mm)	1.08	8.2%
Comp. Ex. 3-1	13Cr	295 (mm)	1.09	917 (mm)	1.08	902 (mm)	1.06	885 (mm)	1.04	4.8%
Comp. Ex. 3-2	9Cr	300 (mm)	1.11	917 (mm)	1.08	902 (mm)	1.06	885 (mm)	1.04	1.2%
Comp. Ex. 3-3	5Cr	300 (mm)	1.11	917 (mm)	1.08	902 (mm)	1.06	885 (mm)	1.04	2.5%
Comp. Ex. 3-4	common	300 (mm)	1.11	917 (mm)	1.08	902 (mm)	1.06	885 (mm)	1.04	4.1%
Comp. Ex. 4-1	13Cr	295 (mm)	1.09	952 (mm)	1.12	926 (mm)	1.09	903 (mm)	1.06	3.8%
Comp. Ex. 4-2	common	300 (mm)	1.11	952 (mm)	1.12	926 (mm)	1.09	903 (mm)	1.06	6.1%
Comp. Ex. 5-1	13Cr	295 (mm)	1.09	917 (mm)	1.08	889 (mm)	1.05	856 (mm)	1.01	5.6%
Comp. Ex. 5-2	common	300 (mm)	1.11	917 (mm)	1.08	889 (mm)	1.05	856 (mm)	1.01	3.9%

O.D. = outer diameter; G.C .= groove circumference; finished = finished circumference

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2006/306292

A. CLASSIFICATION OF SUBJECT MATTER
B21B17/04(2006.01), ***B21B27/02***(2006.01)

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21B17/02, B21B27/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2006
Kokai Jitsuyo Shinan Koho	1971-2006	Toroku Jitsuyo Shinan Koho	1994-2006

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 5-185112 A (Kawasaki Steel Corp.), 27 July, 1993 (27.07.93), Claims; table 1 & US 5218851 A1 & EP 519705 A2 & DE 69202306 C & CA 2071428 A	1-2

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
12 June, 2006 (12.06.06)	20 June, 2006 (20.06.06)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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- JP 2003010907 A **[0007]**
- JP H0871615 A **[0047]**
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