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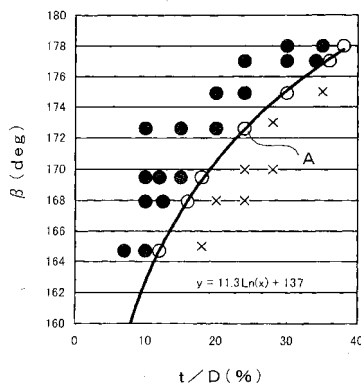
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(54) **TUBE MANUFACTURING METHOD AND APPARATUS FOR FIXED DIAMETER ROLLING**

(57) The present invention provides a method of manufacturing a pipe or tube, comprising the step of rolling the pipe or tube by using a sizing mill comprising a plurality of stands each of which has a plurality of grooved rolls, wherein the grooved rolls are so configured that when tangents are drawn at edge parts facing to each other of adjacent grooved rolls at each stand, assuming that a minimum value of angles defined by the tangents in all stands is β (deg), an outer diameter of the pipe or tube at an output side of the sizing mill is D (mm), and a thickness of the pipe or tube at the output side of the sizing mill is t (mm), the angle β satisfies a following formula (1):

$$\beta \geq 1.13 \times 10 \times \ln(t/D \times 100) + 1.37 \times 10^2 \dots (1).$$

Fig. 4



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Description

TECHNICAL FIELD

[0001] The present invention relates to a pipe or tube manufacturing method and a sizing mill capable of effectively suppressing generation and progression of wrinkles which may be caused on the inner surface of a pipe or tube, when the pipe or tube is rolled by a sizing mill having at least two grooved rolls in each stand.

BACKGROUND ART

[0002] In a step of finishing the outer diameter of a pipe or tube to have a predetermined value, a sizing mill such as a sizer or a stretch reducer is generally used. As such a sizing mill, there is known one of three-roll type in which each stand has three grooved rolls (hereinafter, referred to as "rolling rolls" as appropriate) with an angle of 120° in a rolling direction. Further, there is also known a sizing mill of four-roll type in which each stand has four grooved rolls with an angle of 90° in a rolling direction. Further, there is also known a sizing mill of two-roll type in which each stand has two grooved rolls facing each other.

[0003] Recently, amid growing need of protecting the earth environment, it is required for vehicle bodies to further attain energy saving effects. For this purpose, the need to reduce the weight of a vehicle body is increasing, so there is an attempt to change a drive shaft in automobile parts from a solid member to a hollow member (pipe or tube).

[0004] A drive shaft for a vehicle is an important part to transmit torque of the rotational axis of an engine to a wheel, so sufficient fatigue resisting strength must be secured. Therefore, if a pipe or tube is used as a drive shaft for an automobile, it is required to suppress wrinkle-like irregularities (hereinafter, referred to as "wrinkles") as much as possible, which significantly reduce the fatigue resisting strength of the pipe or tube, generated in the inner face of the pipe or tube.

[0005] The wrinkles are generated frequently in a step of finishing the outer diameter of a pipe or tube so as to have a predetermined value, in the manufacturing process of the pipe or tube. This may be due to the fact that a sizing mill performs rolling of the pipe or tube without using a tool for holding the inner face of the pipe or tube, whereby wrinkles are easily caused in the inner face of the pipe or tube.

DISCLOSURE OF THE INVENTION

[0006] The present invention has been developed to solve such a problem in the conventional art, based on the knowledge newly found by the present inventors. That is, the present inventors have found that generation and progression of wrinkles in a rolling process were influenced significantly by the draft (reduction ratio of the outer diameter) with respect to the whole pipe or tube from the input side to the output side of the sizing mill having a plurality of stands.

[0007] Specifically, as the reduction ratio of the outer diameter of the pipe or tube made by the sizing mill increases, wrinkles are generated in the inner face of the pipe or tube and are progressed (the wrinkles become deep), as shown in Fig. 5. In particular, they have found that wrinkles were progressed rapidly from a point where the reduction ratio of the outer diameter reaches about 50% as a boundary. Note that the reduction ratio of the outer diameter is a value defined by the following equation (2), assuming that the outer diameter of the pipe or tube at the input side of the sizing mill is D_i , and the outer diameter (finishing diameter) of the pipe or tube at the output side of the sizing mill is D :

$$\text{Reduction ratio of outer diameter} = (D_i - D)/D_i \times 100 (\%) \dots (2).$$

[0008] Further, it is also found in Fig. 5 that in a case where the reduction ratio of the outer diameter is about 50% or more, wrinkles are generated and progressed intensively at positions, corresponding to the edge parts, of the pipe or tube (positions of the pipe or tube rolled by the edge parts of rolling rolls at any stand, and when the pipe or tube is rolled by a sizing mill of three-roll type, total six positions in a circumferential direction of the pipe or tube), which are plotted with "●".

[0009] The reason why wrinkles are generated and progressed intensively at positions corresponding to the edges of the pipe or tube may be the groove profile of the rolling rolls being ellipse, so that the compression force applied from the edge parts of the rolling rolls to the pipe or tube are significantly large comparing with other parts.

[0010] In view of the above findings, as a method for suppressing generation and progression of wrinkles effectively, it is considered to restrict the upper limit of the reduction ratio of the outer diameter (e.g., setting the reduction ratio of the outer diameter to less than 50%).

[0011] However, a method of restricting the upper limit of the reduction ratio of the outer diameter causes a problem that when various types of pipes or tubes are manufactured by one sizing mill, pipe or tube stocks of various outer

diameters must be prepared correspondingly, that is, the production efficiency is lowered.

[0012] Accordingly, a method for suppressing generation and progression of wrinkles effectively, without restricting the upper limit of the reduction ratio of the outer diameter, that is, even though the reduction ratio of the outer diameter is 50% or more, is required.

[0013] In view of the above, the inventors of the present invention have intensively studied and found that there was a certain relationship between the curvature radius of the inner face of a position corresponding to the edge part of a pipe or tube, the average inner radius of the pipe or tube (average value of short radius and long radius), and the depth of wrinkles.

[0014] More specifically, in a case where a pipe or tube is rolled by using a sizing mill comprising a plurality of stands each of which has a plurality of grooved rolls, the present inventors have found the following effect: if the pipe or tube was rolled under such conditions that the average value, in all stands, of the ratios between the curvature radii of the inner faces of positions corresponding to the edge parts of the pipe or tube and the average inner radii is 0.55 or more, it was possible to effectively suppress generation and progression of wrinkles which might be caused on the inner face of the pipe or tube even when the reduction ratio of the outer diameter was 50% or more. Note that the "average value, in all stands, of the ratios between the curvature radii of the inner faces of positions corresponding to the edge parts of the pipe or tube and the average inner radii" means a value obtained by averaging the ratios between the curvature radii of the inner faces of positions corresponding to the edge parts of the pipe or tube at the output sides of respective stands and the average inner radii, throughout all stands.

[0015] Based on the above-mentioned findings that wrinkles are generated and progressed intensively at positions corresponding to the edge parts of the pipe or tube is due to the fact that the groove profile of the grooved roll is ellipse, the inventors of the present invention have intensively studied conditions under which grooved rolls become closer to a circular shape and the average value, in all stands, of the ratios between the curvature radii of the inner faces of positions corresponding to the edge parts of the pipe or tube and the average inner radii becomes 0.55 or more. As a result, the inventors of the present invention have found that it is only necessary to draw tangents at edge parts facing each other of adjacent grooved rolls in each stand, and to define the minimum value of the angles formed by the tangents in all stands according to the ratio between the thickness and the outer diameter of the pipe or tube at the output side of the sizing mill, so that the present inventors have completed the present invention.

[0016] Namely, the present invention provides a method of manufacturing a pipe or tube, comprising the step of rolling the pipe or tube by using a sizing mill comprising a plurality of stands each of which has a plurality of grooved rolls, wherein the grooved rolls are so configured that when tangents are drawn at edge parts facing to each other of adjacent grooved rolls at each stand, assuming that a minimum value of angles defined by the tangents in all stands is β (deg), an outer diameter of the pipe or tube at an output side of the sizing mill is D (mm), and a thickness of the pipe or tube at the output side of the sizing mill is t (mm), the angle β satisfies a following formula (1):

$$\beta \geq 1.13 \times 10 \times \ln(t/D \times 100) + 1.37 \times 10^2 \dots (1).$$

[0017] According to the present invention, the compression force applied to positions corresponding to the edge parts of the pipe or tube is reduced (distributed) even though the reduction ratio of the outer diameter of the pipe or tube is 50% or more, by using grooved rolls in which the angle β satisfies the above formula (1). As a result, the average value, in all stands, of the ratios between the curvature radii of the inner faces of positions corresponding to the edge parts of the pipe or tube and the average inner radii can be 0.55 or more, whereby it is possible to effectively suppress generation and progression of wrinkles which may be caused on the inner face of the pipe or tube.

[0018] The present invention also provides a sizing mill comprising a plurality of stands each of which has a plurality of grooved rolls, wherein the grooved rolls are so configured that when tangents are drawn at edge parts facing to each other of adjacent grooved rolls at each stand, assuming that a minimum value of angles defined by the tangents in all stands is β (deg), an outer diameter of the pipe or tube at an output side of the sizing mill is D (mm), and a thickness of the pipe or tube at the output side of the sizing mill is t (mm), the angle β satisfies a following formula (1):

$$\beta \geq 1.13 \times 10 \times \ln(t/D \times 100) + 1.37 \times 10^2 \dots (1).$$

[0019] With the method of manufacturing a pipe or tube and the sizing mill according to the present invention, it is possible to effectively suppress generation and progression of wrinkles which may be caused on the inner face of the pipe or tube, when the pipe or tube is rolled by the sizing mill.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020]

Fig. 1 is a schematic diagram showing a sizing mill of three-roll type to which a method of manufacturing a pipe or tube according to an embodiment of the present invention is applied.

Fig. 2 is a graph showing the relationship between the average value, in all stands, of the ratios between the curvature radii of the inner faces at positions corresponding to the edge parts of the pipe or tube and the average inner radii, and the depth of wrinkles generated on the inner face of the pipe or tube, in a case where the reduction ratio of the outer diameter of the pipe or tube is 50% or more.

Fig. 3 is an illustration for explaining an angle defined by tangential lines drawn at the edge parts of grooved rolls.

Fig. 4 is a graph showing the relationship between the minimum value β in all stands of the angle β_0 shown in Fig. 3, the ratio between the thickness t of a pipe or tube and the outer diameter D at the output side of the sizing mill, and the average value, in all stands, of the ratios between the curvature radii of the inner faces at positions corresponding to the edge parts of the pipe or tube and the average inner radii.

Fig. 5 is a graph showing the relationship between the reduction ratio of the outer diameter of the sizing mill and the maximum depth of wrinkles generated in the inner face of a rolled pipe or tube.

Fig. 6 is a schematic diagram showing the groove profile of the grooved rolls according to this embodiment.

Figs. 7(a) to 7(c) are diagrams each partially showing the groove profile of the grooved rolls according to another embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

[0021] Hereinafter, an embodiment of the present invention will be described with reference to the accompanying drawings as appropriate.

[0022] Fig. 1 is schematic diagram showing a sizing mill of three-roll type to which a method of manufacturing a pipe or tube according to an embodiment of the present invention is applied. As shown in Fig. 1, a sizing mill 1 according to this embodiment (in this embodiment, a stretch reducer for rolling) is so configured that three grooved rolls 10, with an angle of 120° in a rolling direction, are provided to each of a plurality of stands (N number of stands, in this embodiment, $N = 17$) #1 to #N, and the rolling rolls 10 are arranged alternately such that the rolling direction thereof is shifted by 60° between adjacent stands. In grooves formed by the respective rolling rolls of the respective stand, a pipe or tube P, to be rolled, is penetrated, and is rolled such that the outer diameter will have a predetermined value at the output side of the last stand #N. The rolling rolls 10 of each stand are set to have dimensions and mounting positions so as to realize a reduction ratio of the outer diameter defined by the following equation (2), provided that the outer diameter of the pipe or tube P at the input side of the sizing mill 1 is D_i , and the outer diameter thereof at the output side is D:

$$\text{Reduction ratio of outer diameter} = (D_i - D)/D_i \times 100(\%) \dots (2).$$

[0023] Fig. 2 is a graph showing the results, studied by the inventors of the present invention, of the relationship between the average value α , in all stands #1 to #N, of the ratios between the curvature radii of the inner faces of positions, corresponding to the edge parts, of the pipe or tube P and the average inner radii, and the depth of wrinkles generated in the inner face of the pipe or tube P, in a case where the reduction ratio of the outer diameter is 50% or more. More specifically, the graph in Fig. 2 shows the relationship between the average value α , in all stands #1 to #N, of the ratios between the curvature radii of the inner faces of positions, corresponding to the edge parts, of the pipe or tube P and the average inner radii, and the depth of wrinkles generated in the inner face of the pipe or tube P, in a case of rolling a carbon steel pipe or tube with the outer diameter of 100 mm and the thickness of 11 mm into that with the outer diameter of 40 mm and the thickness of 9.6 mm, while varying the conditions of the groove profile of the grooved rolls 10 provided to each stand.

[0024] Here, the average value α is a value obtained by measuring the curvature radius and the average inner radius of the inner face of a position corresponding to the edge part of the pipe or tube P by using a three-dimensional shape measuring device (manufactured by Tokyo Seimitsu Co., Ltd.) at the output side of each stand, and averaging, by the total number of stands, the ratios between the both calculated for the output side of each stand based on the measured values. The average value α is obtained through the following procedures (a) to (c).

(a) At the output side of each stand which is an object of measuring the curvature radius of the inner face of a position, corresponding to the edge part, of the pipe or tube P and the average inner radius, rolling of the pipe or

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tube P is stopped (the pipe or tube P is taken out of the sizing mill 1, or the pipe or tube P is not rolled at stands behind the stand and is carried), and a part of the pipe or tube P is cut away as a sample.

(b) As for the sample cut out, the curvature radius of the inner face of a position corresponding to the edge part and the average inner radius are measured by using a three-dimensional shape measuring device, and the ratio between them is calculated.

More specifically, first, the position of the gravitational center of the inner face of the pipe or tube P is calculated based on inner face shape data (coordinate data of each position constituting the inner face) for one cross section of the pipe or tube P measured by using a three-dimensional shape measuring device. Then, by using the coordinate of the inner face part of the pipe or tube P at a position corresponding to the flange parts of the grooved rolls (that is, an inner face part of the pipe or tube P at a position corresponding to the intermediate position between gaps of edge parts facing each other of adjacent grooved rolls), and the coordinate of each inner face part of the pipe or tube P at a position about $\pm 5^\circ$ around the calculated gravitational center from the part, a radius of a circle passing through these three parts is calculated, and the calculated radius is defined as the curvature radius of the inner face of the position corresponding to the edge part. Next, a distance between the gravitational center and each part constituting the inner face of the pipe or tube P is defined as an inner radius, and the average value of the inner radii along the circumferential direction of the pipe or tube P is defined as the average inner radius. In this way, the curvature radius of the inner face of a position corresponding to an edge part and the average inner radius are calculated respectively, and the ratio between them is obtained.

(c) The above procedures (a) and (b) are repeated at the output side of all stands, and measured values (ratios between the curvature radii of the inner faces of positions corresponding to the edge parts and average inner radii) in all stands are averaged so as to calculate α .

[0025] The above procedures will be explained by means of specific examples. For example, each α at a data point "a" ($\alpha = 0.42$, wrinkle depth = 0.135 mm), a data point "b" ($\alpha = 0.57$, wrinkle depth = 0.05 mm) and a data point "c" ($\alpha = 0.92$, wrinkle depth: 0.04 mm) shown in Fig. 2 is a value obtained by averaging the curvature radius r of the inner face of the position corresponding to an edge part/average inner radius d , calculated for the output side of each stand, by the total number of stands, as shown in Table 1.

Table 1

Stand	Point a			Point b			Point c		
	Curvature radius at edge part inner face r (mm)	Average inner radius d (mm)	r/d	Curvature radius at edge part inner face r (mm)	Average inner radius d (mm)	r/d	Curvature radius at edge part inner face r (mm)	Average inner radius d (mm)	r/d
#1	16.9	37.5	0.45	22.6	37.6	0.60	22.6	37.6	0.60
#2	14.3	34.8	0.41	21.6	34.9	0.62	21.6	34.9	0.62
#3	12.8	32.0	0.40	21.0	32.4	0.65	21.0	32.4	0.65
#4	11.9	29.7	0.40	17.7	29.6	0.60	17.7	29.6	0.60
#5	10.7	27.5	0.39	15.3	27.4	0.56	15.3	27.4	0.56
#6	9.4	25.3	0.37	13.7	25.3	0.54	13.7	25.3	0.54
#7	8.5	23.1	0.37	12.3	23.3	0.53	12.3	23.3	0.53
#8	7.5	21.5	0.35	10.8	21.3	0.51	10.8	21.3	0.51
#9	6.9	19.8	0.35	9.7	19.4	0.50	9.7	19.4	0.50
#10	6.1	17.9	0.34	8.5	17.8	0.48	8.5	17.8	0.48
#11	5.3	16.1	0.33	7.9	16.4	0.48	7.9	16.4	0.48
#12	5.0	14.8	0.34	7.2	14.8	0.49	7.2	14.8	0.49
#13	4.9	13.5	0.36	6.6	13.3	0.50	6.6	13.3	0.50
#14	5.8	12.1	0.48	6.7	12.1	0.55	6.7	12.1	0.55
#15	6.4	10.9	0.59	7.2	11.0	0.65	7.2	11.0	0.65

(continued)

	Point a			Point b			Point c		
Stand	Curvature radius at edge part inner face r (mm)	Average inner radius d (mm)	r/d	Curvature radius at edge part inner face r (mm)	Average inner radius d (mm)	r/d	Curvature radius at edge part inner face r (mm)	Average inner radius d (mm)	r/d
#16	6.3	10.5	0.60	7.0	10.7	0.65	7.0	10.7	0.65
#17	7.2	10.5	0.69	7.3	10.4	0.70	7.3	10.4	0.70
Average value α	-	-	0.42	-	-	0.57	-	-	0.57

[0026] Further, the wrinkle depth shown in Fig. 2 means the maximum value of wrinkle depth of the pipe or tube P measured at the output side of the sizing mill 1. It is a value measured by cutting away a part of the pipe or tube P after rolled as a sample, and micro-observing the section.

[0027] As shown in Fig. 2, it is found that from the point where α is about 0.55 as a boundary, the wrinkle depth increases rapidly when α becomes smaller. Accordingly, if α is 0.55 or more, it is possible to effectively suppress generation and progression of wrinkles which may be caused in the inner face of the pipe or tube P.

[0028] In the sizing mill 1 according to this embodiment, there are arranged the rolling rolls 10 satisfying the conditions in which α of the pipe or tube P, to be rolled by the sizing mill 1, becomes 0.55 or more. Hereinafter, reasons for setting conditions for the rolling rolls 10 and the setting conditions will be explained specifically.

[0029] First, as shown in Fig. 3, a tangent La (tangent of the groove profile near an edge part Ea) was drawn at the edge part Ea of a rolling roll 10a provided to each stand, and among edge parts of a rolling roll 10b adjacent the rolling roll 10a, a tangent Lb (tangent of groove profile near an edge part Eb) was drawn at the edge part Eb facing the edge part Ea, and an angle β defined by the both tangents La and Lb was calculated. Note that as shown in Fig. 6, the groove profile of each rolling roll 10 according to this embodiment has an arc with a radius R having the center O' offset (offset amount S) outward from the groove center O (center of the rolling pass line) (in a direction separating from the groove bottom C of the rolling roll 10), and the arc is shaped so as to directly cross a wall face F of the flange side of the rolling roll 10. Then, an edge part E (that is, the end part of the groove profile PR) of the rolling roll 10 corresponds to an end part of the arc of the radius R. The angle β is calculated geometrically based on the groove profile (the angles β of three parts calculated for respective stands take the same value).

[0030] Next, assuming that the minimum value of the angles β in all stands #1 to #N is β (deg), the outer diameter (target outer diameter) of the pipe or tube P at the output side of the sizing mill 1 is D (mm), and the thickness (target thickness) of the pipe or tube P at the output side of the sizing mill 1 is t (mm), it was found through the studies by the inventors of the present invention that β , t/D and α have the relationship shown in Fig. 4. Here, the horizontal axis in Fig. 4 shows t/D (%), and the vertical axis shows β (deg). Further, data plotted with "o" shows that α of the rolled pipe or tube P is 0.55, data plotted with "●" shows that α of the rolled pipe or tube P is larger than 0.55, and data plotted with "×" shows that α is less than 0.55.

[0031] More specifically, the data point A (t/D = 24.0%, β = 173 deg) shown in Fig. 4, for example, is data obtained when a carbon steel pipe or tube with the outer diameter of 100 mm and the thickness of 11 mm is rolled to be that with the outer diameter of 40 mm and the thickness of 9.6 mm under conditions shown in Table 2. That is, under the conditions shown in Fig. 2, since the minimum value β in all stands #1 to #17 of the angles β is 173 deg, and t/D = 24.0% at the output side of the sizing mill 1 (that is, output side of the stand #17), the data is plotted in the coordinates shown in Fig. 4.

Table 2

Stand	Output side outer diameter D (mm)	Output side thickness t (mm)	β (deg)	Outer diameter reduction ratio at single stand (%)	t/D (%)
#1	97.0	10.9	173	3	11.2
#2	91.2	10.8	173	6	11.8
#3	85.7	10.7	173	6	12.5
#4	80.6	10.6	173	6	13.2
#5	75.7	10.5	173	6	13.9

(continued)

	Stand	Output side outer diameter D (mm)	Output side thickness t (mm)	β_0 (deg)	Outer diameter reduction ratio at single stand (%)	t/D (%)
5	#6	71.2	10.4	173	6	14.6
	#7	66.9	10.3	173	6	15.4
	#8	62.9	10.2	173	6	16.2
10	#9	59.1	10.1	173	6	17.1
	#10	55.6	10.0	173	6	18.0
	#11	52.2	9.9	173	6	18.9
	#12	49.1	9.8	173	6	20.0
15	#13	46.2	9.7	173	6	21.0
	#14	43.4	9.6	173	6	22.1
	#15	41.2	9.6	178	5	23.3
20	#16	40.4	9.6	178	2	23.8
	#17	40.0	9.6	180	1	24.0

[0032] As obvious from Fig. 4, in order to set α to 0.55 or more, β should be set to a predetermined value or more with respect to each t/D. Now, in this embodiment, a value of β with which α is 0.55 to each t/D is approximated by a function (natural logarithmic function) where the variable is t/D, and then the groove profile of the rolling roll 10 is set such that β takes a value of the approximate function or more. More specifically, the groove profile of the rolling roll 10 is set such that the angle β satisfies the following formula (1):

$$\beta \geq 1.13 \times 10 \times \ln(t/D \times 100) + 1.37 \times 10^2 \dots (1).$$

[0033] When rolling is performed by using the rolling rolls 10 in which the above-mentioned settings are performed, it is possible to set α of the pipe or tube P to 0.55 or more as described above, so it is possible to effectively suppress generation and progression of wrinkles which may be caused in the inner face of the pipe or tube P.

[0034] Note that the groove profile PR of each rolling roll 10 according to this embodiment has a single arc with a radius R, and the edge part E of the rolling roll 10 (that is, an end part of the groove profile PR) corresponds to an end part of the arc with the radius R, as described with reference to Fig. 6. However, the groove profile of each rolling roll 10 according to the present invention is not limited to this. It is possible to adopt rolling rolls having various groove profile as shown in Figs. 7(a) to 7(c). Figs. 7(a) to 7(c) are diagrams each showing a part corresponding to the area circled by a dotted line in Fig. 6, for the groove profile of grooved rolls according to other embodiments of the present invention. As shown in Fig. 7(a), as a groove profile PR of each rolling roll 10 according to the present invention, it is possible to adopt a shape composed of a plurality of arcs with different radii and directly crossing the wall face F of the flange side. The edge part E of the rolling roll 10 in such a case corresponds to an end part of an arc (radius Rn) positioned closest to the flange side. Further, it is also possible to adopt a shape (Fig. 7(b)) in which a so-called "escape" is formed of an arc (radius r) protruded inwardly (toward the groove center), and a shape (Fig. 7(c)) in which an "escape" is formed of a line, between the groove profile PR formed of a single arc or a plurality of arcs and the wall face F of the flange side. Even in such cases, the edge part E of the rolling roll 10 corresponds to an end part (end part of an arc positioned closest to the flange side) of the arc constituting the groove profile PR.

[0035] Further, although a sizing mill of three-roll type has been exemplary described in this embodiment, the present invention is not limited to this type. The present invention is applicable to sizing mills with a plurality of grooved rolls at each stand, such as four-roll type and two-roll type, in the similar manner.

Claims

1. A method of manufacturing a pipe or tube, comprising the step of rolling the pipe or tube by using a sizing mill comprising a plurality of stands each of which has a plurality of grooved rolls, wherein

the grooved rolls are so configured that when tangents are drawn at edge parts facing to each other of adjacent grooved rolls at each stand, assuming that a minimum value of angles defined by the tangents in all stands is β (deg), an outer diameter of the pipe or tube at an output side of said sizing mill is D (mm), and a thickness of the pipe or tube at the output side of said sizing mill is t (mm), said angle β satisfies a following formula (1):

$$\beta \geq 1.13 \times 10 \times \ln(t/D \times 100) + 1.37 \times 10^2 \dots (1).$$

2. A sizing mill comprising a plurality of stands each of which has a plurality of grooved rolls, wherein the grooved rolls are so configured that when tangents are drawn at edge parts facing to each other of adjacent grooved rolls at each stand, assuming that a minimum value of angles defined by the tangents in all stands is β (deg), an outer diameter of the pipe or tube at an output side of said sizing mill is D (mm), and a thickness of the pipe or tube at the output side of said sizing mill is t (mm), said angle β satisfies a following formula (1):

$$\beta \geq 1.13 \times 10 \times \ln(t/D \times 100) + 1.37 \times 10^2 \dots (1).$$

Fig. 1

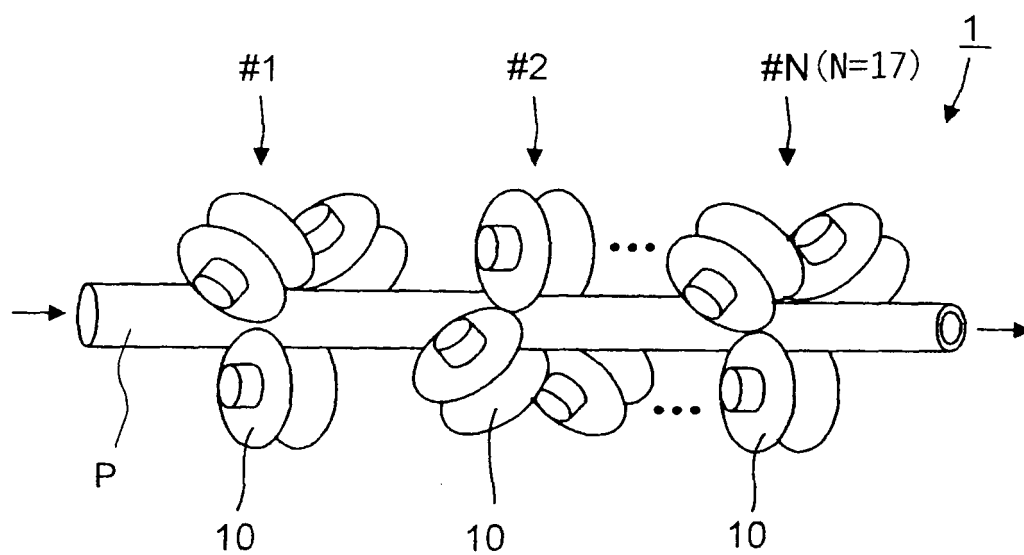


Fig. 2

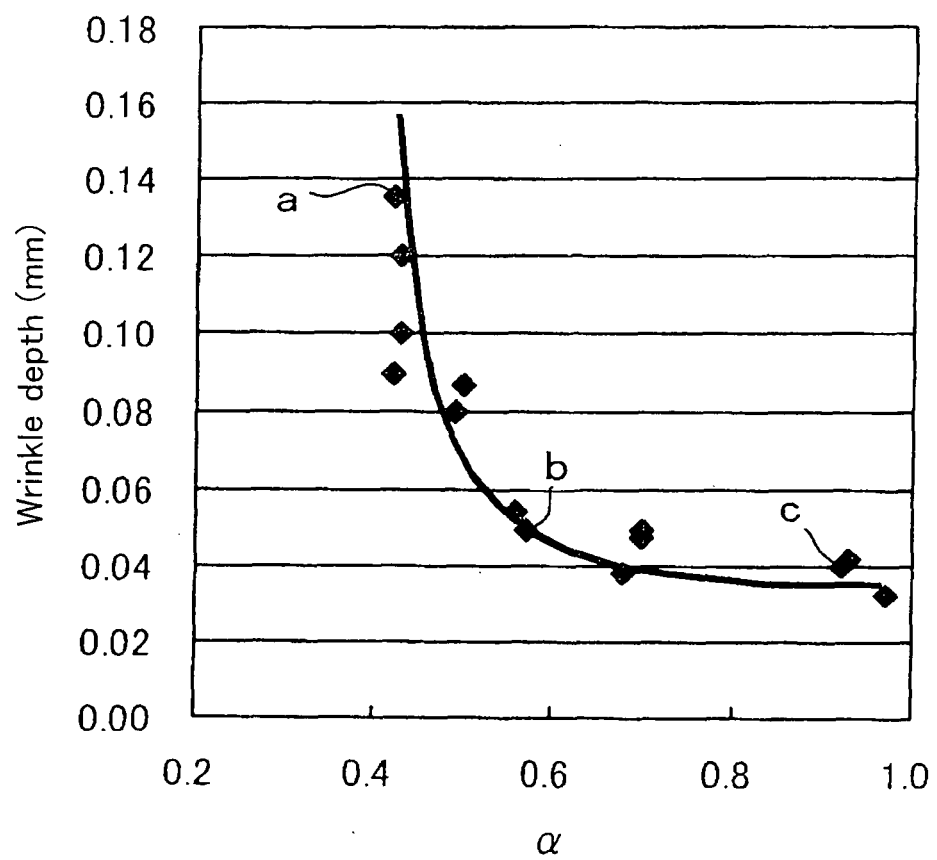


Fig. 3

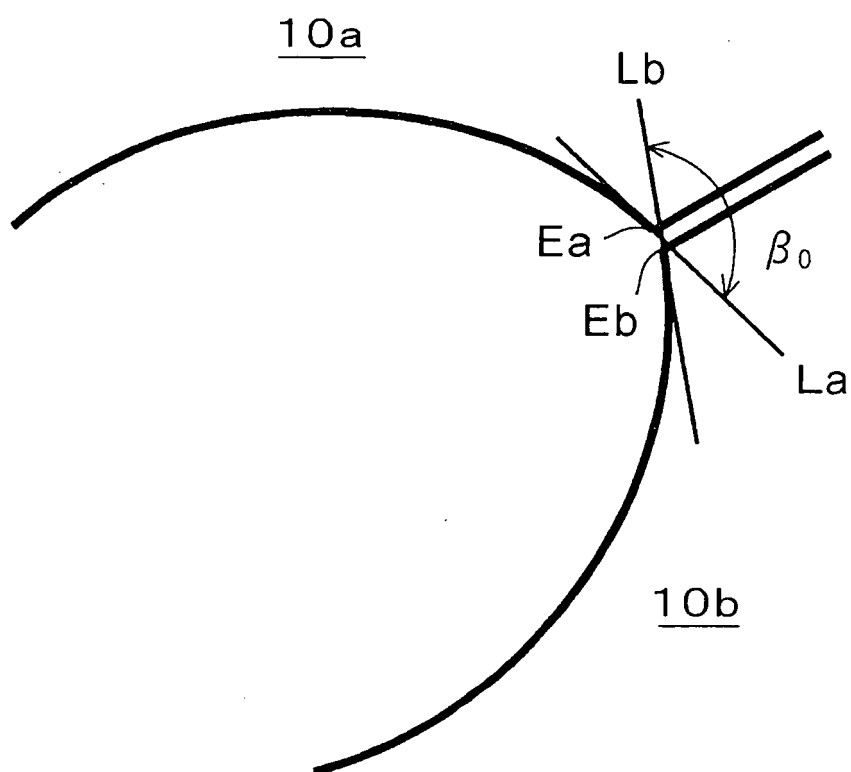


Fig. 4

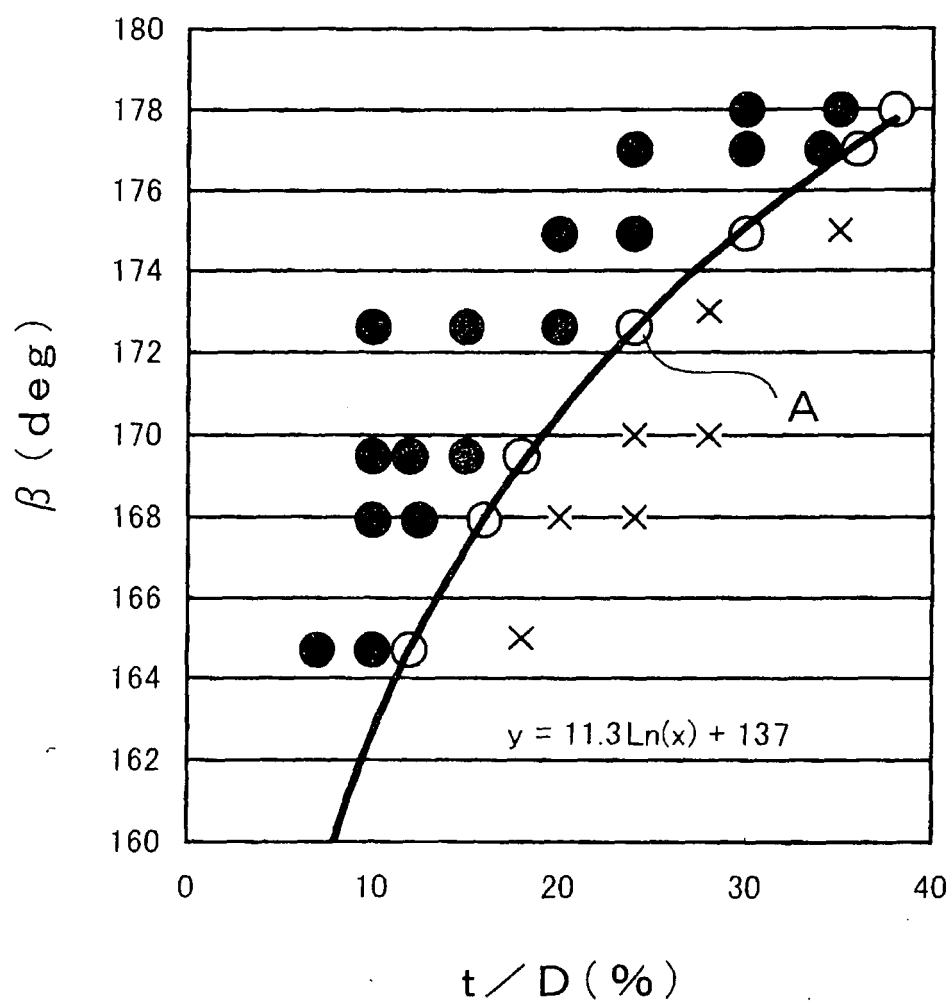


Fig. 5

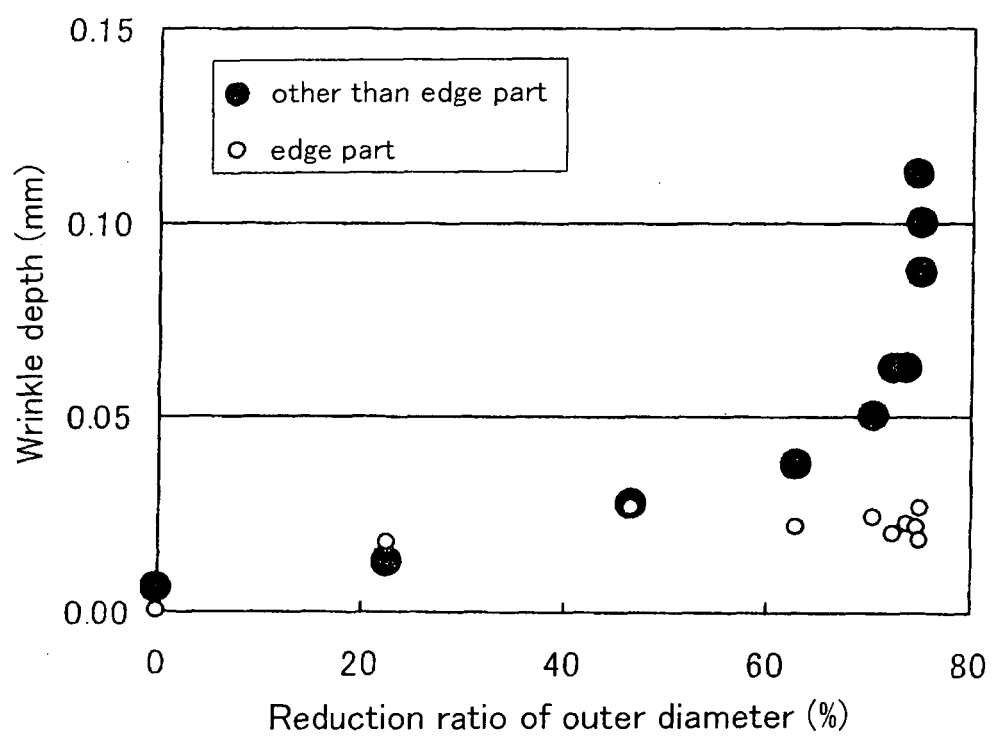


Fig. 6

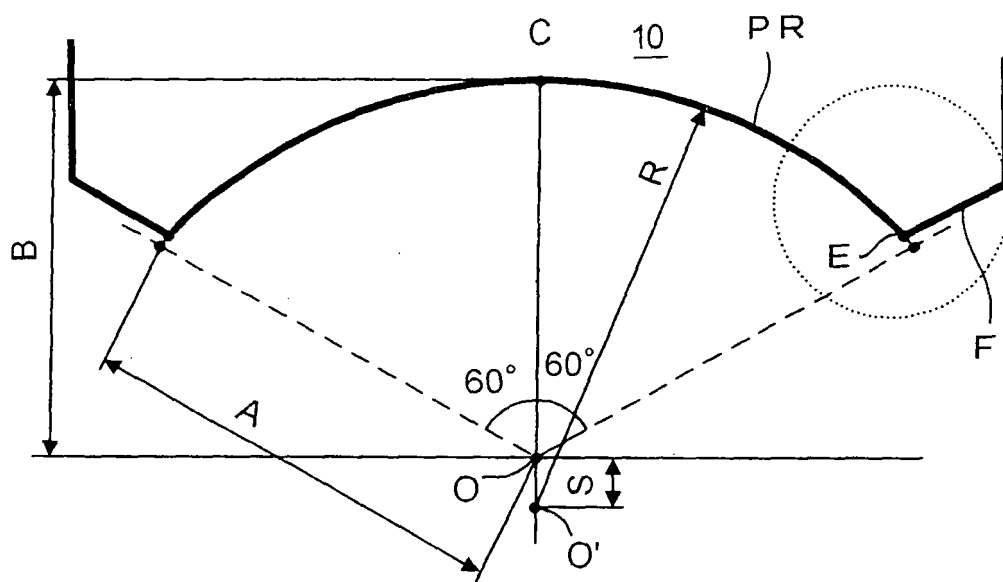
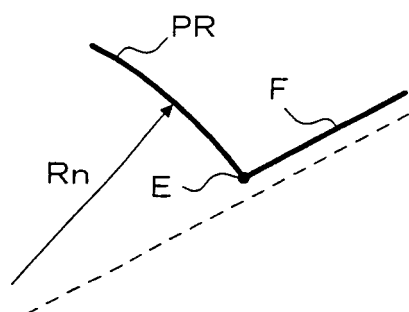
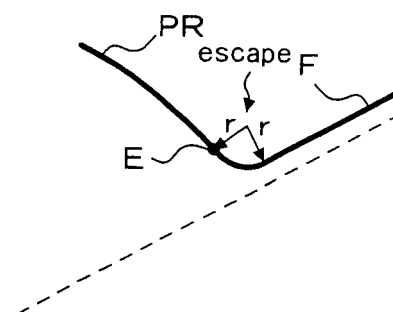


Fig. 7

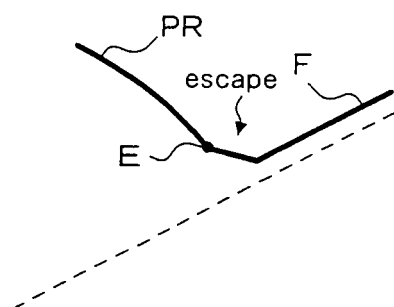
(a)



(b)



(c)



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2005/005198

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl. ⁷ B21B17/14, 27/02		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) Int.Cl. ⁷ B21B17/14, 27/02		
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 1996-2005 Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005		
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 10-156412 A (Sumitomo Metal Industries, Ltd.), 16 June, 1998 (16.06.98), Par. No. [0015]; tables 2, 3; Fig. 4 (Family: none)	1, 2
A	JP 61-216805 A (NKK Corp.), 26 September, 1986 (26.09.86), Full text (Family: none)	1, 2
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 09 May, 2005 (09.05.05)		Date of mailing of the international search report 24 May, 2005 (24.05.05)
Name and mailing address of the ISA/ Japanese Patent Office		Authorized officer
Facsimile No.		Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)