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(71) Applicant: **SUMITOMO METAL INDUSTRIES, LTD.**
Osaka-shi, Osaka 541-0041 (JP)

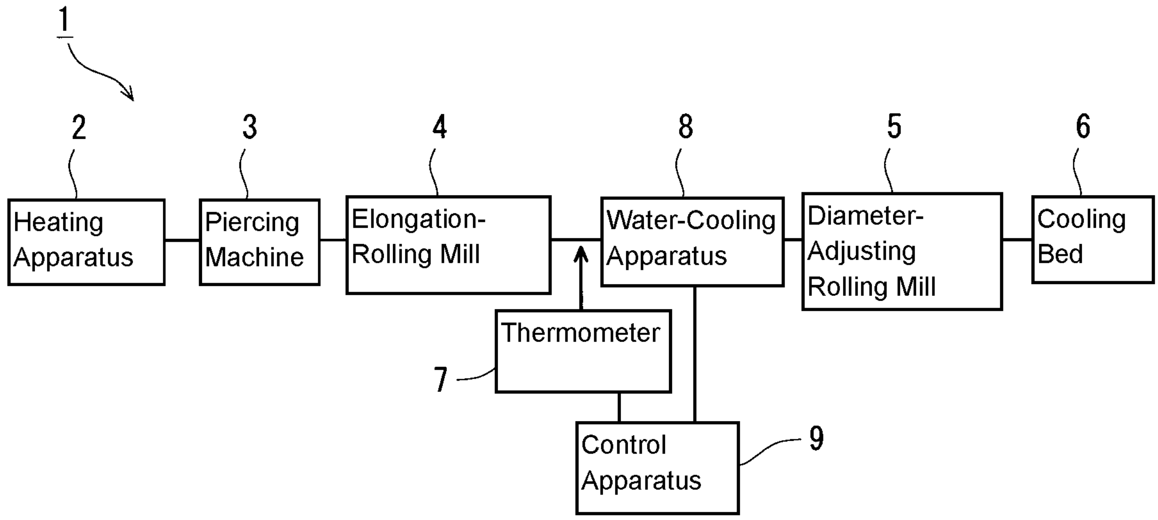
(72) Inventor: **SENDAI Yusuke**
Osaka-shi
Osaka 541-0041 (JP)

(74) Representative: **Zimmermann & Partner**
Postfach 330 920
80069 München (DE)

(54) METHOD OF PRODUCING SEAMLESS PIPE AND APPARATUS FOR PERFORMING THE SAME

(57) In the production of a seamless steel tube by piercing-rolling a heated billet with a piercing machine to form the billet into a hollow blank, and without reheating the hollow blank, by successively subjecting the hollow blank to elongation-rolling with an elongation-rolling mill and diameter-adjusting rolling by a diameter-adjusting rolling mill, it is made possible to prevent non-uniform longitudinal temperature distribution from occurring in a steel tube after diameter-adjusting rolling and enable energy saving to be accomplished by including a step 1 of measuring a temperature of the hollow blank along a longitudinal direction at the exit of the elongation-rolling mill; and a step 2 of spraying water onto the hollow blank to cool the hollow blank at the entrance of the diameter-adjusting rolling mill according to a measured longitudinal temperature distribution of the hollow blank, whereby the longitudinal temperature distribution of the hollow blank becomes uniform.

FIG. 1



EP 2 422 892 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to a method for producing a seamless steel tube by the Mannesmann tube-making process, and a production facility for a seamless steel tube suitable for carrying out the production method.

BACKGROUND ART

[0002] A seamless steel tube can be used for oil well tubes for which high strength and toughness are required and can be produced by the Mannesmann tube-making process. This tube-making process consists of the following steps:

(1) piercing-rolling a billet, which is heated to a predetermined temperature, by a piercing machine (piercer) to form the billet into a hollow blank (hollow shell);
(2) elongation-rolling the hollow blank by an elongation-rolling mill (for example, a mandrel mill);
(3) diameter-adjusting rolling the hollow blank, which was subjected to elongation-rolling, to have a predetermined outer diameter and a wall thickness by a diameter-adjusting rolling mill (for example: a sizer and a stretch reducer); and
(4) air cooling the seamless steel tube obtained by the diameter-adjusting rolling by a cooling bed, or otherwise subjecting the seamless steel tube to quenching and tempering.

[0003] Conventionally, in a production facility that adopts the Mannesmann tube-making process, a tube blank that was subjected to elongation-rolling is heated by a reheating furnace and is subjected to diameter-adjusting rolling. Moreover, when performing the quenching of a steel tube that underwent diameter-adjusting rolling, the steel tube is again heated by a quenching furnace and is quenched.

[0004] Recently, in order to promote the energy saving and improve the production efficiency, a reheating furnace in the diameter-adjusting rolling process and a quenching furnace in the quenching process are eliminated, and a series of processes from piercing-rolling to diameter-adjusting rolling, and in some cases to quenching, may be arranged online as an online production facility. In such a production facility where the reheating furnace and the quenching furnace are eliminated, reheating will not be performed at all even in diameter-adjusting rolling and quenching processes once the workpiece is heated for piercing-rolling. When such a production facility is adopted, it is likely that a steel tube after the diameter-adjusting rolling tends to have non-uniform temperature distribution along a longitudinal direction such that the top part (front end part) of the tube has a lower temperature and the bottom part (rear end part) has a higher temperature. Such phenomenon occurs for the following reason.

[0005] Since the heated billet is pierced by a plug from its top part to the bottom part during piercing-rolling, more heat is dissipated in the top part, which is pierced first and is formed into a tube. As a result, in a hollow blank after piercing-rolling, the top part tends to have a lower temperature and the bottom part tends to have a higher temperature. Since the reheating of the workpiece is inhibited, such non-uniformity in longitudinal temperature distribution also occurs in a similar fashion in the hollow blank after elongation- rolling, and further in a steel tube after diameter-adjusting rolling in a similar fashion. Thus, in a steel tube after diameter-adjusting rolling, non-uniformity of temperature distribution along a longitudinal direction occurs.

[0006] When the temperature distribution along a longitudinal direction is non-uniform in a steel tube after diameter-adjusting rolling, the amount of heat shrinkage of the steel tube varies along a longitudinal direction while cooling, so that the diameter of the steel tube gets non-uniform along a longitudinal direction after cooling. Further, when a steel tube is subjected to quenching after diameter-adjusting rolling, the temperature distribution along a longitudinal direction is non-uniform and causes the level of quenching to vary along a longitudinal direction, whereby the mechanical properties of the steel tube becomes non-uniform along a longitudinal direction after quenching.

[0007] In the prior art regarding the temperature control of the workpiece in the production of a steel tube, the followings can be listed.

[0008] Patent Literature 1 discloses a technology to prevent the temperature of the workpiece from being excessively lowered while undergoing a continuous mill in a multi-stand continuous mill for use in the production of seamless steel tubes. In the technology disclosed in the above mentioned literature, a reheating furnace is disposed at both the entrance and the intermediate position of the continuous mill, and thermometers are disposed at both the entrance and the exit of the intermediate reheating furnace, which is disposed at the intermediate position of the continuous mill, and further at the exit of the continuous mill so that the temperature control of the intermediate reheating furnace is performed based on the temperature of steel tube measured by each thermometer.

[0009] Patent Literature 2 discloses a technology of preventing the occurrence of wall thickness deviation caused by temperature decrease along a circumferential direction of a steel tube in a stretch reducer used in the production of electric resistance welded steel tubes. In the technology disclosed in the above mentioned literature, a plurality of induction heating coils are disposed in series at the entrance of the stretch reducer, and a thermometer is disposed at both the exit side of the induction heating coil and the exit side of the stretch reducer, so that the electric power supply to the induction heating coil is adjusted based on the temperature values measured by the thermometer along a circumferential direction of the steel tube.

[0010] Patent Literature 3 discloses a technology for preventing the occurrence of bends when a rectangular steel tube or a round steel tube which has undergone hot forming is s cooled. In the technology disclosed in the same literature, a reheating furnace is disposed at the preceding stage of the forming means for hot forming a steel tube into a predetermined geometry, and water discharge means is disposed at the subsequent stage of the forming means so that water is sprayed onto the steel tube along its entire circumferential direction, that has undergone the forming means to thereby uniformly cool the steel tube.

[0011] In the technologies disclosed in the above described Patent Literatures 1 to 3, the steel tube is reheated before diameter-adjusting rolling so as to ensure uniform temperature distribution, and therefore there will be no situation where the longitudinal temperature distribution becomes non-uniform in a steel tube after diameter-adjusting rolling. In any of the technologies disclosed in the above described Patent Literatures 1 to 3, however, since a reheating furnace and an induction heating coil are indispensable at the preceding stage of the diameter-adjusting rolling mill, a significant amount of fuel and/or electric power are consumed and therefore any of those technologies can not provide an energy saving measure.

CITATION LIST

PATENT LITERATURE

[0012]

Patent Literature 1: Japanese Patent Application Publication No. 2004-58128
Patent Literature 2: Japanese Patent Application Publication No. 2005-7452
Patent Literature 3: Japanese Patent Application Publication No. 2007-301574

SUMMARY OF INVENTION

TECHNICAL PROBLEM

[0013] It is an object of the present invention to provide a method for producing a seamless steel tube and a production facility therefor, which have the following features:

(1) preventing non-uniform longitudinal temperature distribution from occurring in a steel tube after diameter-adjusting rolling; and
(2) enabling energy saving to be accomplished

SOLUTION TO PROBLEM

[0014] Key aspects of the present invention are as follows.

[0015] (I) A method for producing a seamless steel tube by piercing-rolling a heated billet by a piercing machine to form the billet into a hollow blank, and without reheating the hollow blank, by successively subjecting the hollow blank to elongation-rolling with an elongation-rolling mill and diameter-adjusting rolling with a diameter-adjusting rolling mill, the method including the steps of:

(step 1) measuring a temperature of the hollow blank along a longitudinal direction at the exit of the elongation-rolling mill; and
(step 2) spraying water onto the hollow blank to cool the hollow blank at the entrance of the diameter-adjusting rolling mill according to a measured longitudinal temperature distribution of the hollow blank, whereby the longitudinal temperature distribution of the hollow blank becomes uniform.

[0016] The production method of the above described (I) may be configured such that quenching is performed without reheating subsequently to the diameter-adjusting rolling.

[0017] These production methods are preferably configured such that the amount of water to be sprayed onto the hollow blank in the above described step 2 is adjusted for every plurality of regions of the hollow blank sectioned in the longitudinal direction.

[0018] (II) A production facility for a seamless steel tube including a piercing machine for piercing-rolling a heated billet to form the billet into a hollow blank, and an elongation-rolling mill for elongation-rolling the hollow blank and a diameter-adjusting rolling mill for diameter-adjusting rolling the hollow blank without reheating the hollow blank, the production facility including:

a thermometer disposed at the exit of the elongation-rolling mill and for measuring a temperature of the hollow blank along a longitudinal direction; and
a water-cooling apparatus disposed at the entrance of the diameter-adjusting rolling mill, and for spraying water onto the hollow blank to cool the hollow blank according to a longitudinal temperature distribution of the hollow blank measured by the thermometer such that the longitudinal temperature distribution of the hollow blank becomes uniform.

ADVANTAGEOUS EFFECTS OF INVENTION

[0019] The method for producing a seamless steel tube of the present invention has the following remarkable effects of:

(1) preventing non-uniform longitudinal temperature distribution from occurring in a steel tube after diameter-adjusting rolling; and
(2) enabling energy saving to be accomplished.

[0020] The excellent effects of the production method of the present invention can be fully exerted by the production facility for a seamless steel tube of the present invention.

BRIEF DESCRIPTION OF DRAWINGS

[0021]

[FIG. 1] FIG. 1 is a block diagram to illustrate a configuration example of a production facility for a seamless steel tube of the present invention.
[FIG. 2] FIG. 2 is a diagram to illustrate a configuration example of a water-cooling apparatus in the production facility for a seamless steel tube of the present invention, in which FIG. 2 (a) shows a side sectional view along a traveling direction of a hollow blank, and FIG. 2 (b) shows a front view, respectively.
[FIG. 3] FIG. 3 is a diagram to illustrate the correlation between the water amount to be sprayed per one meter in a longitudinal direction of the hollow blank and the amount of temperature reduction.

DESCRIPTION OF EMBODIMENTS

[0022] In order to achieve the above described object, the present inventors have made an arduous study on a method for preventing non-uniformity of the longitudinal temperature distribution from occurring in a steel tube after diameter-adjusting rolling, based on the precondition that reheating is not performed all the way through diameter-adjusting rolling and quenching, once the workpiece is heated for piercing-rolling. As a result, the following findings (a) and (b) have been obtained.

[0023]

(a) By making the longitudinal temperature distribution uniform in the hollow blank before diameter-adjusting rolling, it is possible to prevent non-uniformity of the longitudinal temperature distribution in the steel tube after diameter-adjusting rolling.
(b) To make the longitudinal temperature distribution uniform in the hollow blank before diameter-adjusting rolling, it is effective to cool the hollow blank by spraying water onto the hollow blank according to the longitudinal temperature distribution of the hollow blank.

[0024] The present invention has been completed based on the above described findings (a) and (b). Hereafter, preferable embodiments of the method for producing a seamless steel tube and the production facility therefor of the present invention will be described.

1. Production facility for seamless steel tube

[0025] FIG. 1 is a block diagram to illustrate a configuration example of a production facility for a seamless steel tube of the present invention. As shown in the same figure, a production facility 1 includes, as a series of equipments in an online facility, a heating apparatus 2, a piercing machine 3 (piercer), an elongation-rolling mill 4 (for example, a mandrel mill), a diameter-adjusting rolling mill 5 (for example, a sizer and a stretch reducer), and a cooling bed 6. Further, the production facility 1 includes a thermometer 7 disposed at the exit of the elongation-rolling mill 4, a water-cooling apparatus 8 disposed at the entrance of the following diameter-adjusting rolling mill 5, and a control apparatus 9, which is connected to the thermometer 7 and the water-cooling apparatus 8.

[0026] The heating apparatus 2 heats a billet as a workpiece to a predetermined temperature suitable for piercing-rolling. The piercing machine 3 pierces and rolls the heated billet to form it into a hollow blank. The elongation-rolling mill 4 elongates and rolls the hollow blank without reheating it. The diameter-adjusting rolling mill 5 performs diameter-adjusting rolling of the hollow blank that underwent elongation-rolling, without reheating it, thereby finishing a steel tube having a predetermined outer diameter and a wall thickness. The steel tube that underwent diameter-adjusting rolling is air-cooled in the cooling bed 6.

[0027] In this production facility 1, when performing diameter-adjusting rolling by the diameter-adjusting rolling mill 5, the temperature of the hollow blank which underwent elongation-rolling by the elongation-rolling mill 4 is measured by the thermometer 7 along a longitudinal direction. The control apparatus 9 successively receives signals of measured temperature from the thermometer 7 and calculates the temperature distribution along a longitudinal direction of the hollow blank to send action signals according to the temperature distribution to the water-cooling apparatus 8. The water-cooling apparatus 8 sprays an appropriate amount of water onto the hollow blank based on the action signals from the control apparatus 9 to cool the hollow blank so that the longitudinal temperature distribution of the hollow blank becomes uniform. The cooled hollow blank is subjected to diameter-adjusting rolling by the diameter-adjusting rolling mill 5.

[0028] In this production facility 1, the hollow blank is transported in its longitudinal direction by a roller conveyor from the piercing machine 3 to the elongation-rolling mill 4, and from the elongation-rolling mill 4 to the diameter-adjusting rolling mill 5 through the water-cooling apparatus 8.

[0029] FIG. 2 is a diagram to illustrate a configuration example of a water-cooling apparatus in the production facility for a seamless steel tube of the present invention, in which FIG. 2 (a) shows a side sectional view along the traveling direction of a hollow blank, and FIG. 2 (b) shows a front view, respectively. In FIG. 2 (a), the traveling direction of the hollow blank is shown by a bold arrow.

[0030] As shown in the same figure, the cooling apparatus 8 includes an annular ring made of pipe 11 wherein the center of the ring is positioned on the traveling path of the hollow blank P that passes through the ring. The annular ring of pipe 11 is connected with a water supply tube 12, which is connected with a water supply pump 13. The water supply pump 13 can be actuated based on the action signal from the control apparatus 9 shown in FIG. 1 described above so as to enable to adjust the amount of water to be supplied.

[0031] In the inner periphery of the annular ring of pipe 11, a plurality of nozzles 14 are disposed at constant intervals along a circumferential direction. Each nozzle 14 sprays out water that is supplied to the annular ring of pipe 11 through the water supply tube 12 when the water supply pump 13 is actuated. As a result, the hollow blank P which is traveled in a longitudinal direction is cooled uniformly along a circumferential direction every time it passes through the annular ring of pipe 11.

[0032] The number of nozzles 14 is, though not particularly limited to, preferably about 4 to 24. This is because, if it is less than 4, uniform cooling may be insufficient along a circumferential direction of the hollow blank P, and if it is more than 24, it becomes redundant since sufficient uniform cooling should be achieved by specified nozzles.

[0033] Each nozzle 14 is preferably slightly inclined toward the opposite direction relative to the traveling direction of the hollow blank P (or the direction toward the bottom part side of the hollow blank). That is to prevent water from entering the inside of the hollow blank P, which has passed the annular ring of pipe 11, from its rear end.

[0034] The production facility 1 shown in FIG. 1 described above may install the water-cooling apparatuses 8 of such configuration at multiple stages along the traveling path of the hollow blank P, but the installation of the water-cooling apparatus 8 at a single stage fares well. A radiation thermometer may be adopted as the thermometer 7.

[0035] The production facility 1 shown in FIG. 1 described above may include a rapid cooling apparatus in place of the cooling bed 6, or in parallel with the cooling bed 6 without a quenching furnace being disposed, to perform quenching of the steel tube after diameter-adjusting rolling. As the rapid cooling apparatus, one of water bath dipping type or one of laminar water downflowing type may be adopted. A tempering furnace may be disposed at the subsequent stage of the rapid cooling apparatus in order to perform tempering of the steel tube after quenching.

2. Method for producing seamless steel tube

[0036] Referring to FIG. 1 described above, the method for producing a seamless steel tube of the present invention will be described. In the production method of the present invention, a heated billet is subjected to piercing-rolling by the piercing machine 3 to be formed into a hollow blank, and is successively subjected to elongation-rolling by the elongation-rolling mill 4 and diameter-adjusting rolling by the diameter-adjusting rolling mill 5 without reheating the hollow blank at all.

[0037] In this process, there is a risk that the hollow blank after piercing-rolling tends to have non-uniform temperature distribution along its longitudinal direction caused by a significant amount of heat dissipation in its top part during piercing-rolling: therefore, the hollow blank after elongation-rolling should also have non-uniform temperature distribution along its longitudinal direction in a similar fashion.

[0038] In this regard, in the production method of the present invention, when performing diameter-adjusting rolling by the diameter-adjusting rolling mill 5, the temperature of the hollow blank is measured along a longitudinal direction by the thermometer 7 at the exit of the elongation-rolling mill 4. Then, water is sprayed onto the hollow blank at the entrance of the diameter-adjusting rolling mill 5 by the water-cooling apparatus 8 to cool the hollow blank according to the measured longitudinal temperature distribution of the hollow blank thereby making the longitudinal temperature distribution of the hollow blank uniform.

[0039] To be specific, the control apparatus 9 connected to the thermometer 7 determines the temperature for each of plural regions that are virtually allotted along the length of the hollow blank in a longitudinal direction, and selects a minimum temperature reading among the temperatures of allotted regions to determine temperature difference values between the minimum temperature and each region temperature. Then, based on the temperature differences, the amount of water to be sprayed onto the hollow blank from the water-cooling apparatus 8 is calculated for every region, and an action signal corresponding to the amount of water is transmitted to the water-cooling apparatus 8. Thereby, the traveling hollow blank is cooled by being sprayed with an appropriate amount of water for each allotted region from the water-cooling apparatus 8, thereby having a uniform longitudinal temperature distribution.

[0040] Here, there is a correlation between the amount of water to be sprayed to the hollow blank, and the amount of temperature reduction. Therefore, the amount of water to be sprayed onto the hollow blank can be calculated, for example, from the correlation with the amount of temperature reduction of the hollow blank shown in FIG. 3 described below, based on the above described temperature difference for each allotted region of the hollow blank.

[0041] FIG. 3 is a diagram to illustrate the correlation between the water amount to be sprayed per one meter of the hollow blank in a longitudinal direction and the amount of temperature reduction. The same figure shows the result of the investigation of the amount of temperature reduction of the area where water is sprayed by performing testing in which hollow blanks with varied outer diameters and wall thicknesses are used, and water is sprayed onto each hollow blank heated to 1100 °C by varying the amount of water to be sprayed per one meter in its longitudinal direction.

[0042] As shown in the same figure, there is a correlation: $\Delta T = 160 \times Q$ between the amount of water Q [m^3] to be sprayed onto the hollow blank and the amount of temperature reduction ΔT [°C] regardless of dimensions of the outer diameter and wall thickness of the hollow blank. From this correlation expression, it is possible to calculate the amount of water Q to be sprayed onto the hollow blank with the above described temperature difference being ΔT for an allotted region of the hollow blank.

[0043] According to the method for producing a seamless steel tube of the present invention, since it is possible to spray water onto the hollow blank thereby making the longitudinal temperature distribution uniform when performing diameter-adjusting rolling, it never happens that the longitudinal temperature distribution becomes non-uniform in a steel tube after diameter-adjusting rolling. As a result, in the steel tube after diameter-adjusting rolling, the amount of heat shrinkage associated with cooling will not vary along a longitudinal direction, so that the outer diameter of the steel tube will become uniform over the entire region in a longitudinal direction after cooling. Moreover, even when the steel tube is subjected to quenching after diameter-adjusting rolling, the level of quenching will not vary along a longitudinal direction, and the mechanical properties of the steel tube become uniform over the entire region in a longitudinal direction after quenching.

[0044] Moreover, according to the method for producing a seamless steel tube of the present invention, since reheating will not be performed all the way through diameter-adjusting rolling and quenching once the heating of the workpiece is performed for piercing-rolling, a significant amount of fuel and electric power will not be consumed, thereby enabling energy saving to be accomplished.

[0045] The effects of the method for producing a seamless steel tube of the present invention can be fully exerted by the production facility for a seamless steel tube of the present invention.

EXAMPLES

(Example 1)

[0046] In order to confirm the effects of the present invention, a full scale testing for producing a seamless steel tube of the specification described as below was carried out by performing piercing-rolling, elongation-rolling, and diameter-adjusting rolling by using the production facility shown in FIG. 1 described above.

Dimensions: Outer diameter 406.4 mm, wall thickness 30.7 mm, and length 12 m

Material grade: Low carbon steel (C: 0.6 wt%)

[0047] When performing diameter-adjusting rolling, the temperature of the hollow blank after elongation-rolling was measured and water was sprayed by the amount shown in Table 1 shown below on the hollow blank according to its longitudinal temperature distribution. Moreover, testing was carried out without spraying water for the comparison purpose.

[0048] [Table 1]

Table 1

Category	Region	Temperature before rolling [°C]	Amount of cooling water [m^3]	Temperature immediately after rolling [°C]	Outer diameter after cooling [mm]
Inventive Example	Top part	1105	0.000	1050	406.4
	Middle part	1125	0.125	1050	406.4
	Bottom part	1145	0.250	1050	406.4
Comparative Example	Top part	1105	None	1050	406.6
	Middle part	1125	None	1070	406.4
	Bottom part	1145	None	1090	406.2

[0049] The temperature of the seamless steel tube was measured immediately after diameter-adjusting rolling and, after further cooling the steel tube, the outer diameter of the steel tube was measured over the entire region in a longitudinal direction. The result thereof is also shown together in Table 1. In Table 1, the results for a top part region which is within 1 to 3 m from the front end of the steel tube, a middle part region which is in the range of 2 m across the length-wise middle of the steel tube, and a bottom part region which is within 1 to 3 m from the rear end of the steel tube are shown.

[0050] The results shown in Table 1 have revealed the followings.

[0051] In Inventive Examples of the present invention, as a result of spraying water onto the hollow blank before diameter-adjusting rolling, the temperature of the steel tube immediately after diameter-adjusting rolling was made uniform in a longitudinal direction. As a result, in the steel tube after cooling, the outer diameter became uniform in the longitudinal direction.

[0052] In Comparative Examples, since water was not sprayed onto the hollow blank before diameter-adjusting rolling, the temperature of the steel tube immediately after diameter-adjusting rolling became non-uniform with a deviation of about 40 °C in a longitudinal direction. As a result, in the steel tube after cooling, the outer diameter became non-uniform with a deviation of about 0.4 mm in the longitudinal direction.

(Example 2)

[0053] A full scale testing for producing a seamless steel tube of the specification described as below was carried out by performing piercing-rolling, elongation-rolling, and diameter-adjusting rolling by using the production facility shown in FIG. 1 described above, thereby confirming the effects of water spraying onto the hollow blank on the mechanical properties of the steel tube.

Dimension: Outer diameter 406 mm, wall thickness 14 mm, and length 12 m
Material grade: Low carbon steel with the chemical composition shown in Table 2 shown below.
Mechanical property: API standard grade X65

[0054] [Table 2]

Table 2

Unit: mass%								
C	Si	Mn	P	S	Cu	Cr	Ni	Mo
0.05 ~ 0.07	0.20~ 0.30	1.47 ~ 1.55	0.013 or less	0.0014 or less	0.02 ~ 0.05	0.25 ~ 0.30	0.02 ~ 0.05	0.26 ~ 0.28
						Ti	V	Nb
						0.017 ~ 0.022	0.01 or less	0.023 ~ 0.033

[0055] When performing diameter-adjusting rolling, the temperature of the hollow blank after elongation-rolling was measured and, according to its longitudinal temperature distribution, water was sprayed onto the hollow blank by the amount of water shown in Table 3 described below. Moreover, for the purpose of comparison, testing was carried out without spraying water.

[0056] [Table 3]

Table 3

Category	Region	Temperature before rolling [°C]	Amount of cooling water [m^3]	Temperature immediately before quenching [°C]	Grain size number	YS [MPa]
Inventive Example	Top part	1105	0.000	1000	11	520
	Middle part	1125	0.125	1000	11	525
	Bottom part	1145	0.250	1000	11	518
Comparative Example	Top part	1105	None	1000	11	520
	Middle part	1125	None	1025	8	555
	Bottom part	1145	None	1050	5	580

[0057] The temperature of the seamless steel tube was measured immediately before quenching and after diameter-adjusting rolling and, after subjecting the steel tube to quenching and tempering, a specimen was collected from each part along a longitudinal direction to measure the grain size and the yield strength (YS). The testing method for measuring the grain size and the yield strength conforms to ASTM testing standards. The results thereof are shown together in Table 3. Similarly to Example 1 described above, results for the top part region, the middle part region, and the bottom part region are shown in Table 3 as well.

[0058] The results shown in Table 3 have revealed the followings.

[0059] In Inventive Examples of the present invention, as a result of spraying water onto the hollow blank before diameter-adjusting rolling, the temperature of the steel tube immediately before quenching was made uniform in a longitudinal direction. As a result, in the steel tube after quenching and tempering, both the grain size and the yield strength became uniform in a longitudinal direction.

[0060] In Comparative Examples, since water was not sprayed onto the hollow blank before diameter-adjusting rolling, the temperature of the steel tube immediately before quenching became non-uniform with a deviation of about 50 °C in a longitudinal direction. As a result, the grain size of the steel tube after quenching and tempering became fine showing a grain size number of 11 in the top part region and coarse showing a grain size number of 5 in the bottom part region, thus exhibiting non-uniformity in a longitudinal direction. The reason why the grain size became coarse in the bottom part region is that the temperature until quenching was higher in the bottom part region than in the top part region, and thereby the crystal grains grew coarse in the bottom part region. Moreover, the yield strength of the steel tube after quenching and tempering became non-uniform with a deviation of about 60 MPa in a longitudinal direction.

INDUSTRIAL APPLICABILITY

[0061] The present invention can be effectively utilized in the production of a seamless steel tube by the Mannesmann tube-making process.

REFERENCE SIGNS LIST

[0062] 1: Production facility, 2: heating apparatus, 3: piercing machine, 4: elongation-rolling mill, 5: diameter-adjusting rolling mill, 6: cooling bed, 7: thermometer, 8: water-cooling apparatus, 9: control apparatus, 11: annular ring of pipe, 12: water supply tube, 13: water supply pump, 14: nozzle, P: hollow blank

Claims

1. A method for producing a seamless steel tube by piercing-rolling a heated billet by a piercing machine to form the billet into a hollow blank, and without reheating the hollow blank, by successively subjecting the hollow blank to elongation-rolling with an elongation-rolling mill and diameter-adjusting rolling with a diameter-adjusting rolling mill, **characterized in that** the method comprising the steps of:

(step 1) measuring a temperature of the hollow blank along a longitudinal direction at the exit of the elongation-rolling mill; and
(step 2) cooling the hollow blank by spraying water onto the hollow blank at the entrance of the diameter-adjusting rolling mill according to a measured longitudinal temperature distribution of the hollow blank, whereby the longitudinal temperature distribution of the hollow blank becomes uniform.

2. The method for producing a seamless steel tube according to claim 1, **characterized in that** subsequently to the diameter-adjusting rolling, quenching is performed without reheating.

3. The method for producing a seamless steel tube according to claim 1 or 2, **characterized in that** in the step 2, an amount of water to be sprayed onto the hollow blank is adjusted for each of regions that are virtually allotted along a longitudinal direction of the hollow blank.

4. A production facility for a seamless steel tube including a piercing machine for piercing-rolling a heated billet to form the billet into a hollow blank, and an elongation-rolling mill for elongation-rolling the hollow blank without reheating the hollow blank and a diameter-adjusting rolling mill for diameter-adjusting rolling the hollow blank without reheating the hollow blank, **characterized in that** the production facility comprising:

a thermometer which is disposed at the exit side of the elongation-rolling mill and is used for measuring a temperature of the hollow blank along a longitudinal direction; and
a water-cooling apparatus which is disposed at the entrance of the diameter-adjusting rolling mill and serves for spraying water onto the hollow blank to cool the hollow blank according to a longitudinal temperature distribution of the hollow blank measured by the thermometer, whereby the longitudinal temperature distribution of the hollow blank becomes uniform.

FIG. 1

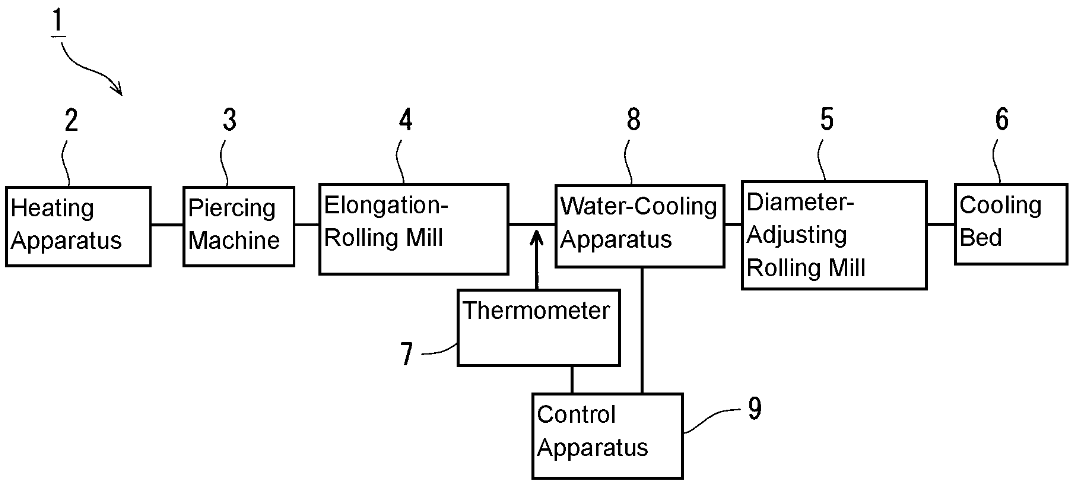

1
2
3
4
8
5
6
Heating Apparatus
Piercing Machine
Elongation-Rolling Mill
Water-Cooling Apparatus
Diameter-Adjusting Rolling Mill
Cooling Bed
Thermometer
7
Control Apparatus
9

FIG. 2

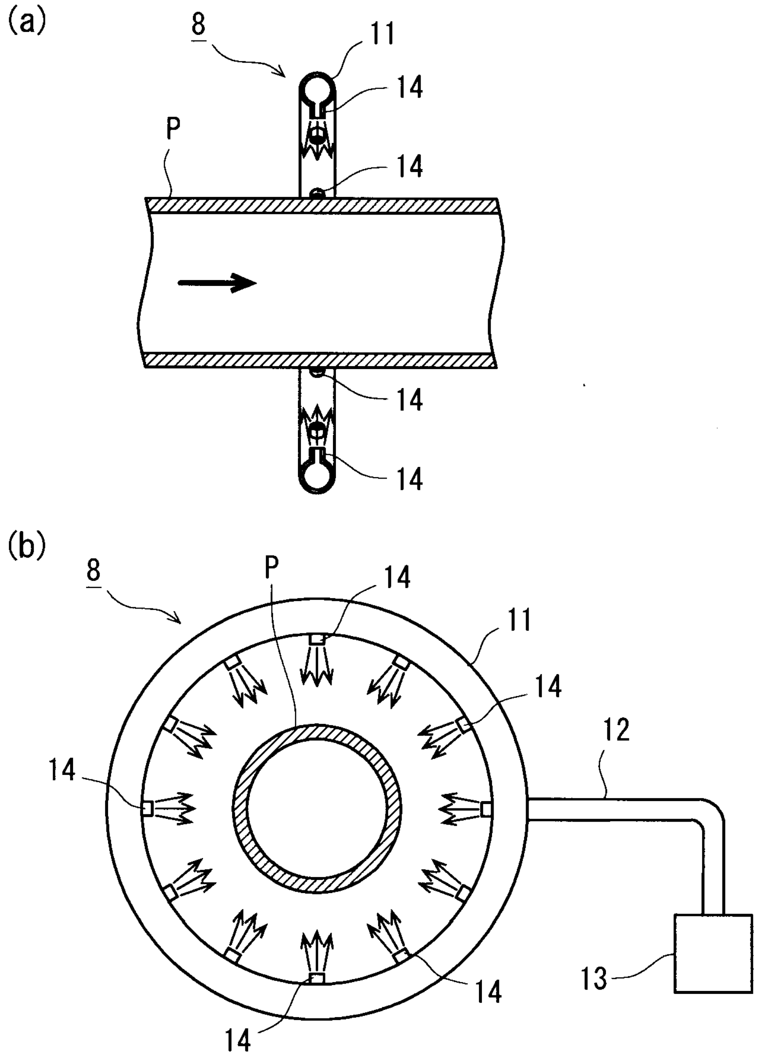

(a)
8
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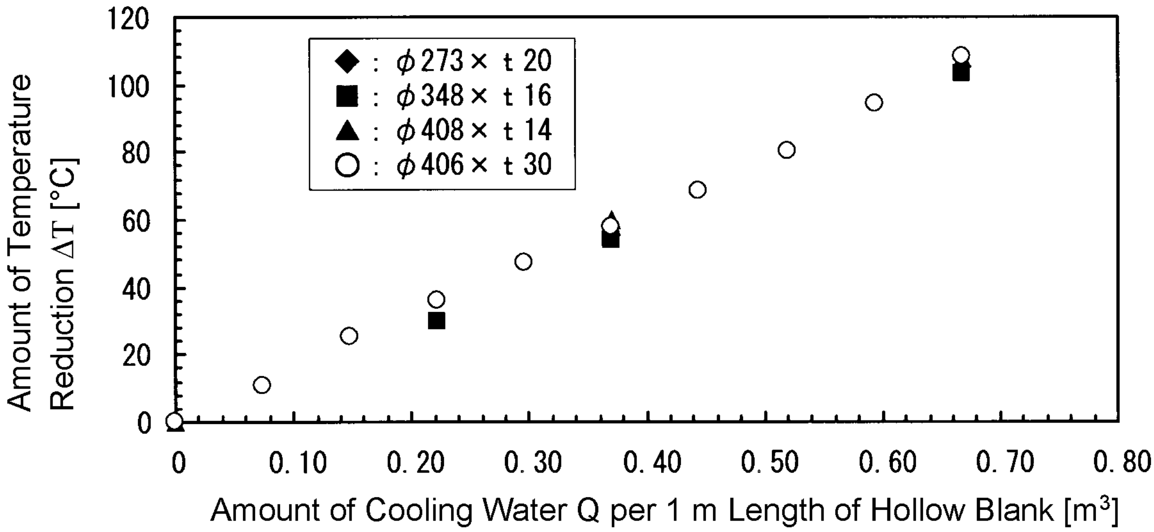
FIG. 3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■ : φ348 × t 16
▲ : φ408 × t 14
○ : φ406 × t 30
Amount of Temperature Reduction ΔT [°C]
120
100
80
60
40
20
0
0
0. 10
0. 20
0. 30
0. 40
0. 50
0. 60
0. 70
0. 80
Amount of Cooling Water Q per 1 m Length of Hollow Blank [m3]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/053824

A. CLASSIFICATION OF SUBJECT MATTER
B21B23/00(2006.01)i, *B21B45/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21B23/00, B21B45/02

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	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 63-215310 A (NKK Corp.), 07 September 1988 (07.09.1988), entire text (Family: none)	1-4
A	WO 96/12574 A1 (Sumitomo Metal Industries, Ltd.), 02 May 1996 (02.05.1996), entire text & JP 2844924 B & US 5873960 A & EP 787541 A1 & DE 69525171 T & MX 9702792 A & CN 1161010 A	1-4

☐ 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
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"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
08 June, 2010 (08.06.10)

Date of mailing of the international search report
15 June, 2010 (15.06.10)

Name and mailing address of the ISA/
Japanese Patent Office

Facsimile No.

Authorized officer

Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2004058128 A **[0012]**
- JP 2005007452 A **[0012]**
- JP 2007301574 A **[0012]**