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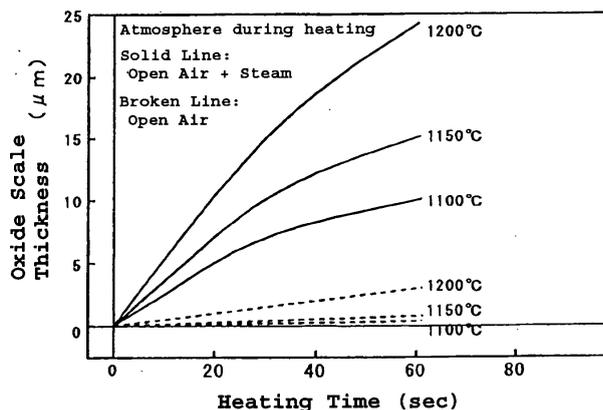
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(54) **METHOD FOR HOT WORKING OF Cr-CONTAINING STEEL**

(57) The hot-working method of Cr-containing steels by the invention, is **characterized in that:** a newly created surface in a Cr-containing steel is held in a steam atmosphere to form an oxide scale including FeO; and then, next processing step in hot-working is applied, whereas, more specifically, in producing seamless steel tubes, moisture is supplied into the inside of the hollow shell made by the piercing-rolling process to hold the newly created inside surface of the shell in the steam

atmosphere, so that the oxide scale including FeO is formed on the shell inside surface: and then, next elongation-rolling process is applied. As such, the above entails just a concise operational procedure and simple device configuration, enabling to decrease the surface defects generated in hot-working and to extend the tool life dramatically. Hence, this invention can greatly contribute to efficiently manufacture Cr-containing steels, 5-18% Cr, which are in growing demand.

FIG. 3



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Description

FIELD OF THE INVENTION

5 **[0001]** The present invention relates to a method for decreasing surface defects as well as for extending a tool-life in hot-working of alloy steels containing 5-18% Cr (hereinafter, simply referred to as a Cr-containing steel). For instance, in a hot-rolling process where hollow shells being produced using a piercing-rolling mill represented by Mannesmann Piercer are subjected to an elongation-rolling process by an elongation-rolling mill such as Plug Mill and Mandrel Mill, further including Pilger Mill, Disher Mill and the like, to obtain seamless steel tubes or pipes (hereinafter, simply referred to as tubes), the invention relates to a method for hot-working of Cr-containing steels that pertains to extend a life of a tool such as a plug and mandrel bar employed in the elongation-rolling process, and also to suppress generation of surface defects.

BACKGROUND ART

15 **[0002]** As Cr-containing steels exhibit excellent function in heat resistance and corrosion resistance, recently, there is a growing demand for Cr-containing steels for use in chemical industry applications accompanying high-temperature and high-pressure environment, and for use in oil well application related to energy. However, Cr-containing steels have less hot-workability in comparison with carbon steels, so surface defects are likely generated on surfaces of hot-worked products and also, a tool-life is likely shortened.

20 **[0003]** Cause why surface defects are generated is often referred to surface characteristics of workpieces in hot-working. For Cr-containing steels, an oxide scale layer formed on the workpiece is dependent on oxidizing parameters such as heating temperatures and atmospheres, and further a Cr content.

25 **[0004]** To be concrete, in pure irons or carbon steels which are oxidized at more than 1000°C in an oxygen atmosphere having a partial pressure near ambient pressure, an oxide scale layer composed of three layers: FeO / Fe₃O₄ / Fe₂O₃, each of which is formed in written order on a metal surface and has a predetermined thickness respectively, is formed. Then, when Cr is added, FeCr₂O₄ that is a spinel-type compound oxide is formed on the genuine metal surface or at the inner side of the parent metal, and the FeO layer becomes thinner, ending up disappearing.

30 **[0005]** As such, when Cr-containing steels are hot-worked, there is made an attempt to rigorously form an oxide scale layer on a workpiece surface.

35 **[0006]** Firstly, Japanese Patent Application Publication No. 05-269507 discloses a method for adhering a scale layer of 10-100 μm in thickness on an outside surface of a steel blank or hollow shell, either of these being a workpiece to be rolled, wherein in manufacturing seamless steel tubes made of a steel containing Cr of 12 wt% or more, an atmosphere and/or temperature in a heating furnace is controlled to thereby adjust a thickness of an oxide scale layer on an outside surface of a primary billet or a hollow shell.

[0007] Secondly, Japanese Patent Application Publication No. 10-60538 discloses a manufacturing method comprising: heating a Cr-containing steel to form a scale of 100 μm or more in gross thickness being composed of an inner layer and outer layer; and subsequently cooling by high-pressure jet water to thereby remove the outer layer scale.

40 **[0008]** Either of these manufacturing methods pays attention to a structure of an oxide scale layer to be formed for a Cr-containing steel, whereas since an outer layer scale comprising porous Fe₂O₃ and Fe₃O₄, either of these having less adhesiveness, and an inner layer scale comprising tight spinel-type compound oxide that has excellent adhesiveness are formed, and removing the outer layer scale homogeneously makes it possible to produce a product having an oxide scale layer, in other words a product with mill scale, which has corrosion resistance and excellent surface characteristics.

45 **[0009]** These methods disclosed in two Patent Application Publications as above effectively utilize an oxide scale that is generated over the workpiece during hot rolling of the Cr-containing steel, and either of these methods can satisfy an immediate purpose.

DISCLOSURE OF THE INVENTION

50 **[0010]** As afore-mentioned; either method disclosed in the prior documents pays attention to a thickness of an oxide scale to be primarily formed. In order to utilize an oxide scale effectively, a deformation behavior of an oxide scale during hot working, namely, deformability of an oxide scale needs to be taken into account. Accordingly, the present inventors made a survey on a stress-strain curve for each type of an oxide scale in order to investigate the deformability of each type of scale structure.

55 **[0011]** Fig. 1 shows a result of the survey on the stress-strain curve for each type of oxide scale, whereas (a) depicts the stress-strain curve of α-Fe₂O₃, (b) for γ-Fe₃O₄, and (c) for FeO respectively.

[0012] Figs. 1(a) and 1(b) teach: Fe₂O₃ only can allow about 5 % in elongation, which is defined to have no deformability: Meanwhile, Fe₃O₄ can be elongated when subjected to tensile deformation experimentally at an extremely slow rate at

heating temperatures of not less than 900°C, so that it is impossible to be elongated at a deformation speed during hot rolling and thus cracking occurs to end up in exfoliation.

[0013] On the other hand, as shown in Fig. 1(c), FeO deforms in a manner to keep pace with a deformation speed during rolling. Namely, FeO has high deformability, and its failure such as cracking does not take place when even high reduction-stress is applied thereon: further, it has lower hardness at elevated temperatures than that of steels, so it can be expected that depression-type defects are unlikely generated. As such, FeO is perceived as the most suitable scale to reduce surface defects and to extend a tool-life, so the best scale structure in hot working can be an oxide scale in which FeO exists.

[0014] An object of the present invention is to provide a method for hot working of Cr-containing steels in which surface defects to be generated after hot working can be reduced, and a tool-life can dramatically be extended, the method being realized by applying a plain operational procedure and/or by employing a simple apparatus configuration.

[0015] The present inventors looked into a method for manufacturing seamless steel tubes and made detail investigations thereon. Besides, in elongation-rolling, a rolling method by the Mandrel Mill is targeted. Therefore, hereinafter, the description bases on the Mandrel Mill rolling method.

[0016] In a manufacturing process by the Mandrel Mill, a billet as a starting material is heated to about 1200°C, subsequently formed into a hollow shell by a piercer mills, thus having a newly created surface inside. Then, a mandrel bar to be a tool for restraint of the inside surface is inserted into the inside of the hollow shell to perform rolling, the mandrel bar being coated over its outside surface with a hot rolling lubricant. In general, temperatures of the in-processing tubing material in a Mandrel Mill rolling process are in the range of 1100-1200°C at an entrance of the Mill, and in the range of 800-1000°C at its exit.

[0017] After rolling by the Mandrel Mill, the tubing material in which the mandrel is withdrawn therefrom is reheated as it is to temperatures in the range of 850-1100°C by a reheating furnace, subsequently being subjected to finish-rolling into a tube having predetermined dimensions by a finish-rolling machine such as a stretch reducer. And then, in the case of a tube made of a Cr-containing steel, quenching is applied from temperatures of not less than 900°C, followed by tempering treatment at temperatures close to 700°C. In the description hereinafter, the tubing material in which the mandrel bar is withdrawn therefrom after the Mandrel Mill rolling can be referred to as a finish-roll tube blank.

[0018] Next, how an oxide scale is formed in hot rolling a Cr-containing steel is explained. In the first place, when piercing is performed by a piercer, only a very limited oxide scale is formed on an inside tube surface which is the newly created surface. Even during a time period of 30-40 seconds for movement to the Mandrel Mill, almost no growth of the oxide scale takes place, while the thickness thereof is merely an order of a few μm or so. This is because the inside atmosphere of the hollow shell is in the state of high temperature and high pressure, thus having substantially no inflow of an open air.

[0019] The oxide scale on the inside surface of the hollow shell made by the piercer is hardly elongated even in Mandrel Mill rolling, so the oxide scale cracks and an exposed substrate metal is brought into direct contact with the mandrel bar surface. In the contacting region, an insulation effect that the oxide scale should inherently hold is not exerted, so the surface temperature of the mandrel bar abruptly rises to induce a severe thermal fatigue, whereby a thermal fatigue cracking occurs on the mandrel bar surface.

[0020] Then, in the region of the exposed substrate metal, not only deformation resistance in hot rolling dramatically increases, but also a metallic seizure between the substrate metal and the mandrel bar takes place very likely, thus giving damages on the mandrel bar surface as well as leaving surface defects on products after rolling.

(Formation of FeO Scale on Cr-Containing Steel Surface)

[0021] In view of above insight, it has been determined to build an oxide scale containing FeO on the newly created surface inside the hollow shell that is made by applying a piercing-rolling process to the Cr-containing steel. To be concrete, during a time period of 30-40 seconds for movement to said Mandrel Mill, moisture is supplied into the inside of the hollow shell to turn the inside into a steam atmosphere, thereby resulting in growing the oxide scale rapidly. This is, as shown in after-mentioned Fig. 2, attributed to an increase of Fe supplied from parent metal to the scale by supplying moisture, whereby formation of FeO is promoted.

[0022] Fig. 2 shows a relationship between a steam concentration and an oxidizing rate constant ($\text{mg}^2 / \text{cm}^4 \cdot \text{sec}$) when oxidizing is performed at a heating temperature of 1200°C with duration of 3600 seconds in each open air atmosphere where a steam concentration is varied. And Fig. 3 shows a relationship between a scale thickness (μm) and an oxidation time (sec) when a steam concentration (volume %) in an atmosphere is varied to 10% and 0% if a parameter be taken as a heating temperature (°C).

[0023] The foregoing Figs. 2 and 3 base on the results of a high temperature oxidation test using test specimens sampled from round billets made of a ferritic stainless steel containing 13 mass% Cr. From the results of Fig. 2, it can be recognized that an oxide scale intensively grows when steam of 2.5-20 volume % is contained in the atmosphere. And from the results of Fig. 3, it can be seen that heating at 1100°C or more in the steam atmosphere with the steam

concentration of 10 volume % makes it possible to secure an oxide scale thickness.

[0024] Table 1 shows the results of collating the oxide scale structures that were obtained in the high temperature oxidation test.

[Table 1]

Table 1

Steam in Atmosphere (%)	Scale Structure	
	Outer Layer Scale	Inner Layer Scale
0 (no steam)	Fe ₂ O ₃ Fe ₃ O ₄	FeCr ₂ O ₄ Fe ₃ O ₄
2.5-20	Fe ₂ O ₃ Fe ₃ O ₄ FeO	FeCr ₂ O ₄ FeO

[0025] As seen from Table 1, irrespective of the atmosphere conditions, any of the scale structures constitutes a dual layer structure composed of an outer and inner layer. Herein, the outer layer scale is the scale to be formed outwardly from the genuine surface of the Cr-containing steel, while the inner layer scale is the one to be formed inwardly from the genuine surface of the Cr-containing steel.

[0026] The scale that is formed in the atmosphere with steam of 2.5% or more comprises: the outer layer scale composed of Fe₂O₃, Fe₃O₄ and FeO; and the inner layer scale composed of FeCr₂O₄ and FeO. In contrast, the scale that is formed in the atmosphere without steam comprises: the outer layer scale composed of Fe₂O₃ and Fe₃O₄; and the inner layer scale composed of FeCr₂O₄ and Fe₃O₄.

[0027] As afore-mentioned, FeO has an excellent deformability in hot-working in comparison with other iron oxides, and has superb following capability to parent metal of hollow shell during an elongation-rolling process. That is, the scale layer having FeO prevents the mandrel bar from directly contacting with the hollow shell, thereby allowing the thermal fatigue to be alleviated, while reducing the metallic seizure.

[0028] Besides, the foregoing FeO plays a role of solid lubricant during hot rolling to lower friction resistance during rolling. Especially, when a lubricant of boric acid type is concurrently applied as an auxiliary lubricant, the thickened oxide scale reacts with B₂O₃ that is contained in the auxiliary lubricant to form B-Fe type compound (mainly oxide), resulting in enhancing the lubrication effect much more.

[0029] The present invention is accomplished based on the above findings and pertains to a method for hot-working of Cr-containing steels as described in the following (1) to (3).

(1) A method for hot-working of a Cr-containing steel in which a processing step for creating a new surface during hot-working is included, characterized in that said newly created surface in the Cr-containing steel is held in a steam atmosphere to thereby form an oxide scale including FeO, and next processing step in hot-working is applied subsequently.

(2) A method for hot-working of a Cr-containing steel in which a seamless steel tube is made by hot-working where a piercing-rolling process is applied, followed by an elongation-rolling process, characterized in that: moisture is supplied into the inside of a hollow shell obtained by said piercing-rolling process; an inside surface of said hollow shell, a newly created surface, is held in a steam atmosphere to thereby form an oxide scale including FeO on the inside surface of the hollow shell; and subsequently next elongation-rolling process is applied. When a lubricant is introduced into the inside of the hollow shell, it is preferable that said moisture is supplied before introducing the lubricant.

(3) The method for hot-working of a Cr-containing steel according to the above (1) or (2), further characterized in that: a steam content of said atmosphere is preferably set in the range of 2.5 to 20 volume %; the inside surface of the hollow shell is preferably held at 1150°C or more; and said steam atmosphere is preferably maintained for 15 seconds or more.

[0030] "Creating a new surface during hot-working" described in the present invention corresponds to the case that a solid blank of a Cr-containing steel is subjected to a piercing-rolling process to create an inside surface as a hollow shell, while other cases correspond to forming a cut surface by shearing a bar steel during hot-rolling or to applying descaling during hot-working.

[0031] A "Cr-containing steel" described in the present invention pertains to an alloy steel containing Cr of 5-18% which can additionally contain other alloy elements such as Ni and Mo where necessary. A seamless steel tube described

in the present invention shall include a seamless steel pipe.

BRIEF DESCRIPTION OF THE DRAWINGS

5 [0032]

Fig. 1 is a diagram showing a result of the survey on the stress-strain curve for each type of oxide scale, whereas (a) depicts the stress-strain curve of α -Fe₂O₃, (b) for γ -Fe₃O₄, and (c) for FeO respectively.

10 Fig. 2 is a diagram showing a relationship between a steam concentration and an oxidizing rate constant (mg² / cm⁴· sec) when oxidizing is performed at a heating temperature of 1200°C with duration of 3600 seconds in each open air with varied steam concentrations (volume %).

Fig. 3 is a diagram showing a relationship between a scale thickness (μm) and an oxidation time (sec) when a steam concentration (volume %) in an atmosphere is varied to 10% and 0% if a parameter be taken as a heating temperature (°C).

15 Fig. 4 is a diagram illustrating a plan view of the layout of Mandrel Mill when it is adopted as an elongation-rolling machine.

Fig. 5 is a diagram showing an evaluation result in terms of "Normalized Life Ratio" when an auxiliary lubricant is not used.

Fig. 6 is a diagram showing an evaluation result in terms of "Normalized Life Ratio" when an auxiliary lubricant is used.

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BEST MODE FOR CARRYING OUT THE INVENTION

[0033] Hereinafter, the hot-working method by the present invention will be recited with reference to the drawings in the Mandrel Mill rolling process where the seamless steel tubes are made while passing through the piercing-rolling and subsequent elongation-rolling process.

25 [0034] Fig. 4 is the diagram illustrating the plan view of the layout of Mandrel Mill when it is adopted as the elongation-rolling machine. Fig. 4 generally outlines that a billet B heated to a prescribed temperature (about 1200°C) at a rotary-hearth type furnace 1 moves through a traverse table 2 toward a piercer 3 to be formed into a hollow shell H, which is subsequently transferred to a traverse table 4.

30 [0035] Steam or water is supplied by a moisture supply device 5A and/or 5B to an inside of the hollow shell H transferred to the traverse table 4, the inside being in the state of high temperature (about 1200°C), to heighten a steam concentration of the inside, thereby enabling to grow an oxide scale of the inside surface of the hollow shell. And then, when necessary, a boric acid type auxiliary lubricant, by way of example, is supplied into the inside by an auxiliary lubricant supply device 6 to form a film of the auxiliary lubricant on the inside surface.

35 [0036] The hollow shell H having the oxide scale thus grown on its inside surface is transferred to a hollow shell charging device 7a where a mandrel bar M is inserted into the bore thereof by means of a mandrel bar inserting device 7b. At this time, a predetermined lubricant is coated over the surface of the mandrel bar M by a lubricant coating device 7c.

40 [0037] Just as it is, the hollow shell H having the mandrel bar M inserted into its bore is subjected to an elongation-rolling process in the Mandrel Mill 7 by the hollow shell charging device 7a and mandrel bar inserting device 7b, thus yielding a finish-roll tube blank.

[0038] The mandrel bar withdrawn from the finish-roll tube blank after the elongation-rolling process moves through a traverse table 8 to a bar circulation path 9, and passes through a bar cooling bath 10 to return to a mandrel bar inserting device 7b, thus enabling it to be used for a hollow shell next in line to be subjected to the elongation-rolling process. In the meantime, a plurality of mandrel bars M are circulated and used.

45 [0039] As afore-mentioned, the processing method by the present invention features that moisture is supplied into the inside of the hollow shell H made by the piercing-rolling process at the piercer 3 to grow the oxide scale of the inside surface thereof, and then the elongation-rolling process is applied. In this regard, the moisture to be supplied into the hollow shell inside can be steam or water itself. This is because even if water itself be supplied, it can be instantly vaporized to become steam since the temperature of the shell inside is very high (about 1200°C).

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(Steam Atmosphere)

55 [0040] As shown in the above Fig. 2, by controlling a steam concentration of the shell inside to be 2.5 volume% or more, the oxidizing rate can be markedly increased, thus resulting in enhancing its effect. The higher the steam concentration, the more its effect can be, but when the steam concentration exceeds 20 volume%, its effect tends to saturate. Accordingly, it is preferable that the steam concentration of the shell inside is set in the range of 2.5 to 20 volume%.

(Temperature at Inside Surface of Hollow Shell and Oxidizing Time)

[0041] The more the FeO be contained in the oxide scale, the better the oxide scale grown by providing the shell inside with a steam atmosphere be, so it is preferable that the temperature at the shell inside is set at 1100°C or more.

[0042] Meanwhile, as the oxidizing time that is a holding time of the steam atmosphere becomes longer, it becomes much better to secure the oxide scale thickness. According to a simulation test of a commercial mill targeted for investigations by the inventors, oxidizing starts under the condition that an oxidizing temperature is 1150°C and a steam atmosphere with a steam concentration of 2.5 volume% is established, in other words, after a lapse of about 15 seconds from the completion of moisture supply into the shell inside, formation of FeO and thickening of the oxide scale are discerned, which confirms that oxidizing for at least 15 seconds can sufficiently secure an oxide scale thickness and an amount of FeO.

[0043] As such, in the hot-working method by the present invention, it is preferable that the temperatures at the inside surface of the hollow shell are set at 1150°C or more and the steam atmosphere is maintained for 15 seconds or more.

(Timing of Moisture Supply into the Shell Inside and Supply Method)

[0044] Incidentally, in the Mandrel Mill rolling, the temperature of the hollow shell just after pierced by the piercer is usually more or less about 1200°C, and there is a time lag of 30-40 seconds until it reaches the entrance of the following Mandrel Mill, in other words, until the mandrel bar is inserted into its inside.

[0045] That is, the moisture supply into the shell inside by about 15 seconds ahead of the start of the Mandrel Mill rolling would be adequate, and more preferably, the moisture is supplied into the shell inside as soon as possible after piercing by the piercer. To be concrete, among the moisture supply devices 5A and 5B, 5A is preferably employed to supply the moisture.

[0046] And, the moisture supply into the shell inside by the moisture supply device 5A is not limited to be only once, and can be applied in several batches by the device 5A or an additional supply can be done by the device 5B, or alternatively, a plurality of the moisture supply devices can be disposed between 5A and 5B wherein by using these devices, the moisture supply can be intermittently performed. Such a moisture supply in several batches makes it possible to maintain a high steam concentration within the shell inside.

[0047] Further, in the case that the auxiliary lubricant like the boric acid type, etc., is used, the similar oxidizing conditions can make an adequate improvement. In such a case, it is preferable that the moisture supply into the hollow shell inside is carried out as early as possible ahead of the introduction of the auxiliary lubricant into the hollow shell inside by the auxiliary lubricant supply device 6.

[0048] This is because the moisture supply after the introduction of the auxiliary lubricant can neither accelerate the formation rate of the oxide scale nor form a sufficient amount of B-Fe type compound contributing to enhance a lubrication effect. By way of example, as the auxiliary lubricant of the boric acid type, etc., a lubricant in common use composed of sodium borate 70% - metal soap 30% can be selected.

[0049] So far is detailed for the case that the Mandrel Mill is employed as the elongation-rolling machine, but the above can likewise be applied in any case that Plug Mill, Assel Mill, Pilger Mill or Disher Mill be employed as the elongation-rolling machine.

EXAMPLES

[0050] Four steel grades having chemical compositions shown in Table 2 are made to prepare round billets measuring 191 mm in outside diameter and 2500 mm in length, while mandrel bars made of SKD61 steel grade are prepared, the mandrel bars measuring 160 mm in outside diameter and 12 m in length, having 400 Vickers Hardness in surface hardness, and being subjected to an oxide scale deposition treatment onto their surfaces.

[0051] The conditions of the oxide scale deposition treatment are: heating in an open air: heating temperature of 630°C: 20 minutes in holding time. The scale structure thus obtained is an afore-mentioned stacking layer structure composed of $(\text{FeCr})_3\text{O}_4$, Fe_3O_4 and Fe_2O_3 , each of which is formed outwardly in written order from the genuine metal surface, and more precisely, a dual layer structure composed of an inner layer and outer layer scale, the inner layer scale comprising FeCr_2O_4 and Fe_3O_4 , the outer layer scale comprising Fe_3O_4 and Fe_2O_3 , wherein a thickness thereof is 7-10 μm .

[Table 2]

[0052]

Table 2

Steel Grade	Chemical Compositions (mass%, Balance: Fe and Impurities)					
	C	Si	Mn	Cr	Ni	Mo
A	0.11	0.41	0.5	4.5	-	0.5
B	0.12	0.21	0.5	9.0	-	1.0
C	0.18	0.25	0.5	13.0	-	-
D	0.18	0.25	0.5	17.0	-	-

[0053] The round billet thus prepared was charged into the rotary hearth furnace to be heated at temperatures in the range of 1200-1250°C, and was rolled by the Mannesmann Piercer to yield a hollow shell measuring 196 mm in outside diameter, 16 mm in thickness and 7500 mm in length.

[0054] As Condition No. 1 (Inventive Example), about 200-300 cm³ of an industrial water at room temperature was immediately injected into the inside of the hollow shell, and then, by using the above mandrel bar, the elongation rolling was applied to produce a finish-roll tube blank measuring 151 mm in outside diameter, 6.25 mm in thickness and 25 m in length by the Mandrel Mill. Meanwhile, it was confirmed by a gas analysis that the injected water vaporized immediately to thereby create an oxidizing atmosphere having a steam concentration of 10-20 volume% inside the shell.

[0055] In the mean time, as Condition No. 2 (Inventive Example), after injecting a similar industrial water as above, an auxiliary lubricant of boric acid type was supplied into the hollow shell inside to form its film just before inserting the mandrel bar while other parameters were exactly the same with that of Condition No. 1, and then, the elongation rolling was applied to produce the finish-roll tube blank measuring 151 mm in outside diameter, 6.25 mm in thickness and 25 m in length.

[0056] As Condition No. 3 (Comparative Example), the water was not supplied into the inside of the hollow shell while other parameters were exactly the same with that of Condition No. 1, and then, the elongation rolling was applied to produce the finish-roll tube blank measuring 151 mm in outside diameter, 6.25 mm in thickness and 25 m in length.

[0057] As Condition No. 4 (Comparative Example), the auxiliary lubricant of boric acid type was supplied into the inside of the hollow shell instead of the water supply while other parameters were exactly the same with that of Condition No. 1, and then, the elongation rolling was applied to produce the finish-roll tube blank measuring 151 mm in outside diameter, 6.25 mm in thickness and 25 m in length.

Besides, the timing of the water supply was set to be either just after piercing-rolling by the piercer or 15 seconds before the elongation rolling, or alternatively both.

[0058] In any Condition, a graphite type lubricant was coated over the mandrel bar so as to form the film thickness of 150 μm after being dried and solidified. Further, as for the auxiliary lubricant of boric acid type, the lubricant composed of sodium borate 70% - metal soap 30% was supplied to cover the shell inside surface with the rate of 150g/m².

[0059] As an evaluation method, a "Normalized Life Ratio" of the mandrel bar was defined and adopted. The "Normalized Life Ratio" is characterized in that: after every run of rolling under each Condition, namely after each run wherein one billet is rolled, a surface of the mandrel bar is examined for surface damage such as a thermal seizure and/or surface cracking: when any damage was discerned, the number of billets that had been rolled so far is tallied: thus, for each steel grade, the "Normalized Life Ratio" is obtained by the equation (1) as below:

$$\text{Normalized Life Ratio} = n / N \quad (1)$$

where,

n: number of billets that had been rolled under Condition 1, 2 or 4

N: number of billets that had been rolled under Condition 3.

[0060] The evaluation result in accordance with the above is compiled in Table 3. In the column of "Steam Supply Position", just after P is a shortened form of "Just After Piercing", designating that the steam is supplied just after piercing-rolling by the piercer, while 15sec before M is a shortened form of "15 Seconds Before Mandrel (Mill Rolling)", designating that the steam is supplied 15 seconds before mandrel mill rolling.

[0061] Fig. 5 is the diagram showing the evaluation result in terms of "Normalized Life Ratio" when the auxiliary

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lubricant is not supplied, whereas Fig. 6 is the diagram showing the evaluation result in terms of "Normalized Life Ratio" when the auxiliary lubricant is supplied.

[Table 3]

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[0062]

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Table 3

Test No	Condition	Steam Supply	Auxiliary Lubrication	Tested Steel Grade	Steam Supply Position	Normalized Life Ratio	Remark
1	3	No	No	A	-	1	Comparative Example
2	4		Yes		-	1	
3	3		No	B	-	1	
4	4		Yes		-	1	
5	3		No	C	-	1	
6	4		Yes		-	1	
7	3		No	D	-	1	
8	4		Yes		-	1	
9	1	Yes	No	A	Just after P	2.0	Inventive Example
10	2		Yes		Just after P	2.2	
11	1		No	B	Just after P	2.1	
12	2		Yes		Just after P	2.3	
13	1		No	C	Just after P	2.2	
14	2		Yes		Just after P	2.1	
15	1		No	D	Just after P	2.1	
16	2		Yes		Just after P	2.3	
17	1		No	A	15sec before M	1.8	
18	2		Yes		15sec before M	2.0	
19	1		No	B	15sec before M	1.8	
20	2		Yes		15sec before M	2.0	
21	1		No	C	15sec before M	2.0	
22	2		Yes		15sec before M	1.9	
23	1		No	D	15sec before M	2.0	
24	2		Yes		15sec before M	2.2	
25	1		No	A	Both	2.7	
26	2		Yes		Both	2.6	
27	1		No	B	Both	2.5	
28	2		Yes		Both	2.5	
29	1		No	C	Both	2.5	
30	2		Yes		Both	2.5	
31	1		No	D	Both	2.5	
32	2		Yes		Both	2.8	

[0063] As seen in Table 3, Figs. 5 and 6, it is evident that the present invention makes it possible to extend the life of the mandrel bar by a factor of about 2 to 3, irrespective of the absence or presence of the auxiliary lubricant application. Likewise, it is also confirmed that the surface defects on the outside and inside surface after the mandrel mill rolling are decreased.

[0064] As regards the moisture supply position, the case where the moisture is supplied both immediately after piercing-rolling and 15 seconds before mandrel mill rolling is mostly effective, whereas next comes the case of just after piercing, and followed by the case of 15 seconds before elongation rolling.

5 INDUSTRIAL APPLICABILITY

[0065] The hot-working method of Cr-containing steels in accordance with the present invention is characterized in that: a newly created surface of Cr-containing steel is held in a steam atmosphere to form an oxide scale including FeO; and then, hot-working next in line is applied. More specifically, in producing seamless steel tubes, moisture is supplied into the inside of the hollow shell being made by the piercing-rolling process to hold the newly created inside surface of the shell in the steam atmosphere, so that the oxide scale including FeO is formed on the shell inside surface: and then, the elongation-rolling process next in line is applied: as such, the above entails just a plain operational procedure and a simple apparatus configuration, thus enabling to decrease the surface defects generated in hot-working and to extend the tool life dramatically. Hence, this invention can greatly contribute to efficiently manufacture Cr-containing steels, 5-18% Cr, which are in growing demand.

Claims

20 1. A method for hot-working of a Cr-containing steel in which a processing step for creating a new surface during hot-working is included, **characterized in that:**

said newly created surface in the Cr-containing steel is held in a steam atmosphere to thereby form an oxide scale including FeO thereon; and
 25 next processing step in hot-working is applied.

2. A method for hot-working of a Cr-containing steel in which a seamless steel tube is made by hot-working where a piercing-rolling process is applied, followed by an elongation-rolling process, **characterized in that:**

30 moisture is supplied into the inside of a hollow shell made by said piercing-rolling process;
 an inside surface of said hollow shell, a newly created surface, is held in a steam atmosphere;
 an oxide scale including FeO is formed on said inside surface; and
 next elongation-rolling process is applied subsequently.

35 3. The method for hot-working of a Cr-containing steel according to claim 1 or claim 2, further **characterized in that** a steam content of said atmosphere is set in the range of 2.5 to 20 volume %.

4. The method for hot-working of a Cr-containing steel according to claim 2 or claim 3, **characterized in that:**

40 the inside surface of said hollow shell is held at 1150°C or more; and
 said steam atmosphere is maintained for 15 seconds or more.

5. The method for hot-working of a Cr-containing steel according to claim 2, **characterized in that**, when a lubricant is introduced into the inside of said hollow shell, said moisture is supplied before introducing the lubricant.

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FIG. 1

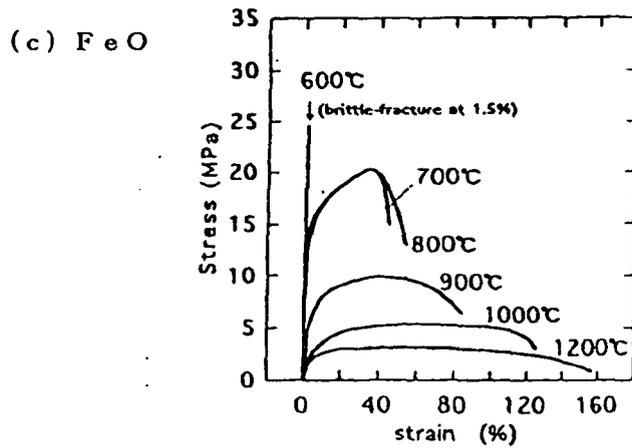
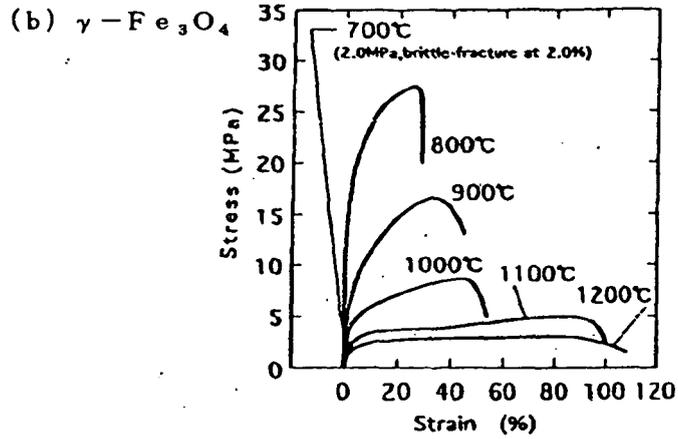
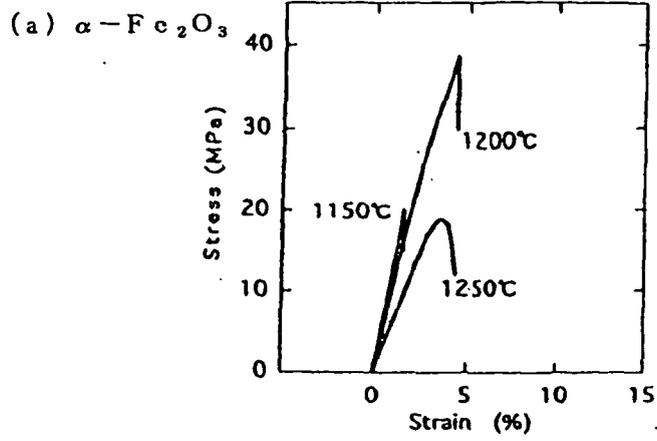


FIG. 2

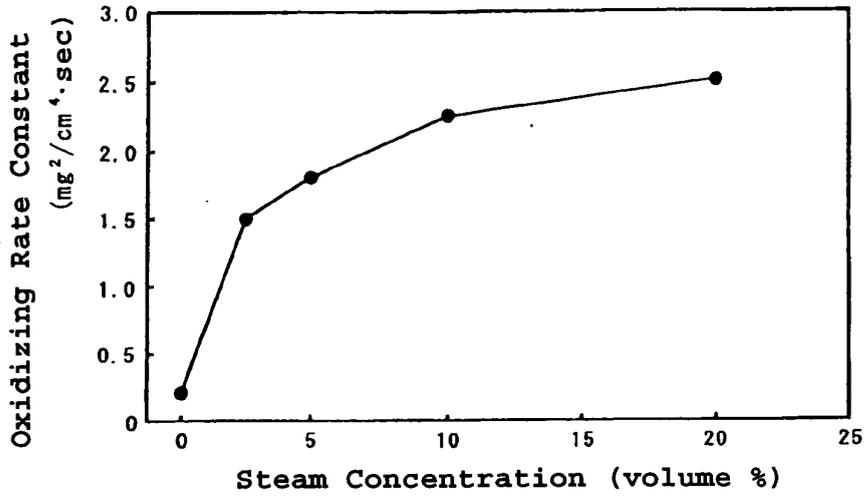


FIG. 3

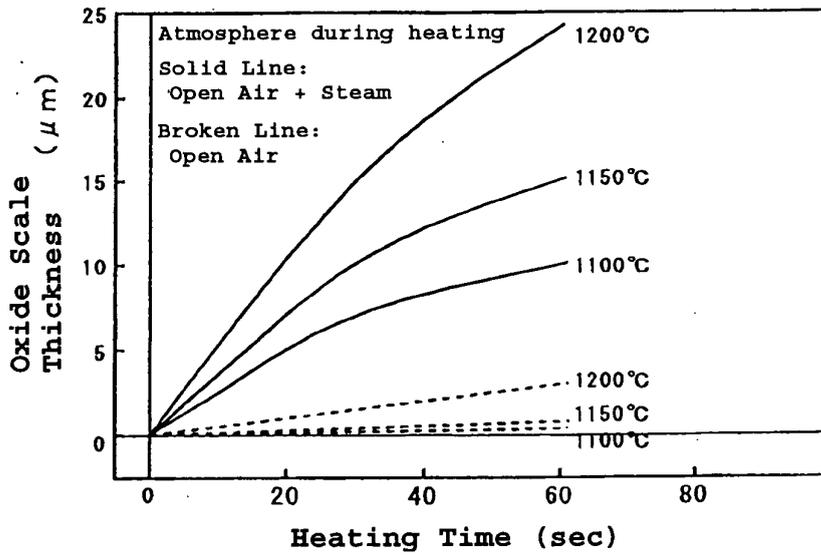


FIG. 4

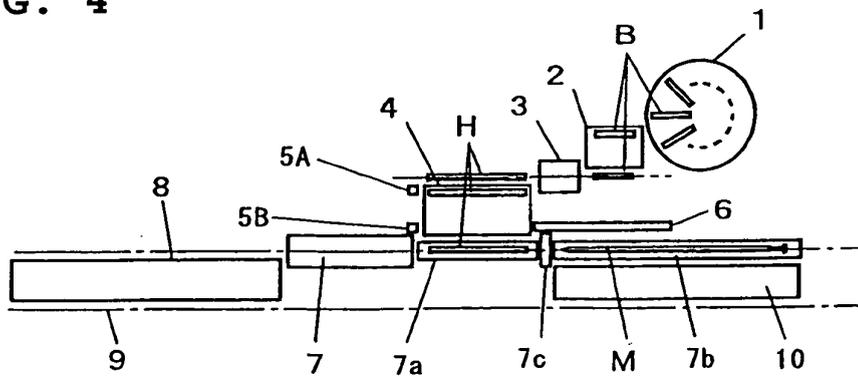


FIG. 5

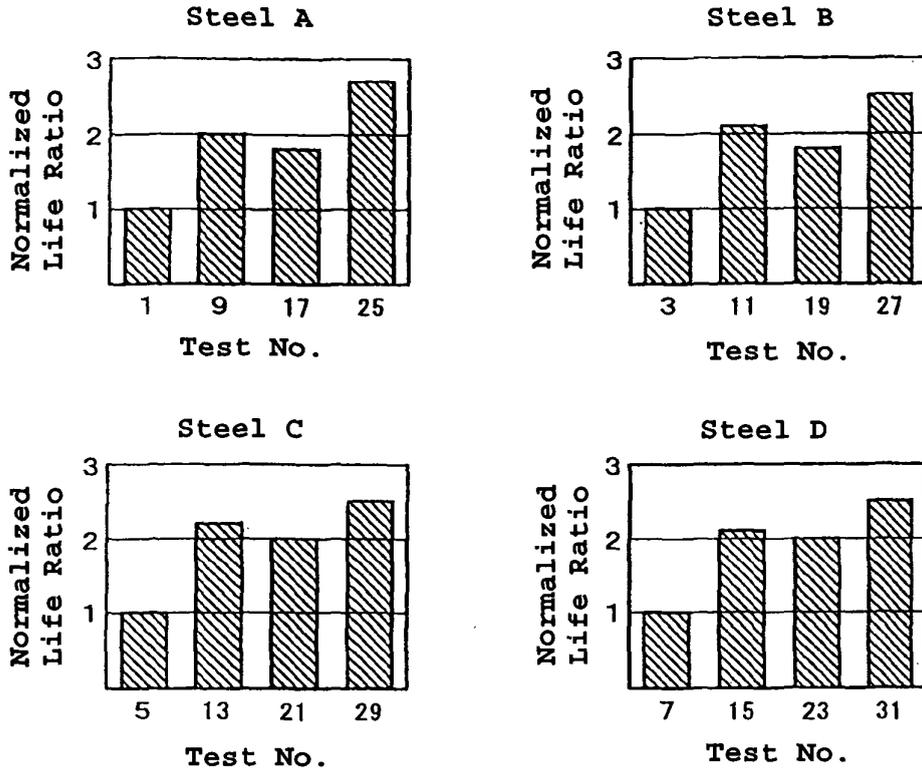
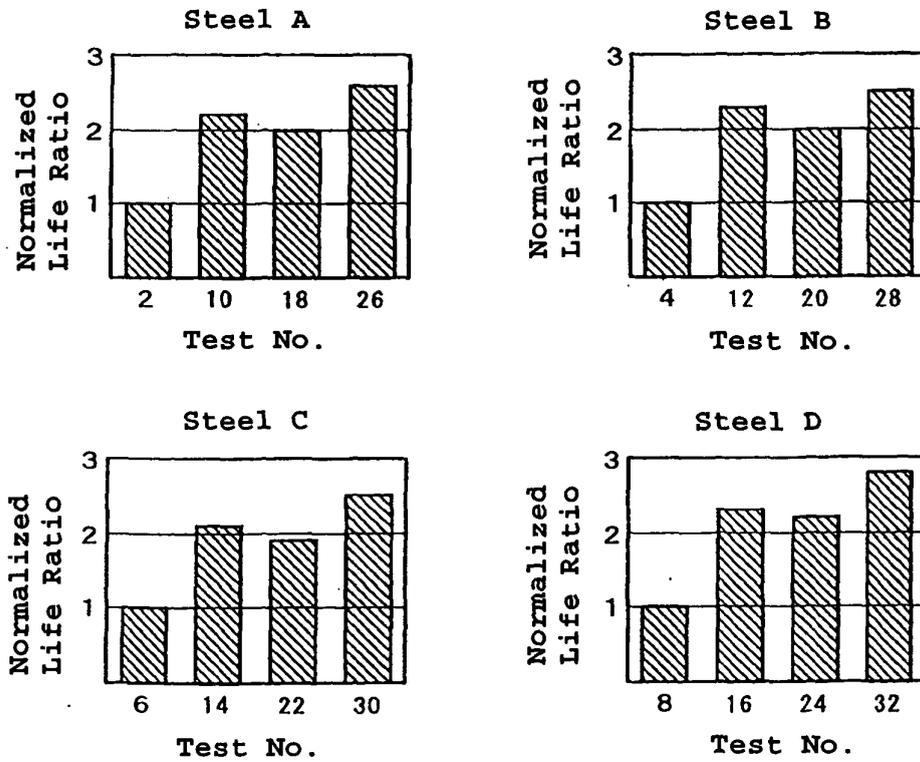


FIG. 6



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/010302

A. CLASSIFICATION OF SUBJECT MATTER Int.Cl ⁷ B21B23/00, B21B17/02		
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 B21B17/00-25/06		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Jitsuyo Shinan Koho 1922-1996 Toroku Jitsuyo Shinan Koho 1994-2004 Kokai Jitsuyo Shinan Koho 1971-2004 Jitsuyo Shinan Toroku Koho 1996-2004		
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 7-241604 A (Sumitomo Metal Industries, Ltd.), 19 September, 1995 (19.09.95), Claims; Par. Nos. [0022] to [0024] (Family: none)	1-5
A	JP 8-90043 A (Sumitomo Metal Industries, Ltd.), 09 April, 1996 (09.04.96), Claims; Par. Nos. [0028] to [0029] (Family: none)	1-5
A	JP 4-294803 A (Kawasaki Steel Corp.), 19 October, 1992 (19.10.92), Claims; Par. No. [0012] (Family: none)	1-5
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.		<input type="checkbox"/> See patent family annex.
* Special categories of cited documents:		"I" 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
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"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family	
Date of the actual completion of the international search 25 August, 2004 (25.08.04)	Date of mailing of the international search report 14 September, 2004 (14.09.04)	
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer	
Facsimile No.	Telephone No.	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2004/010302

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E, X	JP 2004-223528 A (Sumitomo Metal Industries, Ltd.), 12 August, 2004 (12.08.04), Full text (Family: none)	1-5

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

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 5269507 A [0006]
- JP 10060538 A [0007]