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(54) **PROCESS FOR MANUFACTURE OF SEAMLESS STEEL PIPE**

(57) When performing piercing-rolling by use of a plug with a protection film on its surface, applying a lubricant made of an aqueous solution containing a total of 5 to 30% mass% of one or more of boron oxide, boric acid, and amine borate to the protection film on the plug surface, and using this plug for piercing-rolling makes it possible to realize the increase of the life of plug for piercing-rolling without reducing the efficiency of piercing-rolling, consequently allowing the efficient production of a seamless steel tube/pipe. Moreover, it is preferable that

the plug is cooled after the piercing-rolling, the application of the above described lubricant is performed when the surface temperature of the front edge of plug decreases to 100°C or less, and the plug is reused for the piercing-rolling. In this occasion, it is preferable that the protection film on the plug surface is formed by arc spraying iron wire material onto the surface of the base metal of plug, and comprises oxides and Fe.

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**Description**

## TECHNICAL FIELD

5     **[0001]** The present invention relates to a method for producing a seamless steel tube/pipe by a Mannesmann tube-making process, and particularly to a method for producing a seamless steel tube/pipe, which enables efficient production of a seamless steel tube/pipe by increasing the life of the plug to be used without reducing the efficiency during piercing-rolling.

## 10     BACKGROUND ART

**[0002]** A seamless steel tube/pipe can be produced by a Mannesmann tube-making process. This tube making process consists of the following steps:

- 15         (1) A round billet heated to a predetermined temperature is subjected to a piercing-rolling process by using a piercing mill (piercer) to form a hollow blank (hollow shell).  
        (2) The hollow blank is subjected to an elongation-rolling process by using an elongation-rolling mill (for example, a mandrel mill).  
        (3) The hollow shell thus elongated is sized so as to have a predetermined outside diameter and wall thickness by  
 20         using a sizing mill (for example, a stretch reducer).

**[0003]** In piercing-rolling by a piercer, a plug is used as the piercing tool. Since this plug is mounted on the front edge of a mandrel and is used in that state to pierce a billet which is heated to a temperature as high as about 1200°C, the plug is exposed to a hostile condition in which a high surficial pressure with intense heat is imposed. In general, the plug  
 25     is made of base metal of hot-working tool steel and, to protect the base metal, a film of oxide scale is formed on the surface of the base metal in advance by heat treatment before the plug is used for piercing-rolling. During piercing-rolling, the scale film on the plug surface blocks the heat transfer from the billet to the plug base metal, and serves as a protection film for preventing seizing between the billet and the plug.

**[0004]** Meanwhile, the scale film on the plug surface gradually wears as the plug is repetitively used for piecing-rolling. Since the wear of the scale film reduces the thermal insulation effect exerted by the film and accordingly increases the temperature of the plug during piercing, melting-incurred metal loss and thermal deformation of the plug base metal are highly likely to occur. Moreover, when the scale film is lost and the plug base metal comes into direct contact with the  
 30     billet, seizing will occur, thereby causing flaws on the inner surface of the steel tube/pipe. On that account, the plug is regarded as being unusable at a time when the scale film has been lost, thus reaching the end of its life.

**[0005]** In particular, when producing a seamless steel tube/pipe made of high alloy steel such as high Cr-containing steel containing not less than 9% of Cr, Ni-based alloy, and stainless steel, the wear of the scale film on the plug surface becomes intensified during piercing-rolling, thereby tremendously decreasing the life of plug. For example, in the piercing of stainless steel, the scale film on the plug surface wears out in two or three passes (the number of times of successive piercing rolling) and the plug reaches the end of its life. On that account, when producing a seamless steel tube/pipe of  
 40     stainless steel, etc., the plug may have to be frequently replaced, thereby ending up in reducing the production efficiency. Therefore, particularly when producing a seamless steel tube/pipe made of high alloy steel, there is a strong demand for enhancing the life of the plug during piercing-rolling, thereby improving the production efficiency.

**[0006]** To satisfy such demand, there is a known technique in which a lubricant is used and laminated onto the scale film on the plug surface so that the friction resistance between the plug and the billet is reduced and seizing therebetween  
 45     is prevented, thereby increasing the life of the plug for piercing-rolling.

**[0007]** For example, Patent Literature 1 discloses a technique in which a water glass-based aqueous solution is adopted as the lubricant, and the conditions for applying the water glass-based aqueous solution to the scale film on the plug surface are specified. To be specific, when the plug is cooled after piercing-rolling and is successively used for piercing-rolling in a repetitive manner, the cooling is interrupted at the moment when the surface temperature of the plug  
 50     becomes not more than 150°C and inside the plug, a portion with a temperature of not less than 100°C is present, and after the water film on the plug surface evaporates, a water glass-based aqueous solution is applied to the plug surface to form a coating film of a water glass-based lubricant.

**[0008]** However, according to the technique disclosed in Patent Literature 1, although the friction resistance between the plug and the billet will decrease during piercing-rolling, the scale film will excessively react with the water glass-based lubricant, and thereby will peel off so that increase of the life of plug can hardly be expected in reality. Moreover, since it takes long hours to evaporate the crystallization water of the water glass-based aqueous solution applied to the plug surface, a problem of the reduction in the efficiency of piercing-rolling arises.

**[0009]** Further, Patent Literature 2 discloses a technique for performing piecing-rolling, in which a scale-dissolving

substance such as a boric acid-based oxide typified by  $B_2O_3$  is adopted as the lubricant, and the scale-dissolving substance is applied to the scale film of the plug surface.

**[0010]** However, the technique disclosed in Patent Literature 2 has its object to prevent the occurrence of flaws on the inner surface of steel tube/pipe rather than to improve the life of plug, and the boric acid-based oxide is merely selected as the lubricant to be applied to the scale film without paying attention to the specific composition and application conditions of the lubricant at all. Therefore, in the technique disclosed in Patent Literature 2, there is room for improvement in terms of reliably realizing the increase of the life of plug without reducing the efficiency of piercing-rolling.

**[0011]** Further, Patent Literature 3 disclose a technique, in which as the protection film to be formed on the surface of the plug base metal, a film made up of oxides and Fe is formed by arc spraying iron wire material on the surface of the plug base metal, in place of a scale film by heat treatment, and this plug with an arc-sprayed film is used to perform piercing-rolling. Moreover, the same literature describes that lubricant such as boric acid ( $H_3BO_3$ ) may be applied and laminated onto the arc-sprayed film formed on the plug surface. Since the protection film on the plug surface is made up of oxides and Fe, the plug with an arc-sprayed film is excellent in thermal insulation performance and seizing-resistance performance, and thus enables the increase of the life of plug, the effect of which is expected to be further enhanced by the application of the lubricant.

**[0012]** However, in the technique disclosed in Patent Literature 3 as well, the boric acid etc. is merely selected as the lubricant to be applied to the arc-sprayed film without paying attention to the specific composition and application conditions of the lubricant at all. Therefore, in the technique disclosed in Patent Literature 3, there is also room for improvement in terms of reliably realizing the increase of the life of plug without reducing the efficiency of piercing-rolling.

## CITATION LIST

### PATENT LITERATURE

#### **[0013]**

Patent Literature 1: Japanese Patent Application Publication No. 08-117819

Patent Literature 2: Japanese Patent Application Publication No. 2002-248507

Patent Literature 3: Japanese Patent No.4279350

## SUMMARY OF INVENTION

### TECHNICAL PROBLEM

**[0014]** The present invention has been made in view of the above described circumstances, and has its object to provide, focusing on piercing-rolling, a method for producing a seamless steel tube/pipe, which has the following features of:

- (1) reliably realizing the increase of the life of the plug for piercing-rolling without reducing the efficiency of piercing-rolling, and
- (2) improving the production efficiency of a seamless steel tube/pipe.

### SOLUTION TO PROBLEM

**[0015]** The summaries of the present invention are as follows.

**[0016]** A method for producing a seamless steel tube/pipe in which piercing-rolling is performed by using a plug with a protection film on a surface thereof, including:

applying a lubricant made of an aqueous solution containing a total of 5 to 30 mass% of one or more of boron oxide, boric acid, and amine borate to the protection film of the plug for use in the piercing-rolling.

**[0017]** In this production method, it is preferable that the plug is cooled after piercing-rolling, the lubricant is applied when the surface temperature of the front edge of plug decreases to 100° or less, and the plug is reused for piercing-rolling.

**[0018]** Moreover, in the above described production method, the protection film is preferably formed by arc-spraying iron wire material onto the surface of the plug base metal so as to comprise oxides and Fe.

## ADVANTAGEOUS EFFECTS OF INVENTION

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

- (1) it is possible to reliably realize the increase of the life of plug without reducing the efficiency of piercing-rolling by applying a lubricant at appropriate conditions to a protection film formed on the surface of the plug for piercing-rolling,
- (2) it is possible to more efficiently produce a seamless steel tube/pipe as the efficiency of piercing-rolling is secured and the life of plug is increased.

## DESCRIPTION OF EMBODIMENTS

**[0020]** In order to achieve the above described objective, the present inventors have conducted diligent studies on the assumption that a plug, in which a protection film is formed on the surface of the base metal of a plug for piercing-rolling, and a lubricant is applied and laminated onto the protection film, is used for piercing-rolling. Then, as shown by examples described later, they have conducted tests in which piercing-rolling is performed by using plugs, in which kinds of lubricants, chemical compositions, and application conditions, as well as kinds of protection films are variously changed, to evaluate the efficiency of piercing-rolling and the life of plug, consequently obtaining the following findings.

**[0021]** (a) As the lubricant to be applied to the surface of a plug for piercing-rolling, by adopting a boric acid-based aqueous solution containing a total of 5 to 30% in mass% of one or more kinds selected from boron oxide, boric acid, and amine borate, the piercing efficiency significantly is improved and the life of plug also increases steadily.

**[0022]** The "piercing efficiency" as used herein is defined as follows. When piercing-rolling a billet by a piercing-rolling mill, the billet is conveyed along the pass line while being rotated by a plurality of revolving rolls (piercer rolls) installed about the pass line. At this moment, although the speed at which the billet is conveyed (hereafter referred to as a "conveyance speed") is determined by the number of revolutions of the piercer roll, the actual conveyance speed during piercing tends to be lower than the theoretical conveyance speed, which is calculated from the number of revolutions of the piercer roll as being set, due to the effects of the friction resistance between the plug and the billet which are in contact with each other, and others. This speed ratio ( $= (\text{actual conveyance speed}) / (\text{theoretical conveyance speed}) \times 100 [\%]$ ) is referred to as "piercing efficiency". As the piercing efficiency increases, a time period needed for piercing-rolling becomes short, thereby leading to an improvement in the efficiency of piercing-rolling, and the contact period between the plug and billet becomes also short, thereby leading up to an expected increase in the life of plug.

**[0023]** (b) In order to further increase the life of plug, when the plug is cooled after piercing-rolling and is successively used for piercing-rolling in a repetitive manner, it is effective to perform the application of the lubricant of boric acid-based aqueous solution having the composition shown in the above described (a) when the surface temperature of the front edge of plug decreases to 100°C or less.

**[0024]** (c) In order to further dramatically increase the life of plug, as the protection film which is formed on the plug surface and to which the lubricant shown in the above described (a) and (b) is to be applied, it is effective to adopt an arc-sprayed film which is formed by arc-spraying iron wire material and is made up of oxides and Fe, rather than a scale film which is formed by heat treatment.

**[0025]** The method for producing a seamless steel tube/pipe of the present invention has been completed based on the above described findings. Hereafter, the reasons why the production method of the present invention is specified as described above, and preferred embodiments thereof will be described.

## 1. Protection film of plug surface

**[0026]** The plug to be used for piercing-rolling in the present invention is one in which a protection film is formed on the surface of its base metal, and a boric acid-based aqueous solution (lubricant) having a chemical composition described below is applied and laminated onto the protection film. The protection film may be a scale film which is formed by heat treatment, or an arc-sprayed film which is formed by arc-spraying of iron wire material and is made up of oxides and Fe. That is because applying a boric acid-based aqueous solution having an appropriate chemical composition described below as the lubricant will be effective for either of protection films to thereby significantly improve the piercing efficiency and also increase the life of plug in a stable manner.

**[0027]** In particular, in the case of the arc-sprayed film, the life of plug will dramatically increase compared with the case of the scale film. This is because, during piercing-rolling, the arc-sprayed film is more reactive with boric acid-based binders contained in the boric acid-based aqueous solution compared with the scale film, and thereby provides remarkable effects of smoothening the plug surface. On account of that, it is preferable to adopt an arc-sprayed film as the protection film.

## 2. Lubricant applied to plug surface

**[0028]** The lubricant which is adopted in the present invention is one of a boric acid-based aqueous solution, in which oxide-based layered substances such as mica and talc are dispersed along with boric acid-based binders in a solvent (water). This lubricant can contain a dispersant such as water soluble polymer to stably disperse the oxide-based layered substance and the boric acid-based binders. Note that "%" in the content of component means "mass%" in the following description.

**[0029]** The boric acid-based binder causes the oxide-based layered substance in the lubricant to adhere to the surface to be lubricated (the protection film on the plug surface) during application, and further the binder itself melts thereby not only smoothly delivering the oxide-based layered substance to the surface to be lubricated where wear occurs, but also reacting with the protection film to smoothen the plug surface and reduce friction resistance.

**[0030]** As the boric acid-based binder, one or more of boron oxide, boric acid, and amine borate can be selected. However, when the total content of these boric acid-based binders is more than 30% in the lubricant, it becomes excessive, i.e. the amount of the binder itself is more than enough so that the binder tends to condense, making the application of the lubricant difficult. On the other hand, when the content thereof is less than 5%, the amount of melt of the binder itself is insufficient during piercing-rolling, which leads to insufficient supply of the oxide-based layered substance to the surface to be lubricated. On that account, in both cases, sufficient reduction of the friction resistance will not be achieved, the piercing efficiency is reduced, and satisfactory lubrication performance will not be achieved. Therefore, the total content of the boric acid-based binders is within a range of 5 to 30% in the lubricant. A more preferable range is 5 to 25%.

**[0031]** The content of the oxide-based layered substance will not be particularly limited. However, since containing an excessive amount of oxide-based layered substance will cause agglomeration thereof, application of the lubricant becomes difficult. On the other hand, since containing an extremely smaller amount thereof will cause an insufficient supply of the oxide-based layered substance to the surface to be lubricated during piercing-rolling, a satisfactory effect of reducing the friction resistance will not be achieved. On that account, the content of the oxide-based layered substance is preferably within a range of 10 to 40%, when the boric acid-based binders are contained within the above described range.

**[0032]** The content of the dispersant will not be particularly limited as well. However, containing an excessive amount of the dispersant will only increase cost, and an extremely smaller amount thereof will not lead to any effect. On that account, when dispersant is to be contained, its content is preferably within a range of 0.11 to 3.0%.

**[0033]** The method for applying a lubricant having such a chemical composition to the protection film on the plug surface will not be particularly limited. For example, the lubricant may be directly applied with a brush etc. Examples of desired methods include a spraying method whereby a lubricant is sprayed in a mist state by using a nozzle. That is because such method achieves a high operation efficiency and enables uniform application.

## 3. Condition for applying lubricant

**[0034]** As described above, when piercing-rolling is performed by using a plug, in which a lubricant is applied and laminated onto the protection film thereof, and the plug is cooled after the piercing-rolling to be successively used in a repetitive manner, it is preferable that the application of a lubricant made up of a boric acid-based aqueous solution having the chemical composition described above is performed when the surface temperature of the front edge of plug decreases to 100°C or less. Because doing so will make it possible to further increase the life of plug.

**[0035]** In this connection, if the surface temperature of the front edge of plug is more than 100°C when the lubricant of the boric acid-based aqueous solution is applied, since the moisture in the lubricant evaporates to form bubbles, the adhesiveness of the lubricant (oxide-based layered substance and boric acid-based binders) to the protection film will be impaired. As a result, as heat enters from the billet to the plug during piercing-rolling, the temperature of the plug increases, and melting-incurred metal loss of the front edge portion of the plug will occur.

**[0036]** Although the lower limit of the surface temperature of the front edge of plug at the time of application of lubricant will not be particularly limited, cooling the plug to less than 30°C will cause the cooling time to increase, reducing the efficiency of piercing-rolling, and therefore is economically disadvantageous. On that account, the surface temperature of the front edge of plug at the time of application of lubricant is preferably 30°C or more.

**[0037]** Such a method of cooling the plug after piercing-rolling will not be limited. The plug may be cooled by, for example, immersing the plug after piercing-rolling in a water bath, or pouring water on the plug after piercing-rolling.

**[0038]** According to the method for producing a seamless steel tube/pipe of the present invention, it is possible to stably increase the life of plug during piercing-rolling without reducing the efficiency of piercing-rolling, and thereby improve the efficiency as the entire production process of a seamless steel tube/pipe.

## Examples

**[0039]** To confirm advantageous effects of the present invention, piercing-rolling tests shown in the below described Examples 1 and 2 were conducted by suing a piercer

<Example 1>

**[0040]** The test conditions of Example 1 were as follows.

[Test method]

(1) Plug and lubricant

**[0041]** A plurality of plugs were prepared in which a scale film was formed over the entire region of the surface of the base metal by heat treatment. As shown in Table 1 given below, various boric acid-based aqueous solutions, in which types of boric acid-based binders (boron oxide, boric acid and amine borate) and the content thereof were changed, were made as the lubricant, and each of these lubricants was applied to the scale film on the plug surface, thereafter being dried and laminated. Note that those lubricants of the boric acid-based aqueous solutions were arranged to contain 10 to 40% of mica as the oxide-based layered substance, and a total of 0.11 to 3.0% of one or more of water soluble polymer as the dispersant, besides boric acid-based binders.

**[0042]** Moreover, by way of comparison, a plug in which a water glass-based aqueous solution was applied to the scale film on the plug surface as a lubricant, thereafter being dried and laminated, and a plug which had only scale film without application of lubricant.

**[0043]** [Table 1]

Table 1

| Test No. | Protection film | Lubricant       |              |                        | Piercing efficiency [%] | Surface quality of plug after piercing | Overall evaluation |
|----------|-----------------|-----------------|--------------|------------------------|-------------------------|----------------------------------------|--------------------|
|          |                 | Base            | Binder       | Binder Content [mass%] |                         |                                        |                    |
| 1        | Scale film      | Boric acid base | Boron oxide  | 15                     | 82.5                    | Good                                   | ○                  |
| 2        | Scale film      | Boric acid base | Boric acid   | 15                     | 81.3                    | Good                                   | ○                  |
| 3        | Scale film      | Boric acid base | Amine borate | 2.5*                   | 63.2                    | Good                                   | ×                  |
| 4        | Scale film      | Boric acid base | Amine borate | 5                      | 80.2                    | Good                                   | ○                  |
| 5        | Scale film      | Boric acid base | Amine borate | 10                     | 83.0                    | Good                                   | ○                  |
| 6        | Scale film      | Boric acid base | Amine borate | 15                     | 79.0                    | Good                                   | ○                  |
| 7        | Scale film      | Boric acid base | Amine borate | 20                     | 82.2                    | Good                                   | ○                  |
| 8        | Scale film      | Boric acid base | Amine borate | 25                     | 81.5                    | Good                                   | ○                  |
| 9        | Scale film      | Boric acid base | Amine borate | 30                     | 75.0                    | Slight seizing                         | △                  |
| 10       | Scale film      | Boric acid base | Amine borate | 35*                    | 62.4                    | Seizing                                | ×                  |

(continued)

| Test No. | Protection film | Lubricant         |                |                        | Piercing efficiency [%] | Surface quality of plug after piercing | Overall evaluation |
|----------|-----------------|-------------------|----------------|------------------------|-------------------------|----------------------------------------|--------------------|
|          |                 | Base              | Binder         | Binder Content [mass%] |                         |                                        |                    |
| 11       | Scale film      | Water glass base* | Silicon oxide* | 15                     | 76.7                    | Peeling off of film                    | ×                  |
| 12       | Scale film      | None*             | None*          | None*                  | 59.7                    | Seizing                                | ×                  |

Note) \* indicates that result was out of the condition specified in the present invention.

## (2) Piercing-rolling

**[0044]** Piercing-rolling to form the below-described billets, which had been heated to 1230°C, into the below-described hollow shells was carried out in a single pass by using each plug described above.

- Size of billet: Diameter 191 mm, length 2160 mm
- Material of billet: 13% Cr steel
- Hollow shell: Outer diameter 196 mm, wall thickness 16.64 mm, length 6480 mm

## [Evaluation method]

**[0045]** The piercing efficiency during piercing-rolling was investigated, and the appearance of the plug was observed after piercing-rolling to investigate the surface quality and make evaluations by putting those investigation results together. In real operation, the target of piercing efficiency was not less than 70%, and a result of not less than 75%, which exceeded the target, was judged to be good. The investigation results and evaluation results are shown together in Table 1 given above.

**[0046]** In Table 1, the meanings of symbols in the "overall evaluation" column are as follows.

- : Good. The piercing efficiency was not less than 75%, and the surface quality of the plug was good as well.
- △: Fair. Although the piercing efficiency was not less than 75%, a slight seizing was observed on the plug surface.
- ×: Fail. The piercing efficiency was less than 75%, or seizing or peeling off of film was observed on the plug surface.

## [Test results]

**[0047]** The results shown in Table 1 indicate the followings. Any of Test Nos. 1, 2, 4 to 9 satisfied the conditions specified in the present invention. On that account, the piercing efficiency was more than 75% in any of Test Nos. 1, 2, 4 to 9. Moreover, in Test Nos. 1, 2, 4 to 8 among them, neither seizing on the plug surface nor peeling off of film occurred, and the surface quality was good. However, in Test No. 9, observed is a slight seizing the level of which does not impose any hindrance in operation, which attributes to the fact that the content of boric acid-based binders in the lubricant applied to the scale film was 30%, that is, the upper limit in the amount specified in the present invention.

**[0048]** In Test No. 3, the piercing efficiency did not reach 75% because the content of boric acid-based binders in the lubricant was 2.5%, which was less than the amount specified in the present invention. In Test No. 10, since the content of boric acid-based binders in the lubricant was 35%, which was larger than the amount specified in the present invention, the piercing efficiency did not reach 75%, and moreover the seizing occurred on the plug surface.

**[0049]** In Test No. 11, since a water glass-based aqueous solution was adopted as the lubricant to be applied to the scale film, which did not satisfy the conditions specified in the present invention, the peeling off of film occurred on the plug surface, disabling the repetitive usage of the plug, although the piercing efficiency was more than 75%. In Test No. 12, since no lubricant was applied to the scale film at all, which did not satisfy the conditions specified in the present invention, the piercing efficiency did not reach 75%, and moreover, the seizing occurred on the plug surface.

## &lt;Example 2&gt;

**[0050]** The test conditions of Example 2 were as follows.

[Test method]

(1) Plug and lubricant

**[0051]** A plurality of plugs were prepared in which a scale film was formed over the entire region of the surface of the base metal by heat treatment. In addition to these, a plurality of plugs in each of which an arc-sprayed film made up of oxides and Fe was formed by the arc spraying of iron wire material over the entire region of the surface of the base metal were prepared. A boric acid-based aqueous solution which contained an oxide-based layered substance and a dispersant as with the lubricants used in Example 1, and which contained 15% of boric acid-based binder of amine borate was prepared as the lubricant, and this lubricant was applied to the protection film (scale film, arc-sprayed film) on the surface of each plug, thereafter being dried and laminated.

(2) Piercing-rolling

**[0052]** Piercing-rolling to form the below-described billets, which had been heated to 1230°C, into the below-described hollow shells was carried out by repetitively using each plug described above.

- Size of billet: Diameter 225 mm, length 2490 mm
- Material of billet: 13% Cr steel
- Hollow shell: Outer diameter 228 mm, wall thickness 18.75 mm, length 7940 mm

**[0053]** In that occasion, each time when piercing-rolling was completed, the plug was cooled after piercing-rolling, and the surface temperature of the front edge of plug when the above described lubricant was applied was variously changed, as shown in Table 2 given below. This temperature change was conducted by adjusting the cooling time of plug.

**[0054]** [Table 2]

Table 2

| Test No. | Protection film  | Surface temperature of front edge of plug at the time of lubricant application [°C] | Average time needed for cooling the plug [sec] | The number of times of successive piercing [the number of passes] | Overall evaluation |
|----------|------------------|-------------------------------------------------------------------------------------|------------------------------------------------|-------------------------------------------------------------------|--------------------|
| 21       | Scale film       | 20                                                                                  | 540                                            | 4                                                                 | ○                  |
| 22       | Scale film       | 30                                                                                  | 350                                            | 4                                                                 | ○                  |
| 23       | Scale film       | 40                                                                                  | 240                                            | 3                                                                 | ○                  |
| 24       | Scale film       | 60                                                                                  | 110                                            | 4                                                                 | ○                  |
| 25       | Scale film       | 80                                                                                  | 80                                             | 3                                                                 | ○                  |
| 26       | Scale film       | 100                                                                                 | 60                                             | 4                                                                 | ○                  |
| 27       | Scale film       | 110                                                                                 | 50                                             | 2                                                                 | ×                  |
| 28       | Scale film       | 120                                                                                 | 40                                             | 2                                                                 | ×                  |
| 31       | Arc-sprayed film | 20                                                                                  | 540                                            | 9                                                                 | ○                  |
| 32       | Arc-sprayed film | 30                                                                                  | 350                                            | 10                                                                | ○                  |
| 33       | Arc-sprayed film | 40                                                                                  | 240                                            | 10                                                                | ○                  |
| 34       | Arc-sprayed film | 60                                                                                  | 110                                            | 9                                                                 | ○                  |
| 35       | Arc-sprayed film | 80                                                                                  | 80                                             | 9                                                                 | ○                  |
| 36       | Arc-sprayed film | 100                                                                                 | 60                                             | 9                                                                 | ○                  |
| 37       | Arc-sprayed film | 110                                                                                 | 50                                             | 3                                                                 | ×                  |
| 38       | Arc-sprayed film | 120                                                                                 | 40                                             | 3                                                                 | ×                  |

[Evaluation method]

[0055] The appearance of each plug was inspected each time piercing-rolling was completed, to investigate the life of plug. The life of plug was determined as the number of passes at the time when the film peeled off and the plug became unusable, or melting-incurred metal loss or deformation occurred in the front edge portion of plug, that is, the number of billets which were successfully piercing-rolled in succession (the number of times of successive piercing-rolling). The evaluation of the life of plug was conducted with respect to a criterion, that is, the life of plug when the surface temperature of the front edge of plug at the time of application of lubricant was more than 100°C. The investigation results and evaluation results are shown together in Table 2 given above.

[0056] In Table 2, the meanings of symbols in the "overall evaluation" column are as follows.

○: Good. The life of plug is above the criterion.

×: Fail. The life of plug did not reach the criterion.

[Test results]

[0057] The results shown in Table 2 indicate the followings. Test Nos. 21 to 28 show cases where a scale film was adopted as the protection film, and Test Nos. 31 to 38 show cases where an arc-sprayed film was adopted as the protection film.

[0058] In the cases of the scale film, since in any of Test Nos. 21 to 26, the surface temperature of front edge of plug at the time of application of lubricant was not more than 100°C, the life of plug increased by about 2 times compared to Test Nos. 27 and 28 in which the surface temperature was more than 100°C. Further, in the cases of the arc-sprayed film, since in any of Test Nos. 31 to 36, the surface temperature of front edge of plug at the time of application of lubricant was not more than 100°C, the life of plug increased by about 3 times compared to Test Nos. 37 and 38 in which the surface temperature was more than 100°C.

#### INDUSTRIAL APPLICABILITY

[0059] The present invention can be effectively used for the production of seamless steel tube/pipes by the Mannesmann tube-making process, and is useful, most of all, when producing a seamless steel tube/pipe made of high alloy steel such as high Cr-containing steel containing not less than 9% of Cr, Ni-based alloy, and stainless steel.

#### Claims

1. A method for producing a seamless steel tube/pipe in which piercing-rolling is performed by using a plug with a protection film on a surface thereof, **characterized by** comprising:

applying a lubricant made of an aqueous solution containing a total of 5 to 30 mass% of one or more of boron oxide, boric acid, and amine borate to the protection film of the plug for use in the piercing-rolling.

2. The method for producing a seamless steel tube/pipe according to claim 1, **characterized in that** the plug is cooled after piercing-rolling, the lubricant is applied when the surface temperature of the front edge of plug decreases to 100°C or less, and the plug is reused for the piercing-rolling.

3. The method for producing a seamless steel tube/pipe according to claim 1 or 2, **characterized in that** the protection film is formed by arc-spraying iron wire material on the surface of the base metal of plug, and comprises oxides and Fe.

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2011/007092

## A. CLASSIFICATION OF SUBJECT MATTER

B21B19/04(2006.01)i, B21B25/04(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)

B21B19/04, B21B25/04

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 | 1996-2012 |
| Kokai Jitsuyo Shinan Koho | 1971-2012 | Toroku Jitsuyo Shinan Koho | 1994-2012 |

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<br>Y    | JP 2001-234189 A (Sumitomo Metal Industries, Ltd.),<br>28 August 2001 (28.08.2001),<br>table 1; paragraphs [0035], [0040]<br>(Family: none) | 1<br>2, 3             |
| Y         | JP 8-117819 A (Kawasaki Steel Corp.),<br>14 May 1996 (14.05.1996),<br>claims<br>(Family: none)                                              | 2, 3                  |
| Y         | JP 4279350 B1 (Sumitomo Metal Industries, Ltd.),<br>17 June 2009 (17.06.2009),<br>claim 1; paragraph [0079]<br>(Family: none)               | 3                     |

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

\* Special categories of cited documents:

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"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

"&amp;" document member of the same patent family

Date of the actual completion of the international search  
12 January, 2012 (12.01.12)Date of mailing of the international search report  
24 January, 2012 (24.01.12)Name and mailing address of the ISA/  
Japanese Patent Office

Authorized officer

Facsimile No.

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**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- JP 8117819 A [0013]
- JP 2002248507 A [0013]
- JP 4279350 B [0013]