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(54) **MANUFACTURING METHOD FOR PIERCING PLUG**

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**Description**

## TECHNICAL FIELD

5     **[0001]** The present invention relates to a method for producing a plug for piercing-rolling (hereinafter, also referred to simply as a "plug") for use in a piercing-rolling mill (hereinafter, also referred to simply as a "piercer") that produces a seamless steel tube/pipe, particularly to a method for producing a plug for piercing-rolling having a film formed by performing arc-spraying of a spray wire mainly containing iron, on a surface of a plug base metal.

## 10     BACKGROUND ART

**[0002]** A seamless steel tube/pipe is produced by the Mannesmann tube-making process. The Mannesmann tube-making process includes the following steps:

- 15         (1) piercing-rolling a starting material (round billet) heated at a predetermined temperature into a hollow shell by using a piercer;  
            (2) elongation-rolling the hollow shell by an elongation rolling mill (e.g. mandrel mill); and  
            (3) carrying out diameter adjusting rolling on the elongation-rolled hollow shell to have a predetermined outer diameter and wall thickness by using a diameter adjusting rolling mill (e.g. a stretch reducer).

20     **[0003]** In the piercing-rolling by using the piercer, a plug is used as a piercing tool. This plug is mounted to a front end of a mandrel so as to pierce a billet heated at a high temperature of approximately 1200°C; thus the plug is exposed to a hostile environment with a high surficial pressure and a high temperature. In general, the plug includes a base metal made of hot working tool steel, and the film of oxide scale is formed on a surface of the base metal through a heating process in advance for the purpose of protection of the base metal, and thereafter the plug is used in the piercing-rolling. During the piercing-rolling, the scale film on the surface of the plug insulates heat transfer from the billet to the base metal of the plug, and also prevents seizing between the billet and the plug.

25     **[0004]** Repetitive piercing-rolling using such a plug having the scale film causes a gradual abrasion of the scale film. The abrasion of the scale film deteriorates thermal insulation effect of the film, resulting in increased temperature of the plug during the piercing, so that melting-incurred metal loss and deformation by heat are likely to be caused to the plug base metal. If the scale film is exhausted, and the plug base metal comes into direct contact with the billet, seizing is caused, so as to generate flaws on an internal surface of a steel tube/pipe. Consequently, the plug becomes unusable at the moment when the film is exhausted, and its durability life is expired.

30     **[0005]** Particularly in production of a seamless steel tube/pipe made of high alloy steel such as high Cr steel containing Cr of 9% or more, Ni-based alloy, and stainless steel, significant abrasion of the scale film on the surface of the plug is generated during the piercing-rolling, so that the durability life of the plug becomes significantly reduced. For example, in the case of piercing stainless steel, the scale film on the surface of the plug becomes worn away through several passes (number of times of continuous piercing rolling), and the durability life of this plug is expired. This requires a frequent replacement of the plug, which deteriorates the production efficiency of the steel tube/pipe. In production of a seamless steel tube/pipe of high alloy steel, it is required to enhance the durability life of the plug during the piercing-rolling, thereby enhancing the production efficiency of the steel tube/pipe.

35     **[0006]** To satisfy such a requirement, as an example of the film formed on the surface of the plug base metal, Patent Literature 1 discloses such a plug having a film containing Fe oxide and Fe formed on the surface of the plug base metal by performing arc-spraying of iron wire, instead of using the scale film formed through heat treatment. Since the plug having the arc-sprayed film has a film containing Fe oxide and Fe on the surface of the plug, this plug is excellent in thermal insulation performance and seizing prevention, so that enhancement of the durability life of the plug is likely to be achieved.

40     **[0007]** However, even in the plug having the arc-sprayed film disclosed in this Patent Literature, wrinkles are generated on its film due to repetitive heat input if the plug is subjected to repetitive piercing-rolling, which results in expiration of its durability life. A longer duration time in piercing-rolling increases load onto the plug, which causes detachment of the film or wrinkles of the film, resulting in expiration of its durability life. Such a situation frequently occurs in the case of using a billet of a longer length to be pierced or a billet having a greater elevated-temperature strength. In order to reduce occurrence of wrinkles on the arc-sprayed film, it is effective to increase thickness of the film so as to enhance thermal insulation performance of the film, but increase in thickness of the film deteriorates adhesiveness between the plug base metal and the film, which results in detachment of the film at an early stage. Hence, there is still room for further improvement in securing the steadily enhanced durability life of the plug, and thus it has been strongly desired to produce a plug for piercing-rolling that can improve the above points. Patent Literature 2 and Patent Literature 3 are directed to wire arc spraying methods using a cored wire.

CITATION LIST

PATENT LITERATURE

5 [0008]

Patent Literature 1: Japanese Patent No. 4279350

Patent Literature 2: DE 10 2008 024226 A1

Patent Literature 3: DE 103 34 701 A1

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SUMMARY OF INVENTION

TECHNICAL PROBLEM

15 [0009] An object of the present invention, which has been made in order to solve the problems in the prior art, is to provide a method for producing a plug for piercing-rolling having a film formed on a surface of the plug base metal by performing arc-spraying of a spray wire mainly containing iron, and the method has the following feature: securing steady enhancement of the durability life of the plug.

20 SOLUTION TO PROBLEM

[0010] The summary of the present invention is as follows.

[0011] The present invention provides a method for producing a plug for use in a piercing-rolling mill for producing a seamless steel tube/pipe,

25 the method for producing the plug for piercing-rolling comprising the steps of:

shotblasting a surface of the plug; and

arc-spraying a spray wire so as to form a film on a surface of a base metal of the plug that is shotblasted, characterized in that

30 in the arc-spraying step, the arc-spraying is carried out by using, as the spray wire, a cored wire whose iron sheath tube is charged with at least specific particles that contribute to enhancement of the durability life of the plug and, optionally, additionally with iron particles, so as to form the film containing iron oxide, Fe and specific particles, wherein the arc-spraying is performed in air, and wherein the specific particles are preferably low-thermal conductive particles having lower thermal conductivity than that of the iron oxide, wherein the iron oxide is one of iron oxide (II) (FeO), iron oxide (III) (Fe<sub>2</sub>O<sub>3</sub>), and iron oxide (II,III) (Fe<sub>3</sub>O<sub>4</sub>), and the low-thermal conductive particles are ZrO<sub>2</sub> particles, wherein the proportion of the ZrO<sub>2</sub> particles in the cored wire is 2.5 to 30.0 volume%.

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ADVANTAGEOUS EFFECTS OF INVENTION

40 [0012] The method for producing a plug for piercing-rolling according to the present invention achieves the following remarkable effect: securing steady enhancement of the durability life of the plug.

BRIEF DESCRIPTION OF DRAWINGS

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[0013]

[FIG. 1] FIG. 1 is a cross sectional drawing showing a spray wire for use in the arc-spraying in the method for producing a plug for piercing-rolling according to the first embodiment of the present invention.

50 [FIG. 2] FIG. 2 is a cross sectional drawing showing a spray wire for use in the arc-spraying in the method for producing a plug for piercing-rolling according to the second embodiment not according to the present invention.

[FIG. 3] FIG. 3 shows a relation between the proportion of ZrO<sub>2</sub> particles in the cored wire and the deformation of the plug base metal, as a test result of Example 1.

[FIG. 4] FIG. 4 shows a relation between the proportion of BN particles in the cored wire and a plug durability life ratio, as a test result of Comparative Example 2.

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## DESCRIPTION OF EMBODIMENT

**[0014]** In order to achieve the above object, the present inventors conducted various tests and intensive studies on the method for forming a film on a surface of a plug base metal by performing arc-spraying of a spray wire mainly containing iron. As a result, the present inventors have obtained the following findings.

**[0015]** The arc-spraying generates arcs between front ends of two lines of spray wires serving as electrodes, so as to melt the spray wires, and at the same time, a compressed air jet or a nitrogen gas jet is supplied between the front ends of the spray wires so that the molten material is blown off, thereby spraying the molten material onto a target object to form a film thereon, for example. In the arc-spraying disclosed in the Patent Literature 1, an iron wire is used as the spray wire, and thus a film formed on the surface of the plug base metal contains Fe oxide (iron oxide) and Fe. The Fe oxide contained in the film is generated by melting the iron wire during the arc-spraying, and oxidizing the molten iron in the air before the molten iron reaches the surface of the plug base metal. The Fe contained in the film results from the molten iron that has reached the surface of the plug base metal without being oxidized in the air.

**[0016]**

(1) Meanwhile, the film containing Fe oxide (iron oxide), Fe and low-thermal conductive material can be formed on the surface of the plug base metal by performing arc-spraying of a cored wire as the spray wire; and the cored wire comprises an outer sheath tube made of an iron which is the same as that of the iron wire, and is charged with low-thermal conductive particles having lower thermal conductivity than that of iron oxide, and also with iron particles in some cases. The Fe oxide contained in this film is generated such that the iron sheath tube included in the cored wire as well as the iron particles are melted during the arc-spraying and the molten iron is oxidized in the air before reaching the surface of the plug base metal. The Fe contained in the film is generated such that the molten iron reaches the surface of the plug base metal without being oxidized in the air. The low thermal conductive material in the film is generated such that the low thermal conductive particles included in the cored wire reach the surface of the plug base metal.

In this manner, the film formed by the arc-spraying using the cored wire includes low-thermal conductive material having lower thermal conductivity than that of the Fe oxide, which results from the low-thermal conductive particles included in the cored wire, and thus thermal insulation performance becomes enhanced without increasing the film thickness. Accordingly, the plug having such an arc-sprayed film has an excellent thermal insulation performance of the film during the repetitive piercing-rolling, which steadily enhances the durability life of the plug. Specifically, the low-thermal conductive particles are specific particles that contribute to enhancement of the durability life of the plug.

(2) Not according to the invention, a film containing the Fe oxide (iron oxide), the Fe and the solid lubricant can be formed on the surface of the plug base metal by employing the cored wire that comprises an outer sheath tube made of iron which is the same as that of the iron wire, and is charged with solid lubricant particles, and also with iron particles in the iron sheath tube in some cases, and carrying out the arc-spraying using such cored wires. The Fe oxide contained in this film is generated such that the iron sheath tube as well as the iron particles included in the cored wire are melted during the arc-spraying, and the molten iron is oxidized in the air before reaching the surface of the plug base metal. The Fe contained in the film is generated such that the molten iron reaches the surface of the plug base metal without being oxidized in the air. The solid lubricant in the film is generated such that the solid lubricant particles included in the cored wire reach the surface of the plug base metal.

**[0017]** As described above, the film formed by the arc-spraying using the cored wire contains the solid lubricant resulted from the solid lubricant particles included in the cored wire; thus the lubricity during the piercing-rolling becomes enhanced. Accordingly, the plug having such an arc-sprayed film has excellent lubricity of the film during the repetitive piercing-rolling which steadily enhances the durability life of the plug. Specifically, the solid lubricant particles are specific particles that contribute to enhancement of the durability life of the plug.

**[0018]** The present invention has been made based on the findings described in (1) above. Hereinafter, a description will be given of the preferred embodiment of the method for producing the plug according to the present invention.

<First embodiment>

**[0019]** In the method for producing the plug according to the first embodiment of the present invention, prior to the arc-spraying, the shotblasting is carried out on the surface of the plug. In the case of using the plug to be reproduced after the durability life is expired through the repetitive piercing-rolling, the film as piercing-rolled condition remaining on the surface of the plug is removed through the shotblasting so as to expose the surface of the plug base metal, and make the surface of the plug base metal appropriately rough. In the case of producing a new plug, the surface of the plug base metal is moderately roughened through the shotblasting. The reason for the shotblasting treatment is because

the plug base metal having a moderate rough surface free of remaining film enhances adhesiveness between the plug base metal and the film at the time of the arc-spraying.

**[0020]** In the method for producing the plug according to the first embodiment, following the above step, the cored wire mainly containing iron, used as the spray wire, is arc-sprayed on the surface of the plug base metal to which the shotblasting is applied, thereby forming the film thereon.

**[0021]** FIG. 1 is a cross sectional view showing a spray wire for use in the arc-spraying in the method for producing a plug for piercing-rolling according to the first embodiment of the present invention. As shown in this drawing, in the first embodiment, a cored wire 1 is used as the spray wire. This cored wire 1 includes an outer sheath tube 2 made of iron.

**[0022]** The iron sheath tube 2 is charged with the low-thermal conductive particles 3. The low-thermal conductive particles 3 are characterized by lower thermal conductivity than that of the iron oxide, and are hard to be burned out and disappeared during the arc-spraying, and the low-thermal conductive particles 3 are ceramic particles, namely zirconia ( $\text{ZrO}_2$ ) particles having extremely low thermal conductivity. The low-thermal conductive particles 3 are not limited to simply be in a particle form, and may include powders or chopped fibers. Here, iron oxide includes iron oxide (II) ( $\text{FeO}$ ), iron oxide (III) ( $\text{Fe}_2\text{O}_3$ ), and iron oxide (II, III) ( $\text{Fe}_3\text{O}_4$ ).

**[0023]** The iron sheath tube 2 may also be charged with iron particles 4 in addition to the low-thermal conductive particles 3. The iron particles 4 are not limited to simply be in a particle form, and may include powders or chopped fibers.

**[0024]** The arc-spraying using the cored wire (spray wire) 1 having the above configuration enables the film containing Fe oxide (iron oxide), Fe and low-thermal conductivity material to be formed on the surface of the plug base metal. Since the plug having the arc-sprayed film produced in this manner contains in its film low-thermal conductive material whose thermal conductivity is lower than that of the Fe oxide, the thermal insulation performance during the repetitive piercing-rolling is enhanced without increasing the thickness of the film, thereby steadily enhancing the durability life of the plug.

**[0025]** The proportion of the  $\text{ZrO}_2$  particles as the low-thermal conductive particles 3 in the entire cored wire 1 including the iron sheath tube 2, the low-thermal conductive particles 3, and the iron particles 4 is 2.5 to 30.0 volume%. As verified in Example 1 described later, if the proportion of the  $\text{ZrO}_2$  particles is less than 2.5 volume%, the thermal insulation performance during the piercing-rolling cannot be sufficiently enhanced because of insufficient amount of  $\text{ZrO}_2$  contained in the film of the plug, so that the deformation of the plug base metal becomes significant, which is inappropriate for reuse, and hinders the steady enhancement of the durability life of the plug. To the contrary, if the proportion of the  $\text{ZrO}_2$  particles is more than 30.0 volume%, the adhesiveness between the plug base metal and the film becomes deteriorated, the film detachment occurs at an early stage due to excessive amount of  $\text{ZrO}_2$  contained in the film of the plug, and the plug base metal becomes melted, which is also inappropriate for reuse. This proportion is preferably 5.0 to 30.0 volume%.

<Second embodiment, not according to the invention>

**[0026]** In the production method of for the plug according the second embodiment not according to the invention, prior to the arc-spraying, the shotblasting is applied to the surface of the plug, similarly to the first embodiment. Subsequently, the surface of the plug base metal to which the shotblasting is applied is arc-sprayed by using the cored wire mainly containing iron as the spray wires, so as to form the film thereon. The cored wire used in the second embodiment are different from the cored wire of the first embodiment in the following features.

**[0027]** FIG. 2 is a cross sectional view showing a spray wire for use in the arc-spraying in the method for producing a plug for piercing-rolling according to the second embodiment not according to the present invention. As shown in this drawing, in the second embodiment, a cored wire 1 is used as the spray wire. This cored wire 1 includes an outer shell formed by an iron sheath tube 2.

**[0028]** The iron sheath tube 2 is charged with the solid lubricant particles 5. The solid lubricant particles 5 have a function as the solid lubricant during the piercing-rolling, and are hard to be burned out and disappeared during the arc-spraying, and examples of the solid lubricant particles 5 may include metal particles and ceramic particles. Particularly, boron nitride (BN) particles extremely excellent in solid lubricity is preferable. The solid lubricant particles 5 are not limited to simply be in a particle form, but may also include powders and short fibers.

**[0029]** The iron sheath tube 2 may also be charged with iron particles 4 in addition to the solid lubricant particles 5. The iron particles 4 are not limited to simply in a particle form, and may include powders or chopped fibers.

**[0030]** Through the arc-spraying using the cored wire (spray wire) 1 having the above described configuration, the film containing the Fe oxide (iron oxide), the Fe, and the solid lubricant can be formed on the surface of the plug base metal. The plug having the arc-sprayed film produced in this manner includes the solid lubricant in its film, so that the lubricity during the repetitive piercing-rolling is enhanced, thereby steadily enhancing the durability life of the plug.

**[0031]** In the case of applying the BN particles as the solid lubricant particles 5, the proportion of the BN particles in the entire cored wire 1 including the iron sheath tube 2, the solid lubricant particles 5, and the iron particles 4 is preferably 5.0 to 20.0 volume%. As verified in Comparative Example 2 described later, if the proportion of the BN particles is less than 5.0 volume%, the lubricity during the piercing-rolling cannot be sufficiently enhanced because of insufficient amount of BN contained in the film of the plug, which hinders sufficient enhancement of the piercing efficiency, and the durability

life of the plug cannot be steadily enhanced. To the contrary, if the proportion of the BN particles is more than 20.0 volume%, the adhesiveness between the plug base metal and the film becomes deteriorated, and the detachment of the film occurs at an early stage due to excessive amount of BN contained in the film of the plug, and the plug base metal becomes melted, which is also inappropriate for reuse, and hinders steady enhancement of the durability life of the plug. This proportion is preferably 7.5 to 20.0 volume%.

**[0032]** The piercing efficiency herein means as follows. The speed at which the billet is transferred in an axial direction during the piercing-rolling (referred to as the "feed speed", hereinafter) is defined by the number of rotation of the piercer roll, and the actual feed speed is delayed compared to the theoretical feed speed calculated based on the number of rotation of the set piercer rolls, due to the influence of frictional resistance and the like between the plug and the billet that are in contact with each other. Usually, the ratio of the speed (= (actual feed speed) / (theoretical feed speed) × 100 [%]) is referred to as the "piercing efficiency". The piercing efficiency is an index of the lubricity. Greater lubricity not only enhances the production efficiency of the piercing-rolling mill, but also reduces the time in contact between the plug and the billet, thereby increasing the durability life of the plug.

**[0033]** In the method for producing the plug according to the present invention, the arc-spraying may be carried out while the spraying equipment is being gradually distanced away from the surface of the plug base metal, so as to increase the spraying distance gradually during the formation of the film through the arc-spraying. In this manner, such a film is formed on the plug base metal that gradually increases in the ratio of the region containing Fe oxide (referred to as an "oxide ratio", hereinafter) toward the surface. The film having such an oxide ratio that is smaller at a portion adjacent to the plug base metal, and greater on its surface is useful in light of securing thermal insulation performance and seizing preventing performance on the surface of the film as well as securing the adhesiveness between the film and the portion adjacent to the plug base metal.

[Examples]

**[0034]** For the purpose of verifying the effects of the present invention, a piercing-rolling test was conducted in such a manner that plugs for piercing-rolling were produced, and each of the produced plugs was mounted to a piercer so as to carry out the piercing-rolling. The test condition was as follows.

< Example 1 >

[Test method]

(1) Production of plug

**[0035]** A number of bullet-shaped plugs, each having a maximum diameter of 147 mm, were prepared using hot-working tool steel specified by the JIS standard as the base metal. Plugs having the arc-sprayed film were produced such that, after the shotblasting was applied to a surface of each plug, the arc-spraying was carried out by using cored wires shown in FIG. 1, so as to form a film on the surface of the base metal of each plug. In the formation of the arc-sprayed film, the arc-spraying was conducted with the spraying distance from the spray gun to the surface of the plug base metal initially set at 200 mm, and the arc-spraying was carried out while the spray gun was gradually distanced away from the surface of the plug base metal until the spraying distance finally became 1000 mm.

**[0036]** At this time, the ZrO<sub>2</sub> particles were employed as the low-thermal conductive particles in the cored wires, and the cored wires were used in which the proportion of the ZrO<sub>2</sub> particles was changed as shown in Table 1 below. The iron sheath tube of each cored wire was charged with iron particles as well as the ZrO<sub>2</sub> particles in accordance with the proportion of the ZrO<sub>2</sub> particles.

[Table 1]

**[0037]**

Table 1

| No. | Composition of cored wire [volume%] |                  | Deformation of plug base metal [mm] |
|-----|-------------------------------------|------------------|-------------------------------------|
|     | Fe                                  | ZrO <sub>2</sub> |                                     |
| 1   | 100.0                               | 0.0              | 2.8                                 |
| 2   | 97.5                                | 2.5              | 1.9                                 |

(continued)

| No.                                                                                                          | Composition of cored wire [volume%] |                  | Deformation of plug base metal [mm] |
|--------------------------------------------------------------------------------------------------------------|-------------------------------------|------------------|-------------------------------------|
|                                                                                                              | Fe                                  | ZrO <sub>2</sub> |                                     |
| 3                                                                                                            | 95.0                                | 5.0              | 1.5                                 |
| 4                                                                                                            | 90.0                                | 10.0             | 1.2                                 |
| 5                                                                                                            | 80.0                                | 20.0             | 0.9                                 |
| 6                                                                                                            | 70.0                                | 30.0             | 0.5                                 |
| 7                                                                                                            | 60.0                                | 40.0             | -                                   |
| 8                                                                                                            | 40.0                                | 60.0             | -                                   |
| Note) The symbol "-" denotes the film detachment and the melting-incurred metal loss of the plug base metal. |                                     |                  |                                     |

## (2) Piercing-rolling

**[0038]** Using the above various plugs, the following hollow shells were produced by repetitively piercing-rolling the following workpieces (materials) heated at about 1200°C.

- Workpiece size: round billet of 191 mm in diameter and 2200 mm in length
- Workpiece material: 13% Cr steel
- Hollow shell: 196 mm in outer diameter, 16.82 mm in wall thickness, 6520 mm in length

## [Evaluation]

**[0039]** The piercing rolling was repetitively conducted successively ten times for each plug, and thereafter, an inspection was conducted on the appearance of each plug so as to examine its surface condition, that is, occurrence of the melting-incurred metal loss of the plug base metal due to the detachment of the film. In addition, the shotblasting was carried out on the surface of the plug so as to remove the remaining film thereon, and thereafter, the height of the plug base metal (length in an axial direction) was measured so as to assess the deformation after the plug was used, that is, the difference in height of the plug base metal before and after the plug was used. In this case, the deformation of the plug base metal was adjusted to be 2.0 mm or less in a real operation. If the deformation of the plug base metal becomes more than 2.0 mm, this plug is inappropriate for reuse. Accordingly, the case in which the deformation of the plug base metal was 2.0 mm or less with no melting-incurred metal loss of the plug base metal was evaluated as "preferable" in this test.

## [Test result]

**[0040]** The test result is shown in Table 1 and FIG. 3. FIG. 3 shows a relation between the proportion of ZrO<sub>2</sub> particles in the cored wire and the deformation of the plug base metal, as a test result of Example 1. The test result suggests the following findings.

**[0041]** The ZrO<sub>2</sub> particles were used as the low-thermal conductive particles in the cored wire, and the arc-sprayed film was formed by using such cored wires. In this case, as shown in Test Nos. 2 to 6, the proportion of the ZrO<sub>2</sub> particles in the cored wire was set to be 2.5 volume% or more, so that the deformation of the plug base metal was reduced to be 2.0 mm or less. The reason for this is because the appropriate amount of the ZrO<sub>2</sub> particles are contained in the film of the plug, which enhances the thermal insulation performance. Accordingly, it was found that the plug having the arc-sprayed film formed by using the cored wire containing the ZrO<sub>2</sub> particles of 2.5 volume% or more steadily enhances the durability life of the plug, and is appropriate for reuse.

**[0042]** As shown in Test Nos. 7 and 8, in the plug having the arc-sprayed film formed by using the cored wire containing the ZrO<sub>2</sub> particles of more than 30.0 volume%, the film of the plug was detached at an early stage, and the plug base metal was melted. The reason for this is because the excessive amount of ZrO<sub>2</sub> was contained in the film of the plug, and the adhesiveness between the plug base metal and the film became deteriorated although the thermal insulation performance was enhanced. Accordingly, it was found that the plug having the arc-sprayed film formed by using the cored wires containing the ZrO<sub>2</sub> particles of more than 30.0 volume% cannot steadily enhance the durability life of the plug.

**[0043]** On the other hand, as shown in Test No. 1, in the plug having the arc-sprayed film formed by using the cored wires containing the ZrO<sub>2</sub> particles of 0 volume% (equivalent to the case of forming the arc-sprayed film by using the

iron wires as disclosed in Patent Literature<sup>1</sup>), the deformation of the plug base metal was further more than 2.0 mm. The reason for this is because ZrO<sub>2</sub> having low thermal conductivity was not contained in the film of the plug, and thus the thermal insulation performance was not enhanced. Accordingly, it was found that the plug having the arc-sprayed film formed by using the cored wires containing the ZrO<sub>2</sub> particles of less than 2.5 volume% cannot steadily enhance the durability life of the plug.

<Comparative Example 2>

[Test method]

(1) Production of plug

**[0044]** A number of bullet-shaped plugs, each having a maximum diameter of 147 mm, were prepared using hot-working tool steel specified by the JIS standard as the base metal. Plugs having the arc-sprayed film were produced such that, after the shotblasting was applied to the surface of each plug, the arc-spraying was carried out by using cored wires shown in FIG. 2, so as to form a film on the surface of the base metal of each plug. In the formation of the arc-sprayed film, the arc-spraying was conducted with the spraying distance from the spray gun to the surface of the plug base metal initially set at 200 mm, and the arc-spraying was carried out while the spray gun was gradually distanced away from the surface of the plug base metal until the spraying distance finally became 1000 mm.

**[0045]** At this time, the BN particles were employed as the solid lubricant particles in the cored wires, and the core wires were used in which the proportion of the BN particles was changed as shown in Table 2 below. The iron sheath tube of each cored wire is charged with iron particles as well as the BN particles in accordance with the proportion of the BN particles.

[Table 2]

**[0046]**

Table 2

| No.                                                                                                          | Composition of cored wire [volume%] |      | Piercing efficiency [%] | Plug durability life ratio |
|--------------------------------------------------------------------------------------------------------------|-------------------------------------|------|-------------------------|----------------------------|
|                                                                                                              | Fe                                  | BN   |                         |                            |
| 11                                                                                                           | 100.0                               | 0.0  | 60.0                    | 1.00                       |
| 12                                                                                                           | 97.5                                | 2.5  | 65.3                    | 1.04                       |
| 13                                                                                                           | 95.0                                | 5.0  | 70.2                    | 1.08                       |
| 14                                                                                                           | 92.5                                | 7.5  | 73.3                    | 1.13                       |
| 15                                                                                                           | 90.0                                | 10.0 | 76.5                    | 1.17                       |
| 16                                                                                                           | 85.0                                | 15.0 | 80.2                    | 1.25                       |
| 17                                                                                                           | 80.0                                | 20.0 | 82.4                    | 1.33                       |
| 18                                                                                                           | 70.0                                | 30.0 | -                       | -                          |
| 19                                                                                                           | 60.0                                | 40.0 | -                       | -                          |
| 20                                                                                                           | 50.0                                | 50.0 | -                       | -                          |
| Note) The symbol "-" denotes the film detachment and the melting-incurred metal loss of the plug base metal. |                                     |      |                         |                            |

(2) Piercing-rolling

**[0047]** Using the above various plugs, the following hollow shells were produced by repetitively piercing-rolling the following workpieces (materials) heated at about 1200°C.

- Workpiece size: round billet of 191 mm in diameter and 2200 mm in length
- Workpiece material: 13% Cr steel
- Hollow shell: 196 mm in outer diameter, 16.82 mm in wall thickness, 6520 mm in length



[Evaluation]

**[0048]** Assessed was the piercing efficiency during the piercing-rolling for each plug. The piercing efficiency in the real operation is targeted to be 70% or more, and the piercing efficiency more than this target was evaluated as "preferable". In addition, the inspection was conducted on the appearance of each plug every time the piercing-rolling was completed. For each plug, investigated was the number of times of piercing rolling until the plug became unusable due to detachment of the film, or otherwise, exhibits the melting-incurred metal loss or deformation at the front end of the plug, in other words, the number of the billets that successfully got through the continuous piercing-rolling (the number of times of continuous piercing-rolling) was counted. The number of times of continuous piercing-rolling was evaluated as the durability life of the plug. As disclosed in Patent Literature 1, the durability life of the plug was evaluated on each of the plugs based on the ratio of its durability life (referred to as the "plug durability life ratio", hereinafter), where the durability life of the plug equivalent to a plug having the arc-sprayed film formed by using the iron wire, that is, the plug having the arc-sprayed film formed by using the cored wire free of BN particles (0 volume%) as shown in Test No. 11 of Table 2 above was defined as a reference "1.00".

[Test result]

**[0049]** The test result is shown in Table 2 and FIG. 4. FIG. 4 shows a relation between the proportion of BN particles in the cored wire and a plug durability life ratio, as a test result of Comparative Example 2. The test result suggests the following findings.

**[0050]** The BN particles were used as the solid lubricant particles in the cored wire, and the arc-sprayed film was formed by using such cored wires. In this case, as shown in Test Nos. 13 to 17, it was found that the proportion of the BN particles in the cored wire was set to be 5.0 volume% or more, so that the piercing efficiency was assured to be 70% or more, and the plug durability life ratio was enhanced. The reason for this is because the appropriate amount of the BN was contained in the plug film, which enhanced the lubricity. Accordingly, it was found that the plug having the arc-sprayed film formed by using the cored wire containing the BN particles of 5.0 volume% or more steadily enhances the durability life of the plug.

**[0051]** As shown in Test Nos. 18 to 20, in the plug having the arc-sprayed film formed by using the cored wires containing the BN particles of more than 20.0 volume%, the film of the plug was detached at an early stage, and the plug base metal was melted. The reason for this is because the excessive amount of BN was contained in the film of the plug, and the adhesiveness between the plug base metal and the film became deteriorated although the lubricity was enhanced. Accordingly, it was found that, in the plug having the arc-sprayed film formed by using the cored wires containing the BN particles of more than 20.0 volume%, the durability life of the plug cannot be steadily enhanced.

**[0052]** On the other hand, as shown in Test Nos. 11 and 12, in the plug having the arc-sprayed film formed by using the cored wires containing the BN particles of less than 5.0 volume% (including 0 volume%), the piercing efficiency was less than 70%, and a little enhancement of the plug durability life ratio was discerned. The reason for this is because no BN functioning as the solid lubricant was contained, or insufficient amount of BN was contained in the film of the plug, and thus the lubricity was not enhanced sufficiently. Accordingly, it was found that the plug having the arc-sprayed film formed by using the cored wires containing the BN particles of less than 5.0 volume% cannot also steadily enhance the durability life of the plug.

#### INDUSTRIAL APPLICABILITY

**[0053]** The present invention can be effectively used in the production of a seamless steel tube/pipe of high alloy steel.

#### REFERENCE SIGNS LIST

**[0054]**

1: Cored wire (spray wire), 2: Iron sheath tube, 3: Low-thermal conductive particles,  
4: Iron particles, 5: Solid lubricant particles

#### Claims

1. A method for producing a plug for use in a piercing-rolling mill for producing a seamless steel tube/pipe, the method for producing the plug for piercing-rolling comprising the steps of:

shotblasting a surface of the plug; and

arc-spraying a spray wire so as to form a film on a surface of a base metal of the plug that is shotblasted, **characterized in that**

in the arc-spraying step, the arc-spraying is carried out by using, as the spray wire, a cored wire (1) whose iron sheath tube (2) is charged with specific particles that contribute to enhancement of the durability life of the plug and, optionally, additionally with iron particles (4), so as to form the film containing iron oxide, Fe and the specific particles, wherein the arc-spraying is performed in air, and wherein

the specific particles are low-thermal conductive particles (3) having lower thermal conductivity than that of the iron oxide, wherein the iron oxide is one of iron oxide (II) (FeO), iron oxide (III) (Fe<sub>2</sub>O<sub>3</sub>), and iron oxide (II, III) (Fe<sub>3</sub>O<sub>4</sub>); and the low-thermal conductive particles (3) are ZrO<sub>2</sub> particles wherein the proportion of the ZrO<sub>2</sub> particles in the cored wire (1) is 2.5 to 30.0 volume%.

2. The method for producing a plug for piercing-rolling according to claim 1, wherein the arc-spraying is carried out while a spraying equipment is being gradually distanced away from the surface of the plug base metal, so as to increase the spraying distance gradually during the formation of the film through the arc-spraying.

## Patentansprüche

1. Verfahren zum Herstellen eines Dorns zur Verwendung in einem Lochwalzwerk zum Herstellen einer nahtlosen Stahlröhre/eines nahtlosen Stahlrohrs, wobei das Verfahren zum Herstellen des Dorns zum Lochwalzen die folgenden Schritte umfasst:

Kugelstrahlen einer Oberfläche des Dorns; und

Lichtbogenspritzen eines Sprühdrahts, um einen Film auf einer kugelgestrahlten Oberfläche eines Grundmetalls des Dorns zu bilden, **dadurch gekennzeichnet, dass**

beim Lichtbogenspritzschritt das Lichtbogenspritzen ausgeführt wird, indem als Sprühdraht ein Fülldraht (1) verwendet wird, dessen Eisenmantelrohr (2) mit spezifischen Partikeln, die zur Steigerung der Langlebigkeit des Dorns beitragen, und optional zusätzlich mit Eisenpartikeln (4) beladen ist, um den Film zu bilden, der Eisenoxid, Fe und die spezifischen Partikel enthält, wobei das Lichtbogenspritzen in Luft erfolgt, und wobei es sich bei den spezifischen Partikeln um gering wärmeleitfähige Partikel (3) mit einer geringeren Wärmeleitfähigkeit als derjenigen des Eisenoxids handelt, wobei das Eisenoxid Eisenoxid (II) (FeO), Eisenoxid (III) (Fe<sub>2</sub>O<sub>3</sub>) oder Eisenoxid (II, III) (Fe<sub>3</sub>O<sub>4</sub>) ist; und die gering wärmeleitfähigen Partikel (3) ZrO<sub>2</sub>-Partikel sind, wobei der Anteil der ZrO<sub>2</sub>-Partikel im Fülldraht (1) 2,5 bis 30,0 Volumen-% beträgt.

2. Verfahren zum Herstellen eines Dorns zum Lochwalzen nach Anspruch 1, wobei das Lichtbogenspritzen ausgeführt und dabei eine Spritzeinrichtung graduell von der Oberfläche des Dorngrundmetalls wegbewegt wird, um die Spritzdistanz während der Ausbildung des Films durch das Lichtbogenspritzen graduell zu vergrößern.

## Revendications

1. Procédé pour produire un poinçon destiné à être utilisé dans un laminoir perceur pour produire un tube/tuyau en acier sans soudure, le procédé pour produire le poinçon pour laminage perçage comprenant les étapes de :

grenaillage d'une surface du poinçon ; et

fusion en pluie à l'arc d'un fil de fusion en pluie de manière à former un film sur une surface d'un métal de base du poinçon qui est grenaillée, **caractérisé en ce que**

dans l'étape de fusion en pluie à l'arc, la fusion en pluie à l'arc est réalisée en utilisant, comme fil de fusion en pluie, un fil à noyau (1) dont le tube de gaine en fer (2) est chargé avec des particules spécifiques qui contribuent à l'amélioration de la durabilité du poinçon et, éventuellement, en outre avec des particules de fer (4), de manière à former le film contenant de l'oxyde de fer, Fe et les particules spécifiques, où la fusion en pluie à l'arc est réalisée dans l'air, et où

les particules spécifiques sont des particules à faible conductivité thermique (3) ayant une conductivité thermique plus faible que celle de l'oxyde de fer, où l'oxyde de fer est l'un de l'oxyde de fer (II) (FeO), de l'oxyde de fer

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(III) ( $\text{Fe}_2\text{O}_3$ ) et de l'oxyde de fer (II, III) ( $\text{Fe}_3\text{O}_4$ ) ; et les particules à faible conductivité thermique (3) sont des particules de  $\text{ZrO}_2$  où la proportion des particules de  $\text{ZrO}_2$  dans le fil à noyau (1) est 2,5 à 30,0 % en volume.

2. Procédé pour produire un poinçon pour le laminage perçage selon la revendication 1, où la fusion en pluie à l'arc est réalisée tandis qu'un appareillage de fusion en pluie est progressivement éloigné de la surface du métal de base du poinçon, de manière à augmenter la distance de fusion en pluie progressivement pendant la formation du film par la fusion en pluie à l'arc.

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FIG. 1

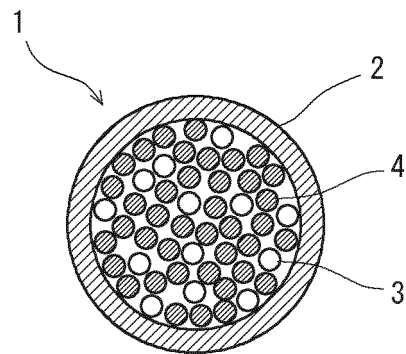


FIG. 2

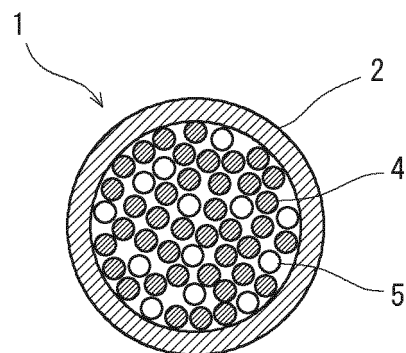


FIG. 3

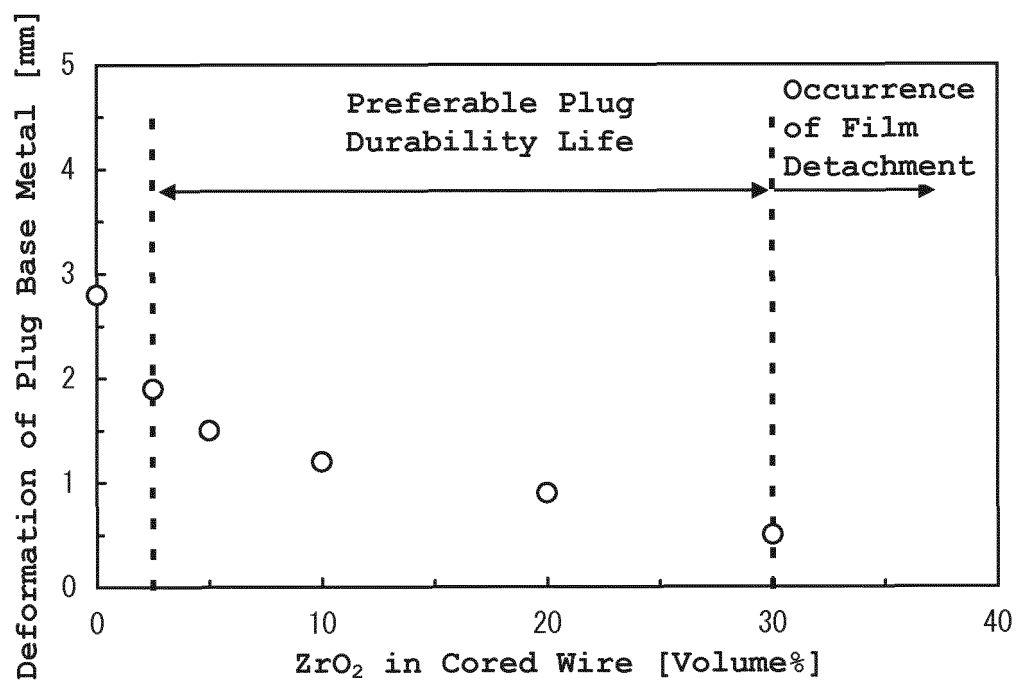
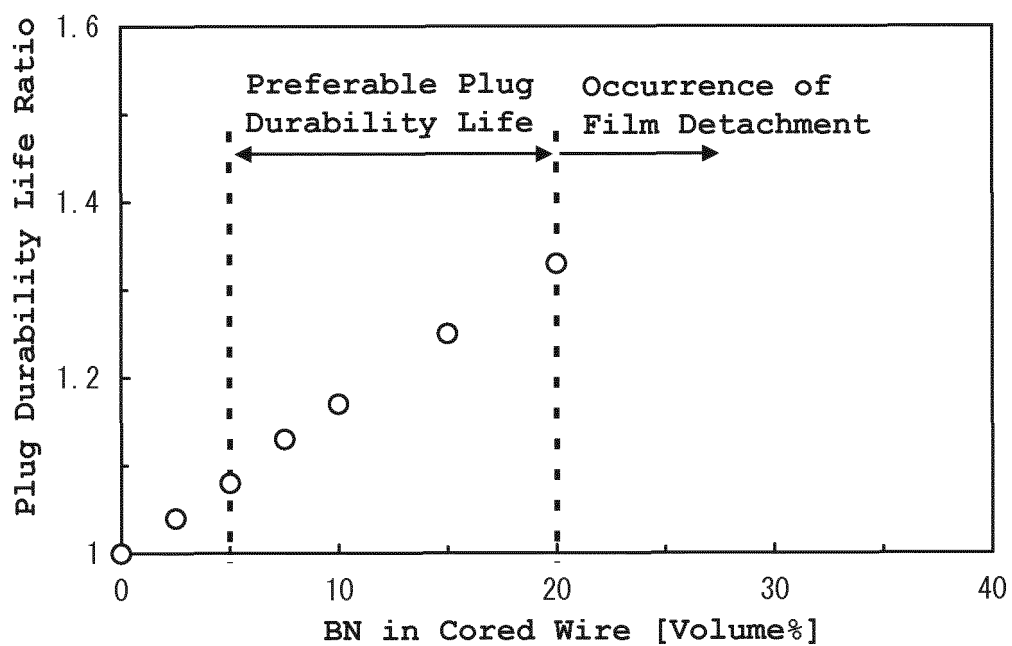


FIG. 4



**REFERENCES CITED IN THE DESCRIPTION**

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