

(19)



(11)

EP 3 357 595 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:

08.08.2018 Bulletin 2018/32

(51) Int Cl.:

B21B 25/00 ^(2006.01)

C23C 4/08 ^(2016.01)

(21) Application number: **16850846.3**

(86) International application number:

PCT/JP2016/072212

(22) Date of filing: **28.07.2016**

(87) International publication number:

WO 2017/056669 (06.04.2017 Gazette 2017/14)

(84) Designated Contracting States:

**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO
PL PT RO RS SE SI SK SM TR**

Designated Extension States:

BA ME

Designated Validation States:

MA MD

(72) Inventors:

- **HIGASHIDA, Yasuto**
Tokyo 100-8071 (JP)
- **HIDAKA, Yasuyoshi**
Tokyo 100-8071 (JP)

(74) Representative: **Zimmermann & Partner**

Patentanwälte mbB
Postfach 330 920
80069 München (DE)

(30) Priority: **28.09.2015 JP 2015190400**

(71) Applicant: **Nippon Steel & Sumitomo Metal
Corporation**
Tokyo 100-8071 (JP)

(54) **PLUG AND METHOD FOR MANUFACTURING SAME**

(57) A plug that achieves prevention of peel-off of the coating and a method of manufacturing such a plug are provided. A plug (10) is used for piercing a billet. The plug (10) includes a plug body (1), a body coating (2), and a surface-layer coating (3). The body coating (2) is provided on a surface of the plug body. The body coating (2) contains iron and iron oxides. The surface-layer coat-

ing (3) is provided on the body coating (2). The surface-layer coating (3) contains iron and iron oxides. The surface-layer coating (3) has a porosity lower than that of a region of the body coating (2) adjacent to the surface-layer coating (3) and having a thickness equal to that of the surface-layer coating (3).

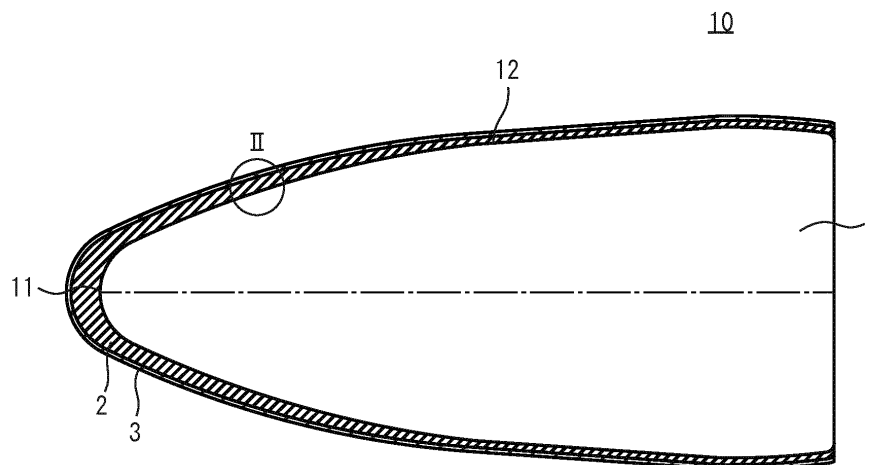


FIG. 1

EP 3 357 595 A1

Description

TECHNICAL FIELD

5 **[0001]** The present disclosure relates to a plug, and more particularly, to a plug used to pierce a billet and a method of manufacturing the same.

BACKGROUND ART

10 **[0002]** The Mannesmann pipe-making method is widely used to manufacture seamless pipes. The Mannesmann pipe-making method involves heating a billet to a predetermined temperature and using a piercing mill to perform piercing/rolling on the billet. The piercing mill includes a pair of skewed rolls and a plug. The plug is positioned on a pass line between the skewed rolls. The piercing mill uses the skewed rolls to rotate the billet in a circumferential direction and, at the same time, pushes it against the plug to perform piercing/rolling on the billet, thereby producing a hollow shell.

15 **[0003]** In the case of a conventional plug, a coating of oxidized scale is formed on the surface of the base material before the piercing/rolling of a billet. The coating of oxidized scale is formed by performing heat treatment on the plug. This provides sufficient heat insulation, lubricity and seizure resistance of the surface of the plug.

20 **[0004]** The coating of oxidized scale gradually wears off due to repeated piercing/rolling. The coating wears off each time piercing/rolling is performed (i.e. for each pass). When part of the coating is completely worn off and lost, part of the base material of the plug is exposed. Then, exposed portions of the base material may be eroded or the plug may seize on the billet, i.e. opposite material, at which point the life of the plug expires.

25 **[0005]** Particularly, the coating of oxidized scale wears off significantly when billets made of stainless steel are pierced, leading to a very short life for the plug. When billets made of stainless steel are pierced, the coating usually wears out in several passes. Each time a coating wears out, a heat treatment is necessary to produce an oxidized scale on the surface of the base material of the plug. The heat treatment typically requires several hours to several tens of hours. Thus, the efficiency with which a coating of oxidized scale is formed is low.

30 **[0006]** To address this, Japanese Patent No. 4279350 proposes forming a coating made of iron and iron oxides on the surface of the base material of the plug by electric-arc spraying. According to Japanese Patent No. 4279350, the coating is made from iron wire only, and the time required to form the coating is several minutes to several tens of minutes, which is relatively short. This enables forming a coating on the surface of the base material at low costs and with high efficiency. The sprayed coating has a higher adhesion with respect to the base material and a higher wear resistance than a coating of oxidized scale. This increases the life of the plug.

35 **[0007]** JP 2013-248619 A discloses forming a sprayed coating containing iron and iron oxides on the surface of the base material of the plug before performing heat treatment on the plug.

40 **[0008]** WO 2014/013963 discloses forming, on the surface of the base material of the plug, an Ni-Cr layer that serves as a foundation for a sprayed coating containing iron and iron oxides.

45 **[0009]** JP S61(1986)-286077 A discloses forming a coating on the surface of a mandrel for a rolling mill for steel pipes by spraying metal-based powder, before performing hot isotropic pressurization on the mandrel.

50 **[0010]** JP H05(1993)-36502 A and JP H03(1991)-125076 A each disclose a method of forming a sprayed coating, although not applied to a plug used for piercing a billet. JP H05(1993)-36502 A discloses forming a sprayed coating of ultrahard alloy on the surface of a base and forming a plated coating of an Ni-P alloy on the sprayed coating before performing hot isostatic pressing on the base. JP H03(1991)-125076 A discloses spraying a wear-resistant material on the surface of a base before performing a sealing treatment thereon by spraying a powder material capable of closing pores, and performing hot isostatic pressing on the base.

DISCLOSURE OF THE INVENTION

55 **[0011]** A coating formed by arc spraying of iron wire (or steel wire) has a high adhesion with respect to the base material of the plug and a high wear resistance, which increases the life for the plug. However, for example, when a billet with high strength made of a high alloy is to be pierced or when the pierced length of the billet is extremely long, part of the coating may peel off the surface of the base material during piercing. If part of the base material is exposed as a result of the peeling of the coating, the plug may be eroded or the billet may seize on the plug, with the exposed portions working as initiation points.

60 **[0012]** An object of the present disclosure is to provide a plug that achieves prevention of peel-off of the coating, and a method of manufacturing such a plug.

65 **[0013]** A plug according to the present disclosure is used for piercing a billet. The plug includes a plug body, a body coating, and a surface-layer coating. The body coating is provided on a surface of the plug body. The body coating contains iron and iron oxides. The surface-layer coating is provided on the body coating. The surface-layer coating

contains iron and iron oxides. The surface-layer coating has a porosity lower than that of a region of the body coating adjacent to the surface-layer coating and having a thickness equal to that of the surface-layer coating.

[0014] The present disclosure is directed to a method of manufacturing a plug. The plug is used for piercing a billet. The method includes: preparing a plug body; forming a body coating on a surface of the plug body by performing arc spraying using iron wire; and forming a surface-layer coating on the body coating by performing arc spraying using iron wire at a spray distance shorter than that at completion of the formation of the body coating.

[0015] The plug according to the present disclosure and the method of manufacturing it achieve prevention of peel-off of the coating.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

[FIG. 1] FIG. 1 is a partial cross-sectional view of a plug according to an embodiment.

[FIG. 2] FIG. 2 is an enlarged view of portion II of the plug shown in FIG. 1.

[FIG. 3] FIG. 3 is an example of a microscopic image of a cross section of the coating.

[FIG. 4] FIG. 4 is a brightness histogram for the microscopic image shown in FIG. 3.

[FIG. 5] FIG. 5 is a brightness histogram for the microscopic image shown in FIG. 3, illustrating how to express the microscopic image using three values.

[FIG. 6] FIG. 6 is a three-value image derived from the microscopic image shown in FIG. 3.

[FIG. 7] FIG. 7 illustrates a method of manufacturing the plug shown in FIG. 1.

[FIG. 8] FIG. 8 is a graph showing the relationship between the spray distance during coating formation and the porosity of the coating.

[FIG. 9] FIG. 9 is a graph showing the relationship between the spray distance during coating formation and the content of oxides in the coating.

[FIG. 10] FIG. 10 is a graph showing the relationship between the spray distance during coating formation and the tensile strength of the coating.

[FIG. 11A] FIG. 11A illustrates the effects of the plug according to the embodiment.

[FIG. 11B] FIG. 11B illustrates the effects of the plug according to the embodiment.

[FIG. 12A] FIG. 12A illustrates the mechanism through which the coating of a conventional plug peels off.

[FIG. 12B] FIG. 12B illustrates the mechanism through which the coating of a conventional plug peels off.

[FIG. 12C] FIG. 12C illustrates the mechanism through which the coating of a conventional plug peels off.

[FIG. 12D] FIG. 12D illustrates the mechanism through which the coating of a conventional plug peels off.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

[0017] The present inventors did extensive research and found out the mechanism through which the coating of a plug that is piercing a billet peels off. FIGS. 12A to 12D illustrate the mechanism through which the coating of a conventional plug peels off. FIGS. 12A to 12D each schematically show a cross section of the plug near its surface.

[0018] As shown in FIG. 12A, before the piercing of a billet, a coating 102 is present on the surface of the plug body 101. The coating 102 includes pores 103.

[0019] As shown in FIG. 12B, when the piercing of the billet begins, the friction between the coating 102 and billet causes a load in a direction along the surface of the coating (i.e. shear direction) to act on the coating. This deforms the coating 102, producing cracks C on the surface of the coating 102, with the deformed portions working as initiation points.

[0020] As shown in FIG. 12C, the load in the shear direction acting on the coating 102 causes cracks C to progress along the interface between the plug body 101 and coating 102. As a result, part of the coating 102 peels off, as shown in FIG. 12D.

[0021] It occurred to the present inventors that the peel-off of the coating may be prevented by preventing deformation and cracking of the coating during the piercing of the billet. The present inventors did further research and completed the plug according to the embodiment and the method of manufacturing it.

[0022] A plug according to an embodiment is used for piercing a billet. The plug includes a plug body, a body coating, and a surface-layer coating. The body coating is provided on a surface of the plug body. The body coating contains iron and iron oxides. The surface-layer coating is provided on the body coating. The surface-layer coating contains iron and iron oxides. The surface-layer coating has a porosity lower than that of a region of the body coating adjacent to the surface-layer coating and having a thickness equal to that of the surface-layer coating (first arrangement).

[0023] In the first arrangement, on the body coating provided on the surface of the plug body is further provided a surface-layer coating. The surface-layer coating has a porosity that is lower than that of a region of the body coating that is located adjacent to the surface-layer coating. Thus, the surface-layer coating is denser and has a higher strength

than the body coating. This will prevent the surface-layer coating and the body coating covered with the surface-layer coating from deforming due to the load in the shear direction, thereby preventing deformation-derived cracks. As a result, the coatings will be prevented from peeling off the surface of the plug body.

[0024] The porosity of the surface-layer coating may be not higher than 2.5 % (second arrangement).

[0025] In the second arrangement, the porosity of the surface-layer coating is low enough to provide a denser surface-layer coating with higher strength. This will further prevent deformation and cracking of the coatings, thereby preventing peel-off of the coatings more reliably.

[0026] The thickness of the surface-layer coating may be not larger than 250 μm (third arrangement).

[0027] In the third arrangement, the thickness of the surface-layer coating is small enough to improve heat removal from the surface-layer coating. This will reduce the temperature increase in the surface-layer coating during piercing, thereby preventing the billet from seizing on the plug.

[0028] A method of manufacturing a plug according to an embodiment includes: preparing a plug body; forming a body coating on a surface of the plug body by performing arc spraying using iron wire; and forming a surface-layer coating on the body coating by performing arc spraying using iron wire at a spray distance shorter than that at completion of the formation of the body coating (fourth arrangement).

[0029] In the fourth arrangement, the surface-layer coating is formed by, after the formation of the body coating, performing arc spraying with reduced spray distance. This will reduce the porosity of the surface-layer coating to be lower than the porosity of a region of the body coating adjacent to the surface-layer coating such that the body coating will be covered with a surface-layer coating that is dense and has a high strength. This will prevent the coatings from deforming due to the load in the shear direction during piercing, thereby preventing deformation-derived cracking. As a result, the coatings will be prevented from peeling off the surface of the plug surface.

[0030] Further, in the fourth arrangement, both the body coating and surface-layer coating are formed by arc spraying of iron wire. That is, the body coating and surface-layer coating are formed from the same material and with the same technique. This will enable successively forming the body coating and surface-layer coating within the same step. This will facilitate producing a plug with a body coating and a surface-layer coating.

[0031] The forming the body coating may perform arc spraying while the spray distance is gradually increased (fifth arrangement).

[0032] For arc spraying, increased spray distance results in increased content of oxides in the coating. In the fifth arrangement, the spray distance used to form a region of the body coating adjacent to the plug body is relatively small. Thus, the region adjacent to the plug body has a high iron content and a low oxide content. This will improve the adhesion of the body coating with respect to the plug body. On the other hand, the spray distance used to form a region of the body coating adjacent to the surface-layer coating is relatively large. Thus, the region adjacent to the surface-layer coating has a high oxide content, which reduces heat conductivity. This will improve the heat insulation of the body coating, thereby preventing the billet from seizing on the plug.

[0033] Embodiments will now be described in detail with reference to the drawings. The same and corresponding elements in the drawings are labeled with the same characters and their description will not be repeated. For convenience of explanation, elements may be simplified or shown schematically in the drawings, and some elements may not be shown.

[Construction of Plug]

[0034] First, the construction of the plug will be described. As shown in FIG. 1, a plug 10 according to an embodiment includes a plug body 1, a body coating 2, and a surface-layer coating 3. FIG. 1 shows a cross section of the plug 10.

[0035] The plug body 1 has a circular transverse section with an outer diameter that increases as it goes from the tip of the plug body 1 toward its rear end. In short, the plug body 1 is generally shaped like a projectile.

[0036] The body coating 2 is formed on the surface of the plug body 1. The body coating 2 covers the entire surface of the plug body 1 except for the rear end surface of the plug body 1. The thickness of the body coating 2 may not be constant over the entire plug. For example, the portions of the body coating 2 that are located on the tip portion 11 of the plug body 1 have larger thicknesses than the portions located on the trunk portion 12 of the plug body 1.

[0037] The surface-layer coating 3 is formed on the body coating 2. The surface-layer coating 3 covers the entire the body coating 2. The thickness of the surface-layer coating 3 is smaller than the thickness of the body coating 2. The thickness of the surface-layer coating 3 is substantially constant over the entire plug. The thickness of the surface-layer coating 3 is preferably not higher than 250 μm , and more preferably not higher than 200 μm . The thickness of the surface-layer coating 3 is preferably not lower than 50 μm .

[0038] FIG. 2 is an enlarged view of portion II shown in FIG. 1. The body coating 2 and surface-layer coating 3 contain iron and iron oxides. While the body coating 2 and surface-layer coating 3 are mainly composed of iron and iron oxides, they may contain small amounts of elements and/or compounds other than iron and iron oxides. In the body coating 2, the iron content decreases and the iron-oxide content increases as it goes from the plug body 1 toward the surface-layer coating 3. The iron content in the surface-layer coating 3 is higher at least than the iron content in the region 21

of the body content 2 discussed below.

[0039] The body coating 2 includes pores. The surface-layer coating 3 also includes pores, although small and few. The porosity of the surface-layer coating 3 is lower than the porosity of the region 21 of the body coating 2. The region 21 is adjacent to the surface-layer coating 3 of the body coating 2. That is, the region 21 is a region of the body coating 2 that is located adjacent to the interface between the body coating and surface-layer coating 3. The thickness of the region 21 is substantially equal to the thickness of the surface-layer coating 3. The porosity of the surface-layer coating 3 is preferably not higher than 2.5 %. The lower the porosity of the surface-layer coating 3, the better; in practice, it is not lower than 0.5 %.

[0040] A method of calculating the iron content and iron-oxide content in and porosity of the body coating 2 and surface-layer coating 3 will be described.

[0041] First, microscopic images of cross sections of the body coating 2 and surface-layer coating 3 are obtained. In the microscopic images, the porosity of the region 21 of the body coating 2 evaluated is that of the portions of the body coating 2 that are adjacent to the interface to the surface-layer coating 3 and have the same thickness as the surface-layer coating 3. The porosity of the surface-layer coating 3 evaluated is that of the entire surface-layer coating 3 captured in the microscopic images. The area of evaluation as measured in a direction perpendicular to the thickness direction (i.e. direction parallel to the plug surface) is about 1000 to 1500 μm . Since it is assumed that pores are basically distributed homogeneously as determined in this direction, an evaluation with a width of about 1000 to 1500 μm will enable calculation of a porosity value that is substantially an average one.

[0042] FIG. 3 is an example of a microscopic image (original image) of a cross section of a coating. Iron, iron oxides and pores in the original image have their respective color tones. More specifically, the color becomes darker in the following order: iron, iron oxides, and pores.

[0043] Next, a brightness histogram is created from the original image, as shown in FIG. 4. The brightness histogram is a graph showing the pixel-brightness distribution in the original image, where the vertical axis represents frequency of occurrence (i.e. number of pixels) and the horizontal axis represents the brightness value. Detecting peaks in this brightness histogram provides three peaks derived from iron, iron oxides, and pores.

[0044] Subsequently, the original image is expressed using three values. As shown in FIG. 5, the thresholds for expression using three values are the middle value M_1 between the brightness value B_1 and brightness value B_2 , and the middle value M_2 between the brightness value B_2 and brightness value B_3 . B_1 , B_2 and B_3 are the brightness value of the peak derived from pores, the brightness value of the peak derived from iron oxides, and the brightness value of the peak derived from iron, respectively.

[0045] FIG. 6 shows a three-value image obtained by expressing the original image using three values. In the three-value image, the pixels having brightness values lower than M_1 in the original image are displayed in black, the pixels having brightness values not lower than M_1 and lower than M_2 are displayed in gray, and the pixels having brightness values not lower than M_2 are displayed in white. In the three-value image, the black regions are treated as pore regions, the gray regions as iron-oxide regions, and the white regions as iron regions, and the number of pixels in the regions of each type is counted. Dividing the number of pixels in the pore regions, the number of pixels in the iron-oxide regions, and the number of pixels in the iron regions by the total number of pixels provides the porosity (%), the content of iron oxides (%) and the content of iron (%), respectively. That is, the porosity, the content of iron oxides and the content of iron are each expressed as a value of the proportion of pixels in the original image (i.e. area ratio).

[Method of Manufacturing Plug]

[0046] A method of manufacturing the plug 10 will be described below.

[0047] First, a plug body 1 is prepared. A body coating 2 and a surface-layer coating 3 are formed on the surface of the plug body 1 by arc spraying.

[0048] Arc spraying may be performed using, for example, arc spraying equipment 4 shown in FIG. 7. The arc spraying equipment 4 includes a spray gun 41 and a turntable 42. The spray gun 41 uses an arc to melt wire to be sprayed, and sprays it through a nozzle by means of compressed air. In the present embodiment, the wire to be sprayed is iron wire. The iron wire is wire of carbon steel (or common steel) mainly composed of iron (Fe). The iron wire is typically a so-called common steel mainly composed of Fe and including carbon (C), silicon (Si), manganese (Mn) and impurities, but may contain elements such as tungsten (W).

[0049] When the body coating 2 and surface-layer coating 3 are to be formed, the plug body 1 is placed on the turntable 42 of the arc spraying equipment 4. Then, while the turntable 42 rotates the plug body 1 about its axis, iron wire is sprayed on the plug body 1 by arc spraying. Thus, a body coating 2 containing iron and iron oxides is formed on the surface of the plug body 1. The formation of the body coating 2 is completed when a desired thickness of material is deposited on the surface of the plug body 1.

[0050] The body coating 2 is preferably formed while the spray distance is gradually increased. Spray distance refers the minimum distance between the tip of the nozzle of the spray gun 41 and the surface of the object to which spraying

is done. The body coating 2 is formed by placing the spray gun 41 at a predetermined distance from the plug body 1 and initiating arc spraying, and continuing arc spraying while the spray gun 41 is gradually moved away from the plug body 1. Alternatively, the spray distance may be kept constant during the formation of the body coating 2.

[0051] Immediately after the formation of the body coating 2, a surface-layer coating 3 is formed. That is, after the body coating 2 is formed, arc spraying is continued without an interruption to form a surface-layer coating 3 on the body coating 2.

[0052] The spray distance during the formation of the surface-layer coating 3 is smaller than the spray distance during the formation of the body coating 2. More specifically, the spray distance during the formation of the surface-layer coating 3 is smaller than at least the spray distance at the completion of the formation of the body coating 2. That is, after the body coating 2 is formed while the spray gun 41 is gradually moved away from the plug body 1, the spray gun 41 is brought close to the plug body with a jerk to form the surface-layer coating 3.

[0053] While the surface-layer coating 3 is formed, the spray distance is kept substantially constant. The spray distance during the formation of the surface-layer coating 3 is preferably not larger than 200 mm. The formation of the surface-layer coating 3 is completed when a desired thickness of material is deposited on the body coating 2. Preferably, the formation of the surface-layer coating 3 is completed before the thickness of the surface-layer coating 3 exceeds 250 μm .

[0054] Spray distance will be described in more detail. FIG. 8 is a graph showing the relationship between spray distance and the porosity of a coating. FIG. 9 is a graph showing the relationship between spray distance and the content of oxides in a coating. FIG. 10 is a graph showing the relationship between spray distance and the tensile strength of a coating.

[0055] As shown in FIG. 8, the larger the spray distance, the higher the porosity of a coating becomes. That is, the porosity of the body coating 2 and surface-layer coating 3 may be controlled by adjusting the spray distance. As discussed above, the spray distance during the formation of the surface-layer coating 3 is smaller than the spray distance at the completion of the formation of the body coating 2. The porosity of the surface-layer coating 3 is lower than the porosity of the region 21 of the body coating 2.

[0056] As shown in FIG. 9, the larger the spray distance, the higher the content of oxides in a coating becomes. That is, the contents of iron and iron oxides in the body coating 2 and surface-layer coating 3 may be controlled by adjusting the spray distance. As discussed above, the body coating 2 may be formed while the spray distance is gradually increased. Thus, in the body coating 2, the iron content decreases and the iron-oxide content increases as it goes from the plug body 1 toward the surface-layer coating 3. The surface-layer coating 3 is formed by reducing the spray distance after the formation of the body coating 2. Thus, the content of iron in the surface-layer coating 3 is higher than at least the content of iron in the region 21 of the body coating 2.

[0057] As shown in FIG. 10, the larger the spray distance, the smaller the tensile strength of a coating becomes. That is, the tensile strength of the body coating 2 and surface-layer coating 3 may be controlled by adjusting the spray distance. The spray distance during the formation of the surface-layer coating 3 is smaller than the spray distance at the completion of the formation of the body coating 2. Thus, the tensile strength of the surface-layer coating 3 is larger than at least the tensile strength of the region 21 of the body coating 2.

[0058] After the body coating 2 and surface-layer coating 3 are thus formed, the plug body 1 is removed from the turntable 42 of the arc spray equipment 4. Thus, the plug 10 (FIG. 1) according to the present embodiment is finished.

[Effects]

[0059] In the plug 10 according to the present embodiment, the surface-layer coating 3 with a low porosity is provided on the body coating 2. This prevents deformation of the body coating 2 and surface-layer coating 3 due to a load in the shear direction during piercing, thereby preventing cracks in the body coating 2 and surface-layer coating 3. These effects will be described in more detail with reference to FIGS. 11A and 11B.

[0060] FIG. 11A is a schematic cross section of portions of the plug 10 located near the surface before the piercing of a billet is initiated. As shown in FIG. 11A, the body coating 2 on the plug body 1 is covered with the surface-layer coating 3. The surface-layer coating 3 is formed by performing arc spraying of iron wire at a spray distance smaller than the spray distance at the completion of the formation of the body coating 2. Thus, the surface-layer coating 3 has a porosity lower than the porosity of the region of the body coating 2 located adjacent to the surface-layer coating 3, and is dense and has a high tensile strength.

[0061] FIG. 11B is a schematic cross section of portions of the plug 10 located near the surface during the piercing of a billet. As shown in FIG. 11B, when the piercing of the billet is initiated, a load in the shear direction acts on the surface of the surface-layer coating 3. However, the surface-layer coating 3 is dense and has a high tensile strength, and thus cannot easily be deformed by the load in the shear direction. The body coating 2 cannot easily be deformed, either, since it is covered with the surface-layer coating 3. Thus, in the body coating 2 and surface-layer coating 3, no crack occurs that would lead to a peel-off. Thus, the body coating 2 and surface-layer coating 3 are prevented from peeling off.

[0062] The body coating 2 and surface-layer coating 3 can be easily formed by arc spraying using iron wire. Further, the body coating 2 and surface-layer coating 3 are successively formed within one and the same step. Thus, the present embodiment will allow a plug 10 with a coating having a high peeling resistance to be manufactured in a simple manner.

[0063] The porosity of the surface-layer coating 3 is preferably not higher than 2.5 %. Thus, the surface-layer coating 3 is denser, providing sufficient tensile strength of the surface-layer coating 3. This will effectively prevent deformation of and cracks in the body coating 2 and surface-layer coating 3. This will prevent peel-off of the body coating 2 and surface-layer coating 3 more reliably. As discussed above, the lower the porosity of the surface-layer coating 3, the better; in practice, it is not lower than 0.5 %.

[0064] The thickness of the surface-layer coating 3 is preferably not higher than 250 μm . This will prevent the temperature of the surface-layer coating 3 from rising during piercing/rolling. As discussed above, the surface-layer coating 3 has a high iron content in the coating, and thus has a high heat conductivity. Thus, the surface-layer coating 3 can easily be heated as it contacts a hot billet during piercing/rolling. If the thickness of the surface-layer coating 3 is too large, heat can be accumulated within the surface-layer coating 3, leading to high temperatures in the surface-layer coating 3. If the surface-layer coating 3 is too hot, the billet can easily seize on the plug 10. A thickness of the surface-layer coating 3 that is not larger than 250 μm will prevent seizure.

[0065] The thickness of the surface-layer coating 3 is preferably not smaller than 50 μm . This will prevent the body coating 2 and surface-layer coating 3 from deforming due to the load in the shear direction during piercing, thereby preventing cracks more reliably.

[0066] The body coating 2 is formed while the spray distance is gradually increased. Thus, the iron content is high in a region of the body coating 2 that is adjacent to the plug body 1, thereby improving the adhesion between the plug body 1 and body coating 2. On the other hand, the iron-oxide content is high in a region of the body coating 2 that is adjacent to the surface-layer coating 2, and thus the heat conductivity is low, thereby improving heat insulation. This will prevent the billet from seizing on the plug 10.

[0067] While embodiments have been described, the present disclosure is not limited to the above-described embodiments, and various modifications are possible without departing from the spirit of the invention.

EXAMPLES

[0068] The present disclosure will be described in more detail below with reference to examples. The present disclosure is not limited to the examples below.

[0069] Six steel plug bodies (1) with a maximum diameter of 77.5 mm, with a total length of 230 mm, and containing 0.15 mass % C and 3.5 mass % W were prepared. Arc spraying using iron wire formed a body coating (2) on the surface of each plug body (1). During the formation of the body coating (2), spraying was performed while the spray distance was changed from 200 mm to 1000 mm. The thickness of the body coating (2) was 1200 μm as measured at the tip (11) of the plug body (1) and 500 μm as measured at the trunk portion (12).

[0070] For five plug bodies (1), a surface-layer coating (3) was formed on the body coating (2) by arc spraying using iron wire to provide plugs according to Inventive Examples 1 to 5. The conditions for forming the surface-layer coating (3) are shown in Table 1. For the remaining one plug body (1), no surface-layer coating (3) was provided, and this provided a plug according to a Comparative Example.

[Table 1]

	Work conditions			Results	
	Spray conditions and coating thickness	Proportion of pores in coating		Life pass number	Peeling of coating on trunk
		Body coating *1	Surface-layer coating		
Comp. Ex.	none	13.8	-	3	poor
Inv. Ex. 1	spray distance: 100 mm 300 μm thick	9.3	1.7	1	good
Inv. Ex. 2	spray distance: 300 mm 100 μm thick	13.8	2.7	4	acceptable

(continued)

	Work conditions			Results	
	Spray conditions and coating thickness	Proportion of pores in coating		Life pass number	Peeling of coating on trunk
		Body coating *1	Surface-layer coating		
Inv. Ex. 3	spray distance: 100 mm 100 μm thick	13.8	1.7	7	good
Inv. Ex. 4	spray distance: 100 mm 200 μm thick	11.3	1.7	8	good
Inv. Ex. 5	spray distance: 200 mm 200 μm thick	11.3	2.2	8	good
*1 The porosity of the body coating evaluated was that of the region adjacent to the surface layer (i.e. interface between the body coating and surface-layer coating) and having the same thickness as the surface-layer coating. The value of the comparative example is the value for the region of 100 μm adjacent to the surface.					

[0071] The plugs according to Inventive Examples 1 to 5 and the Comparative Example were repeatedly used to perform piercing/rolling on billets made of SUS 304 with a diameter of 65 mm and a length of 400 mm that had been heated to 1200 °C. For each of Inventive Examples 1 to 5 and the Comparative Example, the number of piercing rounds performed until the plug was damaged (i.e. life pass number), and how damaged the plug was, were determined. The life pass numbers and how damaged the plugs were for Inventive Examples 1 to 5 and the Comparative Example are shown in Table 1.

[0072] In the plug of the Comparative Example, the coating peeled off the trunk portion (12) during the third pass. In contrast, in Inventive Examples 3 to 5, the coating did not peel off even after seven or eight passes. In Inventive Example 1, seizure occurred during the first pass and piercing rolling was halted at this point, where the coating did not peel off the trunk portion (12). In Inventive Example 2, the coating peeled off the trunk portion (12) during the fourth pass. This demonstrates that providing a surface-layer coating (3) on the body coating (2) prevents peeling of the coating. In each of Inventive Examples 3 to 5, the deformation of the plug tip (11) after the life pass number listed in Table 1 exceeded a permitted range, and the piercing/rolling was halted at this point.

[0073] In Inventive Example 1, the thickness of the surface-layer coating (3) was 300 μm , which is larger than 250 μm . In Inventive Example 1, the billet seized on the plug during the first pass. In contrast, in each of Inventive Examples 2 to 5, where the thickness of the surface-layer coating (3) was not larger than 250 μm , the billet did not seize on the plug. Thus, the thickness of the surface-layer coating (3) is preferably not larger than 250 μm to prevent seizure.

[0074] In each of Inventive Examples 1 and 3 to 5, the porosity of the surface-layer coating (3) was not higher than 2.5 %, meaning that the density and strength of the surface-layer coating (3) were high. Consequently, in each of Inventive Examples 1 and 3 to 5, the coating did not peel off. On the other hand, in Inventive Example 2, the spray distance during the formation of the surface-layer coating (3) was 300 mm and the porosity of the surface-layer coating (3) was 2.7 %. That is, the density and strength of the surface-layer coating (3) in Inventive Example 2 were lower than in Inventive Examples 1 and 3 to 5. Consequently, the coating of Inventive Example 2 peeled off during the fourth pass. These results show that the porosity of the surface-layer coating (3) is preferably not higher than 2.5 % to prevent peeling of the coating more effectively.

Claims

1. A plug used for piercing a billet, comprising:

a plug body;

a body coating provided on a surface of the plug body and containing iron and iron oxides; and

a surface-layer coating provided on the body coating and containing iron and iron oxides,

wherein the surface-layer coating has a porosity lower than that of a region of the body coating adjacent to the surface-layer coating and having a thickness equal to that of the surface-layer coating.

EP 3 357 595 A1

2. The plug according to claim 1, wherein the porosity of the surface-layer coating is not higher than 2.5 %.

3. The plug according to claim 1 or 2, wherein the thickness of the surface-layer coating is not larger than 250 μm .

5 4. A method of manufacturing a plug used for piercing a billet, comprising:

preparing a plug body;

forming a body coating on a surface of the plug body by performing arc spraying using iron wire; and

10 forming a surface-layer coating on the body coating by performing arc spraying using iron wire at a spray distance shorter than that at completion of the formation of the body coating.

5. The method of manufacturing a plug according to claim 4,

wherein the forming the body coating performs arc spraying while the spray distance is gradually increased.

15

20

25

30

35

40

45

50

55

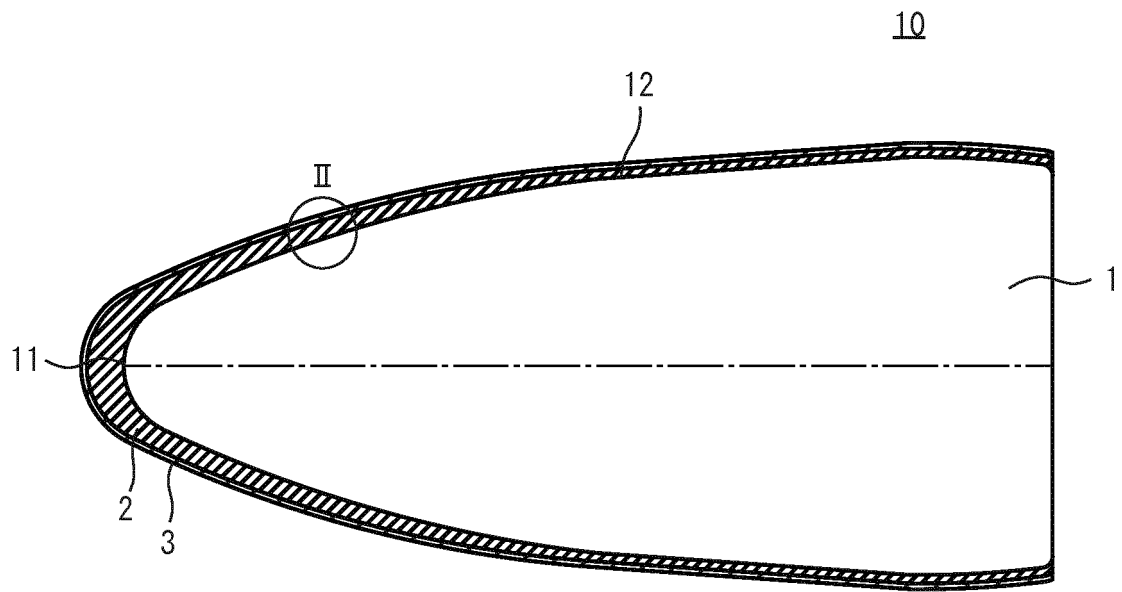


FIG. 1

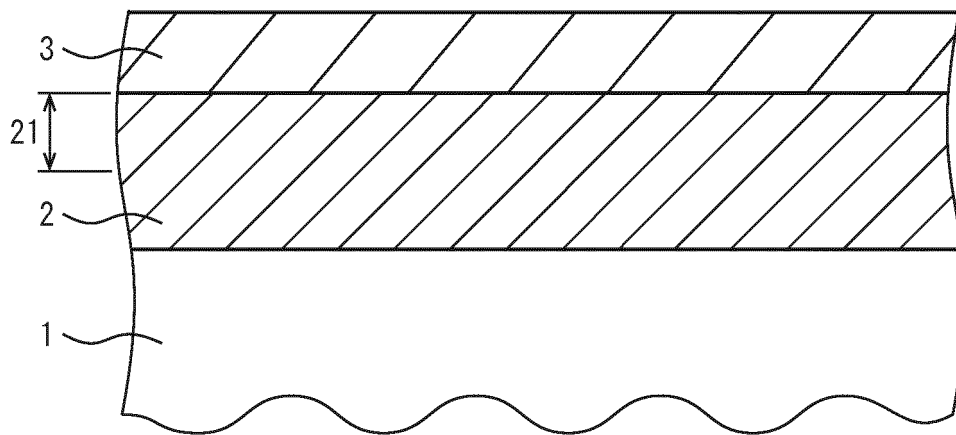


FIG. 2

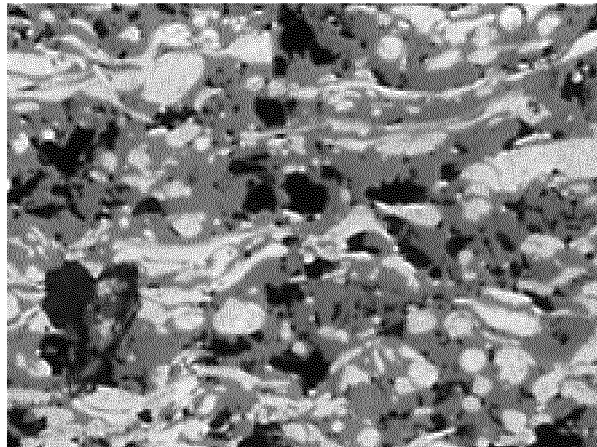


FIG. 3

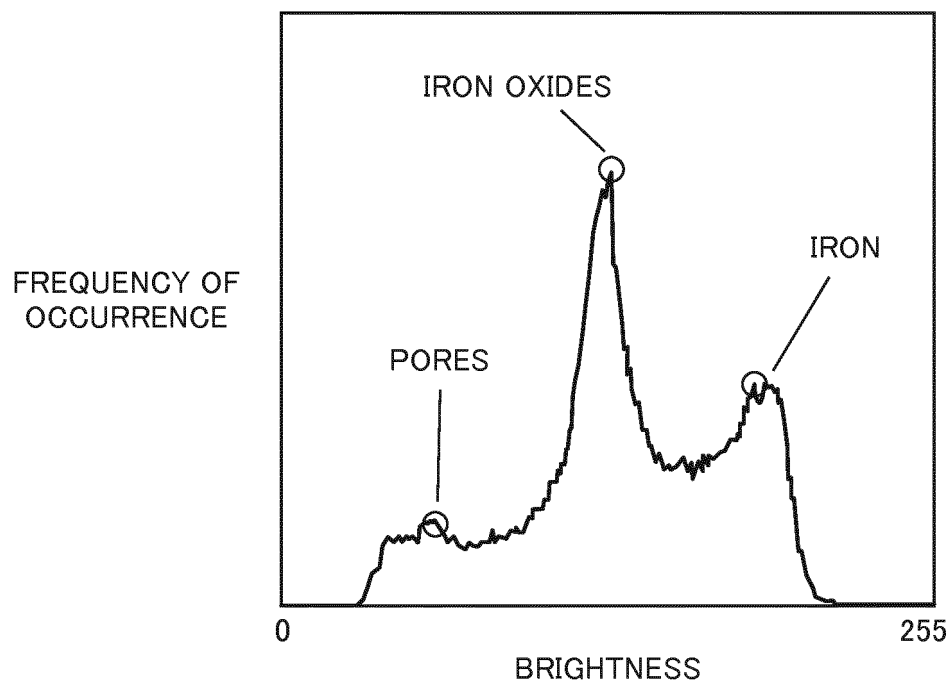


FIG. 4

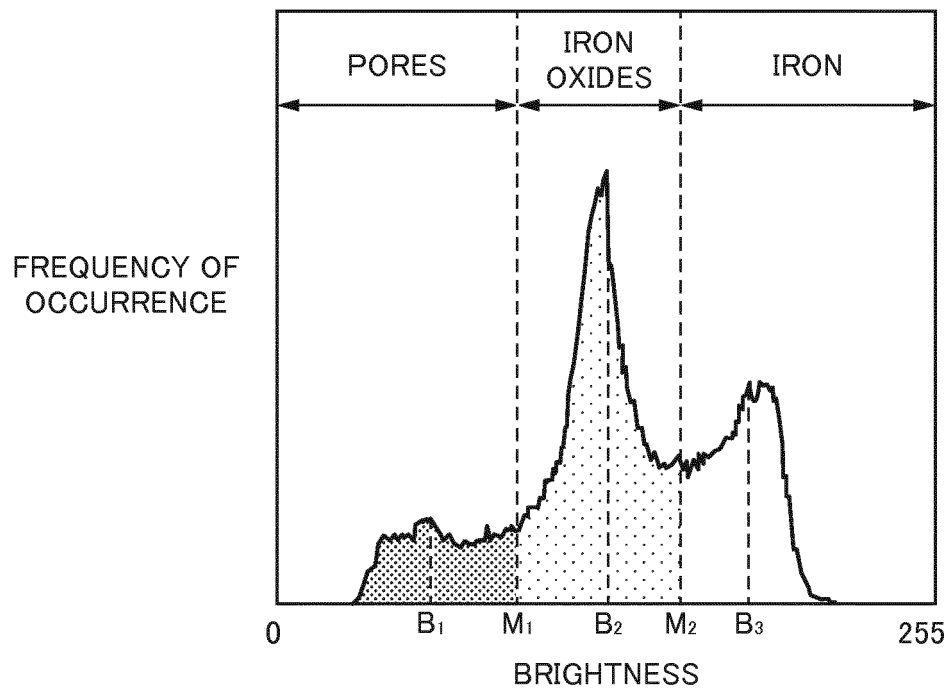


FIG. 5

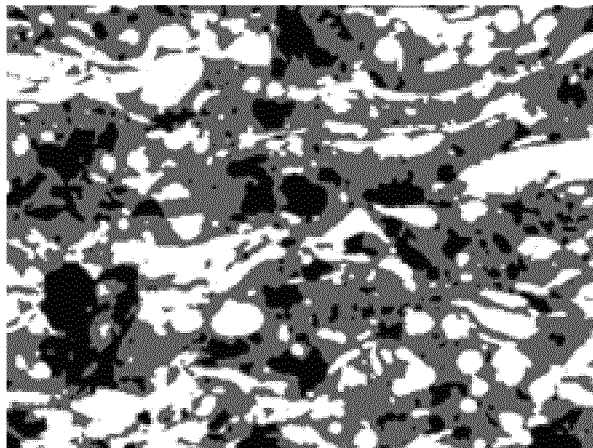


FIG. 6

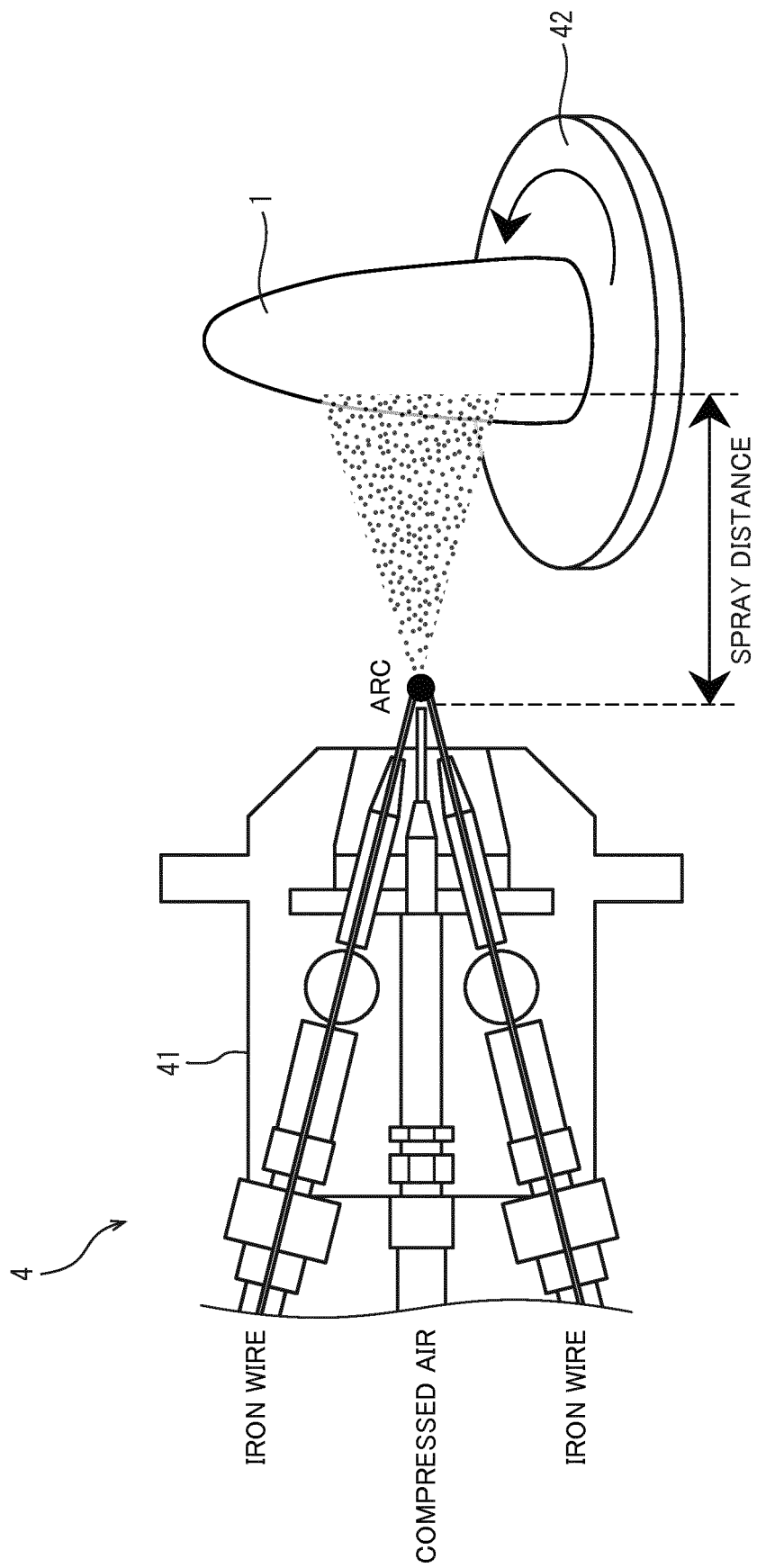


FIG. 7

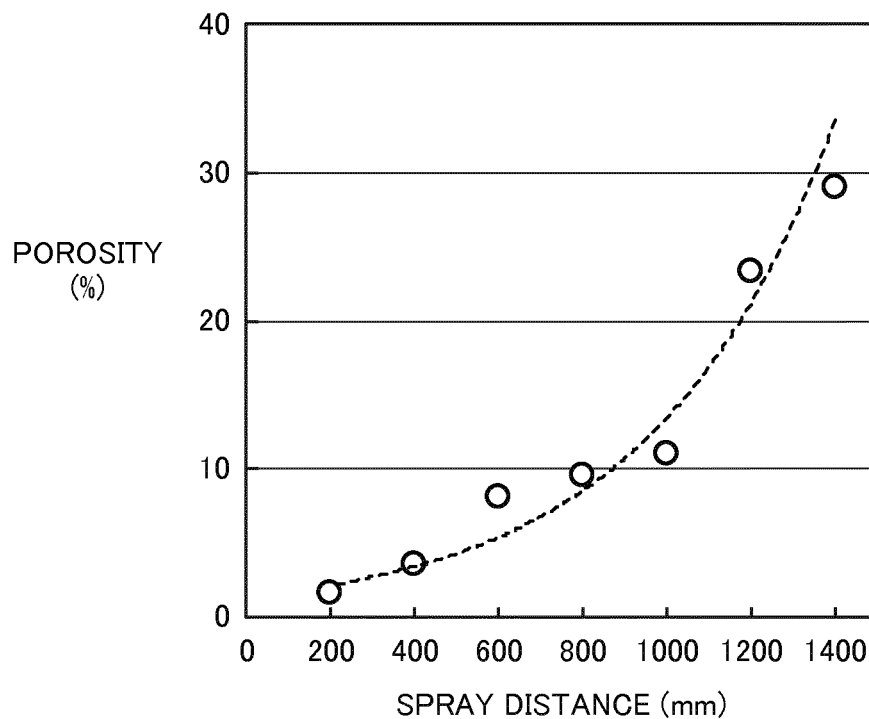


FIG. 8

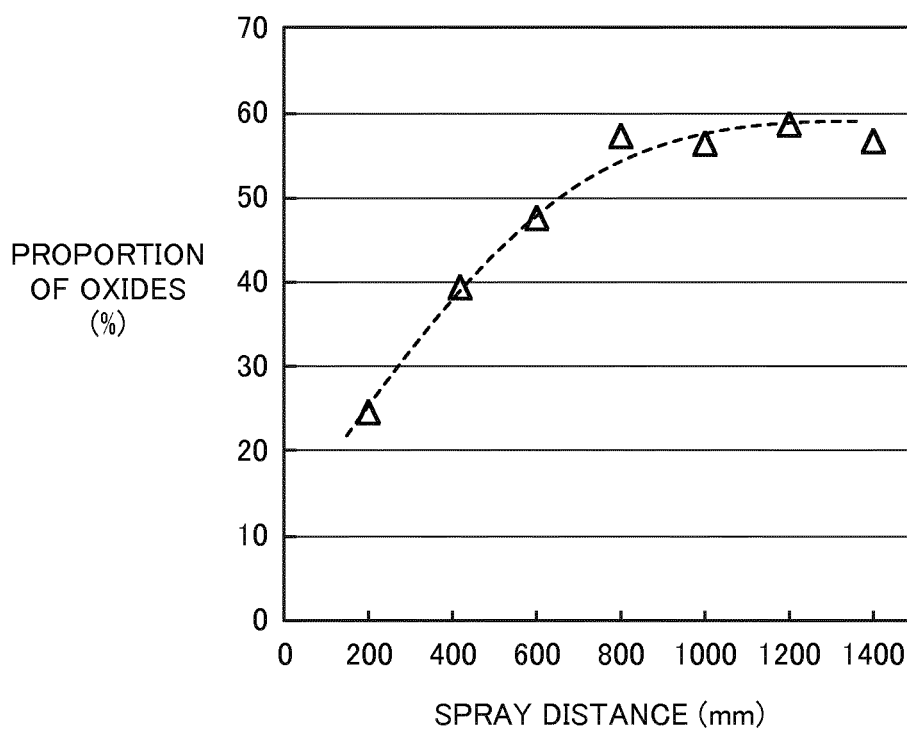


FIG. 9

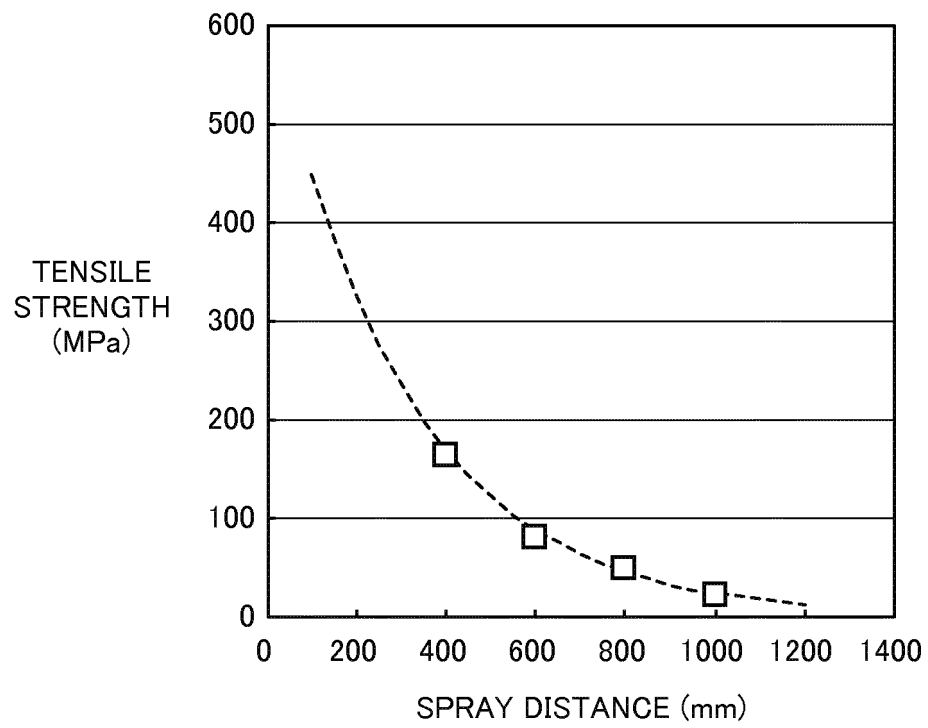


FIG. 10

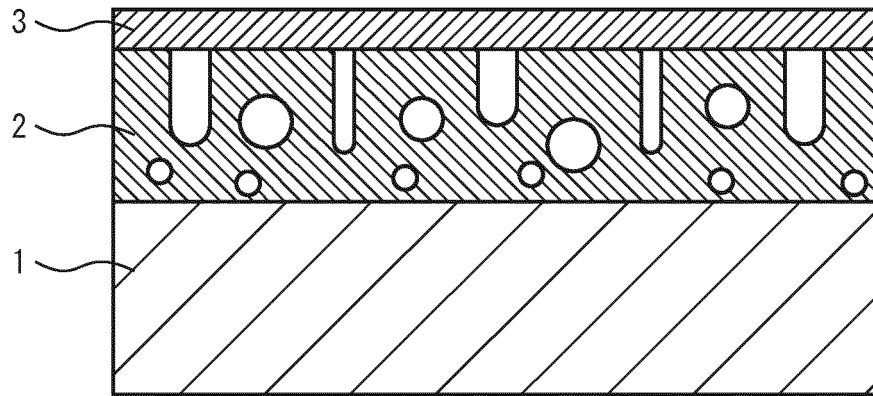


FIG. 11A

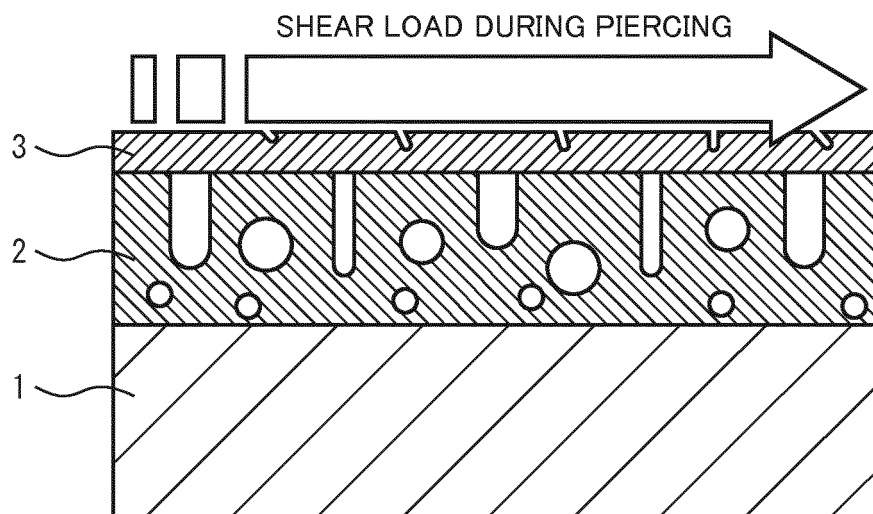


FIG. 11B

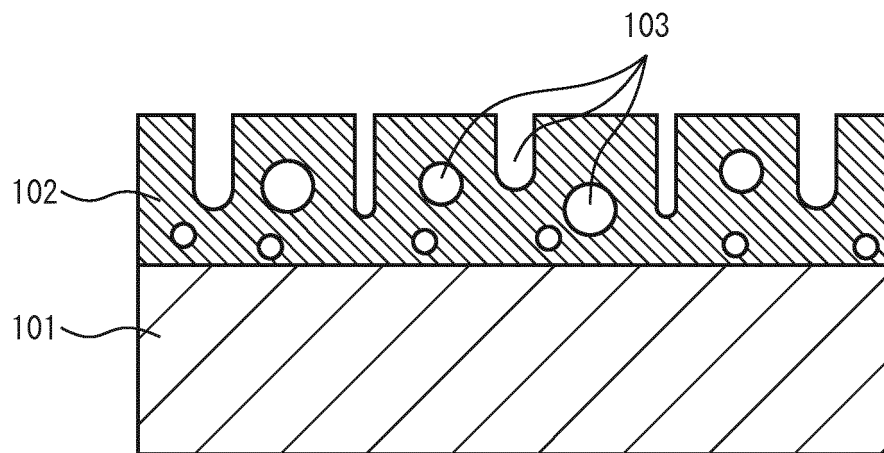


FIG. 12A

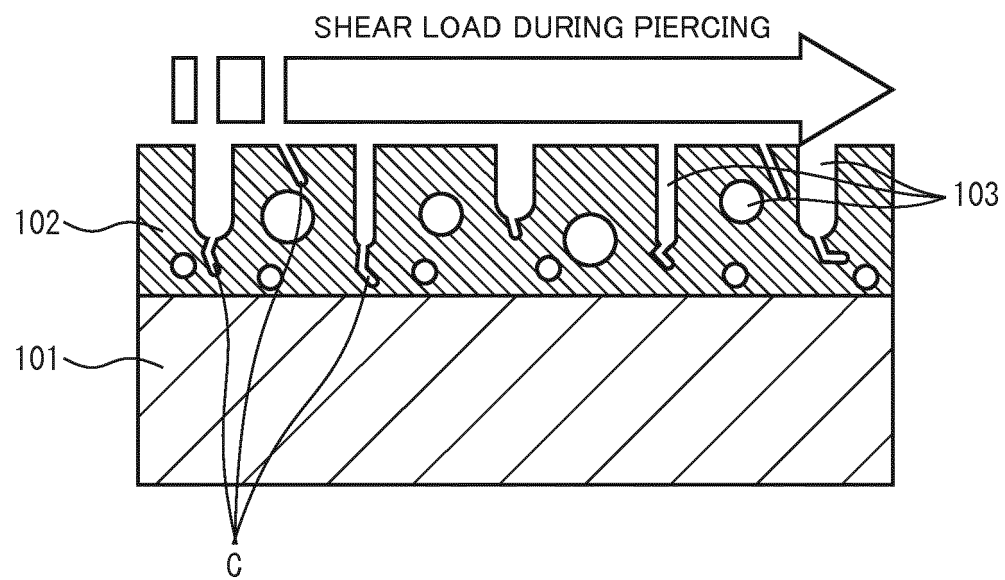


FIG. 12B

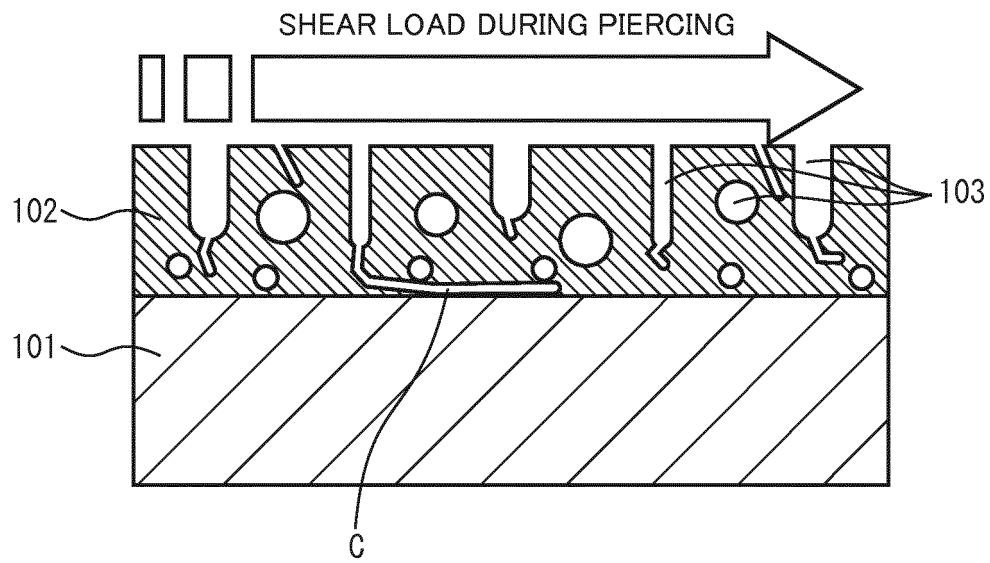


FIG. 12C

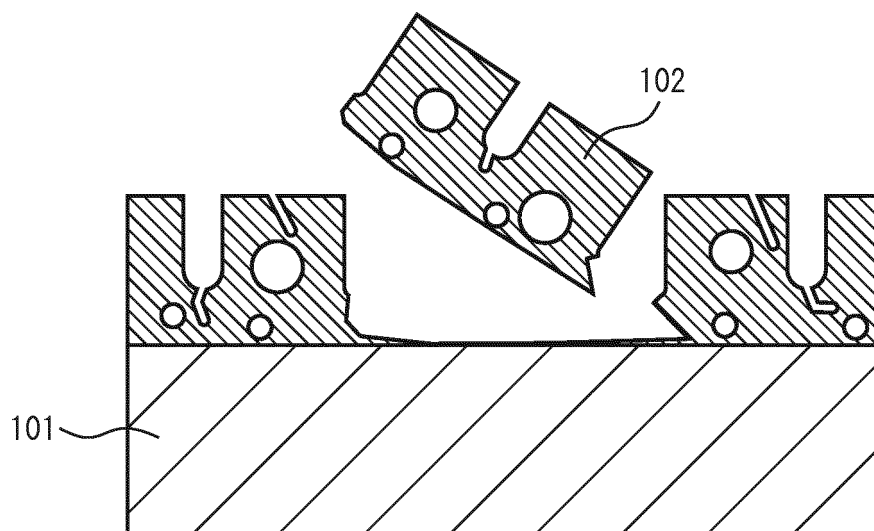


FIG. 12D

INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2016/072212

A. CLASSIFICATION OF SUBJECT MATTER

B21B25/00(2006.01) i, C23C4/08(2016.01) 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)

B21B25/00, C23C4/08

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 1996-2016
 Kokai Jitsuyo Shinan Koho 1971-2016 Toroku Jitsuyo Shinan Koho 1994-2016

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 2013-226565 A (Nippon Steel & Sumitomo Metal Corp.), 07 November 2013 (07.11.2013), & US 2015/0075241 A1 & WO 2013/161177 A1 & EP 2845657 A1 & CA 2867986 A	1-5
A	WO 2014/013963 A1 (Nippon Steel & Sumitomo Metal Corp.), 23 January 2014 (23.01.2014), & US 2015/0321233 A1 & EP 2875876 A1 & CN 104395006 A	1-5

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

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
17 August 2016 (17.08.16)Date of mailing of the international search report
30 August 2016 (30.08.16)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

Telephone No.

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 4279350 B [0006]
- JP 2013248619 A [0007]
- WO 2014013963 A [0008]
- JP S611986286077 A [0009]
- JP H05199336502 A [0010]
- JP H031991125076 A [0010]