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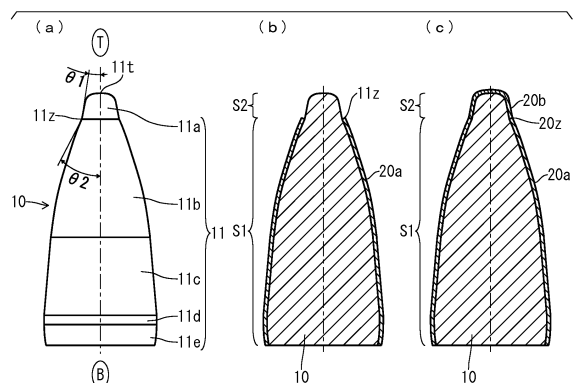
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(54) **METHOD FOR MANUFACTURING PLUG**

(57) A method for producing a plug includes: a step of preparing a plug base metal (10) having a concave portion (11z) along a circumferential direction in an outer peripheral surface (11); and an arc spraying step of spraying a spraying wire rod material onto the outer peripheral surface (11) of the plug base metal (10) by arc spraying to form films (20a and 20b) containing Fe and Fe oxides on the outer peripheral surface (11) of the plug base metal (10). The arc spraying step includes: a separating step of separating the outer peripheral surface (11) of the plug base metal (10) into a plurality of regions (S1 and S2) along an axial direction; and a step of performing arc spraying separately in each of the regions (S1 and S2). In the separating step, a boundary between the regions (S1 and S2) is set at the concave portion (11z). In this way, peeling of films at a connecting portion is prevented, and the lifetime of the plug can be increased.

FIG. 2



Description

TECHNICAL FIELD

5 **[0001]** The present invention relates to a method for producing a plug that is used in a piercing-rolling mill when producing a seamless steel pipe.

BACKGROUND ART

10 **[0002]** A seamless steel pipe can be produced by the Mannesmann pipe making process. This production process, for example, includes the following steps:

- (1) piercing-rolling a starting material (round billet) heated to a predetermined temperature using a piercing-rolling mill (piercer) to form a hollow shell;
- 15 (2) elongation-rolling the hollow shell using an elongation-rolling mill (for example, a mandrel mill); and
- (3) carrying out diameter adjusting rolling on the elongation-rolled hollow shell, so as to have a predetermined outer diameter and wall thickness using a sizing mill (for example, a stretch reducer).

20 **[0003]** The piercing-rolling mill includes: a pair of skew rolls that are each inclined with respect to a pass line; a bullet-shaped plug that is disposed on the pass line; and a mandrel connected to the rear end of the plug. In the piercing-rolling, in a state in which the axial directions of the pass line and the billet are matched, the billet is fed in the axial direction while being rotated in the circumferential direction by the skew rolls. Then, a central portion of the billet is pushed against the plug, and as a result the billet is pierced and rolled into a hollow shell.

25 **[0004]** In the piercing-rolling, because the plug pierces the billet that is heated to a high temperature (for example, 1200°C), a high surficial pressure at a high temperature is imposed on the plug. In order to protect the plug that is exposed to such harsh conditions, a film (hereunder, also referred to as "arc-sprayed film") may be formed by arc spraying on the surface of the plug (base metal). The arc-sprayed film blocks the transfer of heat from the billet to the plug base metal, and can also prevent seizing between the billet and the plug. As a result, the number of times (number of passes) piercing-rolling of a starting material can be performed with a single plug can be increased, that is, the lifetime of the plug can be increased.

30 **[0005]** Plugs that are used in a piercing-rolling mill are disclosed, for example, in Patent Literatures 1 to 3. In Patent Literature 1, a method is proposed in which the surface of the base metal of a plug is divided into a plurality of regions along an axial direction of the plug, and arc-spraying is performed separately in succession in each of the plurality of regions. Further, when performing the arc spraying, an intersection angle between the center line of a spray stream from the arc-sprayer and the surface of the base metal of the plug is maintained within a range of 35° to 90°. In this way, the adhesiveness of the arc-sprayed film formed on the surface of the plug can be made firm, and as a result the lifetime of the plug can be further increased.

35 **[0006]** A plug proposed in Patent Literature 2 has a front end rolling portion, a work portion and a reeling portion. Further, various dimensions, such as the outer diameter, of the plug satisfy a predetermined relational expression. The front end rolling portion includes a columnar portion and a hemispherical portion that is provided at the front end of the columnar portion. The work portion connects to the rear end of the front end rolling portion, and the cross-sectional shape of the work portion is a circular arc shape. The reeling portion connects to the rear end of the work portion, and the cross-sectional shape of the reeling portion is a linear tapered shape.

40 **[0007]** According to Patent Literature 2, by performing piercing-rolling using the above described plug, defective bite of a billet can be prevented and the occurrence of inner surface flaws can also be suppressed.

45 **[0008]** A plug proposed in Patent Literature 3 has a rolling portion, a reeling portion and a relief portion. The rolling portion is divided into a preceding stage rolling portion and a succeeding stage rolling portion. The cross-sectional shape of the outer peripheral surface of the preceding stage rolling portion is a circular arc shape, and a front end of the preceding stage rolling portion is a hemispherical shape. The succeeding stage rolling portion connects to the rear end of the outer peripheral surface of the preceding stage rolling portion, and the cross-sectional shape of the succeeding stage rolling portion is a linear tapered shape. The reeling portion connects to the rear end of the succeeding stage rolling portion, and the cross-sectional shape of the reeling portion is a linear tapered shape. The relief portion connects to the rear end of the reeling portion, and the diameter of the relief portion progressively decreases as the distance from the front end increases. In the plug having the above described shape, dimensions such as the radius of curvature of the front end satisfy a predetermined relational expression.

50 **[0009]** According to the method described in Patent Literature 3, defective bite, end clogging and an uneven wall thickness of a hollow shell can be prevented by using the aforementioned plug, even when performing piercing-rolling with a high expansion ratio of 1.15 or more and a low piercing ratio of less than 2.0.

CITATION LIST

PATENT LITERATURE

5 **[0010]**

Patent Literature 1: JP5365723B

Patent Literature 2: JP3823762B

Patent Literature 3: JP3119160B

10 Patent Literature 4: JP5339016B

SUMMARY OF INVENTION

TECHNICAL PROBLEM

15 **[0011]** As described in the foregoing, Patent Literature 1 proposes a method in which the surface of the base metal of the plug is divided into a plurality of regions along the axial direction of the plug, and arc spraying is then performed separately in succession in each of the plurality of regions. When arc spraying is performed separately in each region in this manner, films are connected together at the boundaries of the regions.

20 **[0012]** FIG. 1 is a SEM image that shows arc-sprayed films at a boundary between regions in a case where arc spraying was performed separately in respective regions. In FIG. 1, a plug base metal 10 and arc-sprayed films 20a and 20b are illustrated, with the arc-sprayed films being composed of the film 20b that is on the front-end side and the film 20a that is on the rear-end side. In this case, the term "front-end side" means the front-end side of the plug, and the term "rear-end side" means the rear-end side of the plug. The film 20b on the front-end side and the film 20a on the rear-end side are connected at a portion that is surrounded by a chain double-dashed line in FIG. 1. In this case, a portion of the film 20b on the front-end side is formed on the film 20a on the rear-end side without coming in contact with the plug base metal 10.

25 **[0013]** Further, in the formation of the arc-sprayed films 20a and 20b shown in FIG. 1, thin layers are stacked on each other by moving the arc-sprayer back and forth. In this case, an angle that is formed by the built-up layers of film and the surface of the plug base metal 10 differs between the film 20b on the front-end side and the film 20a on the rear-end side. This is because the spraying direction (direction of spraying by the arc-sprayer) for the film 20b on the front-end side and the spraying direction for the film 20a on the rear-end side are different. In FIG. 1, the spraying direction for the film 20b on the front-end side and the spraying direction for the film 20a on the rear-end side are indicated by solid-line arrows, respectively.

30 **[0014]** At a portion at which the arc-sprayed films are connected together (hereunder, also referred to simply as "connecting portion"), because another film is formed on a certain film, the adherence of the films decreases in comparison to other portions of the films. Further, a range in which another film is formed on a certain film as well as the thicknesses of the respective films and the like change in the circumferential direction of the plug, and for this reason also the adherence of the films at the connecting portion decreases. Consequently, peeling of a film is liable to occur at the connecting portion (see FIG. 9 of Examples as described later). When peeling of a film occurs on a plug, it is the end of the lifetime of the plug and the plug is not used for piercing-rolling again. Therefore, in a case where arc spraying is performed separately in respective regions, it is desirable to suppress peeling of a film at a connecting portion and thereby increase the lifetime of the plug.

35 **[0015]** Peeling of a film at a connecting portion is liable to occur, in particular, during piercing-rolling of a billet that is made from high alloy steel. This is because high alloy steel has high strength. Note that, the term "high alloy steel" corresponds to, for example, high Cr steel containing 9% or more of Cr, an Ni-based alloy, and stainless steel.

40 **[0016]** Although Patent Literatures 2 and 3 propose the use of plugs that each have a predetermined shape and satisfy a predetermined relational expression, there is no description in Patent Literatures 2 and 3 regarding formation and peeling of a film.

45 **[0017]** An objective of the present invention is to provide a method for producing a plug that can prevent peeling of a film at a connecting portion and thereby increase the lifetime of the plug.

SOLUTION TO PROBLEM

50 **[0018]** A method for producing a plug according to an embodiment of the present invention is a method for producing a plug that is used in a piercing-rolling mill when producing a seamless steel pipe. The method for producing a plug includes: a step of preparing a plug base metal having a concave portion along a circumferential direction in an outer peripheral surface; and an arc spraying step of spraying a spraying wire rod material onto the outer peripheral surface

of the plug base metal by arc spraying to form films containing Fe and Fe oxides on the outer peripheral surface of the plug base metal. The arc spraying step includes: a separating step of separating the outer peripheral surface of the plug base metal into a plurality of regions along an axial direction; and a step of performing arc spraying separately in each of the regions. In the separating step, a boundary between the regions is set at the concave portion.

[0019] In the plug base metal, the outer peripheral surface may be formed by connecting a plurality of divided faces successively in the axial direction, and may have the concave portion at a joint between the divided faces. In this case, at the joint which is the concave portion, a slope θ_1 (°) of a divided face located on a front-end side of the plug and a slope θ_2 (°) of a divided face located on a rear-end side of the plug satisfy the following Formula (1).

$$\theta_1 < \theta_2 \quad \dots (1)$$

ADVANTAGEOUS EFFECTS OF INVENTION

[0020] The method for producing a plug of the present invention uses a plug base metal which has a concave portion along a circumferential direction on the outer peripheral surface thereof. Further, a boundary between regions is set at the concave portion to divide the outer peripheral surface into a plurality of regions, and an arc-sprayed film is formed in each region. In this case, a connecting portion between the films is located at the concave portion, and the amount of reduction in wall-thickness of a billet when performing piercing-rolling is comparatively low at the concave portion. Consequently, peeling of the films can be suppressed and the lifetime of the plug can be increased.

BRIEF DESCRIPTION OF DRAWINGS

[0021]

[FIG. 1] FIG. 1 is a SEM image showing arc-sprayed films at a boundary between regions in a case where arc spraying is performed separately for respective regions.

[FIG. 2] FIG. 2(a) to FIG. 2(c) are schematic diagrams illustrating an example of a processing flow according to the method for producing a plug of the present invention, in which FIG. 2(a) is a view illustrating the shape of a plug base metal, FIG. 2(b) is a cross-sectional view illustrating a state after the end of film formation in a first region, and FIG. 2(c) is a cross-sectional view illustrating a state after the end of film formation in a second region.

[FIG. 3] FIG. 3(a) to FIG. 3(d) are schematic diagrams illustrating an example of a processing flow according to the present invention when using a plug in which a front end of the outer peripheral surface is connected to a planar front end face, in which FIG. 3(a) is a view illustrating the shape of a plug base metal, FIG. 3(b) is a cross-sectional view illustrating a state after the end of film formation in a first region, FIG. 3(c) is a cross-sectional view illustrating a state after the end of film formation in a second region, and FIG. 3(d) is a cross-sectional view illustrating a state after the end of film formation on the front end face.

[FIG. 4] FIG. 4(a) to FIG. 4(c) are schematic diagrams illustrating a processing flow with respect to a Test No. 1 (Comparative Example), in which FIG. 4(a) is a view illustrating the shape of a plug base metal, FIG. 4(b) is a cross-sectional view illustrating a state after the end of film formation in a first region, and FIG. 4(c) is a cross-sectional view illustrating a state after the end of film formation in a second region.

[FIG. 5] FIG. 5(a) and FIG. 5(b) are cross-sectional views that schematically illustrate a processing flow with respect to a Test No. 3 (Comparative Example), in which FIG. 5(a) illustrates a state after the end of film formation in a first region, and FIG. 5(b) illustrates a state after the end of film formation in a second region.

[FIG. 6] FIG. 6(a) to FIG. 6(c) are cross-sectional views that schematically illustrate a processing flow with respect to a Test No. 5 (Comparative Example), in which FIG. 6(a) illustrates a state after the end of film formation in a first region, FIG. 6(b) illustrates a state after the end of film formation in a second region, and FIG. 6(c) illustrates a state after the end of film formation on a front end face.

[FIG. 7] FIG. 7(a) to FIG. 7(d) are schematic diagrams that illustrate a processing flow with respect to a Test No. 6 (Inventive Example of the present invention), in which FIG. 7(a) is a view illustrating the shape of a plug base metal, FIG. 7(b) is a cross-sectional view illustrating a state after the end of film formation in a first region, FIG. 7(c) is a cross-sectional view illustrating a state after the end of film formation in a second region, and FIG. 7(d) is a cross-sectional view illustrating a state after the end of film formation on a front end face.

[FIG. 8] FIG. 8(a) to FIG. 8(c) are cross-sectional views that illustrate a processing flow with respect to a Test No. 7 (Comparative Example), in which FIG. 8(a) illustrates a state after the end of film formation in a first region, FIG. 8(b) illustrates a state after the end of film formation in a second region, and FIG. 8(c) illustrates a state after the end of film formation on a front end face.

[FIG. 9] FIG. 9 is a photograph that shows peeling of a film.

DESCRIPTION OF EMBODIMENTS

[0022] Hereunder, a method for producing a plug according to the present embodiment is described while referring to the accompanying drawings.

[0023] FIG. 2(a) to FIG. 2(c) are schematic diagrams illustrating an example of a processing flow according to the method for producing a plug of the present invention, in which FIG. 2(a) is a view illustrating the shape of a plug base metal, FIG. 2(b) is a cross-sectional view illustrating a state after the end of film formation in a first region, and FIG. 2(c) is a cross-sectional view illustrating a state after the end of film formation in a second region. In FIG. 2, a plug base metal 10 and arc-sprayed films 20a and 20b are shown. Further, a front-end side of the plug is denoted by reference character T, and a rear-end side thereof is denoted by reference character B.

[0024] An outer peripheral surface 11 of the plug base metal 10 shown in FIG. 2(a) is formed by connecting first to fifth divided faces 11a to 11e successively in the axial direction. In other words, the outer peripheral surface 11 is divided into a plurality of sections at a face that is perpendicular to the axial direction. The first divided face 11a and the second divided face 11b each have a cross-sectional shape that is curved, and in which a slope changes in the axial direction. Note that, in this case the term "slope" refers to an angle formed by the divided face and a center line of the plug base metal (see $\theta 1$ and $\theta 2$ in FIG. 2(a)). The third divided face 11c has a cross-sectional shape that is linear, in which the slope is constant. The outer diameters of the first to third divided faces 11a to 11c each increase progressively from the front-end side T toward the rear-end side B.

[0025] The fourth divided face 11d is a cylindrical portion whose outer diameter is constant. Further, the outer diameter of the fifth divided face 11e decreases toward the rear end. The fifth divided face 11e is called a "relief portion". In piercing-rolling that uses such a plug, because the outer diameters of the first to third divided faces 11a to 11c progressively increase, mainly the first to third divided faces 11a to 11c contribute to the piercing-rolling. In other words, the first to third divided faces 11a to 11c strongly contact against the billet, and a high surficial pressure at a high temperature is imposed on these divided faces.

[0026] Among the joints between the divided faces 11a to 11e, a joint between the first divided face 11a and the second divided face 11b is a concave portion 11z. In the method for producing a plug of the present embodiment, a plug base metal having a concave portion along the circumferential direction as illustrated in FIG. 2(a) is prepared.

[0027] The method for producing a plug of the present embodiment includes a step of preparing the plug base metal as described above, and an arc spraying step. In the arc spraying step, a spraying wire rod (for example, steel wire) is heated by arc spraying to produce Fe particles, and the Fe particles are sprayed onto the outer peripheral surface 11 of the base metal of the plug. In this way, Fe particles build up on the outer peripheral surface 11 of the base metal of the plug, and the films 20a and 20b are formed. During the course of forming the films 20a and 20b, some of the Fe particles undergo an oxidation reaction with atmospheric air and form Fe oxides. Consequently, the films 20a and 20b contain Fe and Fe oxides.

[0028] In the arc spraying step, the outer peripheral surface 11 of the base metal of the plug is divided into a plurality of regions in the axial direction, and a film is formed in each of the regions, respectively. In this way, similarly to the aforementioned Patent Literature 1, the adhesiveness of the arc-sprayed films formed on the surface of the plug can be made firm. In the processing flow example illustrated in FIG. 2, the outer peripheral surface 11 of the base metal of the plug is divided into a first region S1 on the rear-end side B and a second region S2 of a front-end side T, and a film is first formed in the first region S1, and thereafter a film is formed in the second region S2.

[0029] In addition, in the method for producing a plug of the present embodiment, when separating the outer peripheral surface 11 into the plurality of regions S1 and S2, the boundary between the regions is set at the concave portion 11z. In this case, in the obtained plug, a connecting portion between the arc-sprayed films as shown in the aforementioned FIG. 1 is located at the concave portion 11z.

[0030] At the time of piercing-rolling, the amount of reduction in wall-thickness of the billet at the concave portion 11z is low in comparison to other portions, and the surficial pressure imposed on the concave portion 11z is also partially lower. As a result, the surficial pressure imposed on the connecting portion 20z of the films is also moderated. In a case where the connecting portion is located at the concave portion 11z, as described above, although the adherence of the films at the connecting portion decreases similarly to the prior art, by moderating the surficial pressure that is interposed on the connecting portion 20z of the films, peeling of the films can be suppressed and the lifetime of the plug can be thereby increased.

[0031] In the present invention, the term "concave portion" refers to a portion at which, among the entire outer peripheral surface of the plug base metal, the amount of reduction in wall-thickness of the billet is lower than at other portions. In other words, a closed curve is formed along the circumferential direction by the following points A, and the vicinity of the closed curve is the concave portion. The points A are points on the outer peripheral surface of the plug base metal, and a slope $\theta 1$ (°) on the front-end side of the points, and a slope $\theta 2$ (°) on the rear-end side of the points satisfy the relation

in the following Formula (1). At the closed curve formed by the points A, because the slope on the front-end side thereof is smaller, the amount of reduction in wall-thickness of the billet is less than at other portions.

$$\theta_1 < \theta_2 \quad \dots (1)$$

[0032] Here, the slope θ_1 on the front-end side of a point is taken as an angle that is formed between the center line of the plug base metal and a tangential line of the outer peripheral surface on the front-end side relative to the relevant point among the entire tangential line of the outer peripheral surface at the relevant point, and the slope θ_2 on the rear-end side of the point is taken as an angle that is formed between the center line of the plug base metal and a tangential line of the outer peripheral surface on the rear-end side relative to the relevant point among the entire tangential line of the outer peripheral surface at the relevant point.

[0033] A plug base metal in which the outer peripheral surface 11 is formed by connecting a plurality of divided faces successively in the axial direction as shown in the above described FIG. 2 can be adopted as the plug base metal. In this case, the concave portion 11z can be made a joint at which the slope θ_1 (see FIG. 2, unit is " $^{\circ}$ ") of the divided face on the front-end side T and the slope θ_2 (see FIG. 2, unit is " $^{\circ}$ ") of the divided face on the rear-end side B satisfy the relation in the above described Formula (1). Here, the slopes θ_1 and θ_2 of the divided faces are taken as angles formed between the respective divided faces and the center line of the plug base metal. Further, in a case where the slope changes in the axial direction, the respective slopes θ_1 and θ_2 of the divided faces are taken as the slope of a tangential line at the relevant joint.

[0034] In a case where the plug base metal has a concave portion at a joint between the divided faces, it is preferable that $d\theta$ is 0.5° or more at the concave portion 11z at which the boundary between the regions is set. In this case, $d\theta$ is the difference ($\theta_2 - \theta_1$) between θ_2 and θ_1 . If $d\theta$ is 0.5° or more, the amount of reduction in wall-thickness of the billet at the concave portion is low, and peeling of the films can be suppressed. On the other hand, if $d\theta$ exceeds 20° , because there will also be a large change in the amount of reduction in wall-thickness, there is a risk that the dimension accuracy of an obtained hollow shell will deteriorate. Therefore, $d\theta$ is preferably made 20° or less.

[0035] The order of the regions in which arc spraying is performed is not particularly limited, and peeling of the films can be suppressed if the boundary between the regions is set at the concave portion. From the viewpoint of suppressing peeling of films to a greater degree, it is preferable that the arc spraying for the respective regions is first performed in the region on the rear-end side of the concave portion, and thereafter is performed in the region on the front-end side of the concave portion. This is because, at the connecting portion, since the film on the front-end side will be formed on the film on the rear-end side, the film on the rear-end side will be covered by the film on the front-end side.

[0036] Separating the outer peripheral surface into regions is not limited to separating the outer peripheral surface into two regions as illustrated in the above described FIG. 2, and the outer peripheral surface may be separated into three or more regions. In such a case, it is preferable that boundaries between the plurality of regions are each set at a concave portion.

[0037] The plug base metal is not limited to the plug base metal illustrated in the above described FIG. 2, and various plug base metals can be used as long as the plug base metal has a concave portion along the circumferential direction on the outer peripheral surface. For example, plugs described in the aforementioned Patent Literatures 2 and 3 may be adopted as the plug base metal. The plug described in the aforementioned Patent Literature 2 has a concave portion at a joint between the front end rolling portion and the work portion. Further, the plug described in the aforementioned Patent Literature 3 has a concave portion at a joint between the preceding stage rolling portion and the succeeding stage rolling portion.

[0038] Although the plug base metal illustrated in the above described FIG. 2 has the cylindrical portion 11d whose outer diameter is constant, a plug base metal that does not have a cylindrical portion may also be adopted. In this case, the rear-end side of the portions 11a to 11c which mainly contribute to piercing-rolling is connected to the relief portion 11e.

[0039] A front end 11t of the outer peripheral surface 11 of the plug base metal is not limited to a case where the front end extends as far as a center line as in the plug base metal shown in the aforementioned FIG. 2, and the front end 11t may connect to a planar front end face.

[0040] FIG. 3(a) to FIG. 3(d) are schematic diagrams illustrating an example of a processing flow according to the present invention in a case of using a plug in which the front end of the outer peripheral surface is connected to a planar front end face, in which FIG. 3(a) is a view illustrating the shape of the plug base metal, FIG. 3(b) is a cross-sectional view illustrating a state after the end of film formation in a first region, FIG. 3(c) is a cross-sectional view illustrating a state after the end of film formation in a second region, and FIG. 3(d) is a cross-sectional view illustrating a state after the end of film formation on the front end face. In FIG. 3(a) to FIG. 3(d), the plug base metal 10 and the arc-sprayed films 20a and 20b are illustrated.

[0041] In the plug base metal illustrated in FIG. 3(a), the front end 11t of the outer peripheral surface 11 is connected

to a planar front end face 12. Further, the outer peripheral surface 11 is formed by successively connecting the first to fifth divided faces 11a to 11e in the axial direction. Further, in the first to third divided faces 11a to 11c, the outer diameter progressively increases from the front-end side T toward the rear-end side B. Among these divided faces, the first divided face 11a has a cross-sectional shape that is a curved shape, and the slope thereof changes in the axial direction. Further, the slopes of the second divided face 11b and the third divided face 11c are constant, and the cross-sectional shape of these divided faces is a linear tapered shape. The fourth divided face 11d is a cylindrical portion, and the fifth divided face 11e is a relief portion.

[0042] Among these divided faces, mainly the first to third divided faces 11a to 11c contribute to piercing-rolling. Further, among the joints of the divided faces, the joint between the second divided face 11b and the third divided face 11c is the concave portion 11z along the circumferential direction.

[0043] In the processing flow example illustrated in FIG. 3(b) to FIG. 3(d), the outer peripheral surface of the plug base metal is separated into a first region S1 on the rear-end side B and a second region S2 on the front-end side T. At such time, the boundary between the first region S1 and the second region S2 is set at the concave portion 11z. When performing arc spraying, the film 20b is formed in the second region S2 after the film 20a is formed in the first region S1, and thereafter a film 20c is formed on the front end face 12.

[0044] When the boundary between regions for the arc spraying step is set at the concave portion in this way, even in a case where the front end 11t of the outer peripheral surface is connected to the planar front end face 12, peeling of a film at the connecting portion 20z can be suppressed, and the lifetime of the plug can thus be increased.

[0045] It is preferable to dispose the concave portion 11z at a portion that mainly contributes to piercing-rolling among the entire outer peripheral surface of the plug base metal, in other words, at a portion excluding the cylindrical portion and relief portion. This is because peeling of films is liable to occur if a connecting portion between the films is located at a portion that mainly contributes to piercing-rolling.

[0046] For example, steel wire can be used as the spraying wire rod. A cored wire as described in Patent Literature 4 can also be used as the spraying wire rod. The cored wire includes a steel sheath tube, and powder that is filled inside the steel sheath tube. For example, ZrO_2 powder or BN powder can be adopted as the powder that is filled inside the tube. Iron oxide powder can also be adopted as the powder, and in such case, steel powder may be additionally filled inside the tube.

[0047] In this case, the steel wire is, for example, a wire rod formed of carbon steel (common steel), the steel sheath tube is, for example, a tube formed of carbon steel (common steel), and the steel powder is, for example, carbon steel (common steel) powder. The carbon steel typically includes Fe as a principal component, and also includes carbon (C), silicon (Si), manganese (Mn) and impurities. The carbon steel is also referred to as "common steel", and may contain optional elements such as tungsten (W).

EXAMPLES

[0048] For the purpose of verifying the effects obtained by the method for producing a plug of the present invention, plugs were produced and piercing-rolling was performed using the plugs.

[Production of Plug]

[0049] To produce the respective plugs, first a plug base metal made of hot working tool steel as defined by the JIS was prepared. A steel wire was atomized and sprayed by an arc-sprayer onto the outer peripheral surface of the plug base metal, and films composed of Fe and Fe oxides were formed. At such time, the outer peripheral surface of the plug base metal was separated into a region on the rear-end side and a region on the front-end side, and a film was first formed in the region on the rear-end side and thereafter a film was formed in the region on the front-end side.

[0050] Test Nos. 1 to 7 were conducted as the present tests, and the shape of the plug base metal as well as a boundary position between the first region and the second region were changed for the respective tests.

[0051] FIG. 4(a) to FIG. 4(c) are schematic diagrams illustrating the processing flow with respect to Test No. 1 (Comparative Example), in which FIG. 4(a) is a view illustrating the shape of the plug base metal, FIG. 4(b) is a cross-sectional view illustrating a state after the end of film formation in the first region, and FIG. 4(c) is a cross-sectional view illustrating a state after the end of film formation in the second region. In Test No. 1, the outer peripheral surface 11 of the plug base metal was constituted by first to third divided faces 11a to 11c. The cross-sectional shape of the first divided face 11a was a curved shape. The second divided face 11b was a cylindrical portion, and the third divided face 11c was a relief portion. Among these divided faces, mainly the first divided face 11a contributes to piercing-rolling.

[0052] In Test No. 1 as described above, a plug base metal that did not have a concave portion was used, and a boundary between the region S1 and S2 was set on the first divided face 11a. The target values for the thickness of the films were set as 300 μm in the first region S1 and 800 μm in the second region S2.

[0053] In Test No. 2 (Inventive Example of the present invention), films were formed in accordance with the processing

flow example illustrated in the above described FIG. 2. Specifically, a plug base metal having the concave portion 11z at a joint between the first divided face 11a and the second divided face 11b was used, and the boundary between the regions S1 and S2 was set at the concave portion 11z. At the concave portion 11z, the slope θ_1 of the first divided face 11a was 10° and the slope θ_2 of the second divided face 11b was 23.5° . The target values for the thickness of the films were set as $300\ \mu\text{m}$ in the first region S1 and $800\ \mu\text{m}$ in the second region S2.

[0054] FIG. 5(a) and FIG. 5(b) are cross-sectional views that schematically illustrate the processing flow with respect to Test No. 3 (Comparative Example), in which FIG. 5(a) illustrates a state after the end of film formation in the first region, and FIG. 5(b) illustrates a state after the end of film formation in the second region. As illustrated in FIGS. 5(a) and 5(b), the plug base metal of Test No. 3 had the concave portion 11z, similarly to Test No. 2. In Test No. 3, unlike Test No. 2, the boundary between the regions S1 and S2 was not set at the concave portion 11z, and was instead set on the second divided face 11b. The target values for the thickness of the films were set to the same values as in Test No. 2.

[0055] In Test No. 4 (Inventive Example of the present invention), films were formed in accordance with the processing flow example illustrated in the above described FIG. 3(b) to FIG. 3(d). Specifically, the plug base metal had the concave portion 11z at a joint between the first divided face 11a and the second divided face 11b, and the front end 1 lt of the outer peripheral surface was connected to the planar front end face 12. In Test No. 4, the boundary between the regions S1 and S2 was set at the concave portion 11z. At the concave portion 11z, the slope θ_1 of the first divided face 11a was 6.5° , and the slope θ_2 of the second divided face 11b was 7.5° . The target values for the thickness of the films were set as $300\ \mu\text{m}$ in the first region S1, $600\ \mu\text{m}$ in the second region S2, and $800\ \mu\text{m}$ at the front end face 12.

[0056] FIG. 6(a) to FIG. 6(c) are cross-sectional views that schematically illustrate the processing flow with respect to Test No. 5 (Comparative Example), in which FIG. 6(a) illustrates a state after the end of film formation in a first region, FIG. 6(b) illustrates a state after the end of film formation in a second region, and FIG. 6(c) illustrates a state after the end of film formation on a front end face. As illustrated in FIGS. 6(a) to 6(c), the plug base metal of Test No. 5 had the concave portion 11z, similarly to Test No. 4. In Test No. 5, unlike Test No. 4, the boundary between the regions S1 and S2 was not set at the concave portion 11z, and was instead set in the first divided face 11a. The target values for the thickness of the films were set to the same values as in Test No. 4.

[0057] FIG. 7(a) to FIG. 7(d) are schematic diagrams that illustrate the processing flow with respect to Test No. 6 (Inventive Example of the present invention), in which FIG. 7(a) is a view illustrating the shape of a plug base metal, FIG. 7(b) is a cross-sectional view illustrating a state after the end of film formation in a first region, FIG. 7(c) is a cross-sectional view illustrating a state after the end of film formation in a second region, and FIG. 7(d) is a cross-sectional view illustrating a state after the end of film formation on a front end face. In Test No. 6, a plug base metal was used in which the outer peripheral surface 11 was composed of first to sixth divided faces 11a to 11f. The front end 1 lt of the outer peripheral surface 11 was connected to the planar front end face 12. Mainly the first to fourth divided faces 11a to 11d contributed to piercing-rolling, the fifth divided face 11e was a cylindrical portion, and the sixth divided face 11f was a relief portion. Among the joints between these divided faces, the joint between the second divided face 11b and the third divided face 11c was the concave portion 11z. The slope θ_1 of the second divided face 11b was 5° , and the slope θ_2 of the third divided face 11c was 8° .

[0058] In Test No. 6, the boundary between the regions S1 and S2 to undergo arc spraying was set at the concave portion 11z. The target values for the thickness of the films was set as $300\ \mu\text{m}$ for the first region S1, $600\ \mu\text{m}$ for the second region S2, and $800\ \mu\text{m}$ for the front end face 12.

[0059] FIG. 8(a) to FIG. 8(c) are cross-sectional views that illustrate a processing flow with respect to Test No. 7 (Comparative Example), in which FIG. 8(a) illustrates a state after the end of film formation in a first region, FIG. 8(b) illustrates a state after the end of film formation in a second region, and FIG. 8(c) illustrates a state after the end of film formation on a front end face. As illustrated in FIGS. 8(a) to 8(c), the plug base metal of Test No. 7 had the concave portion 11z, similarly to Test No. 6. In Test No. 7, unlike Test No. 6, the boundary between the regions S1 and S2 was set at the joint between the first divided face 11a and the second divided face 11b, and not at the concave portion 11z. The target values for the thickness of the films were set to the same values as in Test No. 6.

[0060] In each of the tests, the maximum diameter of the plug was set to 57 mm, and the length of the plug was set to 114 mm as the total length of the divided faces that mainly contribute to piercing-rolling.

[Piercing-rolling]

[0061] Each plug was repeatedly used three times in piercing-rolling utilizing a model mill. The billets that were used were made of SUS 304 stainless steel. Table 1 shows the piercing-rolling conditions, the billet dimensions, and the dimensions of the obtained hollow shell.

[Table 1]

EP 3 257 596 A1

Table 1

Item	Details
Piercing-rolling conditions	Billet heating temperature: 1200°C Roll gap: 60 mm Number of roll revolutions: 80 rpm Plug lead: 51mm
Billet dimensions	Outer diameter: 70 mm Length: 300 mm
Hollow shell dimensions	Outer diameter: 74 mm Wall thickness: 6 mm Length: 900 mm

[Evaluation Procedure]

[0062] After the end of three rounds of piercing-rolling, the state of the films on the relevant plug was visually inspected. The meaning of the symbols in the "Film State" column in Table 2 below is as follows.

○: Indicates there was no peeling of a film at the connecting portion, and the state of the films was good.

×: Indicates there was peeling of a film at the connecting portion, and the state of the films was regarded as failed.

[Test Results]

[0063] The Test Nos., test categories, and film states are shown in Table 2.

[Table 2]

Table 2

Test No.	Category	Film State
No. 1	Comparative Example	×
No. 2	Inventive Example	○
No. 3	Comparative Example	×
No. 4	Inventive Example	○
No. 5	Comparative Example	×
No. 6	Inventive Example	○
No. 7	Comparative Example	×

[0064] The results in Table 2 show that, with respect to Test No. 1 (Comparative Example), when the plug which did not have a concave portion was used, peeling of a film occurred. Further, with respect to Test Nos. 3, 5 and 7 as Comparative Examples, in each test a plug having a concave portion was used, and arc spraying was performed separately in the respective regions without setting a boundary between the regions at the concave portion. As a result, peeling of a film occurred.

[0065] FIG. 9 is a photograph showing peeling of a film. FIG. 9 shows the plug used in Test No. 1 (Comparative Example) after piercing-rolling was performed three times. In FIG. 9, a portion of a region at which a film peeled is surrounded by a chain double-dashed line. As illustrated in FIG. 9, the film 20a on the rear-end side partially peeled in a manner in which the starting point of the peeling was the connecting portion 20z between the film 20a on the rear-end side and the film 20b on the front-end side.

[0066] On the other hand, with respect to Test Nos. 2, 4 and 6 as Inventive Examples of the present invention, a plug having a concave portion was used, and arc spraying was performed separately in each region in a manner in which the concave portion was set as the boundary between the regions. As a result, peeling of a film did not occur. Based

on these results, it was clarified that peeling of films at a connecting portion can be suppressed by using a base metal that has a concave portion along the circumferential direction and performing arc spraying separately in each region in a manner in which the concave portion is set as the boundary between the regions.

5 INDUSTRIAL APPLICABILITY

[0067] The present invention can be effectively utilized in the production of seamless steel pipes made from high alloy steel.

10 REFERENCE SIGNS LIST

[0068]

- 10: plug base metal
- 11: outer peripheral surface
- 11a to 11f: divided face
- 11t: front end of outer peripheral surface
- 11z: concave portion
- 12: front end face
- 20a to 20c: film
- 20z: connecting portion
- S1, S2: separated region
- $\theta 1$, $\theta 2$: slope of divided face

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Claims

1. A method for producing a plug that is used in a piercing-rolling mill when producing a seamless steel pipe, the method comprising:

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a step of preparing a plug base metal having a concave portion along a circumferential direction in an outer peripheral surface, and
an arc spraying step of spraying a spraying wire rod material onto the outer peripheral surface of the plug base metal by arc spraying to form films containing Fe and Fe oxides on the outer peripheral surface of the plug base metal;
wherein:

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the arc spraying step includes:

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a separating step of separating the outer peripheral surface of the plug base metal into a plurality of regions along an axial direction, and
a step of performing arc spraying separately in each of the regions; and
in the separating step, a boundary between the regions is set at the concave portion.

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2. The method for producing a plug according to claim 1, wherein:

in the plug base metal, the outer peripheral surface is formed by connecting a plurality of divided faces successively in the axial direction, and has the concave portion at a joint between the divided faces; and
at the joint which is the concave portion, a slope $\theta 1$ (°) of a divided face located on a front-end side of the plug and a slope $\theta 2$ (°) of a divided face located on a rear-end side of the plug satisfy the following Formula (1).

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$$\theta 1 < \theta 2 \quad \dots (1)$$

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FIG. 1

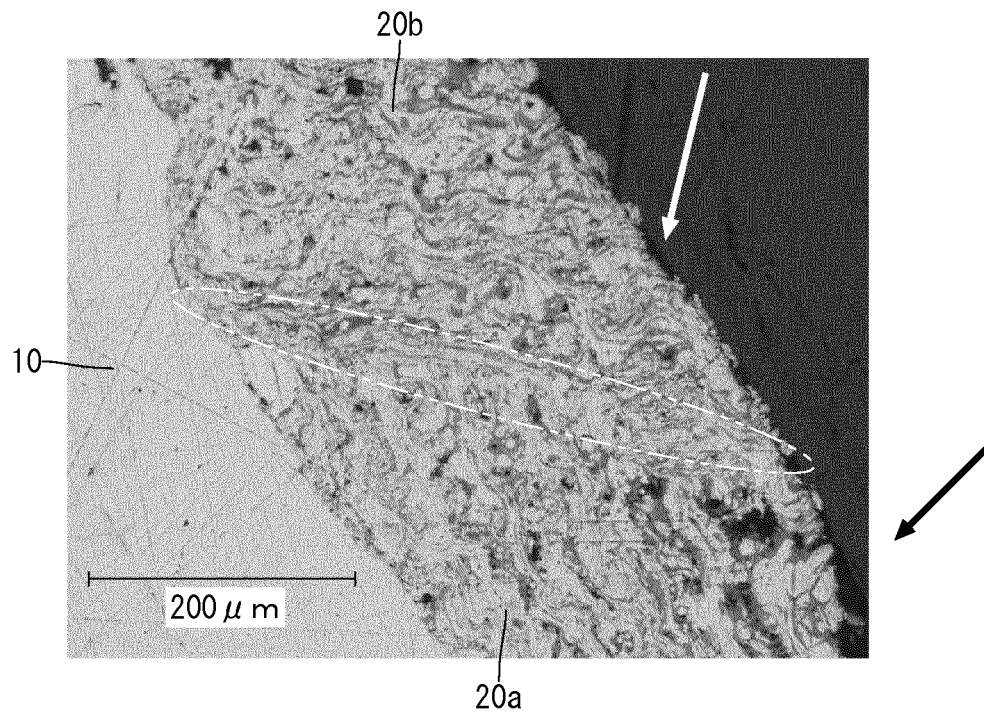


FIG. 2

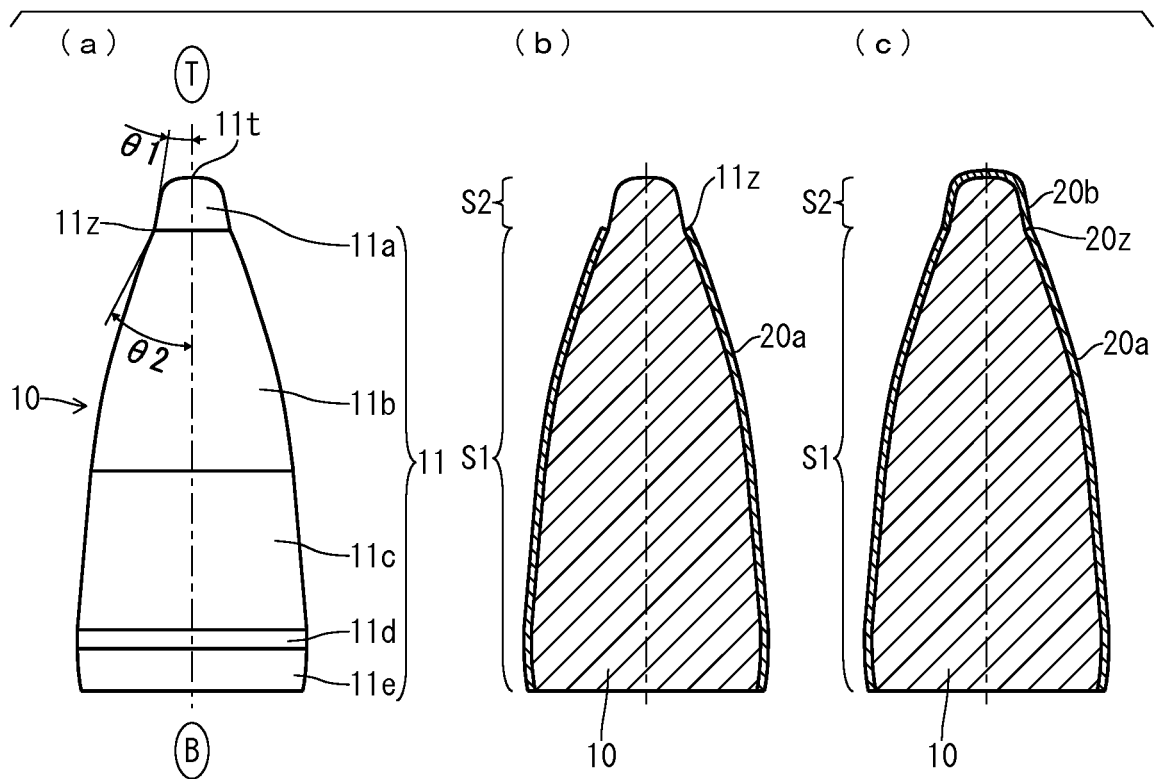


FIG. 3

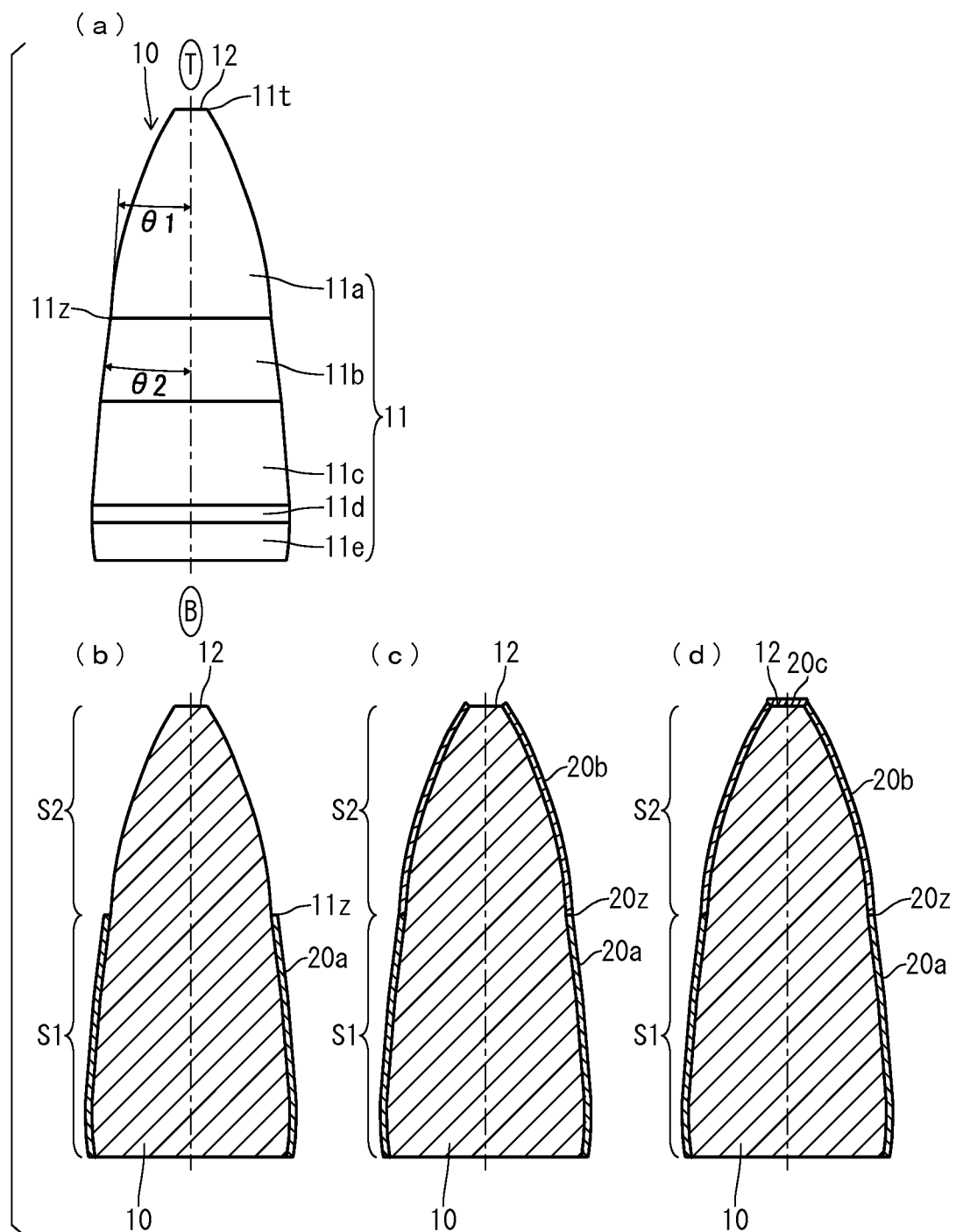


FIG. 4

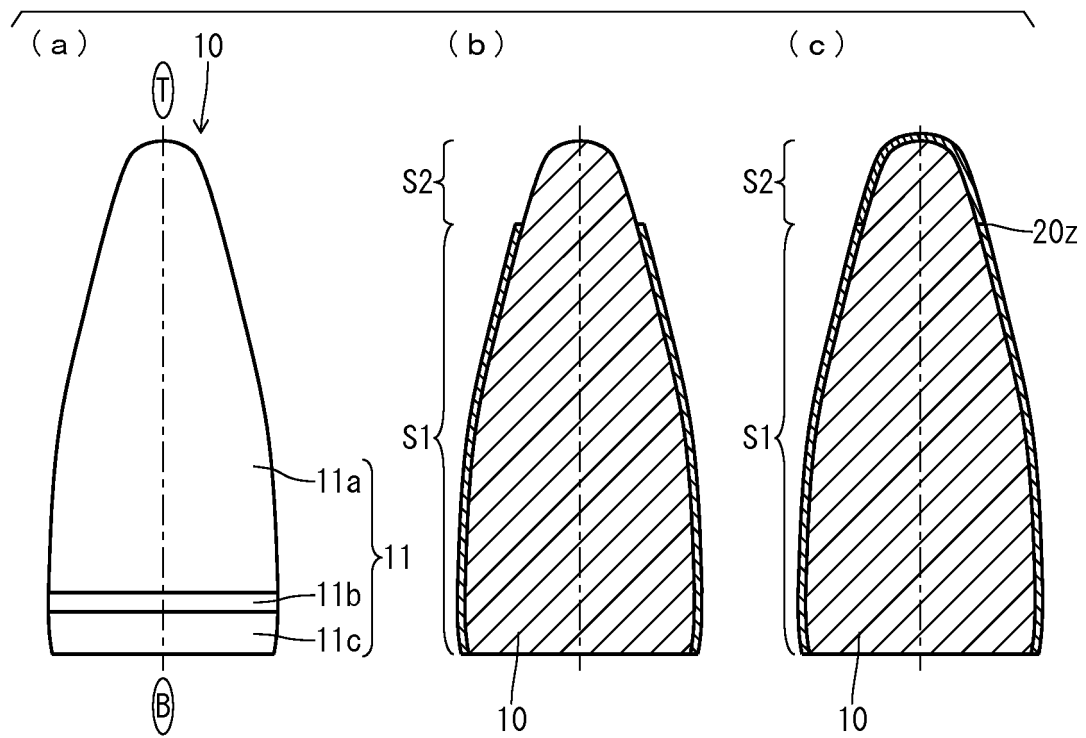


FIG. 5

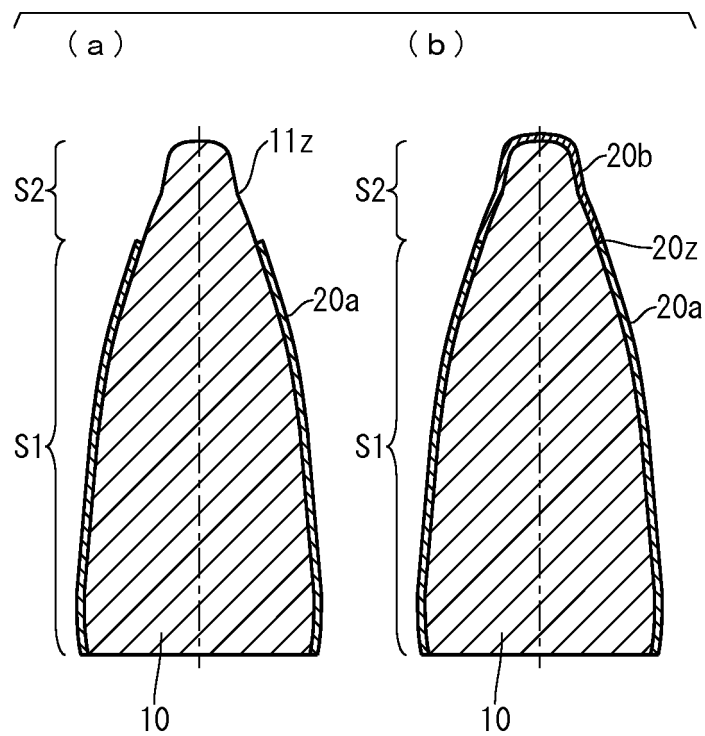


FIG. 6

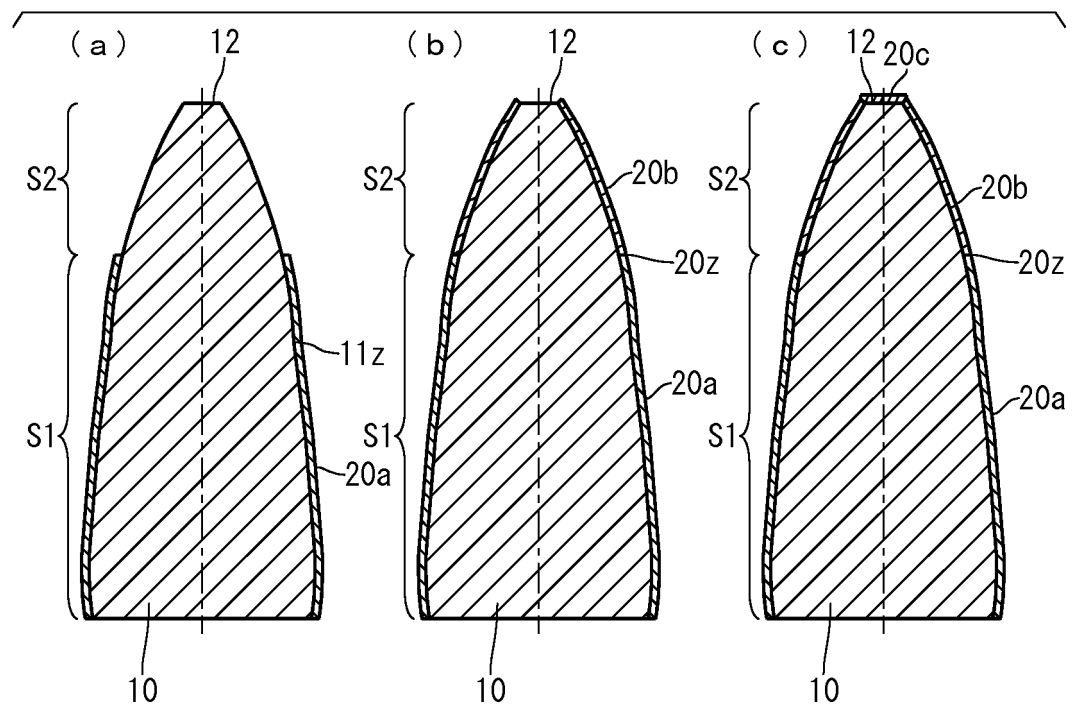


FIG. 7

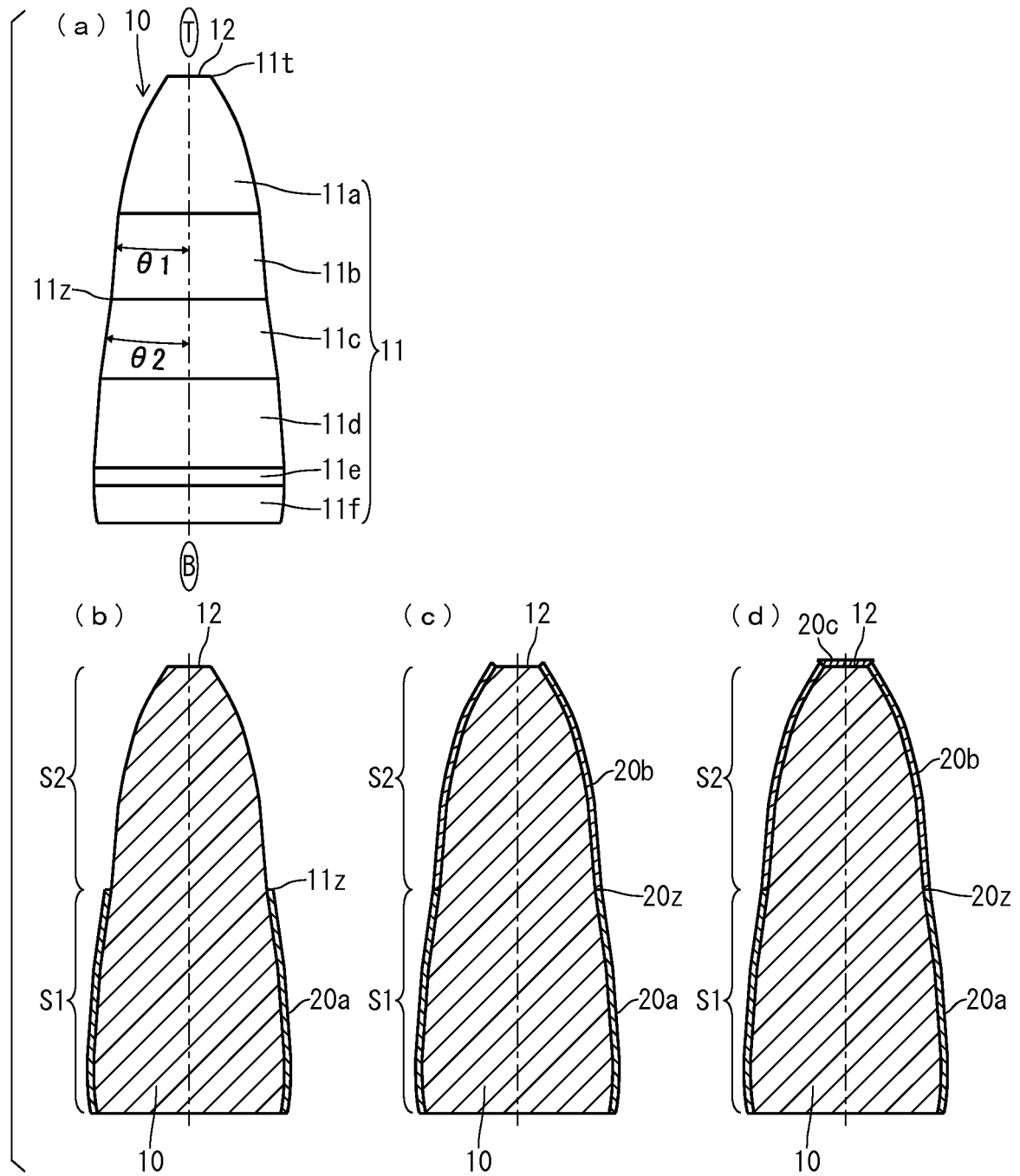


FIG. 8

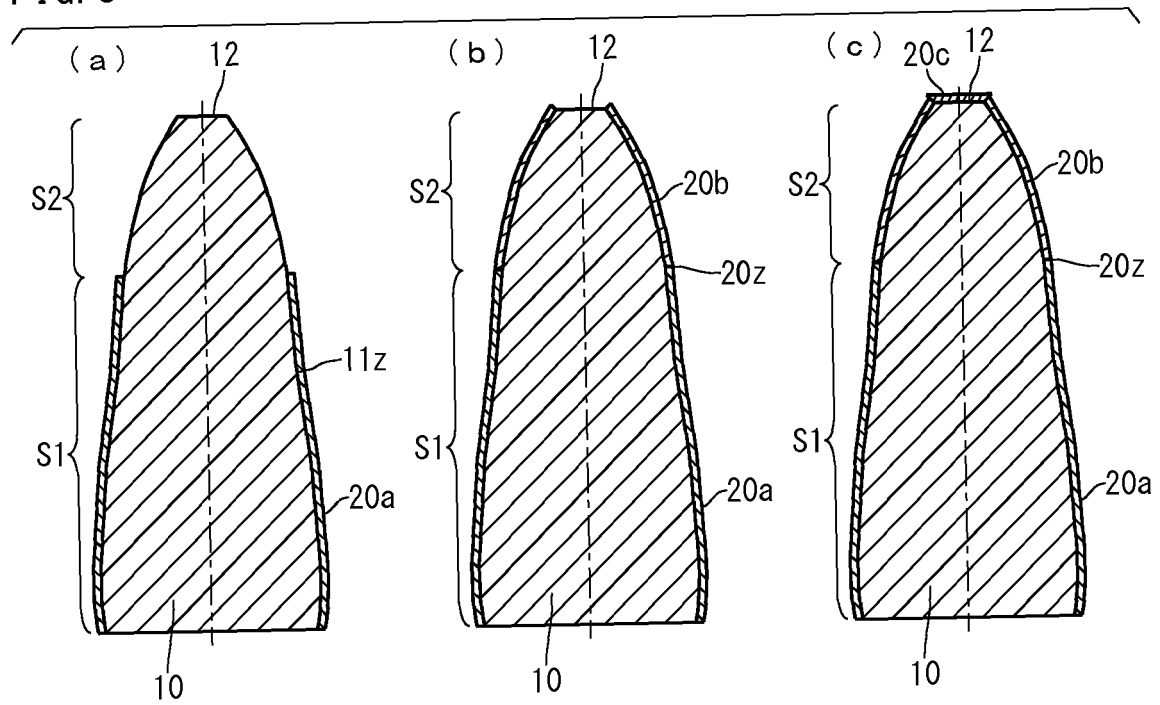
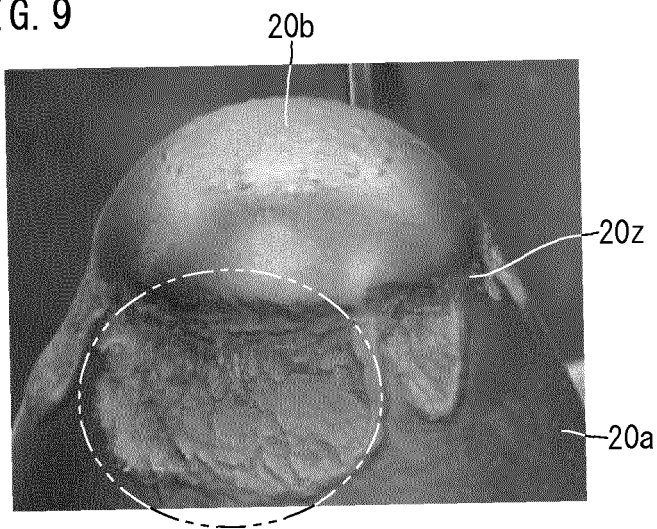


FIG. 9



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/005772

A. CLASSIFICATION OF SUBJECT MATTER

B21B25/00(2006.01)i, C23C4/06(2016.01)i, C23C4/10(2016.01)i, C23C4/12(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, C23C4/06, C23C4/10, C23C4/12

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.
Y	JP 2010-227999 A (Sumitomo Metal Industries, Ltd.), 14 October 2010 (14.10.2010), claims; paragraphs [0054] to [0056]; fig. 6 to 8 & US 2012/0210761 A1 claims; paragraphs [0105] to [0109]; fig. 6 to 8 & WO 2010/100968 A1 & EP 2404680 A1 & CN 102341193 A	1, 2

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

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Date of the actual completion of the international search
18 January 2016 (18.01.16)Date of mailing of the international search report
26 January 2016 (26.01.16)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/005772

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP 2013-226565 A (Nippon Steel & Sumitomo Metal Corp.), 07 November 2013 (07.11.2013), claims; paragraphs [0045] to [0073]; fig. 7, 8 & US 2015/0075241 A1 claims; paragraphs [0060] to [0088]; fig. 7, 8 & WO 2013/161177 A & EP 2845657 A1 & CA 2867986 A & AR 90818 A & CN 104245170 A & MX 2014012760 A	1, 2
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REFERENCES CITED IN THE DESCRIPTION

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- JP 3119160 B [0010]
- JP 5339016 B [0010]