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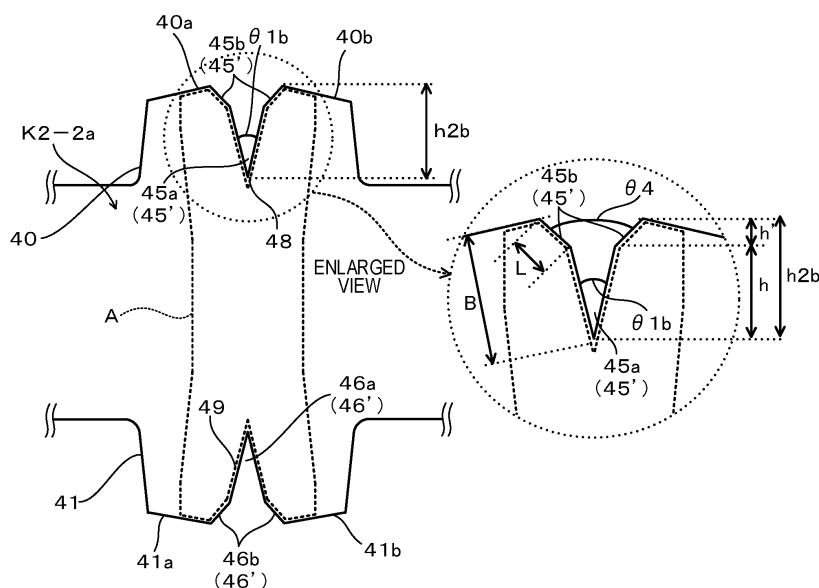
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(54) **METHOD FOR MANUFACTURING STEEL H-BEAM**

(57) A method for producing H-shaped steel, the method includes: a rough rolling step; an intermediate rolling step; and a finish rolling step, wherein: a rolling mill that performs the rough rolling step is engraved with a plurality of calibers configured to shape a material to be rolled; the plurality of calibers include: one or a plurality of split calibers formed with projections configured to create splits vertically with respect to a width direction of the material to be rolled to form divided parts at end parts of

the material to be rolled; and a plurality of bending calibers formed with projections configured to come into contact with the splits and sequentially bend the divided parts formed by the split caliber; and the projections formed in a final split caliber of the split calibers are each composed a tip part in a tapered shape having a predetermined tip angle, and a base part located at a base of the tip part and having a tapered shape with a gentle inclination as compared with the tip part.

FIG.9



Description

[Technical Field]

5 (Cross-Reference to Related Applications)

[0001] This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2017-136551, filed in Japan on July 12, 2017, the entire contents of which are incorporated herein by reference.

10 **[0002]** The present invention relates to a method for producing H-shaped steel using a slab or the like having, for example, a rectangular cross section as a raw material

[Background Art]

15 **[0003]** In the case of producing H-shaped steel, a raw material such as a slab or a bloom extracted from a heating furnace is shaped into a raw blank (a material to be rolled in a so-called dog-bone shape) by a rough rolling mill (BD). Subsequently, a web and flanges of the raw blank are subjected to reduction in thickness by an intermediate universal rolling mill. In addition, flanges of the material to be rolled are subjected to width reduction and forging and shaping of end surfaces by an edger rolling mill close to the intermediate universal rolling mill. Then, an H-shaped steel product is shaped by a finishing universal rolling mill.

20 **[0004]** In recent years, in accordance with the increase in size of a building structure and application to an offshore structure, it is required to produce an H-shaped steel product which is large in size as compared with the conventional one. In particular, a product with increased flange width and flange thickness is desired. As techniques of increasing a flange width and a flange thickness in a production process using a raw material having a rectangular cross section such as a slab, there has been known a technique (so-called wedge method) in which splits are formed in upper and

25 lower end surfaces (slab end surfaces) of a material to be rolled and the splits are spread out.
[0005] Among the techniques, regarding a technique of increasing a flange thickness, for example, Patent Document 1 discloses a technique in which splits are formed without constraining upper and lower end parts (slab end surfaces) of a material to be rolled, and then the splits are spread out by performing edging rolling. This technique makes it possible to increase a flange thickness according to a reduction ratio in the edging rolling.

30 **[0006]** Further, for example, Patent Document 2 discloses a technique of performing the edging rolling of spreading out the splits by applying reduction in a state of constraining both sides of the upper and lower end parts (slab end surfaces) of the material to be rolled. According to this technique, since the reduction is performed while constraining both sides of the upper and lower end parts of the material to be rolled, it is possible to create a metal pool in a flange tip part to increase the thickness.

35 [Prior Art Document]

[Patent Document]

40 **[0007]**

Patent Document 1: Japanese Laid-open Patent Publication No. H11-347601

Patent Document 2: Japanese Laid-open Patent Publication No. H7-88501

45 [Disclosure of the Invention]

[Problems to Be Solved by the Invention]

50 **[0008]** However, when the rolling is performed in a manner that the upper and lower end parts (slab end surfaces) of the material to be rolled are not constrained but spread freely as disclosed, for example, in the aforementioned Patent Document 1, although the flange width is increased, a flange tip part takes a shape of being tapered in thickness and the thickness of the flange tip part becomes insufficient. As a result of this, there is a worry that molding cannot be sufficiently performed in a process at the subsequent stage, failing to greatly increase the thickness. Further, according to the study conducted by the present inventors, there has been obtained a finding that even when the right-left constraining degree of the upper and lower end parts (slab end surfaces) of the material to be rolled is set to be low as compared with that of the conventional one, the flange tip part is similarly tapered and thus the thickness becomes insufficient.

55 **[0009]** Further, as disclosed in the aforementioned Patent Document 2, when the edging rolling is performed while

constraining both sides of the upper and lower end parts (slab end surfaces) of the material to be rolled, the edging rolling is performed in a state where the spread of the right and left flange parts is completely constrained in a caliber. Therefore, elongation in a longitudinal direction of the material to be rolled becomes dominant, the efficiency of the increase in thickness of the flange part is low, and thus there is a limit to the increase in thickness of the flange. For example, even when rolling is performed while properly setting caliber conditions, rolling in which a thickness average value from a flange tip part to a flange root becomes 1/2 or more of a raw material slab thickness, cannot be performed by this technique.

[0010] In other words, in any of the conventional producing techniques represented by the wedge method, the thickness of the flange is possibly insufficient to fail to realize an H-shaped steel product which is large in size as compared with the conventional one.

[0011] In consideration of the above circumstances, an object of the present invention is to provide a method for producing H-shaped steel capable of producing an H-shaped steel product having a large flange thickness as compared with a conventional one, when performing a step of, in a rough rolling step using calibers when producing H-shaped steel, creating deep splits on end surfaces of a raw material such as a slab using projections in acute-angle tip shapes, and sequentially bending flange parts formed by the splits.

[0012] Another object is to provide a method for producing H-shaped steel capable of suppressing a rub-down flaw which possibly occurs on an outside surface of a flange which is a problem when producing the H-shaped steel product having a large flange thickness, and improving the biting property during rolling and shaping.

[Means for Solving the Problems]

[0013] To achieve the above object, there is provided a method for producing H-shaped steel, the method includes: a rough rolling step; an intermediate rolling step; and a finish rolling step, wherein: a rolling mill which performs the rough rolling step is engraved with a plurality of calibers configured to shape a material to be rolled; the plurality of calibers include: one or a plurality of split calibers formed with projections configured to create splits vertically with respect to a width direction of the material to be rolled to form divided parts at end parts of the material to be rolled; and a plurality of bending calibers formed with projections configured to come into contact with the splits and sequentially bend the divided parts formed by the split caliber; and the projections formed in a final split caliber of the split calibers are each composed a tip part in a tapered shape having a predetermined tip angle, and a base part located at a base of the tip part and having a tapered shape with a gentle inclination as compared with the tip part.

[0014] A tapered angle of the base part may be 60° or more and equal to or smaller than the tip angle of the projection formed in a caliber at a foremost stage of the bending calibers.

[0015] A flange thickness of the material to be rolled shaped in the caliber at the foremost stage of the bending calibers may be more than 160 mm.

[0016] When the flange thickness of the material to be rolled shaped in the caliber at the foremost stage of the bending calibers is 180 mm or more, the tip part and the base part may be configured so that a contact width ratio L/B being a ratio of a width L of the base part to a flange contact width B in the final split caliber of the split calibers is 0.20 or more.

[0017] In shaping in the split caliber and the bending caliber, reduction may be performed in a state where end faces of the material to be rolled are in contact with peripheral surfaces of the caliber in shaping in at least one pass or more.

[0018] The split caliber may be provided with caliber side surfaces which come into contact with right and left side surfaces of the material to be rolled and constrain the material to be rolled from right and left.

[Effect of the Invention]

[0019] According to the present invention, it becomes possible to produce an H-shaped steel product having a large flange thickness as compared with a conventional one, when performing a step of, in a rough rolling step using calibers when producing H-shaped steel, creating deep splits on end surfaces of a raw material such as a slab using projections in acute-angle tip shapes, and sequentially bending flange parts formed by the splits. In addition, it becomes possible to suppress a rub-down flaw which possibly occurs on an outside surface of a flange which is a problem when producing the H-shaped steel product having the large flange thickness, and improve the biting property during rolling and shaping.

[Brief Description of the Drawings]

[0020]

[FIG. 1] FIG. 1 is a schematic explanatory view about a production line for H-shaped steel.

[FIG. 2] FIG. 2 is a schematic explanatory view of a first caliber.

[FIG. 3] FIG. 3 is a schematic explanatory view of a second-first caliber.

[FIG. 4] FIG. 4 is a schematic explanatory view of a second-second caliber.

[FIG. 5] FIG. 5 is a schematic explanatory view of a third caliber.

[FIG. 6] FIG. 6 is a schematic explanatory view of a fourth caliber.

[FIG. 7] FIG. 7 is a schematic explanatory view of a fifth caliber (flat shaping caliber).

[FIG. 8] FIG. 8 is an analysis diagram illustrating a finished shape in the first pass of bending shaping in the third caliber.

[FIG. 9] FIG. 9 is a schematic explanatory view about a projection shape after improvement.

[FIG. 10] FIG. 10 is a graph representing the relationships between a wedge angle $\theta 1b$ when changed and numerical values of a flange width and a flange thickness.

[FIG. 11] FIG. 11 is a schematic explanatory view of a second-second caliber K2-2b according to a modification example of the present invention.

[FIG. 12] FIG. 12 is a graph illustrating a slipping velocity in an up-down direction between a roll and the material to be rolled.

[FIG. 13] FIG. 13 is a schematic view illustrating a deformation simulation result by FEM analysis under conditions in a comparative example, Example 1, and Example 2.

[Embodiments for Carrying out the Invention]

[0021] Hereinafter, an embodiment of the present invention will be explained referring to the drawings. Note that in this description and the drawings, the same codes are assigned to components having substantially the same functional configurations to omit duplicated explanation.

[0022] FIG. 1 is an explanatory view about a production line T for H-shaped steel including a rolling facility 1 according to this embodiment. As illustrated in FIG. 1, in the production line T, a heating furnace 2, a sizing mill 3, a rough rolling mill 4, an intermediate universal rolling mill 5, and a finishing universal rolling mill 8 are arranged in order from the upstream side. Further, an edger rolling mill 9 is provided close to the intermediate universal rolling mill 5. Note that a steel material in the production line T is collectively described as a "material to be rolled A" for explanation and its shape is illustrated using broken lines, oblique lines and the like in the drawings as needed in some cases.

[0023] As illustrated in FIG. 1, in the production line T, the material to be rolled A such as a slab 11 extracted from the heating furnace 2 is subjected to rough rolling in the sizing mill 3 and the rough rolling mill 4. Then, the material to be rolled A is subjected to intermediate rolling in the intermediate universal rolling mill 5. During the intermediate rolling, reduction is performed on end parts or the like (later-explained flange parts 80) of the material to be rolled by the edger rolling mill 9 as necessary. In a normal case, about four to six calibers in total are engraved on rolls of the sizing mill 3 and the rough rolling mill 4, and an H-shaped raw blank 13 is shaped by reverse rolling in about a plurality of passes through those calibers. Further, the H-shaped raw blank 13 is subjected to application of reduction in a plurality of passes using a rolling mill train composed of two rolling mills such as the intermediate universal rolling mill 5 and the edger rolling mill 9, whereby an intermediate material 14 is shaped. The intermediate material 14 is then subjected to finish rolling into a product shape in the finishing universal rolling mill 8, whereby an H-shaped steel product 16 is produced.

[0024] Next, caliber configurations and caliber shapes engraved on the sizing mill 3 and the rough rolling mill 4 illustrated in FIG. 1 will be explained below referring to the drawings. FIG. 2 to FIG. 7 are schematic explanatory views about calibers engraved on the sizing mill 3 and the rough rolling mill 4 which perform a rough rolling step. All of the first caliber to the fourth caliber explained here may be engraved, for example, on the sizing mill 3, or five calibers such as the first caliber to the fifth caliber may be engraved separately on the sizing mill 3 and the rough rolling mill 4. In other words, the first caliber to the fourth caliber may be engraved across both the sizing mill 3 and the rough rolling mill 4, or may be engraved on one of the rolling mills. In the rough rolling step in production of standard H-shaped steel, shaping in one or a plurality of passes is performed in each of the calibers.

[0025] Further, the case where the basic configuration of the engraved calibers has six calibers is exemplified in this embodiment, the number of calibers is not necessarily six but may be plural being six or more. In other words, the basic configuration only needs to be a caliber configuration suitable for shaping the H-shaped raw blank 13. Note that in FIG. 2 to FIG. 7, a schematic final pass shape of the material to be rolled A in shaping in each caliber is illustrated by broken lines.

[0026] FIG. 2 is a schematic explanatory view of a first caliber K1. The first caliber K1 is engraved on an upper caliber roll 20 and a lower caliber roll 21 which are a pair of horizontal rolls. The material to be rolled A is subjected to reduction and shaping in a roll gap between the upper caliber roll 20 and the lower caliber roll 21. Further, a peripheral surface of the upper caliber roll 20 (namely, an upper surface of the first caliber K1) is formed with a projection 25 protruding toward the inside of the caliber. Further, a peripheral surface of the lower caliber roll 21 (namely, a bottom surface of the first caliber K1) is formed with a projection 26 protruding toward the inside of the caliber. These projections 25, 26 have tapered shapes, and dimensions such as a protrusion length of the projection 25 and the projection 26 are configured to be equal to each other. A height (protrusion length) of the projections 25, 26 is $h1$ and a tip part angle thereof is $\theta 1a$.

[0027] In the first caliber K1, the projections 25, 26 are pressed against upper and lower end parts (slab end surfaces) of the material to be rolled A and thereby form splits 28, 29. The first caliber K1 is a caliber applying grooves (splits 28,

29) to the slab end surfaces and therefore also referred to as a "grooving caliber". Here, a tip part angle (also referred to as a wedge angle) $\theta 1a$ of the projections 25, 26 is desirably, for example, 25° or more and 40° or less.

[0028] Here, a caliber width of the first caliber K1 is preferably substantially equal to the thickness of the material to be rolled A (namely, a slab thickness). Specifically, when the width of the caliber at the tip parts of the projections 25, 26 formed in the first caliber K1 is set to be the same as the slab thickness, a right-left centering property of the material to be rolled A is suitably secured. Further, it is preferable that such a configuration of the caliber dimension brings the projections 25, 26 and part of caliber side surfaces (side walls) into contact with the material to be rolled A at upper and lower end parts (slab end surfaces) of the material to be rolled A during shaping in the first caliber K1 as illustrated in FIG. 2 so as to prevent active reduction at the upper surface and the bottom surface of the first caliber K1 from being performed on the slab upper and lower end parts divided into four elements (parts) by the splits 28, 29. This is because the reduction by the upper surface and the bottom surface of the caliber causes elongation of the material to be rolled A in the longitudinal direction to decrease the generation efficiency of the flanges (later-explained flange parts 80). In other words, in the first caliber K1, a reduction amount at the projections 25, 26 (reduction amount at wedge tips) at the time when the projections 25, 26 are pressed against the upper and lower end parts (slab end surfaces) of the material to be rolled A to form the splits 28, 29 is made sufficiently larger than a reduction amount at the slab upper and lower end parts (reduction amount at slab end surfaces) and thereby forms the splits 28, 29.

[0029] FIG. 3 is a schematic explanatory view of a second-first caliber K2-1. The second-first caliber K2-1 is engraved on an upper caliber roll 30 and a lower caliber roll 31 which are a pair of horizontal rolls. A peripheral surface of the upper caliber roll 30 (namely, an upper surface of the second-first caliber K2-1) is formed with a projection 35 protruding toward the inside of the caliber. Further, a peripheral surface of the lower caliber roll 31 (namely, a bottom surface of the second-first caliber K2-1) is formed with a projection 36 protruding toward the inside of the caliber. These projections 35, 36 have tapered shapes, and dimensions such as a protrusion length of the projection 35 and the projection 36 are configured to be equal to each other. A tip part angle of the projections 35, 36 is desirably a wedge angle $\theta 1b$ of 25° or more and 40° or less.

[0030] Here, the wedge angle $\theta 1a$ of the above first caliber K1 is preferably the same angle as the wedge angle $\theta 1b$ of the second-first caliber K2-1 at a subsequent stage in order to ensure the thickness of the tip parts of the flange corresponding parts, enhance the inductive property, and secure the stability of rolling.

[0031] A height (protrusion length) $h2a$ of the projections 35, 36 is configured to be larger than a height $h1$ of the projections 25, 26 of the first caliber K1 so as to be $h2a > h1$. In a roll gap between the upper caliber roll 30 and the lower caliber roll 31, the material to be rolled A after passing through the first caliber K1 is further shaped.

[0032] Here, the height $h2a$ of the projections 35, 36 formed in the second-first caliber K2-1 is larger than the height $h1$ of the projections 25, 26 formed in the first caliber K1. An intrusion length into the upper and lower end parts (slab end surfaces) of the material to be rolled A is also similarly larger in the second-first caliber K2-1. An intrusion depth into the material to be rolled A of the projections 35, 36 in the second-first caliber K2-1 is the same as the height $h2a$ of the projections 35, 36. In other words, an intrusion depth $h1'$ into the material to be rolled A of the projections 25, 26 in the first caliber K1 and the intrusion depth $h2a$ into the material to be rolled A of the projections 35, 36 in the second-first caliber K2-1 satisfy a relationship of $h1' < h2a$.

[0033] Further, angles θf formed between caliber upper surfaces 30a, 30b and caliber bottom surfaces 31a, 31b facing the upper and lower end parts (slab end surfaces) of the material to be rolled A, and, inclined surfaces of the projections 35, 36, are configured to be about 90° (almost right angle) at all of four locations illustrated in FIG. 3.

[0034] Since the intrusion length of the projections at the time when pressed against the upper and lower end parts (slab end surfaces) of the material to be rolled A is large as illustrated in FIG. 3, shaping is performed to make the splits 28, 29 formed in the first caliber K1 deeper in the second-first caliber K2-1, to thereby form the splits 38, 39. The second-first caliber K2-1 is also referred to as a "split caliber".

[0035] Further, the shaping in the second-first caliber K2-1 is performed by multi-pass, and in the multi-pass shaping, shaping is performed to bring the upper and lower end parts (slab end surfaces) of the material to be rolled A into contact with the caliber upper surfaces 30a, 30b and the caliber bottom surfaces 31a, 31b facing them in a final pass. This is because if the upper and lower end parts of the material to be rolled A are made to be out of contact with the inside of the caliber in all passes in the second-first caliber K2-1, a shape defect such as flange corresponding parts (parts corresponding to the later-explained flange parts 80) being shaped to be bilaterally asymmetrical possibly occurs, bringing about a problem in terms of a material passing property.

[0036] FIG. 4 is a schematic explanatory view of a second-second caliber K2-2. The second-second caliber K2-2 is engraved on an upper caliber roll 40 and a lower caliber roll 41 which are a pair of horizontal rolls. A peripheral surface of the upper caliber roll 40 (namely, an upper surface of the second-second caliber K2-2) is formed with a projection 45 protruding toward the inside of the caliber. Further, a peripheral surface of the lower caliber roll 41 (namely, a bottom surface of the second-second caliber K2-2) is formed with a projection 46 protruding toward the inside of the caliber. These projections 45, 46 have tapered shapes, and dimensions such as a protrusion length of the projection 45 and the projection 46 are configured to be equal to each other. A tip part angle of the projections 45, 46 is a wedge angle $\theta 1b$

of 25° or more and 40° or less, and is desirably designed to be the same angle as the wedge angle of the above second-first caliber K2-1.

[0037] A height (protrusion length) h2b of the projections 45, 46 is configured to be larger than the height h2a of the projections 35, 36 of the second-first caliber K2-1 so as to be $h2b > h2a$. In a roll gap between the upper caliber roll 40 and the lower caliber roll 41, the material to be rolled A after passing through the second-first caliber K2-1 is further shaped.

[0038] Here, the height h2b of the projections 45, 46 formed in the second-second caliber K2-2 is larger than the height h2a of the projections 35, 36 formed in the second-first caliber K2-1. Further, an intrusion length into the upper and lower end parts (slab end surfaces) of the material to be rolled A is also similarly larger in the second-second caliber K2-2. An intrusion depth into the material to be rolled A of the projections 45, 46 in the second-second caliber K2-2 is the same as the height h2b of the projections 45, 46. In other words, the intrusion depth h2a into the material to be rolled A of the projections 35, 36 in the second-first caliber K2-1 and the intrusion depth h2b into the material to be rolled A of the projections 45, 46 in the second-second caliber K2-2 satisfy a relationship of $h2a < h2b$.

[0039] Further, angles θ_f formed between caliber upper surfaces 40a, 40b and caliber bottom surfaces 41a, 41b facing the upper and lower end parts (slab end surfaces) of the material to be rolled A, and, inclined surfaces of the projections 45, 46, are configured to be about 90° (almost right angle) at all of four locations illustrated in FIG. 4.

[0040] Since the intrusion length of the projections at the time when pressed against the upper and lower end parts (slab end surfaces) of the material to be rolled A is large as illustrated in FIG. 4, shaping is performed to make the splits 38, 39 formed in the second-first caliber K2-1 deeper in the second-second caliber K2-2, to thereby form the splits 48, 49. The second-second caliber K2-2 is also referred to as a "split caliber".

[0041] Note that based on the dimensions of the splits 48, 49 formed here, a flange half-width at the end of a flange shaping step at the rough rolling step is decided.

[0042] Further, the shaping in the second-second caliber K2-2 is performed by multi-pass, and in the multi-pass shaping, shaping is performed to bring the upper and lower end parts (slab end surfaces) of the material to be rolled A into contact with the caliber upper surfaces 40a, 40b and the caliber bottom surfaces 41a, 41b facing them in a final pass. This is because if the upper and lower end parts of the material to be rolled A are made to be out of contact with the inside of the caliber in all passes in the second-second caliber K2-2, a shape defect such as flange corresponding parts (later-explained flange parts 80) being shaped to be bilaterally asymmetrical possibly occurs, bringing about a problem in terms of a material passing property.

[0043] FIG. 5 is a schematic explanatory view of a third caliber K3. The third caliber K3 is engraved on an upper caliber roll 50 and a lower caliber roll 51 which are a pair of horizontal rolls. A peripheral surface of the upper caliber roll 50 (namely, an upper surface of the third caliber K3) is formed with a projection 55 protruding toward the inside of the caliber. Further, a peripheral surface of the lower caliber roll 51 (namely, a bottom surface of the third caliber K3) is formed with a projection 56 protruding toward the inside of the caliber. These projections 55, 56 have tapered shapes, and dimensions such as a protrusion length of the projection 55 and the projection 56 are configured to be equal to each other.

[0044] A tip part angle θ_2 of the projections 55, 56 is configured to be larger than the aforementioned angle θ_{1b} . An intrusion depth h3 into the material to be rolled A of the projections 55, 56 is smaller than the intrusion depth h2b of the above projections 45, 46 (namely, $h3 < h2b$). The angle θ_2 is preferably, for example, 70° or more and 110° or less.

[0045] Further, angles θ_f formed between caliber upper surfaces 50a, 50b and caliber bottom surfaces 51a, 51b facing the upper and lower end parts (slab end surfaces) of the material to be rolled A, and, inclined surfaces of the projections 55, 56, are configured to be about 90° (almost right angle) at all of four locations illustrated in FIG. 5.

[0046] As illustrated in FIG. 5, in the third caliber K3, for the material to be rolled A after passing through the second-second caliber K2-2, the splits 48, 49 formed in the second-second caliber K2-2 at the upper and lower end parts (slab end surfaces) of the material to be rolled A become splits 58, 59 by the projections 55, 56 being pressed against them. Specifically, in a final pass in shaping in the third caliber K3, a deepest portion angle (hereinafter, also referred to as a split angle) of the splits 58, 59 becomes θ_2 . In other words, shaping is performed so that divided parts (parts corresponding to the later-explained flange parts 80) shaped along with the formation of the splits 48, 49 in the second-second caliber K2-2 are bent outward. The third caliber K3 is also referred to as a "bending caliber".

[0047] Besides, the shaping in the third caliber K3 illustrated in FIG. 5 is performed by at least one pass or more. At least one pass or more of them are performed with the upper and lower end parts (slab end surfaces) of the material to be rolled A in contact with the inside of the caliber (the upper surface and the bottom surface of the third caliber K3). In the state where the upper and lower end parts (slab end surfaces) of the material to be rolled A are in contact with the inside of the caliber, it is preferable to perform light reduction on the end parts.

[0048] FIG. 6 is a schematic explanatory view of a fourth caliber K4. The fourth caliber K4 is engraved on an upper caliber roll 60 and a lower caliber roll 61 which are a pair of horizontal rolls. A peripheral surface of the upper caliber roll 60 (namely, an upper surface of the fourth caliber K4) is formed with a projection 65 protruding toward the inside of the caliber. Further, a peripheral surface of the lower caliber roll 61 (namely, a bottom surface of the fourth caliber K4) is formed with a projection 66 protruding toward the inside of the caliber. These projections 65, 66 have tapered shapes,

and dimensions such as a protrusion length of the projection 65 and the projection 66 are configured to be equal to each other.

[0049] A tip part angle $\theta 3$ of the projections 65, 66 is configured to be larger than the angle $\theta 2$. An intrusion depth $h 4$ into the material to be rolled A of the projections 65, 66 is smaller than the intrusion depth $h 3$ of the projections 55, 56 (namely, $h 4 < h 3$).

[0050] Further, angles θf formed between caliber upper surfaces 60a, 60b and caliber bottom surfaces 61a, 61b facing the upper and lower end parts (slab end surfaces) of the material to be rolled A, and, inclined surfaces of the projections 65, 66, are configured to be about 90° (almost right angle) at all of four locations illustrated in FIG. 6, similarly to the above third caliber K3.

[0051] In the fourth caliber K4, the splits 58, 59 formed in the third caliber K3 at the upper and lower end parts (slab end surfaces) of the material to be rolled A after passing through the third caliber K3 are spread out by the projections 65, 66 being pressed against them and thereby become splits 68, 69. Specifically, in a final pass in shaping in the fourth caliber K4, a deepest part angle (hereinafter, also referred to as a split angle) of the splits 68, 69 becomes $\theta 3$. In other words, shaping is performed so that divided parts (parts corresponding to the later-explained flange parts 80) shaped along with the formation of the splits 58, 59 in the third caliber K3 are further bent outward. The fourth caliber K4 is also referred to as a "bending caliber".

[0052] The parts of the upper and lower end parts of the material to be rolled A shaped in this manner are parts corresponding to flanges of a later-explained H-shaped steel product and referred to as the flange parts 80 herein.

[0053] The shaping in the fourth caliber K4 illustrated in FIG. 6 is performed by at least one pass or more, and at least one pass or more of them are performed with the upper and lower end parts (slab end surfaces) of the material to be rolled A in contact with the inside of the caliber (the upper surface and the bottom surface of the fourth caliber K4). In the state where the upper and lower end parts (slab end surfaces) of the material to be rolled A are in contact with the inside of the caliber, it is preferable to perform light reduction on the end parts.

[0054] FIG. 7 is a schematic explanatory view of a fifth caliber K5. The fifth caliber K5 is composed of an upper caliber roll 85 and a lower caliber roll 86 which are a pair of horizontal rolls. As illustrated in FIG. 7, in the fifth caliber K5, the material to be rolled A shaped until the fourth caliber K4 is rotated by 90° or 270° , whereby the flange parts 80 located at the upper and lower ends of the material to be rolled A until the fourth caliber K4 are located on a rolling pitch line. Then, in the fifth caliber K5, reduction of a web part 82 being a connecting part connecting the flange parts 80 at two positions and reduction of the flange tip parts of the flange parts 80 are performed, to thereby perform dimension adjustment of the flange width. Thus, an H-shaped raw blank in a so-called dog-bone shape (H-shaped raw blank 13 illustrated in FIG. 1) is shaped. Note that the fifth caliber K5 thins the web part 82 by reduction, and thus is also referred to as a "web thinning caliber" or a "flat shaping caliber". Note that the rolling and shaping in the flat shaping caliber (fifth caliber K5) is performed by one or an arbitrary plurality of passes.

[0055] The H-shaped raw blank 13 shaped as above is subjected to reverse rolling in a plurality of passes using the rolling mill train composed of two rolling mills of the intermediate universal rolling mill 5 and the edger rolling mill 9 which are already-known rolling mills, whereby an intermediate material 14 is shaped. Subsequently, the intermediate material 14 is subjected to finish rolling into a product shape in the finishing universal rolling mill 8, whereby an H-shaped steel product 16 is produced (refer to FIG. 1).

[0056] As described above, the first caliber K1 to the fourth caliber K4 according to this embodiment are used to create splits in the upper and lower end parts (slab end surfaces) of the material to be rolled A and perform processing of bending to right and left the respective parts separated to right and left by the splits to perform the shaping of forming the flange parts 80. This enables shaping of the H-shaped raw blank 13 having the flange width made wide as compared with that by the rough rolling method for reducing at all times the slab end surfaces conventionally performed, resulting in production of a final product (H-shaped steel) having a large flange width.

[0057] Here, in the method for producing H-shaped steel according to this embodiment, there is a characteristic that the shape of the flange part 80 of the material to be rolled A shaped by the aforementioned first caliber K1 to fourth caliber K4 is a shape close to the shape of the product flange as compared with the shape of the flange part before the shaping in a flat caliber in the conventional production method. This results from employment of a shaping technique of performing the processing of bending the divided parts (flange parts 80) shaped by creating the splits without changing the end part shapes of the raw material (slab) having the rectangular cross section used as the raw material.

[0058] Regarding the rolling and shaping technique having such a characteristic, in the case where an H-shaped steel product having a large size and a large flange thickness such as a height of 1200 mm $\times$ a width of 500 mm is produced, for example, from a raw material slab of 300 mm thick, the flange parts 80 in the production process are sometimes thick as compared with the conventional one. According to the test carried out by the present inventors, in the above case, the occurrence of a rub-down flaw was confirmed on the outside surface of the flange parts 80 during the bending shaping in the third caliber K3 and deterioration in biting property was also confirmed. The rub-down flaw is estimated to occur due to the metal of the flange parts 80 being lowered in the reduction direction by the friction force of the roll during the bending shaping in the third caliber K3.

[0059] FIG. 8 is an analysis diagram illustrating a finished shape in the first pass of the bending shaping in the third caliber K3. Note that FIG. 8 illustrates an enlarged part of the divided part (flange part 80) for explanation, illustrates a flange part shape before the bending shaping by a solid line, illustrates a flange part shape after the bending shaping by a mesh, and also illustrates a roll shape. As illustrated in FIG. 8, the roll is in contact only with a part of the outside surface of the flange part 80 in the first pass during the bending shaping. It is known that, as a result of that, the rub-down flaw occurs as described above at a boundary part (a broken line part in FIG. 8) between the contact portion and a portion other than that.

[0060] In consideration of the above circumstances, the present inventors further conducted a study regarding a condition enabling suppression of the occurrence of the rub-down flaw during the bending shaping and suppression of the deterioration in biting property in the method for producing H-shaped steel according to this embodiment. Hereinafter, this study will be explained referring to the drawings. Note that the above "biting property" is a criterion indicating whether the material to be rolled A independently bites into the rolling mill from the entry side of each rolling mill only by transfer by a transfer system (for example, a table roll or the like). In other words, the biting property represents the criterion about whether the rolling is started only by the table roll drive force on the entry side of each rolling mill.

[0061] It has been confirmed that the rub-down flaw occurs on the outside surface of the flange part when an H-shaped steel product having a large size and a large flange thickness such as a height of 1200 mm $\times$ a width of 500 mm is produced, for example, from a raw material slab of 300 mm thick as explained above referring to FIG. 8. Under this condition, the flaw possibly remains also in a final product, and therefore a rolling and shaping technique capable of avoiding this possibility and suppressing the deterioration in biting property is required.

[0062] As explained above, the rub-down flaw is estimated to occur due to the metal on the outside surface of the flange part being lowered in the reduction direction by the friction force of the roll during the bending shaping. Hence, the present inventors have devised a technique capable of suppressing the occurrence of the rub-down flaw and also avoiding the deterioration in dimensional accuracy and the decrease in flange thickness by making the caliber shape of the second-second caliber K2-2 which performs the rolling and shaping at the stage immediately before the bending and shaping in the third caliber K3 into a suitable shape. Hereinafter, a suitable caliber shape of the second-second caliber K2-2 according to this embodiment will be explained.

[0063] FIG. 9 is a schematic explanatory view about a projection shape after improvement. FIG. 9 is an explanatory view illustrating a configuration of a second-second caliber K2-2a in the case where the shapes of the projections 45, 46 are improved and made into projections 45', 46' in the second-second caliber K2-2 explained above in this embodiment. Note that FIG. 9 additionally illustrates an enlarged view of the upper projection 45' and its surroundings. Regarding the second-second caliber K2-2a illustrated in FIG. 9, components having substantially the same functional configurations as those of the above-explained second-second caliber K2-2 (before improvement) explained referring to FIG. 4 are illustrated using the same codes and their explanation is omitted in some cases.

[0064] As illustrated in FIG. 9, the projection 45', 46' after improvement is composed of a tip part 45a (46a) having a tip part angle (wedge angle) of $\theta 1b$ and a base part 45b (46b) having a tapered shape and a wedge angle of $\theta 4$ which is an angle larger than $\theta 1b$. In other words, the projection 45', 46' is in a caliber shape in which the wedge angle ($= \theta 1b$) of the tip part 45a (46a) and the wedge angle ($= \theta 4$) of the base part 45b (46b) of the projection 45', 46' are made different angles and the inclination of the base of the projection is a gentle inclination as compared with the inclination of the tip.

[0065] Here, the height of the whole projections 45', 46' after improvement is $h2b$ same as the height of the projections 45, 46. When it is assumed that the height of the tip part 45a (46a) is h and the height of the base part 45b (46b) is h' , these heights h , h' can be designed so that a contact width ratio L/B explained below takes a predetermined value within a numerical range of $h2b$. Further, the angle $\theta 1b$ is preferably 25° or more and 40° or less as with the second-second caliber K2-2 explained referring to FIG. 4. Further, the value of $\theta 4$ can be arbitrarily designed as a value larger than that of $\theta 1b$.

[0066] Further, due to the shaping condition of performing the bending shaping in the third caliber K3 after the split shaping in the second-second caliber K2-2a, the value of $\theta 4$ needs to be an angle of equal to or smaller than the wedge angle $\theta 2$ of the bending caliber at the subsequent stage, and is preferably set to the same angle as $\theta 2$. The reason why it is preferable that $\theta 4$ and $\theta 2$ are the same angle will be explained later in a second example.

[0067] Here, the present inventors defined, regarding the caliber shape of the second-second caliber K2-2a, the ratio L/B of a base part width L (width length of the base part 45b) to a flange contact width B (flange half-width before bending shaping) during filling (see FIG. 9) for the material to be rolled A completed to be filled in the caliber in the split shaping in the second-second caliber K2-2a. Setting the contact width ratio L/B to a value within a predetermined range makes it possible to suppress the occurrence of the rub-down flaw and suitably avoid the deterioration in dimensional accuracy and the decrease in flange thickness. In this embodiment, the contact width ratio L/B is preferably 0.20 or more and more preferably 0.20 or more and 0.24 or less. The basis of the numerical range of the contact width ratio L/B will be explained referring to Tables 1 to 4 and so on in later-explained examples.

[0068] In the above split caliber (second-second caliber K2-2a) having the configuration relating to the projections 45', 46' after improvement explained above referring to FIG. 9, the projection 45', 46' is composed of the tip part 45a (46a)

and the base part 45b (46b) different in wedge angle. Therefore, the relative slipping velocity in the roll reduction direction between the roll and the outside surface of the flange part decreases in the process when the projections 55, 56 come into contact with the material to be rolled A (namely, bending shaping) in the third caliber K3 being the next step. Accordingly, the phenomenon that the metal on the outside surface of the flange part is lowered in the reduction direction by the friction force of the roll is suppressed, so that the occurrence of the rub-down flaw is suppressed.

[0069] In recent years, in accordance with the increase in size of a building structure and application to an offshore structure, it is required to produce an H-shaped steel product which is large as compared with the conventional one. More specifically, an H-shaped steel product having a large flange width and a large flange thickness is demanded. It is required to produce an H-shaped steel product having a large size and large flange thickness such as a height of 1200 mm $\times$ a width of 500 mm, for example, from a raw material slab of 300 mm thick. In such a case, the reduction in flange thickness is not preferable.

[0070] The verification conducted by the present inventors shows that when the wedge angle $\theta 1b$ of the split caliber is changed during the split rolling and shaping, the flange generation efficiency after the bending shaping changes. FIG. 10 is a graph representing the relationships between the wedge angle $\theta 1b$ when changed and the numerical values of the flange width and the flange thickness. FIG. 10 is a graph representing the result of analyzing by FEM the relationships between the wedge angle $\theta 1b$ of the split caliber and the numerical values of the flange thickness and the flange width when the wedge angle $\theta 1b$ is changed, at the step (bending shaping) at the subsequent stage. It has been found that as illustrated in FIG. 10, as the wedge angle $\theta 1b$ increases, the flange width and the flange thickness decrease. Therefore, from the viewpoint of securing the flange generation efficiency, it is estimated that there is an upper limit value in the wedge angle $\theta 4$ of the base part 45b (46b) in the projection 45', 46' after improvement.

[0071] As explained referring to FIG. 10, there are preferable numerical ranges for the height h of the tip part 45a (46a), the height h' of the base part 45b (46b), and the wedge angle $\theta 4$ of the base part in the technique according to this embodiment. In the technique of the present invention, it is also important to specify the preferable numerical ranges, and concrete numerical ranges will be explained later in examples.

[0072] As explained above, in the method for producing H-shaped steel according to this embodiment, use of the split caliber (second-second caliber K2-2a) having the configuration relating to the projections 45', 46' after improvement makes it possible to perform rolling and shaping without the occurrence of the rub-down flaw on the outside surface of the flange part 80 even when the flange part 80 is thick as compared with the conventional one. This makes it possible to efficiently produce an H-shaped steel product having a large flange thickness as compared with the conventional one, in a state having no flaw at the flange.

[0073] One example of the embodiment of the present invention has been explained above, but the present invention is not limited to the illustrated embodiment. It should be understood that various changes or modifications are readily apparent to those skilled in the art within the scope of the spirit as set forth in claims, and those should also be covered by the technical scope of the present invention.

[0074] In the above-described embodiment, the technique of shaping the material to be rolled A by using a caliber group illustrated and explained as the first caliber K1 to the fourth caliber K4, and then performing the flat shaping and rolling by using the fifth caliber K5 has been explained. However, the number of calibers for performing the rough rolling step is not limited to this. In other words, the caliber configuration described in the above embodiment is one example, and the number of calibers engraved on the sizing mill 3 and the rough rolling mill 4 can be arbitrarily changed, and appropriately changed to an extent at which the rough rolling step can be suitably performed. In particular, the so-called "split shaping" has been explained as being performed in the two kinds of the second-first caliber K2-1 and the second-second caliber K2-2 different in split length. However, the split caliber may be composed of one caliber, or it may also be composed of three or more kinds of calibers different in split length. Note that when the split caliber is composed of a plurality of kinds of calibers, the technique of improving the projection shape according to the present invention is applied to the final split caliber.

(Modification example of the present invention)

[0075] In the above embodiment, when producing the H-shaped steel product having a large flange thickness, the split shaping is performed by pressing the projections (the above projections 45', 46') having the base parts configured to have gentle inclination as compared with the tip parts against the material to be rolled A at the outside surfaces of the flange parts 80 before the bending shaping. However, since the split caliber (second-second caliber K2-2a) having the configuration relating to the projections 45', 46' after improvement illustrated in FIG. 9 does not employ the configuration of constraining the side surfaces of the material to be rolled A by the caliber, there is a worry that a shape defect such as falling of the flange tip parts is caused by the characteristic and the like by the shapes of the flange parts 80.

[0076] In view of such circumstances, the present inventors further conducted a study regarding the caliber shape of the split caliber having the configuration relating to the projections 45', 46', and have come to devise a caliber shape capable of eliminating the problem about the above-explained shape defect. Hereinafter, a second-second caliber K2-2b

having the newly devised configuration will be explained as a modification example of the present invention referring to the drawings.

[0077] FIG. 11 is a schematic explanatory view of the second-second caliber K2-2b according to the modification example of the present invention. In FIG. 11, the same codes are assigned to components having substantially the same functional configurations as those of the second-second caliber K2-2a (see FIG. 9) explained in the above embodiment for illustration to omit their explanation. As illustrated in FIG. 11, the basic caliber configuration of the second-second caliber K2-2b according to this modification example is almost the same as that of the second-second caliber K2-2a. On the other hand, as a different point, the second-second caliber K2-2b is configured to be in contact with the material to be rolled A so as for caliber side surfaces 40c, 41c formed on the right and left of the caliber to constrain the material to be rolled A. In other words, the second-second caliber K2-2a explained in the above embodiment has a configuration provided with no side walls, whereas the second-second caliber K2-2b according to this modification example has a configuration (caliber design) provided with side walls.

[0078] The contact positions of the material to be rolled A with the caliber side surfaces 40c, 41c are desirably positions where the thickness of the material to be rolled A immediately after introduced into the second-second caliber K2-2b is the largest. The contact positions are generally near middle parts of the outside surfaces of the flange corresponding parts (flange parts 80) of the material to be rolled A. This results from that the outside surface shape of the material to be rolled A becomes an almost vertical shape when the wedge angle $\theta 1a$ of the first caliber K1 and the wedge angle $\theta 1b$ of the second-second caliber K2-2b are the same angle.

[0079] Besides, during the rolling and shaping in the second-second caliber K2-2b performed in a plurality of passes, the material to be rolled A is not in contact with the caliber in middle passes except for the projections 45', 46' at the upper and lower end parts (slab end surfaces) of the material to be rolled A, so that the active reduction of the material to be rolled A is not performed in these passes. This is because the reduction causes elongation of the material to be rolled A in the longitudinal direction to decrease the generation efficiency of the flange corresponding parts (flange parts 80).

[0080] However, from the viewpoint of improving the dimensional accuracy of the flange width and the flange thickness, it is desirable to set a shaping pass schedule in which the upper and lower end parts of the material to be rolled A come into full contact with the caliber in the final pass or several passes before the final pass. In other words, it is desirable to perform shaping of adjusting the shape under the condition that the elongation of the material to be rolled in the longitudinal direction is suppressed as much as possible.

[0081] Further, in the caliber configuration illustrated in FIG 11, the shapes of the caliber side surfaces 40c, 41c are preferably a vertical shape vertical to the caliber roll axis from the viewpoint of efficiently constraining the material to be rolled A from right and left, but are desirably a shape with a taper angle of about 5 to 10% with respect to the vertical direction for facilitating the repair of the roll accompanying the roll abrasion.

[0082] Use of the second-second caliber K2-2b according to the modification example illustrated in FIG. 11 as explained above suppresses the shape defect such as falling of the flange tip part of the material to be rolled A during the rolling and shaping in the caliber, and can realize the improvement in biting property during the rolling and shaping and the improvement in product dimensional accuracy.

[0083] Note that though the slab has been explained as an example of the raw material when producing the H-shaped steel, the present invention is applicable also to other raw materials in similar shapes.

[Examples]

(First example)

[0084] As a first example of the present invention, the verification was carried out about the presence or absence of the occurrence of the rub-down flaw in the material to be rolled after the bending shaping in the case of using the split caliber (second-second caliber K2-2a, see FIG. 9) having the configuration relating to the projections 45', 46' after improvement explained in the above embodiment. Note that, as a comparative example, the verification was carried out also about the presence or absence of the occurrence of the rub-down flaw in the material to be rolled after the bending shaping in the case of using the caliber configuration before improvement (second-second caliber K2-2, see FIG. 4).

[0085] Table 1 is a table listing the caliber basic design when increasing the flange thickness in each caliber in the case of producing an H-shaped steel product of 1000×500 mm using a slab having a 2000×250 mm cross section or a 2000×300 mm cross section as a raw material. More specifically, the caliber design when performing edging rolling on the slab upper and lower end parts in each of the second-first caliber K2-1, the second-second caliber K2-2, the third caliber K3, and the fourth caliber K4 is listed. Note that the projection height (wedge height) in Table 1 is the projection height at one of caliber top and bottom in each caliber. In this example, the verification was carried out with the improvement of the projection explained in the above embodiment performed on the second-second caliber K2-2 of the caliber basic design listed in Tale 1.

[Table 1]

MILL	SM				BD	
CALIBER	K1	K2-1	K2-2	K3	K4	K5
FUNCTION	GROOVING	SPLIT	SPLIT	BENDING	BENDING	FLAT
WEDGE TIP ANGLE °	30	30	30	90	140	~
EDGING (BETWEEN TIPS)	1,740	1,190	1,190	1,190	1,180	1,280
PROJECTION HEIGHT	130	223	316	248	0	~
FLANGE WIDTH	-	483	624	764	810	~

[0086] In this example, the comparative example (conventional method) was the case using the caliber configuration before improvement (second-second caliber K2-2, see FIG. 4) in the caliber design listed in Table 1. On the other hand, the wedge angle (= θ_4) of the base part was set to 60° in the split caliber (second-second caliber K2-2a, see FIG. 9) having the configuration relating to the projections 45', 46' after improvement in Example 1 (Condition 1). Further, the wedge angle (= θ_4) of the base part was set to 90° in the split caliber (second-second caliber K2-2a, see FIG. 9) having the configuration relating to the projections 45', 46' after improvement in Example 2 (Condition 2).

[0087] Following Table 2 to Table 4 list the relationship between the flange thickness of the material to be rolled and the occurrence of a flaw in the comparative example, Example 1, and Example 2. The contact width ratio L/B in the comparative example is 0.00, the contact width ratio L/B in Example 1 is 0.20, and the contact width ratio L/B in Example 2 is 0.24.

[Table 2]

RAW MATERIAL THICKNESS (mm)	250	250	250	300	300
FLANGE THICKNESS (mm)	150	160	180	200	210
FLAW (PRESENT: ×, ABSENT: ○)	○	○	×	×	×

[Table 3]

RAW MATERIAL THICKNESS (mm)	250	250	250	300	300
FLANGE THICKNESS (mm)	150	160	180	200	210
FLAW (PRESENT: ×, ABSENT: ○)	○	○	○	×	×

[Table 4]

RAW MATERIAL THICKNESS (mm)	250	250	250	300	300
FLANGE THICKNESS (mm)	150	160	180	200	210
FLAW (PRESENT: ×, ABSENT: ○)	○	○	○	○	○

[0088] As listed in Table 2, no flaw (rub-down flaw) occurred in the case of using the caliber configuration before improvement (second-second caliber K2-2, see FIG. 4) and shaping a 250 thick slab down to a flange thickness of 160 mm, but the occurrence of the flaw was confirmed when the flange thickness was shaped down to 180 mm.

[0089] As listed in Table 3, no flaw occurred in the case of setting the wedge angle (= θ_4) of the base part to 60° and setting the contact width ratio L/B to 0.20 in the split caliber (second-second caliber K2-2a, see FIG. 9) having the configuration relating to the projections 45', 46' after improvement and when the flange thickness was shaped down to 180 mm, but the occurrence of the flaw was confirmed when the flange thickness was shaped down to 200 mm.

[0090] As listed in Table 4, in the case of setting the wedge angle (= θ_4) of the base part to 90° in the split caliber (second-second caliber K2-2a, see FIG. 9) having the configuration relating to the projections 45', 46' after improvement and setting the contact width ratio L/B to 0.24, the occurrence of the flaw was not confirmed even when the flange thickness was shaped down to any of 160 mm to 210 mm.

[0091] Referring to Table 2 to Table 4, the flaw occurred in the comparative example (conventional method) when the shaping was performed to set the flange thickness to more than 160 mm. On the other hand, the occurrence of the flaw was suppressed even by the shaping of setting the flange thickness to 180 mm in Example 1 (Condition 1). Further, the occurrence of the flaw was suppressed even by the shaping of setting the flange thickness to 200 mm, 210 mm in Example 2 (Condition 2). In short, it is found that applying the improvement of the projection shape according to the technique of the present invention enables production of the H-shaped steel product having a larger flange thickness while suppressing the occurrence of the flaw.

[0092] For example, in the case of rolling and shaping the H-shaped steel product using a so-called 300 thick slab (a slab having a thickness of 290 mm to 310 mm) as a raw material by the method for producing H-shaped steel according to the present invention explained in the above embodiment, the flange thickness basically becomes a half of the slab thickness (about 150 mm). The active edging rolling is performed on the slab tip part from the state of the flange thickness becoming a half of the slab thickness to increase the flange thickness, thereby achieving a process design of producing, for example, a product of a flange thickness of about 180 mm or more. In such a process design, the bending resistance during the bending shaping increases with an increase in the thickness of the flange, so that the pressure of the material to be rolled at a portion in contact with the roll increases. Therefore, the deformation locally occurs, so that the rub-down flaw is more likely to occur along with the decrease in relative slipping velocity in the roll reduction direction as explained above. Hence, the present inventors have devised the projection shape having the base part explained in the above embodiment to increase the contact area between the roll and the material to be rolled, thereby decreasing the pressure to suppress the occurrence of the rub-down flaw.

[0093] It is considered from the above viewpoint that in order to suppress the occurrence of the rub-down flaw, it is desirable to increase the contact area between the roll and the material to be rolled and to secure the value of the contact width ratio L/B to some extent.

[0094] For example, as is found referring to the above Table 2 to Table 4, in the case of shaping the flange thickness to 180 mm or more, it is desirable to set the value of the contact width ratio L/B to 0.20 or more. Note that as listed in Table 4, the rolling and shaping can be performed without the occurrence of the rub-down flaw within a range of the flange thickness of more than 200 mm when the contact width ratio L/B is 0.24, so that the preferable range of the contact width ratio L/B may be set to 0.20 to 0.24.

[0095] Further, regarding the comparative example, Example 1, Example 2, it is considered that the rub-down flaw occurs by lowering the surface of the material to be rolled from the up-down direction (reduction direction) by the friction force of the roll. Hence, the present inventors have organized into a graph the slipping velocity (maximum velocity in a roll bite) in the up-down direction between the roll and the material to be rolled in the roll bite about conditions of the comparative example, Example 1, Example 2. FIG. 12 is a graph illustrating the slipping velocity in the up-down direction between the roll and the material to be rolled under each condition. Note that the above "roll bite" means the region where the material to be rolled and the roll are in contact with each other. The slipping velocity in the up-down direction between the roll and the material to be rolled in the roll bite represents the velocity difference at a site where the difference in velocity between the roll and the material to be rolled in the region where the material to be rolled and the roll are in contact with each other becomes maximum at a certain point in time in the steady state of rolling.

[0096] As illustrated in FIG. 12, under both conditions of Example 1 (Condition 1) and Example 2 (Condition 2), the slipping velocity decreases as compared with the comparative example (conventional method). Further, the slipping velocity in Example 2 decreases as compared with Example 1. This result shows that application of the technique of the present invention slows the deformation accompanying the bending shaping of the portion where the deformation amount locally increases in the material to be rolled to realize the suppression of the rub-down flaw.

[0097] FIG. 13 is a schematic view illustrating the deformation simulation result by FEM analysis under the conditions in the comparative example, Example 1, and Example 2. (a) illustrates the comparative example, (b) illustrates Example 1, and (c) illustrates Example 2. Note that in FIG. 13, solid lines illustrate the shape before the bending shaping and the shape after the bending shaping, and a mesh illustrates the finished shape in the first pass of the bending shaping. Further, (b), (c) additionally illustrate the shapes by the conventional method by way of comparison. Here, the pass schedule design is common to the conditions of (a) to (c), and the roll shape of the subsequent caliber (third caliber K3) is the same.

[0098] As illustrated in FIG. 13, it is found that even with the same pass schedule and the bending shaping in the same subsequent caliber, the contact width between the caliber and the material to be rolled increases during the bending shaping in Examples 1, 2 with respect to the comparative example. Therefore, the gradient of the deformation change decreases in Examples 1, 2, so that the occurrence of the flaw is suppressed.

[0099] As explained in the above first example, according to the technique of the present invention, the projection shape is the shape having the base part (see the second-second caliber K2-2a according to the above embodiment) in the split caliber at the stage before the bending shaping. Thus, it has been verified that even when the flange part of the material to be rolled is thick as compared with the conventional one, the rolling and shaping can be performed without the occurrence of the rub-down flaw on the outside surface of the flange part.

(Second example)

[0100] As a second example of the present invention, the verification was carried out about the presence or absence of the occurrence of the rub-down flaw in the material to be rolled after the bending shaping in the case of shaping using the split caliber (second-second caliber K2-2a, see FIG. 9) having the configuration relating to the projections 45', 46' after improvement explained in the above embodiment and when the wedge angle $\theta 2$ of the bending caliber at the foremost stage (third caliber K3, see FIG. 5) and the wedge angle $\theta 4$ of the base part were made equal and their angle ranges were changed in 60° to 110° .

[0101] Following Table 5 lists the relationship between the flange thickness of the material to be rolled and the occurrence of the flaw in the case where wedge angle $\theta 1b$ of the split caliber and the above angles $\theta 2$, $\theta 4$ were set to respective conditions. As listed in Table 5, when the wedge angle ($= \theta 4$) of the base part was made equal to the wedge angle $\theta 2$ of the bending caliber at the foremost stage (third caliber K3, see FIG. 5) in the split caliber (second-second caliber K2-2a, see FIG. 9) having the configuration relating to the projections 45', 46' after improvement, no flaw (rub-down flaw) occurred when the shaping was performed with a flange thickness in a range of 150 mm to 200 mm. On the other hand, when the shaping was performed with a flange thickness set to 210 mm, the occurrence of the flaw was confirmed under a part of conditions.

[Table 5]

FLANGE THICKNESS [mm]	150	160	180	200	210
$\theta 1b = 30^\circ, \theta 2 = \theta 4 = 60^\circ$	○	○	○	○	○
$\theta 1b = 30^\circ, \theta 2 = \theta 4 = 70^\circ$	○	○	○	○	○
$\theta 1b = 30^\circ, \theta 2 = \theta 4 = 80^\circ$	○	○	○	○	○
$\theta 1b = 30^\circ, \theta 2 = \theta 4 = 90^\circ$	○	○	○	○	○
$\theta 1b = 30^\circ, \theta 2 = \theta 4 = 100^\circ$	○	○	○	○	×
$\theta 1b = 30^\circ, \theta 2 = \theta 4 = 110^\circ$	○	○	○	○	×
$\theta 1b = 40^\circ, \theta 2 = \theta 4 = 100^\circ$	○	○	○	○	○
$\theta 1b = 40^\circ, \theta 2 = \theta 4 = 110^\circ$	○	○	○	○	×
$\theta 1b = 50^\circ, \theta 2 = \theta 4 = 110^\circ$	○	○	○	○	○
FLAW (PRESENT: ×, ABSENT: ○)					

[0102] The result of the second example listed in Table 5, it has been verified that under the shaping condition that the flange thickness after the bending shaping was in a range of 150 mm to 200 mm, the wedge angle $\theta 2$ of the bending caliber at the foremost stage and the wedge angle $\theta 4$ of the base part were made equal, thereby making it possible to perform the rolling and shaping without the occurrence of the rub-down flaw on the outside surface of the flange part irrespective of the value of the wedge angle $\theta 1b$ of the split caliber.

[Industrial Applicability]

[0103] The present invention is applicable to a method for producing H-shaped steel using, for example, a slab having a rectangular cross section as a raw material.

[Explanation of Codes]

[0104]

- 1 rolling facility
- 2 heating furnace
- 3 sizing mill
- 4 rough rolling mill
- 5 intermediate universal rolling mill
- 8 finishing universal rolling mill
- 9 edger rolling mill

11	slab
13	H-shaped raw blank
14	intermediate material
16	H-shaped steel product
5 20	upper caliber roll (first caliber)
21	lower caliber roll (first caliber)
25, 26	projection (first caliber)
28, 29	split (first caliber)
30	upper caliber roll (second-first caliber)
10 31	lower caliber roll (second-first caliber)
35, 36	projection (second-first caliber)
38, 39	split (second-first caliber)
40	upper caliber roll (second-second caliber)
41	lower caliber roll (second-second caliber)
15 45, 46	projection (second-second caliber)
45a, 46a	tip part
45b, 46b	base part
48, 49	split (second-second caliber)
50	upper caliber roll (third caliber)
20 51	lower caliber roll (third caliber)
55, 56	projection (third caliber)
58, 59	split (third caliber)
60	upper caliber roll (fourth caliber)
61	lower caliber roll (fourth caliber)
25 65, 66	projection (fourth caliber)
68, 69	split (fourth caliber)
80	flange part
82	web part
85	upper caliber roll (fifth caliber)
30 86	lower caliber roll (fifth caliber)
K1	first caliber
K2-1	second-first caliber
K2-2	second-second caliber
K3	third caliber
35 K4	fourth caliber
K5	fifth caliber (flat shaping caliber)
T	production line
A	material to be rolled

40

Claims

1. A method for producing H-shaped steel, the method comprising:

45 a rough rolling step;
an intermediate rolling step; and
a finish rolling step, wherein:

50 a rolling mill which performs the rough rolling step is engraved with a plurality of calibers configured to shape a material to be rolled;
the plurality of calibers comprise:

55 one or a plurality of split calibers formed with projections configured to create splits vertically with respect to a width direction of the material to be rolled to form divided parts at end parts of the material to be rolled; and
a plurality of bending calibers formed with projections configured to come into contact with the splits and sequentially bend the divided parts formed by the split caliber; and

the projections formed in a final split caliber of the split calibers are each composed a tip part in a tapered shape having a predetermined tip angle, and a base part located at a base of the tip part and having a tapered shape with a gentle inclination as compared with the tip part.

- 5 **2.** The method for producing the H-shaped steel according to claim 1, wherein a tapered angle of the base part is 60° or more and equal to or smaller than the tip angle of the projection formed in a caliber at a foremost stage of the bending calibers.
- 10 **3.** The method for producing the H-shaped steel according to claim 1 or 2, wherein a flange thickness of the material to be rolled shaped in the caliber at the foremost stage of the bending calibers is more than 160 mm.
- 15 **4.** The method for producing the H-shaped steel according to any one of claims 1 to 3, wherein when the flange thickness of the material to be rolled shaped in the caliber at the foremost stage of the bending calibers is 180 mm or more, the tip part and the base part are configured so that a contact width ratio L/B being a ratio of a width L of the base part to a flange contact width B in the final split caliber of the split calibers is 0.20 or more.
- 20 **5.** The method for producing the H-shaped steel according to any one of claims 1 to 4, wherein in shaping in the split caliber and the bending caliber, reduction is performed in a state where end faces of the material to be rolled are in contact with peripheral surfaces of the caliber in shaping in at least one pass or more.
- 25 **6.** The method for producing the H-shaped steel according to any one of claims 1 to 5, wherein the split caliber is provided with caliber side surfaces which come into contact with right and left side surfaces of the material to be rolled and constrain the material to be rolled from right and left.
- 30
- 35
- 40
- 45
- 50
- 55

FIG.1

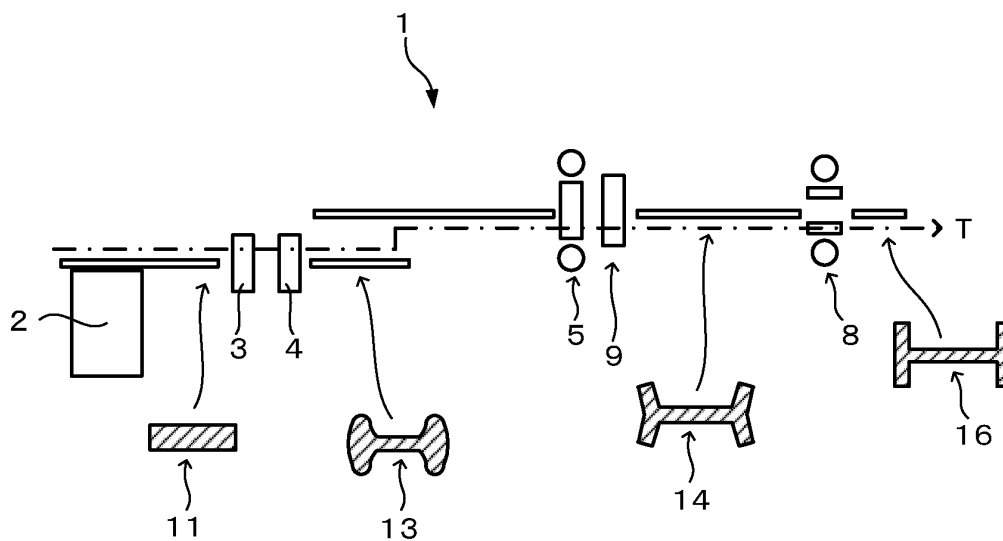


FIG.2

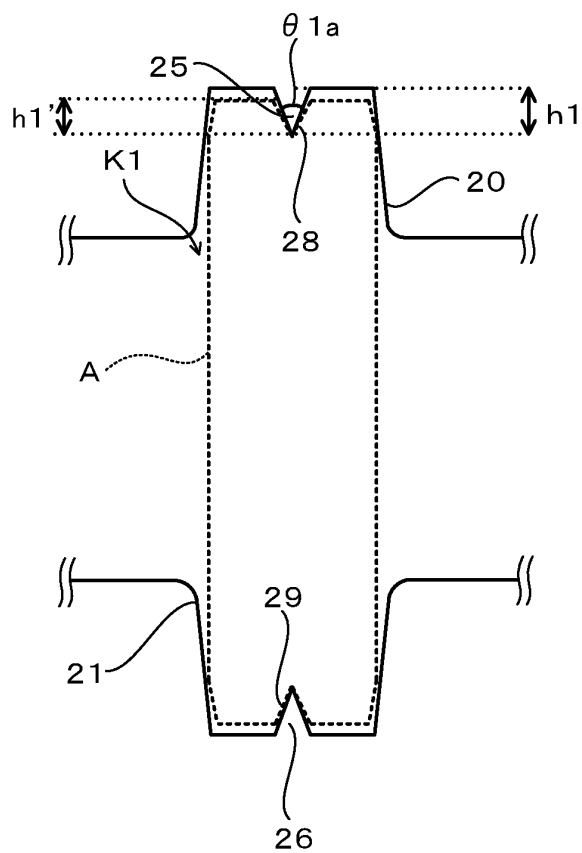


FIG. 3

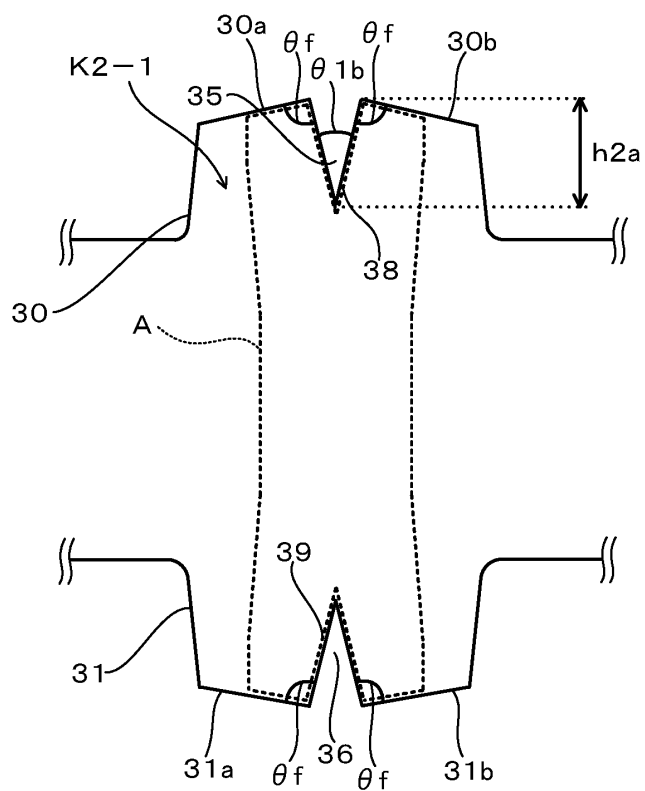


FIG. 4

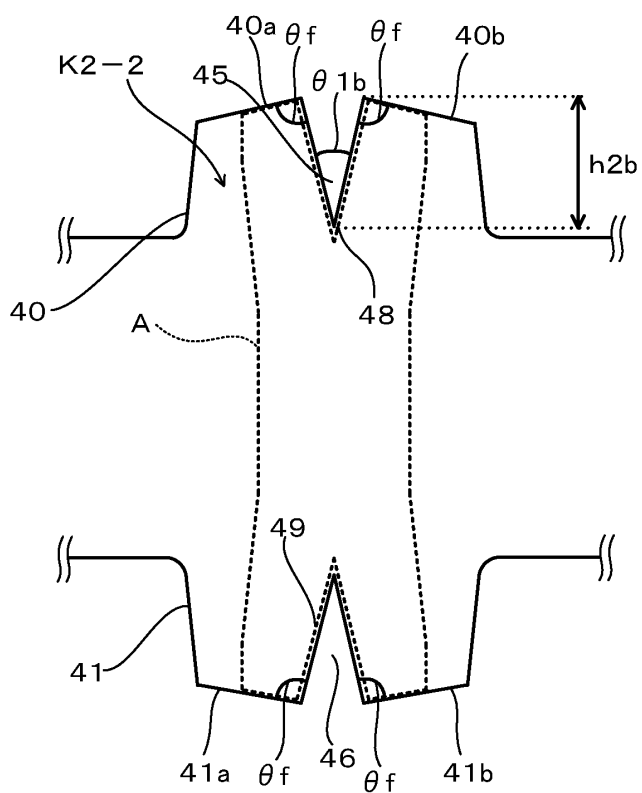


FIG.5

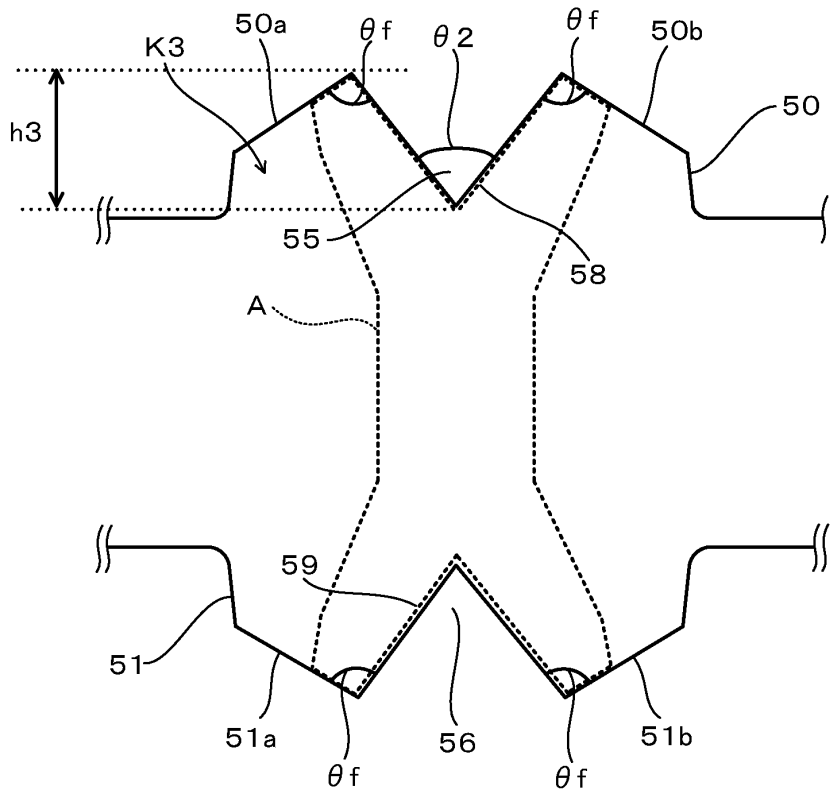


FIG.6

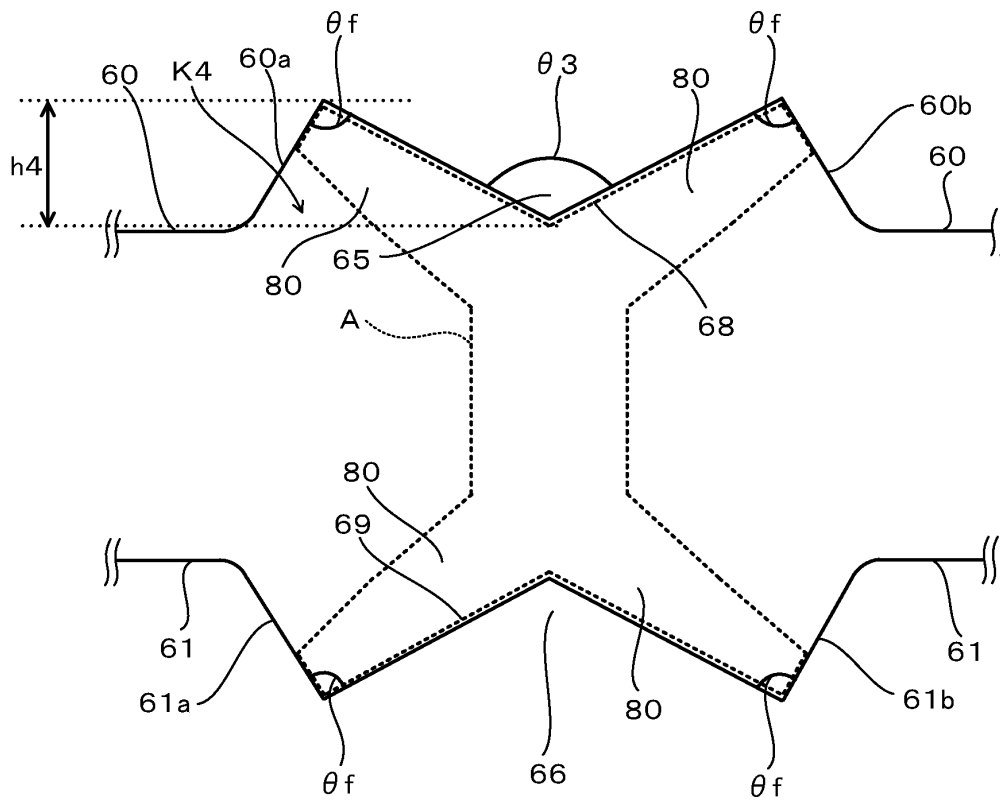


FIG. 7

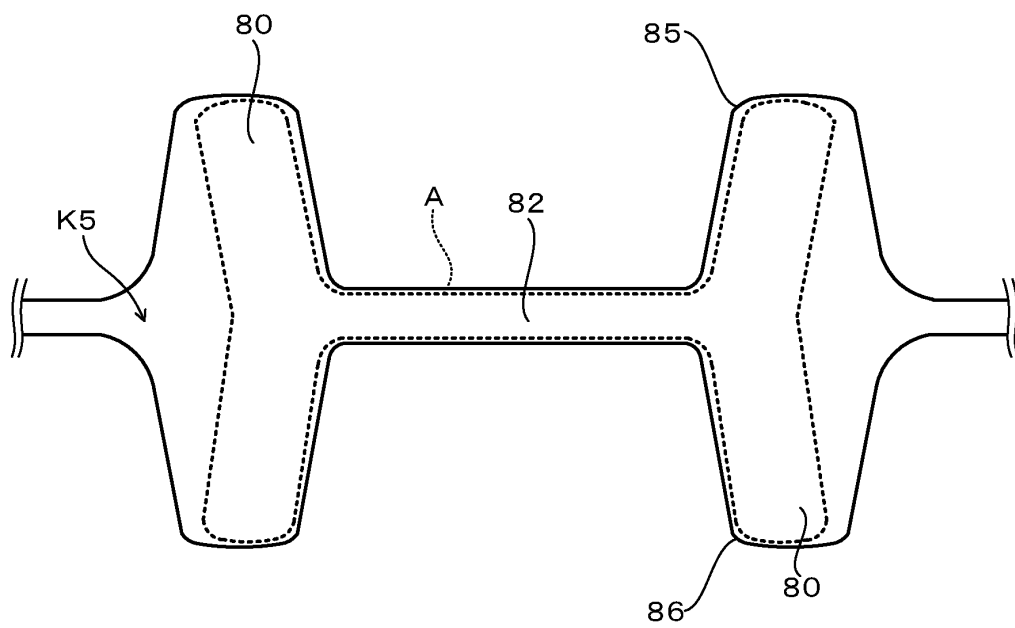


FIG. 8

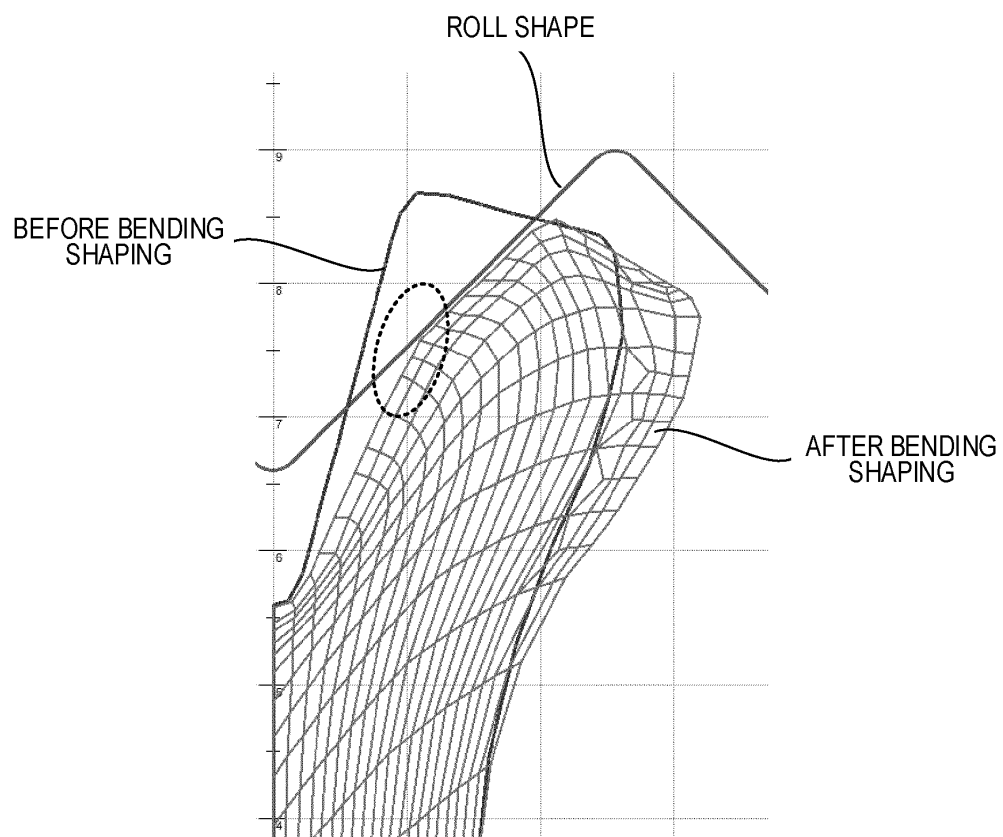


FIG.9

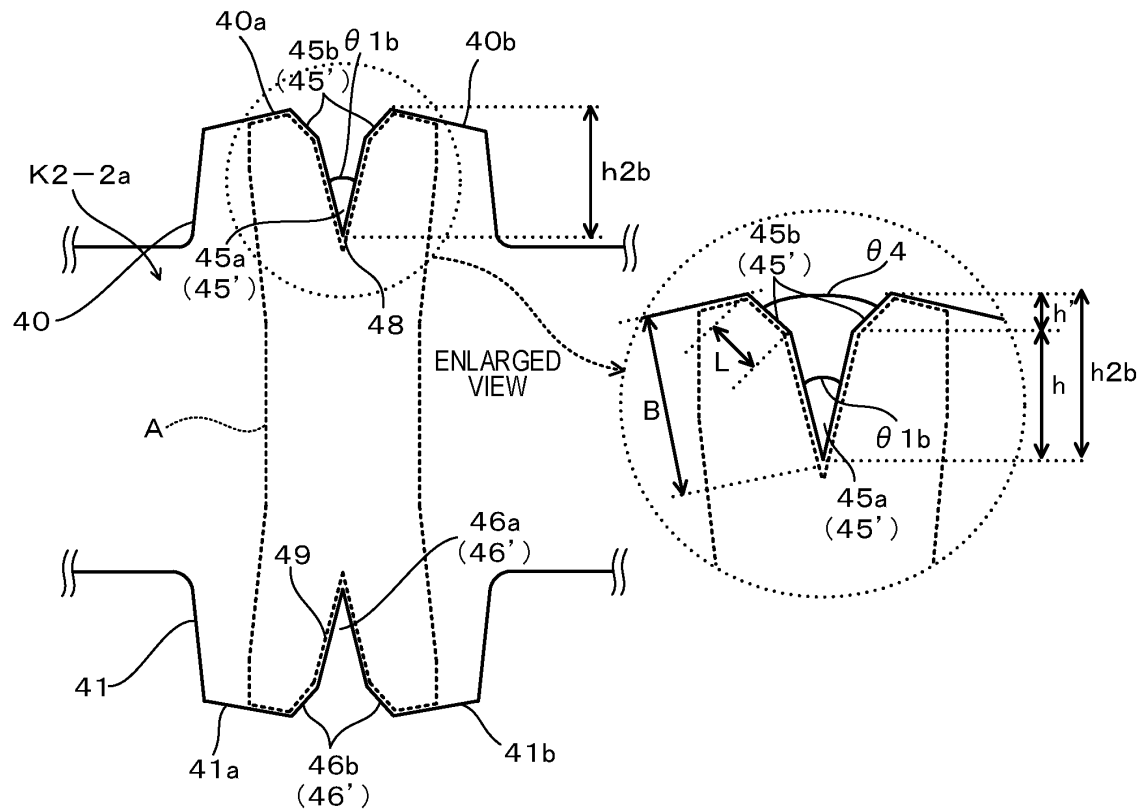


FIG.10

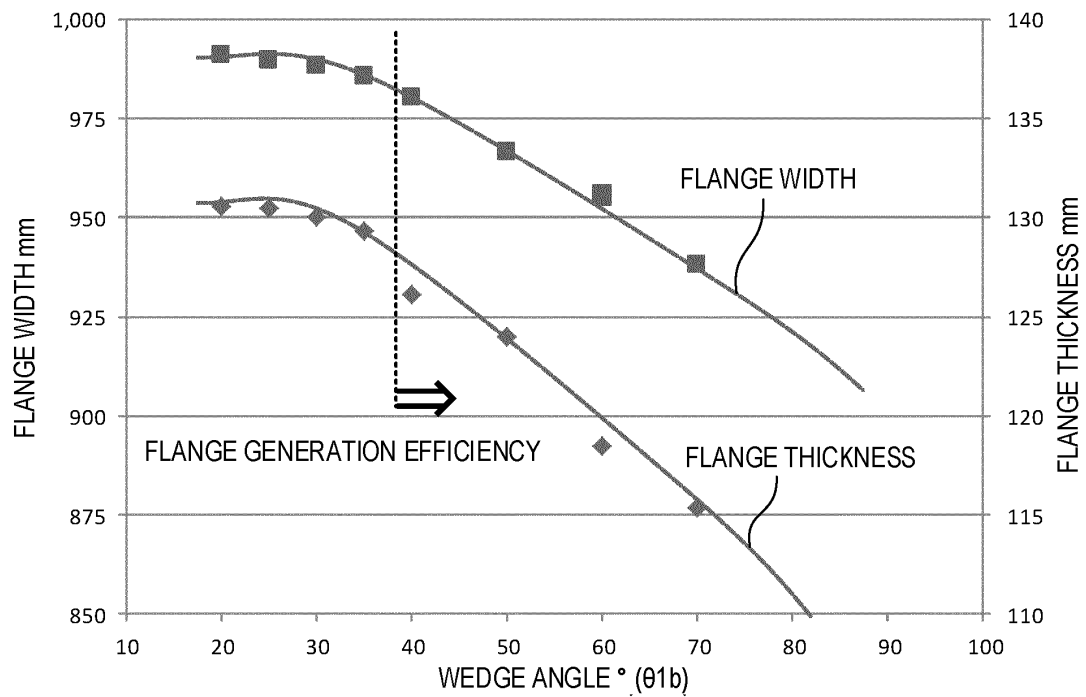


FIG.11

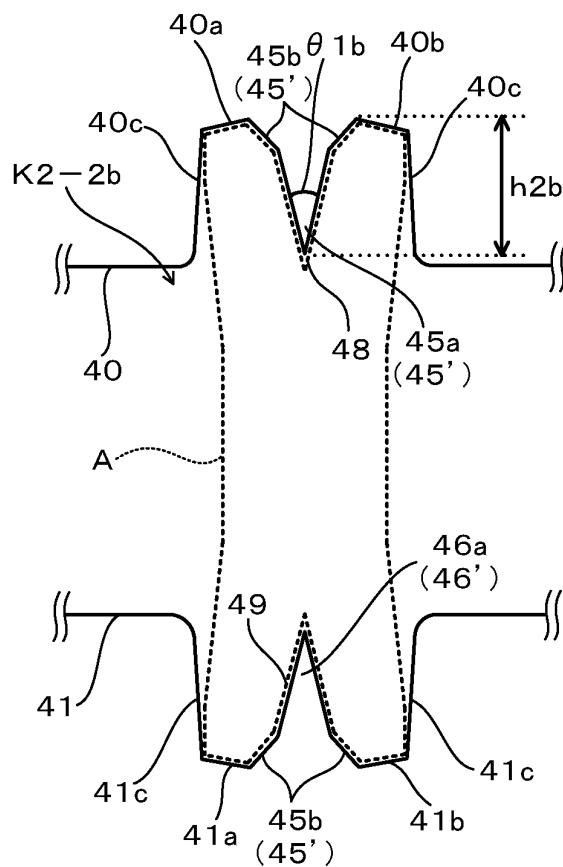


FIG.12

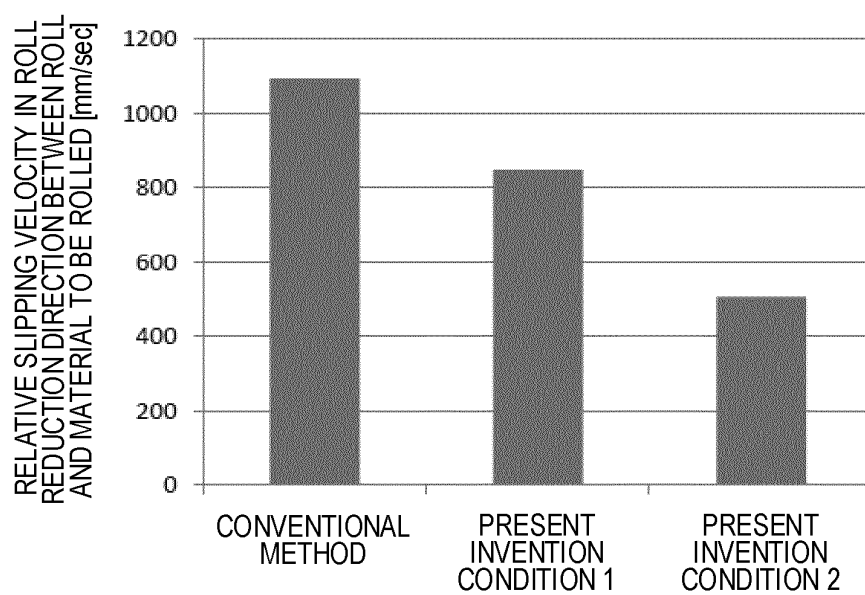
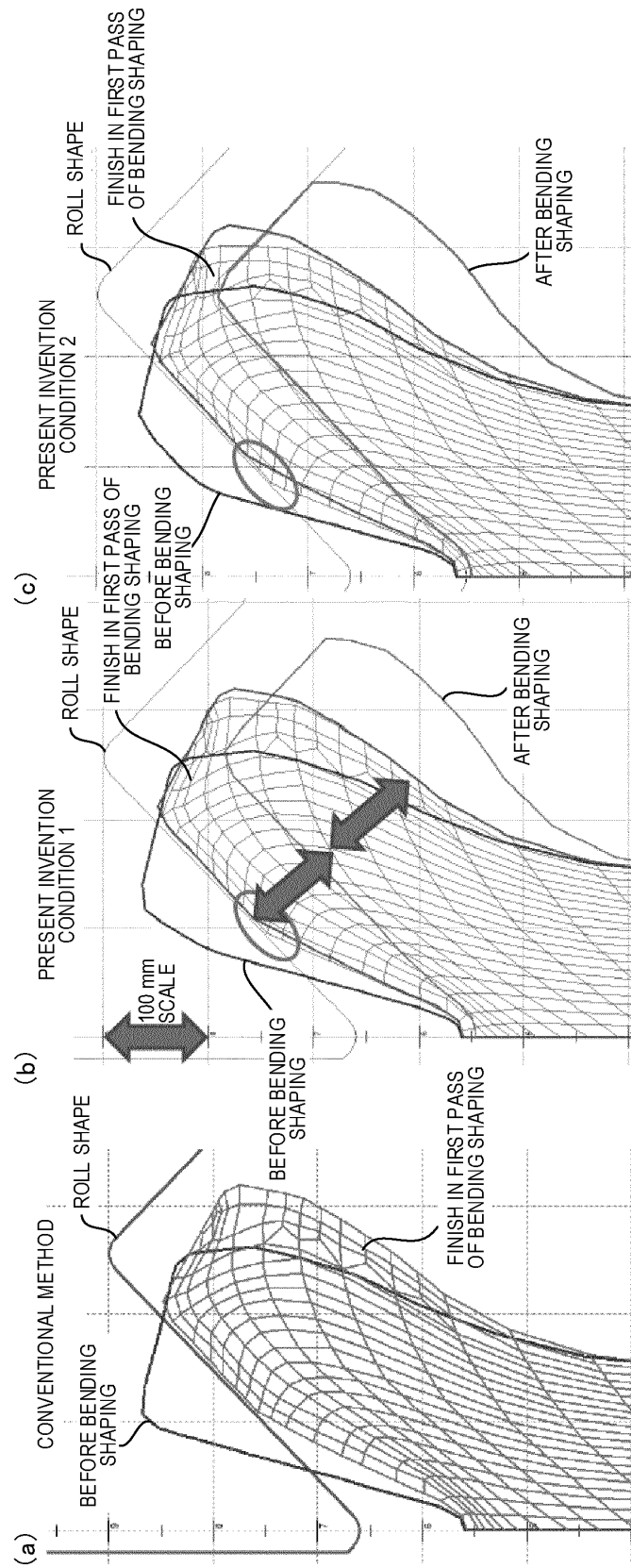


FIG.13



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/026218

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B21B1/08 (2006.01)i, B21B27/02 (2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl. B21B1/08, B21B27/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Published examined utility model applications of Japan 1922-1996

Published unexamined utility model applications of Japan 1971-2018

Registered utility model specifications of Japan 1996-2018

Published registered utility model applications of Japan 1994-2018

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 7-88501 A (NIPPON STEEL CORP.) 04 April 1995 (Family: none)	1-6
A	JP 2016-144811 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 12 August 2016 (Family: none)	1-6



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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

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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

05 September 2018 (05.09.2018)

Date of mailing of the international search report

18 September 2018 (18.09.2018)

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

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- JP H11347601 B [0007]
- JP H788501 B [0007]