



(11)

EP 3 610 959 A1

(12)

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

(43) Date of publication:
19.02.2020 Bulletin 2020/08

(51) Int Cl.:
B21B 1/08 (2006.01) B21B 1/088 (2006.01)

(21) Application number: **18872514.7**

(86) International application number:
PCT/JP2018/040716

(22) Date of filing: **01.11.2018**

(87) International publication number:
WO 2019/088225 (09.05.2019 Gazette 2019/19)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
KH MA MD TN

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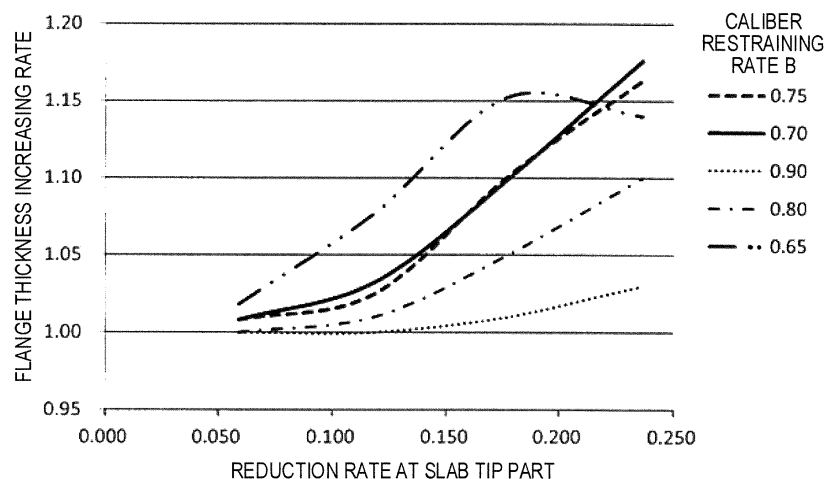
(30) Priority: **02.11.2017 JP 2017212914**

(54) **H-SHAPED STEEL MANUFACTURING METHOD**

(57) Plural calibers which perform a rough rolling step include: a grooving caliber configured to perform grooving vertically with respect to end parts in a width direction of a material to be rolled; one or plural split calibers formed with projections configured to create splits vertically with respect to the end parts in the width direction of the material to be rolled after being grooved to form divided parts on the end parts of the material to be rolled; and plural bending calibers formed with projections configured to abut against the splits and sequentially bend

the formed divided parts, at least the split caliber of the last stage out of the one or plural split calibers is provided with caliber side surfaces configured to abut against right and left side surfaces of the material to be rolled and restrain the material to be rolled from right and left, and in the split caliber provided with the caliber side surfaces, rolling and shaping is performed under a condition where a caliber restraining rate B becomes 0.7 or more and less than 1.0.

FIG.11



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Description

[Technical Field]

(Cross-Reference to Related Applications)

[0001] This application is based upon and claims the benefit of priority of the prior Japanese Patent Application No. 2017-212914, filed in Japan on November 2, 2017, the entire contents of which are incorporated herein by reference.

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

[Background Art]

[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). A web and flanges of the raw blank are subjected to reduction in thickness by an intermediate universal rolling mill, and 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.

[0004] In recent years, in accordance with the increase in size of a building structure and application to an offshore structure, it has been required to produce an H-shaped steel product which is larger than that of the prior art, and a product in which a flange width and a flange thickness are increased has been demanded, in particular. 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 lower end surfaces (slab end surfaces) of a material to be rolled, and then the shape of the splits is changed while performing edging on the slab end surfaces.

[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 restraining upper and lower end parts (slab end surfaces) of a material to be rolled, and then the shape of the splits is changed while performing edging on the slab end surfaces in a state where the slab end surfaces are not in contact with caliber side walls. This technique makes it possible to increase a flange thickness according to a reduction rate in the edging rolling.

[0006] Further, for example, Patent Document 2 discloses a technique in which a shape of splits is changed while performing edging on slab end surfaces in a state of restraining both sides of upper and lower end parts (slab end surfaces) of a material to be rolled. With the use of this technique, since the reduction is performed by restraining the 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 a thickness.

[0007] Further, for example, Patent Document 3 discloses a technique in which when producing an H-shaped steel product with a large flange width, a defective shape such as non-uniform flange part thickness is suppressed to improve a dimension and a shape. With the use of this technique, it is possible to stably perform rolling and shaping such as one realizing both widening of the flange width and improvement of a dimensional accuracy of a product.

[Prior Art Document]

[Patent Document]

[0008]

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

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

Patent Document 3: Japanese Laid-open Patent Publication No. 2017-121655

[Disclosure of the Invention]

[Problems to Be Solved by the Invention]

[0009] 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 restrained but spread freely as disclosed in the aforementioned Patent Document 1, for example, although the flange width is increased, a flange tip part takes a tapered shape in thickness and the thickness

of the flange tip part is insufficient, and thus there is a worry that molding cannot be performed sufficiently in a process of a subsequent stage and it is not possible to greatly increase the thickness. Further, according to the studies conducted by the present inventors, there has been obtained a finding that even when the restraining degree in the horizontal direction of the upper and lower end parts (slab end surfaces) of the material to be rolled is set to be lower than that of the prior art, the flange tip part is tapered and thus the thickness becomes insufficient in a similar manner.

[0010] Further, as disclosed in the aforementioned Patent Document 2, for example, when the edging rolling is performed by restraining the 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 restrained in a caliber, so that elongation in a longitudinal direction of the material to be rolled becomes dominant, efficiency regarding 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 the rolling is performed by 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 the present technique.

[0011] Further, in the technique disclosed in the aforementioned Patent Document 3, for example, it is not configured to actively perform the reduction on the flange part, and thus the technique cannot realize a sufficient increase in thickness of the flange part.

[0012] 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 larger 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.

[Means for Solving the Problems]

[0013] To achieve the above object, according to the present invention, there is provided a method for producing H-shaped steel, the method including: 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 plural calibers configured to roll and shape a material to be rolled; the plural calibers include a grooving caliber configured to perform grooving vertically with respect to end parts in a width direction of the material to be rolled, one or plural split calibers formed with projections configured to create splits vertically with respect to the end parts in the width direction of the material to be rolled after being grooved to form divided parts on the end parts of the material to be rolled, and plural bending calibers formed with projections configured to abut against the splits and sequentially bend the divided parts formed by the split caliber; at least the split caliber of the last stage out of the one or plural split calibers is provided with caliber side surfaces configured to abut against right and left side surfaces of the material to be rolled and restrain the material to be rolled from right and left; and in the split caliber provided with the caliber side surfaces, rolling and shaping is performed under a condition where a caliber restraining rate B represented by the following equation (1) becomes 0.7 or more and less than 1.0,

$$B = t / t_0 \quad \dots (1)$$

where t indicates a flange tip thickness when the split rolling and shaping, and the bending rolling and shaping are performed under the restraint in the caliber, and t₀ indicates a thickness of a slab end surface corresponding to a thickness of a flange tip formed by the grooving caliber.

[0014] The rolling and shaping may be performed under a condition where a cumulative reduction rate until when the rolling and shaping in the split caliber provided with the caliber side surfaces is completed is 0.20 or more and 0.25 or less.

[0015] A tip angle of the projections formed on the one or plural split calibers may be 25° or more and 40° or less.

[0016] In the one or plural split calibers and the plural bending calibers, light reduction may be performed in a state where end surfaces of the material to be rolled are in contact with caliber surfaces facing the end surfaces in shaping of at least one pass or more.

[0017] The plural calibers may include a flat shaping caliber configured to perform flat shaping and rolling on the material to be rolled after passing through the plural split calibers and the plural bending calibers, and the rolling and shaping in the flat shaping caliber may be performed under a condition where a ratio l between a flange half-width and a flange thickness is 1.30 or more in a flange part of the material to be rolled corresponding to the divided part.

[0018] It is possible that a raw material having a rectangular cross section and a thickness of 280 mm or more and 320 mm or less is used, and the flange half-width of the flange part of the material to be rolled before being subjected to the rolling and shaping in the flat shaping caliber is set to 200 mm or more.

[Effect of the Invention]

[0019] According to the present invention, it becomes possible to produce an H-shaped steel product having a larger 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.

[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 2-1st caliber.

[FIG. 4] FIG. 4 is a schematic explanatory view of a 2-2nd 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 a schematic explanatory view illustrating a configuration of a split caliber according to an embodiment of the present invention.

[FIG. 9] FIG. 9 is a FEM analytic view comparing shapes of flange corresponding parts after being subjected to split rolling and shaping.

[FIG. 10] FIG. 10 is a FEM analytic view illustrating shapes of flange parts after being subjected to bending rolling and shaping when final split rolling and shaping is performed by calibers with different restraining situations.

[FIG. 11] FIG. 11 is a graph indicating a relationship between a reduction rate at a slab tip part and a flange thickness increasing rate when a caliber restraining rate is set to have plural various values.

[Embodiments for Carrying out the Invention]

[0021] Hereinafter, an embodiment of the present invention will be explained while referring to the drawings. Note that in this description and the drawings, components having substantially the same functional configurations are denoted by the same numerals 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 the present 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, hereinafter, a steel material in the production line T is collectively described as a "material to be rolled A" for explanation and its shape is appropriately illustrated using broken lines, oblique lines and the like in some cases in the respective drawings.

[0023] As illustrated in FIG. 1, in the production line T, a material to be rolled A such as a slab 11, for example, 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-described 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 plural passes through those calibers, and the H-shaped raw blank 13 is subjected to application of reduction in plural passes using a rolling mill train composed of two rolling mills of the intermediate universal rolling mill 5 and the edger rolling mill 9, 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.

(Basic caliber configurations)

[0024] Next, basic configurations of 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 while 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 a first caliber to a fourth caliber explained here may be engraved, for example, on the sizing mill 3, or five calibers of the first caliber to a 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 plural passes is performed in each of the calibers.

[0025] Besides, a case where the basic configuration of the calibers to be engraved employs six calibers will be described as an example in the present embodiment, and the number of the calibers does not always need to be six, but the number of the calibers may be plural such as six or more. In short, the caliber configuration only needs to be 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, and 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 set to h_1 , and a tip part angle thereof is set to θ_{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, to thereby form splits 28, 29 (grooving shaping). The first caliber K1 is a caliber that forms the grooves (splits 28, 29) on the slab end surfaces, so that it is also referred to as a "grooving caliber". Here, the tip part angle (also referred to as a wedge angle) θ_{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). Concretely, when the width of the caliber at the tip parts of the projections 25, 26 formed on 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 parts 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-described 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), to thereby form the splits 28, 29, and a thickness t_0 of the flange tip part is decided.

[0029] FIG. 3 is a schematic explanatory view of a 2-1st caliber K2-1. The 2-1st 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 2-1st 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 2-1st 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 θ_{1b} of 25° or more and 40° or less.

[0030] Here, the wedge angle θ_{1a} of the above first caliber K1 is preferably the same angle as the wedge angle θ_{1b} of the 2-1st caliber K2-1 at a subsequent stage in order to ensure the thickness of the tip parts of the flange corresponding parts, enhance inductive property, and secure stability of rolling.

[0031] A height (protrusion length) h_{2a} of the projections 35, 36 is configured to be larger than the height h_1 of the projections 25, 26 of the first caliber K1 so as to be $h_{2a} > h_1$. Further, the tip part angle of the projections 35, 36 is preferably the same as the tip part angle of the projections 25, 26 in the first caliber K1 in terms of rolling dimension accuracy. 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 h_{2a} of the projections 35, 36 formed in the 2-1st caliber K2-1 is larger than the height h_1 of the projections 25, 26 formed in the first caliber K1, and 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 2-1st caliber K2-1. An intrusion depth into the material to be rolled A of the projections 35, 36 in the 2-1st caliber K2-1 is the same as the height h_{2a} of the projections 35, 36. In other words, an intrusion depth $h_{1'}$ into the material to be rolled A of the projections 25, 26 in the first caliber K1 and the intrusion depth h_{2a} into the material to be rolled A of the projections 35, 36 in the 2-1st caliber K2-1 satisfy a relationship of $h_{1'} < h_{2a}$.

[0033] Further, angles θ_f 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 2-1st caliber K2-1, to thereby form the splits 38, 39 (split rolling and shaping). The 2-1st caliber K2-1 is also referred to as a "split caliber".

[0035] Further, the shaping in the 2-1st 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 2-1st caliber K2-1, a shape defect such as flange corresponding parts (parts corresponding to the later-described 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 2-2nd caliber K2-2. The 2-2nd 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 2-2nd 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 2-2nd 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 θ_{1b} of 25° or more and 40° or less, and is desirably designed to be an angle same as the wedge angle of the above 2-1st caliber K2-1.

[0037] A height (protrusion length) h_{2b} of the projections 45, 46 is configured to be larger than the height h_{2a} of the projections 35, 36 of the 2-1st caliber K2-1 so as to be $h_{2b} > h_{2a}$. 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 2-1st caliber K2-1 is further shaped.

[0038] Here, the height h_{2b} of the projections 45, 46 formed in the 2-2nd caliber K2-2 is larger than the height h_{2a} of the projections 35, 36 formed in the 2-1st caliber K2-1, and 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 2-2nd caliber K2-2. An intrusion depth into the material to be rolled A of the projections 45, 46 in the 2-2nd caliber K2-2 is the same as the height h_{2b} of the projections 45, 46. In other words, the intrusion depth h_{2a} into the material to be rolled A of the projections 35, 36 in the 2-1st caliber K2-1 and the intrusion depth h_{2b} into the material to be rolled A of the projections 45, 46 in the 2-2nd caliber K2-2 satisfy a relationship of $h_{2a} < h_{2b}$.

[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 2-1st caliber K2-1 deeper in the 2-2nd caliber K2-2, to thereby form the splits 48, 49 (split rolling and shaping). The 2-2nd caliber K2-2 is also referred to as a "split caliber", similarly to the 2-1st caliber K2-1.

[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 2-2nd caliber K2-2 is normally 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 2-2nd caliber K2-2, a shape defect such as flange corresponding parts (parts corresponding to the later-described 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} , and an intrusion depth h_3 into the material to be rolled A of the projections 55, 56 is smaller than the intrusion depth h_{2b} of the above projections 45, 46 (namely, $h_3 < h_{2b}$). 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, the splits 48, 49 formed in the 2-2nd caliber K2-2 at the upper and lower end parts (slab end surfaces) of the material to be rolled A after passing through the 2-2nd caliber K2-2 become splits 58, 59 by the projections 55, 56 being pressed against thereon. Specifically, in a final pass in shaping in the third caliber K3, a deepest part 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 (the parts corresponding to the later-described flange parts 80) shaped along with the formation of the splits 48, 49 in the 2-2nd caliber K2-2 are bent outward (bending rolling and shaping). 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, 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 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 θ_3 of the projections 65, 66 is configured to be larger than the aforementioned angle θ_2 , and 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, $h_4 < h_3$). The angle θ_3 is preferably, for example, 130° or more and 170° or less.

[0050] Further, angles θ_f 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 pressed to spread by the projections 65, 66 being pressed against thereon, to 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 θ_3 . In other words, shaping is performed so that divided parts (the parts corresponding to the later-described flange parts 80) shaped along with the formation of the splits 58, 59 in the third caliber K3 are further bent outward (bending rolling and shaping). 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-described 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 (the 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 (the fifth caliber K5) is performed by one or arbitrary plural passes.

[0055] The H-shaped raw blank 13 shaped as described above is subjected to reverse rolling in plural 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 the present 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, thereby enabling shaping of the H-shaped raw blank 13 having the flange width made wider as compared with the rough rolling method of 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 the present 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 closer 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 (the flange parts 80) shaped by creating splits without changing the end part shapes of the raw material (slab) having the rectangular cross section used as the raw material.

[0058] In the rolling and shaping technique having such a characteristic, the thickness of the flange parts 80 is sometimes further increased in order to efficiently produce large-size H-shaped steel such that an H-shaped steel product having a flange width of 400 mm or more is produced from a slab being a raw material having a rectangular cross section and a width of 1800 mm and a thickness of 280 mm to 320 mm, for example. When increasing the thickness of the flange parts 80, it can be considered that it is effective to perform edging rolling at a time of split rolling and shaping, for example, but, when edging rolling is performed on a material to be rolled A having a shape in which a flange width is large and a flange thickness is small, there is a possibility that inefficient flange shaping is performed such that the thickness of only the flange tip part is increased. Further, when a reduction amount in the edging rolling is large, there is a possibility that a vertical and horizontal balance of thickness amount of the flange parts 80 becomes non-uniform, which deteriorates a dimensional accuracy.

[0059] Specifically, the present inventors obtained findings such that since, in the rolling and shaping in the split caliber as described above, a configuration of restraining side surfaces of the material to be rolled A by the caliber is not employed, the deformation intensively occurs only on the flange tip part, which increases the thickness of only the tip part, and at the same time, a centering defect such as a groove displacement regarding the horizontal direction of the material to be rolled A is concerned, which makes thicknesses of flange corresponding parts to be shaped become non-uniform in the vertical and horizontal directions, and in particular, a difference in right-left thickness of the flanges is likely to occur. Note that the groove displacement is a phenomenon in which when the split is formed by the projection in the rolling and shaping in the split caliber, a center part of the formed split is displaced relative to a center part in a thickness direction of the material to be rolled A.

[0060] In view of such circumstances, the present inventors further conducted studies regarding the shape of the split caliber, and invented a split caliber capable of solving a problem such that thicknesses of flange corresponding parts to be shaped become non-uniform in vertical and horizontal directions due to the aforementioned groove displacement and the like, and in particular, a difference in right-left thickness of the flanges occurs. Besides, the present inventors quantitatively verified an index for maximizing a thickness increasing efficiency when a flange thickness is increased in the invented split caliber with improved shape, resulting in that they invented efficient thickness increasing conditions. Hereinafter, the shape of the split caliber having the newly invented configuration will be described while referring to the drawing, and conditions under which the flange thickness can be efficiently increased in the split caliber will be described.

(Configuration of split caliber according to embodiment of present invention)

[0061] FIG. 8 is a schematic explanatory view illustrating a configuration of a split caliber according to an embodiment of the present invention, and illustrates an improved caliber K2-2a corresponding to the above 2-2nd caliber K2-2. Note that regarding the configuration of the caliber illustrated in FIG. 8, components same as those of the 2-2nd caliber K2-2 described above with reference to FIG. 4 will be illustrated by using the same numerals, and explanation thereof will be omitted.

[0062] As illustrated in FIG. 8, a basic caliber configuration of the improved 2-2nd caliber K2-2a is substantially the same as that of the 2-2nd caliber K2-2 before the improvement, and there can be cited, as a point of difference, that caliber side surfaces 40c and 41c formed on right and left of the improved 2-2nd caliber K2-2a are configured to abut against the material to be rolled A so as to restrain the material to be rolled A. Specifically, although the 2-2nd caliber K2-2 before the improvement (refer to FIG. 4) is configured such that it is not provided with side walls, the improved 2-2nd caliber K2-2a has a configuration (caliber design) such that it is provided with a side wall width.

[0063] Here, the shaping in the 2-2nd caliber K2-2a is performed by multi-pass, for example, and in at least one pass or more in the multi-pass shaping, it is preferable that the upper and lower end parts (slab end surfaces) of the material to be rolled A and the inside of the caliber (caliber upper surfaces 40a, 40b and caliber bottom surfaces 41a, 41b of the 2-2nd caliber K2-2a) are in contact with each other, as illustrated in FIG. 8. This is for improving the dimensional accuracy of the flange parts 80 to be shaped later by aligning lengths of the flange corresponding parts (which will become flange

parts 80 later) at four locations in the rolling and shaping in the 2-2nd caliber K2-2a.

[0064] In the caliber configuration illustrated in FIG. 8, the shape of the caliber side surfaces 40c, 41c is preferably a vertical shape such that it becomes perpendicular to a caliber roll axis, from a viewpoint of efficiently restraining the material to be rolled A from right and left, but, regarding a case where the shape of the material to be rolled A does not display perfect bilateral symmetry and the like, the shape of the caliber side surfaces 40c, 41c is desirably set to a tapered shape having a predetermined inclination angle θ_s with respect to a direction perpendicular to the caliber roll axis, in order to induce the material to be rolled while suppressing the occurrence of flaws. Further, the tapered shape is also desirable in order to easily repair the roll due to abrasion of the roll. A concrete value of the inclination angle θ_s is preferably set to equal to or more than 3° being a minimum angle required for performing the roll repair, and equal to or less than 6° as an angle for suitably inducing the material to be rolled.

[0065] The present inventors estimated that when performing the split rolling and shaping in the caliber (the improved 2-2nd caliber K2-2a) having the shape of restraining the flange corresponding parts (flange parts 80) of the material to be rolled A as illustrated in FIG. 8, there is generated a difference in a flange thickness after shaping by changing the design, the dimensions, and so on of the caliber K2-2a, and they performed analysis using a FEM to conduct verification regarding suitable caliber design and dimensions.

[0066] FIG. 9 is a FEM analytic view comparing, in final split rolling and shaping (rolling and shaping in the 2-2nd caliber) with respect to the materials to be rolled A with the same dimensions, shapes of flange corresponding parts (flange parts 80) after the split rolling and shaping between a case where the caliber performing the rolling and shaping is designed to perform no restraint (namely, the caliber K2-2 with basic caliber configuration described above, refer to FIG. 4), and a case where the restraint is performed (namely, the improved caliber K2-2a, refer to FIG. 8). Note that FIG. 9 also illustrates a case, as a reference view, in which a reduction amount in the edging rolling is not provided at all when performing the split rolling and shaping.

[0067] As illustrated in FIG. 9, it can be understood that in the final split rolling and shaping, when the caliber is provided with the side walls to restrain the material to be rolled A, the tip parts of the flange corresponding parts (flange parts 80) are restrained, and thus a thickness of a part other than the restrained part (namely, a flange root part and the like) is increased, when compared with the case where the caliber is not provided with the side walls and the material to be rolled A is not restrained. Note that a situation regarding the increase in thickness of the flange root part and the like can be considered to depend on a contact situation of the material to be rolled A when being restrained in the caliber with respect to the roll, and the like. The analytic view illustrated in FIG. 9 is one example, and is an analytic view when the final split rolling and shaping is performed by bringing a range of about 1/2 of a tip of a flange half-width into contact with the roll.

[0068] Further, although FIG. 9 illustrates the case where the final split rolling and shaping is performed by bringing the range of about 1/2 of the tip of the flange half-width into contact with the roll, the present inventors also conducted analysis regarding a case of changing the roll contact range. FIG. 10 is a FEM analytic view illustrating shapes of flange parts after bending rolling and shaping when the final split rolling and shaping with respect to the materials to be rolled A with the same dimensions is performed by calibers with different restraining situations (roll contact situations). Note that FIG. 10 also illustrates, as reference views, shapes of flange parts in a case where the restraint in the caliber is not performed at the time of split rolling and shaping and a case where a reduction amount in the edging rolling is not provided at the time of split rolling and shaping.

[0069] As illustrated in FIG. 10, it can be understood that the increase in thickness of the part other than the restrained part (namely, the flange root part and the like) is realized in the case of high caliber restraining rate, when compared with the case of low caliber restraining rate. It can be considered that this is because the restraining range of the flange tip part is increased so as to enlarge the contact range between the material to be rolled and the roll to increase the restraining degree, resulting in that reduction penetration due to the edging rolling is facilitated to increase the thickness of a center part of a flange half-width, the root part, and the like. Specifically, it can be considered that as the caliber restraining degree increases, a range of influence exerted by the edging rolling at the time of final split rolling and shaping is increased and exerts influence in a direction of a center part of the flange corresponding part, resulting in that the increase in thickness is facilitated. Note that regarding the increase in thickness of the flange corresponding part, a center part of a half-width of the flange corresponding part is defined as a representative point of the flange thickness, for example, and the increase in thickness is judged based on the thickness at the representative point. Further, the above "reduction penetration" indicates a state where even a further inner part of the material to be rolled is subjected to deformation in the rolling direction due to the influence of the rolling with respect to the material to be rolled.

[0070] From such analysis results illustrated in FIG. 9, FIG. 10, the present inventors invented to introduce a parameter of "caliber restraining rate B" to quantify the caliber restraining degree in the final split rolling and shaping, and further conducted verification to specify a suitable range of the caliber restraining rate B based on a relationship between the caliber restraining rate B and a flange thickness increasing rate. Hereinafter, this verification will be described with reference to FIG. 11.

[0071] Here, the "caliber restraining rate B" is a ratio of a flange tip thickness t when the split rolling and shaping and

the bending rolling and shaping are performed under the restraint in the caliber, to a thickness t_0 (refer to FIG. 2) of the flange tip corresponding part of the material to be rolled defined by a caliber bottom width corresponding to the tip thickness of the flange corresponding part in the grooving caliber ($= t / t_0$) (refer to FIG. 10). The following equation (1) is a definition of the caliber restraining rate B.

$$B = t / t_0 \quad \dots (1)$$

[0072] FIG. 11 is a graph indicating a relationship between a reduction rate at a slab tip part and a flange thickness increasing rate when the caliber restraining rate B is set to have plural various values in a case of performing the final split rolling and shaping in a state of performing restraint in the caliber in the method for producing the H-shaped steel according to the present embodiment. Here, the reduction rate at the slab tip part indicates a cumulative reduction rate at the slab tip part in the split rolling and shaping. Namely, the reduction rate at the slab tip part is a ratio of cumulative edging amounts before starting the split rolling and shaping and after completion of the final split rolling and shaping in a distance between upper and lower wedges (namely, cumulative reduction rate in the split rolling and shaping). Further, the flange thickness increasing rate is a thickness increasing ratio of a flange maximum thickness when the split rolling and shaping and the bending rolling and shaping are performed under the restraint in the caliber, to a flange maximum thickness when the split rolling and shaping and the bending rolling and shaping are performed without performing the restraint in the caliber. These flange thicknesses indicate a flange thickness at a center part of a flange half-width illustrated in the reference view in FIG. 10 (refer to a part surrounded by broken lines in FIG. 10). Note that for the flange thickness, a value measured in a direction perpendicular to a flange outer surface is employed.

[0073] As illustrated in FIG. 11, basically, there is a tendency that the flange thickness increasing rate is increased as the reduction rate at the slab tip part increases. Further, there is a tendency that as the caliber restraining rate B increases, the value of the flange thickness increasing rate is reduced, and when the caliber restraining rate B is 0.90, for example, even if the reduction rate at the slab tip part becomes large, the flange thickness increasing rate is still a value close to 1.00. If the value of the caliber restraining rate B is too large, the rolling and shaping proceeds in a state where the material to be rolled A is restrained too much at the time of final split rolling and shaping, resulting in that elongation in the longitudinal direction becomes significant and the increase in flange thickness is not sufficiently realized. Specifically, in order to realize a certain degree of the increase in flange thickness, for example, the caliber restraining rate B is preferably 0.90 or less.

[0074] Note that the technique according to the above Patent Document 1 (Japanese Laid-open Patent Publication No. 2017-121655) discloses the configuration in which the caliber side surfaces abut against right and left of the material to be rolled A to restrain the material to be rolled A, and it is possible to understand that the condition such that the caliber restraining rate B is 1.0, for example, is disclosed. However, there is no description in Patent Document 1 that the reduction of the slab tip part is performed in a state of performing the restraint in the caliber, and Patent Document 1 does not mention at all the relationship between the reduction rate at the slab tip part and the flange thickness increasing rate.

[0075] From the data obtained in FIG. 11, it is possible to define, at first, that the caliber restraining rate B with which the flange thickness increasing rate takes a high value (the flange thickness increasing effect can be sufficiently obtained) regardless of the reduction rate at the slab tip part, is 0.70 or more. The caliber restraining rate B of 0.70 or more is preferable because, in a case where the caliber restraining rate B is 0.65, the flange thickness tends to be reduced when the reduction rate at the slab tip part is too large.

[0076] Note that the condition of the caliber restraining rate B = 1.0 is a condition in which active reduction of the slab tip part is not performed and the increase in flange thickness is not realized, so that the caliber restraining rate B is preferably set to less than 1.0, and further, it is preferably set to 0.9 or less based on the data in FIG. 11.

[0077] Further, from the data obtained in FIG. 11, it can be understood that when performing the rolling and shaping under a condition where the reduction rate (cumulative reduction rate) at the slab tip part is in a range of 0.20 or more and 0.25 or less, a phenomenon of reducing the flange thickness is significantly observed when the caliber restraining rate B is 0.65, in particular, so that when performing the rolling and shaping in the above range, it is possible to secure a sufficient flange thickness increasing rate by defining the caliber restraining rate B to 0.70 or more.

[0078] Here, for example, as described in Non-Patent Document "Journal of Japan Society for Technology of Plasticity, Spring Conference in 1978 (1978. 5. 17 to 19 in Hiroshima), pages 209 and 210", a deformation configuration (deformation mode) due to rolling according to a material to be rolled having a rectangular cross section, is mainly classified broadly into a configuration referred to as single bulging and a configuration referred to as double bulging. Based on these findings, when attention is focused on the rolling and shaping of the flange part 80, and a roll diameter, a reduction rate, a sheet width, and a sheet thickness described in the above Non-Patent Document are respectively applied to normal production conditions of H-shaped steel, a boundary between the single bulging and the double bulging is known to be

a case where a value of a ratio I (also simply described as I , hereinafter) between a flange half-width and a flange thickness of a material having a rectangular cross section is about 1.30, and it is understood that if I exceeds 1.30, a deformation due to rolling intensively occurs on an end part of a material to be rolled to form a double bulging shape, and if I is 1.30 or less, the deformation due to the rolling intensively occurs on a center of the material to be rolled to form a single bulging shape.

[0079] When the rolling and shaping is performed by the above-described basic caliber configuration, a condition under which the above-described double bulging shape is exhibited by the rolling and shaping in the fifth caliber K5 is a case where I exceeds 1.30, and in such a case, a vicinity of a part at 1/2 of a flange half-width is shaped to be thinner than the tip. Table 1 presents values of I when thicknesses of raw materials (generally-known slab thicknesses) are 250 mm and 300 mm, and flange widths of H-shaped steels to be produced are 300 mm, 400mm, 500 mm, and 600 mm. Note that in the rolling and shaping according to the present embodiment, a shape closer to the shape of the product flange can be obtained as a shape of the flange part 80 after slab edging shaping, so that large reduction in a flange width direction is not performed. For this reason, a flange half-width after rough rolling and a flange half-width of an H-shaped steel product are substantially equal, and a half-width of the flange part 80 after the rough rolling may be considered as 150 mm, 200 mm, 250 mm, or 300 mm each being a value of about a half a flange width of each of the H-shaped steels to be produced.

[Table 1]

	PRODUCT FLANGE WIDTH	300mm	400mm	500mm	600mm
	FLANGE HALF-WIDTH AFTER ROUGH ROLLING	150mm	200mm	250mm	300mm
250 mm THICKNESS	FLANGE THICKNESS AFTER ROUGH ROLLING	125mm	125mm	125mm	125mm
	RATIO I BETWEEN WIDTH AND THICKNESS	1.20	1.60	2.00	2.40
300 mm THICKNESS	FLANGE THICKNESS AFTER ROUGH ROLLING	150mm	150mm	150mm	150mm
	RATIO I BETWEEN WIDTH AND THICKNESS	1.00	1.33	1.67	2.00

[0080] As indicated in Table 1, when a shaping method of creating splits in a slab thickness and bending divided parts is employed, approximately 1/2 of the slab thickness directly becomes a finished flange thickness after finishing the edging rolling, so that when producing H-shaped steel products with product flange widths of 400 mm, 500 mm, and 600 mm from raw materials each having a thickness of 250 mm, I takes a value exceeding 1.30. Further, also when H-shaped steel products with product flange widths of 400 mm, 500 mm, and 600 mm are produced from raw materials each having a thickness of 300 mm, I takes a value exceeding 1.30.

[0081] As explained with reference to Table 1, when the rolling and shaping is performed based on the above-described basic caliber configuration at a time of producing an H-shaped steel product with a flange width of 400 mm or more, in particular, in the flat shaping and rolling in the fifth caliber K5, a vicinity of a part at 1/2 of a flange half-width is shaped to be thinner than a tip, which results in forming a so-called double bulging shape. Accordingly, a method of increasing a flange thickness so as to avoid this is required, and it is particularly required to increase a thickness of the vicinity of the part at 1/2 of the flange half-width.

[0082] Regarding such circumstances, even under a condition such that a so-called double bulging shape has been formed in the flat shaping and rolling in the fifth caliber K5 in the past, by employing the caliber design (the caliber restraining the material to be rolled) provided with the side walls according to the present embodiment which is used when performing the final split rolling and shaping, and further, by setting the caliber restraining rate in the caliber design to a value within a predetermined suitable numerical range, it is possible to efficiently realize a sufficient increase in the flange thickness.

[0083] As described above, in the method for producing the H-shaped steel according to the present embodiment, the basic caliber configuration is provided, and in addition to that, the caliber design of the final caliber out of the calibers performing the split rolling and shaping is set to have the configuration provided with the side walls to provide the caliber which restrains the material to be rolled A, resulting in that the flange thickness increasing rate can be set to a high value, and it is possible to efficiently realize the increase in thickness of the flange part 80 (the flange root part, in particular). In this case, by defining the caliber restraining rate B to 0.70 or more, in particular, it is possible to secure a sufficient flange thickness increasing rate.

[0084] Note that it is understood that the caliber design which realizes a high flange thickness increasing rate as described above is particularly effective when the rolling and shaping is performed under a condition in which the value of the ratio I between the flange half-width and the flange thickness in the flange part 80 becomes 1.30 or more.

[0085] 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.

[0086] In the above-described embodiment, the technique of rolling and shaping the material to be rolled A 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, but, the number of calibers for performing the rough rolling step is not limited to this, and it is possible to perform the rough rolling step by using calibers whose number is larger than the above. 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.

[0087] Further, the above embodiment illustrates and explains the case where the 2-1 st caliber K2-1 and the 2-2nd caliber K2-2 being two calibers with different wedge heights are engraved as the configuration of the split caliber, and explains that it is preferable that the 2-2nd caliber K2-2 being the final caliber of the split caliber is improved to have the configuration provided with the side walls (namely, K2-2a), but, the split caliber may be configured by one caliber, or it may also be configured by plural calibers of three or more. However, when the split caliber is configured by plural calibers of three or more, the caliber employing the above-described caliber design such that it is provided with the side walls to restrain the material to be rolled A, is desirably set to a final caliber of a caliber group performing the split rolling and shaping.

[0088] Further, explanation has been made by exemplifying a slab as a raw material when producing H-shaped steel, but, the present invention is naturally applicable also to other raw materials in a similar shape.

[Industrial Applicability]

[0089] The present invention is applicable to a production method for producing H-shaped steel using, for example, a slab having a rectangular cross section or the like as a raw material.

[Explanation of Codes]

[0090]

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
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 (2-1st caliber)
31	lower caliber roll (2-1st caliber)
35, 36	projection (2-1st caliber)
38, 39	split (2-1st caliber)
40	upper caliber roll (2-2nd caliber)
41	lower caliber roll (2-2nd caliber)
45, 46	projection (2-2nd caliber)
48, 49	split (2-2nd caliber)
50	upper caliber roll (third caliber)
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)

	65, 66	projection (fourth caliber)
	68, 69	split (fourth caliber)
	80	flange part
	82	web part
5	85	upper caliber roll (fifth caliber)
	86	lower caliber roll (fifth caliber)
	K1	first caliber
	K2-1	2-1st caliber
	K2-2	2-2nd caliber
10	K2-2a	(improved) 2-2nd caliber
	K3	third caliber
	K4	fourth caliber
	K5	fifth caliber (flat shaping caliber)
	T	production line
15	A	material to be rolled

Claims

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

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

25 a rolling mill that performs the rough rolling step is engraved with plural calibers configured to roll and shape a material to be rolled;
the plural calibers include:

30 a grooving caliber configured to perform grooving vertically with respect to end parts in a width direction of the material to be rolled;
one or plural split calibers formed with projections configured to create splits vertically with respect to the end parts in the width direction of the material to be rolled after being grooved to form divided parts on the end parts of the material to be rolled; and
35 plural bending calibers formed with projections configured to abut against the splits and sequentially bend the divided parts formed by the split caliber;
at least the split caliber of the last stage out of the one or plural split calibers is provided with caliber side surfaces configured to abut against right and left side surfaces of the material to be rolled and restrain the material to be rolled from right and left; and
40 in the split caliber provided with the caliber side surfaces, rolling and shaping is performed under a condition where a caliber restraining rate B represented by the following equation (1) becomes 0.7 or more and less than 1.0,

$$45 \quad B = t / t_0 \quad \dots (1)$$

where t indicates a flange tip thickness when the split rolling and shaping, and the bending rolling and shaping are performed under the restraint in the caliber, and t₀ indicates a thickness of a slab end surface corresponding to a thickness of a flange tip formed by the grooving caliber.

50 2. The method for producing the H-shaped steel according to claim 1, wherein the rolling and shaping is performed under a condition where a cumulative reduction rate until when the rolling and shaping in the split caliber provided with the caliber side surfaces is completed is 0.20 or more and 0.25 or less.

55 3. The method for producing the H-shaped steel according to claim 1 or 2, wherein a tip angle of the projections formed on the one or plural split calibers is 25° or more and 40° or less.

4. The method for producing the H-shaped steel according to any one of claims 1 to 3, wherein in the one or plural split calibers and the plural bending calibers, light reduction is performed in a state where end surfaces of the material to be rolled are in contact with caliber surfaces facing the end surfaces in shaping of at least one pass or more.

5. The method for producing the H-shaped steel according to any one of claims 1 to 4, wherein:

the plural calibers include a flat shaping caliber configured to perform flat shaping and rolling on the material to be rolled after passing through the plural split calibers and the plural bending calibers; and the rolling and shaping in the flat shaping caliber is performed under a condition where a ratio l between a flange half-width and a flange thickness is 1.30 or more in a flange part of the material to be rolled corresponding to the divided part.

6. The method for producing the H-shaped steel according to claim 5, wherein a raw material having a rectangular cross section and a thickness of 280 mm or more and 320 mm or less is used, and the flange half-width of the flange part of the material to be rolled before being subjected to the rolling and shaping in the flat shaping caliber is set to 200 mm or more.

FIG.1

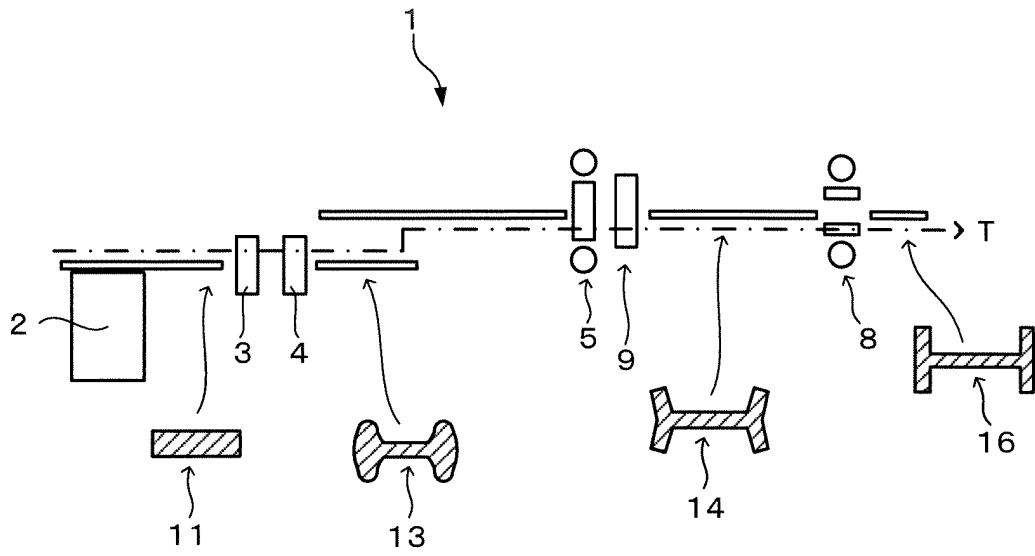


FIG.2

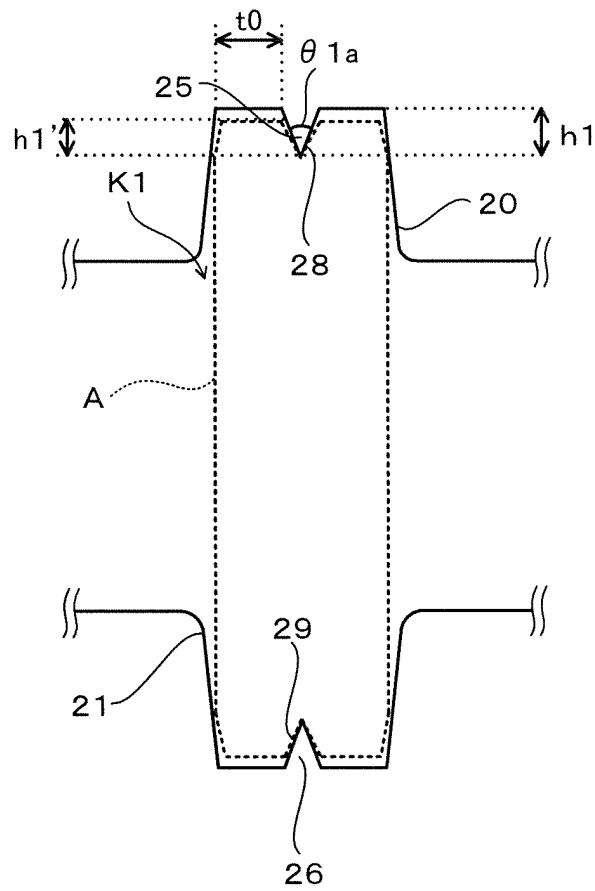


FIG.3

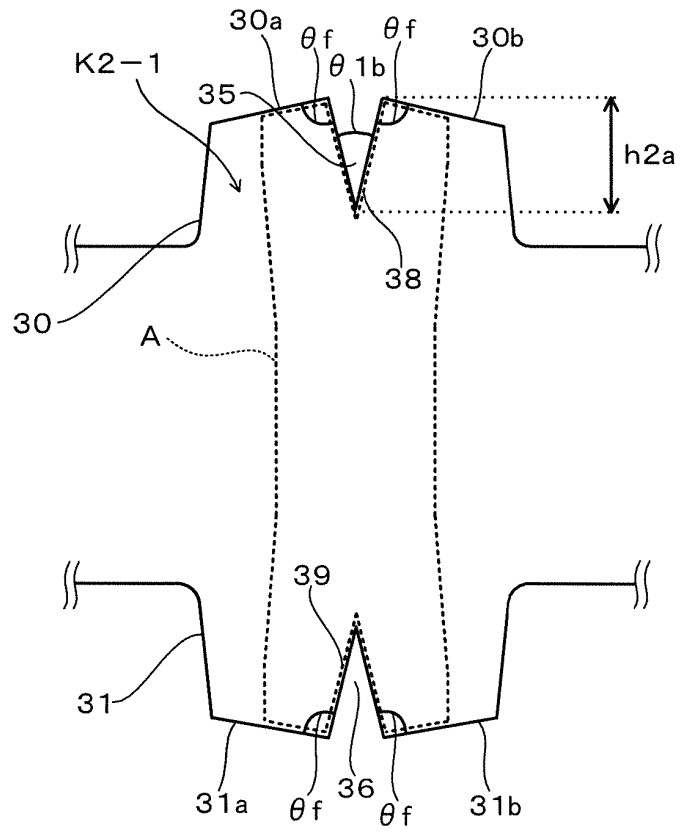


FIG.4

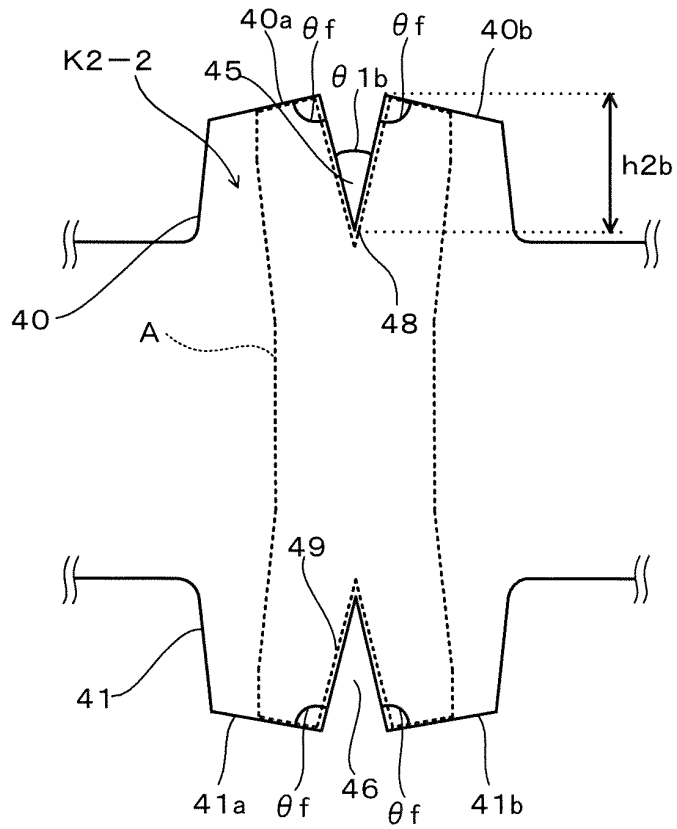


FIG.5

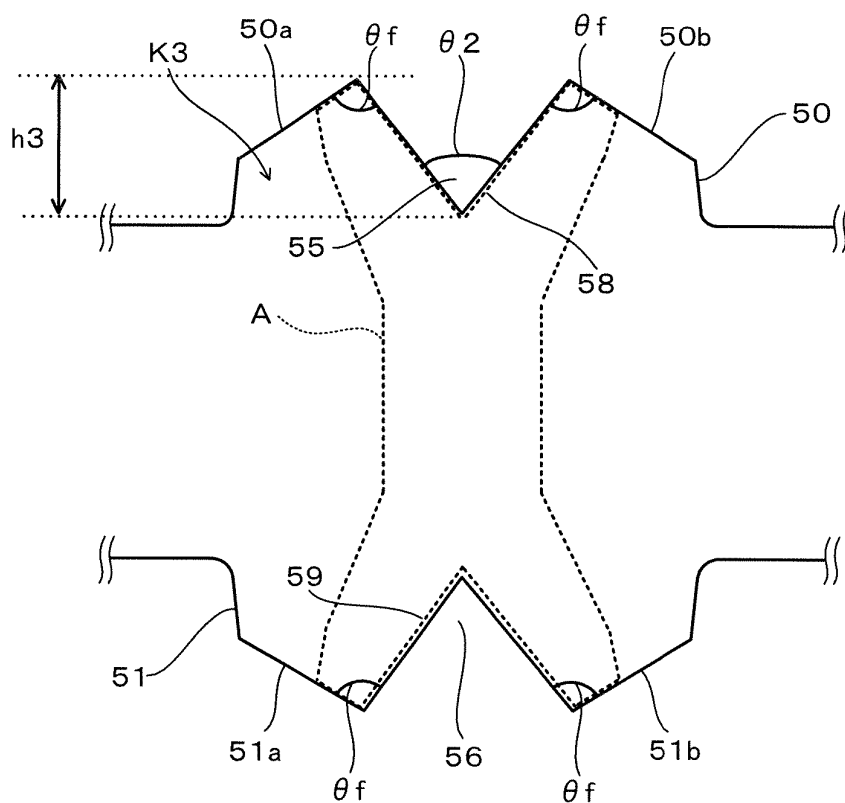


FIG.6

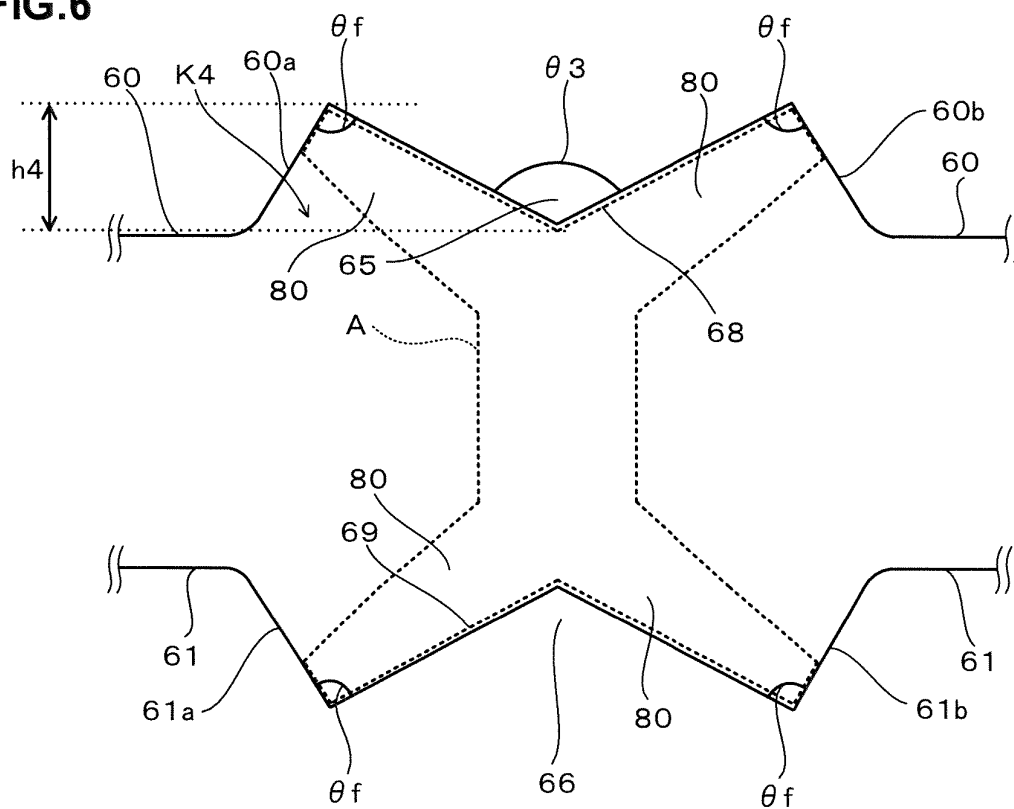


FIG.7

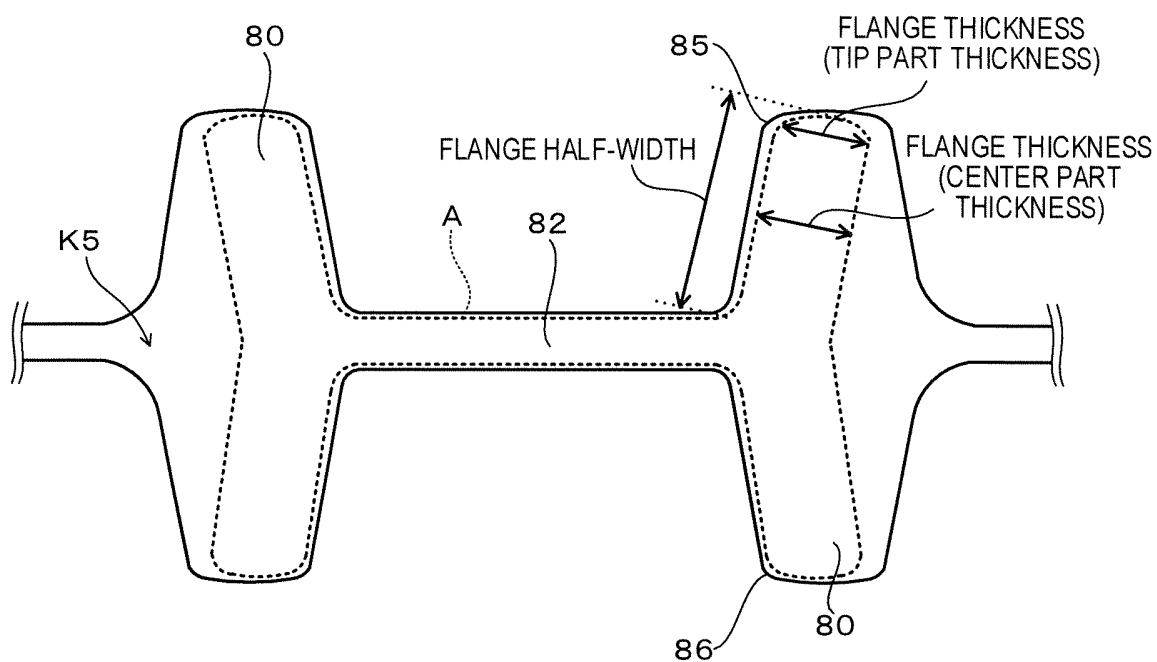


FIG.8

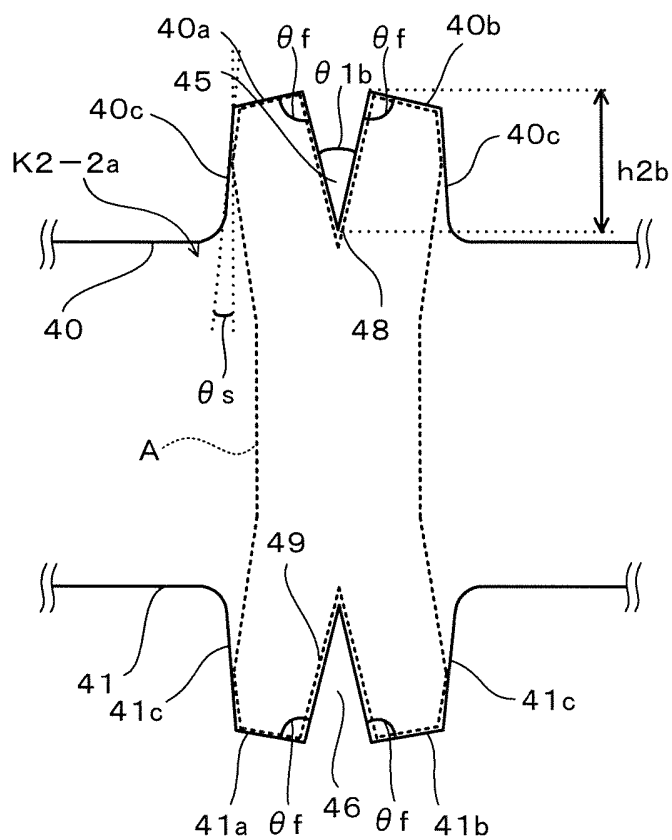


FIG.9

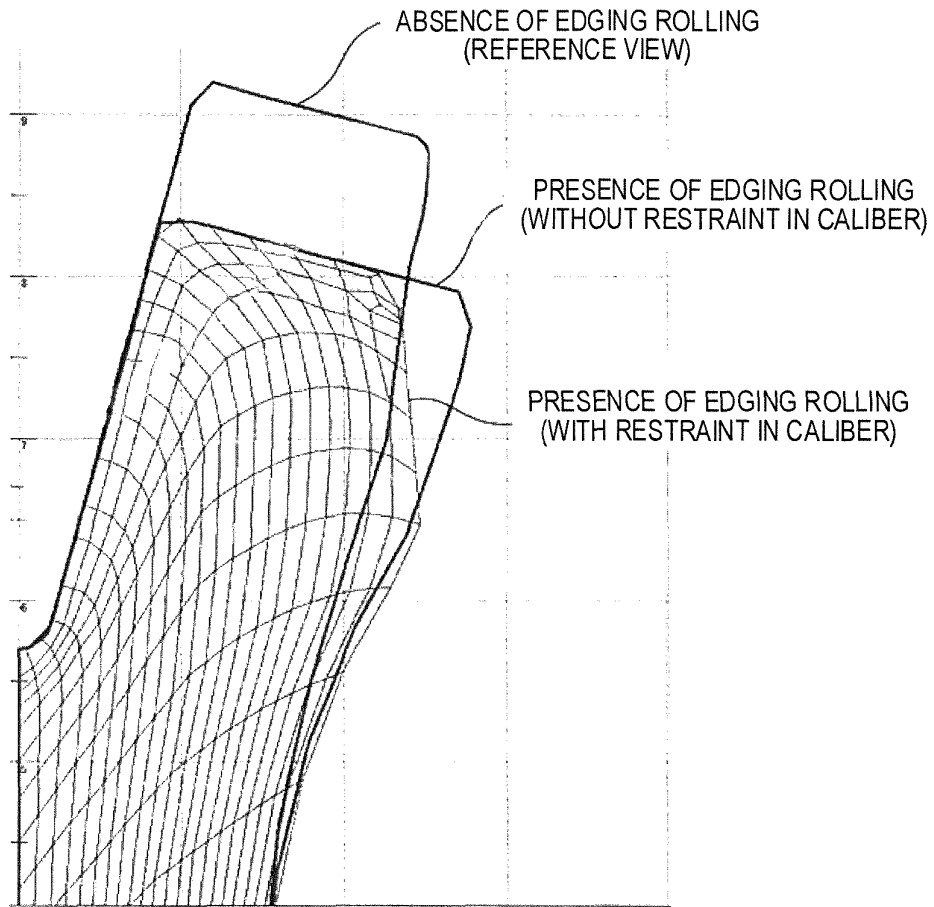


FIG.10

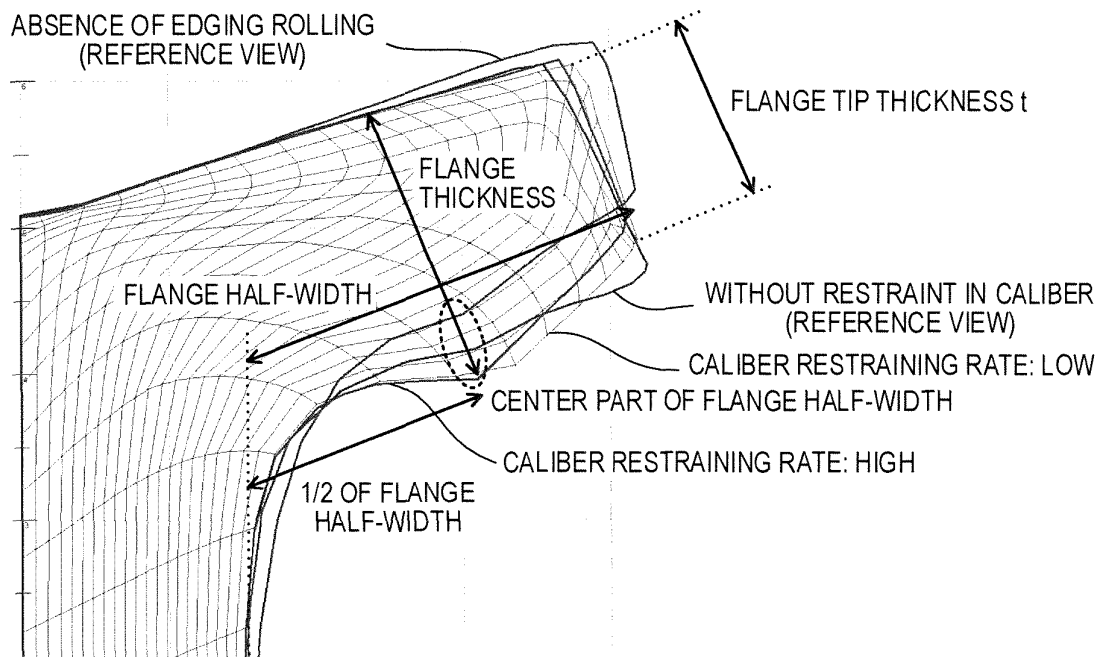
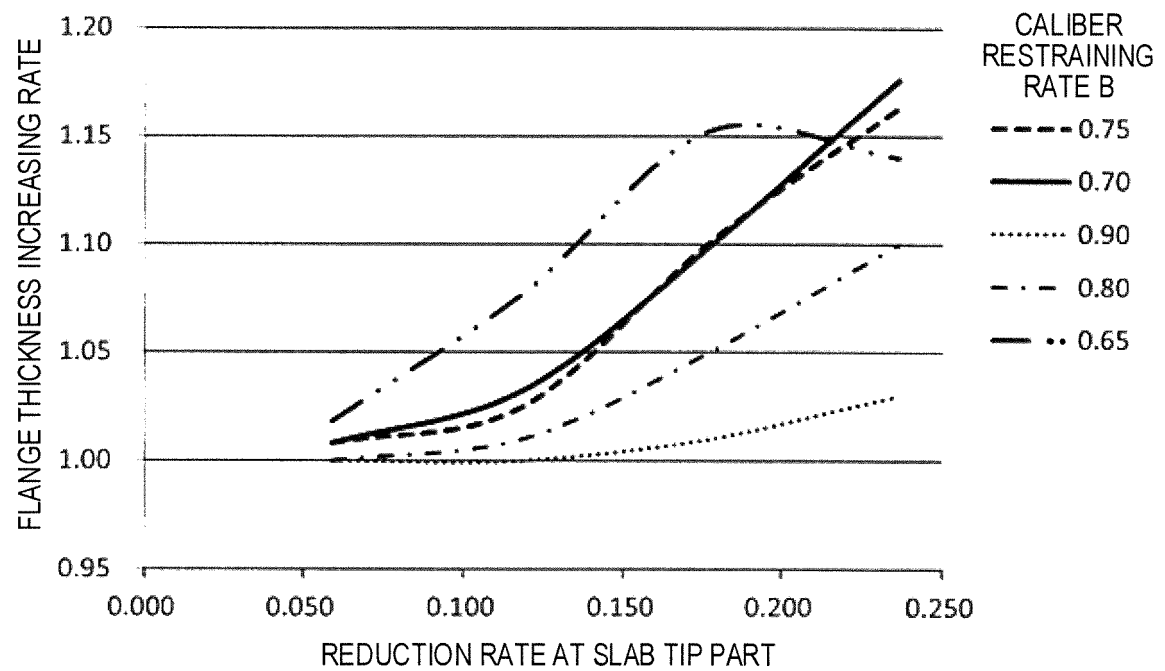


FIG.11



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2018/040716

A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl. B21B1/08(2006.01)i, B21B1/088(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. B21B1/00-11/00, B21B47/00-99/00

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 2007-136508 A (NIPPON STEEL CORP.) 07 June 2007, entire text, all drawings (Family: none)	1-6
A	JP 2017-121655 A (NIPPON STEEL & SUMITOMO METAL CORPORATION) 13 July 2017, entire text, all drawings (Family: none)	1-6
A	JP 2003-170202 A (NIPPON STEEL CORP.) 17 June 2003, entire text, all drawings (Family: none)	1-6

☐ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
25 December 2018 (25.12.2018)Date of mailing of the international search report
15 January 2019 (15.01.2019)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 2017121655 A [0008] [0074]

Non-patent literature cited in the description

- *Journal of Japan Society for Technology of Plasticity, Spring Conference, 1978, vol. 5 (17 to 19), 209, , 210*
[0078]