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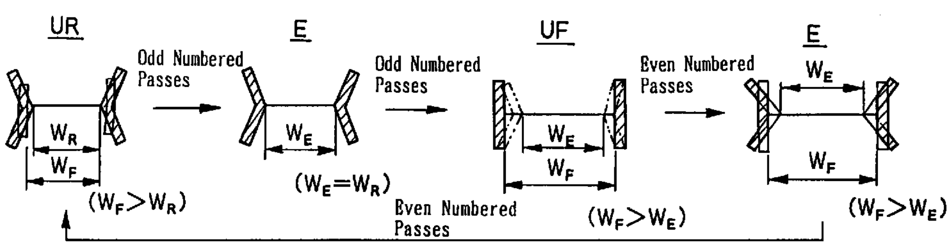
(54) METHOD OF AND APPARATUS FOR HOT ROLLING H-STEEL

(57) Object: In order to prevent (1) problems occurred at the time of biting of flanges by rolls, (2) wear of lateral surfaces of horizontal rolls of the fixed-width type as well as need for a frequent roll exchange, (3) wear of lateral surfaces of horizontal rolls of the fixed-width type, and (4) formation of rolling flaws on the inner surfaces of flanges, during tandem rolling through a roll arrangement of UR + E + UF .

Constitution: A reverse rolling is carried out with a UR mill having a width W_R of horizontal rolls, a UF mill having a width W_F of horizontal rolls, and an E mill having a width W_E of horizontal rolls under the conditions $W_F > W_E$, W_R, or $W_E < W_F$, W_R.

Fig. 1 0



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Description

(Technical Field)

The present invention relates to a method of hot rolling H-shaped steel products for use in technical fields such as civil engineering and building construction, as well as to an apparatus for carrying out the method. More particularly, the invention relates to a hot rolling method of H-shaped steel products and apparatuses therefor, in which rolling stands are compactly arranged in a limited space. According to the present invention, hot rolling can be carried out efficiently with a high yield, and it is possible to reduce the number of inventory rolls.

(Background Art)

Tandem rolling is a method of rolling with a plurality of rolling stands arranged in series in close proximity to each other. In the case of H-shaped steel products, since it was necessary to synchronize a rolling speed and to secure biting properties of rolls for each of the stands, it was a general practice in the past that a universal roughing mill (UR) and an edging mill (E) were arranged in tandem, but a universal finishing mill (UF) was provided independently remote from these mills. Thus, it was unavoidable that the length of a rolling stand line to produce H-shaped steel products was large, even if the tandem rolling was employed.

In order to shorten such a long-extended line of rolling stands for H-shaped steel products, it has been proposed that the UF mill also be arranged in tandem, i.e., the line of rolling stands of UR-E-UF in which each of the rolling stands is arranged closely to each other has been proposed. See Japan Patent Publication No.57-4401/1982. However, this is substantially the same as the prior art so long as the rolling operations are concerned, since the UF mill is off-duty while usual shape rolling with a reduction in thickness is carried out, and just the last finish pass is carried out through the line of UR-E-UF. The difference from the before-mentioned rolling line is that the UF is placed close to the E in the proposed one, but the UF is placed remote from the E in the conventional one.

The rolling efficiency, therefore, is reduced markedly and the installation capacity is not utilized thoroughly, compared with conventional long-extended equipment. This is because high speed shaping rolling cannot be started until the low speed finishing pass is carried out through a tandem rolling stands of UR-E-UF.

Furthermore, although the UF mill is not used during the usual shape rolling, an increase in operation costs is unavoidable since the UF mill suffers from wear and thermal affects of the lower rolls when the rolling material passes through the rolling stand.

Thus, from the viewpoint that tandem rolling be achieved, improvement in not only rolling operations but also roll stand arrangement of UR-E-UF have been proposed. However, since the flange angle for a UR is different from that for a UF, biting of shaped steels by the rolls does not occur smoothly. If a shaped steel is forced into a roll gap, the lateral surfaces of the horizontal rolls and the inner surfaces of the flange are rubbed against each other, and scratches will be formed on these surfaces with a degradation in the quality of the product. Regarding this problem, the following methods have been proposed in the prior art.

Japanese Patent Publication No.6-83845/1994 discloses a method of rolling shaped steels using three mills, such as UR, E, and UF mills, which are installed close to each other in series, the work rolls of the UR mill comprising an X-shaped caliber, i.e., vertical rolls have a double-conical shape in section, and the UF mill comprising an H-shaped caliber, i.e., the vertical rolls are flat rolls. The method comprises carrying out forward and reverse rolling of shaped-steels in a tandem roll arrangement using these three mills and finishing the shaped steels with the H-shaped caliber in the final pass through the UF mill.

Figure 1 shows an example of the roll pass design which is employed in the above rolling method employing X caliber + X caliber + H caliber. In the drawings, the H-shaped steel piece 1 is subjected to reverse rolling, i.e., UR- E - UF, and then UF - E - UR. Angles θ_R, θ_E, and θ_F are tilting angles, i.e., open angles of flanges of H-shaped steel products of horizontal rolls 10, 12, and 14, respectively, for the UR, E, and UF mills. Reference figures 16 and 18 indicate vertical rolls of UR and UF mills, respectively.

The angle θ_R is adjusted to be about 5 - 10° for the universal roughing mill (UR), and the angle θ_E is adjusted to be $\theta_E \fallingdotseq \theta_R$.

The universal finishing mill (UF) is provided with an H-caliber and the angle θ_F is nearly equal to zero ($\theta_F \fallingdotseq 0$).

However, prior art methods have the following disadvantages.

(1)Since the tilting angle θ_F of a horizontal roll of the UF mill is nearly equal to zero ($\theta_F \fallingdotseq 0$), the same level of rolling load as in the UR mill is applied in the UF mill, so wear of the horizontal roll is severe, resulting in a degradation in the dimensional accuracy and yield of products.

(2) Since the width of the horizontal roll of the UF mill is fixed, it is not possible to suppress the degradation in dimensional accuracy and yield, which are caused for the reasons mentioned in (1) above, by expanding the width of horizontal rolls to a predetermined width. A frequent change of rolls is inevitable.

(3) When the H-shaped steel piece 1 is passed from the UF mill to the E mill during rolling, it is necessary to expand the angle of a flange from θ_F to θ_E. However, as shown in Figure 2, when the roll width is not properly adjusted for each mill, there will be flaws 22 formed in the inner surface of flanges 20 of the H-shaped steel piece 1. Sometimes, as shown in Figure 3, there will occur the problem that flanges 30 of the H-shaped steel piece 1 will not be inserted into rolls 12 of the E mill.

Japan Kokai No. 4-258301/1992 discloses a rolling apparatus for shaped steels having parallel flanges, the apparatus comprising three mills, i.e., a universal roughing mill, an edging mill, and a universal finishing mill in a tandem line. Either one of the horizontal rolls for the universal roughing mill and the universal finishing mill has a variable width, and the other one has a fixed-width. The angle of the edge surfaces of the horizontal rolls is preferably 0°. According to the disclosure, the web height of the shaped steels can be controlled by means of either one of the universal roughing mill and the universal finishing mill.

Figure 4 shows one example of the roll pass design of the above-described method of rolling, in which the UR, E, and UF mills are all provided with an H-caliber. An H-shaped steel piece 1 is successively rolled through horizontal rolls 40, 42, 44 and vertical rolls 46, 48 for the UR, E, and UF mills, respectively. The E and UF mills are provided with variable-width horizontal rolls, and the UF mill can expand or reduce the web height, as shown by the drawings labeled UF_1 and UF_2, respectively.

However, this prior art method has the following disadvantages.

(1) Since an angle of the side surface of a horizontal roll, i.e., the angle (taper angle) of a horizontal roll is the same (= 0°) for the UR (universal roughing mill), the E (edging mill), and the UF (universal finishing mill), it is very possible that when a rolling material is inserted into the mill, a flange thereof will be crushed, i.e., flange contact troubles occur if the width of a horizontal roll of each of the mill is not set properly. In order to avoid such troubles, it is necessary, for example, to reduce the feed speed at the time of contact so as to insert the rolling material between the rolls carefully, resulting in a marked decrease in productivity. Such troubles easily occur not only when the rolling material is inserted into the universal mills, but also when it is inserted into the E mill. There is no mention in the document about the roll width and adjustment procedures thereof for each of the mills.

(2) Since the angle (taper angle) of a horizontal roll is 0°, i.e., the same for each of the UR, E, and UF mills, severe wear is inevitable on the lateral surfaces, i.e., the surface portions contacting the inner surface of flanges for each of the horizontal rolls. In addition, since the UR mill employs horizontal rolls of the fixed-width type, which are not employed in the E mill and UF mill, horizontal rolls of the UR mill must be frequently changed in order not to result in a degradation in thickness accuracy as well as rolling yield.

(3) When the flange contacting trouble occurs as mentioned in Item (1), rolling defects such as flaws occur easily on the inner flange surface.

Figures 5a and 5b show an example of the flange contacting troubles which occur in the above-mentioned rolling method. Figure 5a illustrates an H-shaped steel piece which has just entered the UR mill, and Figure 5b illustrates the H-shaped steel piece just before leaving the UR mill.

As shown in Figure 5a, the UR mill comprises horizontal rolls 50 and vertical rolls 56, and the center of the UR mill and the center of the rolling material, i.e., the H-shaped steel piece 1 are separated by the distance α. The horizontal rolls 50 therefore contact the top edges of the flanges in the area A. As a result, as shown in Figure 5b, the widths of the flanges are different from each other when leaving the UR mill, i.e., the width of flange 2a of H-shaped steel piece 1 is small, and the width of flange 2b is large.

(Disclosure of the Invention)

An object of the present invention is to provide a method of hot rolling H-shaped steel products through a tandem rolling mill of UR-E-UF and an apparatus for carrying out the method, which can achieve the following advantages.

(1) There are no problems at the time of biting of flanges by rolls.

(2) Wear of the lateral surfaces of horizontal rolls of the fixed-width type of the UR or UF mill is reduced to extend their service life.

(3) Wear of the lateral surfaces of horizontal rolls of the fixed-width type of the UF mill is reduced to prevent a degradation in dimensional accuracy and yield of rolled products.

(4) There is no formation of rolling defects, such as flaws on the inner surfaces of a flange.

The inventor of the present invention carried out numerous rolling experiments including reverse rolling of beam blanks obtained by reverse breakdown rolling using UR-E-UF tandem rolling mills, as shown in Figure 6. The mills comprised a universal roughing mill (UR), an edging mill (E), and a universal finishing mill (UF). The horizontal roll of the UR was of the fixed-width type, that of the E was of the variable-width type, and that of the UF was of the variable-width type.

Namely, the inventor carried out rolling experiments on H-shaped steel piece 1 under hot rolling conditions, using a three-mill rolling line, as detailed in Figure 7, which comprised a universal roughing mill (UR), an edging mill (E), and a universal finishing mill (UF), in which the horizontal rolls of the E and UF mills were divided into two pieces and had a variable-width in the roll axis direction.

According to the roll pass design in the experiments, as shown in Figure 7, the lateral surface of the horizontal roll 72 of the universal roughing mill (UR) had a taper at an angle θ_R (θ_R = 3° - 5°), and the vertical rolls 74 had a double-conical shape in section with a taper at an angle θ_R.

The horizontal rolls 76 of the edging mill (E) also had a taper at an angle θ_E in the barrel portion thereof. The angle θ_E was the same as the angle θ_R. The taper angle θ_F of the lateral surface of the horizontal rolls 78 of the universal finishing mill (UF) was adjusted to be approximately 0°.

Thus, the roll path design was X caliber ⇄ X caliber ⇄ H caliber.

On the basis of experimental data, the inventor obtained the following important findings. (1) According to an embodiment, if the inner web width of the rolling material is W_E and the roll width of the variable-width horizontal rolls is W_F, even if $W_F > W_E$, the rolling material smoothly enters the universal finishing mill, and there are no flaws or troubles when flanges are inserted into rolls.

The relationship between an H-shaped steel piece and rolls is schematically shown by Figure 8a and Figure 8b, wherein Figure 8a illustrates an H-shaped steel piece 1 just before entering into the universal finishing mill (UF), and Figure 8b illustrates the H-shaped steel piece just after leaving the UF mill. It was discovered that the distance δ between the lateral surface of the variable-width horizontal roll 78 and each inner top edge of flanges 2 is, as shown in Figure 8a, preferably 3 - 4 mm or more. The upper limit thereof varies depending on the flange width. When the flange width is 200 mm, for example, the distance may be 8 mm or less.

After finishing rolling, as shown in Figure 8b, the inner web width of the rolling material is expanded from W_E to W_F, and simultaneously the taper angle of the flange 2 decreases from θ_E ($\fallingdotseq \theta_R$) to θ_F ($\fallingdotseq$ 0°), as shown in Figure 7. (2) According to another embodiment, if the inner web width of the rolling material after the universal finishing mill is W_F and the roll width of the variable-width horizontal rolls of the edging mill is W_E and if $W_E < W_F$, the rolling material smoothly enters the edging mill and there are no flaws or troubles when flanges are inserted into rolls. However, if $W_E = W_F$ or $W_E > W_F$, troubles inevitably occur.

The relationship between an H-shaped steel piece and rolls in this embodiment is schematically shown by Figure 9a and Figure 9b, wherein Figure 9a illustrates an H-shaped steel piece 1 just before entering the edging mill (E), and Figure 9b illustrates the H-shaped steel piece just after leaving E. It was discovered that the distance δ between the lateral surface of the variable-width horizontal roll 76 and each inner top edge of flanges 2 is, as shown in Figure 9a, preferably 2 - 4 mm or more. When the distance is too large, such a large distance causes a large difference between the widths of the right and left flanges. The upper limit thereof is preferably 15 mm. Thus, the distance δ is preferably within the range of 2 - 15 mm. More desirably, the distance is 8 mm or less.

After rolling with the edging mill, as shown in Figure 9b, the inner web width W_F of the rolling material is maintained, but the taper angle of the flange 2 slightly increases from θ_F ($\fallingdotseq$ 0°) to the taper angle θ_E of the edging mill.

The symbols W_F and W_E indicate the inner web widths of the H-shaped steel piece just after leaving the universal finishing mill and edging mill, respectively. These symbols sometimes indicate the widths of the variable-width horizontal rolls of these respective mills, too. Since the lengths of these widths are the same, respectively, the same symbols are used to describe these respective widths in this specification for the purposes of convenience.

The present invention has been completed on the basis of the above-mentioned discoveries, and is summarized as follows:

(1) A method of hot rolling an H-shaped steel product, in which a rough rolled steel stock having webs and flanges which has been subjected to break-down rolling is rolled under hot conditions through reverse rolling using three rolling mills including a universal roughing mill having horizontal rolls of the fixed-width type, an edging mill having horizontal rolls of the fixed-width or variable-width type, and a universal finishing mill having horizontal rolls of the variable-width type, characterized in that the universal roughing mill has an X-caliber, the edging mill has an X-caliber, and the universal finishing mill has an H-caliber, and that, in the course of continuous rolling through three rolling mills except for the last pass, the width W_F of the horizontal rolls of the variable-width type of the universal finishing mill is adjusted to be larger than the widths W_R and W_E, which are the widths of horizontal rolls of the universal roughing mill and the barrel portions of horizontal rolls of the edging mill, respectively, so that the inner web width of the H-shaped steel stock after rolling with the edging mill is increased during the successive rolling through the universal finishing mill.

(2) A method of hot rolling an H-shaped steel product as defined in (1) above, wherein the widths W_R of horizontal rolls of the universal roughing mill are adjusted to be substantially the same as the width W_E of the barrel portions of horizontal rolls of the edging mill.

(3) A method of hot rolling an H-shaped steel product as defined in (1) above, wherein the inner web width is finished to a final target size by means of a final pass through the universal finishing mill.

(4) A method of hot rolling an H-shaped steel as defined in (1) above, wherein horizontal rolls of the variable-width type are employed for the universal roughing mill.

(5) A method of hot rolling an H-shaped steel, in which a rough rolled steel stock having webs and flanges which has been subjected to break-down rolling is rolled under hot conditions through reverse rolling using three rolling mills including a universal roughing mill having horizontal rolls of the fixed-width type, an edging mill having horizontal rolls of the variable-width type, and a universal finishing mill having horizontal rolls of the variable-width type, characterized in that the universal roughing mill has an X-caliber, the edging mill has an X-caliber, and the universal finishing mill has an H-caliber, and that the width W_E of the barrel portions of horizontal rolls of the edging mill is adjusted to be smaller than the widths W_R and W_F, which are the widths of horizontal rolls of the universal roughing mill and the universal finishing mill, respectively, at each path during continuous rolling from the downstream side to the upstream side through these three mills.

(6) A method of hot rolling an H-shaped steel as defined in (5) above, wherein the widths W_R of horizontal rolls of the universal roughing mill are adjusted to be substantially the same as the width W_F of horizontal rolls of the universal finishing mill.

(7) A method of hot rolling an H-shaped steel as defined in (5) above, wherein the inner web width is finished to a final target size by means of a final pass through the universal finishing mill.

(8) A method of hot rolling an H-shaped steel as defined in (5) above, wherein horizontal rolls of the variable-width type are employed for the universal roughing mill.

(9) An apparatus for hot rolling H-shaped steel products, which comprises, in tandem, a universal roughing mill having an X-caliber, an edging mill having an X-caliber and having fixed-width or variable-width rolls, and a universal finishing mill having an H-caliber and having variable-width rolls.

(10) An apparatus for hot rolling H-shaped steel products as defined in (9) above, wherein the universal roughing mill comprises variable-width rolls.

(Brief Description of Drawings)

Figure 1 is an illustration of an example of a roll path design of conventional universal mills.

Figure 2 is a schematic perspective view of flaws formed on the inner surface of a flange.

Figure 3 is an illustration of problems which occur when flanges are inserted into rolls.

Figure 4 is an illustration of another example of a roll pass design of conventional universal mills.

Figures 5a and 5b illustrate another example of problems which occur when flanges are inserted into rolls.

Figure 6 is a schematic illustration of a production line of H-shaped steel stocks with which the present invention can be practiced.

Figure 7 is an illustration of an example of a roll pass design with which the present invention can be practiced.

Figures 8a and 8b are schematic illustrations of how H-shaped steel products are produced through the UF mill in accordance with the present invention. Figure 8a shows an H-shaped steel piece just before being inserted into the universal finishing mill (UF), and Figure 8b shows the H-shaped steel product after finish rolling.

Figures 9a and 9b are schematic illustrations of how H-shaped steel products are produced through the edging mill (E) in accordance with the present invention. Figure 9a shows an H-shaped steel piece just before inserting into the edging mill (E), and Figure 9b shows the H-shaped steel stock after rolling through the edging mill.

Figure 10 is a schematic illustration of a deforming process of a rolling material in accordance with the process of the present invention for rolling H-shaped steel products.

Figure 11 is a schematic illustration of another example of deforming process of a rolling material in accordance with the process of the present invention for rolling H-shaped steel products.

Figures 12a and 12b are illustrations of another example of a production line of H-shaped steel products with which the present invention can be practiced, and Figure 12a and Figure 12b illustrate a mill layout and a roll pass design, respectively, of the production line in which the UR mill employs horizontal rolls each of which can be divided into three portions.

(Best mode for Carrying Out the Invention)

In conjunction with the accompanying drawings, the operation of the present invention will be described in further detail.

As already described, Figure 6 illustrates an example of a production line for H-shaped steel products, which is an embodiment of the present invention. On the basis of this embodiment, the structure and effect of the present invention will be described in further detail.

Figure 7 illustrates pass designs of rolls installed on each of the universal roughing mill (UR), edging mill (E), and universal finishing mill (UF) in tandem rolling mills. The E mill and UF mill have horizontal rolls each of which is divided into two pieces in the axial direction and has a width which can be varied.

As is apparent from Figure 6, in the present invention the break-down rolling can be carried out in a conventional manner so as to prepare a rough-rolled workpiece from a starting material for intermediate rolling. The resulting rolling material is then subjected to reverse rolling by a plurality of passes through three rolling mills arranged in tandem, which comprises the universal roughing mill, edging mill, and universal finishing mill in the arrangement of UR-E-UF. After the reverse rolling, the H-shaped steel stocks can be finished to final target sizes of flange width, inner web width, flange thickness, and web thickness by a final pass through the UF mill.

It has been a general practice that the width of a horizontal roll of each mill, as shown in Figure 7, is adjusted such that the width W_R of the horizontal rolls of the UR mill is equal to the inner web width of a final H-shaped steel product. The present invention, therefore, follows this general practice to determine the width W_R. In fact, however, it is necessary to allow ±5 mm plus a width of product for wear of a roll. The width W_E of a barrel portion of each horizontal roll of the edging mill (E) is adjusted to be the same as the width W_R, and the width W_F is adjusted to be several millimeters to ten some millimeters larger than the width W_E. Namely, $W_F > W_E \fallingdotseq W_R$. At the final pass through the UF mill, $W_F = W_R$, i.e., a final inner web width is achieved.

The taper angle, i.e., the slope angle of the lateral surfaces of horizontal rolls of each mill is adjusted such that the slope angle θ_R is 3° - 5° for the horizontal rolls 72 of the UR mill, the slope angle θ_E is equal to the slope angle θ_R for the horizontal rolls 76 of the E mill, and the slope angle θ_F is 0° - 0.5° for the horizontal rolls 78 of the UF mill.

Although the horizontal rolls 76 of the E mill have been described as being of the variable-width type, they may be of the fixed-width type. In such a case, it is generally desirable that the width W_E of a barrel portion of the roll be equal to the width W_R, and the width W_E may be several millimeters smaller than the width W_R.

According to the rolling method of the present invention, reverse rolling can be carried out with these rolling mills which are arranged in tandem.

Figure 10 illustrates the course of deformation of a rolling material through the above-described rolling method of the present invention. In the figure, W_R is the width of the horizontal rolls of the UR mill, W_E is the width of barrel portions of the horizontal rolls of the E mill, and W_F is the width of the horizontal rolls of the UF mill. Since $W_F > W_E$, the inner web width is expanded at the UF mill. The passes going from the upstream side to the downstream side are called odd passes, and the reverse ones are called even passes.

According to the present invention, in the course of rolling from the E mill to the UF mill, as shown in Figures 8a and 8b, except for at the final pass, the inner web width is expanded by a given amount (W_F - W_E) at the UF mill, and in the course of the succeeding reverse rolling from the UF mill to the E mill, the rolling material is bit by rolls at the E mill as shown in Figures 9a and 9b. It is possible, therefore, to avoid problems when flanges are inserted into rolls and formation of rolling defects such as flaws on the inner surfaces of flanges.

In this manner, repeated rolling is carried out, and after a given amount of reduction in thickness and shaping has been achieved, the rolling material is finished by a final pass through the UF mill in which the width W_F of the horizontal rolls 78 of the variable-width type is adjusted so as to obtain predetermined sizes of H-shaped steel products (web height, flange thickness, and flange width).

According to still another embodiment of the present invention illustrated in Figure 11, an H-shaped steel production line as shown in Figure 6 is used, in which each rolling mill is provided with rolls having a specific roll pass design as shown in Figure 7, and the width W_R of horizontal rolls of the UR mill is adjusted to be substantially equal to the inner web width of the H-shaped steel product, as described with respect to the before-mentioned embodiment.

In this embodiment, however, as is apparent from Figure 11, the variable width W_E of the barrel portions of horizontal rolls of the edging mill (E) is adjusted in an "on-line" manner to be equal to the width W_R ($W_E = W_R$) in the course of rolling proceeding in the direction from the UR mill to the E mill, the width W_E is adjusted in an "on-line" manner to be equal to the width W_F ($W_E = W_F$) which is the width of horizontal rolls of the universal finishing mill in the course of rolling proceeding in the direction from the E mill to the UF mill, and the width is also adjusted in an "on-line" manner to be $W_E < W_F$ during rolling proceeding from the UF mill to the E mill.

In such a case, the horizontal rolls of the E mill comprise a mechanism by which the width thereof can be varied in an "on-line" manner in a short period of time. Such a mechanism is described in Japan Unexamined Laid-Open Specification No. 60-72603/1985, for example.

Regarding the taper angle of each of the mills, as mentioned before, the taper angle θ_R of the horizontal rolls of the UR mill is adjusted to be 3° - 5°, the taper angle θ_E of the horizontal rolls of the E mill is adjusted to be equal to the taper angle θ_R ($\theta_E = \theta_R$), and the taper angle θ_F of the horizontal rolls of the UF mill is adjusted to be 0° - 0.5°.

Figure 11 illustrates the course of deformation of a rolling material through the above-described rolling method of the present invention.

Namely, according to the present invention in this embodiment, at each pass in the course of rolling proceeding in the direction from the downstream side to the upstream side, i.e., at each of the even passes in the direction from the UF mill to the E mill, the inner web width is equal to the width W_F when the rolling material is introduced into the E mill, i.e., $W_F > W_E$, and the rolling material is bit by rolls at the E mill as shown in Figures 9a and 9b. It is possible, therefore, to avoid problems when flanges are inserted into rolls and formation of rolling defects such as flaws on the inner surfaces of flanges.

The rolling material is next finished by the final pass through the UF mill in which the width W_F of the horizontal rolls of the variable-width type is adjusted so as to obtain predetermined sizes of H-shaped steel products (web height, flange thickness, and flange width).

In this embodiment, compared with the embodiment shown in Figure 10, the advantages can be obtained that there is no need to expand the inner width of a web by an odd pass at the UF mill, and wear on the lateral surfaces, particularly at the corners of the variable-width horizontal rolls of the UF mill can be reduced.

The symbols used in Figure 11 are the same as those used in Figure 10, but the width W_E at the even pass means the width of barrel portions of the horizontal rolls of the E mill.

According to still another embodiment of the present invention, an H-shaped steel production line shown in Figure 6 is used to carry out reverse rolling in three rolling mills arranged in tandem as in UR-E-UF, in which each of the horizontal rolls of the universal roughing mill comprises two pieces divided in the widthwise direction and has a variable-width.

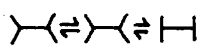
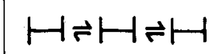
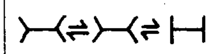
Figures 12a and 12b illustrate a layout of a rolling mill arrangement and roll pass design, respectively, in which the UR mill comprises three piece, variable-width horizontal rolls, the E mill comprises two-piece, variable-width horizontal rolls, and the UF mill comprises two-piece, variable-width horizontal rolls.

According to this embodiment, compared with the cases shown in Figure 10 and Figure 11, it is possible to expand the range of the inner web width of the H-shaped steel products which can be produced using a universal roughing mill with horizontal rolls having the width W_R, so that a marked reduction in the number of inventory rolls can be achieved.

Namely, it is possible to produce H-shaped steel products having different web heights (inner web width) continuously without exchanging rolls. It is also possible to expand the width of the horizontal rolls of the UR mills depending on the amount of wear, so that the initial roll width distribution through the three mills can be maintained the same during rolling, resulting in stabilized tandem rolling.

Table 1 below compares the prior art disclosed in Japan Patent Publication No. 6-83845/1994 and Japan Unexamined Laid-Open Specification No. 4-258301/1992 with the present invention with respect their structure and effect. As is apparent therefrom, the present invention exhibits marked synergistic effects over those of the prior art.

Table 1

		JPP 83845/1994	J. Kokai 258301/1991	Presenrt Invention
Mill Layout		UR−E−UF	UR−E−UF	UR−E−UF
Roll Pass Design				
Variable-Width Rolls		none	E, UF or UR, E	UF or E, UF or UR, E, UF
Evaluation	Prevention of Problems during being bit	×	××	○
	Prevention of Rolling Defects such as Flaws	×	×	○
	Resistance to wear	△	△	○
	Yield	×	○~△	◎~○

Note − × : Poor, △ : Fair, ○ : Good, ◎ : Excellent

Examples

(Example 1)

A working example of the present invention will be explained with emphasis on the process of deformation of H-shaped steel stocks while referring to Figure 10.

The mill layout used in this example was that shown in Figure 6.

The size of the final product was H500 X 200 X 10/16 (mm), and the roll pass design was that shown in Figure 7, the dimensions of which were as follows:

$\theta_R = \theta_E = 5°$, $\theta_F = 0.5°$, δ (UF) = 3 mm (See Figure 8)
W_R = 470 mm (at the beginning), W_E = 470 mm
W_F = 470 mm (for the last pass), 480 mm (for the other passes)

The roll pass schedule was as shown in Table 2 (starting rolling material: 700W X 300t, cc slabs)

The rolling of the present invention proceeded as follows.

Comparative Example 1 was done by repeating the present invention except that, as shown in Figure 7, W_F was adjusted to be W_F = 470 mm for all the passes.

The results are shown below.

	Occurrence of troubles on flanges	Rolling Flaws
Example 1	0% (zero out of 130 pieces)	Substantially no flaws
Comparative 1	15% (12 out of 80 pieces)	Most inner flange surfaces suffered from flaws

(Example 2)

A working example of the present invention will be explained with emphasis on the process of deformation of H-shaped steel stocks while referring to Figure 11.

The mill layout used in this example was that shown in Figure 6.

The size of the final product was H500 X 200 X 10/16 (mm), and the roll pass design was that shown in Figure 7, the dimensions of which were as follows:

$\theta_R = \theta_E = 5°$, $\theta_F = 0.5°$, δ (E) = 5 mm (See Figure 9)
W_R = 470 mm (at the beginning),
W_E = 470 mm (odd numbered passes), 460 mm (even numbered passes)
W_F = 470 mm

The roll pass schedule was as shown in Table 2 (starting rolling material: 700W X 300t, cc slabs)

The rolling of the present invention proceeded as follows.

Comparative Example 2 was done by repeating the present invention except that, as shown in Figure 7, W_E was adjusted to be W_E = 472 mm for all the passes.

The results are shown below.

	Occurrence of troubles on flanges	Rolling Flaws
Example 2	0% (zero out of 160 pieces)	No flaws at all
Comparative 2	100% (32 out of 32 pieces)	Quite large flaws

(Example 3)

The present invention will be explained by a working example, in which rolling was carried out in accordance with pass schedule of Figure 11 using a UR mill in which horizontal rolls of the variable-width type were installed.

The mill layout used in this example was that shown in Figure 12a.

The size of the final product was H500 X 200 X 10/16 (mm), and the roll pass design was that shown in Figure 12b, the dimensions of which were as follows:

$\theta_R = \theta_E = 3°$, $\theta_F = 0°$, δ (E) = 2.5 mm (See Figure 9)
W_R = 470 mm,
W_E = 470 mm (odd numbered passes), 465 mm (even numbered passes)
W_F = 470 mm

The widths W_R, W_E, and W_F were adjusted in an "on-line" manner so that the predetermined widths could be maintained even after wear of rolls took place.

The roll pass schedule was as shown in Table 2 (starting rolling material: 700W X 300t, cc slabs)

The rolling of the present invention proceeded without rolling troubles, and 150 slabs could be rolled successfully without formation of any rolling defects. The resulting final products had highly accurate dimensions with a high yield.

Table 2

Pass No.	UR mill		UF mill	
	Web Thickness	Flange Thickness	Web Thickness	Flange Thickness
After BD	80	108	-	-
1	70	105	60	102
2	40	77	50	93
3	34	64	28	54
4	21	38	24	46
5	18	31	15.4	26
6	11.7	19.5	13.4	23
7	10.2	16.8	10.0	16.0

(Industrial Applicability)

The present invention, as is apparent from the foregoing, provides a rolling method which can avoid formation of flaws on the inner flange surfaces, as well as problems at the time of biting of flanges by rolls, i.e., prior art problems. According to the present invention, it is also possible to achieve highly efficient rolling of H-shaped steel pieces by means of reversible continuous rolling through three mills. In addition, not only a finish universal rolling mill, but also a universal roughing mill have variable-width horizontal rolls, so it is possible to produce final products of the high quality with a high yield without the need for frequent roll exchanging which is usually required to make up for wear of rolls. Thus, the present invention has great value from an industrial viewpoint.

Claims

1. A method of hot rolling an H-shaped steel product, in which a rough rolled steel stock having webs and flanges which has been subjected to break-down rolling is rolled under hot conditions through reverse rolling using three rolling mills including a universal roughing mill having horizontal rolls of the fixed-width type, an edging mill having horizontal rolls of the fixed-width or variable-width type, and a universal finishing mill having horizontal rolls of the variable-width type, characterized in that the universal roughing mill has an X-caliber, the edging mill has an X-caliber, and the universal finishing mill has an H-caliber, and that, in the course of continuous rolling through three rolling mills except for the final pass, the width W_F of the horizontal rolls of the variable-width type of the universal finishing mill is adjusted to be larger than the widths W_R and W_E, which are the widths of horizontal rolls of the uni-

versal roughing mill and the barrel portions of horizontal rolls of the edging mill, respectively, so that the inner web width of the H-shaped steel stock after rolling with the edging mill is increased during the successive rolling through the universal finishing mill.

2. A method of hot rolling an H-shaped steel product as defined in claim 1, wherein the width W_R of horizontal rolls of the universal roughing mill is adjusted to be substantially the same as the width W_E of the barrel portions of horizontal rolls of the edging mill.

3. A method of hot rolling an H-shaped steel product as defined in claim 1, wherein the inner web width is finished to a final target size by means of a final pass through the universal finishing mill.

4. A method of hot rolling an H-shaped steel as defined in claim 1, wherein horizontal rolls of the variable-width type are employed for the universal roughing mill.

5. A method of hot rolling an H-shaped steel, in which a rough rolled steel stock having webs and flanges which has been subjected to break-down rolling is rolled under hot conditions through reverse rolling using three rolling mills including a universal roughing mill having horizontal rolls of the fixed-width type, an edging mill having horizontal rolls of the variable-width type, and a universal finishing mill having horizontal rolls of the variable-width type, characterized in that the universal roughing mill has an X-caliber, the edging mill has an X-caliber, and the universal finishing mill has an H-caliber, and that the width W_E of the barrel portions of horizontal rolls of the edging mill is adjusted to be smaller than the widths W_R and W_F, which are the widths of horizontal rolls of the universal roughing mill and the universal finishing mill, respectively, at each pass during continuous rolling from the downstream side to the upstream side through these three mills.

6. A method of hot rolling an H-shaped steel as defined in claim 5, wherein the widths W_R of horizontal rolls of the universal roughing mill are adjusted to be substantially the same as the width W_F of horizontal rolls of the universal finishing mill.

7. A method of hot rolling an H-shaped steel as defined in claim 5, wherein the inner web width is finished to a final target size by means of a final pass through the universal finishing mill.

8. A method of hot rolling an H-shaped steel as defined in claim 5, wherein horizontal rolls of the variable-width type are employed for the universal roughing mill.

9. An apparatus for hot rolling H-shaped steel products, which comprises, in tandem, a universal roughing mill having an X-caliber, an edging mill having an X-caliber and having fixed-width or variable-width rolls, and a universal finishing mill having an H-caliber and having variable-width rolls.

10. An apparatus for hot rolling H-shaped steel products as defined in claim 9, wherein the universal roughing mill comprises variable-width rolls.

Fig. 1

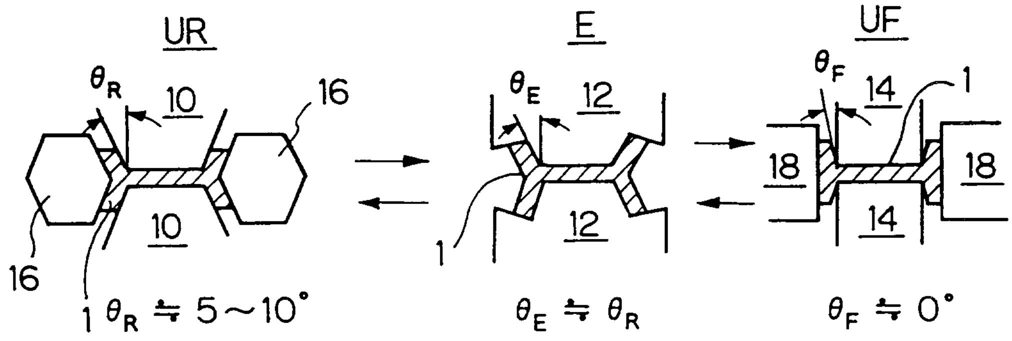


Fig. 2

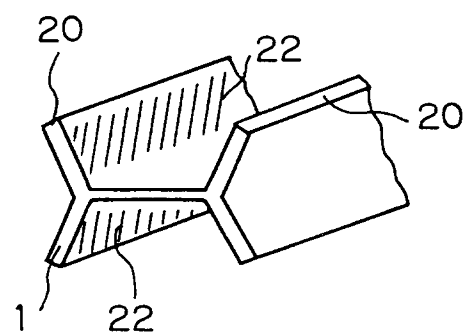


Fig. 3

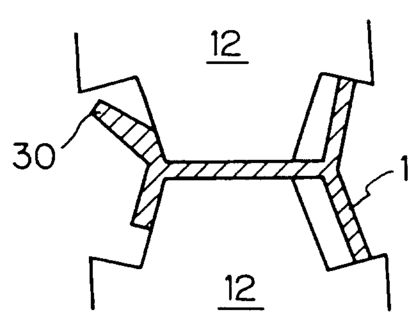


Fig. 4

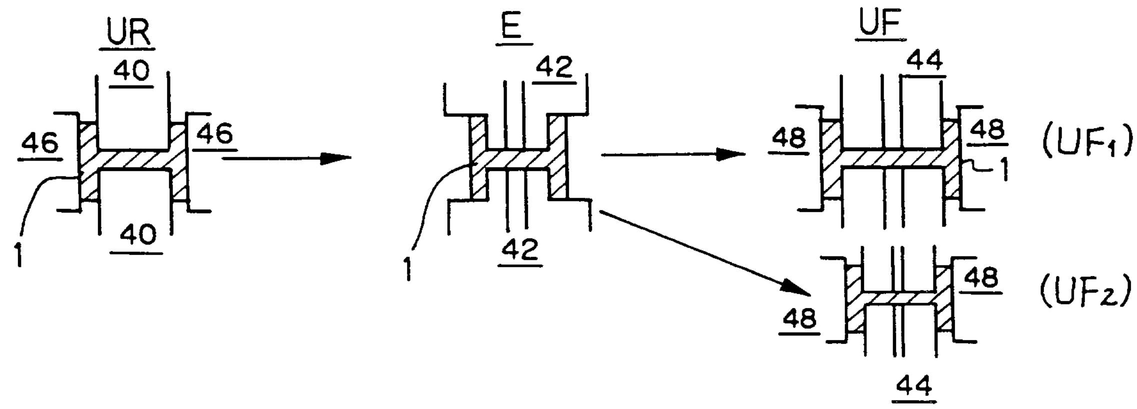


Fig. 5 a

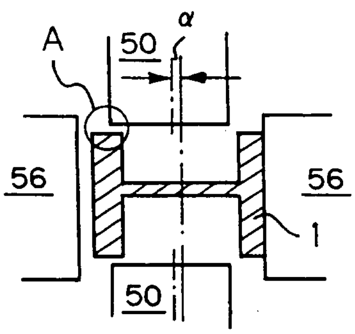


Fig. 5 b

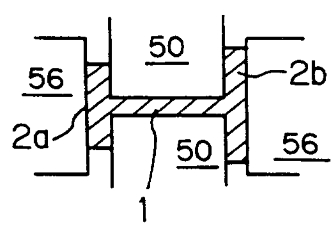


Fig. 6

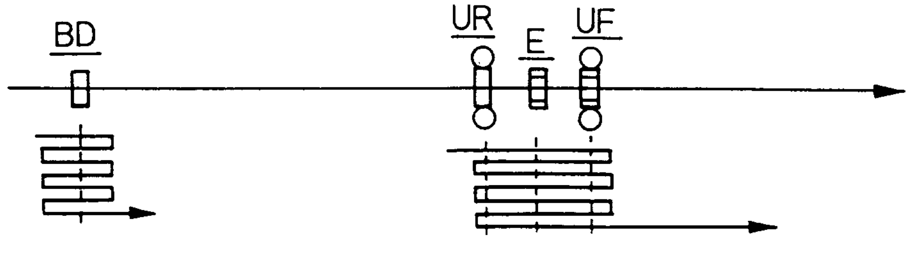


Fig. 7

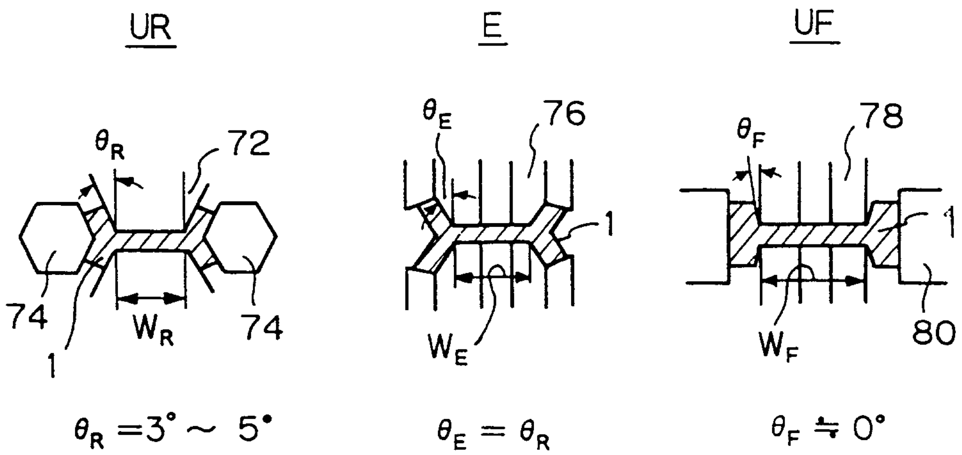


Fig. 8 a

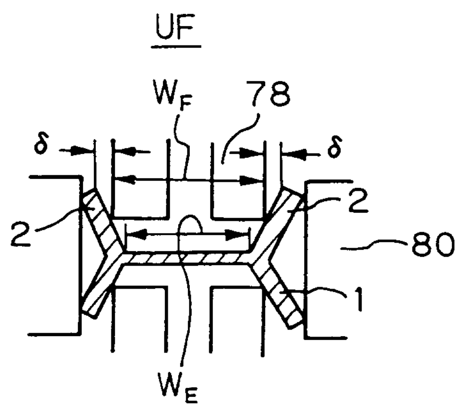


Fig. 8 b

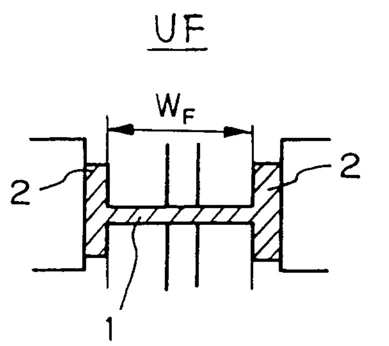


Fig. 9 a

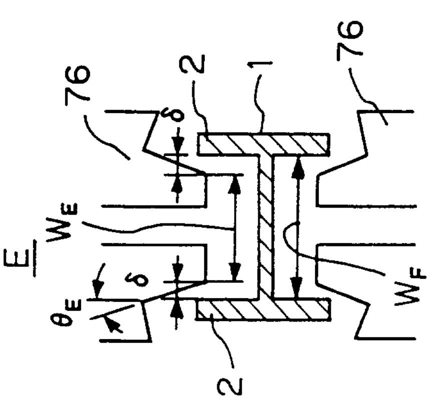


Fig. 9 b

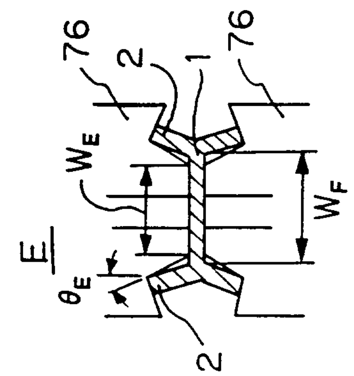


Fig. 1 0

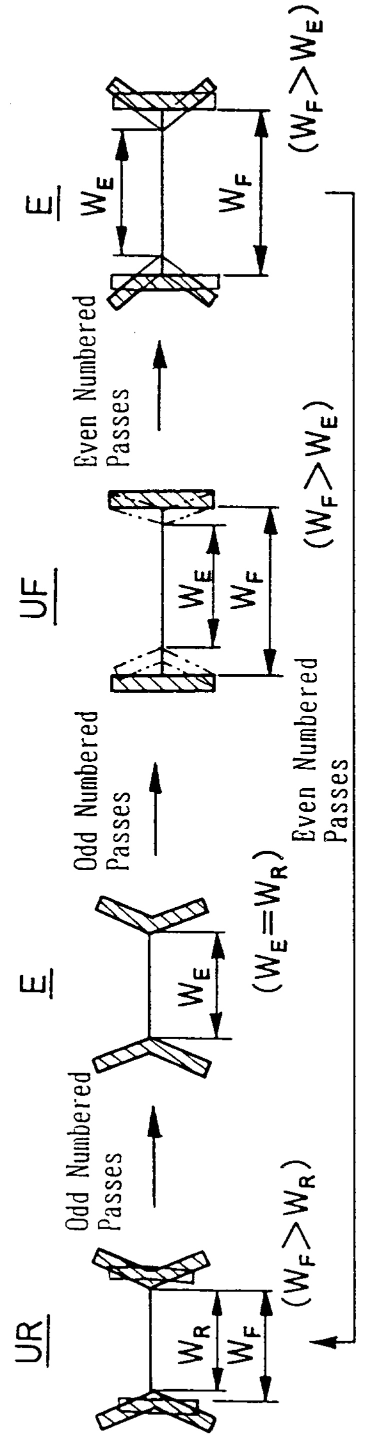
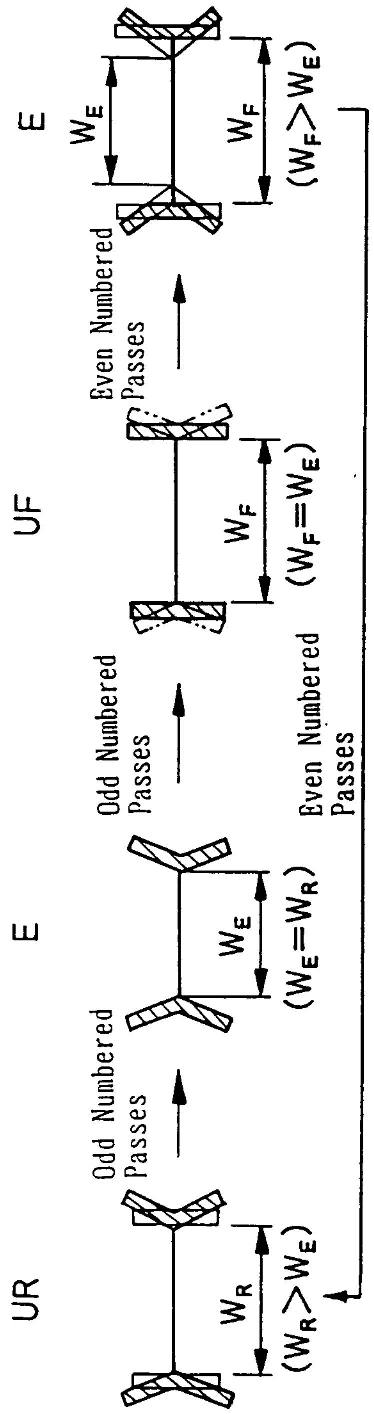


Fig. 11



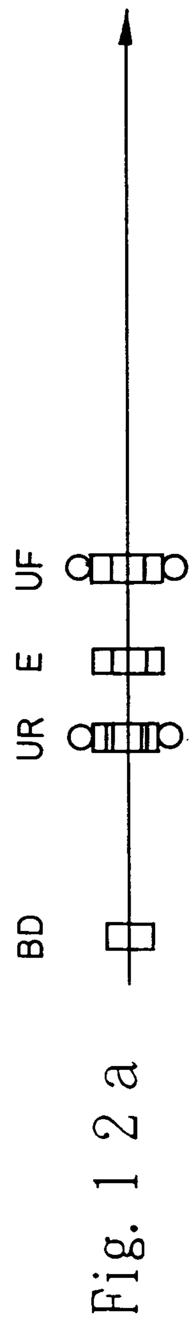


Fig. 12a

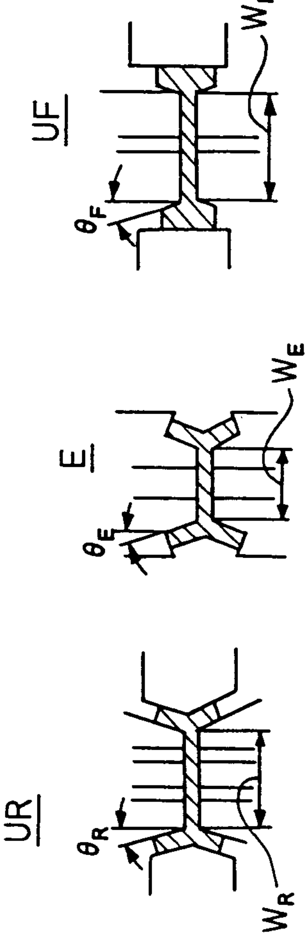


Fig. 12b

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP96/00688

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 B21B1/08

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^6 B21B1/08

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

Jitsuyo Shinan Koho	1926 - 1996
Kokai Jitsuyo Shinan Koho	1971 - 1996
Toroku Jitsuyo Shinan Koho	1994 - 1996

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 63-52701, A (SMS Schloemann-Siêmag AG.), March 5, 1988 (05. 03. 88), Line 3, upper right column to line 3, lower left column, page 4 & DE, 3627729, A1 & EP, 256409, A2 & US, 4791799, A	1 - 10
Y	JP, 4-258301, A (Sumitomo Metal Industries, Ltd.), September 14, 1992 (14. 09. 92), Line 25, column 4 to line 9, column 7 (Family: none)	1 - 10
A	JP, 5-329521, A (Kawasaki Steel Corp.), December 14, 1993 (14. 12. 93), Line 9, column 2 to line 2, column 5 (Family: none)	1 - 10
A	JP, 61-262404, A (Kawasaki Steel Corp.), November 20, 1986 (20. 11. 86), Line 11, upper left column, page 4 to line 6, upper right column, page 5 (Family: none)	1 - 10

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
June 11, 1996 (11. 06. 96)	June 18, 1996 (18. 06. 96)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)