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(54) PRODUCTION METHOD FOR STEEL PRODUCT EXHIBITING EXCELLENT INTERNAL PROPERTIES

(57) When a steel raw material of a round section is subjected to rolling at 3 or more passes to form a steel product of round section, the rolling is conducted by using a pair of upper and lower flat rolls at first pass, using a pair of upper and lower same or different caliber rolls at second or more passes until just before a last pass, and using a pair of upper and lower round caliber rolls at the last pass, under a condition that an area reduction in the first pass is within a range of less than a total area reduction from the raw material to the product. In this case, it is preferable that the area reduction in the first pass is not less than 50% of a total area reduction in the second or more passes.

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Description

TECHNICAL FIELD

[0001] This invention relates to a method of producing steel products having an excellent internal quality.

RELATED ART

[0002] In general, when a steel raw material with a round section (which is also called as a circular section) is rolled, the resulting product has also a round section. In this case, a series of caliber rolls with oval (ellipsoid; brevity code O) - round (circle; brevity code R) are frequently used. On the contrary, when the shape of the raw material is rectangular, a sectional area (cross sectional area for details, the same is used hereafter) is reduced by caliber rolls with a groove shape of square (square; brevity code S), box (hexagon; brevity code B) - diamond (rhombus; brevity code D) or the like to finally provide a desired shape. Of course, when the raw material has a square section, a combination of square (S) - oval (O) or the like is also used (Non-patent Document 1). In FIG. 4 are shown various examples of the above shapers for the caliber roll together with a shape of a flat roll (flat roll; brevity code F). Moreover, FIG. 4 shows a sectional view of upper and lower rolls cut by a plain surface passing through their shaft center lines. In FIG. 4, F/F is an abbreviation of upper and lower flat rolls, O/O is an abbreviation of upper and lower oval caliber rolls, R/R is an abbreviation of upper and lower round caliber rolls, S/S is an abbreviation of upper and lower square caliber rolls, B/B is an abbreviation of upper and lower box caliber rolls, and D/D is an abbreviation of upper and lower diamond caliber rolls (the same is used hereafter).

[0003] Especially, when the shape of the raw material or an intermediate material is approximately circular, a final shape of a circular section is manufactured by oval (O) or round (R) rolls as mentioned above.

[0004] On the other hand, when the raw material is an as-cast steel billet or retains defects in a sectional center portion of the steel billet, it is unsuitable as a final product or a raw material directing to another production line. Because the retaining defects lead to cause flaw through further working or begin at the occurrence of breakage or the like in subsequent rolling. When a product is manufactured from the steel billet such as slab or the like, a strong drafting way is known as a method of solving the defects in the central center of the raw material by rolling (Non-patent Document 2). Thus, when the drafting of, for example, 30 mm is necessary in the production of the steel sheet, products having an excellent internal quality are obtained by conducting the drafting of 30 mm at once rather than three times of rolling of 10 mm/pass.

[0005] Moreover, Patent Document 1 discloses that as a rolling method for the prevention of rolling crack in the continuously cast steel billet (particularly rolling crack of side face), when a steel bar is manufactured from the continuously cast steel billet by direct rolling, a continuously cast steel billet of a round section is used and a caliber roll is used in a first pass of rough rolling and a flat roll is used in second pass or more of the rough rolling.

PRIOR ART DOCUMENTS

PATENT DOCUMENT

[0006] Patent Document 1: Japanese Patent No. 3649054

NON-PATENT DOCUMENTS

[0007]

Non-patent Document 1: Journal of Nippon Plastic Working Associate, Vol. 24-273 (1983. 10) p.1070-1077
Non-patent Document 2: The Iron and Steel, '81-S339

SUMMARY OF THE INVENTION

PROBLEM TO BE SOLVED BY THE INVENTION

[0008] However, when the raw material has a round section and further the product has also a round section, it is not necessarily easy to apply the technique capable of simply repressing the strong drafting. Because, an area reduction ratio of decreasing a cross sectional area of a steel billet or cast slab as a raw material to a cross sectional area of a final product (shortly referred to as area reduction; = 1 - sectional area of product/sectional area of raw material), i.e. rolling reduction is previously decided and also a groove shape or rolling reduction required in shaping is limited to a certain extent. Alternatively, there is a method of increasing a sectional area of the raw material. In each case, however,

many times and labor are taken for changing groove shape or optimizing the rolling reduction, which is industrially difficult. In addition, when the raw material is produced from a mold, there is a large restriction and is practically difficult. As previously mentioned, a groove shape of approximately an ellipsoid is usually used in case of rolling the round section, but when the strong drafting is conducted with such a groove shape, protruding from the groove shape and over-filling is caused, which is feared to retain a flaw on the surface of the product. If the drafting is deficient, a portion not filled in the groove shape retains on the surface of the final product without over-filling, so that it is difficult to apply the strong drafting way, and hence the internal quality and shape may not be satisfied sufficiently, which becomes problem.

MEANS FOR SOLVING PROBLEM

[0009] In order to solve the above problems, the inventors have examined a way wherein defects existing in the round sectional center of the raw material is effectively blocked even if the rolling reduction is not necessarily high in the hot rolling of 3 or more passes usually adapting the caliber rolling for providing a desired product shape, and found out that the strong drafting way can be easily applied when the rolling in only first pass of the hot rolling is conducted with upper and lower flat rolls and second or more passes are conducted by caliber rolling to thereby obtain a product having sufficient internal quality and shape, and as a result, the invention has been accomplished with the following summary and constructions.

[0010] That is, the invention is a method of producing steel products having an excellent internal quality by subjecting a steel raw material of a round section to rolling of 3 or more passes to provide a steel product of a round section, characterized in that the rolling is conducted by using a pair of upper and lower flat rolls at first pass, using a pair of upper and lower same or different caliber rolls at second or more passes until just before a last pass, and using a pair of upper and lower round caliber rolls at the last pass, under a condition that an area reduction in the first pass is within a range of less than a total area reduction from the raw material to the product. In the invention, it is preferable that the area reduction in the first pass is not less than 50% of a total area reduction in the second or more passes.

EFFECT OF THE INVENTION

[0011] According to the invention, defects existing in the center of the round section can be sufficiently blocked by strong draft rolling with the upper and lower flat rolls at the first pass, while the section flattened by the strong drafting can be sufficiently circles by the caliber rolling with a relatively light drafting at the second or more passes, whereby a steel product of round section having a satisfactory internal quality is obtained without deteriorating the shape.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is a graph showing an influence of a roll shape upon an interrelation between defect blocking ratio and area reduction in one pass rolling (results of Experiment 1);
FIG. 2 is a graph showing an influence of a roll shape upon an interrelation between defect blocking ratio and area reduction in one pass rolling (results of Experiment 2);
FIG. 3 is a graph showing an influence of a roll shape upon an interrelation between defect blocking ratio and area reduction in one pass rolling (results of Experiment 3); and
FIG. 4 is a schematic view illustrating various shapes of caliber rolls and a shape of as flat roll.

EMBODIMENST FOR CARRYING OUT THE INVENTION

[0013] As a clue searching means for solving the above problems, the inventors have made experimental investigations on how to change an interrelation between a defect blocking ratio (= 1 - sectional area of defect after rolling/sectional area of defect in raw material) and an area reduction (= 1 - sectional area of rolled product/sectional area (including sectional area of defect) of raw material) in accordance with a shape of a roll used when a raw material of a round section provided with an artificial defect passing through a central portion of the round section is rolled at one pass. In this experiment, a lead raw material was used to conduct cold rolling. This can be adopted as a good approach because cold deformation behavior of lead is close to hot deformation behavior (1000~1200°C) of steel and also deformation resistance of lead at room temperature tends to be substantially equal to hot deformation resistance of steel.

(Experiment 1)

[0014] In Experiment 1, the raw material has an outer diameter = 50 mmϕ and a defect diameter = 5 mmϕ, and shapes

of upper and lower rolls are four kinds of F/F, D/D, O/O and B/B (see FIG. 4), and the roll diameter is 5 times of the diameter of the raw material (wherein a diameter of a roll flange portion is used for a roll diameter of a caliber roll), and the area reduction is varied within a range of not more than about 25%. The sectional area of the defect after the rolling is determined from an image of the defect shot in a section of a rolled product. Moreover, when the defect is not observed from the shot image, a color check test is carried out on the section to be shot to confirm no transudation of a penetrating solution (the same is used hereafter).

[0015] The results are shown in FIG. 1. As seen from FIG. 1, the defect blocking ratio increases together with the area reduction even in any roll shape, but the increasing tendency is particularly steep in the case of F/F as compared with the other cases, and also complete blocking (defect blocking ratio = 1) is attained at an area reduction = about 21%, which indicates that the defect blocking ratio can be largely enhanced by the strong drafting with the upper and lower flat rolls.

(Experiment 2)

[0016] In Experiment 2 is used the same specification as in Experiment 1 except that the defect diameter is 2.5 mmϕ. The results are shown in FIG. 2. As seen from FIG. 2, the defect blocking ratio increases together with the area reduction even in any roll shape, but the increasing tendency is particularly steep in the case of F/F as compared with the other cases, and also complete blocking (defect blocking ratio = 1) is attained at an area reduction = about 21%, which indicates that the defect blocking ratio can be largely enhanced by the strong drafting with the upper and lower flat rolls.

(Experiment 3)

[0017] In Experiment 3 is used the same specification as in Experiment 1 except that the outer diameter of the raw material is 30 mmϕ and the defect diameter is 3 mmϕ. The results are shown in FIG. 3. As seen from FIG. 3, the defect blocking ratio increases together with the area reduction even in any roll shape, but the increasing tendency is particularly steep in the case of F/F as compared with the other cases, and also complete blocking (defect blocking ratio = 1) is attained at an area reduction = about 9%, which indicates that the defect blocking ratio can be largely enhanced by the strong drafting with the upper and lower flat rolls.

[0018] Next, a pass applying F/F (upper and lower flat rolls) rolling is examined among 3 or more rolling passes, and hence the following conclusion is obtained. Since the strong draft is conducted in the F/F rolling, when the strong draft is carried out at second or more passes, if there is a limit in the pass number, the number of caliber rolling passes from the pass after the strong draft to final pass is decreased, and hence it is difficult to render the final section into a true circle. If there is no limit in the pass number, the formation of the true circle may be made possible by further adding caliber rolling stands, but the number of the stands is increased, which is large demerit in the rolling efficiency and economical reasons. Therefore, the F/F rolling should be carried out only at the first pass.

[0019] The area reduction in the F/F rolling (first pass) should be less than a given total area reduction from the raw material to the product. In general, a total area reduction from an entry side of mth pass to an exit side of nth pass (m<n) (which is represented by symbol of $Z_{m/n}$) is defined by an equation (1) from sectional area at the entry side of mth pass S_{m-1} and sectional area at the exit side of nth pass S_n:

$$Z_{m/n} = 1 - S_n/S_{m-1} \ldots\ldots (1)$$

When total area reduction is a range from the raw material (entry side of first pass) to the product (exit side of final Nth pass), the equation (1) is changed into an equation (2) since m = 1 and n = N.

$$Z_{1/N} = 1 - S_N/S_0 \ldots\ldots (2)$$

[0020] The equation (2) is deformed to an equation (3) by using sectional area Si and area reduction z_i (= 1 - S_i/S_{i-1}) at an exit side of ith pass:

$$Z_{1/N} = 1 - {}_i\Pi_{1/N}(1 - z_i) \ldots\ldots (3)$$

wherein ${}_i\Pi_{1/N}(1 - z_i) \equiv (1- z_1)(1 - z_2) \ldots (1 - z_N)$.

[0021] Since each of the sectional area So of the raw material and target sectional area S_N of the product is a given

value, the total area reduction $Z_{1/N}$ from the raw material to the product is also a given value. When $z_1 \geqq Z_{1/N}$, $1 - {}_i\Pi_{2/N}$ $(1 - z_i) = Z_{2/N} \leqq 0$ from the equation (3), so that the caliber rolling at second or more passes cannot be conducted and hence the target shape of round section is not obtained. Therefore, there should be $z_1 < Z_{1/N}$.

[0022] On the other hand, when z_1 is less than 50% of $Z_{2/N}$, the strong draft is not obtained, so that there is a possibility that the defect blocking effect is poor. Since it is considered that when the defect blocking is carried out at the first pass, only the arrangement of the shape is sufficient at the remaining passes, the area reduction z_1 of the F/F rolling (first pass) is preferable to be not less than 50% of the total area reduction $Z_{2/N}$ of the caliber rolling.

EXAMPLE

[0023] A through-hole (circular section) is pierced in a sectional center of a steel raw material of a round section as an artificial defect to form a test specimen, which is heated and hot rolled under various rolling conditions to provide a steel product having a target round section. Then, there are examined right and wrong in the defect blocking ratio and shape of the resulting steel product. In Table 1 are shown dimension (outer diameter, defect diameter) of the raw material used, target size (outer diameter) of the steel product, total area reduction $Z_{1/N}$ and rolling conditions (total pass number N, shape of roll used (F/F $\rightarrow$ O/O ..... $\rightarrow$ R/R and so on), area reduction at first pass z_1, total area reduction of second or more passes $Z_{2/N}$) from entry side of first pass to exit side of final Nth pass. Moreover, the heating temperature is 1100°C. The roll diameter of the flat roll is 200 mm, and the roll diameter of the caliber roll (roll diameter at flange end) is 200 mm. The temperature at exit side of the final pass is lowered to about 50-100°C from the heating temperature.

[0024] The defect blocking ratio of the resulting steel product is examined by the same manner as in the above experiments. As the right and wrong of the shape, a ratio of minimum diameter/maximum diameter in circumferential direction is measured as an indication of true circle, and the shape is judged to be good (○) when the indication of true circle is not less than 0.975 and bad (×) other than that. These results are shown in Table 1.

[0025] As seen from Table 1, the defect is completely blocked and the shape is good in Invention Examples (F/F only at first pass, and $z_1 < Z_{1/N}$).

Table 1

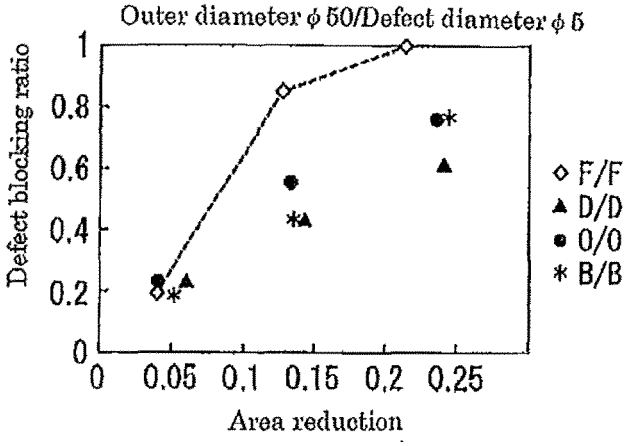
No.	Raw material		Target outer diameter of steel product (mm)	Z1/N (%)	N	Shape of rolls used	Z1 (%)	Z2/N (%)	Defect blocking ratio	Shape	Remarks
	Outer diameter (mm)	Defect diameter (mm)									
1	50	5	37.0	45	4	F/F→O/O→O/O-→R/R	25	27	1	○	Invention Example
2	50	3	33.5	55	4	F/F→D/D→O/O→R/R	25	40	1	○	Invention Example
3	50	3	33.5	55	4	F/F→O/O→O/O→R/R	33	33	1	○	Invention Example
4	30	3	22.3	45	4	F/F→O/O→O/O→R/R	15	35	1	○	Invention Example
5	30	3	24.0	36	4	F/F→O/O→O/O→R/R	15	25	1	○	Invention Example
6	30	3	25.5	27	3	F/F→O/O→R/R	15	14	1	○	Invention Example
7	50	5	32.5	58	4	F/F→D/D→O/O→R/R	40	30	1	×	Comparative Example
8	50	3	37.0	45	4	F/F→D/D→O/O→R/R	15	35	0.81	○	Comparative Example
9	30	3	22.3	45	4	F/F→D/D→O/O→R/R	8	40	0.7	○	Comparative Example
10	50	5	40.0	36	3	F/F→O/O→R/R	25	15	1	×	Comparative Example
11	50	5	37.0	45	4	F/F→O/O→O/O→R/R	16	35	0.85	○	Comparative Example
12	50	5	40.0	37	3	F/F→O/O→R/R	13	28	0.68	×	Comparative Example

Claims

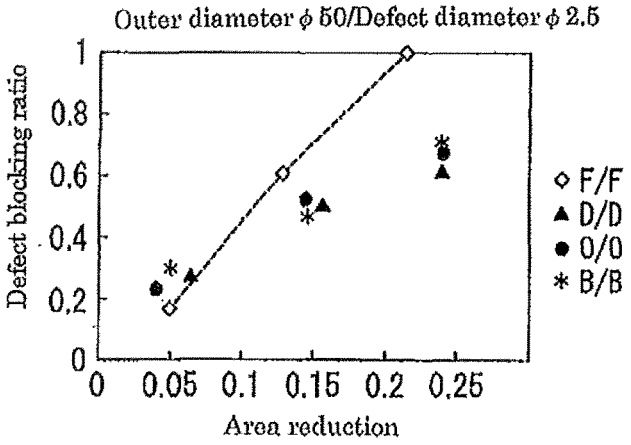
1. A method of producing a steel product having an excellent internal quality by subjecting a steel raw material of a round section to rolling at 3 or more passes to form a steel product of round section, **characterized in that** the rolling is conducted by using a pair of upper and lower flat rolls at first pass, using a pair of upper and lower same or different caliber rolls at second or more passes until just before a last pass, and using a pair of upper and lower round caliber rolls at the last pass, under a condition that an area reduction in the first pass is within a range of less than a total area reduction from the raw material to the product.

2. A method of producing a steel product having an excellent internal quality according to claim 1, **characterized in that** the area reduction in the first pass is not less than 50% of a total area reduction in the second or more passes.

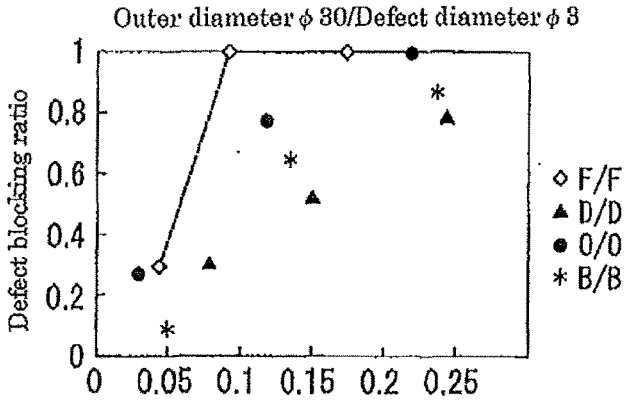
[Fig.1]



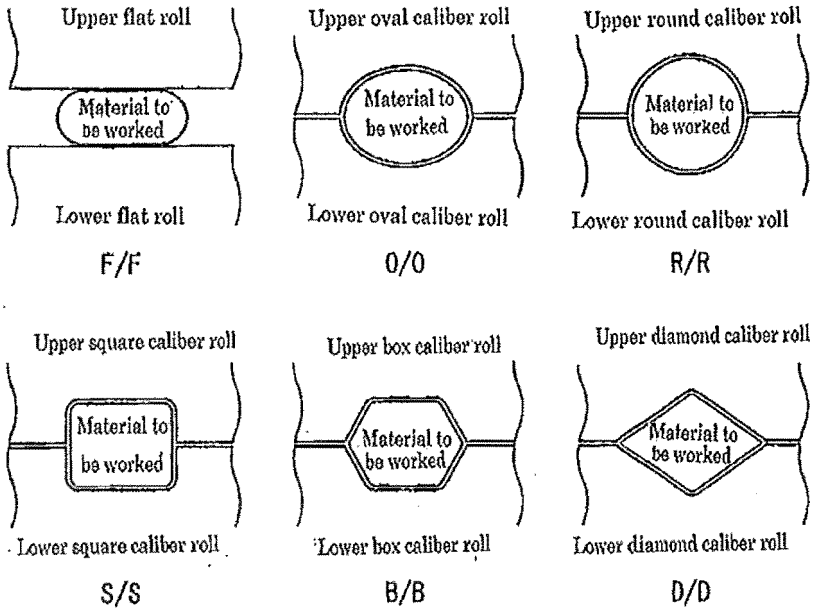
[Fig.2]



[Fig.3]



[Fig.4]


Upper flat roll
Material to be worked
Lower flat roll
F/F
Upper oval caliber roll
Material to be worked
Lower oval caliber roll
O/O
Upper round caliber roll
Material to be worked
Lower round caliber roll
R/R
Upper square caliber roll
Material to be worked
Lower square caliber roll
S/S
Upper box caliber roll
Material to be worked
Lower box caliber roll
B/B
Upper diamond caliber roll
Material to be worked
Lower diamond caliber roll
D/D

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/053626

A. CLASSIFICATION OF SUBJECT MATTER
B21B1/00(2006.01)i, *B21B1/02*(2006.01)i, *B21B1/16*(2006.01)i, *B21B27/02*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B21B1/00, B21B1/02, B21B1/16, B21B27/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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.
X Y	JP 58-188502 A (Sumitomo Metal Industries, Ltd.), 04 November 1983 (04.11.1983), fig. 1 to 3; page 1, right column, lines 7 to 20; page 2, lower left column, line 8 to page 3, upper left column, line 20 (Family: none)	1 2
Y	JP 58-132303 A (Nippon Steel Corp.), 06 August 1983 (06.08.1983), table 2 (Family: none)	2

☐ 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
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"O" document referring to an oral disclosure, use, exhibition or other means
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"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
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Date of the actual completion of the international search 28 February, 2013 (28.02.13)	Date of mailing of the international search report 12 March, 2013 (12.03.13)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3649054 B **[0006]**

Non-patent literature cited in the description

- *Journal of Nippon Plastic Working Associate,* October 1983, vol. 24-273, 1070-1077 **[0007]**
- *The Iron and Steel,* 1981, S339 **[0007]**