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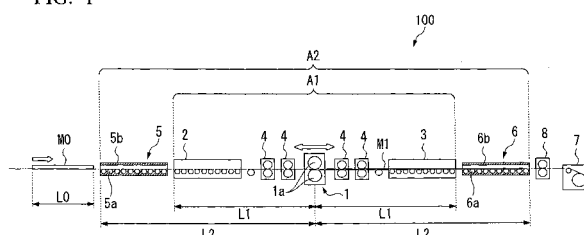
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(54) **MAGNESIUM HOT ROLLING METHOD AND MAGNESIUM HOT ROLLING APPARATUS**

(57) A magnesium alloy hot rolling method includes: a first rolling step in which a magnesium plate (M0, M1) is rolled reciprocatingly between an upstream heating furnace (2) which is located on an upstream side of a rolling mill (1) and which heats the magnesium plate (M0, M1), and a upstream heating furnace (3) which is located on a downstream side of the rolling mill (1) and which heats the magnesium plate (M0, M1); and a second rolling step in which the temperature of respective end portions of the magnesium plate (M0, M1) on both the upstream and downstream sides is maintained while the magnesium plate (M0, M1) is being rolled reciprocatingly

between an upstream temperature maintaining apparatus (5) which transports the heated magnesium plate (M0, M1) while maintaining the temperature thereof, and a downstream temperature maintaining apparatus (6) which transports the heated magnesium plate (M0, M1) while maintaining the temperature thereof. According to the magnesium hot rolling apparatus of the present invention and to the magnesium hot rolling method of the present invention which uses this apparatus, it is possible to prevent any deterioration in the quality of a product which is due to temperature variations during the hot rolling of magnesium alloy.

FIG. 1



**Description**

[Technical Field]

5 **[0001]** The present invention relates to a magnesium hot rolling method and to a magnesium hot rolling apparatus. Priority is claimed on Japanese Patent Application No. 2007-269058, filed October 16, 2007, the contents of which are incorporated herein by reference.

[Technical Background]

10 **[0002]** To manufacture a magnesium sheet from magnesium alloy, a round bar-shaped billet having, for example, a diameter of approximately 300 to 400 mm and a length of approximately 500 to 600 mm is molded by hot extrusion molding into a thick plate having a thickness of, for example, 10 mm or less. This thick plate is then cut to a predetermined length (for example, 3 m) so as to form a cut plate material, and this cut plate material is then rolled to a thickness of  
15 not more than 1 mm by rough rolling.

**[0003]** In order to roll magnesium alloy at room temperature a large amount of pressure is required. However, even if a large amount of pressure is applied, it still cracks easily. Accordingly, it is preferably rolled using hot rolling. Conventional examples of apparatuses for the hot rolling of magnesium alloy are disclosed in FIG. 1 of patent document 1 and FIG. 1 of patent document 2.

20 The hot rolling apparatuses disclosed in these patent documents are provided with a rolling mill which rolls the magnesium alloy while transporting it reciprocatingly, and with two heating furnaces which are located on the upstream side and the downstream side of the rolling mill. The magnesium alloy is heated to a predetermined temperature by these heating furnaces and is rolled in the rolling mill.

25 [Patent document 1] Japanese Patent Publication No. 3521863

[Patent document 2] Japanese Patent Publication No. 3821074

[Disclosure of the Invention]

30 [Problems to be Solved by the Invention]

**[0004]** However, in the hot rolling apparatuses disclosed in the aforementioned patent documents, because heating furnaces are only provided on both sides of the rolling mill, as the magnesium cut plate material becomes gradually elongated by the reciprocating rolling, the ends of the magnesium cut plate material begin to protrude from the heating  
35 furnaces and these protruding portions cool down. The reason why this is a problem is because temperature variations in the magnesium cut plate material during the hot rolling cause errors in the dimensional accuracy and a deterioration in the quality of a finished product.

**[0005]** The present invention was conceived in view of the above described circumstances and it is an object thereof to provide a magnesium hot rolling method and a magnesium hot rolling apparatus which are able to prevent any reduction  
40 in the quality of a product which is due to temperature variations during the hot rolling of a magnesium alloy.

[Means for Solving the Problem]

45 **[0006]** In order to solve the above described problems, the following apparatuses and methods are employed in the present invention.

As a first aspects of the present invention, a magnesium alloy hot rolling method is employed which has: a first rolling step in which a magnesium plate is rolled reciprocatingly between an upstream heating furnace which is located on an upstream side of a rolling mill and which heats the magnesium plate, and a upstream heating furnace which is located on a downstream side of the rolling mill and which heats the magnesium plate; and a second rolling step in which the  
50 temperature of respective end portions of the magnesium plate on both the upstream and downstream sides is maintained while the magnesium plate is being rolled reciprocatingly between an upstream temperature maintaining apparatus which is located further on the upstream side than the upstream heating furnace and which transports the magnesium plate which has been heated by the upstream heating furnace while maintaining the temperature thereof, and a downstream temperature maintaining apparatus which is located further on the downstream side than the upstream heating  
55 furnace and which transports the magnesium plate which has been heated by the upstream heating furnace while maintaining the temperature thereof.

**[0007]** In the magnesium alloy hot rolling method according to the above described first aspects of the present invention, it is also possible for there to be provided a wind-on step in which, while tension is applied by a tension applying apparatus

which is located on the downstream side of the downstream temperature maintaining apparatus to the magnesium plate which has been rolled to a predetermined thickness, the magnesium plate is wound onto a winder which is placed further on the downstream side than the downstream temperature maintaining apparatus.

**[0008]** As a second aspects of the present invention, a magnesium alloy hot rolling apparatus is employed which is provided with: a rolling mill which performs reciprocating rolling on a magnesium plate; an upstream heating furnace which is located on the upstream side of the rolling mill and which heats the magnesium plate; a upstream heating furnace which is located on the downstream side of the rolling mill and which heats the magnesium plate; an upstream temperature maintaining apparatus which is located further on the upstream side than the upstream heating furnace, and which transports the magnesium plate which has been heated by the upstream heating furnace and also maintains the temperature of upstream side end portions thereof; and a downstream temperature maintaining apparatus which is located further on the downstream side than the upstream heating furnace, and which transports the magnesium plate which has been heated by the upstream heating furnace and also maintains the temperature of downstream side end portions thereof.

**[0009]** In the magnesium alloy hot rolling apparatus according to the above described second aspects of the present invention, it is also possible for a plurality of groups of pinch rollers which sandwich the magnesium plate in the thickness direction thereof and adjust the transporting speed thereof to be provided respectively between the rolling mill and the upstream heating furnace and between the rolling mill and the upstream heating furnace.

**[0010]** In the magnesium alloy hot rolling apparatus according to the above described second aspects of the present invention, it is also possible for working rollers of the rolling mill and the plurality of groups of pinch rollers which are located on the upstream and downstream sides of the rolling mill to be heating rollers.

**[0011]** In the magnesium alloy hot rolling apparatus according to the above described second aspects of the present invention, it is also possible for there to be provided: a tension applying apparatus which is located on the downstream side of the downstream temperature maintaining apparatus and which applies tension to the magnesium plate; and a winder which is located further on the downstream side than the tension applying apparatus and onto which the magnesium plate is wound.

[Effects of the Invention]

**[0012]** According to the present invention, because a magnesium plate is rolled while substantially the entire length thereof is being heated and held at a predetermined temperature, it is possible to suppress any drop in the temperature of the magnesium plate, and to prevent errors in the dimensional accuracy of a product as well as any consequent deterioration in product quality which are due to temperature variations during hot rolling, and to thus maintain a superior quality in a finished product.

[Brief description of the drawings]

**[0013]**

[FIG. 1] FIG. 1 is a schematic front view showing the schematic structure of a hot rolling apparatus in an embodiment of the present invention.

[FIG. 2] FIG. 2 is a typical view showing the schematic structure of a leveler. [Description of the Reference Numerals]

**[0014]**

- 100 Hot rolling apparatus (magnesium hot rolling apparatus)
- 1 Rolling mill
- 2 First heating furnace (upstream heating furnace)
- 3 Second heating furnace (upstream heating furnace)
- 4 Pinch roller (feed roller pair)
- 5 First table roller (upstream temperature maintaining apparatus)
- 6 Second table roller (downstream temperature maintaining apparatus)
- 7 Winder
- 8 Pinch rollers (tension applying apparatus)
- M0 Magnesium cut plate material (magnesium plate)
- M1 Magnesium sheet (magnesium plate)

[Best Embodiments for Implementing the Invention]

**[0015]** An embodiment of the present invention will now be described with reference made to the drawings.

FIG. 1 is a schematic front view showing the schematic structure of a hot rolling apparatus 100 (i.e., a magnesium alloy hot rolling apparatus) in the present embodiment.

As is shown in FIG. 1, the hot rolling apparatus 100 according to the present embodiment is provided with a rolling mill 1, a first heating furnace 2, a second heating furnace 3, pinch rollers 4, a first table roller 5, a second table roller 6, a winder 7, and pinch rollers 8.

**[0016]** The rolling mill 1 has a pair of working rollers 1a that are in parallel with each other and also face each other, and with a drive source (not shown) which drives the working rollers 1a to rotate.

The working rollers 1a are heating rollers whose surface temperature is raised to a suitable temperature and which, while feeding a magnesium cut plate material M0 (i.e., a magnesium plate) which is passing between the working rollers 1a in one direction, apply predetermined pressure to this magnesium cut plate material M0. As a result of this, the rolling mill 1 reduces the thickness of the magnesium cut plate material M0 so as to cause it to become elongated.

Moreover, the rolling mill 1 performs reciprocating rolling by reversing the feed direction of the magnesium cut plate material M0 at a predetermined timing. By doing this, the rolling mill 1 reduces the thickness of the magnesium cut plate material M0 from, for example, a thickness of approximately 6 mm and a length of approximately 3 m to a thickness of approximately 1 mm and a length of approximately 18 m.

Note that the above described magnesium cut plate material M0 (i.e., magnesium plate) which forms a work piece for this hot rolling apparatus 100 is a plate material formed from magnesium alloy.

**[0017]** The first heating furnace 2 (i.e., the upstream heating furnace) is a heating furnace which is located on the upstream side of the rolling mill 1. The second heating furnace 3 (i.e., the upstream heating furnace) is a heating furnace which is located on the downstream side of the rolling mill 1.

The pair of heating furnaces 2 and 3 have a length which is longer than that of the magnesium cut plate material M0 prior to rolling, and are also provided with heaters and transporting rollers (neither are shown). The magnesium cut plate material M0 is heated by the heaters to a predetermined temperature (approximately 100 to 350 °C with 200 to 300 °C being preferable), and the magnesium cut plate material M0 is transported by the transporting rollers.

**[0018]** The pinch rollers 4 are heating rollers whose surface temperature is raised to a suitable temperature, and they provide auxiliary transporting for the magnesium cut plate material M0 which is traveling reciprocatingly in conjunction with the reciprocating rolling of the rolling mill 1. A plurality of sets of these pinch rollers 4 are provided respectively between the rolling mill 1 and the first heating furnace 2, and between the rolling mill 1 and the second heating furnace 3. By adjusting the transporting speed, the pinch rollers 4 can be made to apply suitable tension to the magnesium cut plate material M0 which is being rolled by the rolling mill 1.

**[0019]** The first table roller 5 (i.e., the upstream temperature maintaining apparatus) is located on the upstream side of the first heating furnace 2, while the second table roller 6 (i.e., the downstream temperature maintaining apparatus) is located on the downstream side of the second heating furnace 3. These table rollers 5 and 6 each have transporting rollers 5a and 6a and temperature maintaining covers 5b and 6b.

When the magnesium cut plate material M0 becomes elongated by being reverse rolled by the rolling mill 1, the end portions thereof protrude from the heating furnaces 2 and 3. The table rollers 5 and 6 transport and support the end portions of the magnesium cut plate material M0 which are protruding from the heating furnaces 2 and 3 using the transporting rollers 5a and 6a, and also shield them from the outside air by covering them with the temperature maintaining covers 5b and 6b. As a result, the table rollers 5 and 6 maintain the temperature of the magnesium cut plate material M0 by not allowing heat to escape therefrom. Moreover, during reverse rolling the temperature maintaining portion of the end portion of the magnesium cut plate material M0 which is positioned on the downstream side is moved inside the heating furnace during the subsequent rolling in the opposite direction. In addition, the heating portion of the end portion which is positioned on the downstream side is placed inside the temperature maintaining apparatus during the rolling in the opposite direction, and by repeating this process alternately, it is possible to minimize any reduction in the temperature of the end portions.

**[0020]** The winder 7 is a machine onto which is wound the manufactured product obtained by rolling the magnesium cut plate material M0, namely, a magnesium sheet M1 (i.e., a magnesium plate).

The pinch rollers 8 (i.e., the tension applying apparatus) are located in front of the winder 7 and by adjusting the transporting speed of the magnesium sheet M1, they are able to apply tension to the magnesium sheet M1 in the opposite direction from the wind-on direction of the winder 7.

**[0021]** Using this type of structure, the hot rolling apparatus 100 performs rough rolling on the magnesium cut plate material M0. Hereinafter, an operation of the hot rolling apparatus 100 will be described.

**[0022]** Firstly, the magnesium cut plate materials M0 which are the objects to be rolled by this hot rolling apparatus 100 are manufactured by performing hot extrusion molding (at between approximately 100 and 300 °C with 200 °C being preferable) on a rod-shaped billet having, for example, a diameter of 300 to 400 mm and a length of 500 to 600 mm so

as to mold it into a thick plate having a thickness of, for example, 10 mm or less (for example, 6 mm). This thick plate is then cut into predetermined lengths (for example, 3 m).

Because the crystal grains of the magnesium forming the magnesium cut plates M0 which have been molded by hot extrusion molding are mechanically refined by being extruded, they are extremely strong and are of high quality. They are also difficult to break and have superior press-moldability.

**[0023]** The magnesium cut plate materials M0 are transported from the first table rollers 5 to the first heating furnace 2. They are then heated to a predetermined temperature (approximately 100 to 350 °C with 200 to 300 °C being preferable) inside the first heating furnace 2 and are then transported to the rolling mill 1.

The rolling mill 1 rolls the magnesium cut plate material M0 and, at the same time as this, transports it to the second heating furnace 3. The temperature of the magnesium cut plate materials M0 drops somewhat as it moves from the first heating furnace 2 to the second heating furnace 3. However, because the working rollers 1a and the plurality of pinch rollers 4 are heating rollers, and because the magnesium cut plate material M0 is once again heated to the predetermined temperature inside the second heating furnace 3, there is little temperature variation.

**[0024]** When the terminal end of a magnesium cut plate material M0 has passed through the rolling mill 1, the hot rolling apparatus 100 reverses the rolling direction. The hot rolling apparatus 100 repeats this process so that the magnesium cut plate material M0 is rolled reciprocatingly, and the thickness of the magnesium cut plate material M0 is sequentially reduced. As a result, a magnesium sheet M1 is manufactured.

Here, specific examples of the respective numerical values for the rough rolling performed by this hot rolling apparatus 100 are shown below in Table 1.

**[0025]**

[Table 1]

| Pass No.                | Entry side thickness (mm) | Reduction amount (mm) | Rolling temperature (°C) | Rolling speed (m/min) | Rolling load (ton) |
|-------------------------|---------------------------|-----------------------|--------------------------|-----------------------|--------------------|
| 1                       | 6.00                      | 1.80                  | 200                      | 10                    | 180                |
| 2                       | 4.20                      | 1.26                  | 200                      | 10                    | 165                |
| 3                       | 2.94                      | 0.88                  | 200                      | 10                    | 150                |
| 4                       | 2.06                      | 0.62                  | 200                      | 10                    | 140                |
| 5                       | 1.44                      | 0.43                  | 200                      | 10                    | 135                |
| Final thickness 1.01 mm |                           |                       |                          |                       |                    |

**[0026]** In the above specific examples, the magnesium cut plate material M0 has a material quality of AZ31B, and has dimensions of a thickness of 6.00 mm, a width of 300 mm, and a length of 3000 mm. The diameter of the working rollers 1a is 400 mm and the barrel length thereof is 500 mm, while the diameter of the pinch rollers 4 is 250 mm.

Moreover, in the above described examples, the heating temperature in the heating furnaces 2 and 3 is 220 °C, while the pinch rollers 4 and the working rollers 1a are heating rollers having internal heaters and the surface temperature of these heating rollers is 200 °C.

In addition, in the above example, a magnesium cut plate material M0 having a thickness of 6.00 mm is changed by five passes of reciprocating rolling (i.e., by two and a half reciprocations) into a magnesium sheet M1 having a thickness of 1.01 mm, and this is then wound onto the winder 7 after the five passes.

**[0027]** The magnesium cut plate material M0 becomes gradually more elongated as it is rolled, and when the terminal end thereof has passed through the rolling mill 1, the end portions including the starting end protrude from the heating furnaces 2 and 3.

The table rollers 5 and 6 support the end portions which are protruding from the heating furnaces 2 and 3 using the transporting rollers 5a and 6a, and also maintain the temperature thereof by means of the temperature maintaining covers 5b and 6b.

**[0028]** This will now be described in more detail using FIG. 1. For example, a magnesium cut plate material M0 having a length L0 prior to rolling is rolled in a section A1 until it attains a length L1 (first rolling step). It is then rolled in a section A2 until it exceeds the length L1 and attains a length L2 (second rolling step). It is then wound on (winding-on step).

Thus, this hot rolling apparatus 100 performs reciprocating rolling using the first rolling step in the section A1, namely, in the section formed by the first heating furnace 2, the rolling mill 1, and the second heating furnace 3 while the magnesium cut plate material M0 has a length between L0 and L1. The hot rolling apparatus 100 then performs reciprocating rolling using the second rolling step in the section A2, that is, in the section formed by the first table roller 5, the first heating furnace 2, the rolling mill 1, the second heating furnace 3, and the second table roller 6 after the magnesium cut plate

material M0 has exceeded the length L1 and until it attains the length L2. The finished product, namely, the magnesium sheet M1 is then wound onto the winder 7.

**[0029]** As a result, the magnesium cut plate M0 is heated or has its temperature maintained over its entire length, and is kept at a temperature which remains substantially within a fixed range. Accordingly, it is possible to prevent any reduction in the quality of a product which is due to temperature variations in the magnesium cut plate material M0, and it is possible to maintain a superior quality in the finished product, namely, in the magnesium sheet M1.

**[0030]** The magnesium cut plate material M0 is soft during the rolling process due to the high temperature, and there is a possibility that pitting will remain if high pressure is also applied to areas other than those areas where the rolling mill 1 is used. However, in contrast to this, in this hot rolling apparatus 100, because the magnesium cut plate material M0 is nipped in a plurality of locations by a plurality of groups of pinch rollers 4, the force with which each pinch roller 4 nips the magnesium cut plate material M0 is small as a result of being dispersed, and any concern that pitting from the pinch rollers 4 will remain is reduced.

**[0031]** In addition, once the thickness of the magnesium cut plate material M0 has been rolled down to a predetermined thickness (for example, 1 mm) so as to form the magnesium sheet M1, the hot rolling apparatus 100 winds this magnesium sheet M1 onto the winder 7 so as to form a coil material.

At this time, the pinch rollers 8 adjust the transporting speed of the magnesium sheet M1 so that predetermined tension is applied to the magnesium sheet M1 being wound onto the winder 7, and thereby apply tensile force to the magnesium sheet M1 in the opposite direction from the wind-on direction of the winder 7.

**[0032]** According to the hot rolling apparatus 100 of the present invention, because the magnesium cut plate material M0 is rolled while substantially the entire length thereof is being heated and held at a predetermined temperature, it is possible to suppress any drop in the temperature of the magnesium cut plate material M0, and to prevent any reduction in the product quality which is due to temperature variations during the hot rolling, and it is thereby possible to maintain a superior quality in the finished product, namely, in the magnesium sheet M1.

**[0033]** Note that in the present embodiment, the pinch rollers 8 function as a tension applying apparatus, however, the tension applying apparatus may also be formed by a leveler which flattens the magnesium sheet M1.

Here, as is shown in FIG. 2, the leveler is formed by alternately combining three or more rollers in two rows in a beehive pattern when viewed in cross-section, and the magnesium sheet M1 is flattened as a result of the sheet-shaped material being passed between these rollers.

[Industrial applicability]

**[0034]** According to the magnesium hot rolling apparatus of the present invention and to the magnesium hot rolling method of the present invention which uses this apparatus, it is possible to prevent errors in the dimensional accuracy of a product as well as any consequent deterioration in product quality which are due to temperature variations during hot rolling, and to also maintain a superior quality in a finished product.

## Claims

1. A magnesium alloy hot rolling method comprising:

a first rolling step in which a magnesium plate is rolled reciprocatingly between an upstream heating furnace which is located on an upstream side of a rolling mill and which heats the magnesium plate, and a upstream heating furnace which is located on a downstream side of the rolling mill and which heats the magnesium plate; and

a second rolling step in which the temperature of respective end portions of the magnesium plate on both the upstream and downstream sides is maintained while the magnesium plate is being rolled reciprocatingly between an upstream temperature maintaining apparatus which is located further on the upstream side than the upstream heating furnace and which transports the magnesium plate which has been heated by the upstream heating furnace while maintaining the temperature thereof, and a downstream temperature maintaining apparatus which is located further on the downstream side than the upstream heating furnace and which transports the magnesium plate which has been heated by the upstream heating furnace while maintaining the temperature thereof.

2. The magnesium alloy hot rolling method according to claim 1, wherein there is provided a wind-on step in which, while tension is applied by a tension applying apparatus which is located on the downstream side of the downstream temperature maintaining apparatus to the magnesium plate which has been rolled to a predetermined thickness, the magnesium plate is wound onto a winder which is placed further on the downstream side than the downstream temperature maintaining apparatus.

3. A magnesium alloy hot rolling apparatus comprising:

a rolling mill which performs reciprocating rolling on a magnesium plate;  
an upstream heating furnace which is located on the upstream side of the rolling mill and which heats the magnesium plate;  
a downstream heating furnace which is located on the downstream side of the rolling mill and which heats the magnesium plate;  
an upstream temperature maintaining apparatus which is located further on the upstream side than the upstream heating furnace, and which transports the magnesium plate which has been heated by the upstream heating furnace and also maintains the temperature of upstream side end portions thereof; and  
a downstream temperature maintaining apparatus which is located further on the downstream side than the upstream heating furnace, and which transports the magnesium plate which has been heated by the upstream heating furnace and also maintains the temperature of downstream side end portions thereof.

4. The magnesium alloy hot rolling apparatus according to claim 3, wherein a plurality of groups of pinch rollers which sandwich the magnesium plate in the thickness direction thereof and adjust the transporting speed thereof are provided respectively between the rolling mill and the upstream heating furnace and between the rolling mill and the upstream heating furnace.

5. The magnesium alloy hot rolling apparatus according to claim 4, wherein working rollers of the rolling mill and the plurality of groups of pinch rollers which are located on the upstream and downstream sides of the rolling mill are heating rollers.

6. The magnesium hot rolling apparatus according to claim 3 or 4, wherein there are provided:

a tension applying apparatus which is located on the downstream side of the downstream temperature maintaining apparatus and which applies tension to the magnesium plate; and  
a winder which is located further on the downstream side than the tension applying apparatus and onto which the magnesium plate is wound.

FIG. 1

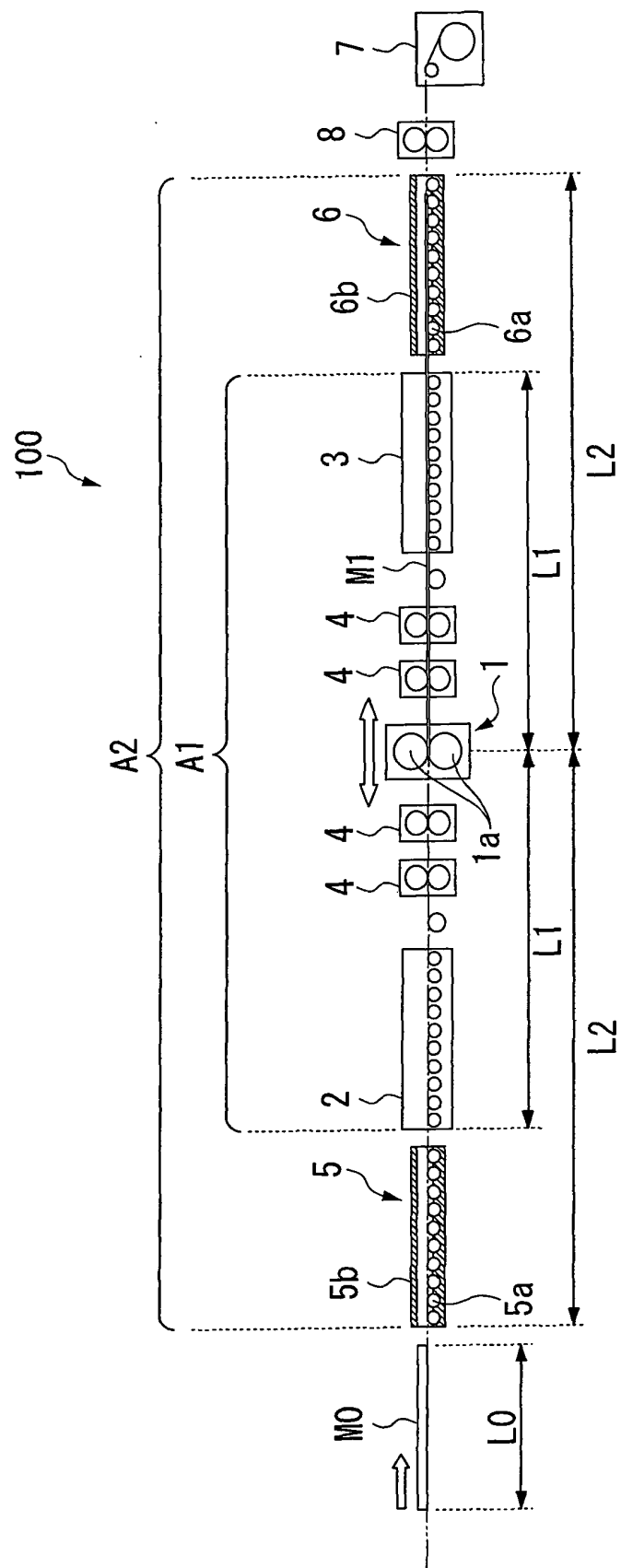


FIG. 2



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/068654

## A. CLASSIFICATION OF SUBJECT MATTER

B21B3/00(2006.01) i, B21B1/26(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)

B21B3/00, B21B1/26

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

|                           |           |                            |           |
|---------------------------|-----------|----------------------------|-----------|
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| Kokai Jitsuyo Shinan Koho | 1971-2008 | Toroku Jitsuyo Shinan Koho | 1994-2008 |

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

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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

|                                                                                                                                                                         |                                                                                                                                                                                                                                                  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| * Special categories of cited documents:                                                                                                                                | "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                                              |
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Date of the actual completion of the international search  
04 November, 2008 (04.11.08)Date of mailing of the international search report  
18 November, 2008 (18.11.08)Name and mailing address of the ISA/  
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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2008/068654

| C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT |                                                                                                                              |                       |
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Form PCT/ISA/210 (continuation of second sheet) (April 2007)

**REFERENCES CITED IN THE DESCRIPTION**

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