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(54) Method for producing aluminum strip excellent in degree of flatness

(57) Disclosed herein is a method for producing aluminum strips by rolling an aluminum strip at least twice as the final product, dividing the rolled strip into two halves, and winding up each of the divided strips into a coil. The method includes the steps of hot rolling an aluminum ingot, cold rolling the hot-rolled aluminum strip, thereby giving a strip at least twice as wide as the final product, cutting the wide strip longitudinally into two or more portions in the widthwise direction, and cold rolling the divided narrow strip. The secondary cold rolling is followed by trimming, stretch-leveling, and coiling. The resulting aluminum strip maintains good degree of flatness even though it experiences a high coil tension.

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Description

[0001] The present invention relates to a method for producing an aluminum strip (or hoop) required to have good degree of flatness for use as lithographic plates.

[0002] Aluminum strips or aluminum alloy strips are usually transported and stored in the form of coil or flat sheet if they are thin. (The term "aluminum strips" used in this specification embraces aluminum alloy strips.) The aluminum strip in the form of coil or sheet is required to be excellent in degree of flatness if it is to be used as lithographic plates. Therefore, it usually undergoes stretch-leveling by a stretch-leveler after rolling so that it is freed of surface irregularities due to uneven stress it receives at the time of rolling.

[0003] The applications for aluminum strips requiring good degree of flatness include, for example, the substrate for lithographic plates. The aluminum strip to be used as the substrate for lithographic plates is usually one which is 0.1-0.5 mm in thickness and 500-1600 mm in width and is made of so-called 1052 aluminum (which is aluminum conforming to JIS A1050, A1100, A3003, or A1050, incorporated with Mg). Such an aluminum strip is produced usually by the steps of preparing an ingot of the above-mentioned alloy composition, subjecting the ingot to facing, homogenizing, hot rolling, cold rolling, optional intermediate annealing, final cold rolling, and optional temper annealing to attain a desired thickness, passing the rolled strip through a stretch-leveler to attain desired degree of flatness, and then coiling the finished strip. The thus produced aluminum strip in the form of coil or flat sheet is delivered to a factory for surface treatment.

[0004] There has recently been a demand for making the coil of aluminum strip larger than before. This demand has arisen to improve efficiency in production of lithographic plates and the like by reducing time required to replace coils and carrying out surface treatment under stable conditions. One way to meet these requirements is by enlarging the size of the coil. Unfortunately, large coils pose another problem with degree of flatness. That is, aluminum strips are often found to have deteriorated in degree of flatness when unpacked and uncoiled in a lithographic plate manufacturer after storage and transportation for a long period of time even though they were made flat immediately after production by passage through a stretch-leveler.

[0005] A conceivable cause for deterioration in degree of flatness is discussed as follows. As the coil becomes larger in diameter, the number of windings increases. An aluminum strip wound many times forms a large number of layers, so that even a slight difference in thickness (due to thicker center and edges than other portion) across the width accumulates. Thus the presence of thicker portions in an aluminum strip results in an uneven distribution of winding tension even though the aluminum strip is given a uniform winding load when it is coiled originally. In other words, thicker portions receive a large tension and hence undergo creep deformation with time after coiling. When an aluminum strip with such defects is uncoiled at a user, those portions under a large tension appear with center buckle and edge buckle due to their superfluous length. The foregoing problem is more serious when the coil (wound on a core 20 inches in inside diameter) is larger than 1200 mm, particularly larger than 1500 mm, in outside diameter.

[0006] In order to tackle the foregoing problem, there have been proposed several methods for improving degree of flatness by controlling the winding tension in the final winder according to the crown height of the strip. See Japanese Patent Laid-open Nos. Hei-10-71425, 2003-81504, and 2004-298947. Another method for improving degree of flatness includes rolling a strip twice as wide as the intended product, dividing the strip into two halves, and adequately controlling the crown ratio of each half. See Japanese Patent Laid-open No. Hei-9-202063. The aluminum strip produced in this manner retains good degree of flatness when it is unpacked at a user even after an extended period of storage.

[0007] However, another problem has recently arisen in users of aluminum strips. Such users as lithographic plate manufacturers are running their production line faster than before in order to improve productivity. The fast-running production line requires high-temperature drying that follows surface treatment, and this in turn makes it necessary to increase tension to ensure the smooth passage of aluminum strips. The increased coil tension deteriorates degree of flatness after surface treatment in the production of lithographic plates even though the aluminum strip has no sign of deterioration in degree of flatness when it is uncoiled at the lithographic plate manufacturer.

[0008] The present invention was completed in view of the foregoing. It is an object of the present invention to provide a method for producing aluminum strips, which method includes: rolling an aluminum strip at least twice as wide as the final product, dividing the rolled strip into two halves, and winding up each of the divided strips into a coil. The resulting aluminum strip excels in degree of flatness and hardly deteriorates in degree of flatness even when the coil tension is increased for its efficient processing.

[0009] According to the present invention, the method for producing aluminum strips includes the following steps.
A step of heat treatment to homogenize an ingot of aluminum or aluminum alloy.
A step of hot rolling to be performed on the heat-treated ingot in such a way that the hot-rolled strip has a crown ratio no larger than 1.5% (as an absolute value) in the widthwise direction.
A step of primary cold rolling to be performed on the hot-rolled strip in such a way that the cold-rolled strip has at least twice the width of the final product.
A step of dividing the cold-rolled strip into two or more portions in the widthwise direction.
A step of secondary cold rolling to be performed on the divided portions.

A final step of stretch-leveling, trimming, and winding to be performed on the divided portions which have undergone secondary cold rolling.

[0010] The primary and secondary cold rolling may be accomplished in one pass or more than one pass.

[0011] The final step may be performed in the order of stretch-leveling, trimming, and winding, or trimming, stretch-leveling, and winding.

[0012] The present invention produces the effect of eliminating deterioration in degree of flatness because the aluminum strip is divided into narrow strips after primary cold rolling and the narrow strips undergo secondary cold rolling so that edge burrs resulting from division disappear.

Fig. 1 is a sectional view in the widthwise direction of the aluminum strip which has just undergone primary cold rolling in the first embodiment of the present invention.

Fig. 2 is an ideal sectional view in the widthwise direction of the aluminum strip which has just been divided into two halves.

Fig. 3 is a sectional view in the widthwise direction of the aluminum strip which has just been divided into two halves in the first embodiment of the present invention.

Figs. 4A to 4C are sectional views in the widthwise direction of the aluminum strip which has just undergone secondary cold rolling and trimming in the first embodiment of the present invention.

Figs. 5A and 5B are sectional views in the widthwise direction of the aluminum strip which has just undergone trimming and stretch-leveling in the second embodiment of the present invention.

Fig. 6 is a schematic diagram showing the aluminum strip wound around a core.

Fig. 7 is a schematic diagram showing the edge waving.

Fig. 8 is a sectional view in the widthwise direction of the aluminum strip having burrs.

Fig. 9 is a diagram showing quarter buckles.

Fig. 10 is a diagram illustrating the definition of the crown ratio for the positive crown.

Fig. 11 is a diagram illustrating the definition of the crown ratio for the negative crown.

Figs. 12A to 12D are sectional views illustrating the definition of the crown ratio for the one-side crown.

[0013] The embodiment of the present invention will be described in more detail with reference to the accompanying drawings. Figs. 1, 3, and 4 are sectional views in the widthwise direction showing the steps of producing the aluminum strip according to the first embodiment of the present invention. These sectional views exaggerate the thickness relative to the width in order to clearly show the difference in shape among products. Fig. 1 shows an aluminum strip 1 (wide strip) with a positive crown at the center in the widthwise direction. The aluminum strip 1 is obtained from an aluminum ingot or aluminum alloy ingot by facing, hot rolling, optional intermediate annealing, and primary cold rolling. It is at least twice as wide as the final product. In other words, it is wide enough to be divided into two or more than two portions (in the widthwise direction) after hot rolling. The one shown in Fig. 1 is to be divided into two portions. For the sake of brevity, the following description is based on an assumption that the aluminum strip 1 (which has undergone hot rolling) will be divided into two portions.

[0014] Usually, there are the following additional steps between hot rolling and primary cold rolling. In the case of a material, like H14 to H18, which undergoes intermediate annealing, the ingot (continuously cast slab) is hot-rolled into a strip 3 mm in thickness, followed by winding into a coil. The strip is uncoiled and cold-rolled for thickness reduction to 1.7 mm, followed by winding into a coil. The strip is uncoiled and cold rolled for thickness reduction to 1.1 mm, followed by winding into a coil. The strip is uncoiled and subjected to intermediate annealing, followed by winding into a coil. The strip is uncoiled and cold-rolled for thickness reduction to 0.6 mm. On the other hand, in the case of a material, like H19, which does not undergo intermediate annealing, the hot-rolled strip (3 mm thick) is cold-rolled for thickness reduction to 1.6 mm and then, e.g., to 1.0 mm. The cold-rolled strip undergoes cold rolling again, without intermediate annealing preceding it, for thickness reduction to 0.6 mm. That is, the hot-rolled strip is made as thin as 0.6 mm by three passes of cold rolling. In this case, therefore, the primary cold rolling is composed of three passes of cold rolling. Also, a material, like H19, which does not undergo intermediate annealing, may undergo the primary cold rolling by a tandem rolling mill. In this case the hot rolling is carried out so that the thickness is reduced to 5 mm, followed by winding into a coil. After uncoiling, the strip undergoes tandem cold rolling for thickness reduction to 0.33 mm. In this case, therefore, the primary cold rolling is accomplished by one pass. Incidentally, the intermediate annealing mentioned above may be accomplished batchwise or continuously in the usual way. According to the present invention, one pass of cold rolling by the above-mentioned tandem rolling mill is defined as the steps of uncoiling, cold rolling repeated twice, and coiling.

[0015] Then, the aluminum strip 1 which has undergone the primary cold rolling is uncoiled and cut in its lengthwise direction into two halves by a slitter. This step yields a pair of aluminum strips 3, each being as wide as the final product, as shown in Fig. 3. Each of the halved strips is wound into a coil. Incidentally, according to Japanese Patent Laid-open No. Hei-9-202063, the halved strips should have a smooth cross section (free of burrs) as shown Fig. 2; in actual, however, they have burrs 4 at the cut edges as shown in Fig. 3, and these burrs 4 result in an uneven thickness in the widthwise direction. The burrs 4 at the side edges of the aluminum strip 1, as shown in Fig. 3, are due to trimming to cut off cracked edges resulting from rolling. In other words, slitting is accomplished by using two slitting blades arranged 5-10 mm apart in the widthwise direction, so that the central part (5-10 mm wide) is removed from the aluminum strip 1. At the same time as slitting, the aluminum strip 1 undergoes edge trimming to remove its edges (5-10 mm wide). The removal of the central part is not always necessary; slitting may be accomplished by using a single blade instead of two.

[0016] The halved aluminum strip 3 having burrs 4 at the cut edge poses a problem when it is coiled around a core 13 as shown in Fig. 6. The problem is that the thick parts 11 originating from the crown of the aluminum strip 1 (which has not yet been slit) is tightly coiled and the thin parts 12 are loosely coiled. The present inventors' investigation into the deterioration in degree of flatness that occurs in conventional aluminum strips revealed that the thick parts 11 frequently cause edge waving 14 and this edge waving 14 makes the aluminum strip poor in degree of flatness.

[0017] The thick parts 11 (shown in Fig. 6) have burrs 4 as shown in Fig. 3, and these burrs 4 accumulate as the aluminum strip 3 is coiled in many layers. Therefore, the thick parts 11 (of half-crown with burrs) experience an uneven tension in proportion to the number of coiled layers. The uneven tension causes creep deformation and edge waving 14 with the lapse of time after winding. Even in the case where no creep deformation is noticed after storage for 6 months, the uneven tension due to the thick parts 11 gives rise to a latent internal stress. The internal stress releases itself, thereby causing the edge waving 14, when the aluminum strip is heated for drying (that follows surface treatment), exposed to high temperatures for heat treatment, or subjected to high tension for stable passage through the production line. The foregoing results of investigation led the present inventors to a conclusion that deterioration in degree of flatness, such as edge waving 14, that occurs in the aluminum strip results from the burrs 4 that spring from the cut edges of the center (crown) of the aluminum strip to increase the thickness further. The present invention is based on the investigation mentioned above.

[0018] According to the present invention, the aluminum strip 3 which has burrs 4 as shown in Figs. 3 and 4A undergoes cold rolling again as shown in Fig. 4B. This step is referred to as the secondary cold rolling. In other words, the aluminum strip 3, which has undergone the primary cold rolling, undergoes slitting for division into two halves and the secondary cold rolling, so that the aluminum strip 5 as shown in Fig. 4B is obtained. The aluminum strip 3 shown in Fig. 4A has the thickest part at the cut edge from which the burr 4 has sprung. The cut edge is rolled first by the secondary cold rolling, so that the aluminum strip 5 which has undergone the secondary cold rolling slightly decreases in thickness at 6b which has been the cut edge, as shown in Fig. 4B. In other words, the aluminum strip 5 which has undergone the secondary cold rolling becomes slightly thinner at 6b and thickest at 6a in the neighborhood of 6b.

[0019] The secondary cold rolling is accomplished as follows if the aluminum strip (as the final product having a thickness of 0.30 mm) is to be produced by using a single rolling mill for the primary cold rolling. The aluminum strip formed from an ingot undergoes slitting and the resulting halved strip 3 (0.6 mm thick) is uncoiled and subjected to cold rolling (down to 0.45 mm), followed by coiling. The aluminum strip is uncoiled and then cold-rolled down to a thickness of the final product (or the aluminum strip 5). The cold-rolled strip is coiled.

[0020] On the other hand, the secondary cold rolling is accomplished as follows if the aluminum strip (as the final product having a thickness of 0.30 mm) is to be produced by using a tandem rolling mill for the primary cold rolling. The aluminum strip formed from an ingot undergoes slitting and the resulting halved strip 3 (0.33 mm thick) is uncoiled and subjected to cold rolling to give the strip 5 which has a thickness of the final product. The thus obtained strip is wound up into a coil.

[0021] In other words, the secondary cold rolling includes one to three passes if the primary cold rolling is accomplished by using a single rolling mill, and the second cold rolling includes only one pass if the primary cold rolling is accomplished by using a tandem rolling mill.

[0022] Incidentally, the secondary cold rolling should preferably be carried out in such a way that the draft is less than 5%. The secondary cold rolling usually includes four or less passes. The secondary cold rolling is carried out such that the finishing thickness is 0.30 mm, for example. The nominal thickness of lithographic plates is 0.15 mm, 0.20 mm, 0.24 mm, 0.30 mm, 0.40 mm, and 0.50 mm. Of these thicknesses, 0.24 mm and 0.30 mm are most popular.

[0023] In the stretch-leveling step that follows the secondary cold rolling, the aluminum strip 5 passes through a roller leveler with stretch for improvement in degree of flatness. The leveled aluminum strip 7 undergoes trimming so that the width after trimming equals that of the final product, as shown in Fig. 4C. This trimming step causes burrs 8b to spring from both edges of the aluminum strip 7. It is to be noted that the burrs 8b do not spring from the thickest part 8a of the aluminum strip 7.

[0024] Therefore, when the aluminum strip 7 is wound up into a coil, it is not the burrs 8b but the part 8a where its upper and lower layers come into contact with each other. Thus the aluminum strip 7 is free of edge waving 14 when it is uncoiled after storage.

[0025] The aluminum strip in the form of coil is packed, stored, and finally shipped to the customer (lithographic plate manufacturer), where it undergoes surface treatment.

[0026] The above-mentioned method for producing the aluminum strip includes the steps of making an ingot into a strip by hot rolling, cold-rolling the hot-rolled strip (followed by optional annealing), cold-rolling the cold-rolled strip again, cutting the cold-rolled strip into two halves in the lengthwise direction, and cold-rolling each half of the strip. The advantage of this method is that the cutting into two halves causes burrs 4 to spring at the cut edges but the secondary cold rolling that follows the cutting makes the cut edge 6b (where burrs 4 spring) slightly thin and makes its neighboring part 6a thickest. This means that the cut edge is not the thickest part and hence it is not subject to creep deformation during storage in the coiled form. In addition, the secondary cold rolling eliminates the adverse effect of burrs 4 and hence the uncoiled aluminum strip is not subject to edge waving due to released internal stress which would otherwise exist when the aluminum strip is heated at high temperatures for drying that follows surface treatment and experiences high tension for stable line passage in the lithographic plate manufacturing process.

[0027] Incidentally, the burrs that spring after cutting into two halves take on various shapes as indicated by 4a, 4b, and 4c in Figs. 8A, 8B, and 8C, respectively, in addition to the one shown in Fig. 3. The secondary cold rolling suppresses any burrs, thereby preventing the aluminum strip from deteriorating in degree of flatness (due to edge waving) in the lithographic plate manufacturing process.

[0028] The following section deals with the second embodiment of the present invention. The method according to the second embodiment is composed of two stages. The first stage is identical with the first embodiment, and the second stage is an addition to the first embodiment. The first stage includes the steps of making an ingot of aluminum or aluminum alloy into a strip by hot rolling, cold-rolling the hot-rolled strip (followed by optional annealing), cold-rolling the cold-rolled strip again, cutting the cold-rolled strip into two halves in the lengthwise direction, and cold-rolling each half of the strip. The second stage includes the steps of trimming the aluminum strip (obtained in the first stage), passing the trimmed strip through a leveler for improvement in degree of flatness, and winding up the leveled strip into a coil.

[0029] That is, the first embodiment is **characterized in that** the secondary cold rolling is followed by stretch-leveling, trimming, and coiling, whereas the second embodiment is **characterized in that** the secondary cold rolling is followed by trimming, stretch-leveling, and coiling.

[0030] The second embodiment offers the advantage of reducing burrs 6c, which spring in the trimming step as shown in Fig. 5A, in the stretch-leveling step as shown in Fig. 5B. In other words, the thickness at the cut edge is slightly decreased and the thickest part 6a is shifted inward from the cut edge as the result of the secondary cold rolling as shown in Fig. 5B, and trimming to achieve the width of the final product causes burrs 6c to spring from the trimmed edge. In the subsequent stretch-leveling step, the trimmed aluminum strip is passed through a roller leveler. This stretch-leveling imparts a tensile stress to the aluminum strip in contact with leveling rolls under stretch. As the result, the aluminum strip 9 that has passed through the leveler has very few burrs 6c as shown in Fig. 5B, and the cut edge 9b close to the thickest part 9a becomes almost free of burrs.

[0031] Thus, the second embodiment makes it possible to produce the aluminum strip 9 which is free of burrs which spring at the time of trimming and which does not have the cut edge as the thickest part 9a. The aluminum strip 9 produced in this manner does not suffer edge waving but keeps good degree of flatness when it is delivered after storage and uncoiled for lithographic plate manufacturing.

[0032] According to the present invention, the aluminum strip which has undergone hot rolling should preferably have a crown ratio no larger than 1.5% (in terms of absolute value) in the widthwise direction. The present inventors investigated how degree of flatness is affected by the crown ratio in the widthwise direction of the aluminum strip which has undergone hot rolling. The result of the investigation revealed that the aluminum strip having a thickness of 0.14-0.5 mm and a width of 570-1050 mm exhibits good degree of flatness if it has a crown ratio no larger than 1.5% (in terms of absolute value). It also revealed that, with a crown ratio larger than 1.5%, the aluminum strip tends to have large quarter buckles 15 as shown in Fig. 9. The quarter buckles are surface irregularities exceeding 2.0 mm in height that appear at the thickest part in the widthwise direction of the strip, and they aggravate the degree of flatness of the strip. Therefore, it is desirable that the aluminum strip that has undergone hot rolling should have a crown ratio no larger than 1.5% (in terms of absolute value) in its widthwise direction.

[0033] The crown ratio in the widthwise direction of the hot-rolled strip can be controlled by any known method. This object is achieved by, for example, adjusting the force of work roll bending according to the difference between the set crown ratio and the actual crown ratio.

[0034] Incidentally, the crown ratio in the present invention is defined as shown in Figs. 10 to 12. Fig. 10 is a diagram showing a positive crown which has the maximum thickness at the center in the widthwise direction. The thickness at the thickest part is represented by Tmax and the thicknesses at the edges are represented by T1 and T2, respectively. Hmax is represented by:

$$Hmax = \{Tmax \cdot (T1+T2)/2\}/2$$

[0035] If Tave represents the average value of the thickness in the widthwise direction, the crown ratio of the positive crown is represented by:

$$(Hmax/Tave) \times 100\ (\%)$$

[0036] After all, the crown ratio is represented by the following formula 1.

$$\text{Crown ratio}\ (\%) = [\{Tmax - (T1+T2)/2\}/\{Tave\}] \times 100$$

[0037] Incidentally, the average thickness Tave is measured in the following manner. First, a sample is cut out of the long strip in the direction perpendicular to the direction in which the strip is passed. (The sample is 35 mm wide and has a length equal to the width of the finished aluminum strip.) This sample is examined for thickness continuously by using an automatic thickness measuring apparatus of contact type. The average thickness (Tave) is an average value of the continuously measured thicknesses. Incidentally, the measurement is performed at intervals of 1 mm in the widthwise direction of the strip (or in the lengthwise direction of the sample). However, no measurement is taken in the regions within 5 mm from the edges (in the lengthwise direction of the sample) so as to avoid the influence of burrs.

[0038] Likewise, the negative crown shown in Fig. 11 also has its crown ratio defined by the formula 2 below.

$$\text{Crown ratio}\ (\%) = [\{(Tmin - Tmax)/2\}\ /\ \{Tave\}] \times 100$$

where Tmax is the maximum thickness and Tmin is the minimum thickness. The crown ratio in this case is a negative value. In the case of the so-called half-crown that appears after cutting into two halves, as shown in Figs. 12A to 12D, Hmax is defined as Hmax = (Tmax·Tmin)/2, where Tmax is the maximum thickness and Tmin is the minimum thickness. Thus, the crown ratio (%), which is (Hmax/Tave) × 100, is represented by the following formula 3.

$$\text{Crown ratio}\ (\%) = [\{(Tmax - Tmin)/2\}\ /\ \{Tave\}] \times 100$$

[0039] Incidentally, the crowns shown in Figs. 12B and 12D are also called quarter crowns.

[0040] The method according to the present invention can be applied to not only the production of aluminum strips for lithographic plates but also the production of any aluminum strips that require good degree of flatness.

EXAMPLES

[0041] The following deals with Examples which are intended to prove the effect of the present invention and Comparative Examples which are outside the scope of the present invention.

[0042] In each example, an aluminum ingot was prepared, which measures 600 mm thick, 2200 mm wide, and 5000 mm long, and has a composition (equivalent to JIS 1050) containing 0.06% Si, 0.33% Fe, 0.02% Cu, and 0.01% Ti, with the remainder being Al and inevitable impurities. The ingot underwent facing, homogenizing, and hot rolling in the usual way, so that the resulting hot-rolled strip has a thickness and crown ratio as shown in Tables 1-1 to 1-5 for examples and comparative examples in the first embodiment and Tables 2-1 to 2-5 for examples and comparative examples in the second embodiment. The hot-rolled strip was coiled temporarily. Each hot-rolled strip underwent primary cold rolling, width slitting, secondary cold rolling, and finish processing (which includes stretch-leveling → trimming → coiling or trimming → stretch-leveling → coiling), according to any one of the manufacturing patterns A to L shown in Tables 1 and 2. Thus there was obtained a coiled aluminum strip having a thickness of 0.3 mm. Coiling was carried out with a tension of 1.0 kg/mm^2. Width slitting was accomplished in such a way that the strip was divided into two strips (1000 mm wide each) or three strips (680 mm wide each). Incidentally, the strips in Comparative Example 1 and Examples 2, 10, and 17 have their central part (10 mm wide) removed at the time of width slitting. The thus obtained strip was coiled around a core (20 inches in inside diameter), so that the resulting coil had an outside diameter of 1700 mm.

[0043] The coiled strip which had undergone hot rolling and the coiled strip which had passed through the final processing were cut (by shearing) at intervals of 30 mm in the lengthwise direction.
In other words, the coiled strip (which is 1000 mm wide or 680 mm wide) was cut in the direction parallel to the widthwise direction. Thus there was obtained a hoop which is 300 mm wide and 1000 mm or 680 mm long. The hoop was examined for thickness at intervals of 10 mm in the lengthwise direction (or in the widthwise direction of coil) by using a micrometer.

The thus measured thickness was converted into the crown ratio by calculations explained above. The results are shown in Table 1.

Table 1-1

		Pattern of manufacturing step	Finish thickness after hot rolling (mm)	Crown ratio after hot rolling (%)
Comparative Example 1		A	3	0.3
First embodiment	Example 1	B	3	0.2
First embodiment	Example 2	B	3	0.6
First embodiment	Example 3	B	3	0.9
First embodiment	Example 4	B	3	1.3
First embodiment	Example 5	B	3	-1.2
First embodiment	Comparative Example 2	B	3	1.7
First embodiment	Comparative Example 3	B	3	-1.6
First embodiment	Example 6	C	3	0.2
First embodiment	Example 7	C	3	0.4
First embodiment	Example 8	C	3	1.5
First embodiment	Example 9	C	3	-0.7
First embodiment	Example 10	C	3	-1.1
First embodiment	Comparative Example 4	C	3	1.8
First embodiment	Comparative Example 5	C	3	-1.6
First embodiment	Example 11	D	3	0.4
First embodiment	Example 12	D	3	0.4
First embodiment	Example 13	D	3	1.2
First embodiment	Comparative Example 6	D	3	1.7
First embodiment	Example 14	E	5	0.1
First embodiment	Example 15	E	5	1.2
First embodiment	Comparative Example 7	E	5	1.8
First embodiment	Example 16	F	3	0.0
First embodiment	Example 17	F	3	0.3
First embodiment	Example 18	F	3	-1.1
First embodiment	Comparative Example 8	F	3	-1.6

Table 1-2

		Primary cold rolling					
		Thickness after one pass (mm)	Thickness after two passes (mm)	Thickness before interme-diate annealing (mm)	Thickness after three passes (mm)	Thickness after four passes (mm)	Thickness after five passes (mm)
Comparative Example 1		1.7	1.3	1.3	0.7	0.45	0.3
First embodiment	Example 1	1.7	1.3	1.3	0.7	–	–
	Example 2	1.7	1.3	1.3	0.7	–	–
	Example 3	1.7	1.3	1.3	0.7	–	–
	Example 4	1.7	1.3	1.3	0.7	–	–
	Example 5	1.7	1.3	1.3	0.7	–	–
	Comparative Example 2	1.7	1.3	1.3	0.7	–	–
	Comparative Example 3	1.7	1.3	1.3	0.7	–	–
	Example 6	1.7	1.3	–	0.7	–	–
	Example 7	1.7	1.3	–	0.7	–	–
	Example 8	1.7	1.3	–	0.7	–	–
	Example 9	1.7	1.3	–	0.7	–	–
	Example 10	1.7	1.3	–	0.7	–	–
	Comparative Example 4	1.7	1.3	–	0.7	–	–
	Comparative Example 5	1.7	1.3	–	0.7	–	–
	Example 11	1.7	1.3	1.3	0.7	0.45	0.32
	Example 12	1.7	1.3	1.3	0.7	0.45	0.32
	Example 13	1.7	1.3	1.3	0.7	0.45	0.32
	Comparative Example 6	1.7	1.3	1.3	0.7	0.45	0.32
	Example 14	0.32	–	–	–	–	–
	Example 15	0.32	–	–	–	–	–
	Comparative Example 7	0.32	–	–	–	–	–
	Example 16	1.7	1.3	–	0.7	–	–
	Example 17	1.7	1.3	–	0.7	–	–
	Example 18	1.7	1.3	–	0.7	–	–
	Comparative Example 8	1.7	1.3	–	0.7	–	–

Table 1-3

		Slitting		Secondary cold rolling		
		Thickness (mm)	Number of widthwise divisions	Thickness after one pass (mm)	Thickness after two passes (mm)	Thickness after three passes (mm)
Comparative Example 1		0.3	2	–	–	–
First embodiment	Example 1	0.7	2	0.45	0.3	–
	Example 2	0.7	2	0.45	0.3	–
	Example 3	0.7	2	0.45	0.3	–
	Example 4	0.7	2	0.45	0.3	–
	Example 5	0.7	2	0.45	0.3	–
	Comparative Example 2	0.7	2	0.45	0.3	–
	Comparative Example 3	0.7	2	0.45	0.3	–
	Example 6	0.7	2	0.45	0.33	0.3
	Example 7	0.7	2	0.45	0.33	0.3
	Example 8	0.7	2	0.45	0.33	0.3
	Example 9	0.7	2	0.45	0.33	0.3
	Example 10	0.7	2	0.45	0.33	0.3
	Comparative Example 4	0.7	2	0.45	0.33	0.3
	Comparative Example 5	0.7	2	0.45	0.33	0.3
	Example 11	0.32	2	0.3	–	–
	Example 12	0.32	2	0.3	–	–
	Example 13	0.32	2	0.3	–	–
	Comparative Example 6	0.32	2	0.3	–	–
	Example 14	0.32	2	0.3	–	–
	Example 15	0.32	2	0.3	–	–
	Comparative Example 7	0.32	2	0.3	–	–
	Example 16	0.7	3	0.45	0.33	0.3
	Example 17	0.7	3	0.45	0.33	0.3
	Example 18	0.7	3	0.45	0.33	0.3
	Comparative Example 8	0.7	3	0.45	0.33	0.3

Table 1-4

		Sequence of final steps	Pattern of crown in product	Crown ratio of product (%)
Comparative Example 1		Stretch-leveling → trimming → winding	Fig. 3	0.3
First embodiment	Example 1	Stretch-leveling → trimming → winding	Fig. 4C	0.1
First embodiment	Example 2	Stretch-leveling → trimming → winding	Fig. 4C	0.5
First embodiment	Example 3	Stretch-leveling → trimming → winding	Fig. 4C	0.8
First embodiment	Example 4	Stretch-leveling → trimming → winding	Fig. 4C	1.4
First embodiment	Example 5	Stretch-leveling → trimming → winding	Fig. 4C	1.2
First embodiment	Comparative Example 2	Stretch-leveling → trimming → winding	Fig. 4C	1.6
First embodiment	Comparative Example 3	Stretch-leveling → trimming → winding	Fig. 4C	1.6
First embodiment	Example 6	Stretch-leveling → trimming → winding	Fig. 4C	0.3
First embodiment	Example 7	Stretch-leveling → trimming → winding	Fig. 4C	0.3
First embodiment	Example 8	Stretch-leveling → trimming → winding	Fig. 4C	1.5
First embodiment	Example 9	Stretch-leveling → trimming → winding	Fig. 4C	0.8
First embodiment	Example 10	Stretch-leveling → trimming → winding	Fig. 4C	1.1
First embodiment	Comparative Example 4	Stretch-leveling → trimming → winding	Fig. 4C	1.7
First embodiment	Comparative Example 5	Stretch-leveling → trimming → winding	Fig. 4C	1.6
First embodiment	Example 11	Stretch-leveling → trimming → winding	Fig. 4C	0.5
First embodiment	Example 12	Stretch-leveling → trimming → winding	Fig. 4C	0.5
First embodiment	Example 13	Stretch-leveling → trimming → winding	Fig. 4C	1.3
First embodiment	Comparative Example 6	Stretch-leveling → trimming → winding	Fig. 4C	1.6
First embodiment	Example 14	Stretch-leveling → trimming → winding	Fig. 4C	0.1
First embodiment	Example 15	Stretch-leveling → trimming → winding	Fig. 4C	1.1
First embodiment	Comparative Example 7	Stretch-leveling → trimming → winding	Fig. 4C	1.8
First embodiment	Example 16	Stretch-leveling → trimming → winding	Similar to Fig. 1	0
First embodiment	Example 16	Stretch-leveling → trimming → winding	Fig. 4C	0.1
First embodiment	Example 17	Stretch-leveling → trimming → winding	Similar to Fig. 1	0.1
First embodiment	Example 17	Stretch-leveling → trimming → winding	Fig. 4C	0.3
First embodiment	Example 18	Stretch-leveling → trimming → winding	Similar to Fig. 1	1.2
First embodiment	Example 18	Stretch-leveling → trimming → winding	Fig. 5B	1.2
First embodiment	Comparative Example 8	Stretch-leveling → trimming → winding	Similar to Fig. 1	1.5
First embodiment	Comparative Example 8	Stretch-leveling → trimming → winding	Fig. 5B	1.6

Table 1-5

		Rating of degree of flatness					
		Immediately after winding		After storage for 6 months		After coating and drying	
		Edge waving	Others	Edge waving	Others	Edge waving	Others
Comparative Example 1		○	○	○	○	×	○
First embodiment	Example 1	○	○	○	○	△	○
	Example 2	○	○	○	○	△	○
	Example 3	○	○	○	○	△	○
	Example 4	○	○	○	△	△	△
	Example 5	○	○	○	△	△	△
	Comparative Example 2	○	○	○	×	△	×
	Comparative Example 3	○	○	○	△	△	×
	Example 6	○	○	○	○	△	○
	Example 7	○	○	○	○	△	○
	Example 8	○	○	○	△	△	△
	Example 9	○	○	○	○	△	○
	Example 10	○	○	○	△	△	△
	Comparative Example 4	○	○	○	×	△	×
	Comparative Example 5	○	○	○	△	△	×
	Example 11	○	○	○	○	△	○
	Example 12	○	○	○	○	△	○
	Example 13	○	○	○	△	○	△
	Comparative Example 6	○	○	○	×	○	×
	Example 14	○	○	○	○	△	○
	Example 15	○	○	○	△	○	△
	Comparative Example 7	○	○	○	×	○	×
	Example 16	○	○	○	○	○	○
		○	○	○	○	△	○
	Example 17	○	○	○	○	○	○
		○	○	○	○	△	○
	Example 18	○	○	○	△	○	△
		○	○	○	△	○	△
	Comparative Example 8	○	○	○	△	○	×
		○	○	○	△	○	×

Table 2-1

		Pattern of manu-facturing steps	Finish thickness after hot rolling (mm)	Crown ratio after hot rolling (%)
Second embodiment	Example19	G	3	-1.2
	Example20		3	-0.3
	Example21		3	0.4
	Example22		3	0.5
	Example23		3	1.3
	Comparative Example9		3	1.7
	Comparative Example10		3	-1.7
	Example24	H	3	-0.5
	Example25		3	0.8
	Example26		3	0.9
	Example27		3	1.5
	Comparative Example11		3	1.9
	Example28	I	3	0.2
	Example29		3	0.0
	Example30	J	3	0.4
	Example31	K	5	0.6
	Example32	L	5	0.4
	Example33		5	0.4

Table 2-2

		Primary cold rolling					
		Thickness after one pass (mm)	Thickness after two passes (mm)	Thickness after inter-mediate annealing (mm)	Thickness after three passes (mm)	Thickness after four passes (mm)	Thickness after five passes (mm)
Second embodiment	Example19	1.7	1.3	–	0.7	–	–
	Example 20	1.7	1.3	–	0.7	–	–
	Example 21	1.7	1.3	–	0.7	–	–
	Example 22	1.7	1.3	–	0.7	–	–
	Example 23	1.7	1.3	–	0.7	–	–
	Comparative Example 9	1.7	1.3	–	0.7	–	–
	Comparative Example 10	1.7	1.3	–	0.7	–	–
	Example 24	1.7	1.3	–	0.7	–	–
	Example 25	1.7	1.3	–	0.7	–	–
	Example 26	1.7	1.3	–	0.7	–	–
	Example 27	1.7	1.3	–	0.7	–	–
	Comparative Example 11	1.7	1.3	–	0.7	–	–
	Example 28	1.7	1.3	1.3	0.7	0.45	0.32
	Example 29	1.7	1.3	1.3	0.7	0.45	0.32
	Example 30	1.7	1.3	–	0.7	0.45	0.32
	Example 31	0.32	–	–	–	–	–
	Example 32	0.32	–	–	–	–	–
	Example 33	0.32	–	–	–	–	–

Table 2-3

		Slitting		Secondary cold rolling		
		Thickness (mm)	Number of width-wise divisions	Thickness after one pass (mm)	Thickness after two passes (mm)	Thickness after three passes (mm)
Second embodiment	Example 19	0.7	2	0.45	0.33	0.3
	Example 20	0.7	2	0.45	0.33	0.3
	Example 21	0.7	2	0.45	0.33	0.3
	Example 22	0.7	2	0.45	0.33	0.3
	Example 23	0.7	2	0.45	0.33	0.3
	Comparative Example 9	0.7	2	0.45	0.33	0.3
	Comparative Example 10	0.7	2	0.45	0.33	0.3
	Example 24	0.7	2	0.45	0.33	0.3
	Example 25	0.7	2	0.45	0.33	0.3
	Example 26	0.7	2	0.45	0.33	0.3
	Example 27	0.7	2	0.45	0.33	0.3
	Comparative Example 11	0.7	2	0.45	0.33	0.3
	Example 28	0.32	2	0.3	–	–
	Example 29	0.32	2	0.3	–	–
	Example 30	0.32	2	0.3	–	–
	Example 31	0.32	2	0.3	–	–
	Example 32	0.32	3	0.3	–	–
	Example 33	0.32	3	0.3	–	–

Table 2-4

		Sequence of final steps	Pattern of crown in product	Crown ratio of product (%)
Second embodiment	Example 19	Stretch-leveling → trimming → winding	Fig. 5B	1.2
	Example 20			0.2
	Example 21			0.3
	Example 22			0.6
	Example 23			1.3
	Comparative Example 9			1.7
	Comparative Example 10			1.7
	Example 24			0.4
	Example 25			0.9
	Example 26			0.7
	Example 27			1.4
	Comparative Example 11			1.9
	Example 28			0.3
	Example 29			±0.0
	Example 30			0.5
	Example 31			0.5
	Example 32		Similar to Fig. 1	0.1
			Fig. 5B	0.3
	Example 33		(Fig. 1)	0.4
			Fig. 5B	0.4

Table 2-5

		Rating of degree of flatness					
		Immediately after winding		After storage for 6 months		After coating and drying	
		Edge waving	Others	Edge waving	Others	Edge waving	Others
Second embodiment	Example 19	○	○	○	△	○	△
	Example 20	○	○	○	○	○	○
	Example 21	○	○	○	○	○	○
	Example 22	○	○	○	○	○	○
	Example 23	○	○	○	△	○	△
	Comparative Example 9	○	○	○	×	○	×
	Comparative Example 10	○	○	○	×	○	×
	Example 24	○	○	○	○	○	○
	Example 25	○	○	○	○	○	○
	Example 26	○	○	○	○	○	○
	Example 27	○	○	○	△	○	△
	Comparative Example 11	○	○	○	×	○	×
	Example 28	○	○	○	○	○	○
	Example 29	○	○	○	○	○	○
	Example 30	○	○	○	○	○	○
	Example 31	○	○	○	○	○	○
	Example 32	○	○	○	○	○	○
		○	○	○	○	○	○
	Example 33	○	○	○	○	○	○
		○	○	○	○	○	○

[0044] The coiled strip prepared as mentioned above was coiled again, and a sample (1.5 m long and as wide as the product) was cut out of the periphery of the coil. The sample was examined for degree of flatness. In addition, each coil was allowed to stand at room temperature (from 0˚C to 40˚C) for 6 months. Then, a sample (1.5 m long and as wide as the product) was cut out of the periphery of the coil. The sample was examined for degree of flatness again. The coiled aluminum strip was coated and heated for drying in an oven at 130˚C for 2 minutes. During heating, the strip was stretched with a tension of 2.0 kg/mm^2. After drying, the coated aluminum strip was coiled, and a sample (1.5 m long and as wide as the product) was cut out of the periphery of the coil. The sample was examined for degree of flatness three times. The degree of flatness examined immediately after coiling, after storage for 6 months, and after coating and drying is shown in Tables 1 and 2.

[0045] Degree of flatness was rated in terms of difference between the peak and the trough of surface irregularities of the aluminum strip which are measured according to the method described in Aluminum Handbook (7th edition), p. 232. In Tables 1 and 2, the rating of degree of flatness is indicated by any of three symbols -- ○, Δ, and ×, with the former two meaning acceptable and the last one meaning unacceptable. Samples are given ○, Δ, or × depending on whether their edge waving is none, smaller than 0.5 mm, or larger than 0.5 mm, respectively. Samples are also given ○, Δ, or × depending on whether their center buckle or quarter belly is smaller than 2.0 mm (maximum), from 2.0 to 3.0 mm, or larger than 3.0 mm, respectively.

[0046] Examples 1 to 18 (shown in Table 1) demonstrate the samples which underwent secondary cold rolling, stretch-leveling, and trimming, sequentially, as shown in Figs. 4A to 4C. Examples 19 to 33 (shown in Table 2) demonstrate the samples which underwent secondary cold rolling, trimming, and stretch-leveling, sequentially, as shown in Figs. 5A and 5B. Comparative Example 1 demonstrate the sample which underwent cold rolling and division into two halves but did not undergo subsequent rolling, as described in Japanese Patent Laid-open No. Hei-9-202063. The sample (coiled aluminum strip) in Comparative Example 1 shown in Table 1 had burrs 4 as shown in Fig. 3. These burrs cause edge waving after coating and drying, thereby deteriorating degree of flatness. By contrast, the samples in Examples 1 to 18 had burrs 8b

after trimming as shown in Fig. 4C, but these burrs did not significantly affect degree of flatness. Therefore, these samples were given the rating of ○ or Δ. The samples (coiled aluminum strip as finished product) in Examples 19 to 33 had no burrs as shown in Fig. 5B, and they were given the rating of ○ for degree of flatness. Incidentally, in Table 1, the column with a caption of "Product crown pattern" indicates "similar to Fig. 1" for Examples 16, 17, 18, 32, and 33.
This wording means that when the strip is divided into three portions, the central portion has a bulge (or crown) as shown in Fig. 1. Although it has burrs (due to cutting) at its edges, it has no burrs at its thickest part, and hence it has good degree of flatness.

[0047] Incidentally, the samples in Examples 1, 2, 3, 6, 7, 9, 11, 12, 14, 16, and 17 have a crown ratio smaller than 1.0% (as absolute value) after hot rolling, and hence they have a low crown ratio of product and were given a good rating for degree of flatness. The samples in Examples 4, 5, 8, 10, 13, 15, 19, 23, and 27 have a crown ratio exceeding 1.0% after hot rolling, and hence they are slightly poor in degree of flatness (in the column "Others").

[0048] Comparative Examples 2 to 8 demonstrate the samples prepared by the process shown in Fig. 4A to 4C. Comparative Examples 9 to 11 demonstrate the samples prepared by the process shown in Fig. 5A and 5B. It is noted from Comparative Examples 2 to 11 that the samples are rated poor in degree of flatness (with many occurrences of center buckle or quarter belly) if their crown ratio exceeds 1.5% (as absolute value) after hot rolling even though they are produced according to the process of the present invention.

Claims

1. A method for producing aluminum strips comprising:

a step of heat treatment to homogenize an ingot of aluminum or aluminum alloy,
a step of hot rolling to be performed on the heat-treated ingot in such a way that the hot-rolled strip has a crown ratio no larger than 1.5% (as an absolute value) in the widthwise direction,
a step of primary cold rolling to be performed on the hot-rolled strip in such a way that the cold-rolled strip has at least twice the width of the final product,
a step of dividing the cold-rolled strip into two or more portions in the widthwise direction,
a step of secondary cold rolling to be performed on the divided portions, and
a final step of stretch-leveling, trimming, and winding to be performed on the divided portions which have undergone secondary cold rolling.

2. The method for producing aluminum strips as defined in Claim 1, wherein the final step that follows the secondary cold rolling is performed in the order of stretch-leveling, trimming, and winding.

3. The method for producing aluminum strips as defined in Claim 1, wherein the final step that follows the secondary cold rolling is performed in the order of trimming, stretch-leveling, and winding.

Amended claims in accordance with Rule 137(2) EPC.

1. A method for producing aluminum strips comprising:

a step of heat treatment to homogenize an ingot of aluminum or aluminum alloy,
a step of hot rolling to be performed on the heat-treated ingot in such a way that the hot-rolled strip has a crown ratio no larger than 1.5% (as an absolute value) in the widthwise direction,
a step of primary cold rolling to be performed on the hot-rolled strip in such a way that the cold-rolled strip has at least twice the width of the final product,
a step of dividing the cold-rolled strip into two or more portions in the widthwise direction,
a step of secondary cold rolling to be performed on the divided portions, and
a final step of stretch-leveling, edge trimming to remove the edges, and winding to be performed on the divided portions which have undergone secondary cold rolling.

2. The method for producing aluminum strips as defined in Claim 1, wherein the final step that follows the secondary cold rolling is performed in the order of stretch-leveling, trimming, and winding.

3. The method for producing aluminum strips as defined in Claim 1, wherein the final step that follows the secondary cold rolling is performed in the order of trimming, stretch-leveling, and winding.

FIG. 1

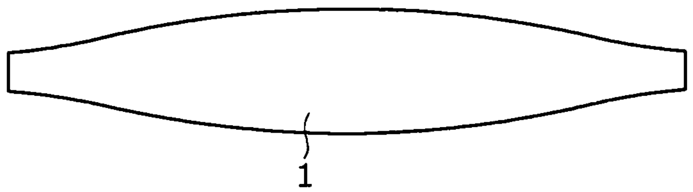


FIG. 2

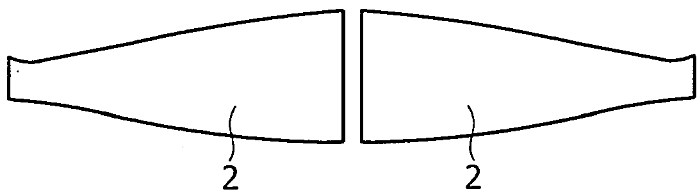


FIG. 3

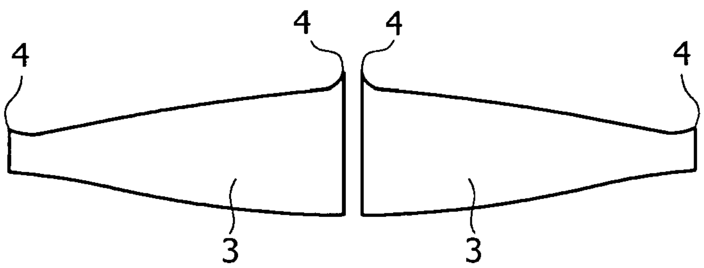


FIG.4A

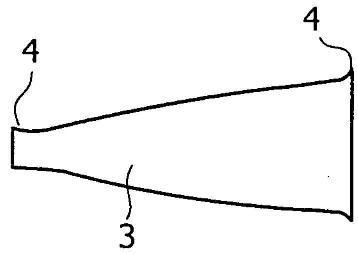


FIG.4B

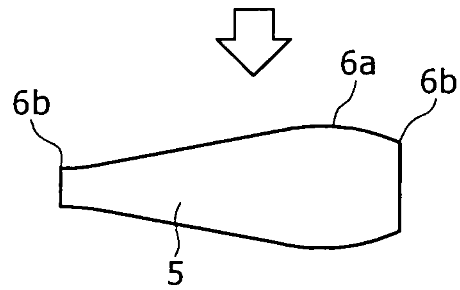


FIG.4C

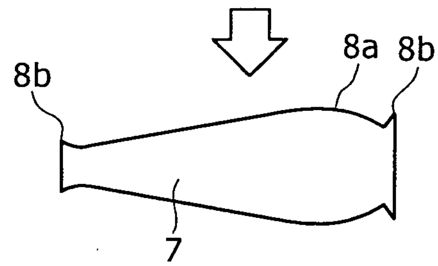


FIG.5A

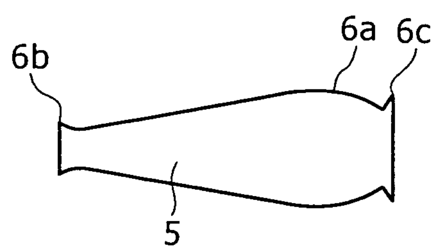


FIG.5B

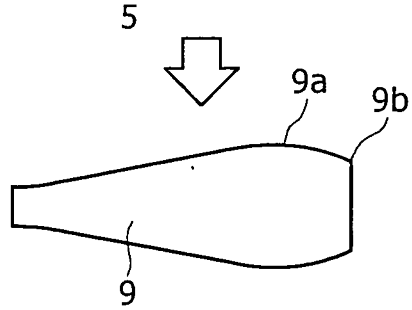


FIG.6

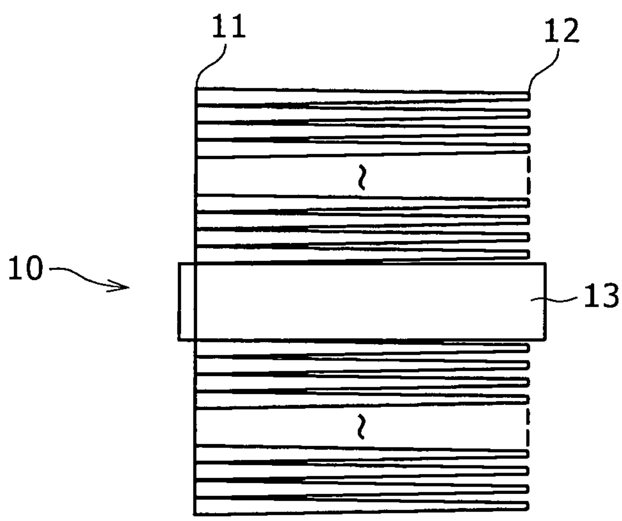


FIG.7

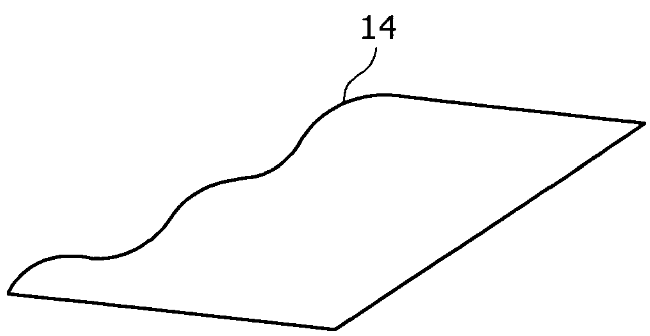


FIG.8A

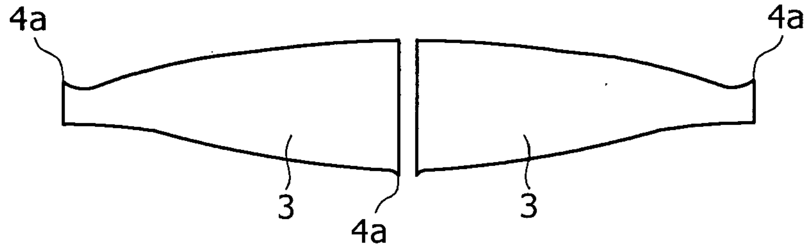


FIG.8B

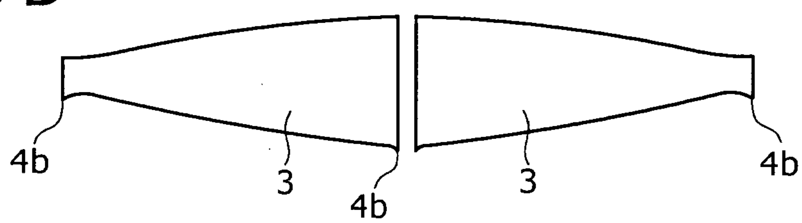


FIG.8C

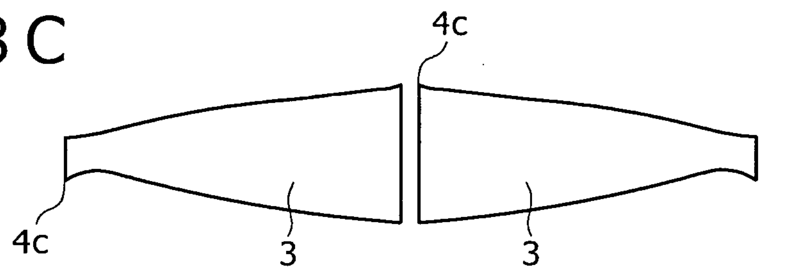


FIG.9

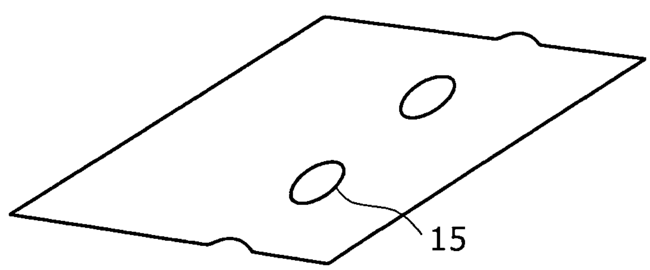


FIG.10

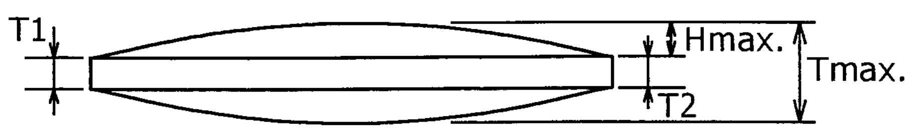


FIG.11

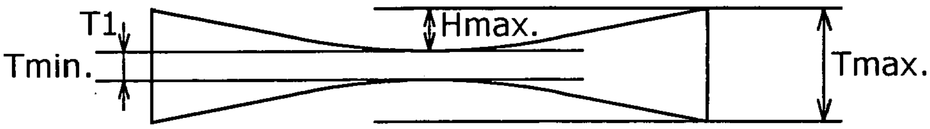


FIG.12A

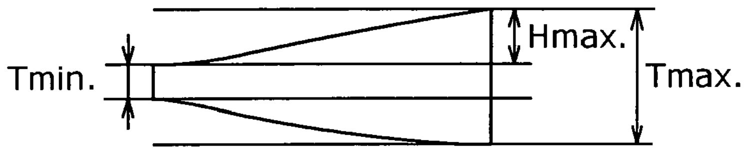


FIG.12B

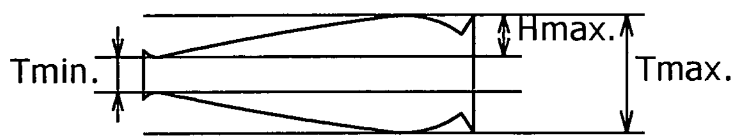


FIG.12C

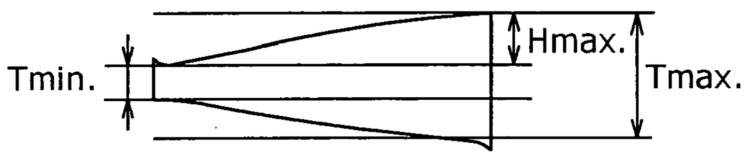
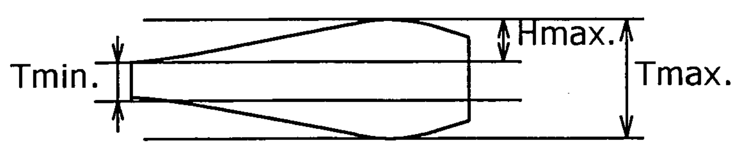


FIG.12D



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EUROPEAN SEARCH REPORT

Application Number
EP 09 00 0307

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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