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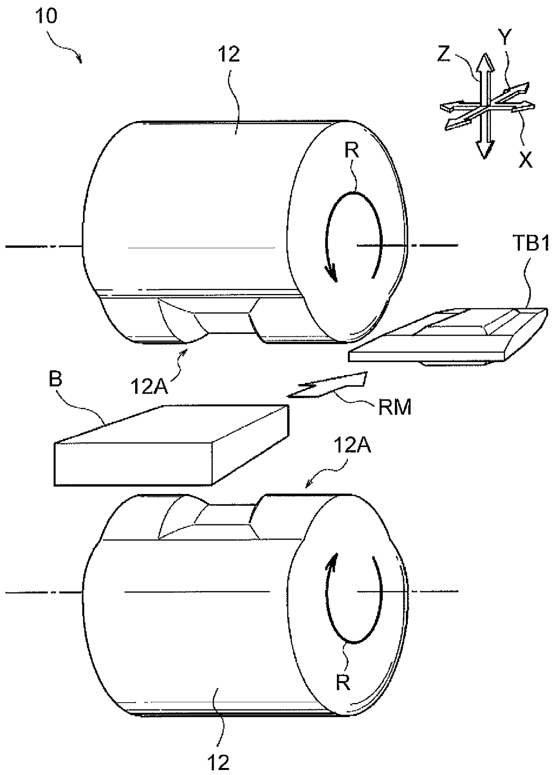
(54) MANUFACTURING METHOD OF THICKNESS-VARIED METAL PLATE, MANUFACTURING METHOD OF PRESSED PART, AND PROCESSING MACHINE

(57) In a manufacturing method of a thickness-varied metal plate, first, a cut plate (B) is manufactured by cutting a metal plate having a constant plate thickness into a predetermined shape. Next, the thickness-varied metal plate (TB1) is manufactured by rolling the cut plate (B) using a processing machine (10) including a pair of work rolls. Here, a radius of one of the pair of work rolls is varied in a circumferential direction and an axial direction. Accordingly, the thickness-varied metal plate (TB1) manufactured by rolling the cut plate (B) using the processing machine (10) has a plate thickness varied in two different directions orthogonal to a plate thickness direction.

FIG. 1



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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to a manufacturing method of a thickness-varied metal plate, a manufacturing method of a pressed part from a thickness-varied metal plate, and a processing machine used to manufacture a thickness-varied metal plate.

2. Description of Related Art

[0002] In the manufacturing method of a thickness-varied steel plate described in Japanese Patent Application Publication No. 2015-033719, at least one of a pair of work rolls of a two-stage rolling machine is formed so that the radius is varied in a circumferential direction. A steel plate (metal plate) is inserted between the pair of work rolls and rolled, and thus a thickness-varied steel plate (thickness-varied metal plate) of which the plate thickness is partially varied is manufactured.

SUMMARY OF THE INVENTION

[0003] However, the above manufacturing method of a thickness-varied steel plate can vary the plate thickness of a steel plate in only one direction orthogonal to a plate thickness direction (only a feed direction of the steel plate). Thus, there is room for improvement from the viewpoint of allowing greater flexibility in setting a variation in plate thickness.

[0004] The present invention provides a manufacturing method of a thickness-varied metal plate, a manufacturing method of a pressed part, and a processing machine that allow greater flexibility in setting a variation in plate thickness of a thickness-varied metal plate.

[0005] A first aspect of the present invention relates to a manufacturing method of a thickness-varied metal plate, the manufacturing method including: manufacturing a cut plate by cutting a metal plate into a predetermined shape; and manufacturing the thickness-varied metal plate of which the plate thickness is varied in two different directions orthogonal to a plate thickness direction by processing the cut plate by at least one of rolling and forging, using a processing machine including a first work roll and a second work roll of which the radius is varied in a circumferential direction and an axial direction of a rotational axis.

[0006] According to the first aspect of the present invention, first, the cut plate is manufactured by cutting a metal plate (e.g., steel plate) into the predetermined shape. Next, the thickness-varied metal plate is manufactured by processing the cut plate by at least one of rolling and forging using the (single) processing machine including the pair of work rolls (the first work roll and the second work roll). Here, the radius of the second work roll of the processing machine is varied in the circumferential direction and the axial direction of the rotational axis. Accordingly, the thickness-varied metal plate manufactured by processing the cut plate using the processing machine has the plate thickness varied in two different directions orthogonal to the plate thickness direction. Thus, according to the first aspect, greater flexibility is allowed in setting a variation in plate thickness of the thickness-varied metal plate.

[0007] In the first aspect of the present invention, the processing machine may be provided with a first backup roll that is disposed on the opposite side of the first work roll from the second work roll and comes in contact with the first work roll, and a second backup roll that is disposed on the opposite side of the second work roll from the first work roll and comes in contact with the second work roll. When the thickness-varied metal plate manufactures, the cut plate may be processed by rotating the first work roll in forward and reverse directions within a range in which a region with a constant radius of the first work roll comes in contact with the first backup roll, and rotating the second work roll in forward and reverse directions within a range in which a region with a constant radius of the second work roll comes in contact with the second backup roll.

[0008] According to this first aspect, the processing machine includes the pair of backup rolls (the first backup roll and the second backup roll), so that so-called crowning is possible be prevented or suppressed. Moreover, to process the cut plate using the processing machine, the first work roll is rotated in the forward and reverse directions within the range in which the region with a constant radius of the first work roll comes in contact with the first backup roll, and the second work roll is rotated in the forward and reverse directions within the range in which the region with a constant radius of the second work roll comes in contact with the second backup roll. It is possible to prevent an unstable behavior that occurs when region with a varied radius of the first work roll or the second work roll comes in contact with the corresponding backup roll, so that the pair of work rolls is possible to be rotated stably (smoothly). As a result, the pair of work rolls is possible to give a variation in plate thickness to the plate to be processed with high accuracy.

[0009] A second aspect of the present invention relates to a manufacturing method of a thickness-varied metal plate, the manufacturing method including: manufacturing a cut plate by cutting a metal plate into a predetermined shape; and manufacturing the thickness-varied metal plate of which a plate thickness is varied in two different directions orthogonal to a plate thickness direction by sequentially processing the cut plate by at least one of rolling and forging, using a first processing machine including a first work roll and a second work roll of which a radius is varied in a circumferential direction or an axial direction of a rotational axis, and a second processing machine including a pair of work rolls that are different in shape from the work rolls (the first work roll and the second work roll) of the first processing machine.

[0010] According to the second aspect of the present invention, first, the cut plate is manufactured by cutting a metal plate (e.g., steel plate) into the predetermined shape. Next, the thickness-varied metal plate is manufactured by sequentially processing the cut plate by at least one of rolling and forging, using the first processing machine including the first work roll and the second work roll of which the radius is varied in the circumferential direction or the axial direction of the rotational axis, and the second processing machine including the pair of work rolls that are different in shape from the work rolls of the first processing machine. Here, the pair of work rolls of the first processing machine and the pair of work rolls of the second processing machine are different from each other. As the cut plate is sequentially processed by the first processing machine and the second processing machine, the thickness-varied metal plate of which the plate thickness is varied in two different directions orthogonal to the plate thickness direction is possible to be manufactured. Thus, according to the second aspect, greater flexibility is allowed in setting a variation in plate thickness of the thickness-varied metal plate.

[0011] In the second aspect, when the thickness-varied metal plate manufactures, a direction in which the cut plate is fed into the first processing machine may be changed to a direction that is different from a direction in which the cut plate is fed into the second processing machine.

[0012] According to this second aspect, to manufacture the thickness-varied metal plate, the direction in which the cut plate is fed into the first processing machine is changed to a direction that is different from the direction in which the cut plate is fed into the second processing machine. Thus changing a feed direction is possible to change the direction in which the plate thickness of the cut plate is varied, so that even greater flexibility is allowed in setting a variation in plate thickness of the thickness-varied metal plate.

[0013] In the second aspect, the first processing machine may include a first backup roll that is disposed on the opposite side of the first work roll from the second work roll and comes in contact with the first work roll, and a second backup roll that is disposed on the opposite side of the second work roll from the first work roll and comes in contact with the second work roll. When the thickness-varied metal plate manufactures, the cut plate may be processed by rotating the first work roll in forward and reverse directions within a range in which a region with a constant radius of the first work roll comes in contact with the first backup roll, and rotating the second work roll in forward and reverse directions within a range in which a region with a constant radius of the second work roll comes in contact with the second backup roll.

[0014] According to this second aspect, the first processing machine is provided with the pair of backup rolls (the first backup roll and the second backup roll), so that so-called crowning is possible to be prevented or suppressed. Moreover, to process the cut plate using the first processing machine, the first work roll is rotated in the forward and reverse directions within the range in which the region with a constant radius of the first work roll comes in contact with the first backup roll, and the second work roll is rotated in the forward and reverse directions within the range in which the region with a constant radius of the second work roll comes in contact with the second backup roll. It is possible to prevent an unstable behavior that occurs when region with a varied radius of the first work roll and the second work roll comes in contact with the corresponding backup roll, so that the pair of work rolls can be rotated stably (smoothly). As a result, the pair of work rolls is possible to give a variation in plate thickness to the cut plate high accuracy.

[0015] A third aspect of the present invention relates to a manufacturing method of a pressed part, the manufacturing method including: manufacturing a partially processed thickness-varied metal plate by the manufacturing method of a thickness-varied metal plate of the first or second aspect; and manufacturing a pressed part by performing cold-press bending on an unprocessed portion of the thickness-varied metal plate.

[0016] According to the third aspect, the thickness-varied metal plate is manufactured by the manufacturing method of the thickness-varied metal plate of the first aspect or the second aspect. Accordingly, the third aspect can offer the same operational advantages as the first aspect and the second aspect. Next, a pressed part is manufactured by performing cold-press bending on the unprocessed portion of the thickness-varied metal plate. The yield strength of the processed portion of this pressed part has been enhanced by work hardening while the plate thickness thereof has been reduced. Thus, according to the third aspect, a lightweight pressed part that is partially enhanced in strength is possible to be manufactured.

[0017] A fourth aspect of the present invention relates to a processing machine including a first work roll and a second work roll of which the radius is varied in a circumferential direction and an axial direction of a rotational axis.

[0018] Including the same configuration as the processing machine described in the first aspect, the processing machine of the fourth aspect is possible to be applied to the manufacturing method of a thickness-varied metal plate of the first aspect. Accordingly, the fourth aspect is possible to offer the same operational advantages as the first aspect.

[0019] In the fourth aspect, the second work roll may include a second roll main body of which the radius is constant in the circumferential direction and the axial direction of the rotational axis, and a second cam that is detachably mounted at a part of an outer circumferential surface of the second roll main body.

[0020] According to this fourth aspect, the second work roll of which the radius is varied in the circumferential direction and the axial direction of the rotational axis is formed by mounting the second cam at the part of the outer circumferential surface of the second roll main body of which the radius is constant in the circumferential direction and the axial direction of the rotational axis. As the second cam is detachably mounted on the second roll main body, an arbitrary variation in plate thickness is possible to be given to the cut plate by replacing the second cam. Moreover, the second cam is possible to be separately replaced during maintenance, which contributes to improving the maintainability.

[0021] In the fourth aspect, the radius of the first work roll may be varied in a circumferential direction and an axial direction of a rotational axis.

[0022] In the fourth aspect, the first work roll may include a first roll main body of which the radius is constant in the circumferential direction and the axial direction of the rotational axis, and a first cam that is detachably mounted at a part of an outer circumferential surface of the first roll main body.

[0023] As has been described above, the manufacturing method of a thickness-varied metal plate, the manufacturing method of a pressed part, and the processing machine of the present invention allow greater flexibility in setting a variation in plate thickness of a thickness-varied metal plate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Features, advantages, and technical and industrial significance of exemplary embodiments of the invention will be described below with reference to the accompanying drawings, in which like numerals denote like elements, and wherein:

FIG. 1 is a perspective view illustrating a single-step rolling process in a manufacturing method of a thickness-varied metal plate (thickness-varied steel plate) according to an embodiment of the present invention;
FIG. 2 is a side view illustrating the single-step rolling process;
FIG. 3 is a perspective view illustrating a first step of a multi-step rolling process in the manufacturing method of a thickness-varied steel plate according to the embodiment of the present invention;
FIG. 4 is a perspective view illustrating a second step of the multi-step rolling process in the manufacturing method of a thickness-varied steel plate according to the embodiment of the present invention;
FIG. 5 is a perspective view illustrating a third step of the multi-step rolling process in the manufacturing method of a thickness-varied steel plate according to the embodiment of the present invention;
FIG. 6 is a perspective view of a material to be rolled (thickness-varied steel plate) that has been rolled by a manufacturing method of a thickness-varied steel plate of the related art;
FIG. 7 is a plan view illustrating an example of blanking performed on the thickness-varied steel plate that has been rolled by the manufacturing method of a thickness-varied steel plate of the related art;
FIG. 8 is a perspective view illustrating an example of blanking in a cutting process according to the embodiment of the present invention;
FIG. 9 is a perspective view of blank materials that are combination-cut by blanking according to the embodiment of the present invention;
FIG. 10 is a perspective view showing an image of the blank material being rolled according to the embodiment;
FIG. 11 is a side view showing a modified example of a processing machine according to the embodiment of the present invention;
FIG. 12 is a front view of a center pillar reinforcement that is manufactured using, as material, a thickness-varied steel plate manufactured by the manufacturing method of a thickness-varied steel plate according to the embodiment of the present invention;
FIG. 13 is a sectional view taken along the line XIII-XIII of FIG. 12;
FIG. 14 is a perspective view of the center pillar reinforcement;
FIG. 15 is a front view of a front pillar lower part that is manufactured using, as material, a thickness-varied steel plate manufactured by the manufacturing method of a thickness-varied steel plate according to the embodiment of the present invention; and
FIG. 16 is a perspective view of a front floor that is manufactured using, as material, a thickness-varied steel plate manufactured by the manufacturing method of a thickness-varied steel plate according to the embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0025] In the following, a manufacturing method of a thickness-varied metal plate, a manufacturing method of a pressed part, and a processing machine according to an embodiment of the present invention will be described using FIG. 1 to FIG. 16. The manufacturing method of a thickness-varied metal plate according to this embodiment is a method for manufacturing a thickness-varied steel plate (thickness-varied metal plate) that is used as material for a vehicle body component (pressed part) composing a part of a vehicle body of a vehicle, for example, and the method has a cutting process and a rolling process (working process). Hereinafter, the manufacturing method of a thickness-varied metal plate according to this embodiment will be referred to as a manufacturing method of a thickness-varied steel plate.

[0026] In the cutting process, a steel plate (metal plate) having a constant plate thickness is cut into a predetermined shape (in this example, a rectangular shape) by press working etc., and thus a blank material (a cut plate, a plate to be processed, or a plate to be rolled) B shown in FIG. 1 and FIG. 3 is manufactured. The shape of the blank material B is not limited to a rectangular shape but may be an arbitrary shape. In addition, the manufacturing method of a thickness-varied steel plate according to this embodiment is applicable not only to steel plates but also to other metal plates having plasticity.

[0027] Next, in the rolling process, the blank material B is rolled using a rolling machine (processing machine) (the blank material B can be processed by at least one of rolling and forging), and thus a thickness-varied steel plate TB1 (see FIG. 1 and FIG. 2) or a thickness-varied steel plate TB2 (see FIG. 5) is manufactured. There are two types of this rolling process: a single-step rolling process (single-step working process) shown in FIG. 1 and FIG. 2, and a multi-step rolling process (multi-step working process) shown in FIG. 3 to FIG. 5, and either one of these processes is adopted. These two types of rolling process will be described below.

Single-step Rolling Process

[0028] In the single-step rolling process shown in FIG. 1 and FIG. 2, the blank material B is rolled by a (single) rolling machine 10 to manufacture the thickness-varied steel plate TB1. The rolling machine 10 is a two-stage rolling machine, and includes a pair of substantially columnar work rolls 12 that are arranged one on top of the other in a position parallel to each other. The work rolls 12 are rotatably supported by a housing (not shown), and are configured to be driven to rotate in synchronization with each other by a driving unit (not shown). A specified clearance (a clearance smaller than the plate thickness of the blank material B) is provided between the work rolls 12. For the convenience of description, FIG. 1 and FIG. 2 show the work rolls 12 at a greater distance from each other than in reality. The same applies to FIG. 3 to FIG. 5.

[0029] As shown in FIG. 1 and FIG. 2, a recess (shaping surface) 12A that gives a variation in plate thickness (thickness-varied shape) to the blank material B is formed in an outer circumferential surface (processing surface) of each work roll 12. The recess 12A may instead be formed only in one of work rolls 12. In addition, the shaping surface may be a protrusion instead of the recess 12A. The recess 12A is formed in a shape corresponding to a target shape of the thickness-varied steel plate TB1 to be manufactured by the single-step rolling process. The target shape is a shape corresponding to a variation in plate thickness (thickness-varied shape) required of a pressed part (a vehicle body component of a vehicle) to be manufactured using the thickness-varied steel plate TB1.

[0030] The recess 12A is formed only at a part of the outer circumferential surface of each work roll 12 in a circumferential direction. Accordingly, the radius of each work roll 12 is smaller at the circumferential region in which the recess 12A is provided than at the other circumferential region in which the recess 12A is not provided. The depth of the recess 12A is larger at a central part of each work roll 12 in an axial direction, and the radius of each work roll 12 is even smaller at this deeper region. Thus, each work roll 12 has the radius varied in both the circumferential direction and the axial direction. The work rolls 12 are configured to be driven to rotate in synchronization while always maintaining a vertically symmetrical position of rotation (see the arrows R in FIG. 1 and FIG. 2). The above-described shape of the recess 12A is a mere example and can be changed as appropriate.

[0031] In the single-step rolling process using the rolling machine 10 of the above configuration, the blank material B is inserted between the work rolls 12 of the rolling machine 10 and rolled (see the arrow RM in FIG. 1 and FIG. 2), and thereby the shapes of the processing surfaces of the work rolls 12 are impressed on the blank material B. Thus, the thickness-varied steel plate TB1 (see FIG. 1 and FIG. 2) of which the plate thickness is varied in two different directions (the directions of the arrow X and the arrow Y in FIG. 1) orthogonal to a plate thickness direction (the direction of the arrow Z in FIG. 1) is manufactured.

Multi-step Rolling Process

[0032] On the other hand, the multi-step rolling process includes a plurality of steps (in this example, a first step to a third step) shown in FIG. 3 to FIG. 5, and the thickness-varied steel plate TB2 is manufactured by sequentially rolling the blank material B using a plurality of (in this example, three) rolling machines 20, 30, 40. The rolling machine 20 includes basically the same configuration as the rolling machine 10, and includes a pair of work rolls 22 including recesses 22A formed in outer circumferential surfaces thereof. The rolling machine 30 includes basically the same configuration as the rolling machine 10, and includes a pair of work rolls 32 including recesses 32A formed in outer circumferential surfaces thereof. The rolling machine 40 includes basically the same configuration as the rolling machine 10, and includes a pair of work rolls 42 including recess 42A formed in outer circumferential surfaces thereof. Only one of work rolls 22 may instead have the recess 22A formed therein. Only one of work rolls 32 may instead have the recess 32A formed therein. Only one of work rolls 42 may instead have the recess 42A formed therein. In addition, protrusions instead of the recesses 22A, 32A, 42A may be provided on the outer circumferential surfaces. The work rolls 22, 32, 42 are different in shape from the work rolls 12. Moreover, the pairs of work rolls 22, 32, 42 are different in shape from one another.

[0033] Specifically, the rolling machine 20 (see FIG. 3) used in the first step includes the work rolls 22 of which the radii are respectively varied in a circumferential direction. The recess 22A is formed in the outer circumferential surface (processing surface) of each work roll 22. The recess 22A is formed only at a part of the outer circumferential surface of the work roll 22 in the circumferential direction, and is formed in a constant shape along an axial direction of the work roll 22.

[0034] The rolling machine 30 (see FIG. 4) used in the second step includes the work rolls 32 of which the radii are respectively varied in an axial direction. The recess 32A is formed in the outer circumferential surface (processing surface) of each work roll 32. The recess 32A is formed at a central part of the outer circumferential surface of the work roll 32 in the axial direction, and is formed in a constant shape along a circumferential direction of the work roll 32.

[0035] The rolling machine 40 (see FIG. 5) used in the third step includes the work rolls 42 of which the radii are respectively varied in a circumferential direction. The recess 42A is formed in the outer circumferential surface (processing surface) of the work roll 42. The recess 42A is formed only at a part of the outer circumferential surface of the work roll 42 in the circumferential direction, and is formed in a constant shape along an axial direction of the work roll 42.

[0036] In the multi-step rolling process using the rolling machines 20, 30, 40 of the above configurations, first, in the first step shown in FIG. 3, the blank material B is inserted between the work rolls 22 of the rolling machine 20 and rolled (see the arrow RM in FIG. 3), and thereby the shapes of the processing surfaces of the work rolls 22 are impressed on the blank material B. Next, in the second step shown in FIG. 4, a blank material B1 having undergone the first step is inserted between the work rolls 32 of the processing machine 30 and rolled (see the arrow RM in FIG. 4), and thereby the shapes of the processing surfaces of the work rolls 32 are impressed on the blank material B1.

[0037] Next, in the third step shown in FIG. 5, first, a blank material B2 having undergone the second step is turned 90 degrees as seen in a plan view (see the arrow T in FIG. 5). Then, the blank material B2 is inserted between the work rolls 42 of the rolling machine 40 and rolled (see the arrow C and the arrow RM in FIG. 5). Thus, the thickness-varied steel plate TB2 (see FIG. 5) of which the plate thickness is varied in the two different directions (the directions of the arrow X and the arrow Y in FIG. 5) orthogonal to a plate thickness direction (the direction of the arrow Z in FIG. 5) is manufactured. In this embodiment, as the blank material B1 undergoes the second step before the third step, the blank material B2 (thickness-varied steel plate) of which the plate thickness is varied in the two different directions orthogonal to the plate thickness direction is manufactured. Therefore, the third step may be omitted.

[0038] In the above multi-step rolling process, the blank material B2 is turned 90 degrees as seen in a plan view in the third step, and thereby a direction in which the blank material B2 is fed into the rolling machine 40 is changed to a direction that is different from a direction in which the blank materials B, B1 are fed into the rolling machines 20, 30. The feed direction of the blank material B2 refers to the orientation of the blank material B2 in a plan view relative to the rolling machine 40 during rolling of the blank material B2 by the rolling machine 40. The feed direction of the blank materials B, B1 refers to the orientation of the blank materials B, B1 in a plan view relative to the rolling machines 20, 30 during rolling of the blank materials B, B1 by the rolling machines 20, 30. The distribution and combination of the rolling work in the multi-step rolling process can be changed arbitrarily.

Heat Treatment

[0039] Next, a heat treatment for the thickness-varied steel plates TB1, TB2 will be described. In this embodiment, the thickness-varied steel plates TB1, TB2 manufactured by the above rolling process (the single-step rolling process or the multi-step rolling process) is shaped into a predetermined shape by being bent in a subsequent pressing process. However, work hardening has occurred at rolled portions of the thickness-varied steel plates TB1, TB2, which represents difficult conditions for plastic forming to be performed later. Therefore, this embodiment is based on a premise that a heat treatment is performed on the thickness-varied steel plates TB1, TB2 having undergone the rolling process.

[0040] Specifically, for example, the pressing process after the rolling process is a hot pressing process. In the hot pressing process, the thickness-varied steel plates TB1, TB2 are heated to a predetermined temperature by high-frequency induction heating etc. before press working. During this heating, work hardening resulting from rolling (thickness varying processing) is removed.

[0041] For example, in the case where the pressing process after the rolling process is a cold pressing process, an annealing process of annealing the thickness-varied steel plates TB1, TB2 is additionally performed before the cold pressing process. The work hardening is removed in this annealing process. Thus, although the number of processes is increased by the addition of the annealing process, the annealing process makes the thickness-varied steel plates TB1, TB2 usable as ordinary cold-pressed parts.

[0042] The thickness-varied steel plates TB1, TB2 according to this embodiment are not limited to those that undergo the above-described heat treatment. That is, it is possible to partially enhance the strength of the thickness-varied steel plates TB1, TB2 according to this embodiment by maintaining the work-hardened conditions and taking advantage of the enhanced yield strength. As a result, compared with if the plate thickness of the entire thickness-varied steel plate is increased to enhance the strength, for example, a reduction in thickness and weight of the thickness-varied steel plate can be achieved.

Operations and Advantages

[0043] Next, operations and advantages of this embodiment will be described.

[0044] According to the manufacturing method of a thickness-varied steel plate of this embodiment, in the cutting process, the blank material B is manufactured by cutting a steel plate having a constant plate thickness into a predetermined shape. Next, the rolling process is performed. The rolling process is either the single-step rolling process or the multi-step rolling process. When the rolling process is the single-step rolling process, the thickness-varied steel plate TB1 is manufactured by rolling the blank material B using the single rolling machine 10 including the pair of work rolls 12. Here, each work roll 12 of the rolling machine 10 has the radius varied in the circumferential direction and the axial direction. Accordingly, the thickness-varied steel plate TB1 manufactured by rolling the blank material B using the rolling machine 10 has the plate thickness varied in two different directions orthogonal to the plate thickness direction. Thus, this manufacturing method allows greater flexibility in setting a variation in plate thickness than the manufacturing method of a thickness-varied steel plate described in the section of Description of Related Art (hereinafter referred to simply as a manufacturing method of a thickness-varied steel plate of the related art).

[0045] On the other hand, when the rolling process is the multi-step rolling process, the thickness-varied steel plate TB2 is manufactured by sequentially rolling the blank material B by the plurality of rolling machines 20, 30, 40 respectively including the work rolls 22, 32, 42 of which the radii are varied in the circumferential directions or the axial directions. Here, the pairs of work rolls 22, 32, 42 of the plurality of rolling machines 20, 30, 40 are different in shape from one another. As the blank material B is sequentially rolled by the plurality of rolling machines 20, 30, 40, the thickness-varied steel plate TB2 of which the plate thickness is varied in two different directions orthogonal to the plate thickness direction can be manufactured. Thus, this manufacturing method allows greater flexibility in setting a variation in plate thickness than the manufacturing method of a thickness-varied steel plate of the related art.

[0046] As has been described above, according to this embodiment, whether the rolling process is the single-step rolling process or the multi-step rolling process, the thickness-varied steel plate TB1 or TB2 of which the plate thickness is varied in two different directions orthogonal to the plate thickness direction (arbitrary directions within a plane orthogonal to the plate thickness direction) can be manufactured. Thus, the plate thickness of a vehicle body component manufactured using the thickness-varied steel plate TB1 or TB2 can be varied in an arbitrary direction, such as a vehicle up-down direction or a vehicle front-rear direction. As a result, it is possible to secure the strength and rigidity required of the vehicle body and yet to reduce the weight of the vehicle body, and thereby to improve the fuel efficiency and kinematic performance of the vehicle.

[0047] In the single-step rolling process, the thickness-varied steel plate TB1 is manufactured simply by rolling the blank material B using the single rolling machine 10. Thus, this process simplifies the manufacturing process and contributes to cost reduction. On the other hand, in the multi-step rolling process, the thickness-varied steel plate TB2 is manufactured by sequentially rolling the blank material B using the plurality of rolling machines 20, 30, 40. Thus, a processing force required to roll the blank material B can be distributed among the rolling machines 20, 30, 40. Accordingly, the durability of the rolling machines 20, 30, 40 can be more easily secured.

[0048] Moreover, in the multi-step rolling process, the direction in which the blank material B is fed into the rolling machine 40 that is one of the plurality of rolling machines 20, 30, 40 is changed to a direction different from the direction in which the blank material B is fed into the other rolling machines 20, 30. Thus changing the feed direction can change the direction in which the plate thickness of the blank material B is varied, so that even greater flexibility is allowed in setting a variation in plate thickness, and a complicated shape can be given to the thickness-varied steel plate TB2.

[0049] In this embodiment, rolling (thickness varying processing) is performed on the blank material B (cut plate) that can be cut into an arbitrary shape. Thus, the direction in which the blank material B is fed into each rolling machine (i.e., the direction in which a variation in plate thickness is given to the blank material B) can be set arbitrarily, without being limited to the example in the above-described multi-step rolling process. Accordingly, a complicated thickness-varied shape required of a vehicle body component etc. can be easily processed.

[0050] Moreover, in this embodiment, rolling is performed on the blank material B as described above, which can improve the material yield compared with the manufacturing method of a thickness-varied steel plate of the related art. Specifically, in the manufacturing method of a thickness-varied steel plate of the related art, as shown in FIG. 6, rolling (thickness varying processing) is performed on a steel plate (metal strip) S that is a material to be rolled, in a state where the steel plate S is wound around a payoff reel R1 and a take-up reel R2, and then the steel plate S is cut along blank lines L1, L2 shown in FIG. 6. Thereafter, a cut steel plate SB (see FIG. 7) is cut into a shape P of a part to be manufactured (see FIG. 6 and FIG. 7). Thus, combination processing cannot be performed unless the distribution of the plate thickness is symmetrical relative to the part shape P.

[0051] More specifically, in the case where rolling is performed on the steel plate S wound around the payoff reel R1 and the take-up reel R2, for example, the dotted area in FIG. 6 and FIG. 7 constitutes a thick plate part S1 having a large plate thickness, while the other areas constitute thin plate parts S2 having a small plate thickness. Pluralities of thick plate parts S1 and thin plate parts S2 are formed at a regular pitch. Thus, if the arrangement of the thick plate part S1 relative to the part shape P is asymmetrical as shown in FIG. 6 and FIG. 7, only one part can be cut out of one steel plate SB, so that a large amount of scrap SC (a part of the steel plate SB outside the part shape P) is generated. Depending on the shape of the part, therefore, the material yield is very low and the manufacturing cost is high.

[0052] In this embodiment, by contrast, the blank material B is manufactured by cutting the steel plate before rolling, and rolling is performed on the blank material B. Therefore, as shown in FIG. 8 and FIG. 9, to manufacture the blank material B, a plurality of blank materials B can be cut out (so-called combination-cut) from the steel plate SB before being rolled. Thereafter, the blank material B having been cut out is rolled (see FIG. 10). Accordingly, the amount of scrap SC generated can be significantly reduced and the material yield is significantly improved, so that the manufacturing cost can be reduced. FIG. 10 shows the first step of the multi-step rolling process.

[0053] Moreover, in this embodiment, the thickness-varied steel plates TB1, TB2 are manufactured by rolling using the rolling machines (rolls), which can significantly reduce the required processing force compared with if a thickness-varied steel plate is manufactured by forging using an ordinary pressing machine. Specifically, for example, several tens of thousands of tons of processing force is required when an ordinary pressing machine is used. By contrast, when a rolling machine is used, thickness varying processing can be performed, for example, with a processing force not larger than a tenth of the processing force required for the pressing machine. Alternatively, the blank material B may be heated before being rolled by the rolling machine. Thus, the processing force can be further reduced, and a more complicated thickness-varied shape can be given to the blank material B.

Modified Example of Rolling Machine 10

[0054] Next, a modified example of the rolling machines 10, 20, 30, 40 according to this embodiment will be descried using FIG. 11. Like the rolling machine 10, a rolling machine 50 of this modified example includes a pair of work rolls 52. However, each work roll 52 include a columnar roll main body 54 of which the radius is constant in a circumferential direction and an axial direction, and a cam 56 that is detachably mounted at a part of an outer circumferential surface of the roll main body 54. Each cam 56 has a substantially semicircular arc shape as seen from the axial direction of the roll main body 54. The cam 56 has a shape that gives a variation in plate thickness (thickness-varied shape) to the blank material B.

[0055] The rolling machine 50 further includes a pair of backup rolls 58 that support the pair of work rolls 52 from upper and lower sides. The backup rolls 58 are disposed with the work rolls 52 therebetween, and are opposed to each other. The backup rolls 58 are disposed parallel to the pair of work rolls 52. Each backup roll 58 is in contact with a side of the roll main body 54 of the corresponding one of the work rolls 52 at which the cam 56 is not mounted. During rolling of the blank material B by the pair of work rolls 52, the backup rolls 58 prevent or suppress elastic deformation (deflection) of the pair of work rolls 52 caused by an excessive reaction force from the blank material B (workpiece). Thus, so-called crowning can be prevented or suppressed.

[0056] To roll the blank material B using the rolling machine 50, eachwork roll 52 is rotated in forward and reverse directions like a pendulum within a range in which a region with a constant radius (in this example, a region of the outer circumferential surface of the roll main body 54 in which the cam 56 is not mounted) of the work roll 52 comes in contact with the corresponding one of the backup rolls 58 (see the arrows SW1 and SW2 in FIG. 11).

[0057] Thus, as the rolling machine 50 performs rolling on the blank material B, it is not absolutely necessary that the work rolls 52 are continuously rotated during rolling. It is therefore possible, as with the rolling machine 50, to adopt a half-split structure of the cams 56 (processing parts) of the pair of work rolls 52, and to perform rolling by rotating the pair of work rolls 52 like a pendulum in the forward and reverse directions. This can prevent an unstable behavior that occurs when region with a varied radius of the work roll 52 and the pair of backup roll 58 comes in contact with each other, so that the pair of work rolls 52 can be rotated stably (smoothly). As a result, the pair of work rolls 52 can give a variation in plate thickness to the blank material B with high accuracy.

[0058] Specifically, in FIG. 5 of JP 2015-033719 A that discloses the manufacturing method of a thickness-varied steel plate, a configuration is shown in which backup rolls 33, 34 that are different in cross-sectional shape from columnar work rolls 31, 32 are provided for the work rolls 31, 32, and a thickness-varied shape is given to a material to be rolled as the work rolls 31, 32 are moved up and down along the shapes of the backup rolls 33, 34. However, according to this configuration, rotation of the work rolls 31, 32 and the backup rolls 33, 34 becomes momentarily very unstable when these rolls come in contact with each other at corners (ends) of regions with a radius r4 of the backup rolls 33, 34. For this reason, it would be difficult to stably give a thickness-varied shape to a material to be rolled. In this respect, according to this modified example, a thickness-varied shape can be stably given to the blank material B through the stable rotation of the pair of work rolls 52.

[0059] In the rolling machine 50, the work roll 52 of which the radius is varied in the circumferential direction and the axial direction is formed by mounting the cam 56 at a part of the outer circumferential surface of the roll main body 54 of which the radius is constant in the circumferential direction and the axial direction. As the cam 56 is detachably mounted on the roll main body 54, an arbitrary variation in plate thickness can be given to the blank material B by replacing the cam 56. Moreover, the cam 56 can be separately replaced during maintenance, which contributes to improving the maintainability.

Examples

[0060] Next, examples of a vehicle body component (vehicle frame member) manufactured using a thickness-varied steel plate according to this embodiment will be described using FIG. 12 to FIG. 16. The arrows FR, UP, and OUT indicated as necessary in FIG. 12 to FIG. 16 indicate a vehicle front side, a vehicle upper side, and an outer side in a vehicle width direction, respectively.

[0061] FIG. 12 to FIG. 14 show a center pillar reinforcement 60 that is manufactured using a thickness-varied steel plate according to this embodiment. The center pillar reinforcement 60 has: a side wall 60A; a front wall 60B and a rear wall 60C that extend respectively from a front side and a rear side of the side wall 60A toward an inner side in the vehicle width direction; and a front flange 60D and a rear flange 60E that extend respectively from ends of the front wall 60B and the rear wall 60C on the inner side in the vehicle width direction toward the opposite sides.

[0062] In the center pillar reinforcement 60, a thick plate part 62 (see the dotted area in FIG. 12 to FIG. 14) is provided at an upper part of the side wall 60A, the front wall 60B, and the rear wall 60C, while the other parts have a smaller plate thickness. More specifically, the center pillar reinforcement 60 is formed so that the plate thickness decreases gradually toward both sides of the thick plate part 62 in a vehicle up-down direction, and that the plate thickness of the front wall 60B and the rear wall 60C decreases gradually toward the front flange 60D and the rear flange 60E at a level at which the thick plate part 62 is provided (see the arrows A1 to A3 in FIG. 13 and FIG. 14). Thus, the strength of an upper part of the center pillar reinforcement 60 that protects a cabin is enhanced, while a lower part thereof that absorbs energy in the event of a lateral collision of the vehicle etc. and the front and rear flanges 60D, 60E that are not required to be strong are reduced in thickness and weight.

[0063] Similarly, FIG. 15 shows a front pillar lower part 70 that is manufactured using a thickness-varied steel plate according to this embodiment. The front pillar lower part 70 has: a side wall 70A; a front wall 70B and a rear wall 70C that extend respectively from a front side and a rear side of the side wall 70A toward the inner side in the vehicle width direction; and a front flange 70D and a rear flange 70E that extend respectively from ends of the front wall 70B and the rear wall 70C on the inner side in the vehicle width direction toward the opposite sides. In the front pillar lower part 70, a thick plate part 72 (see the dotted area in FIG. 15) is provided at a middle part of the side wall 70A, the front wall 70B, and the rear wall 70C in an up-down direction, while the other parts have a smaller plate thickness. The front pillar lower part 70 is formed so that the plate thickness decreases gradually from the thick plate part 72 toward both sides in the vehicle up-down direction, and that the plate thickness of the front wall 70B and the rear wall 70C decreases gradually toward the front flange 70D and the rear flange 70E at a level at which the thick plate part 72 is provided. The front pillar lower part 70 can offer the same operational advantages as the center pillar reinforcement 60.

[0064] On the other hand, FIG. 16 shows a front floor 80 that is manufactured using a thickness-varied steel plate according to this embodiment. In the front floor 80, a floor tunnel 80A provided at a central part in the vehicle width direction bulges toward the upper side of the vehicle, and a left floor part 80B and a right floor part 80C located one on each side of the floor tunnel 80A in the vehicle width direction are formed in a substantially flat plate shape. In the front floor 80, middle parts (see the dotted areas in FIG. 16) of the left floor part 80B and the right floor part 80C in a vehicle front-rear direction constitute thin plate parts 82 having a smaller plate thickness than the other parts.

[0065] The front floor 80 corresponds to the pressed part in the present invention, and is manufactured by performing cold press working on the thickness-varied steel plate TB1 or the thickness-varied steel plate TB2 without performing a heat treatment such as annealing thereon. Thus, the thin plate parts 82, i.e., the portions rolled by the manufacturing method of a thickness-varied steel plate according to this embodiment, maintain the work-hardened conditions after being reduced in thickness. The yield strength of the thin plate parts 82 has been enhanced due to work hardening. According to the front floor 80, the middle parts of the left floor part 80B and the right floor part 80C in the vehicle front-rear direction that tend to lack strength is enhanced in strength by work hardening, and at the same time these middle parts are reduced in plate thickness. Thus, the strength of the front floor 80 is locally enhanced and the weight thereof is reduced.

[0066] The present invention is highly versatile, as there are a wide variety of vehicle body components in which locally causing work hardening as described above is expected to have advantageous effects. The plate thickness of a vehicle body component (vehicle frame part) is typically set according to a portion thereof that is required to be strong, so that the plate thicknesses of the other portions that are not required to be strong often have an excessively large plate thickness. However, using a thickness-varied steel plate according to the present invention can eliminate such excess of plate thickness. Thus, the present invention is a technology that is widely applicable to vehicle frame parts to reduce the weight of the vehicle.

[0067] The present invention has been described above by showing the embodiment and some examples, but the invention can be implemented with various modifications made thereto within the scope of the gist of the invention. It should be understood that the scope of right of the present invention is not limited to the above embodiment.

Claims

1. A manufacturing method of a thickness-varied metal plate, the manufacturing method comprising:

   manufacturing a cut plate (B) by cutting a metal plate into a predetermined shape; and
   manufacturing a thickness-varied metal plate (TB1) of which a plate thickness is varied in two different directions orthogonal to a plate thickness direction by processing the cut plate (B) through at least one of rolling and forging, using a processing machine (10) including a first work roll and a second work roll of which a radius is varied in a circumferential direction and an axial direction of a rotational axis.

2. The manufacturing method of a thickness-varied metal plate according to claim 1, wherein
   the processing machine (50) includes a first backup roll that is disposed on an opposite side of the first work roll from the second work roll and comes in contact with the first work roll, and a second backup roll that is disposed on an opposite side of the second work roll from the first work roll and comes in contact with the second work roll, and
   when the thickness-varied metal plate (TB1) manufactures, the cut plate (B) is processed by rotating the first work roll in forward and reverse directions within a range in which a region with a constant radius of the first work roll comes in contact with the first backup roll, and rotating the second work roll in forward and reverse directions within a range in which a region with a constant radius of the second work roll comes in contact with the second backup roll.

3. A manufacturing method of a thickness-varied metal plate, the manufacturing method comprising:

   manufacturing a cut plate (B) by cutting a metal plate into a predetermined shape; and
   manufacturing a thickness-varied metal plate (TB2) of which a plate thickness is varied in two different directions orthogonal to a plate thickness direction by sequentially processing the cut plate (B) through at least one of rolling and forging, using a first processing machine (20) including a first work roll and a second work roll of which a radius is varied in a circumferential direction or an axial direction of a rotational axis, and a second processing machine (30) including a pair of work rolls that are different in shape from the first work roll and the second work roll of the first processing machine.

4. The manufacturing method of a thickness-varied metal plate according to claim 3, wherein, when the thickness-varied metal plate (TB2) manufactures, a direction in which the cut plate is fed into the first processing machine (20) is changed to a direction that is different from a direction in which the cut plate is fed into the second processing machine (30).

5. The manufacturing method of a thickness-varied metal plate according to claim 3 or 4, wherein
   the first processing machine (20) includes a first backup roll that is disposed on an opposite side of the first work roll from the second work roll and comes in contact with the first work roll, and a second backup roll that is disposed on an opposite side of the second work roll from the first work roll and comes in contact with the second work roll, and
   when the thickness-varied metal plate (TB2) manufactures, the cut plate is processed by rotating the first work roll in forward and reverse directions within a range in which a region with a constant radius of the first work roll comes in contact with the first backup roll, and rotating the second work roll in forward and reverse directions within a range in which a region with a constant radius of the second work roll comes in contact with the second backup roll.

6. A manufacturing method of a pressed part, the manufacturing method comprising:

   manufacturing a partially processed thickness-varied metal plate (TB1; TB2; 82) by the manufacturing method according to any one of claims 1 to 5; and
   manufacturing a pressed part by performing cold-press bending on an unprocessed portion of the partially processed thickness-varied metal plate (TB1; TB2; 82).

7. A processing machine for manufacturing a thickness-varied metal plate, the processing machine comprising:

   a first work roll; and
   a second work roll of which a radius is varied in a circumferential direction and an axial direction of a rotational axis.

8. The processing machine according to claim 7, wherein the second work roll includes a second roll main body of which a radius is constant in the circumferential direction and the axial direction of the rotational axis, and a second cam that is detachably mounted at a part of an outer circumferential surface of the second roll main body.

9. The processing machine according to claim 7 or 8, wherein a radius of the first work roll is varied in a circumferential direction and an axial direction of a rotational axis.

10. The processing machine according to claim 9, wherein the first work roll includes a first roll main body of which a radius is constant in the circumferential direction and the axial direction of the rotational axis, and a first cam that is detachably mounted at a part of an outer circumferential surface of the first roll main body.

FIG. 1

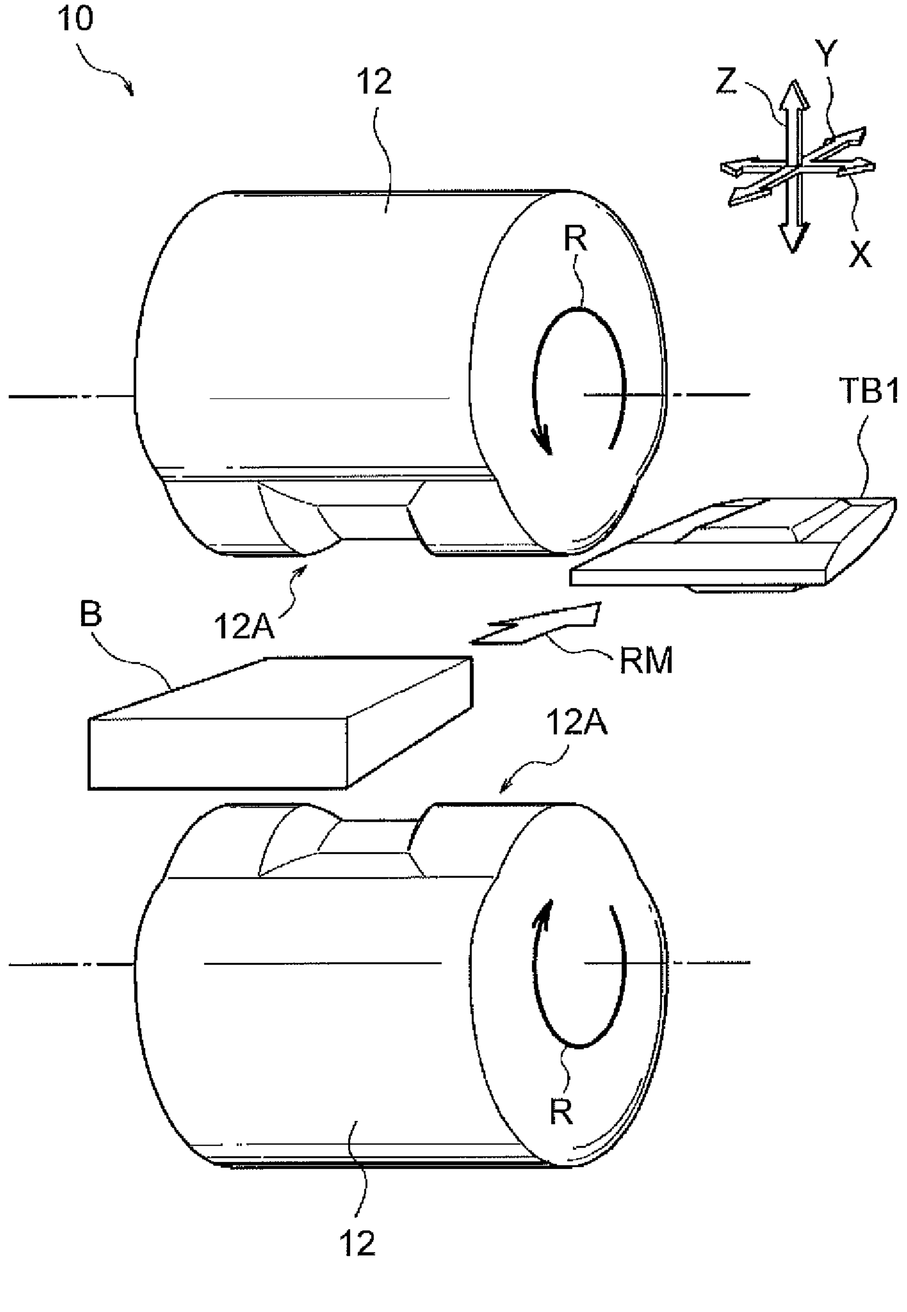


FIG. 2

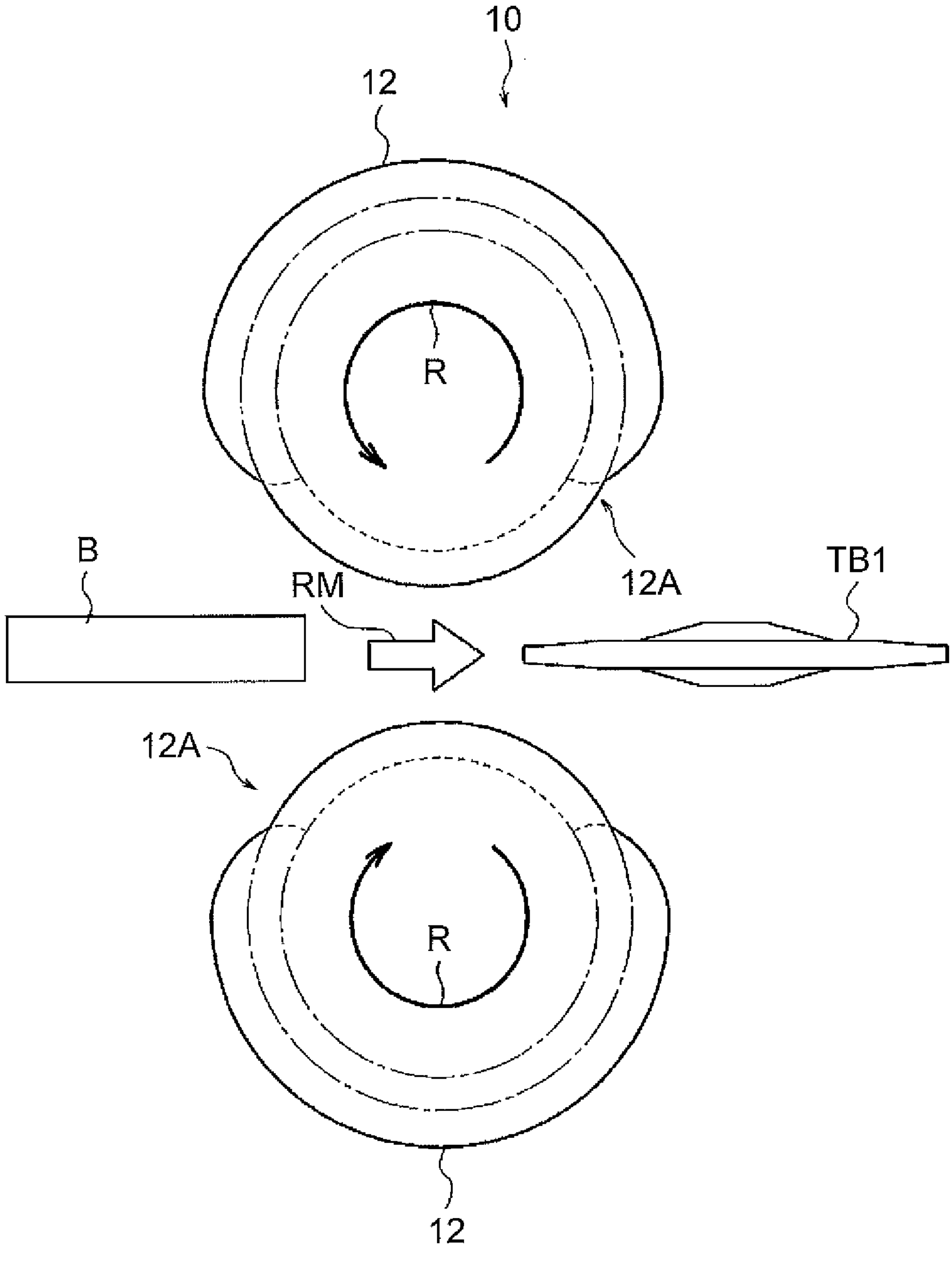


FIG. 3

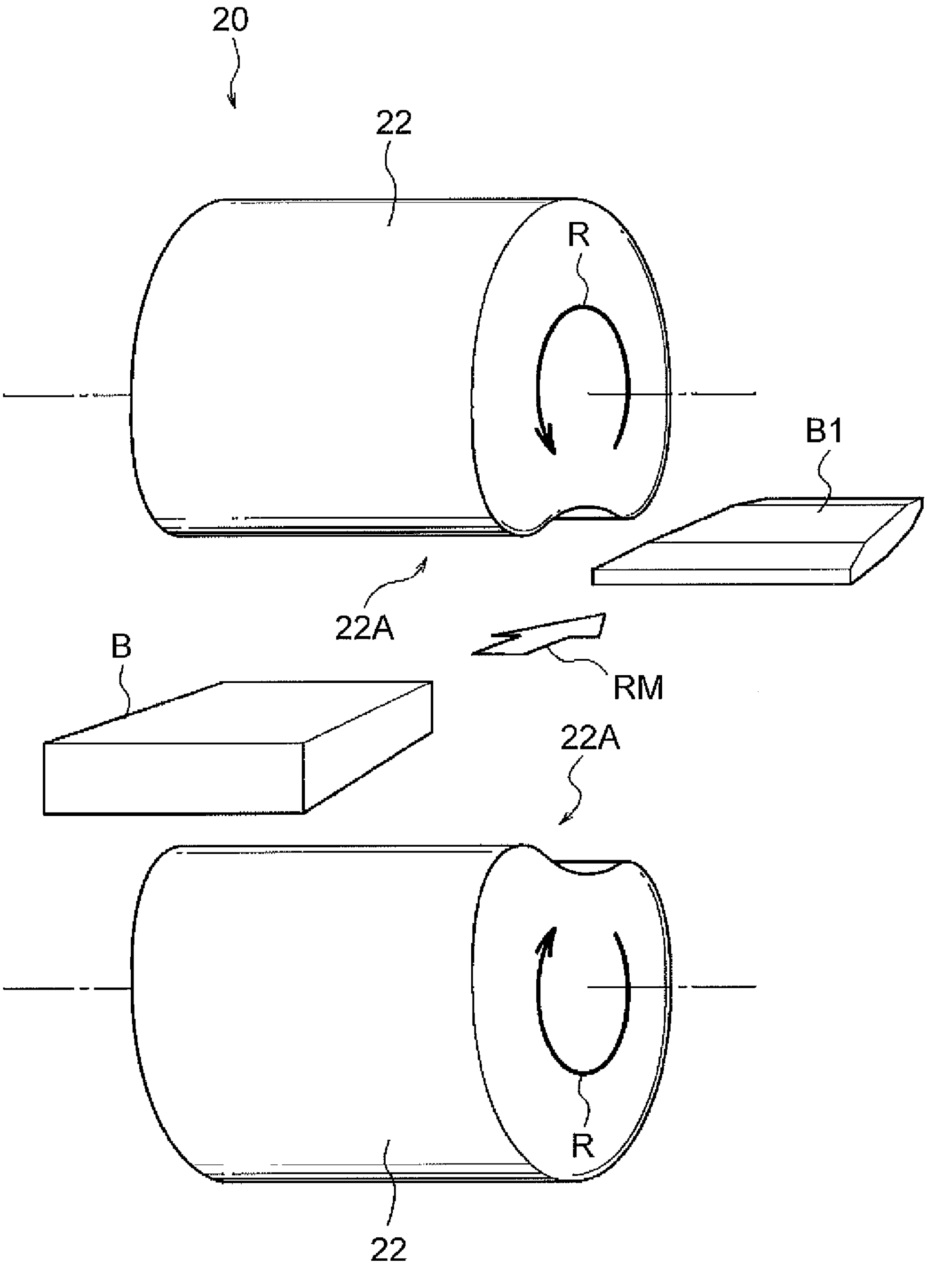


FIG. 4

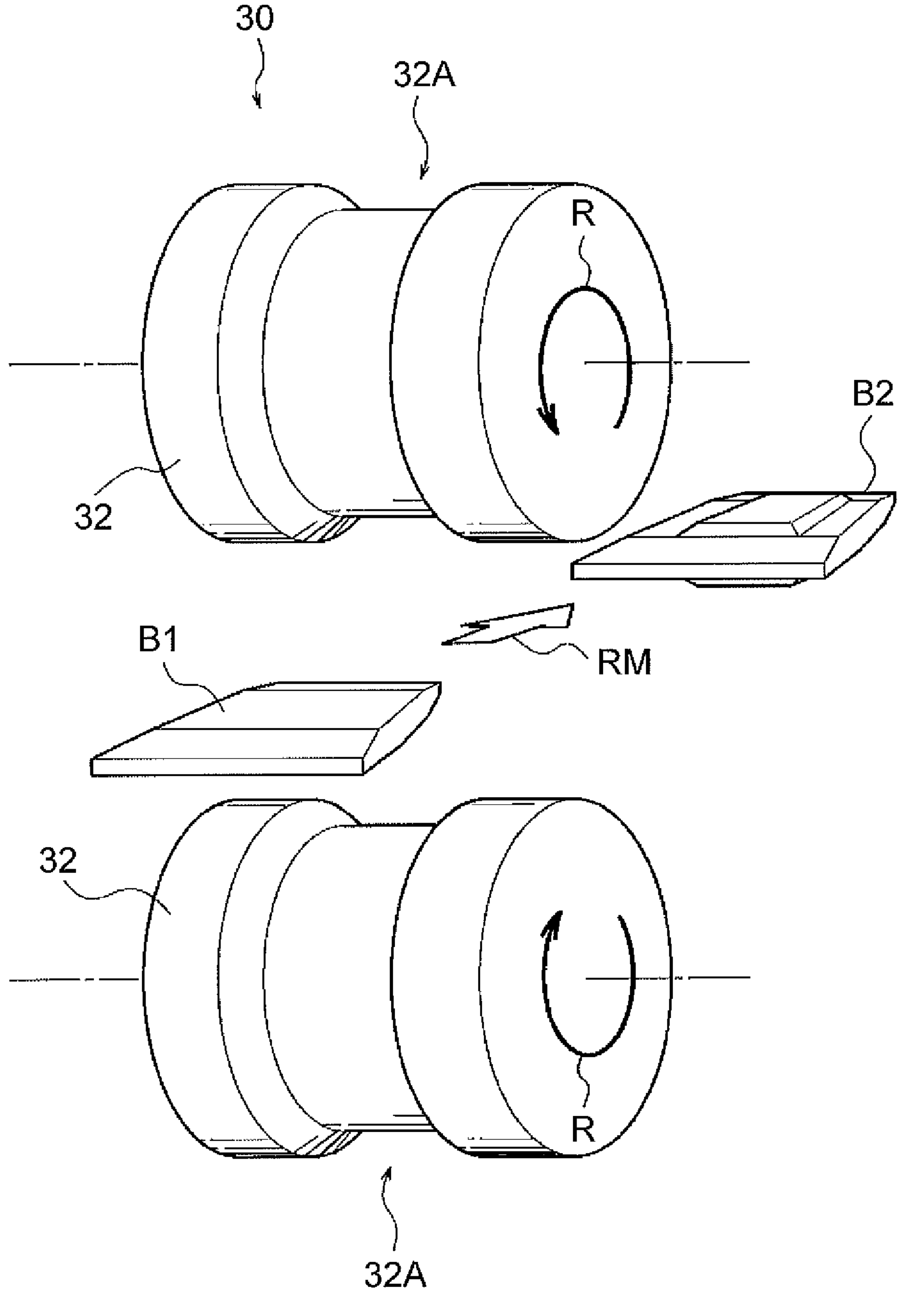


FIG. 5

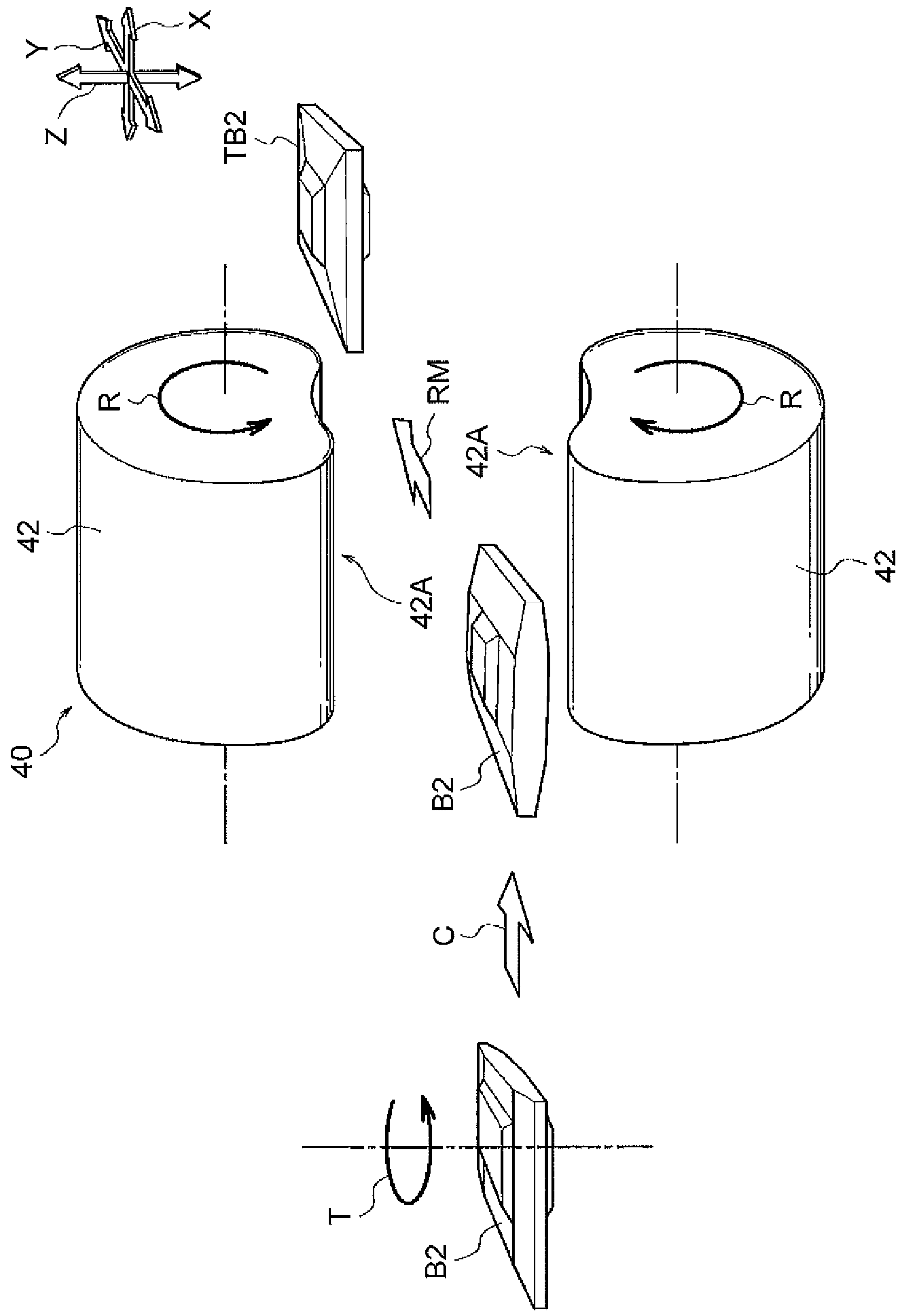


FIG. 6

RELATED ART

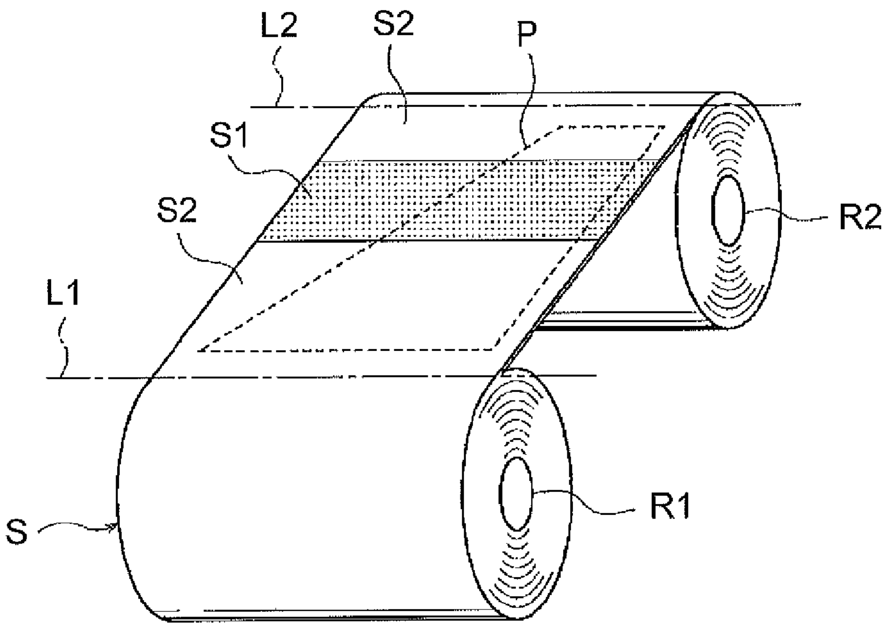


FIG. 7

RELATED ART

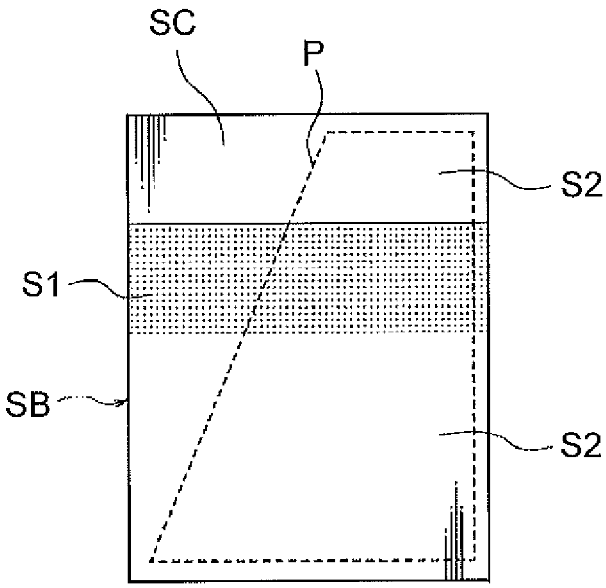


FIG. 8

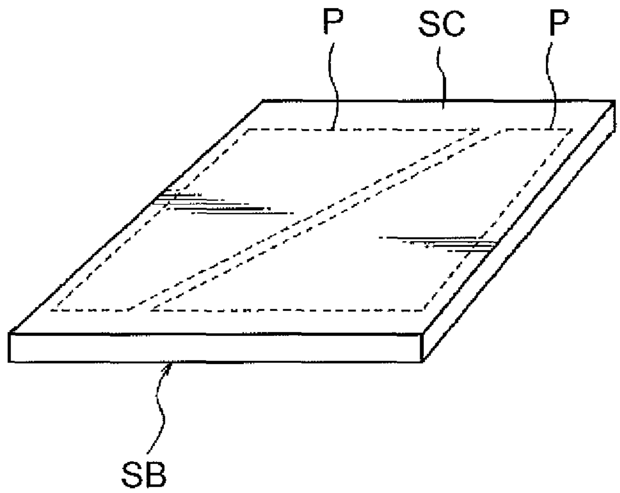


FIG. 9

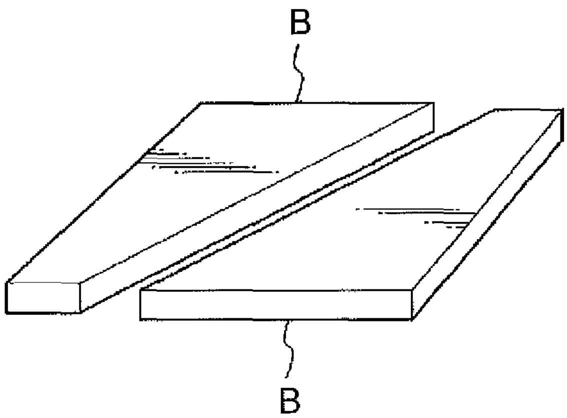


FIG. 10

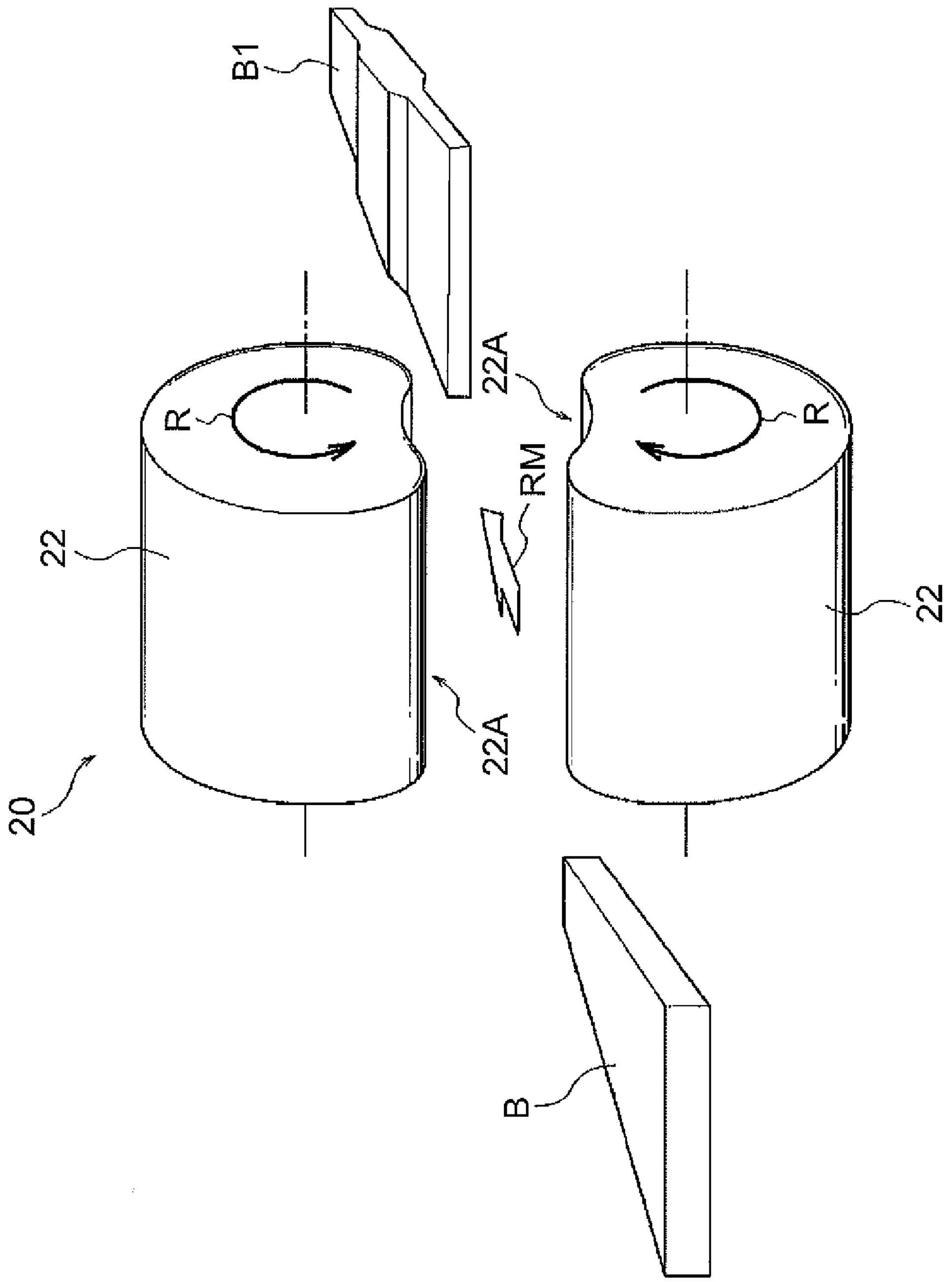


FIG. 11

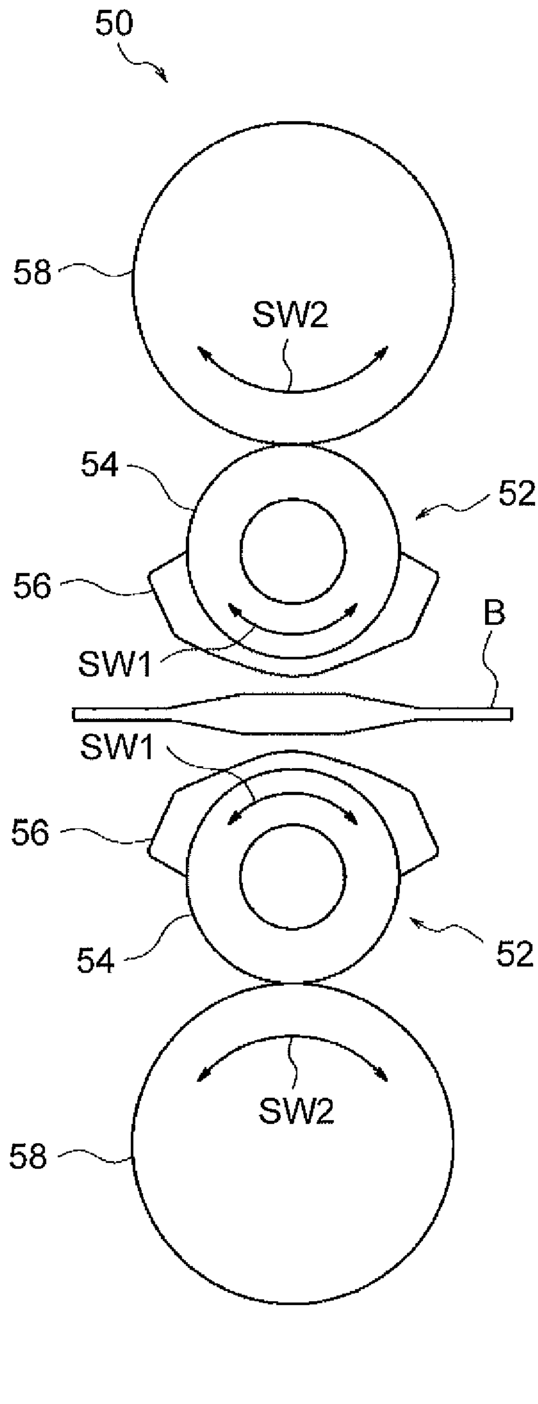


FIG. 12

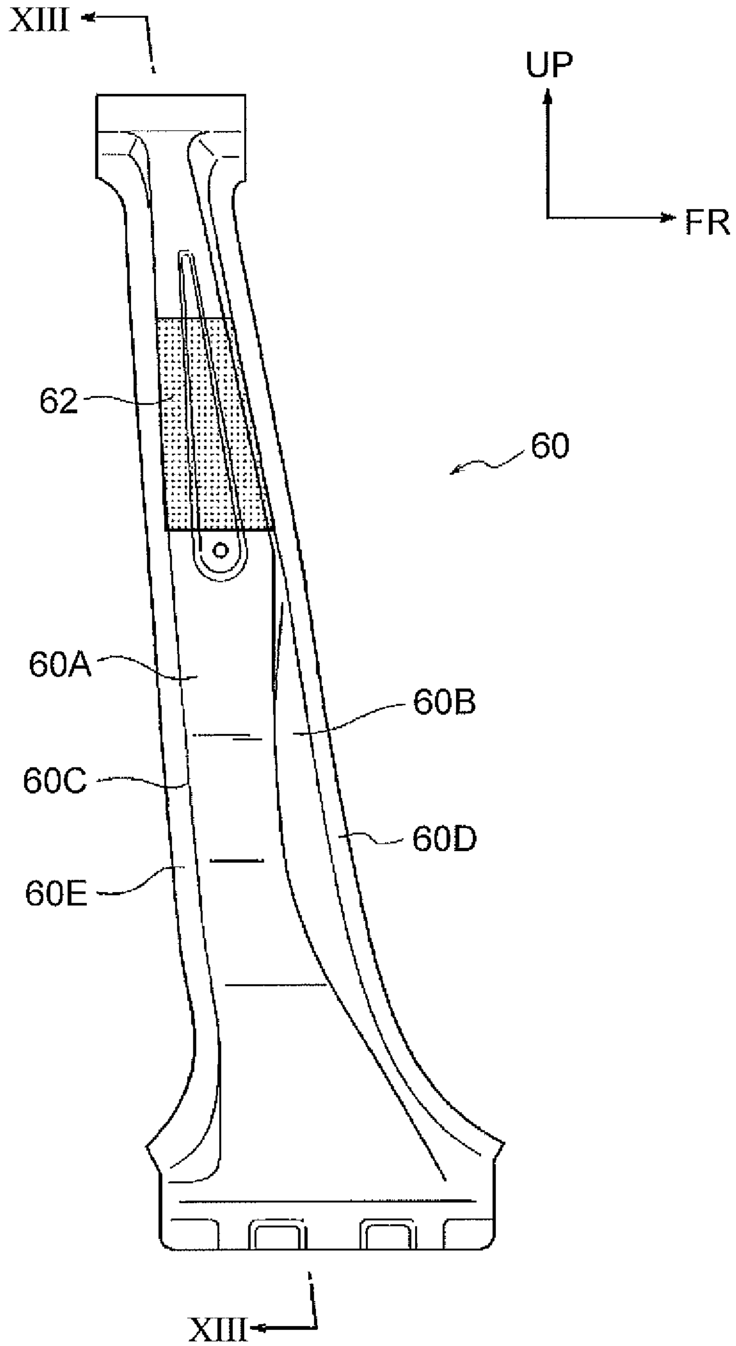


FIG. 13

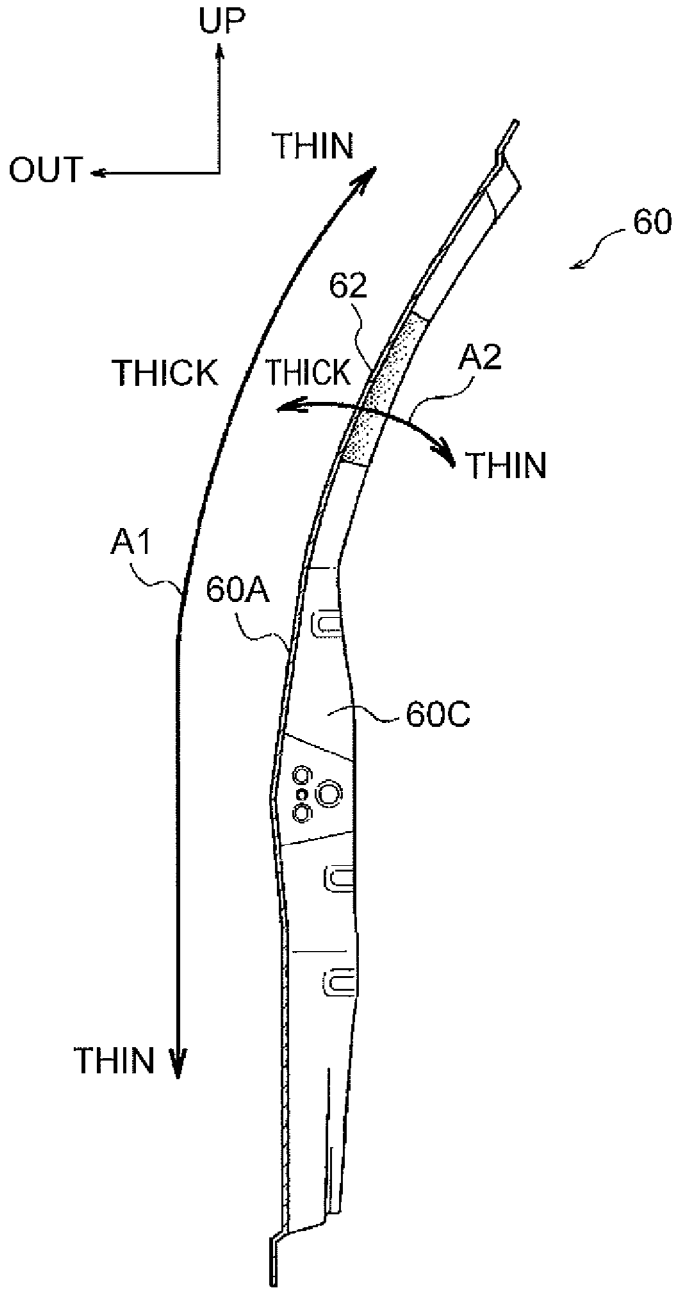


FIG. 14

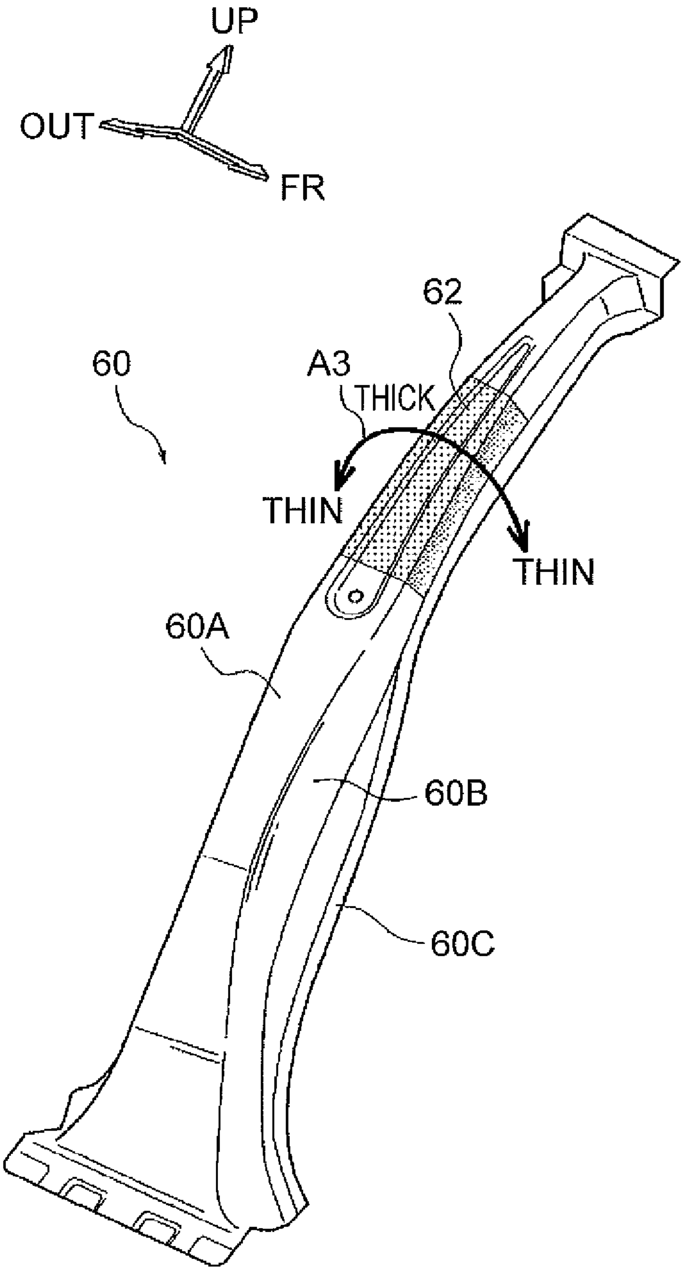


FIG. 15

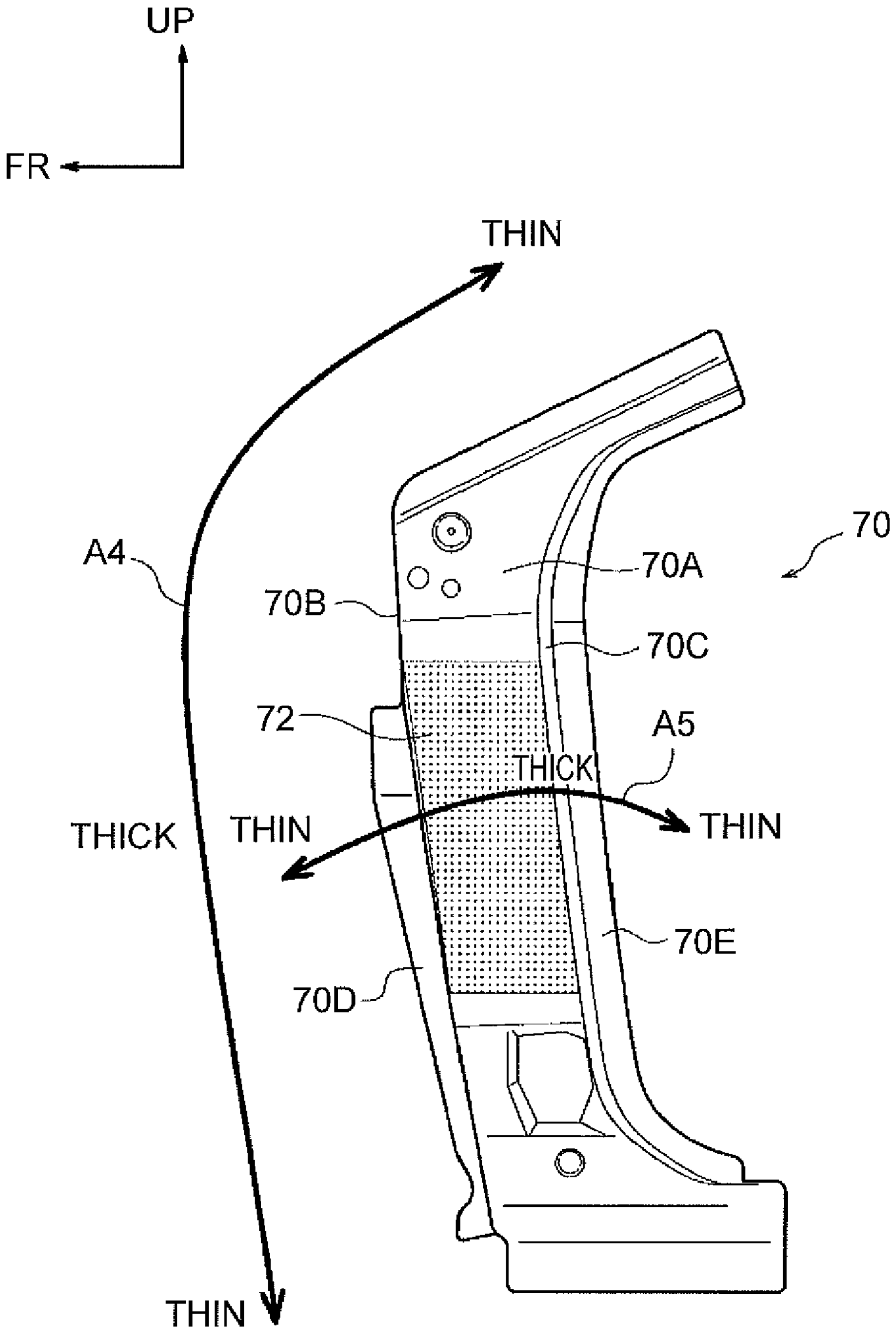
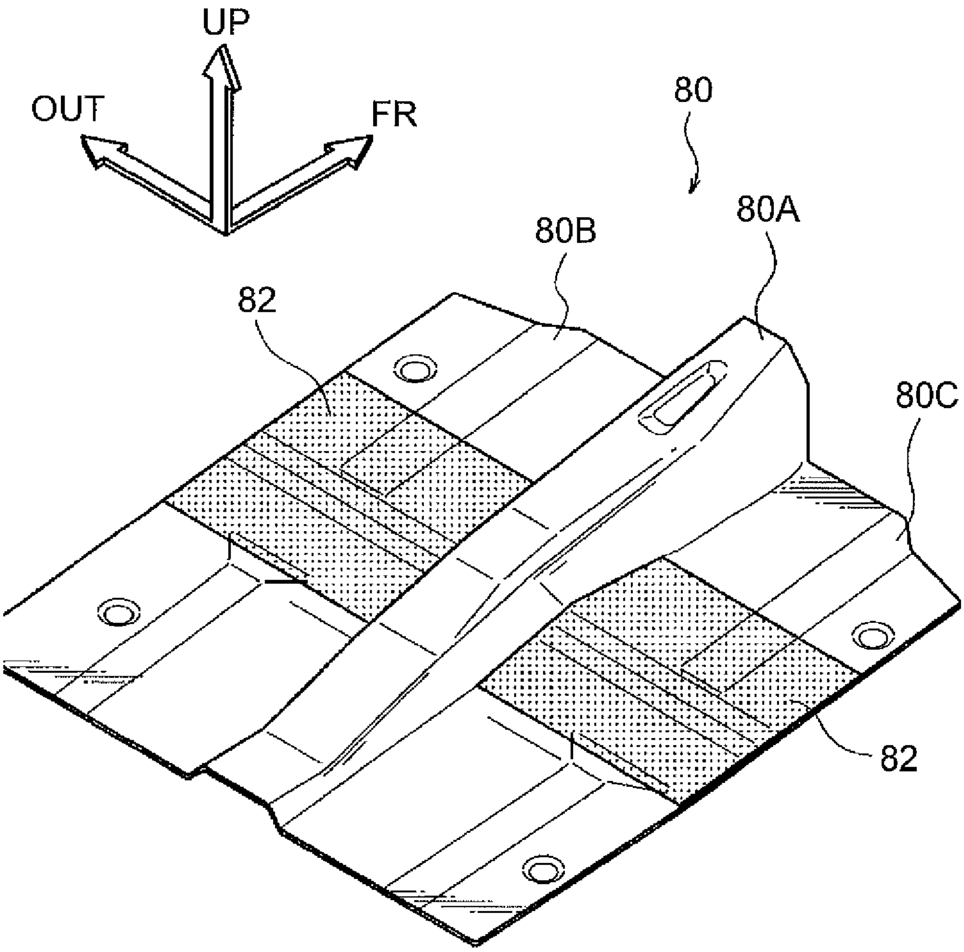

UP
FR
THIN
A4
70B
70A
70
70C
72
A5
THICK
THICK
THIN
THIN
70E
70D
THIN

FIG. 16



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EUROPEAN SEARCH REPORT

Application Number
EP 17 20 6480

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1

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	23 April 2018	Ritter, Florian

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EUROPEAN SEARCH REPORT

Application Number
EP 17 20 6480

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The present search report has been drawn up for all claims

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Place of search	Date of completion of the search	Examiner
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