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(71) Applicant *(for all designated States except US)*: **TOYOTA JIDOSHA KABUSHIKI KAISHA** [JP/JP]; 1, Toyota-cho, Toyota-shi, Aichi-ken 471-8571 (JP).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **OGURA, Shuhei** [JP/JP]; C/o Toyota Jidosha Kabushiki Kaisha, of 1, Toyota-cho, Toyota-shi, Aichi-ken 471-8571 (JP). **KAWAKITA, Atsushi** [JP/JP]; C/o Toyota Jidosha Kabushiki Kaisha, of 1, Toyota-cho, Toyota-shi, Aichi-ken 471-8571 (JP). **YUI, Toshiki** [JP/JP]; C/o Toyota Jidosha Kabushiki Kaisha, of 1, Toyota-cho, Toyota-shi, Aichi-ken 471-8571 (JP).

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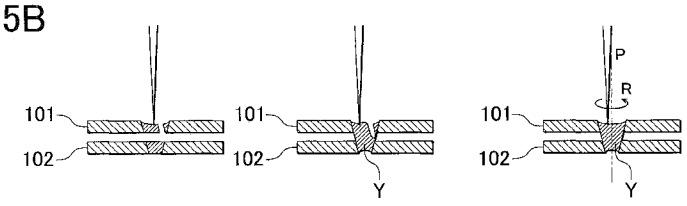
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(54) **Title**: LASER WELDING APPARATUS AND LASER WELDING METHOD

FIG. 5B



(57) **Abstract**: A laser welding apparatus generates laser by a laser oscillator, converges the laser by a condenser lens, and applies the laser to an upper sheet (101) and a lower sheet (102) superposed together so as to weld the upper sheet (101) and the lower sheet (102) to each other. According to this apparatus, by laser irradiation, a melt pool Y is formed in the upper sheet (101) and the lower sheet (102) superposed together. Furthermore, by laser irradiation, the melt pool Y is caused to flow, and the upper sheet (101) and the, lower sheet (102) are welded together.

LASER WELDING APPARATUS AND LASER WELDING METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to a technology concerning a laser welding apparatus and a laser welding method.

2. Description of Related Art

[0002] The laser welding is a welding method in which laser generated by a laser oscillator is converged by a condenser lens, and is applied to superposed steel sheets so as to weld the sheets. However, in the laser welding, the joint strength declines in the case where the sheet gap between steel sheets that are superposed together is large. For example, if there is an inter-sheet gap larger than or equal to 0.3 mm, the weld bead surface sometimes sinks, resulting in a reduced joint strength. Besides, if the inter-sheet gap is larger than 0.5 mm, it sometime happens that a penetration hole forms and the joint strength declines.

[0003] In the welding of a three-dimensional shape object, for example, a motor vehicle body, etc., it is difficult to properly control the inter-sheet gap to, for example, 0.3 mm or less. Meanwhile, an inter-sheet gap of about 1 mm is permitted practically, in the case of manufacturing of motor vehicle bodies and the like. Therefore, it has become an issue to weld steel sheets with an inter-sheet gap of about 1 mm without a decline in the joint strength. Now, some measures against the reduction of the joint strength of the laser welding of a large inter-sheet gap are taken in practice.

[0004] Japanese Patent Application Publication No. 2004-025219 (JP 2004-025219 A) discloses a method in which an inter-sheet gap is welded by using a shim roller. However, in the case where a motor vehicle body or the like is welded, two or three steel sheets are sometimes welded. Therefore, in the welding method disclosed by JP 2004-025219 A, there is a need to highly frequently carry out the replacement of shims or the like, and therefore the production efficiency declines.

[0005] Japanese Patent Application Publication No. 2005-131707 (JP 2005-131707 A) discloses a method in which laser tack welding is performed alternately with welding sites with the use of a clamp. However, in a method disclosed by JP 2005-131707 A, a dedicated large-size clamp is needed for the welding of a motor vehicle body or the like. Besides, in the welding method disclosed in the JP 2005-131707 A, when a zinc-plated steel is to be welded, the laser tack welding results in a welding failure caused by plating vapor blow.

[0006] In Japanese Patent Application Publication No. 2010-023047 (JP 2010-023047 A), the first laser irradiation is performed in a defocused state to melt the upper sheet so that a protrusion is formed toward the lower sheet side and therefore the gap is reduced, and then the second laser irradiation is performed to accomplish a penetrating weld. However, according to the welding method disclosed in the JP 2010-023047 A, since the first laser irradiation is low-energy irradiation, the first laser irradiation achieves the heat conduction melting in the upper sheet instead of the keyhole melting. Therefore, the processing time becomes long, and the productivity declines.

SUMMARY OF THE INVENTION

[0007] The invention provides a laser welding apparatus and a laser welding method capable of welding a plurality of sheets without a decline in the joint strength even in the case where there is a large inter-sheet gap.

[0008] A first aspect of the invention is a laser welding apparatus for welding a plurality of sheets superposed together, the laser welding apparatus including: a laser oscillator that generates laser; and a condenser lens that converges the laser, wherein the laser welding apparatus is configured to weld the plurality of sheets superposed together by applying the laser to the plurality of sheets superposed together so as to form a melt pool in the plurality of sheets, and applying the laser to the melt pool so that the melt pool flows.

[0009] In the first aspect of the invention, the laser welding apparatus may be

configured to cause the melt pool to flow by scanning the laser applied to the melt pool, by driving the condenser lens.

[0010] In the first aspect of the invention, the laser welding apparatus may further include a jig that is drivable while holding the plurality of sheets, and the laser welding apparatus may be configured to cause the melt pool to flow by scanning the laser applied to the melt pool, by driving the jig.

[0011] In the first aspect of the invention, the laser welding apparatus may be configured to cause the melt pool to flow in a predetermined rotation direction about a predetermined axis that extends through the melt pool, by scanning the laser applied to the melt pool in the predetermined rotation direction about the predetermined axis.

[0012] In the first aspect of the invention, the laser welding apparatus may be configured to cause the melt pool to flow by scanning the laser in the predetermined rotation direction along an outer edge portion of the melt pool after the melt pool is caused to flow in the predetermined rotation direction about the predetermined axis.

[0013] In the first aspect of the invention, the laser welding apparatus may be configured to cause the melt pool to flow in the predetermined rotation direction about the predetermined axis that extends through the melt pool and converge toward the predetermined axis by scanning the laser in the predetermined rotation direction about the predetermined axis so that scanning converges to the predetermined axis.

[0014] A second aspect of the invention is a laser welding method, by which a plurality of sheets superposed together are welded, the laser welding method including: generating laser by a laser oscillator; converging the laser by a condenser lens; forming a melt pool in the plurality of sheets superposed together by applying the laser to the plurality of sheets; and causing the melt pool to flow by applying the laser to the melt pool.

[0015] In the second aspect of the invention, when the melt pool is caused to flow, the laser applied to the melt pool may be scanned by driving the condenser lens.

[0016] In the second aspect of the invention, when the melt pool is caused to flow, the laser applied to the melt pool may be scanned by driving a jig that holds the

plurality of sheets.

[0017] In the second aspect of the invention, when the melt pool is caused to flow, the melt pool may be caused to flow in a predetermined rotation direction about a predetermined axis that extends through the melt pool by scanning the laser applied to the melt pool in the predetermined rotation direction about the predetermined axis.

[0018] In the second aspect of the invention, when the melt pool is caused to flow, the melt pool may be caused to flow and enlarge by scanning the laser in the predetermined rotation direction along an outer edge portion of the melt pool after causing the melt pool to flow in the predetermined rotation direction about the predetermined axis.

[0019] In the second aspect of the invention, when the melt pool is caused to flow, the melt pool may be caused to flow in the predetermined rotation direction about the predetermined axis so as to converge toward the predetermined axis by scanning the laser in the predetermined rotation direction about the predetermined axis so that scanning converges to the predetermined axis.

[0020] According to the laser welding apparatus and the laser welding method according to the invention, it is possible to weld a plurality of sheets without a decline in the joint strength, even if the inter-sheet gap is large.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] 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 construction diagram showing a construction of a laser welding apparatus in accordance with an embodiment of the invention;

FIG. 2 is a flowchart showing a flow of a welding method in accordance with a first embodiment;

FIGS. 3A and 3B show schematic perspective views and their corresponding

sectional views each taken along line B-B, respectively, showing operation of the welding method of the first embodiment;

FIG. 4 is a flowchart showing a flow of a welding method in accordance with a second embodiment;

FIGS. 5A and 5B show schematic perspective views and their corresponding sectional views each taken along line B-B, respectively, showing operation of the welding method of the second embodiment;

FIG. 6 is a flowchart showing a flow of a welding method in accordance with a third embodiment;

FIGS. 7A and 7B show schematic perspective views and their corresponding sectional views each taken along line B-B, respectively, showing operation of the welding method of the third embodiment;

FIG. 8 is a flowchart showing a flow of a welding method in accordance with a fourth embodiment; and

FIGS. 9A and 9B show schematic perspective views and their corresponding sectional views each taken along line B-B, respectively, showing operation of the welding method of the fourth embodiment.

DETAILED DESCRIPTION OF EMBODIMENTS

[0022] With reference to FIG. 1, a laser welding apparatus 10 will be described. The laser welding apparatus 10 is an embodiment of the laser welding apparatus of the invention. The laser welding apparatus 10 is an apparatus that performs laser welding. The laser welding is a welding method in which while laser light is applied, as a heat source, to metal pieces while focused on the metal pieces so that the metal pieces are locally melted and solidified to join together.

[0023] In the embodiment described below, it is assumed that in order to construct a motor vehicle body, two superposed steel sheets, that is, an upper sheet 101 and a lower sheet 102, are welded together by the laser welding that uses the laser

welding apparatus 10. It is also assumed that the upper sheet 101 and the lower sheet 102 superposed have an inter-sheet gap of 1 mm.

[0024] The construction of the laser welding apparatus 10 will be described. The laser welding apparatus 10 includes a laser oscillator 11, an optical path 12, a laser irradiation head 13, and condenser lenses 14. The laser oscillator 11 generates CO_2 laser or YAG laser as a welding heat source. The optical path 12 guides the laser generated by the oscillator to the laser irradiation head 13. The optical path 12 transmits the laser by bending it via mirrors, or transmits the laser by freely curving it through an optical fiber.

[0025] The laser irradiation head 13 applies the laser transmitted through the optical path 12, to the upper sheet 101 and the lower sheet 102 from above the upper sheet 101. The laser irradiation head 13 is moved to a position over the upper sheet 101 by a robot (not shown). The condenser lenses 14 condense the laser transmitted through the optical path 12 to an appropriate size for irradiation, and scans the laser on an object to be welded. The condenser lenses 14 are housed within the laser irradiation head 13.

[0026] Operation of the laser welding apparatus 10 will be described. The laser welding apparatus 10 generates laser by the laser oscillator 11, and converges the laser generated by the laser oscillator 11 through the use of the condenser lenses 14, and applies the laser converged by the condenser lenses 14 to the upper sheet 101 and the lower sheet 102 superposed together, and thus welds the upper sheet 101 and the lower sheet 102 together.

[0027] With reference to FIG. 2 and FIG. 3, a laser welding method S100 will be described. The laser welding method S100 is a first embodiment of the laser welding method that uses the laser welding apparatus of the invention. Incidentally, steps in FIG. 2 correspond to steps in FIGS. 3A and 3B. Besides, FIG. 3B shows sectional views each taken along line B-B in FIG. 3A.

[0028] With reference to FIG. 2, a flow of the laser welding method S100 will be described. In step S110, the laser welding apparatus 10 applies a laser beam to the upper sheet 101 and the lower sheet 102 superposed together, from above the upper sheet

101. At this time, the laser welding apparatus 10 scans the applied laser beam so that a region occupied by the trace of irradiation with the laser beam forms a rectangular shape in a plan view, whereby a melt pool Y is formed in the upper sheet 101 and the lower sheet 102 superposed together. Incidentally, although in this embodiment, the trace of irradiation with laser forms a rectangular shape, the shape of the trace of irradiation may also be a different shape such as a circular shape, an elliptic shape, etc.

[0029] In step S120, the laser welding apparatus 10 applies a laser beam to the melt pool Y formed as described above, and scans the laser beam so that the trace of irradiation with the laser beam becomes a line bead, whereby an interior of the melt pool Y formed between the upper sheet 101 and the lower sheet 102 is caused to flow. Although the trace of irradiation with laser is a line bead in this case, any other trace of laser irradiation is appropriate as long as it is a trace of laser irradiation that causes the melt pool Y to flow.

[0030] With reference to FIG. 3, operation of the laser welding method S100 will be described. In step S110, the laser welding apparatus 10 applies a laser beam, from above, to the upper sheet 101 and the lower sheet 102 superposed together so that the melt pool Y is formed in the upper sheet 101 and the lower sheet 102 superposed together. In this case, it does not matter if a penetration hole or a separate bead forms in the formed melt pool Y.

[0031] In step S120, the scanning of laser irradiation by the laser welding apparatus 10 causes flow of the melt pool Y formed as described above. At this time, undulation occurs in the flowing melt pool Y. The melt pool Y in which undulation occurs is gathered due to surface tension, and forms a junction portion without a penetration hole nor a separate bead.

[0032] Effects of the laser welding method S100 will be described. In the field of the welding of a three-dimensional shape object, such as a motor vehicle body and the like, it has been difficult to properly manage the inter-sheet gap so that the inter-sheet gap is less than or equal to, for example, 0.3 mm. On the other hand, when a motor vehicle body or the like is to be manufactured, an inter-sheet gap of about 1 mm has been

permitted in practice. Therefore, it has been an issue to perform welding with an inter-sheet gap of about 1 mm without decline in the joint strength. According to the laser welding method S100, the upper sheet 101 and the lower sheet 102 with an inter-sheet gap of 1 mm can be welded together without decline in the joint strength.

[0033] With reference to FIGS. 4, 5A, and 5B, a laser welding method S200 will be described. The laser welding method S200 is a second embodiment of the laser welding method that uses the laser welding apparatus of the invention. Incidentally, steps in FIG. 4 correspond to steps in FIGS. 5A and 5B. Besides, FIG. 5B shows sectional views each taken on line B-B in FIG. 5A.

[0034] With reference to FIG. 4, a flow of a laser welding method S200 will be described. In step S210, the laser welding apparatus 10, using the laser irradiation head 13, applies a laser beam to the upper sheet 101 and the lower sheet 102 superposed together, from above. At this time, the laser welding apparatus 10 scans the applied laser beam so that a region occupied by the trace of laser irradiation forms a circular shape in a plan view, whereby a melt pool Y is formed in the upper sheet 101 and the lower sheet 102 superposed together. Incidentally, although in this embodiment, the trace of laser irradiation forms a circular shape, it suffices that the shape of the trace of laser irradiation is a concentric shape such as an elliptic shape, etc.

[0035] In step S220, the laser welding apparatus 10 scans the laser irradiation so as to cause flow in the melt pool Y formed in the upper sheet 101 and the lower sheet 102. Herein, an axis that extends in the vertical direction through a center of the melt pool Y in a plan view is defined as an axis P. In step S220, the laser irradiation is scanned so as to rotate in a predetermined direction about the axis P (the direction of an arrow R in FIGS. 5A and 5B).

[0036] With reference to FIGS. 5A and 5B, operation of the laser welding method S200 will be described. In step S210, the laser welding apparatus 10 applies a laser beam to the upper sheet 101 and the lower sheet 102 superposed together, from above, so that the melt pool Y that is circular in a plan view is formed between the upper sheet 101 and the lower sheet 102 superposed together. In this case, it does not matter if

a penetration hole or a separate bead forms in the melt pool Y formed as described above.

[0037] In step S220, the scanning of the laser irradiation by the laser welding apparatus 10 causes rotation of the melt pool Y formed as described above. Specifically, the scanning of the laser irradiation by the laser welding apparatus 10 causes the formed melt pool Y to circumferentially flow and be stirred. At this time, the melt pool Y that is turning flows in a circumferential direction, so as to be formed in a bowl or mortar shape. Simultaneously, undulation occurs in the flowing melt pool Y. The melt pool Y in which undulation occurs is gathered due to surface tension, and forms a junction portion without a penetration hole or a separate bead.

[0038] Effects of the laser welding method S200 will be described. According to the laser welding method S200, the upper sheet 101 and the lower sheet 102 that have an inter-sheet gap of 1 mm therebetween can be welded together without decline in the joint strength.

[0039] With reference to FIGS. 6, 7A, and 7B, a laser welding method S300 will be described. The laser welding method S300 is a third embodiment of the laser welding method that uses the laser welding apparatus of the invention. Incidentally, steps in FIG. 6 correspond to steps in FIGS. 7A and 7B. Besides, FIG. 7B shows sectional views each taken on line B-B in FIG. 7A.

[0040] With reference to FIG. 6, a flow of the laser welding method S300 will be described. The flow from step S310 to step S320 is substantially the same as the flow from step S210 to step S220 in the second embodiment, and therefore will not be described.

[0041] In step S330, the laser welding apparatus 10 scans the laser beam along an outer edge portion of the melt pool Y formed in a mortar shape in step S320. At this time, as in step S320, the scanning of the laser irradiation is performed so as to rotate in a predetermined direction (the direction of an arrow R1 in FIGS. 7A and 7B) about the axis P.

[0042] With reference to FIGS. 7A and 7B, operation of the laser welding method S300 will be described. The process of step S310 to step S320 operates in

substantially the same manner as the process of step S210 to step S220 in the second embodiment, and will not be described again.

[0043] In step S330, the scanning of the laser irradiation by the laser welding apparatus 10 enlarges the diameter of the melt pool Y formed. At this time, the radial expansion of the melt pool Y is performed using as a base the melt pool Y that flows wholly as a mass in step S320, and therefore a penetration hole does not form in the melt pool Y. In the case where it is tried to form a radially expanded melt pool Y from the beginning, a melt pool Y with a large diameter is formed from the beginning, and therefore the probability of formation of a penetration hole is high. However, in step S330, the diameter of the melt pool Y is increased by using as a base the melt pool Y that flows wholly as a mass, and therefore the probability of formation of a penetration hole is low.

[0044] Effects of the laser welding method S300 will be described. According to the laser welding method S300, the upper sheet 101 and the lower sheet 102 with an inter-sheet gap of 1 mm can be welded together without decline in the joint strength.

[0045] With reference to FIGS. 8, 9A, and 9B, a laser welding method S400 will be described. The laser welding method S400 is a fourth embodiment of the laser welding method that uses the laser welding apparatus of the invention. Incidentally, steps in FIG. 8 correspond to steps in FIGS. 9A and 9B. Besides, FIG. 9B shows sectional views each taken on line B-B in FIG. 9A.

[0046] With reference to FIG. 8, a flow of the laser welding method S400 will be described. The flow from step S410 to step S420 is substantially the same as the flow from step S210 to step S220 in the second embodiment, and therefore will not be described.

[0047] In step S430, the laser welding apparatus 10 scans the laser beam so that the scanning converges toward the center of the melt pool Y formed in a mortar shape in step S320. That is, the laser irradiation is scanned so as to converge toward the axis P. At this time, as in step S320, the scanning of the laser irradiation is performed so as to rotate in a predetermined direction (the direction of an arrow R2 in FIGS. 9A and 9B)

about the axis P. In other words, the laser is scanned spirally about the axis P.

[0048] With reference to FIGS. 9A and 9B, operation of the laser welding method S400 will be described. The process of steps S410 to S420 operates in substantially the same manner as the process of steps S210 to S220 in the second embodiment, and will not be described below.

[0049] In step S430, the scanning of the laser irradiation by the laser welding apparatus 10 causes a central portion of the formed melt pool Y to extend downward. At this time, the melt pool Y flowing wholly as a mass in step S420 extends downward, so that the lower sheet 102 is welded with higher strength.

[0050] Effects of the laser welding method S400 will be described. According to the laser welding method S400, the upper sheet 101 and the lower sheet 102 that have an inter-sheet gap of 1 mm can be welded together without decline in the joint strength.

[0051] Although in the foregoing first to fourth embodiments, laser is applied from above the upper sheet 101 and the lower sheet 102 (two steel sheets) superposed together, the invention is not limited to this construction. Even in a construction in which laser is applied from above three or more steel sheets superposed together, substantially the same effects can be achieved.

[0052] Although in the first to fourth embodiments, the object to be welded is steel sheets, this does not limit the invention. For example, in a construction in which the object to be welded is aluminum sheets, substantially the same effects can be achieved.

[0053] Although in the first and fourth embodiments, laser is applied from above the upper sheet 101 and the lower sheet 102 superposed together, the invention is not limited to this. Even in a construction in which laser is applied to a side surface (end surface) of the upper sheet 101 and the lower sheet 102 superposed together, substantially the same effects can be achieved.

[0054] Incidentally, the scanning of laser may be carried out by changing the focusing position of laser through, for example, driving the condenser lens as in the foregoing embodiments, or may also be carried out by moving a plurality of sheets

relatively to the laser through driving jigs (not shown) that hold the plurality of sheets. That is, it suffices that the laser and a plurality of sheets move relatively to each other so that a melt pool is caused to flow. However, in the case where a plurality of sheets to be welded are large so that it is hard to move the sheets, it is preferable to scan the laser by changing the focusing position of the laser through, for example, driving the condenser lenses.

[0055] Besides, examples of jigs for use in the invention include a clamp that clamps a plurality of sheets so that the sheets are fixed immovably relative to each other, a table on which a plurality of sheets are placed, combinations of these jigs, etc.

[0056] The invention has been described with reference to example embodiments for illustrative purposes only. It should be understood that the description is not intended to be exhaustive or to limit form of the invention and that the invention may be adapted for use in other systems and applications. The scope of the invention embraces various modifications and equivalent arrangements that may be conceived by one skilled in the art.

CLAIMS

1. A laser welding apparatus for welding a plurality of sheets superposed together, characterized by comprising:

a laser oscillator that generates laser; and

a condenser lens that converges the laser, wherein

the laser welding apparatus is configured to weld the plurality of sheets superposed together by applying the laser to the plurality of sheets superposed together so as to form a melt pool in the plurality of sheets, and applying the laser to the melt pool so that the melt pool flows.

2. The laser welding apparatus according to claim 1, wherein

the laser welding apparatus is configured to cause the melt pool to flow by scanning the laser applied to the melt pool, by driving the condenser lens.

3. The laser welding apparatus according to claim 1 or 2, further comprising

a jig that is drivable while holding the plurality of sheets, wherein

the laser welding apparatus is configured to cause the melt pool to flow by scanning the laser applied to the melt pool, by driving the jig.

4. The laser welding apparatus according to any one of claims 1 to 3, wherein

the laser welding apparatus is configured to cause the melt pool to flow in a predetermined rotation direction about a predetermined axis that extends through the melt pool, by scanning the laser applied to the melt pool in the predetermined rotation direction about the predetermined axis.

5. The laser welding apparatus according to claim 4, wherein

the laser welding apparatus is configured to cause the melt pool to flow and enlarge by scanning the laser in the predetermined rotation direction along an outer edge portion

of the melt pool after the melt pool is caused to flow in the predetermined rotation direction about the predetermined axis.

6. The laser welding apparatus according to claim 4, wherein

the laser welding apparatus is configured to cause the melt pool to flow in the predetermined rotation direction about the predetermined axis that extends through the melt pool and converge toward the predetermined axis by scanning the laser in the predetermined rotation direction about the predetermined axis so that scanning converges to the predetermined axis.

7. A laser welding method, by which a plurality of sheets superposed together are welded, characterized by comprising:

generating laser by a laser oscillator;

converging the laser by a condenser lens;

forming a melt pool in the plurality of sheets superposed together by applying the laser to the plurality of sheets; and

causing the melt pool to flow by applying the laser to the melt pool.

8. The laser welding method according to claim 7, wherein

when the melt pool is caused to flow, the laser applied to the melt pool is scanned by driving the condenser lens.

9. The laser welding method according to claim 7 or 8, wherein

when the melt pool is caused to flow, the laser applied to the melt pool is scanned by driving a jig that holds the plurality of sheets.

10. The laser welding method according to any one of claims 7 to 9, wherein

when the melt pool is caused to flow, the melt pool is caused to flow in a predetermined rotation direction about a predetermined axis that extends through the melt

pool by scanning the laser applied to the melt pool in the predetermined rotation direction about the predetermined axis.

11. The laser welding method according to claim 10, wherein

when the melt pool is caused to flow, the melt pool is caused to flow and enlarge by scanning the laser in the predetermined rotation direction along an outer edge portion of the melt pool after causing the melt pool to flow in the predetermined rotation direction about the predetermined axis.

12. The laser welding method according to claim 10, wherein

when the melt pool is caused to flow, the melt pool is caused to flow in the predetermined rotation direction about the predetermined axis so as to converge toward the predetermined axis by scanning the laser in the predetermined rotation direction about the predetermined axis so that scanning converges to the predetermined axis.

FIG. 1

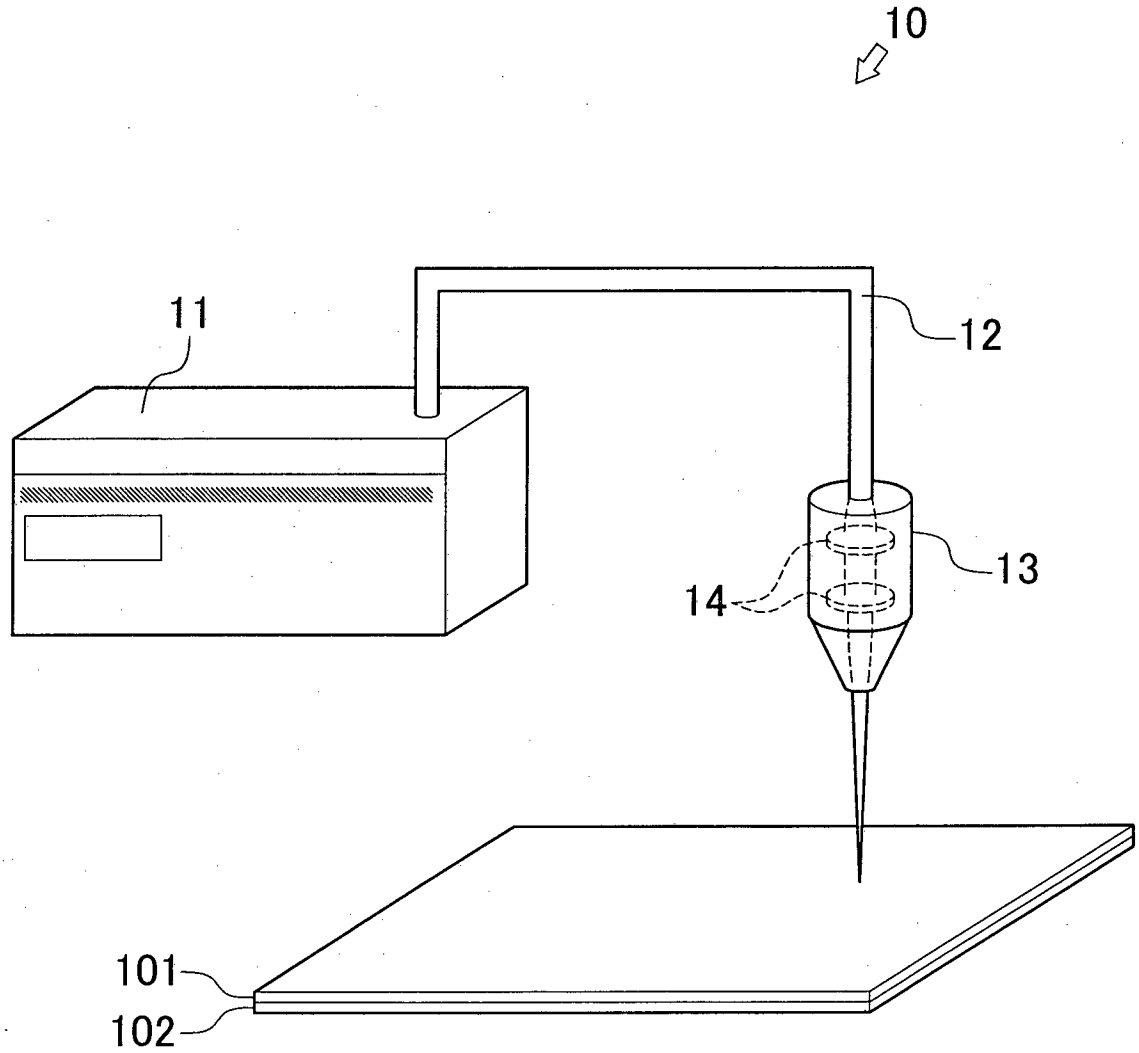


FIG. 2

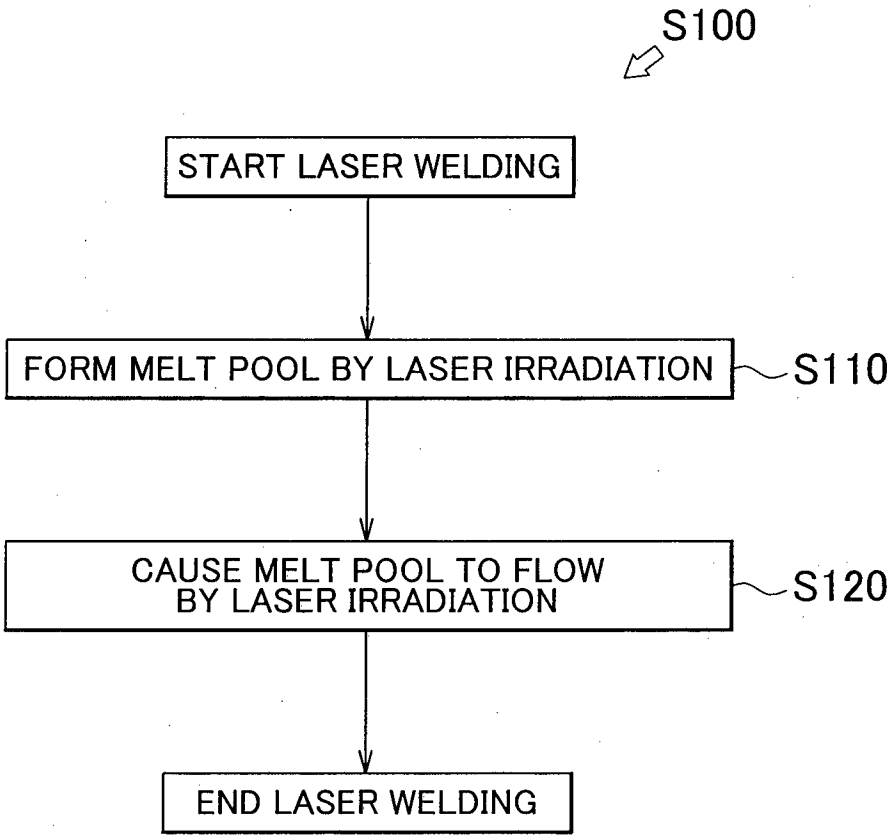

S100
START LASER WELDING
FORM MELT POOL BY LASER IRRADIATION
S110
CAUSE MELT POOL TO FLOW BY LASER IRRADIATION
S120
END LASER WELDING

FIG. 3A

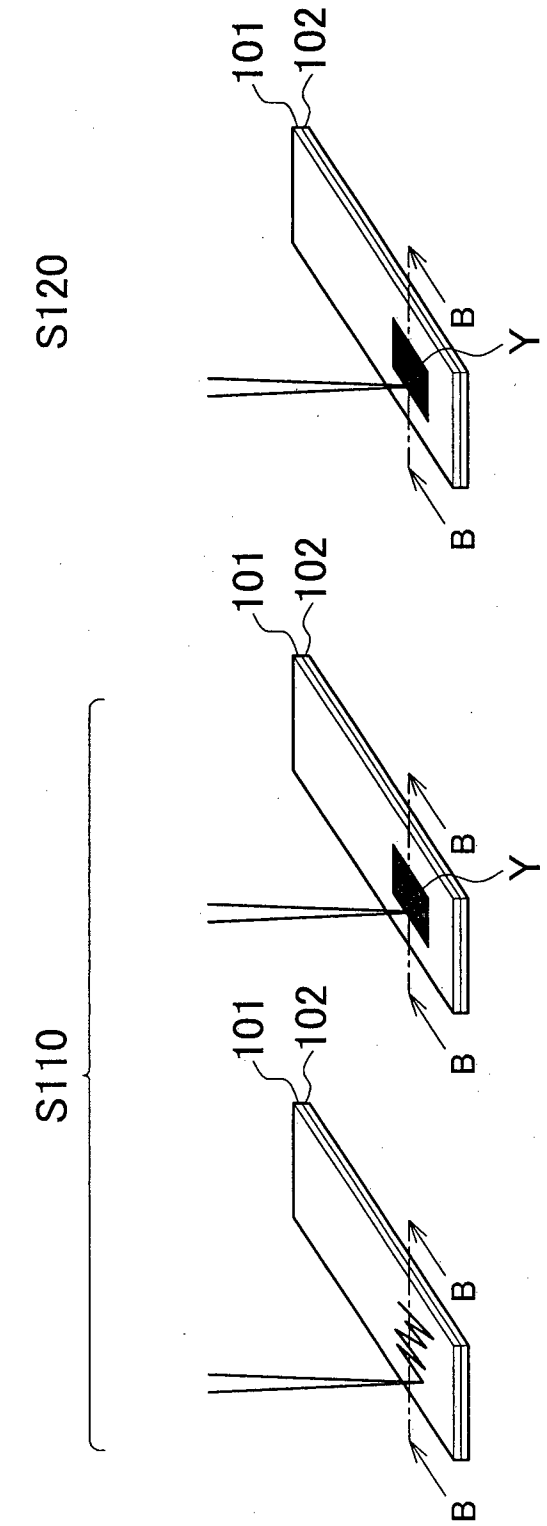


FIG. 3B

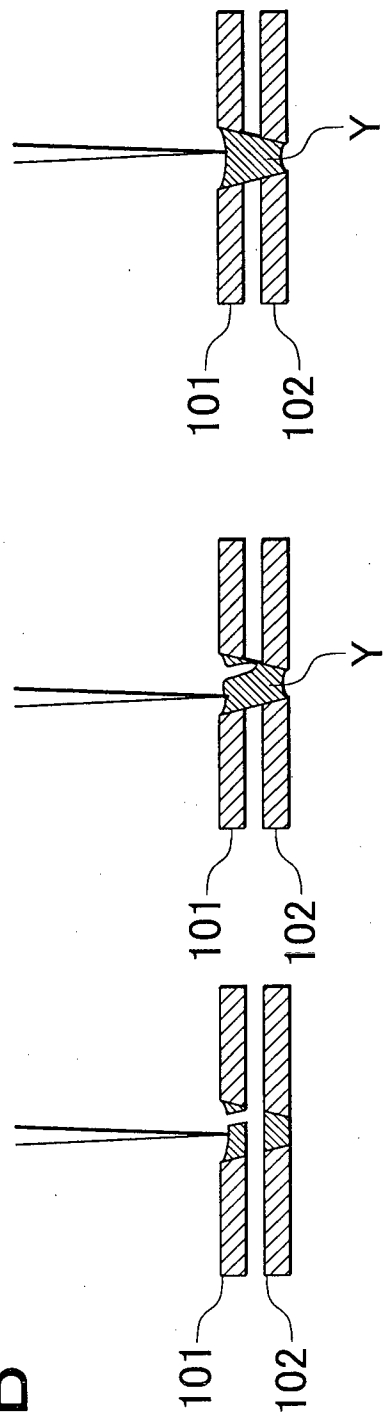
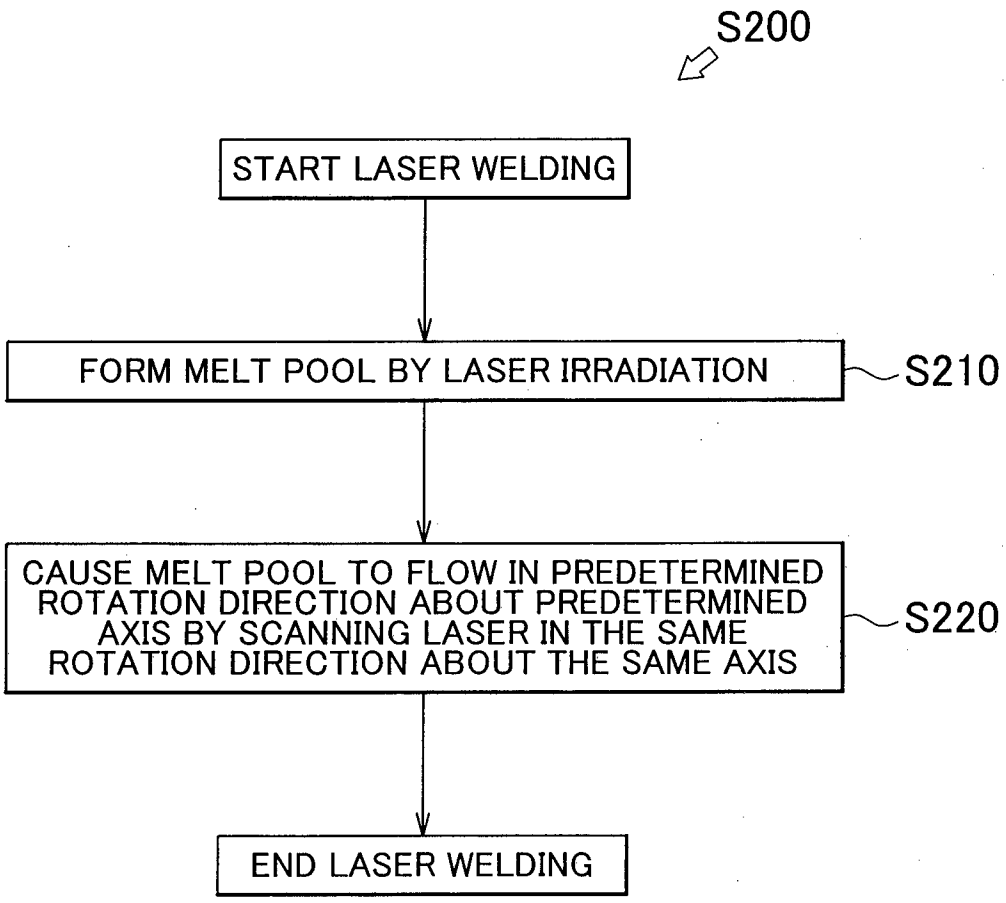


FIG. 4


S200
START LASER WELDING
FORM MELT POOL BY LASER IRRADIATION
S210
CAUSE MELT POOL TO FLOW IN PREDETERMINED ROTATION DIRECTION ABOUT PREDETERMINED AXIS BY SCANNING LASER IN THE SAME ROTATION DIRECTION ABOUT THE SAME AXIS
S220
END LASER WELDING

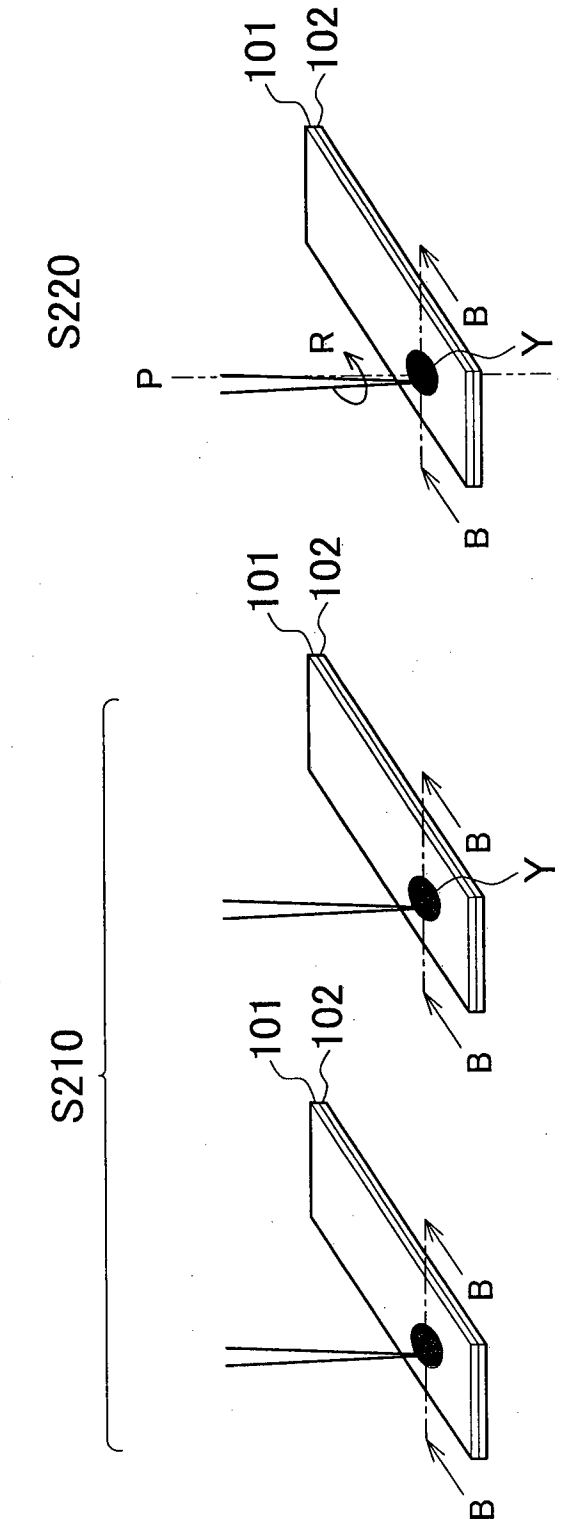


FIG. 5A

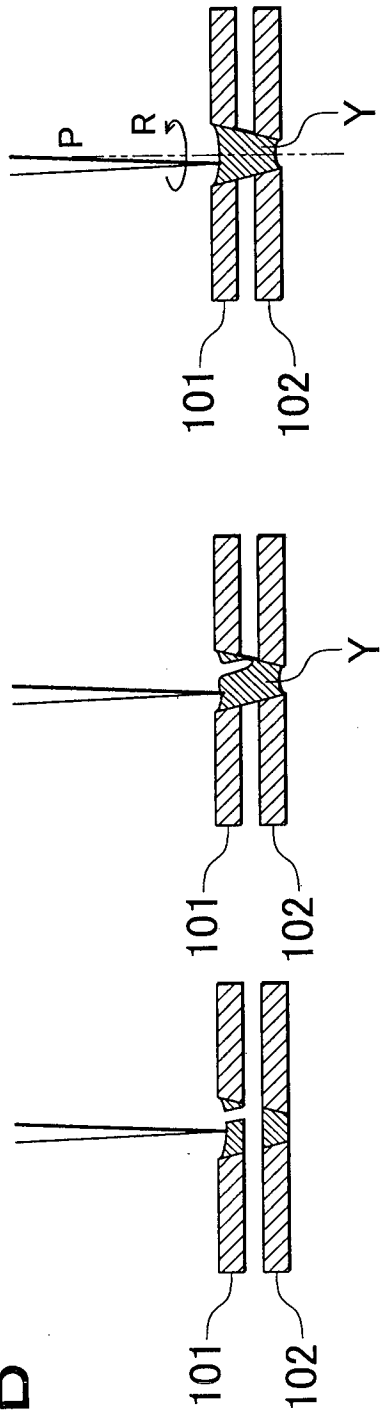


FIG. 5B

FIG. 6

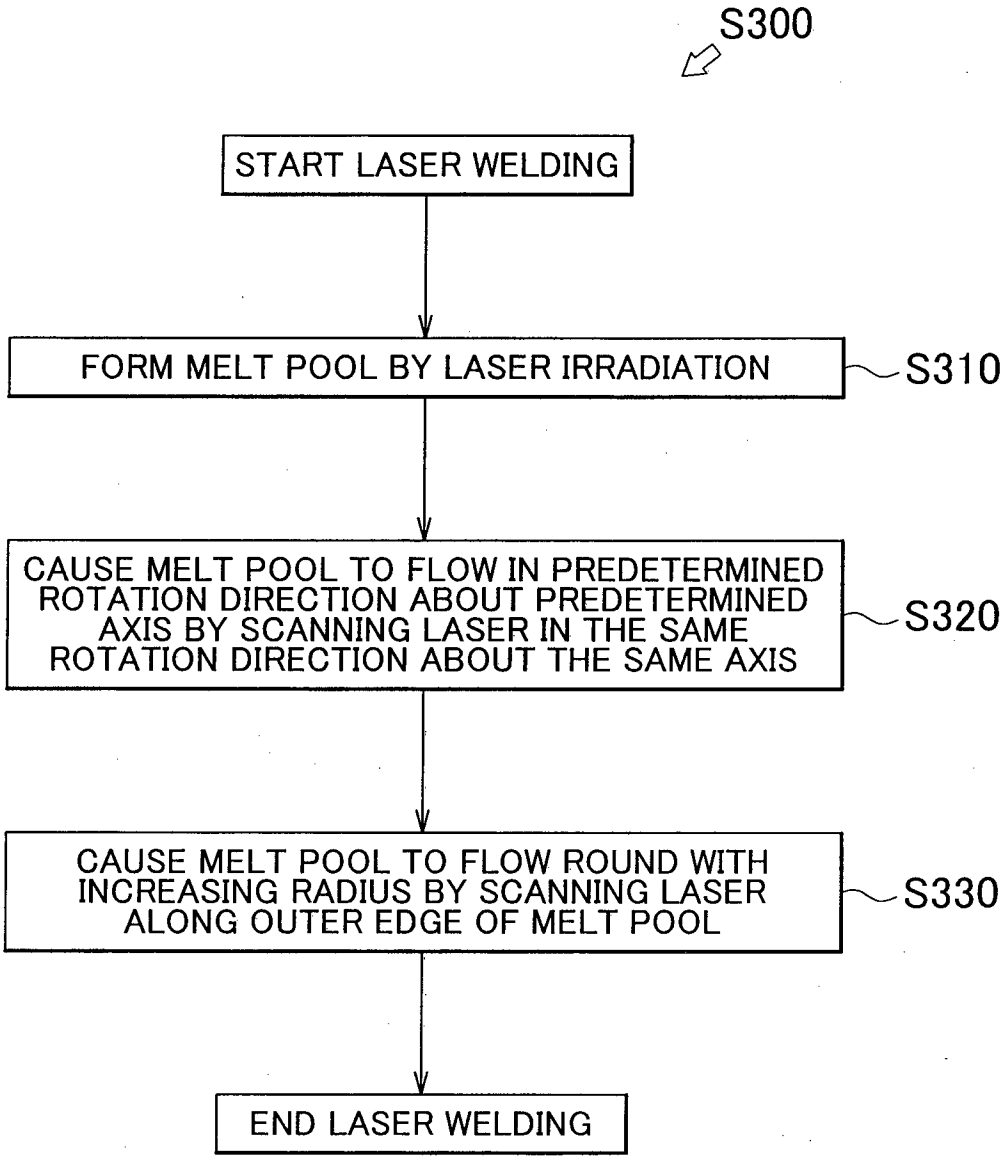

S300
START LASER WELDING
FORM MELT POOL BY LASER IRRADIATION
S310
CAUSE MELT POOL TO FLOW IN PREDETERMINED ROTATION DIRECTION ABOUT PREDETERMINED AXIS BY SCANNING LASER IN THE SAME ROTATION DIRECTION ABOUT THE SAME AXIS
S320
CAUSE MELT POOL TO FLOW ROUND WITH INCREASING RADIUS BY SCANNING LASER ALONG OUTER EDGE OF MELT POOL
S330
END LASER WELDING

FIG. 7A

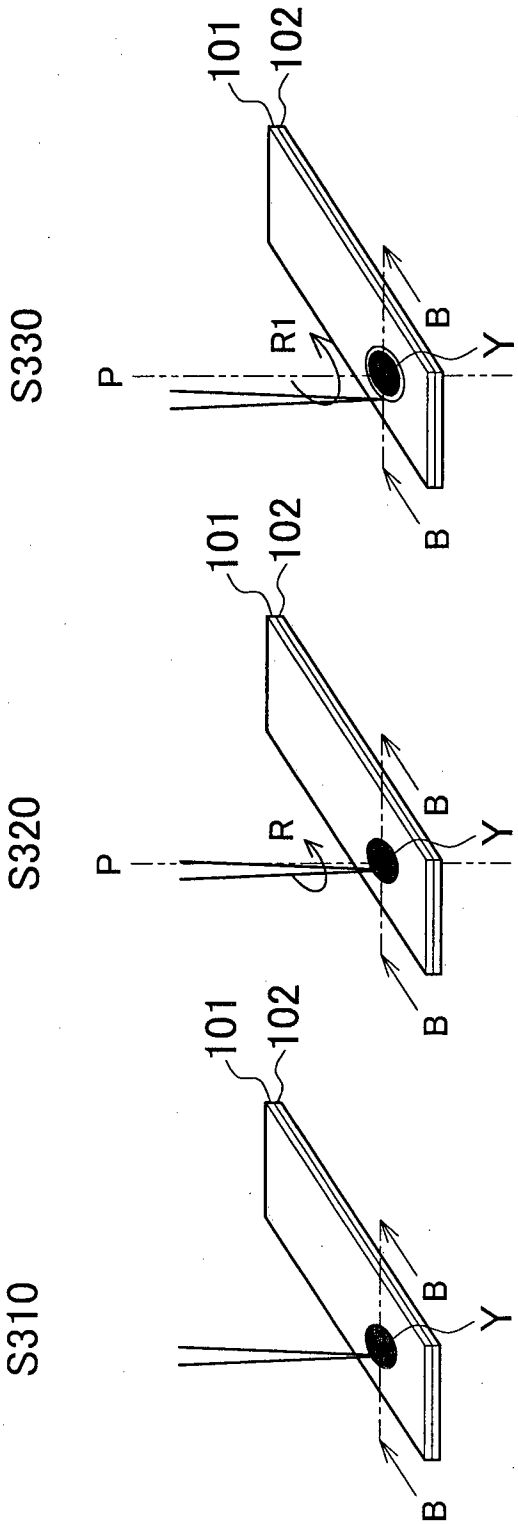


FIG. 7B

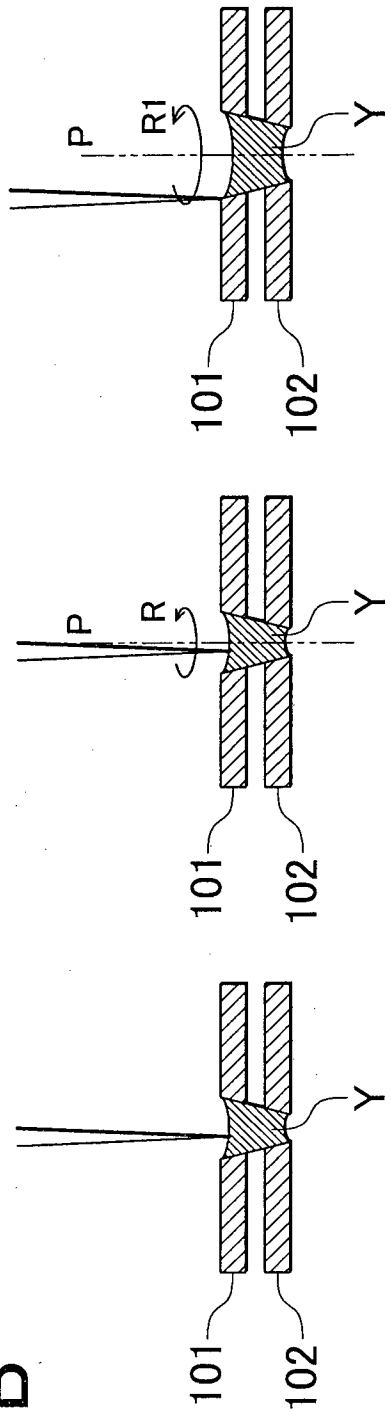


FIG. 8

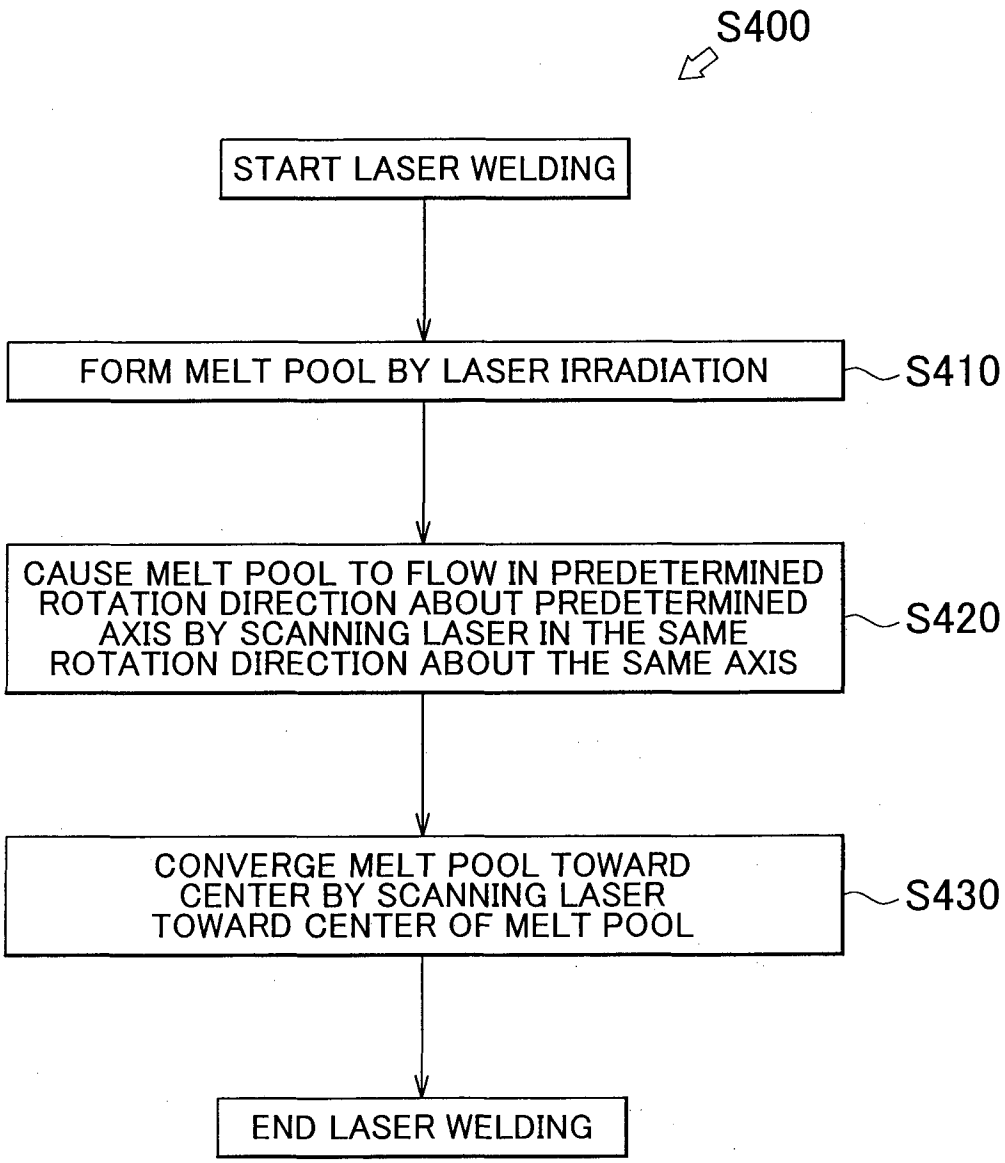

S400
START LASER WELDING
FORM MELT POOL BY LASER IRRADIATION
S410
CAUSE MELT POOL TO FLOW IN PREDETERMINED ROTATION DIRECTION ABOUT PREDETERMINED AXIS BY SCANNING LASER IN THE SAME ROTATION DIRECTION ABOUT THE SAME AXIS
S420
CONVERGE MELT POOL TOWARD CENTER BY SCANNING LASER TOWARD CENTER OF MELT POOL
S430
END LASER WELDING

FIG. 9A

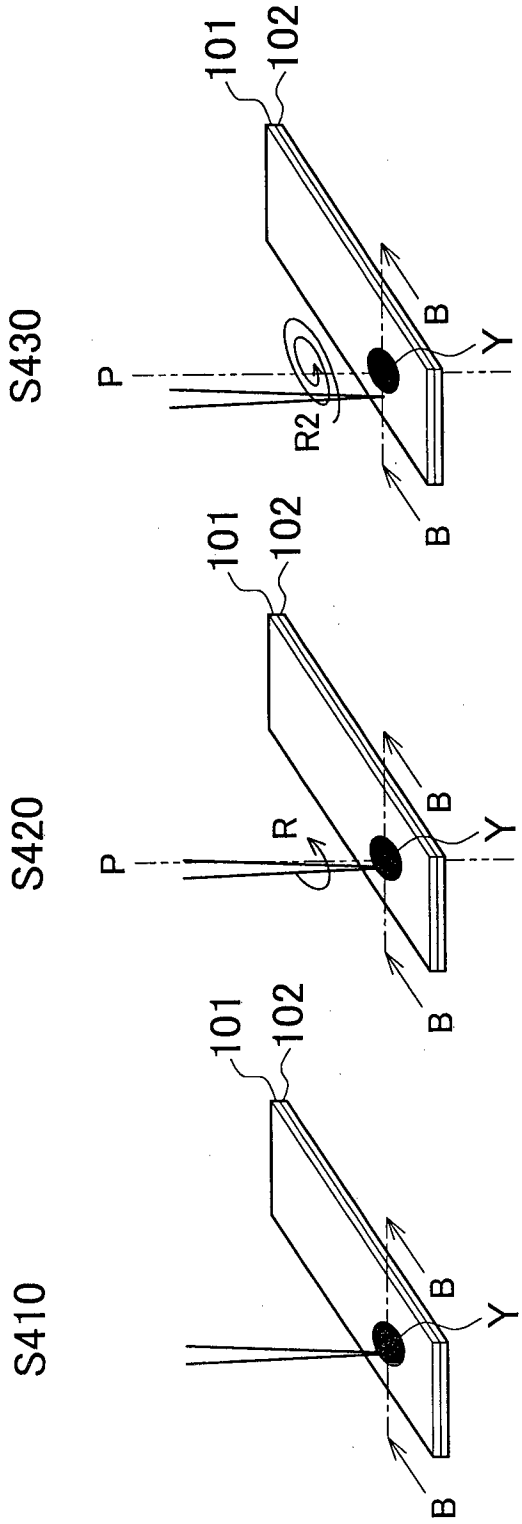
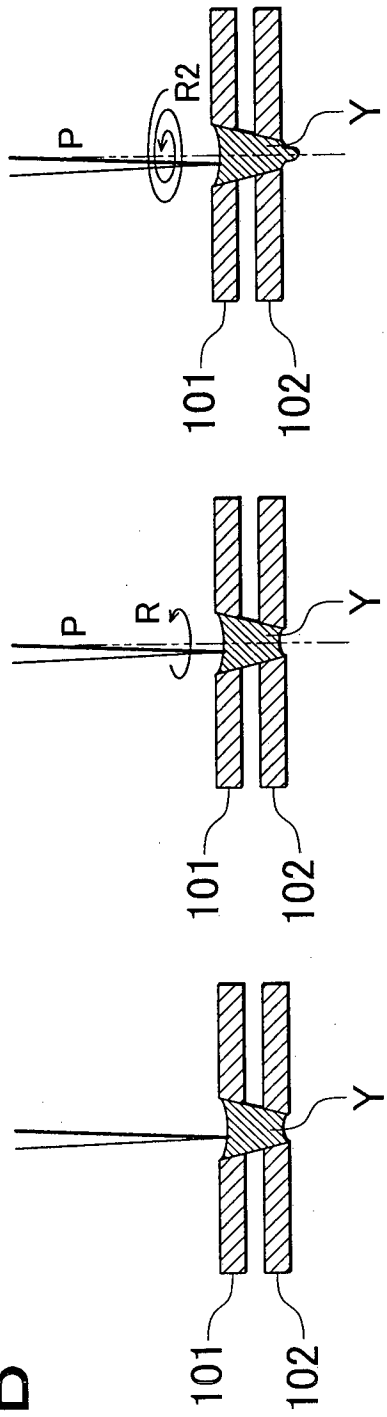


FIG. 9B



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/000785

A. CLASSIFICATION OF SUBJECT MATTER
INV. B23K26/08 B23K26/24
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B23K

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2006/116722 A2 (PENNSYLVANIA STATE RES FOUNDAT [US]; MARKTUKANITZ RICHARD P [US]; TRES) 2 November 2006 (2006-11-02)	1,4,5,7, 10,11
Y	page 6, line 5 - line 13; claim 18; figures 1,5 page 10, line 14 - line 19 page 12, line 3 - line 7	2,8
X	WO 2009/021716 A1 (FRAUNHOFER GES FORSCHUNG [DE]; SCHULZ WOLFGANG [DE]; OLOWINSKY ALEXAND) 19 February 2009 (2009-02-19) page 12, line 12 - line 14; claims 1, 31, 32; figures 1,2 page 14, line 5 - line 6	3-7,9-12

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
25 July 2012	07/08/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Möller, Sebastian

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/000785

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP 0 131 487 A1 (SCIAKY SA [FR]) 16 January 1985 (1985-01-16) abstract; figure 2 -----	1
A	WO 2005/009667 A1 (KUKA SCHWEISSANLAGEN GMBH [DE]; RIPPL PETER [DE]) 3 February 2005 (2005-02-03) claims 1, 3; figures 2,3,6 -----	1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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