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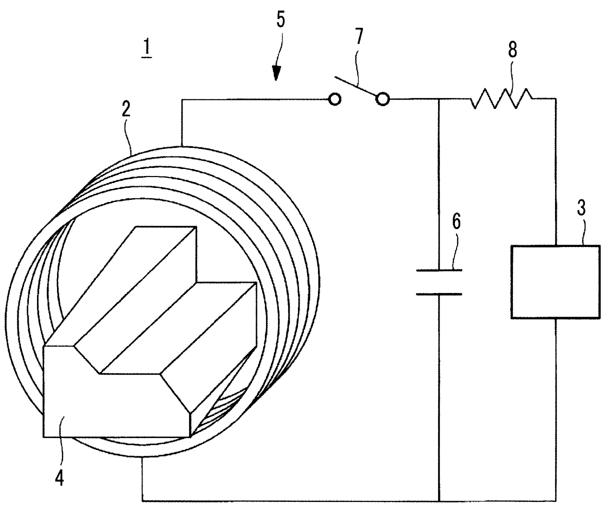
(54) ELECTROMAGNETIC FORMING DEVICE

(57) The purpose of the present invention is to enable accurate formation of an elongate member while suppressing the occurrence of a shape defect. An electromagnetic forming device (1) is provided with an electromagnetic coil (2), and a forming mold (4) which is disposed along the electromagnetic coil (2) and provides an elongate material to be formed with a formed shape, wherein an electromagnetic force generated by means of the electromagnetic coil (2) is caused to act on the material to be formed and the material to be formed is pressed onto the forming mold (4). In the electromagnetic forming device (1), the forming mold (4) has a cross sectional shape that varies from one end to another in a longitudinal direction of the material to be formed. The forming mold (4) is formed such that, as the material to be formed is moved parallel to the longitudinal direction, the shape of the material to be formed is gradually changed to a desired shape.

FIG. 1



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Description

Technical Field

[0001] The present invention relates to an electromagnetic forming device.

Background Art

[0002] For example, aircraft components such as a fuselage and a main wing of an aircraft are configured so that structural members such as plate-shaped skins, elongated frames, and stringers are combined with each other. The elongated structural member (elongated member) is a mold material, and has a cross-sectional shape whose cross section has a Z-shape, for example. As illustrated in Fig. 16B, the elongated member includes those which have a plurality of steps (joggles) in which a plate thickness is changed at each site along a longitudinal direction. An elongated member 60 illustrated in Fig. 16B has a thick plate portion 61 and a thin plate portion 62.

[0003] In a case of manufacturing the elongated member having a cross-sectional shape bent in the Z-shape, as illustrated in Fig. 16A, roll forming is performed on an elongated material 50 having a flat plate shape which is not bent. In a roll forming device which performs the roll forming, multiple sets of two rolls interposing the elongated member therebetween are installed along a line. The elongated material is caused to sequentially pass from one end side to the other end side of the line in which the multiple sets of rolls are installed. In this manner, the elongated material is gradually formed from a cross-sectional shape having the flat plate shape to a cross-sectional shape required as a product. In this way, the elongated material is gradually formed using the multiple sets of rolls. Accordingly, it is possible to prevent defect occurrence such as cracks caused by a rapid change in the cross-sectional shape.

Citation List

Patent Literature

[0004]

[PTL 1] Japanese Unexamined Patent Application Publication No. 2007-296553

[PTL 2] Japanese Unexamined Patent Application Publication No. 6-23442

Summary of Invention

Technical Problem

[0005] However, in a case where the elongated material is formed by performing the above-described roll forming, distortion and residual stress occur in the formed elongated member due to wear of a roll or a subtle change in a pressure mechanism which applies pressure to the roll. Consequently, shape defects such as twisting, warping (horizontal warping or vertical warping), and waving occur. In addition, depending on a degree of the wear or the change in the applied pressure, the distortion or the residual stress occurring in each material may differ, thereby causing a possibility that the shape may be changed in various ways including the twisting, the warping, or the waving.

[0006] Furthermore, in a case where the cross-sectional shape to be obtained after forming is changed, the roll forming device needs to replace the roll in accordance with the shape. In an initial stage after the replacement, the above-described shape defect is likely to occur. It is necessary to adjust the role or the pressure mechanism.

[0007] Furthermore, in a case of the elongated member in which the plurality of steps are formed in the longitudinal direction, a pressing way of the roll differs between the thick plate portion and the thin plate portion. Therefore, in some cases, a bending angle may not be a predetermined angle in each site. In addition, in the roll forming, the elongated member passes through the two rolls arranged up and down. Accordingly, as illustrated in Fig. 17A, one surface side is less likely to serve as a step surface, and the other surface side is less likely to serve as a flat surface. As illustrated in Fig. 17B, the step surface is also formed on the other surface side. As a result, when the elongated member having the plurality of steps are combined with the other member so as to be assembled together as an aircraft component, a gap is generated between the elongated member and the other member.

[0008] On the other hand, a technology is known in which a forming target material is formed using an electromagnetic forming device instead of the roll forming device. However, no technology is known in which forming an elongated material is formed so as to have a cross-sectional shape bent in the Z-shape or the forming is performed on the elongated member having the plurality of steps. PTL 1 described above discloses a technology in which a thin plate is formed into a desired shape by using the electromagnetic forming device. PTL 2 discloses a technology in which an electromagnetic force is applied in a multistage manner to a predetermined portion of a hollow material by using an electromagnetic plastic processing method.

[0009] The present invention is made in view of the above-described circumstances, and an object thereof is to provide an electromagnetic forming device which can perform highly accurate forming by preventing a shape defect in forming an elongated member.

Solution to Problem

[0010] According to an aspect of the present invention, there is provided an electromagnetic forming device including an electromagnetic coil, and a forming die installed along the electromagnetic coil so as to provide a formed shape for a forming target material having an elongated shape. An electromagnetic force generated by the electromagnetic coil is applied to the forming target material so that the forming target material is pressed against the forming die. The forming die has a cross-sectional shape which differs from one end side thereof toward the other end side thereof along a longitudinal direction of the forming target material. In the forming die, the forming target material moves parallel to the longitudinal direction so that the forming target material is gradually formed and changed to have a desired shape.

[0011] According to this configuration, the electromagnetic force generated by performing the electromagnetic coil is applied to the forming target material having the elongated shape, and the forming die provides the formed shape for the forming target material. The forming die has the cross-sectional shape which differs from one end side to the other end side along the longitudinal direction of the forming target material. The forming target material moves parallel to the longitudinal direction so that the forming target material is gradually formed and changed to have the desired shape. In this manner, the forming target material is moved parallel to the longitudinal direction so that the electromagnetic force is repeatedly applied to the forming target material. Accordingly, the forming target material deformed by being pressed against the forming die is gradually changed to have the desired shape.

[0012] In the above-described aspect, the electromagnetic coil may be continuously formed along the forming die.

[0013] In the above-described aspect, the electromagnetic coils may be respectively installed at a plurality of locations. The plurality of electromagnetic coils may be respectively shorter than the forming target material, and may be installed along the longitudinal direction of the forming target material.

[0014] In the above-described aspect, a plurality of the forming dies may be installed. The plurality of forming dies may be respectively shorter than the forming target material, and may be installed along the longitudinal direction of the forming target material.

[0015] In the above-described aspect, the plurality of forming dies may have an inclined surface formed in an end portion.

[0016] In the above-described aspect, the plurality of forming dies may be formed so that the forming target material is provided with a recessed shape or a projecting shape in the longitudinal direction.

Advantageous Effects of Invention

[0017] According to the present invention, highly accurate forming can be performed by preventing a shape defect in forming an elongated member.

Brief Description of Drawings

[0018]

Fig. 1 is a schematic configuration diagram illustrating an electromagnetic forming device according to a first embodiment of the present invention.

Fig. 2 is a schematic configuration illustrating a modification example of an electromagnetic coil of the electromagnetic forming device according to the first embodiment of the present invention.

Fig. 3 is a perspective view illustrating a forming die of the electromagnetic forming device according to the first embodiment of the present invention.

Fig. 4 is a plan view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention.

Fig. 5 is a front view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention.

Fig. 6 is a front view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention.

Fig. 7 is a front view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention.

Fig. 8 is a plan view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention.

Fig. 9 is a front view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention.

Fig. 10 is a longitudinal sectional view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention, and is a view taken along arrow X-X in Fig. 6.

Fig. 11 is a longitudinal sectional view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention, and is a view taken along arrow XI-XI in Fig. 8.

Fig. 12 is a longitudinal sectional view illustrating the forming die of the electromagnetic forming device according to the first embodiment of the present invention, and is a view taken along arrow XII-XII in Fig. 8.

Fig. 13 is a perspective view illustrating a forming die of an electromagnetic forming device according to a second embodiment of the present invention.

Fig. 14 is a plan view illustrating the forming die of the electromagnetic forming device according to the second embodiment of the present invention.

Fig. 15 is a front view illustrating the forming die of the electromagnetic forming device according to the second embodiment of the present invention.

Fig. 16A is a perspective view illustrating an elongated material.

Fig. 16B is a perspective view illustrating the elongated material.

Fig. 17A is a perspective view and a partial side view illustrating the elongated member.

Fig. 17B is a perspective view and a partial side view illustrating the elongated member.

Description of Embodiments

[0019] Hereinafter, embodiments according to the present invention will be described with reference to the drawings.

[First Embodiment]

[0020] Hereinafter, a first embodiment according to the present invention will be described with reference to Figs. 1 to 12. As illustrated in Fig. 16A, an electromagnetic forming device 1 according to the present embodiment uses a forming die 4 so as to provide a cross-sectional shape, for example, a Z-shape, for an elongated material 50 serving as a forming target material made of an aluminum alloy, for example. As illustrated in Fig. 16B, an elongated member 60 formed by performing the electromagnetic forming device 1 is used as a structural member such as a frame and a stringer which configure aircraft components such as a fuselage and a main wing of an aircraft.

[0021] As illustrated in Fig. 1, the electromagnetic forming device 1 according to the present embodiment has an electromagnetic coil 2, a power supply unit 3 for supplying an electric current to the electromagnetic coil 2, and the forming die 4.

[0022] The electromagnetic coil 2 is continuously formed along the forming die 4. For example, as illustrated in Fig. 1, the electromagnetic coil 2 may have a cylindrical shape, and a cross-sectional shape thereof may be circular. As illustrated in Fig. 2, the electromagnetic coil 2 may be located along a surface of the forming die 4.

[0023] A large current is supplied to the electromagnetic coil 2 from the power supply unit 3. A power supply circuit 5 is configured to include a circuit as follows. For example, as illustrated in Fig. 1, a capacitor 6 is installed in parallel with the electromagnetic coil 2. A switch 7 is installed between a connection point of the power supply unit 3 and the capacitor 6 and the electromagnetic coil 2. In this configuration, when the switch 7 is turned on, the capacitor 6 is electrically charged from the power supply unit 3 via an electric resistance 8. Then, the switch 7 is turned off, and the capacitor 6 is electrically discharged, thereby generating the large current to the electromagnetic coil 2.

[0024] The large current is instantaneously applied to the electromagnetic coil 2, thereby generating an induced current on a surface of the elongated material 50 located along the electromagnetic coil 2. As a result, an electromagnetic force is applied to the surface of the elongated material 50, and the elongated material 50 moves in a direction of the forming die 4 so as to be pressed against the forming die 4.

[0025] The forming die 4 is installed along the longitudinal direction of the elongated material serving as the forming target material. The forming die 4 provides the formed shape for the elongated material. In order to prevent defect occurrence such as cracks caused by a rapid change in the cross-sectional shape, as illustrated in Figs. 3 to 5, the forming die 4 has a cross-sectional shape which differs from one end 4a side toward the other end 4b side along the longitudinal direction of the elongated material 50. That is, as illustrated in Figs. 4 to 9, the elongated material 50 moves parallel to the longitudinal direction. In this manner, the elongated material 50 is formed so as to be gradually changed to the desired shape.

[0026] For example, the electromagnetic coil 2 and the forming die 4 have substantially the same length as the elongated material 50. Without being limited to a case where only one electromagnetic coil 2 is continuously formed in the longitudinal direction, the electromagnetic coil 2 may be divided into a plurality of pieces in the longitudinal direction. In this case, the plurality of electromagnetic coils 2 are disposed to be separate from each another.

[0027] A forming method of the formed elongated member 60 (refer to Fig. 16B) will be described with reference to Figs. 3 and 10 to 12. The elongated member 60 has horizontal flange portions 63 and 64, and a web portion 65 which forms an angle of 90° with the flange portions 63 and 64. As illustrated in Fig. 3, a forming surface 9a on one end 4a side in the forming die 4 has a horizontal flat surface shape. Then, a forming surface 9b for forming the web portion 65 on the forming surface 9 of the forming die 4 has the same width from one end 4a side to the other end 4b side, and an inclination angle thereof is constant while a horizontal state is maintained. Forming surfaces 9c and 9d for forming the flange portions 63 and 64 have the same width from one end 4a side to the other end 4b side, and an inclination angle thereof is gradually inclined from the horizontal state to a vertical state.

[0028] In an electromagnetic forming method using the electromagnetic forming device 1 according to the present embodiment, first, as illustrated in Figs. 4 and 5, only one end 50a side of the flat plate-shaped elongated material 50 is one end 4a of the forming die 4 is installed on one end 4a side of the forming die 4. Then, the current is supplied to the electromagnetic coil 2, and the elongated material 50 is pressed against the forming die 4. As a result, as illustrated in Figs. 4 and 5, one end 50a of the elongated material 50 is formed along the forming die 4.

[0029] Thereafter, as illustrated in Figs. 6 and 7, the elongated material 50 is shifted to the other end side as much as a predetermined distance along the longitudinal direction. Then, the current is supplied to the electromagnetic coil 2, and the elongated material 50 is pressed against the forming die 4. As a result, the elongated material 50 is shifted in the longitudinal direction. In this manner, the flat plate-shaped elongated material 50 falling within a range of the electromagnetic coil 2, and one end 50a side of the elongated material 50 previously formed along the forming die 4 are formed along the forming die 4.

[0030] The above-described procedure is repeatedly performed, thereby causing the elongated material 50 to gradually deform into a final shape from the one end 50a side to the other end 50b side. The elongated material 50 passing through the other end 4b side of the forming die 4 has the final shape obtained by performing the electromagnetic forming. Until the other end 50b of the elongated material 50 completely passes therethrough, the forming is repeatedly performed by shifting the position of the elongated material 50 and supplying the current to the electromagnetic coil 2. If the other end 50b of the elongated material 50 completely passes therethrough, the elongated member 60 has the final shape obtained by performing the electromagnetic forming over the entire longitudinal direction of the elongated material 50 (refer to Fig. 16B).

[0031] As described above, according to the electromagnetic forming using the electromagnetic forming device 1 of the present embodiment, a mold is less worn compared to the roll forming, and a compression mechanism such as the roll forming device is not provided. Accordingly, during the forming, there is no subtle change in the compression mechanism. Therefore, the shape defect is less likely to occur in the elongated member 60 formed by performing the electromagnetic forming. In addition, the forming die 4 has a continuous shape in the longitudinal direction. Accordingly, a setup time for roll clearance adjustment in the roll forming device can be reduced.

[0032] Furthermore, the forming is performed at high speed by utilizing the electromagnetic force. Accordingly, a spring-back volume can be reduced, the forming can be highly accurately performed, and work for correcting distortion after the forming can be reduced.

[Second Embodiment]

[0033] Next, a second embodiment according to the present invention will be described with reference to Figs. 13 to 15. In the above-described first embodiment, a case of using the forming die 4 having the continuous shape in the longitudinal direction has been described. However, the present invention is not limited to this example.

[0034] The forming die 4 according to the second embodiment of the present invention is divided into a plurality of pieces in the longitudinal direction, and split molds 10A, 10B, and 10C are arranged to be separate from each other. In this manner, cost can be reduced, compared to a case of using the forming die 4 having the continuous shape in the longitudinal direction.

[0035] The electromagnetic coil 2 is divided into each position corresponding to the respective split molds 10A, 10B, and 10C, and the respective split molds 10A, 10B, and 10C are installed to be separate from each other. The forming die 4 and the electromagnetic coil 2 are divided into three in an example illustrated in Fig. 13, but may be divided into two, and four or more.

[0036] A forming surface 11 of the split molds 10A, 10B, and 10C has a forming surface 11a for forming the web portion 65, a forming surface 11b for forming the flange portion 63, and a forming surface 11c for forming the flange portion 64. In the respective split molds 10A, 10B, and 10C, the forming surfaces 11a, 11b, and 11c have the same width from one end side to the other end side. The present invention is not limited to this example. As in the first embodiment, the forming surfaces 11b and 11c may be gradually inclined from one end side to the other end side, and the inclination angle may be gradually inclined from the horizontal side to the vertical side.

[0037] An end portion of the forming surface 11a for forming the web portion 65 in the respective split molds 10A, 10B, and 10C may have a tapered surface 11d inclined toward the adjacent split molds 10A, 10B, and 10C. In this manner, the elongated material 50 can be smoothly moved without the elongated material 50 being caught thereon.

[0038] According to the present embodiment, as in the first embodiment, the following procedure is also repeated performed. The current is supplied to the electromagnetic coil 2 so that the elongated material 50 is pressed against the forming die 4. Thereafter, the elongated material 50 is shifted to the other end side as much as the predetermined distance along the longitudinal direction. Figs. 14 and 15 illustrate an example of a positional relationship between the elongated material 50 and the split molds 10A, 10B, and 10C during the forming.
Then, the elongated material 50 is caused to gradually deform into the final shape from the one end 50a side to the other end 50b side.

[0039] The elongated material 50 formed according to the present embodiment may have a uniform thickness in the longitudinal direction. Alternatively, as illustrated in Fig. 16A, the elongated material 50 may have a plurality of steps (joggles) in which the plate thickness is changed at each site along the longitudinal direction. In this case, when the elongated material 50 is formed by performing the electromagnetic forming, the forming surfaces 11a, 11b, and 11c of the respective split molds 10A, 10B, and 10C may have a recessed shape or a projecting shape corresponding to each shape of the plurality of steps so that the plurality of steps are formed in the longitudinal direction. In this manner, the electromagnetic forming device 1 not only provides the cross-sectional shape of the Z-shape, but also simultaneously forms the plurality of steps in the longitudinal direction. Therefore, the forming process can be reduced, and the cost can be reduced.

[0040] In a case of the present embodiment, compared to the first embodiment adopting the forming die 4 having the continuous shape in the longitudinal direction, the cost for manufacturing the forming die 4 can be reduced.

In addition, as in the first embodiment, the mold is less worn compared to the roll forming, and the compression mechanism such as the roll forming device is not provided. Accordingly, during the forming, there is no subtle change in the compression mechanism. Therefore, the shape defect is less likely to occur in the elongated member 60 formed by performing the electromagnetic forming. In addition, the forming is performed at high speed by utilizing the electromagnetic force. Accordingly, a spring-back volume can be reduced, the forming can be highly accurately performed, and work for correcting distortion after the forming can be reduced.

Reference Signs List

[0041]

1: electromagnetic forming device
2: electromagnetic coil
3: power supply unit
4: forming die
5: power supply circuit
6: capacitor
7: switch
8: electric resistance
9: forming surface
9a, 9b, 9c, 9d: forming surface
10A, 10B, 10C: split mold
11: forming surface
11a, 11b, 11c: forming surface
11d: tapered surface
50, 60: elongated material
61: thick plate portion
62: thin plate portion
63, 64: flange portion
65: web portion

Claims

1. An electromagnetic forming device comprising:

an electromagnetic coil; and
a forming die installed along the electromagnetic coil so as to provide a formed shape for a forming target material having an elongated shape,
wherein an electromagnetic force generated by the electromagnetic coil is applied to the forming target material so that the forming target material is pressed against the forming die,
wherein the forming die has a cross-sectional shape which differs from one end side thereof toward the other end side thereof along a longitudinal direction of the forming target material, and
wherein in the forming die, the forming target material moves parallel to the longitudinal direction so that the forming target material is formed to be gradually changed into a desired shape.

2. The electromagnetic forming device according to Claim 1,
wherein the electromagnetic coil is continuously formed along the forming die.

3. The electromagnetic forming device according to Claim 1,
wherein a plurality of the electromagnetic coils are installed, and
wherein the plurality of electromagnetic coils are respectively shorter than the forming target material, and are installed along the longitudinal direction of the forming target material.

4. The electromagnetic forming device according to Claim 1,
wherein a plurality of the forming dies are installed, and
wherein the plurality of forming dies are respectively shorter than the forming target material, and are installed along the longitudinal direction of the forming target material.

5. The electromagnetic forming device according to Claim 4,
wherein the plurality of forming dies have an inclined surface formed in an end portion.

6. The electromagnetic forming device according to Claim 4 or 5,
wherein the plurality of forming dies are formed to give the forming target material a recessed shape or a projecting shape in the longitudinal direction.

FIG. 1

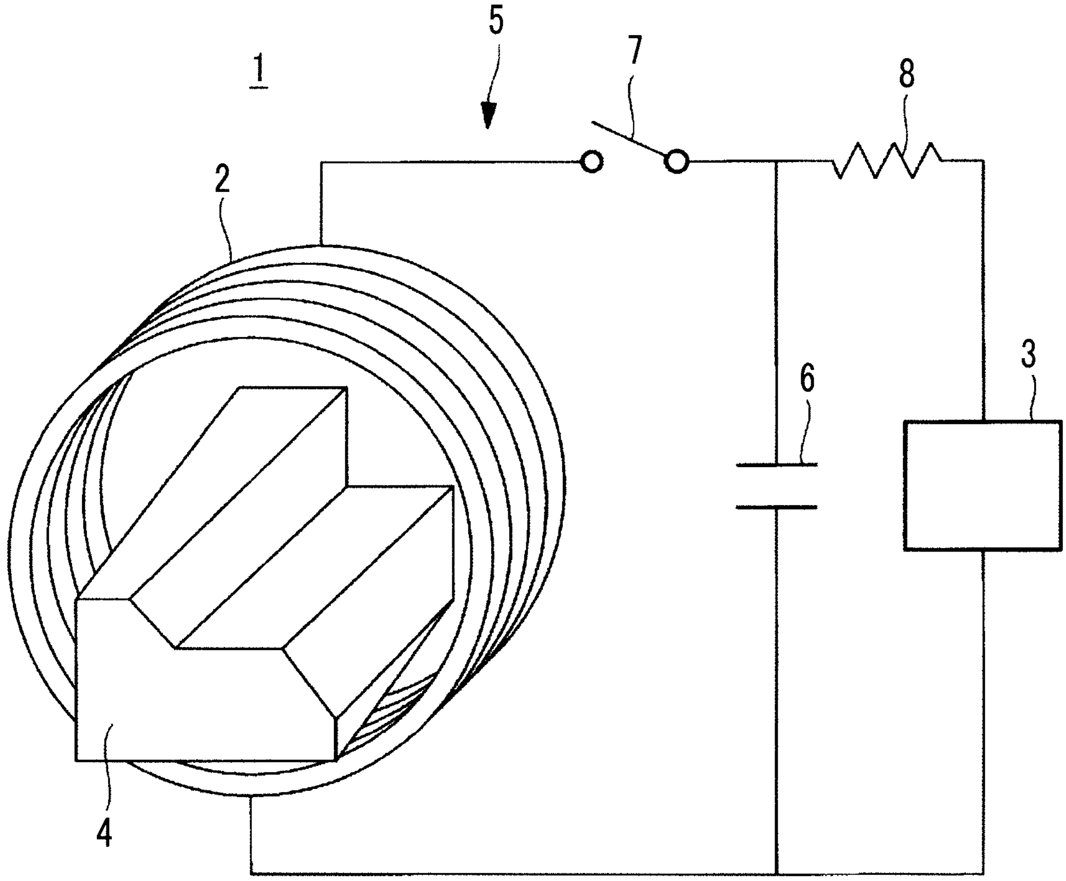


FIG. 2

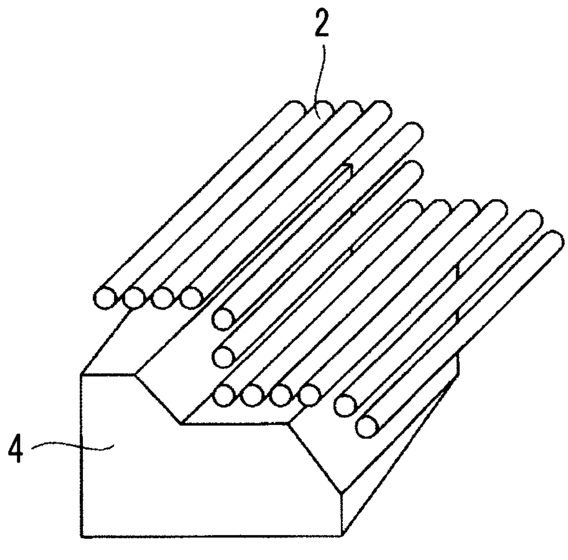


FIG. 3

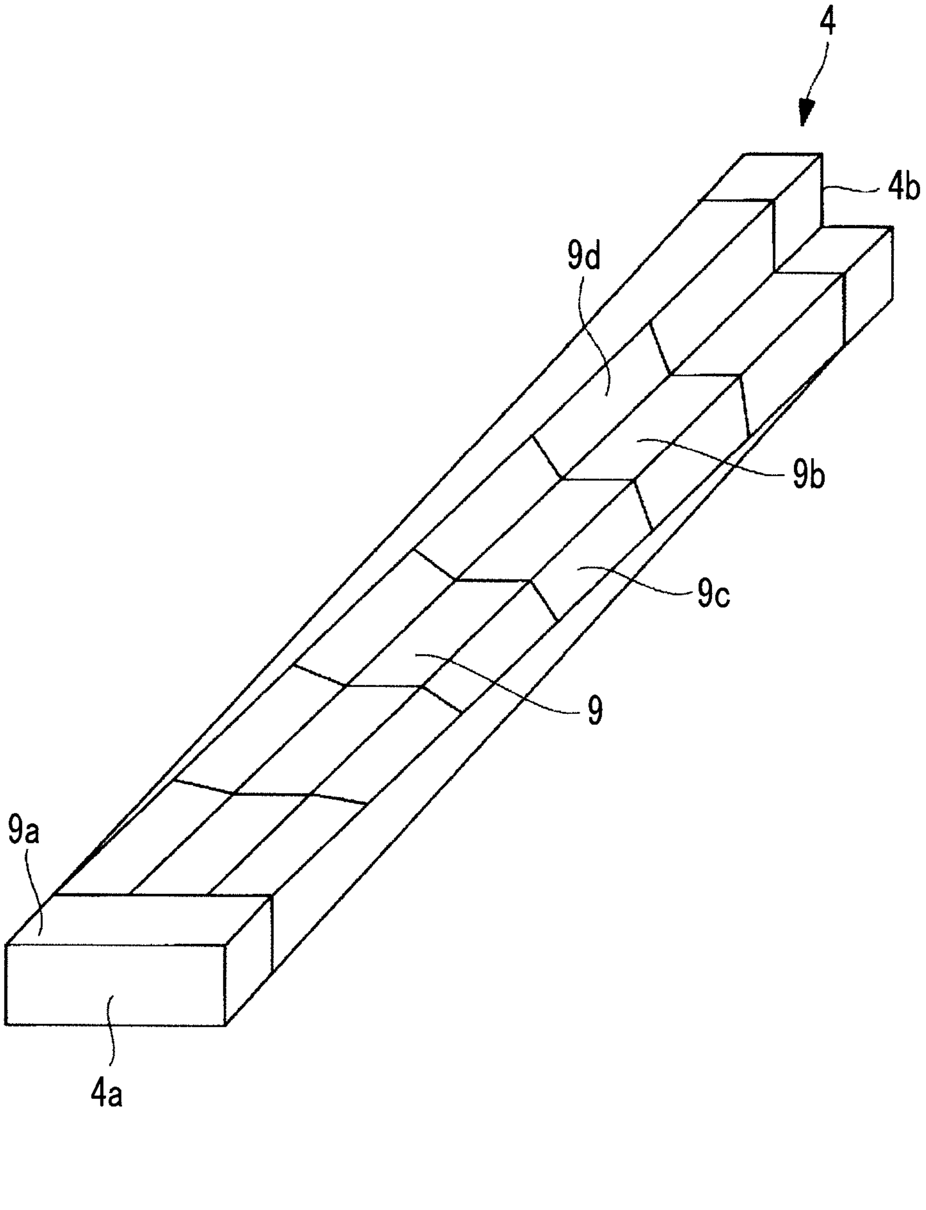


FIG. 4

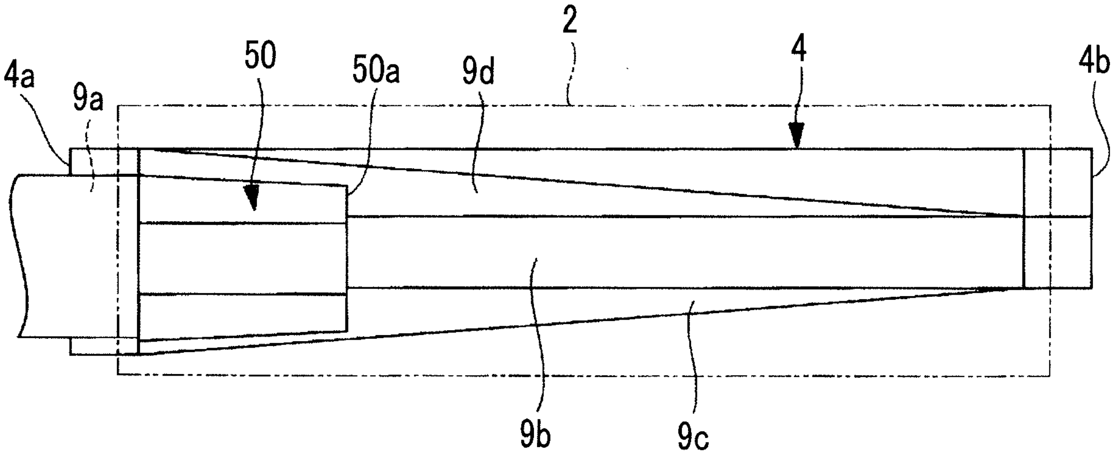


FIG. 5

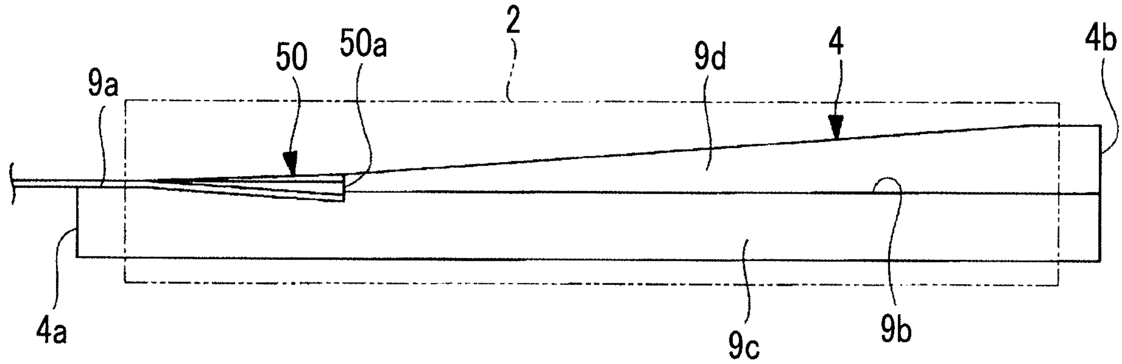


FIG. 6

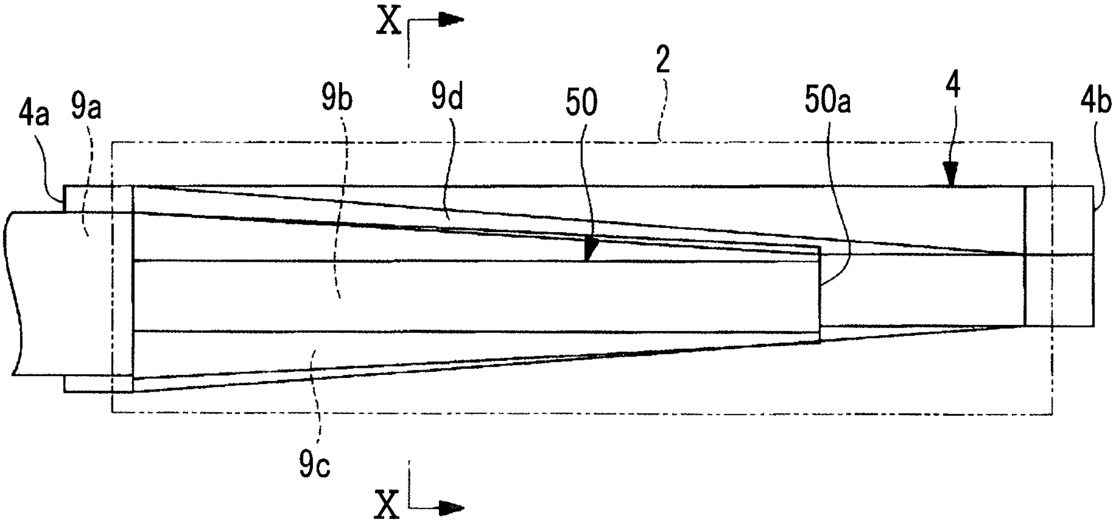


FIG. 7

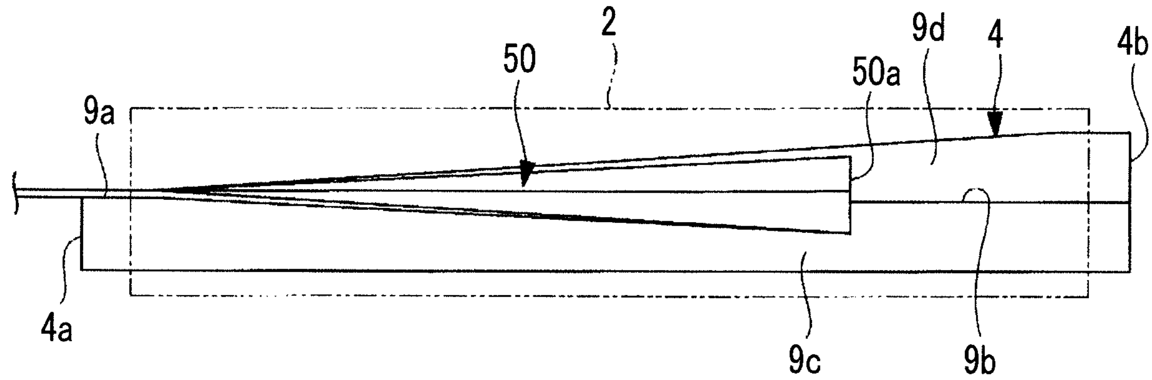


FIG. 8

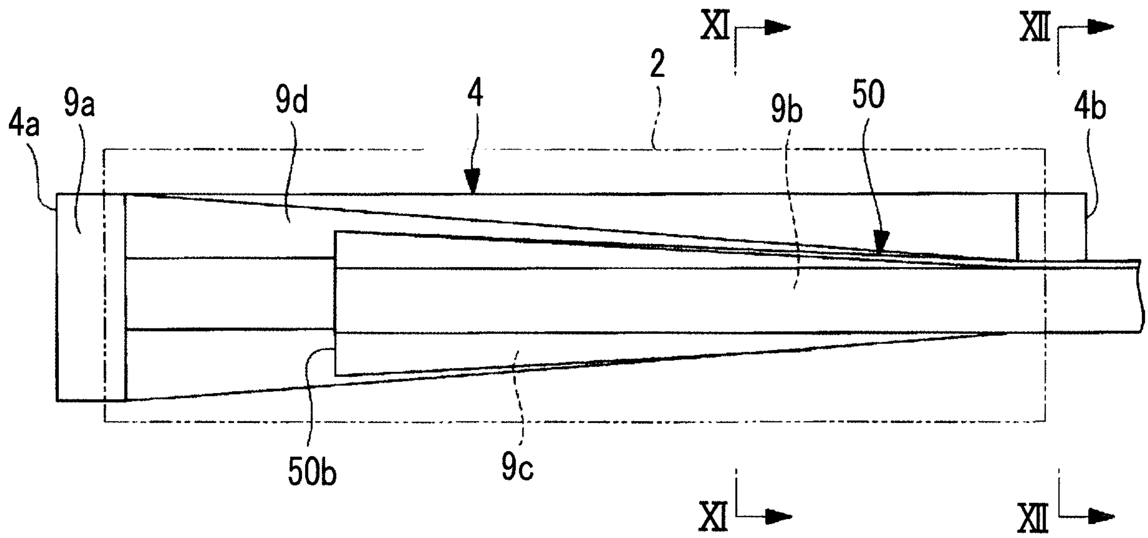


FIG. 9

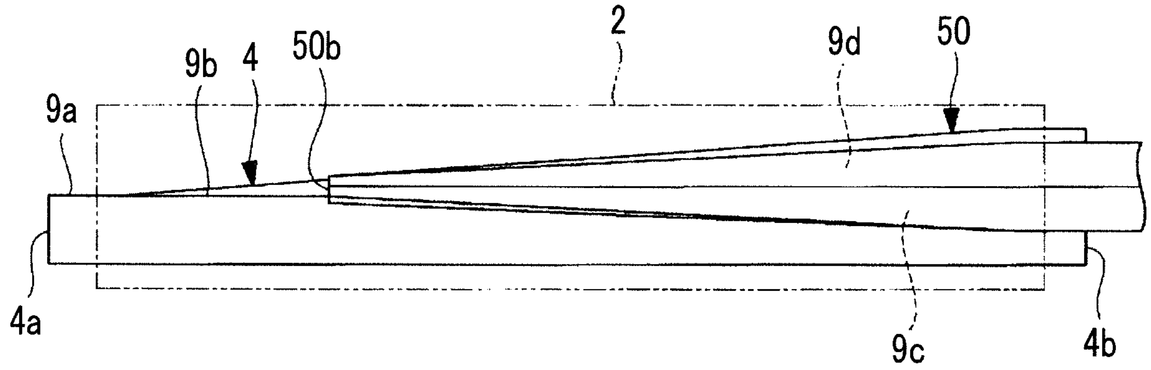


FIG. 10

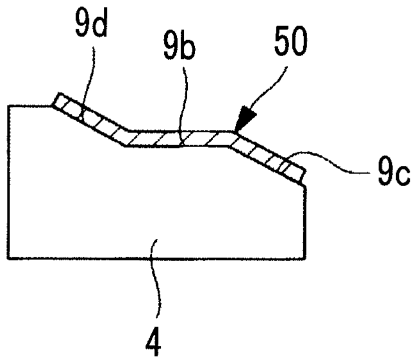


FIG. 11

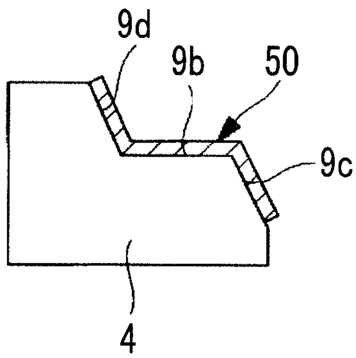


FIG. 12

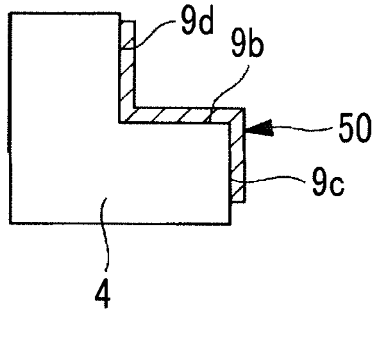


FIG. 13

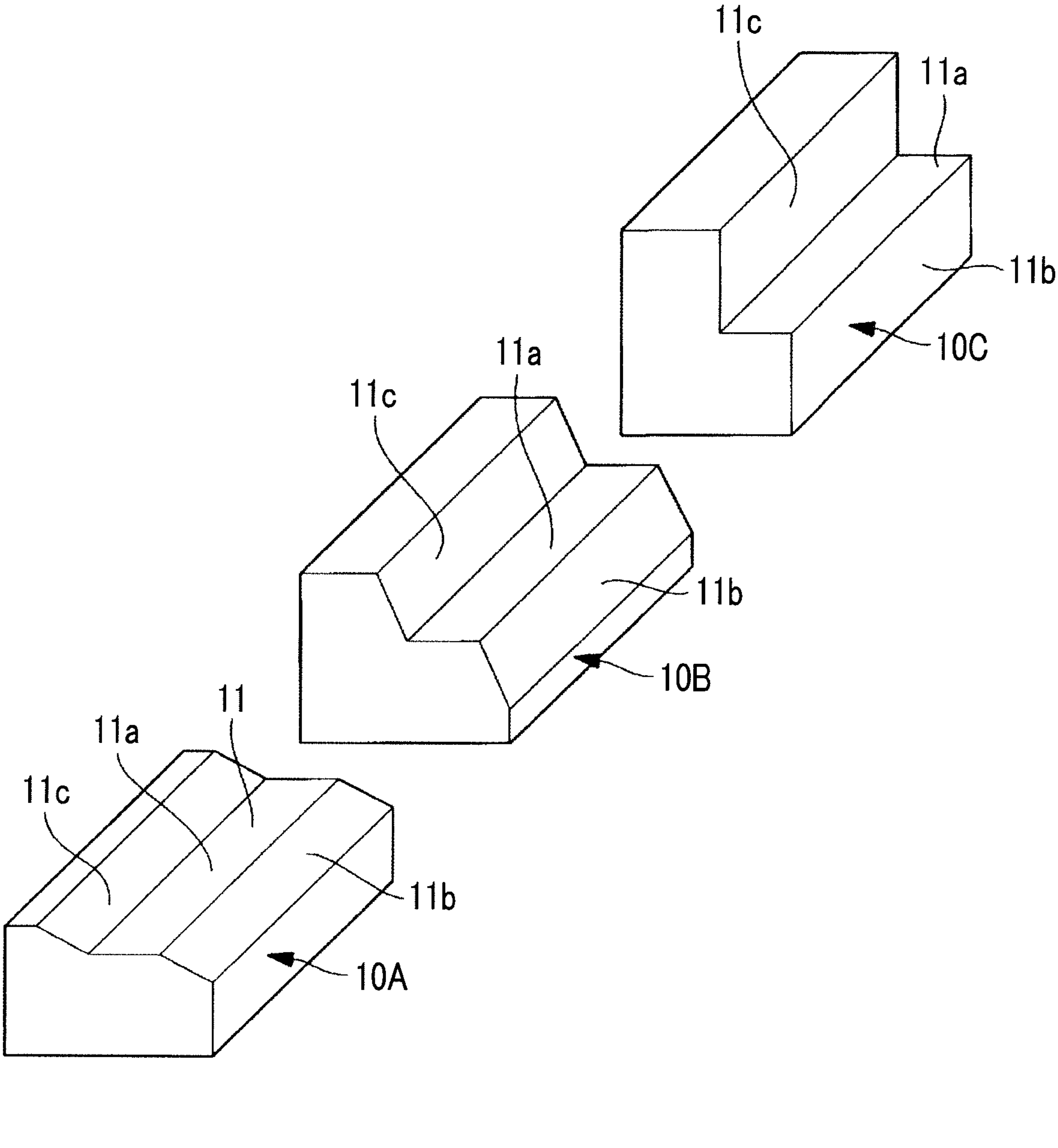


FIG. 14

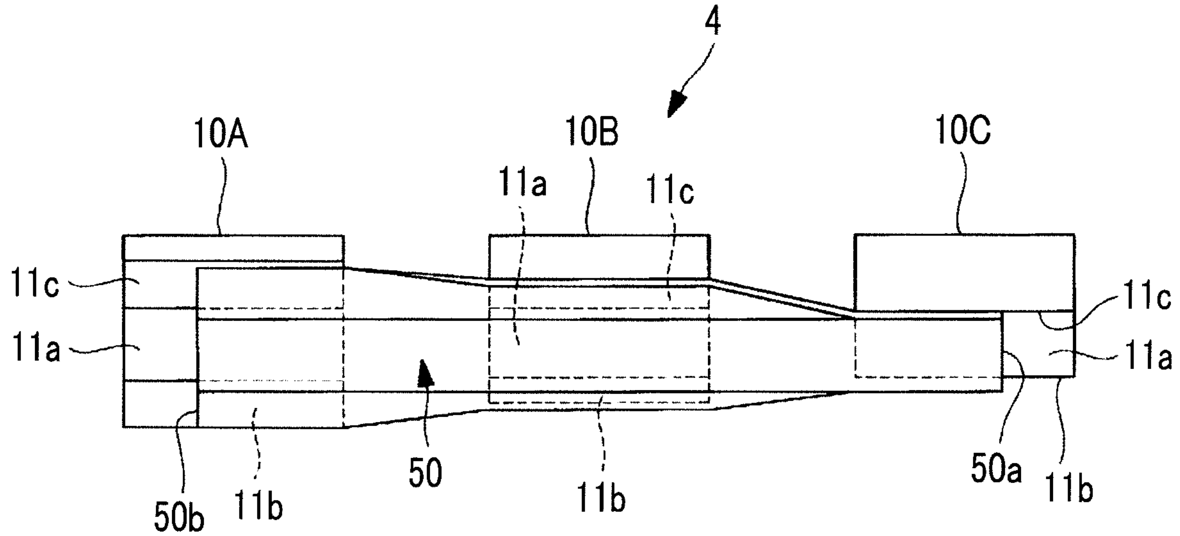
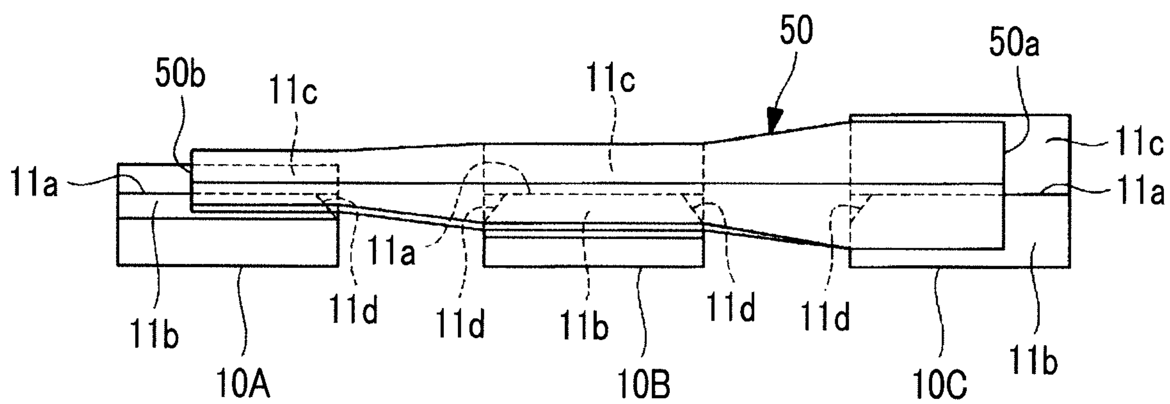

4
10A
10B
10C
11a
11c
11c
11a
11c
11a
50
50b
11b
11b
50a
11b

FIG. 15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10B
10C
11b

FIG. 16A

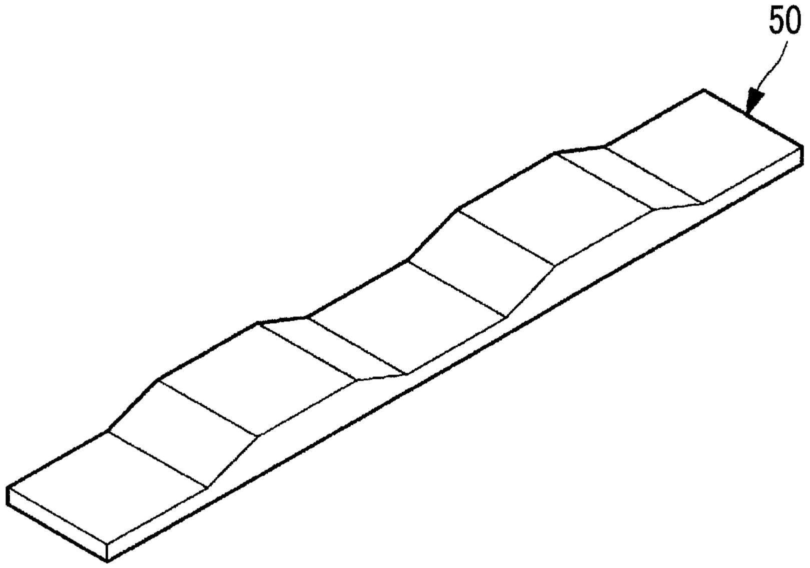


FIG. 16B

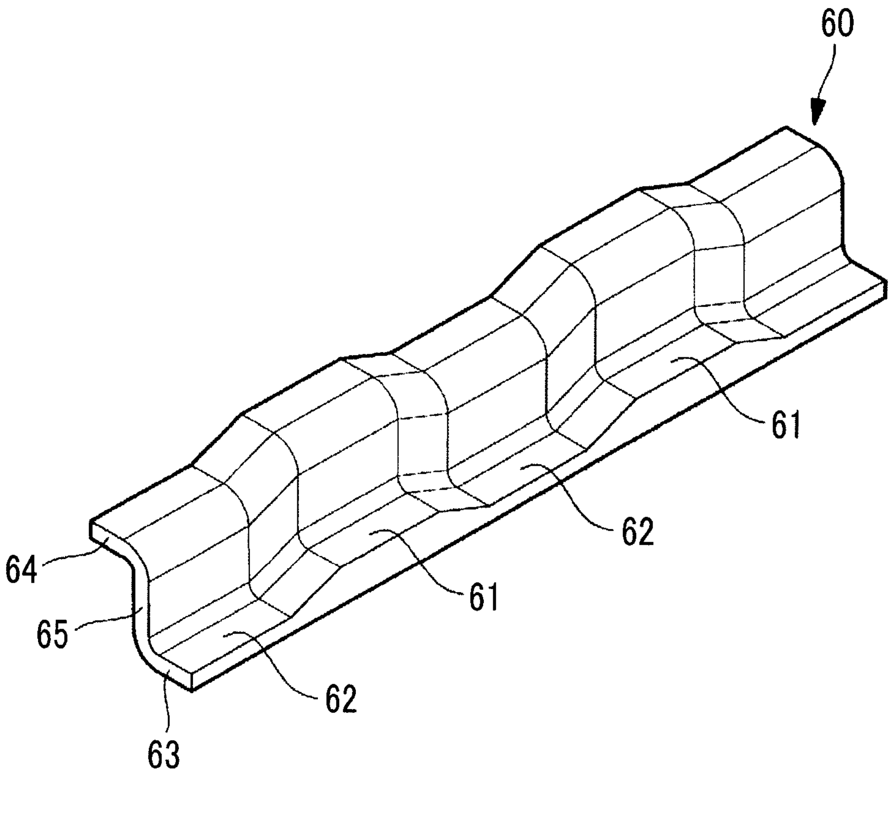


FIG. 17A

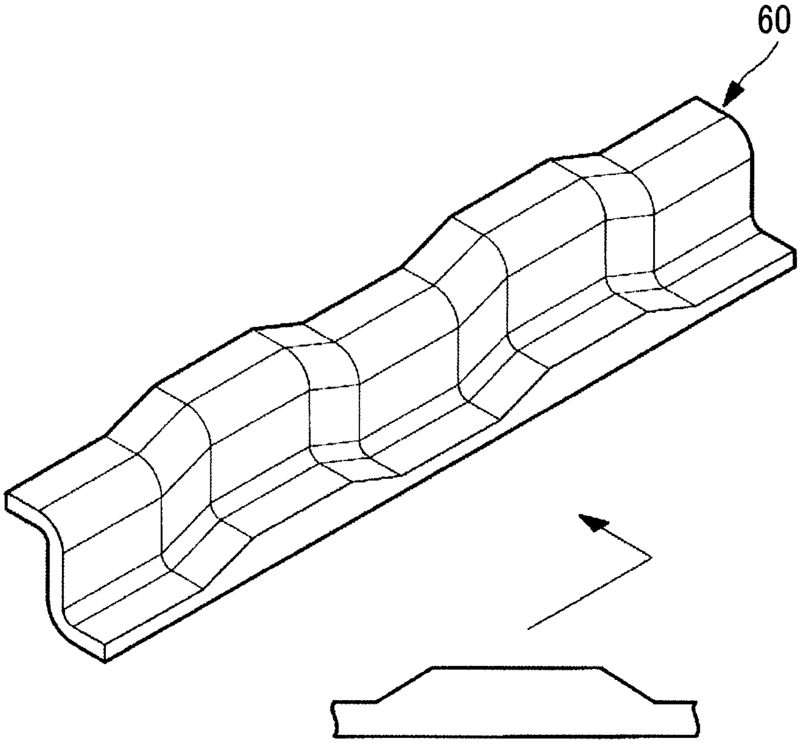
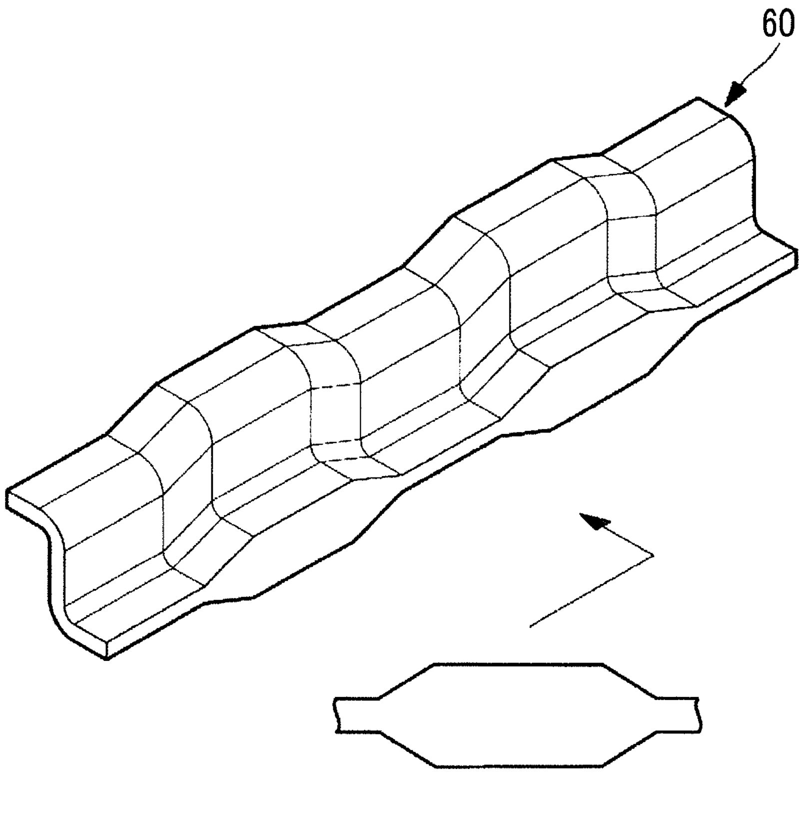


FIG. 17B



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2018/018914

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl. B21D26/14(2006.01)i, B21D53/92(2006.01)n

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)
Int.Cl. B21D26/14, B21D53/92

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

Published examined utility model applications of Japan	1922-1996
Published unexamined utility model applications of Japan	1971-2018
Registered utility model specifications of Japan	1996-2018
Published registered utility model applications of Japan	1994-2018

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	JP 58-6732 A (NIPPON GAKKI CO., LTD.) 14 January 1983, page 2, upper right column, line 10 to page 3, upper left column, line 6, all drawings (Family: none)	1-2 3-6
Y A	JP 2-117723 A (NIPPON STEEL CORPORATION) 02 May 1990, page 3, lower right column, line 2 to page 4, upper left column, line 14, fig. 5 (Family: none)	3-6 1-2
Y A	EP 2415537 A1 (FUNDACION LABEIN) 08 February 2012, paragraphs [0035]-[0047], all drawings & WO 2010/109028 A1	6 1-5

☒ Further documents are listed in the continuation of Box C. ☐ 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
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Date of the actual completion of the international search 14.06.2018	Date of mailing of the international search report 26.06.2018
Name and mailing address of the ISA/ Japan Patent Office 3-4-3, Kasumigaseki, Chiyoda-ku, Tokyo 100-8915, Japan	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2018/018914

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 6-312226 A (SHOWA ALUMINUM CORPORATION) 08 November 1994, paragraphs [0013]-[0035], all drawings (Family: none)	1-6
A	US 2013/0133389 A1 (KOO, D. H.) 30 May 2013, paragraphs [0061]-[0071], fig. 3 & KR 10-1286676 B1 & CN 103128191 A	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2007296553 A **[0004]**
- JP 6023442 A **[0004]**