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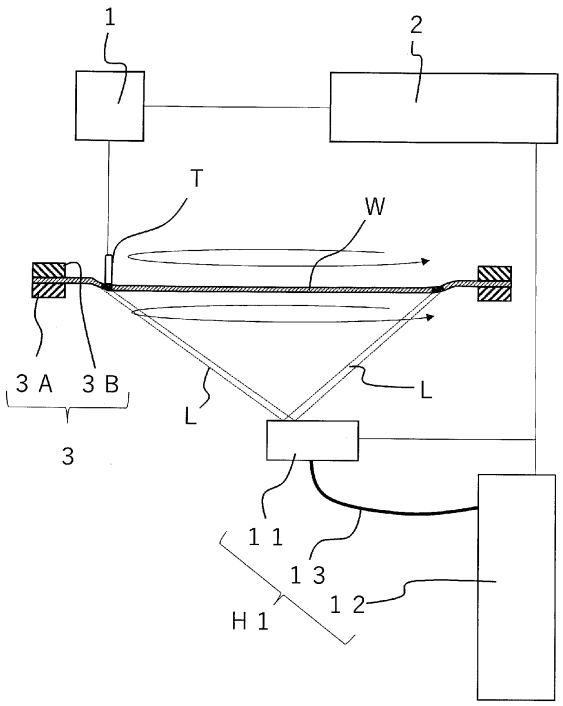
(54) SEQUENTIAL SHAPING METHOD

(57) Provided is a sequential shaping method for shaping a metal sheet W into a three-dimensional form by pressing and moving a rod-form tool T against the metal sheet W, wherein: the rod-form tool T, which is disposed on one side of the metal sheet W, and a heating device H1 that is disposed on the other side of the metal sheet W are used; a local movement region for the rod-form tool T on the metal sheet W is determined on the basis of a preset movement path and movement speed of the rod-form tool T, the local movement region is heated for a fixed time from a reverse side, and the metal sheet W is shaped by using the rod-form tool T; and the metal sheet W is then shaped while heating that corresponds to a subsequent local movement region following a preceding local movement region is performed in turn. As a result, portions that are plastically deformed by the rod-form tool T are heated and annealed during a shaping step, residual stress produced in the metal sheet W is removed, and shape-retention properties of a shaped article are enhanced.

[FIG. 1]



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Description

Technological Field

[0001] The present invention relates to a sequential shaping method for shaping a metal sheet into a three-dimensional form using a rod-form tool, and particularly relates to a sequential shaping method and a sequential shaping apparatus that are configured to anneal shaping portions of a metal sheet.

Background Technology

[0002] A prior-art sequential shaping method is disclosed in, e.g., Patent Document 1. A rod-form tool provided with a laser irradiator serving as a heating means is used in the sequential shaping method disclosed in Patent Document 1. The laser irradiator is provided to a movement-direction front side of the rod-form tool. In this sequential shaping method, when the rod-form tool is pressed and moved against a metal sheet, the metal sheet is heated by being irradiated with laser light at the front side of the rod-form tool, and the heated portion of the metal sheet is pressed and plastically deformed by the rod-form tool, thereby releasing and lowering residual stress in the metal sheet.

Prior Art Documents

Patent Documents

[0003] Patent Document 1: Japanese Patent No. 3959455

Disclosure of the Invention

Problems to Be Solved by the Invention

[0004] In a sequential shaping method configured as described above, the rod-form tool describes an indeterminate number of orbital movements in a form resembling contour lines and shapes the metal sheet. However, because the rod-form tool and the laser irradiator move integrally in the aforementioned prior-art sequential shaping method, it is difficult to ensure a laser light transmission path from an exterior portion to the laser irradiator when the front side of the rod-form tool is constantly irradiated with laser light. Additionally, in the aforementioned prior-art sequential shaping method, portions prior to shaping by the rod-form tool are heated, therefore making it possible that residual stress cannot be removed after shaping and making it difficult to enhance shape-retention properties of a shaped article. It is necessary to lower a movement speed of the rod-form tool in order to sufficiently carry out heating, but this approach greatly reduces productivity and is therefore impractical.

[0005] The present invention was contrived in consideration of the aforementioned state of the prior art, it being an object of the present invention to provide a sequential shaping method and a sequential shaping apparatus with which portions that are plastically deformed by a rod-form tool are annealed by heating a metal sheet from a reverse-surface side during a shaping step, residual stress produced in the metal sheet is removed, and shape-retention properties of a shaped article can be enhanced.

Means Used to Solve the Above-Mentioned Problems

[0006] A sequential shaping method according to the present invention includes shaping a metal sheet into a three-dimensional form by pressing and moving a distal end of a rod-form tool against the metal sheet, wherein the rod-form tool, which is disposed on one main-surface side of the metal sheet, and a heating device that is disposed on the other main-surface side of the metal sheet and that heats the metal sheet are used. The sequential shaping method comprising: a local movement region for the rod-form tool on the metal sheet is determined on the basis of a preset movement path and movement speed of the rod-form tool, the local movement region is heated for a fixed time from a reverse side, and the metal sheet is shaped by using the rod-form tool; and the metal sheet is then shaped while heating that corresponds to a subsequent local movement region following a preceding local movement region is performed in turn along the movement path of the rod-form tool.

[0007] A sequential shaping apparatus according to the present invention is used in the aforementioned sequential shaping method. The sequential shaping apparatus comprises the rod-form tool disposed on the one main-surface side of the metal sheet, the heating device disposed on the other main-surface side of the metal sheet, a tool-driving device that drives the rod-form tool in at least three orthogonal axial directions, and a main control device that controls the tool-driving device. The sequential shaping apparatus comprising: the heating device is capable of individually heating a plurality of local movement regions, into which the movement path of the rod-form tool is divided, from reverse sides thereof; and the main control device has a function for controlling the heating device on the basis of data pertaining to driving the rod-form tool.

Effect of the Invention

[0008] Due to employing the aforementioned configurations, the sequential shaping method and the sequential shaping apparatus according to the present invention are such that regions that are plastically deformed by a rod-form tool are annealed by heating a metal sheet from a reverse side during a shaping step, residual stress produced in the metal sheet is removed, and shape-

retention properties of a shaped article can be enhanced.

Brief Description of the Drawings

[0009]

Figure 1is a schematic diagram showing an example of a sequential shaping apparatus that can be applied to a sequential shaping method according to the present invention in a first embodiment of the sequential shaping method.

Figure 2 is a plan view showing a relationship between a movement path of a rod-form tool on a metal sheet and a region over which a heating device applies heat.

Figure 3 is a side view showing a region over which the rod-form tool projects onto the metal sheet.

Figure 4 is a graph showing a relationship between time and temperature when the metal sheet is heated.

Figure 5 is a schematic diagram showing another example of a heating device in a second embodiment of the sequential shaping method according to the present invention.

Figure 6 is a plan view showing yet another example of a heating device in a third embodiment of the sequential shaping method according to the present invention.

Figure 7 is a side view of the heating device shown in Fig. 6.

Figure 8 is a perspective of a nozzle shown in Fig. 6.

Figure 9 is a plan view showing yet another example of a heating device in a fourth embodiment of the sequential shaping method according to the present invention.

Figure 10 is a side view of the heating device shown in Fig. 8.

Figure 11 is a perspective view of a nozzle shown in Fig. 8.

Preferred Embodiments of the Invention

<First Embodiment >

[0010] Figure 1 shows an example of a sequential shaping apparatus that can be applied to a sequential shaping method according to the present invention in a first embodiment of the sequential shaping method. The sequential shaping apparatus shown in Fig. 1 comprises a rod-form tool T that is disposed on one main-surface side (upper-surface side in Fig. 1) of a metal sheet W, and a heating device H1 that is disposed on the other main-surface side (lower-surface side in Fig. 1) of the metal sheet W.

[0011] The sequential shaping apparatus also comprises a tool-driving device 1 that drives the rod-form tool T in at least three orthogonal axial directions, and a main control device 2 that controls the tool-driving device 1. The heating device H1 is capable of individually heating a plurality of local movement regions, into which the movement path of the rod-form tool T is divided, from reverse sides thereof. The main control device 2 has a function for controlling the heating device H1 on the basis of data pertaining to driving the rod-form tool T.

[0012] The metal sheet W is a flat sheet that serves as a material for a shaped article. The metal sheet W is held at a periphery thereof by a clamp 3 during successive shaping. The clamp 3 is provided with a lower frame part 3A that is fixed, and an upper frame part 3B that can be raised and lowered relative to the lower frame part 3A. The periphery of the metal sheet W is firmly sandwiched between the lower frame part 3A and the upper frame part 3B.

[0013] In the example shown in Fig. 1, the rod-form tool T is a well-known variant that is held in an orientation in which an axis thereof is aligned with a vertical direction, a distal-end part that serves as a lower side being spherical or having another suitable shape. The rod-form tool T is driven in three orthogonal axial directions by the tool-driving device 1. A multiaxis-controlled work robot or an NC machine tool can be used as the tool-driving device 1. The tool-driving device 1 can cause the rod-form tool T mounted thereon to move in X and Y directions, which are horizontal directions, and a Z direction, which is the vertical direction. The tool-driving device 1 is also capable of causing the rod-form tool T to rotate about various axes.

[0014] The heating device H1 preferably heats the metal sheet W in a contactless manner. The heating device H1 in the present embodiment irradiates the metal sheet W with laser light L to heat the metal sheet W. Specifically, the heating device H1 is provided with a laser oscillator 11, a laser scanner 12 that scans the laser light L over the metal sheet W, and an optical fiber 13 that transmits the laser light from the laser oscillator 11 to the laser scanner 12.

[0015] The laser scanner 12 is capable of scanning the laser light L over the other main surface (lower surface) of the metal sheet W at high speed over a discretionarily set region. This makes it possible for the heating device H to individually heat discretionary set regions, i.e., a plurality of local movement regions into which a movement path of the rod-form tool T is divided, from reverse sides thereof.

[0016] The main control device 2 is a computer. The movement path, the movement speed, and the amount of pressure applied to the metal sheet W from a shaping start point to a shaping end point are inputted in advance to the main control device 2 as data pertaining to driving the rod-form tool T for shaping the metal sheet W into a shaped article.

[0017] The main control device 2 has a function for controlling the heating device H1 on the basis of the data pertaining to driving the rod-form tool T. Specifically, the local movement region for the rod-form tool T on the metal sheet W is determined on the basis of the movement path and the movement speed of the rod-form tool T, and

mainly the laser scanner 12 is controlled so that the laser light L is scanned over the reverse-surface side of the local movement region and said reverse side is heated for a fixed time.

[0018] Actions of the aforementioned sequential shaping apparatus and a sequential shaping method shall be described next. In well-known sequential shaping methods, as shown in Fig. 1, the distal end part of the rod-form tool T is pressed and moved against the metal sheet W held along the periphery thereof by the clamp 3. Specifically, the rod-form tool T is moved along a circling path, after which the rod-form tool T is displaced inward and downward by a prescribed pitch (pitch-fed), and then the movement following a subsequent circling path and the pitch-feeding action are repeated. As a result, in the sequential shaping method, the rod-form tool T is moved in a form resembling contour lines, the metal sheet W is shaped so that a bottom portion is gradually pressed down, and a three-dimensional shaped article is ultimately obtained.

[0019] In the sequential shaping method according to the present invention, when successive shaping is performed as described above, the local movement region for the rod-form tool T on the metal sheet W is determined on the basis of the preset movement path and movement speed of the rod-form tool T, the local movement region is heated for a fixed time from a reverse side, and the metal sheet W is shaped by using the rod-form tool T. Additionally, in the sequential shaping method, the metal sheet W is shaped while heating that corresponds to a subsequent local movement region following a preceding local movement region is performed in turn.

[0020] In the sequential shaping method of the present embodiment, as shown in Fig. 2, a single circling path P shown using a solid line is determined as the local movement region for the rod-form tool T on the metal sheet W, and the local movement region is heated for a fixed time from the reverse side, as shown using a dotted line A in Fig. 2. Specifically, the laser scanner 12 is controlled so that the laser light L is scanned over the reverse side of the local movement region and said reverse side is heated for a fixed time, as shown in Fig. 1, on the basis of the data pertaining to driving the rod-form tool T in the main control device 2. The laser light L is repeatedly scanned in one direction at high speed. The scanning speed of the laser light L is clearly higher than the movement speed of the rod-form tool T.

[0021] In the sequential shaping method, as a more preferable embodiment, when the local movement region for the rod-form tool T on the metal sheet W is heated for a fixed time from the reverse side, the heating is started from a region over which the rod-form tool T projects in an axial direction, as shown in Fig. 3. Additionally, the metal sheet W is heated for a time of $2.4 \times t$ (minutes) or greater, where t (mm) is a sheet thickness of the metal sheet W.

[0022] In successive shaping using the sequential shaping apparatus described above, it is also possible for a region within which the metal sheet W is plastically deformed by the rod-form tool T to be heated for a fixed time at time points when, for example, the rod-form tool T is moved by a fixed distance. However, in the sequential shaping method described above, the local movement region is determined, the heating is started from the region over which the rod-form tool T projects in the axial direction, and the metal sheet W is shaped by using the rod-form tool T.

[0023] Thus, in the sequential shaping method described above, preliminary heating is performed from the reverse side of a region which has not yet been shaped and over which the rod-form tool T has not yet passed, and the rod-form tool T continues to move during the preliminary heating. Therefore, heating for a fixed time is resultantly performed from the reverse side in the entirety of the region that is plastically deformed by the rod-form tool T.

[0024] The heating device H1 that repeatedly scans the laser light L in one direction is used in the sequential shaping method of the present embodiment. Therefore, although a temperature fluctuates up and down as indicated by a dotted line in Fig. 4, sufficient annealing is possible provided that a temperature fluctuation region exceeds a target temperature.

[0025] The reason for using a time of $2.4 \times t$ (minutes) or greater to heat the metal sheet is as follows. By way of reference, the time for retaining heat needed for annealing in heat-treatment industries is 1 hr/inch of sheet thickness, and the sheet thickness was expressed in units of millimeters. Furthermore, an experiment was carried out in which a steel sheet was heated at 510°C by using electromagnetic induction heating, the heating time being varied from 1 to 8 minutes in one-minute increments. As a result, it was ascertained that the heating time is preferably set to $2.4 \times t$ (minutes) or greater.

[0026] Furthermore, in the sequential shaping method described above, depending on an amount by which the rod-form tool T is pitch-fed or a magnitude of a spot diameter of the laser light L, it is possible to perform heating including the preliminary heating not only at the reverse side of the region that is plastically deformed by the rod-form tool T but also in nearby regions, i.e., portions of the subsequent circling path or a pitch-feeding path, which are regions that have not yet been shaped.

[0027] In the sequential shaping method described above, as mentioned previously, the metal sheet W is shaped by moving the rod-form tool T to the shaping end point while heating that corresponds to a subsequent local movement region (e.g., subsequent circling path) following a preceding local movement region is performed in turn. In this process in the aforementioned sequential shaping method, if the heating performed on the preceding local movement region does not exceed a fixed time, then a region over which the laser light L is scanned is expanded in the preceding local movement region and in the subsequent local movement region, and at a point in time when the heating performed on the

preceding local movement region exceeds the fixed time, the region over which the laser light L is scanned is set to the subsequent local movement region. The heating performed on the preceding local movement region is thereby ended.

[0028] Thus, in the sequential shaping method and the sequential shaping apparatus described in the present embodiment, the regions that are plastically deformed by the rod-form tool are annealed by heating the metal sheet from the reverse side during a shaping step, residual stress produced in the metal sheet is removed, and shape-retention properties of a shaped article can be enhanced. Additionally, in the sequential shaping method and the sequential shaping apparatus described above, the rod-form tool T and the heating device are disposed with the metal sheet W interposed therebetween, eliminating any concern that free movement of the rod-form tool T will be obstructed.

[0029] In the sequential shaping method described above, the heating is started from the region over which the rod-form tool T projects in the axial direction, and the metal sheet W is shaped by using the rod-form tool T, making it possible to perform preliminary heating from the reverse side of a region which has not yet been shaped and over which the rod-form tool T has not yet passed. This makes it possible to efficiently heat and anneal the regions within which the metal sheet W is plastically deformed, sufficiently remove residual stress, and contribute to enhancement of shape-retention properties.

[0030] In the sequential shaping method described above, the metal sheet W is heated for a time of $2.4 \times t$ (minutes) or greater, making it possible to efficiently heat and anneal the regions within which the metal sheet W is plastically deformed, sufficiently remove residual stress, and contribute to further enhancement of shape-retention properties.

[0031] In the sequential shaping method described above, the metal sheet W is shaped while being held along the periphery thereof, making it possible to successively shape the metal sheet W by using a comparatively simple device without using a shaping die or the like. In the sequential shaping method described above, the shape-retention properties of a shaped article are favorably maintained, simplifying work for retrieving the shaped article from the clamp 3.

[0032] In the sequential shaping method described above, the heating device H1 heats the metal sheet W in a contactless manner, and in particular irradiates the metal sheet W with the laser light L to heat the metal sheet W, enabling the region over which the laser light L is scanned to be freely set on the basis of the data pertaining to driving the rod-form tool T and making it possible to focus concentrated heating on a necessary region. Although the metal sheet W is shaped so as to jut out downward in the sequential shaping method described above, the metal sheet W can be heated even if a height position of the laser scanner 12 is changed.

[0033] Figures 5 to 11 illustrate sequential shaping apparatuses that can be applied to a sequential shaping method according to the present invention in second to fourth embodiments of the sequential shaping method. In the embodiments described below, constituent portions that are the same as those in the first embodiment are assigned the same reference symbols and are not described in detail.

<Second Embodiment >

[0034] In the sequential shaping method according to the present invention, a device that heats the metal sheet W in a contactless manner is used as a heating device H2. In the sequential shaping apparatus shown in Fig. 5, the heating device H2 is an electromagnetic induction heating device. The heating device H2 has a structure in which a plurality of heating units capable of operating independently are disposed on a surface (upper surface in Fig. 5) facing the other main surface of the metal sheet W, although this feature is not illustrated in detail. The heating device H2 is capable of heating the metal sheet W in a localized manner.

[0035] In the sequential shaping method, the bottom portion of the metal sheet W is shaped so as to gradually be pressed down. However, depending on the degree to which the metal sheet W is to be shaped, the heating device H2 can be configured to be capable of moving up and down in order to maintain a fixed spacing between the heating device H2 and the bottom portion of the metal sheet W. The heating device H2 can be formed such that the upper-surface form thereof has recesses and protrusions that match a form in which the metal sheet W is to be shaped, and the heating units can be disposed on the upper surface of the heating device H2. However, the upper surface of the heating device H2 can correspond to a variety of shaped forms provided that a structure is employed in which the plurality of heating units are disposed on a flat plane and the entire heating device H2 is moved up and down.

[0036] In the sequential shaping method using the sequential shaping apparatus described above, in the same manner as in the previous embodiment: the local movement region for the rod-form tool T on the metal sheet W is determined on the basis of the preset movement path and movement speed of the rod-form tool T, the local movement region is heated for a fixed time from the reverse side, and the metal sheet W is shaped by using the rod-form tool T; and the metal sheet W is then shaped while heating that corresponds to a subsequent local movement region following a preceding local movement region is performed in turn.

[0037] In this embodiment, the heating device H2 operates the heating units corresponding to the reverse side of the local movement region for the rod-form tool T and heats the local movement region from the reverse side, and operation of the corresponding heating units is sequentially started and stopped in association with updating of the local movement region.

[0038] Thus, in the sequential shaping method and the sequential shaping apparatus described above, the regions that are plastically deformed by the rod-form tool T are annealed by heating the metal sheet W from the reverse side during a shaping step, residual stress produced in the metal sheet W is removed, and shape-retention properties of a shaped article can be enhanced.

<Third Embodiment>

[0039] Figures 6 to 8 illustrate yet another example of a sequential shaping apparatus that can be applied to a sequential shaping method according to the present invention in a third embodiment of the sequential shaping method. In the sequential shaping apparatus shown in Fig. 6, a heating device H3 has a structure in which numerous heating elements 14 are disposed on the other main-surface side of the metal sheet W. In the heating elements 14, nozzles 17 that eject hot air heated by heaters 15 are provided to distal ends of pipes 16 where the heaters 15 are provided at intermediate portions, as shown in Figs. 7 and 8.

[0040] In the sequential shaping method, as described in the previous embodiments, the rod-form tool (T) is moved along a circling path, after which the rod-form tool is displaced inward and downward from the circling path and the rod-form tool is moved along a subsequent circling path. Specifically, in the sequential shaping method, the metal sheet W is shaped so that the bottom portion of the metal sheet W is gradually pressed down while the rod-form tool is moved in a form resembling contour lines.

[0041] However, in the heating device H3 in the example shown in Figs. 6 to 8, a heating element 14 having a square nozzle 17 is disposed centrally, and four heating elements 14 having slitted nozzles 17 are disposed therearound. In this embodiment, the nozzles 17 are disposed so as to form four sides of a quadrilateral. In the heating device H3, the four heating elements 14 form a single set, and the nozzles 17 of the plurality of heating elements 14 are disposed so as to resemble contour lines. Therefore, the heating elements 14 have nozzles 17 long enough to face outward.

[0042] In the sequential shaping method using the sequential shaping apparatus having the heating device H3 described above, the local movement region for the rod-form tool on the metal sheet W is determined in the same manner as in the previous embodiments, and in the heating device H3, the heating elements 14 corresponding to the reverse side of the local movement region for the rod-form tool T are operated, hot air is supplied to the reverse side of the local movement region to heat the local movement region, and operation of the corresponding heating elements 14 is sequentially started and stopped in association with updating of the local movement region.

[0043] Thus, in the sequential shaping method and the sequential shaping apparatus described above, the regions that are plastically deformed by the rod-form tool are annealed by heating the metal sheet W from the reverse side during a shaping step, residual stress produced in the metal sheet W is removed, and shape-retention properties of a shaped article can be enhanced.

[0044] The heating device H3 in the sequential shaping apparatus of the present embodiment may have a structure in which individual heating elements 14 are changed in height to match the form in which the metal sheet W is to be shaped or may be configured so that the individual heating elements 14 are capable of individually moving up and down or so that all of the heating elements 14 are capable of moving up and down simultaneously.

<Fourth Embodiment >

[0045] Figures 9 to 11 illustrate yet another example of a sequential shaping apparatus that can be applied to a sequential shaping method according to the present invention in a fourth embodiment of the sequential shaping method. In the sequential shaping apparatus shown in Fig. 9, a heating device H4 has a structure in which numerous heating elements 14 are disposed in columns and rows on the other main-surface side of the metal sheet W. In the heating elements 14, square nozzles 17 that eject hot air heated by heaters 15 are provided to distal ends of pipes 16 where the heaters 15 are provided at intermediate portions, as shown in Figs. 10 and 11. The nozzles 17 are disposed so as to be aligned in columns and rows.

[0046] In the sequential shaping method using the sequential shaping apparatus having the heating device H4 described above, the local movement region for the rod-form tool on the metal sheet W is determined in the same manner as in the previous embodiments, and in the heating device H4, the heating elements 14 corresponding to the reverse side of the local movement region for the rod-form tool T are operated, the local movement region is heated from the reverse side thereof by the hot air, and operation of the corresponding heating elements 14 is sequentially started and stopped in association with updating of the local movement region.

[0047] Thus, in the sequential shaping method and the sequential shaping apparatus described above, the regions that are plastically deformed by the rod-form tool are annealed by heating the metal sheet W from the reverse side during a shaping step, residual stress produced in the metal sheet W is removed, and shape-retention properties of a shaped article can be enhanced.

[0048] The heating device H4 in the sequential shaping apparatus of the present embodiment may have a structure in which individual heating elements 14 are changed in height to match the form in which the metal sheet W is to be shaped or may be configured so that the individual heating elements 14 are capable of individually moving up and down or so that all of the heating elements 14 are capable of moving up and down simultaneously.

[0049] Although no detailed structure of the heating units of the heating device H2 in the second embodiment

(see Fig. 5) described above is given, heating units that perform electromagnetic induction heating can be disposed in lieu of the nozzles 17 shown in Figs. 6 and 8.

[0050] The structure of the sequential shaping method and the sequential shaping apparatus according to the present invention is not limited to the embodiments described above and can be suitably modified within a range that does not depart from the gist of the present invention. Cases where the metal sheet W is held horizontal were described as examples in the embodiments, but in successive shaping in which no shaping die is used (dieless forming), it is also possible to shape the metal sheet W while holding the metal sheet W in a vertical state or an inclined state.

Key

[0051]

1	Tool-driving device
2	Main control device
H1 to H4	Heating device
T	Rod-form tool
W	Metal sheet

Claims

1. A sequential shaping method for shaping a metal sheet into a three-dimensional form by pressing and moving a distal end of a rod-form tool against the metal sheet, the sequential shaping method comprising:

using the rod-form tool disposed on one main-surface side of the metal sheet, and a heating device disposed on another main-surface side of the metal sheet to heat the metal sheet;
determining a local movement region for the rod-form tool on the metal sheet based on a preset movement path and movement speed of the rod-form tool;
heating the local movement region for a fixed time from a reverse side, and shaping the metal sheet using the rod-form tool; and
then shaping the metal sheet while sequentially heating a subsequent local movement region following a preceding local movement region.

2. The sequential shaping method according to claim 1, wherein when heating the local movement region for the rod-form tool on the metal sheet for a fixed time from the reverse side, the heating is started from a region over which the rod-form tool projects in an axial direction.

3. The sequential shaping method according to claim 1, wherein

the metal sheet is heated for a time of 2.4 $\times$ t (minutes) or greater,
where t (mm) is a sheet thickness of the metal sheet.

4. The sequential shaping method according to claim 1, wherein the metal sheet is shaped while being held along a periphery thereof.

5. The sequential shaping method according to claim 1, wherein the heating device heats the metal sheet in a contactless manner.

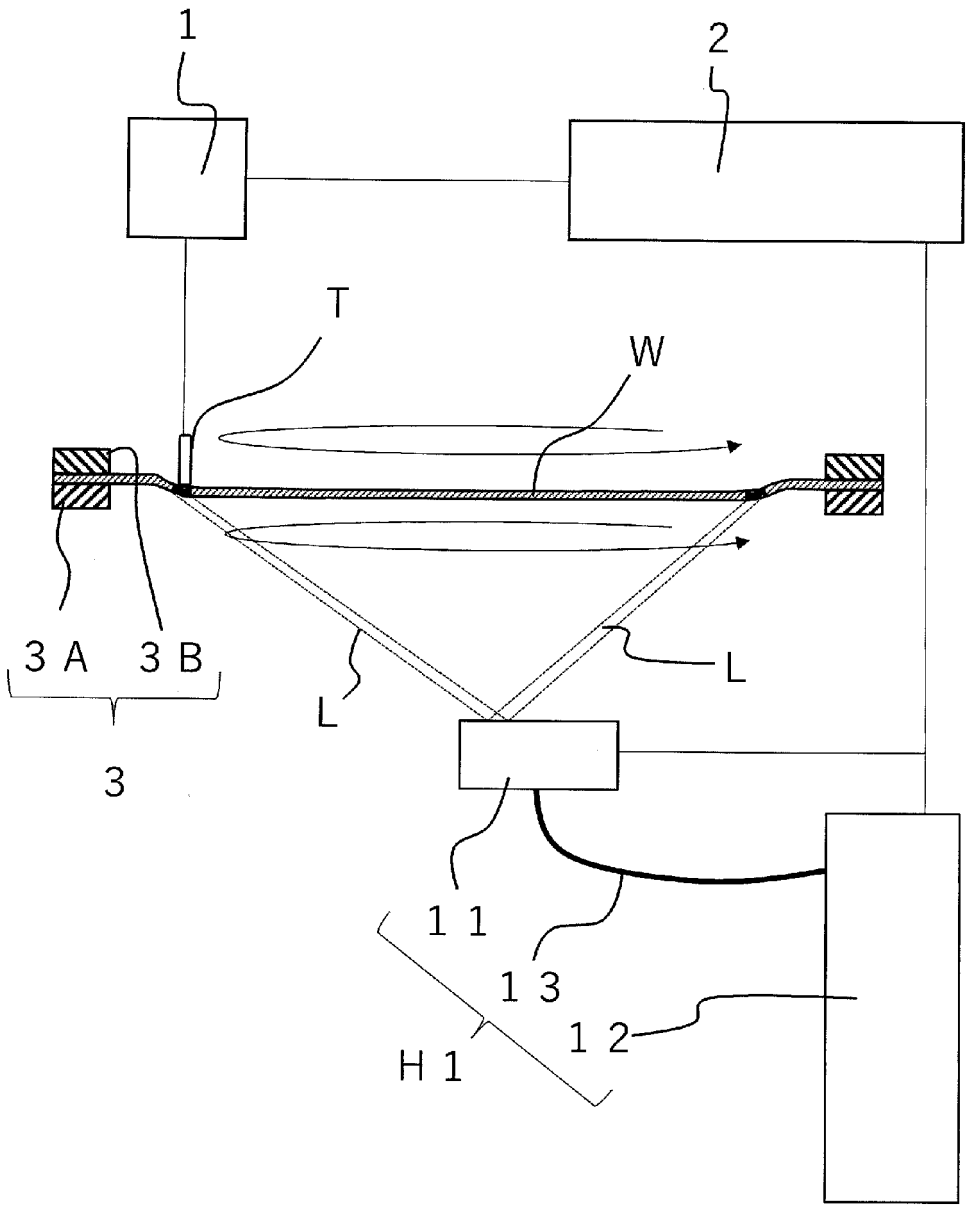
6. The sequential shaping method according to claim 5, wherein the heating device irradiates the metal sheet with laser light to heat the metal sheet.

7. The sequential shaping method according to claim 5, wherein the heating device blows hot air onto the metal sheet to heat the metal sheet.

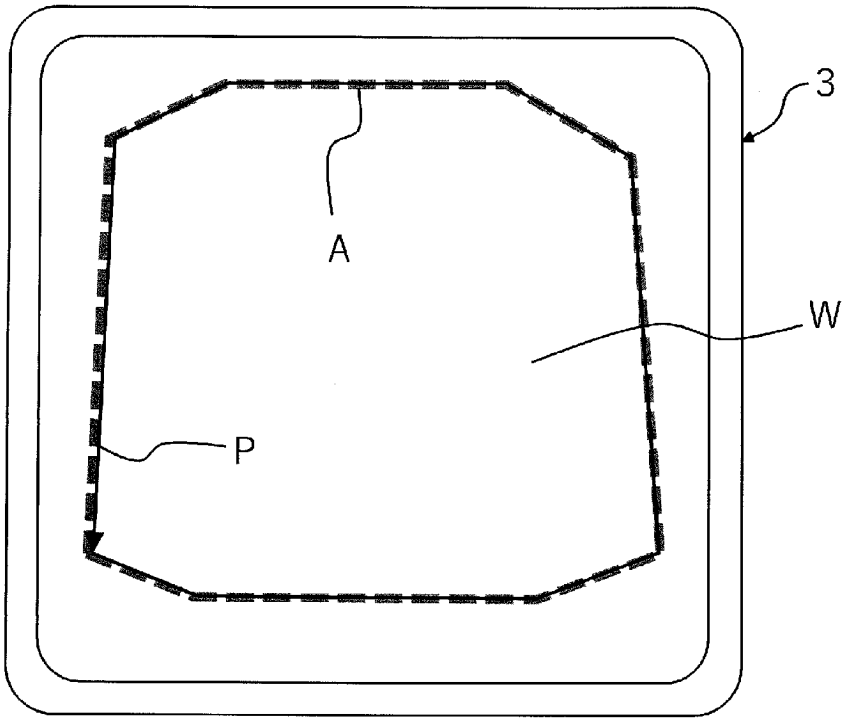
8. A sequential shaping apparatus used in the sequential shaping method according to claim 1, the sequential shaping apparatus comprising:

the rod-form tool disposed on the one main-surface side of the metal sheet;
the heating device disposed on another main-surface side of the metal sheet;
a tool-driving device that drives the rod-form tool in at least three orthogonal axial directions; and
a main control device configured to control the tool-driving device,
the heating device being configured to individually heat a plurality of local movement regions, into which the movement path of the rod-form tool is divided, from reverse sides thereof, and
the main control device being configured to control the heating device based on data pertaining to driving the rod-form tool.

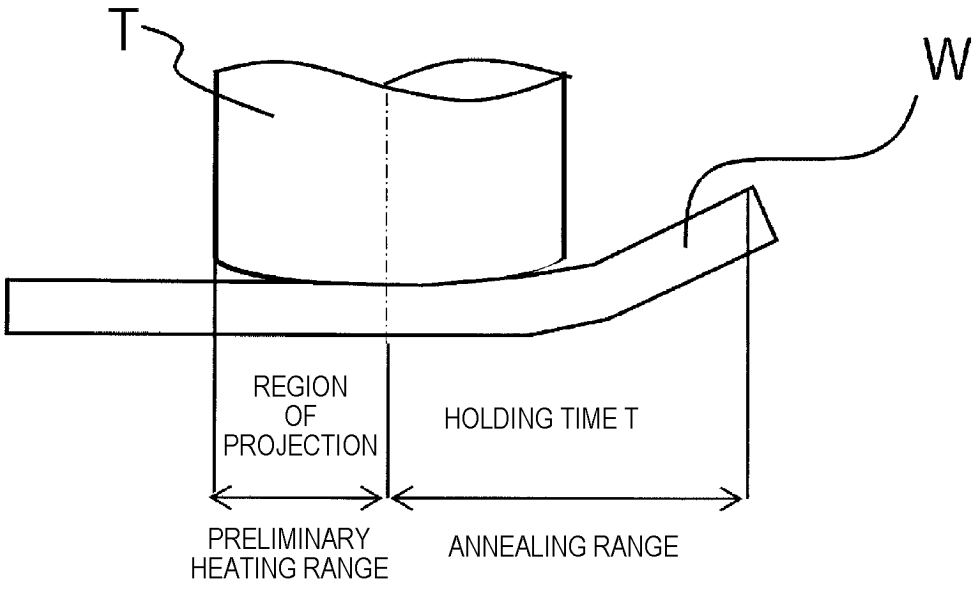
[FIG. 1]



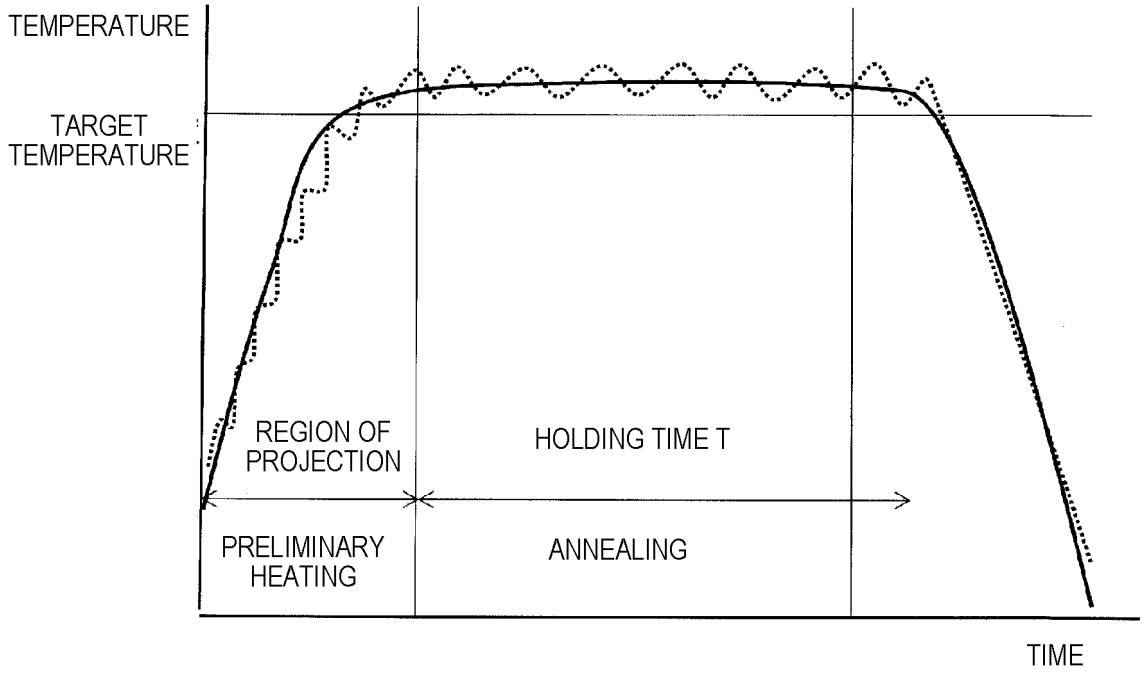
[FIG. 2]


3
A
W
P

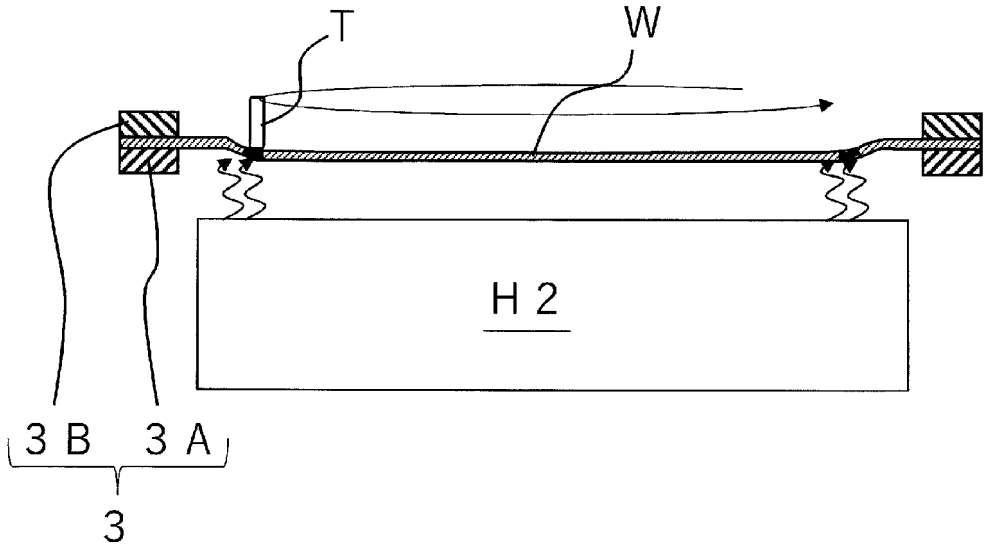
[FIG. 3]


T
W
REGION OF PROJECTION
HOLDING TIME T
PRELIMINARY HEATING RANGE
ANNEALING RANGE

[FIG. 4]


TEMPERATURE
TARGET TEMPERATURE
REGION OF PROJECTION
HOLDING TIME T
PRELIMINARY HEATING
ANNEALING
TIME

[FIG. 5]


T
W
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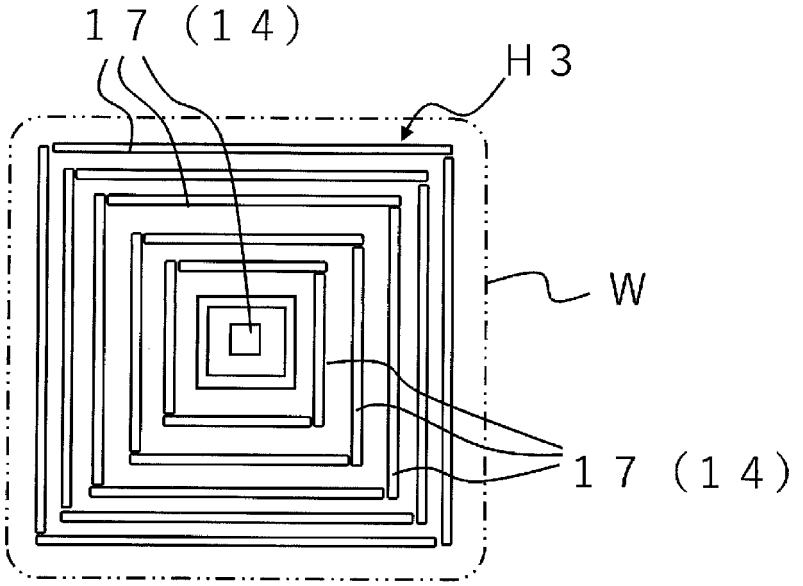
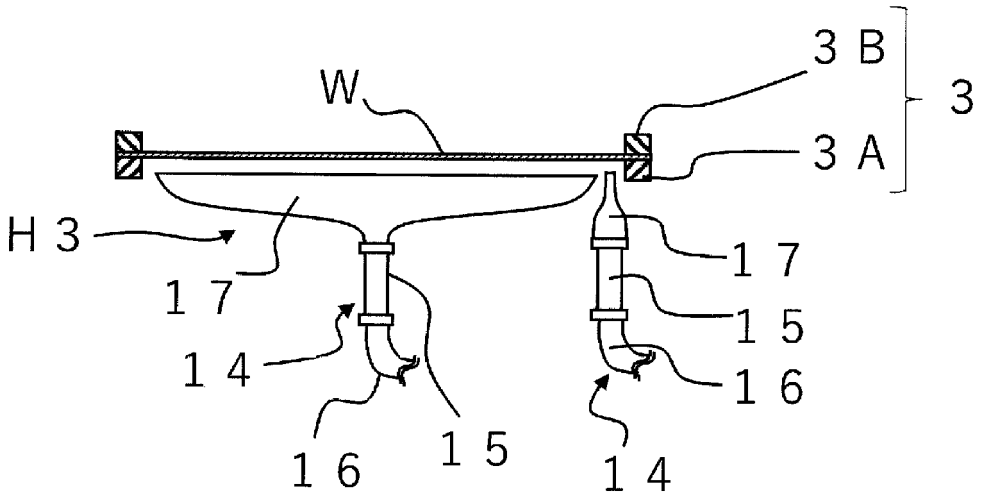
3 A
3

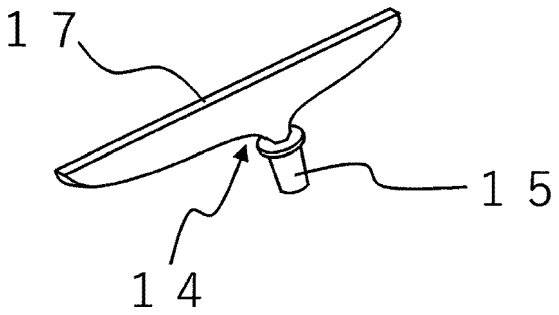
[FIG. 6]



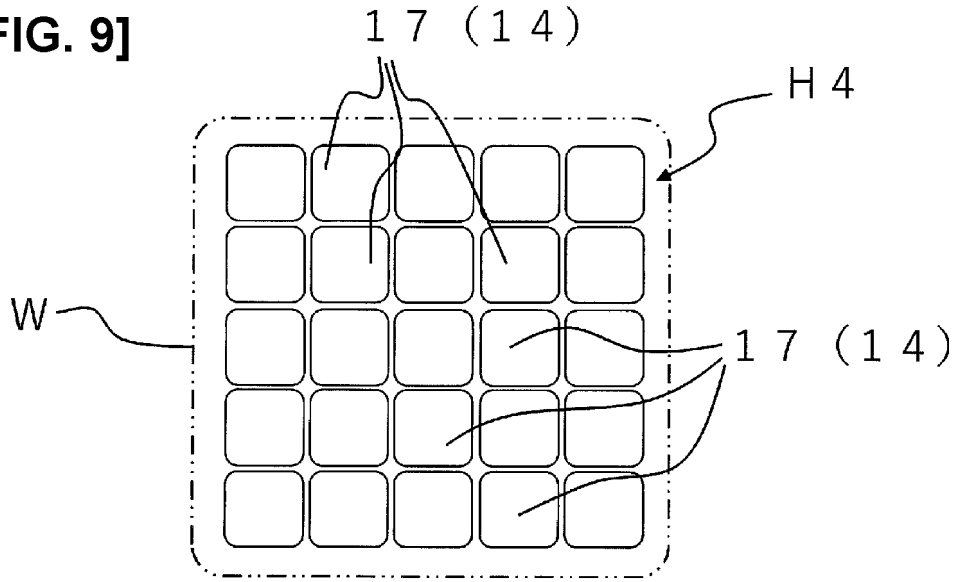
[FIG. 7]



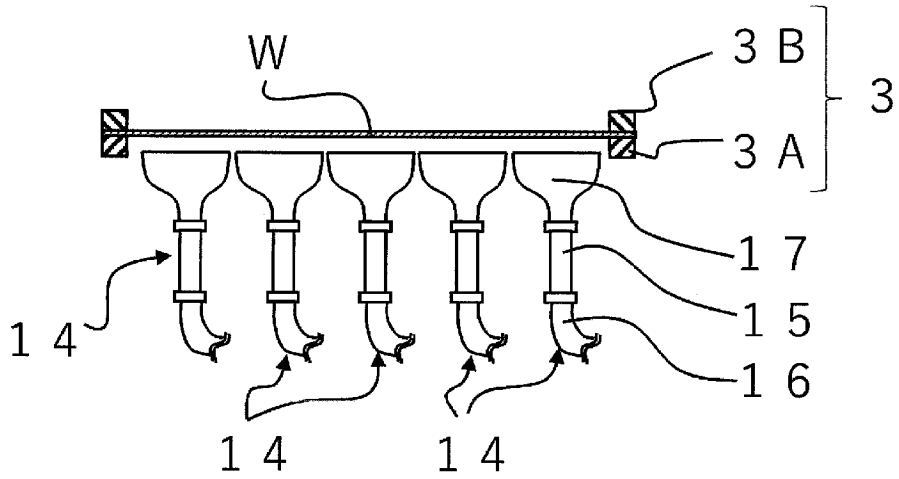
[FIG. 8]



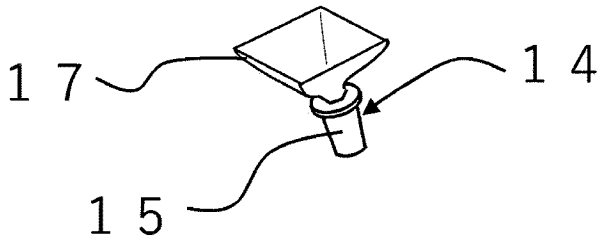
[FIG. 9]



[FIG. 10]



[FIG. 11]



INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/024185

A. CLASSIFICATION OF SUBJECT MATTER

B21D 22/18(2006.01)i; ***B21D 31/00***(2006.01)i
FI: B21D22/18; B21D31/00 Z

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)

B21D22/18; B21D31/00

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 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

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	KR 10-2011-0124557 A (KOREA ADVANCED INSTITUTE OF SCIENCE AND TECHNOLOGY) 17 November 2011 (2011-11-17) paragraphs [0018], [0024], [0029]-[0031], [0042], fig. 1, 3	1-8
A	CN 113042618 A (WUHAN UNIVERSITY OF TECHNOLOGY) 29 June 2021 (2021-06-29) entire text, all drawings	1-8

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
28 July 2022	**09 August 2022**
Name and mailing address of the ISA/JP **Japan Patent Office (ISA/JP)** **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/024185

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
KR 10-2011-0124557 A	17 November 2011	(Family: none)	
CN 113042618 A	29 June 2021	(Family: none)	

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 3959455 B **[0003]**