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(71) Applicant: **Kawasaki Jukogyo Kabushiki Kaisha**
Kobe-shi, Hyogo 650-8670 (JP)

(72) Inventors:
- **KIMURA, Tsuyoshi**
  Kobe-shi
  Hyogo 650-8670 (JP)
- **KAWANO, Seishiro**
  Kobe-shi
  Hyogo 650-8670 (JP)
- **NAKANO, Shinichi**
  Akashi-shi
  Hyogo 673-8666 (JP)
- **HONDA, Fumihiro**
  Akashi-shi
  Hyogo 673-8666 (JP)

(74) Representative: **Jeffrey, Philip Michael**
Dehns
St Bride's House
10 Salisbury Square
London
EC4Y 8JD (GB)

(54) STRETCH FORMING SYSTEM AND STRETCH FORMING METHOD

(57) A stretch forming system has jaws clamping a workpiece at end edge portions, a die disposed between the jaws and coming into contact with the workpiece, and a plurality of control axes changing relative positions and orientations of the jaws with respect to the die, and has a jaw path calculating unit calculating paths of the relative positions and orientations of the jaws with respect to the die when the workpiece is wrapped onto the die by moving the die in a vertical direction under a restricting condition that the positions and orientations of the jaws are freely changeable except for movement in a vertical direction being regulated, and a control axis operation pattern calculating unit calculating operation patterns of the plurality of the control axes achieving the paths of the jaws.

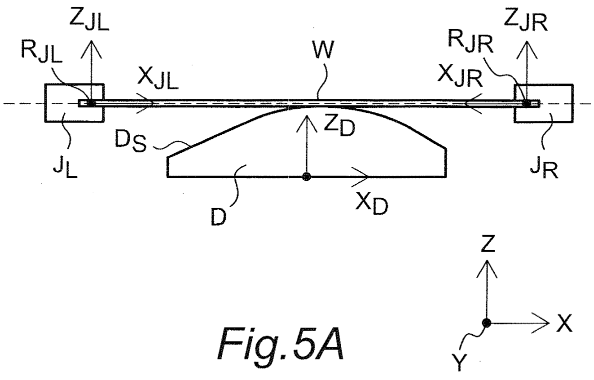

Fig.5A

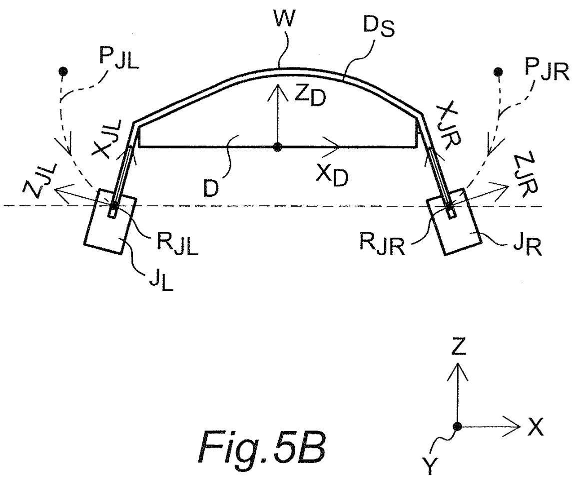

Fig.5B

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Description

TECHNICAL FIELD

[0001] The present invention relates to a stretch forming system and a stretch method for performing stretch forming of a workpiece.

BACKGROUND ART

[0002] A stretch forming is conventionally performed for stretch forming of a workpiece into a desired shape. For example, as depicted in Patent Document 1, the stretch forming is performed by using a stretch forming apparatus including first and second jaws clamping a plate-shaped workpiece at respective end edge portions opposite to each other, a die disposed between the first and second jaws and coming into contact with the workpiece, and multiple axes changing the relative positions and orientations of the jaws with respect to the die. When an operator manually operates each of the multiple control axes to change the relative positions and orientations of the jaws with respect to the die, the workpiece is wrapped onto the die for stretch forming into a desired shape.

PRIOR ART DOCUMENT

Patent Document

[0003] [Patent Document 1] Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2009-523613

SUMMARY OF THE INVENTION

Problem to Be Solved by the Invention

[0004] To acquire a favorable formed product from stretch forming, a burden and skill of an operator is required. Specifically, the stretch forming must be performed such that a workpiece is prevented from wrinkling, that the thickness of the workpiece is substantially uniformly changed across the entire part, and that no gap is generated between the workpiece and the die. Therefore, the operator must devise paths of the relative positions and orientations of the jaws with respect to the die necessary for achieve this stretch forming as well as respective operation patterns of the multiple control axes necessary for achieving the paths of the positions and orientations of the jaws. This is time-consuming and therefore a burden for the operator, and is difficult unless the worker is skilled.

[0005] it is therefore a problem of the present invention to calculate the paths of the relative positions and orientations of the jaws with respect to the die, i.e., the respective operation patterns of the multiple control axes, necessary for acquiring a favorable formed product from the stretch forming on behalf of an operator in a short period of time so as to reduce the burden of the operator. Means for Solving the Problem

[0006] To achieve the object, the present invention is configured as follows.

[0007] According to a first aspect of the present invention, there is provided a stretch forming system comprising:

first and second jaws clamping a workpiece at respective end edge portions opposite to each other;
a die disposed between the first and second jaws and coming into contact with the workpiece; and
a plurality of control axes changing relative positions and orientations of the first and second jaws with respect to the die;
a jaw path calculating unit calculating respective paths of the relative positions and orientations of the first and second jaws with respect to the die when the workpiece is wrapped onto the die by moving the die in a vertical direction under a restricting condition that respective positions and orientations of the first and second jaws are freely changeable except for movement in a vertical direction being regulated; and
a control axis operation pattern calculating unit calculating respective operation patterns of the plurality of the control axes achieving the respective paths of the relative positions and orientations of the first and second jaws with respect to the die calculated by the jaw path calculating unit.

[0008] According to a second aspect of the present invention, there is provided a stretch forming system comprising:

first and second jaws clamping a workpiece at respective end edge portions opposite to each other;
a die disposed between the first and second jaws and coming into contact with the workpiece; and
a plurality of control axes changing relative positions and orientations of the first and second jaws with respect to the die;
a jaw path calculating unit calculating respective paths of the relative positions and orientations of the first and second jaws with respect to the die when the workpiece is wrapped onto the die by moving the die in a vertical direction under a restricting condition that respective positions and orientations of the first and second jaws are freely changeable except for movement in a vertical direction being regulated and rotation around a rotation center line being regulated, the rotation center line extending in a direction that is a horizontal direction orthogonal to a jaw facing direction; and
a control axis operation pattern calculating unit calculating respective operation patterns of the plurality of the control axes achieving the respective paths of the relative positions and orientations of the first and

second jaws with respect to the die calculated by the jaw path calculating unit.

[0009] According to a third aspect of the present invention, there is provided the stretch forming system according to the first or second aspect, wherein the jaw path calculating unit calculates the respective paths of the relative positions and orientations of the first and second jaws with respect to the die by using a workpiece having a thickness thinner than the thickness of the actual workpiece.

[0010] According to a fourth aspect of the present invention, there is provided the stretch forming system according to any one of the first to third aspect, further comprising a die movement amount calculating unit calculating first and second intersections between the respective paths of the relative positions of the first and second jaws with respect to the die calculated by the jaw path calculating unit and respective tangent lines at the both end edge portions of a forming surface of the die,

the die movement amount calculating unit calculating first and second vertical direction distances from the calculated first and second respective intersections to an apex of the die,

the die movement amount calculating unit comparing the calculated first and second vertical direction distances with each other to determine the greater one as a relative vertical-direction movement amount of the die with respect to the first and second jaws.

[0011] According to a fifth aspect of the present invention, there is provided a stretch forming method of using first and second jaws clamping a workpiece at respective end edge portions opposite to each other, a die disposed between the first and second jaws and coming into contact with the workpiece, and a plurality of control axes changing relative positions and orientations of the first and second jaws with respect to the die to wrap the workpiece onto the die by the first and second jaws for forming, the method including

calculating respective paths of the relative positions and orientations of the first and second jaws with respect to the die when the workpiece is wrapped onto the die by moving the die in a vertical direction under a restricting condition that the respective positions and orientations of the first and second jaws are freely changeable except for movement in a vertical direction being regulated, and calculating respective operation patterns of the plurality of the control axes achieving the calculated respective paths of the relative positions and orientations of the first and second jaws with respect to the die.

[0012] According to a sixth aspect of the present invention, there is provided a stretch forming method of using first and second jaws clamping a workpiece at respective end edge portions opposite to each other, a die disposed between the first and second jaws and coming into contact with the workpiece, and a plurality of control axes changing relative positions and orientations of the first and second jaws with respect to the die to wrap the workpiece onto the die by the first and second jaws for forming, the method including

calculating respective paths of the relative positions and orientations of the first and second jaws with respect to the die when the workpiece is wrapped onto the die by moving the die in a vertical direction under a restricting condition that the respective positions and orientations of the first and second jaws are freely changeable except for movement in a vertical direction being regulated and rotation around a rotation center line being regulated, the rotation center line extending in a direction that is a horizontal direction orthogonal to a jaw facing direction, and calculating respective operation patterns of the plurality of the control axes achieving the calculated respective paths of the relative positions and orientations of the first and second jaws with respect to the die.

Effect of the Invention

[0013] The present invention enables the calculation of the paths of the relative positions and orientations of the jaws with respect to the die, i.e., the respective operation patterns of the multiple control axes, necessary for acquiring a favorable formed product from the stretch forming on behalf of an operator in a short period of time. As a result, the burden of the operator can be reduced.

BRIEF DESCRIPTION OF DRAWINGS

[0014] These aspects and features of the present invention will be apparent from the following description related to preferable embodiments with regard to the accompanied drawings. The drawings are as follows.

Fig. 1 is a model diagram of a configuration of control axes of a stretch forming apparatus included in a stretch forming system according to an embodiment of the present invention.

Fig. 2 is a schematic perspective view of jaws and a die of the stretch forming apparatus depicted in Fig. 1.

Figs. 3A-3D are diagrams for explaining a flow of exemplary stretch forming.

Fig. 4 is a schematic configuration diagram of a control program creating apparatus creating a control program for automatically controlling the operations of the control axes.

Figs. 5A and 5B are diagrams for explaining the paths of the jaws calculated by a jaw path calculating unit.

Fig. 6 is a diagram for explaining a die rise amount calculated by a die movement amount calculating unit.

Figs. 7A and 7B are diagrams for explaining another stretch forming.

Fig. 8 is a diagram for explaining yet another stretch forming.

Fig. 9 is a diagram for explaining further stretch forming.

MODES FOR CARRYING OUT THE INVENTION

[0015] Fig. 1 is a schematic of a configuration of a stretch forming apparatus included in a stretch forming system according to an embodiment of the present invention.

[0016] As shown in Fig. 1, a stretch forming apparatus 10 has two jaws J_L, J_R opposite to each other and a die D. As shown in Fig. 2, which is a schematic perspective view of the jaws J_L, J_R and the die D, the jaws J_L, J_R are configured to clamp a plate-shaped workpiece W in the thickness direction at respective end edge portions opposite to each other. The die D is disposed between the jaws J_L, J_R and is configured to come into contact with the workpiece W from below. The die D includes a curved forming surface Ds coming into contact with the workpiece W.

[0017] The stretch forming apparatus 10 has a system coordinate system ΣS defined by an X axis, a Y axis, and a Z axis orthogonal to each other. An X direction and a Y direction are horizontal directions and a Z direction is a vertical direction.

[0018] The die D is has a die coordinate system ΣD defined by an X_D axis, a Y_D axis, and a Z_D axis orthogonal to each other as shown in Figs. 1 and 2.

[0019] The respective jaws J_L, J_R have jaw coordinate systems ΣJ_L, ΣJ_R defined as orthogonal coordinate systems as shown in Figs. 1 and 2. The origins of the jaw coordinate systems ΣJ_L, ΣJR are located at reference points R_{JL}, R_{JR} of the jaws J_L, J_R positioned at the grip centers of the workpiece W of the jaws J_L, J_R. When the jaws J_L, J_R clamp the workpiece W in the thickness direction thereof, the reference points R_{JL}, R_{JR} are located at the centers of the portions of the workpiece W clamped by the jaws J_L, J_R and the surfaces of the portions of the workpiece W clamped by the jaws J_L, J_R are orthogonal to a Z_{JL} axis and a Z_{JR} axis.

[0020] The stretch forming apparatus 10 also has control axes for the die for changing the position and orientation of the die D, which are a die elevating/lowering axis J_{D1} for elevating and lowering the die D in the vertical direction (Z direction) relative to a base B of the stretch forming apparatus 10 and a die tilt axis J_{D2} for rotating the die D around a rotation center line C_{D1} extending in parallel with the X axis.

[0021] The stretch forming apparatus 10 also has control axes for the jaw J_L changing the position and orientation of the jaw J_L, which are, in the order from the base B of the stretch forming apparatus 10 to the jaw J_L, a carriage axis J_{L1} for stroking the jaw J_L in parallel with the X axis, an angulation axis J_{L2} for rotating the jaw J_L around a rotation center line C_{L1} extending in parallel with the Z axis, a slider axis J_{L3} for stroking the jaw J_L in the horizontal direction (parallel with an X-Y plane), a swing axis J_{L4} for rotating the jaw J_L around a rotation center line C_{L2} extending in parallel with the stroke direction of the slider axis J_{L3}, a tension axis J_{L5} for stroking the jaw J_L in the linear direction orthogonal to the rotation center line C_{L2} of the swing axis J_{L4}, and a rotation axis J_{L6} for rotating the jaw J_L around a rotation center line C_{L3} extending in the stroke direction of the tension axis J_{L5}. The stroke direction of the tension axis J_{L5} matches the X_{JL} direction of the jaw coordinate system ΣJ_L.

[0022] Similarly, the stretch forming apparatus 10 also has control axes for the jaw J_R for changing the position and orientation of the jaw J_R, which are, in the order from the base B of the stretch forming apparatus 10 to the jaw J_R, a carriage axis J_{R1} for stroking the jaw J_R in parallel with the X axis, an angulation axis J_{R2} for rotating the jaw J_R around a rotation center line C_{R1} extending in parallel with the Z axis, a slider axis J_{R3} for stroking the jaw J_R in the horizontal direction (parallel with the X-Y plane), a swing axis J_{R4} for rotating the jaw J_R around a rotation center line C_{R2} extending in parallel with the stroke direction of the slider axis J_{R3}, a tension axis J_{R5} for stroking the jaw J_R in the linear direction orthogonal to the rotation center line C_{R2} of the swing axis J_{R4}, and a rotation axis J_{R6} for rotating the jaw J_R around a rotation center line C_{R3} extending in the stroke direction of the tension axis J_{R5}. The stroke direction of the tension axis J_{R5} matches the X_{JR} direction of the jaw coordinate system ΣJ_R.

[0023] Because of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} as described above, the jaws J_L, J_R can have six degrees of freedom in the die coordinate system ΣD. In other words, the jaws J_L, J_R can move in parallel in the X_D, Y_D, and Z_D directions of the die coordinate system ΣD and can rotate around the X_D, Y_D, and Z_D axes.

[0024] Additionally, the stretch forming apparatus 10 has a control unit (not shown) controlling the 14 control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6}. Specifically, the stretch forming apparatus 10 has driving cylinders (not shown) driving the control axes for the respective control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} and the control unit controls the driving cylinders.

[0025] The driving cylinders driving the control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} are fluid pressure cylinders (e.g., hydraulic cylinders) and an oil pressure is supplied to each of a rod-side cylinder chamber and a head-side cylinder chamber adjacent across a piston. The control unit controls hydraulic system constituent elements such as an electromagnetic valve and a hydraulic pump (not depicted) to adjust the respective oil pressures supplied to the rod-side cylinder chamber and the head-side cylinder chamber, thereby controlling the respective driving cylinders of the control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6}.

[0026] The control unit of the stretch forming apparatus 10 is configured to provide to the driving cylinders the position control for controlling a piston position or the pressure control for controlling a cylinder output. The stretch forming apparatus 10 is configured such that an operator can select whether the position control or the pressure control of the driving cylinder is provided, for each of the control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6}.

[0027] The rotation axes such as the die tilt axis J_{D2}, the angulation axes J_{L2}, J_{R2}, the swing axes J_{L4}, J_{R4}, and the rotation axes J_{L6}, J_{R6} are used for rotating the die D and the jaws J_L, J_R within a predetermined angular range via crank mechanisms by advance and retreat of rods of the driving cylinders. When the control unit provides the position control of the driving cylinders, the angular positions of the die and the jaws are controlled around the rotation center lines of the rotation axes. Alternatively, when the control unit provides the pressure control of the driving cylinders, the torque of the rotation axes is controlled.

[0028] The translation axes such as the die elevating/lowering axis J_{D1}, the carriage axes J_{L1}, J_{R1}, the slider axes J_{L3}, J_{R3}, and the tension axes J_{L5}, J_{R5} are used for stroking the die D and the jaws J_L, J_R within a predetermined range by advance and retreat of the driving cylinders. When the control unit provides the position control of the driving cylinders, the positions of the die and the jaws are controlled within the stroke ranges of the translation axes. Alternatively, when the control unit provides the pressure control of the driving cylinders, the thrust force of the translation axes is controlled.

[0029] As a result of operation of each of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} as described above, the relative positions and orientations of the jaws J_L, J_R are changed with respect to the die D and the workpiece W is consequently wrapped onto the forming surface Ds of the die D and is stretch-formed (formed).

[0030] For example, first, as depicted in Fig. 3A, the jaws J_L, J_R hold the workpiece W in a horizontally extending orientation. The jaws J_L, J_R are in a horizontal orientation such that the stroke directions of the tension axes C_{L5}, C_{R5} of the jaws J_L, J_R (i.e., the X_{JL} and X_{JR} directions) match the horizontal direction.

[0031] In this case, the load control of the tension axes C_{L5}, C_{R5} of the jaws J_L, J_R (the pressure control of the cylinders thereof) may be provided to stretch the workpiece W by a predetermined amount, for example, about 1 % of a workpiece length (the length of the workpiece W in the X direction shown in Fig. 2) (hereinafter, such a stretch is referred to as "pre-stretch").

[0032] As shown in Fig. 3B, the die D then rises and the forming surface Ds comes into contact with the workpiece W.

[0033] Subsequently, as shown in Fig. 3C, while the die D is rising, the positions and orientations of the respective jaws J_L, J_R are changed to wrap the workpiece W onto the forming surface Ds of the die D. The orientations of the jaws J_L, J_R are changed such that the stroke directions of the tension axes J_{L5}, J_{R5} (i.e., the X_{JL} and X_{JR} directions) match the extending directions of the workpiece W (i.e., the directions of the workpiece W extending from the die D toward the jaws J_L, J_R). Therefore, for example, respective angle sensors are disposed on the jaws J_L, J_R to detect angles between the main bodies of the jaws J_L, J_R and portions of the workpiece W extending from the jaws J_L, J_R. The orientations of the jaws J_L, J_R are changed such that the angle sensors continuously detect the angles at which the stroke directions of the tension axes J_{L5}, J_{R5} match the extending directions of the workpiece W.

[0034] In this case, the workpiece W may be wrapped onto the die D while the workpiece W is stretched by the jaws J_L, J_R. For example, the load control of the tension axes J_{L5}, J_{R5} of the jaws J_L, J_R (the pressure control of the cylinders thereof) is provided to stretch the workpiece W by about 1 % of the workpiece length from the start to the end of wrapping (hereinafter, such a stretch is referred to as "wrapping-time stretch").

[0035] As shown in Fig. 3D, when the jaws J_L, J_R arrive on tangent lines at the end edge portions of the forming surface Ds of the workpiece W and the workpiece W comes into contact with the entire forming surface Ds of the die D, the stretch forming is completed. After the workpiece W comes into contact with the entire forming surface Ds of the die D, the load control of the tension axes C_{L5}, C_{R5} of the jaws J_L, J_R (the pressure control of the cylinders thereof) may be provided to stretch the workpiece W by a predetermined amount, for example, about 1 % of the workpiece length (hereinafter, such a stretch is referred to as "post-stretch").

[0036] The stretch forming system of this embodiment including the stretch forming apparatus 10 is configured such that the exemplary stretch forming shown in Figs. 3A-3D can be performed by an operator manually operating the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} or by automatically controlling the operations of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6}. To automatically control the operations of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6}, the stretch forming system of this embodiment is configured such that a control program can be created for automatically controlling the operations of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6}. The creation of the control program for automatically controlling the operations of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} will hereinafter be described.

[0037] To acquire a favorable formed product after the end of the stretch forming, the operator must devise paths (changes) of the relative positions and orientations of the jaws J_L, J_R with respect to the die D (hereinafter referred to as "paths of the jaws J_L, J_R") such that the workpiece W is prevented from wrinkling, that the thickness of the workpiece W is substantially uniformly changed across the entire part, and that no gap is generated between the workpiece W and the die D. The operator must also devise the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} achieving the paths of the jaws J_L, J_R. However, this is time-consuming and therefore a burden for the operator, and is difficult unless the operator is skilled.

[0038] Therefore, the stretch forming system of this embodiment is configured to calculate the paths of the jaws J_L, J_R necessary for acquiring a favorable formed product. The stretch forming system is also configured to calculate the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} necessary for achieving the calculated paths of the jaws J_L, J_R. The stretch forming system is configured to create a control program for operating the respective control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} in the calculated operation patterns.

[0039] Fig. 4 schematically shows configuration of a control program creating apparatus included in the stretch forming system of this embodiment. The control program creating apparatus is made up of a personal computer in which software for creating the control program is installed, for example. A method of creating the control program will hereinafter be described while describing the configuration of the control program creating apparatus.

[0040] As shown in Fig. 4, a control program creating apparatus 50 has a forming condition acquiring unit 52, a jaw path calculating unit 54, a die movement amount calculating unit 56, a control axis operation pattern calculating unit 58, an FEM analyzing unit 60, and a control program creating unit 62.

[0041] The forming condition acquiring unit 52 is configured to acquire from the operator the forming conditions required for performing the stretch forming by wrapping the workpiece W onto the die D. For example, if the control program creating apparatus 50 is made up of a personal computer, the forming conditions are acquired from the operator via input devices such as a mouse and a keyboard and graphic user interfaces such as a display.

[0042] The forming conditions acquired by the forming condition acquiring unit 52 from the operator include, for example, a shape of the die D, a shape of the workpiece W, a material (mechanical property) of the workpiece W, an initial position and an initial orientation of the workpiece W, initial positions and initial orientations of the respective jaws J_L and J_R, a pre-stretch amount (a stretch amount due to the pre-stretch), a wrapping-time stretch amount (a stretch amount due to a stretch at the time of wrapping), and a post-stretch amount (a stretch amount due to the post-stretch). The initial positions and the initial orientations in this case refer to the start positions and the start orientations at the start of wrapping of the workpiece W onto the die D.

[0043] The jaw path calculating unit 54 is configured to perform simulation using a model of the stretch forming apparatus 10 based on the forming conditions acquired by the forming condition acquiring unit 52 from the operator so as to calculated the paths of the jaws J_L, J_R necessary for acquiring a favorable formed product, i.e., necessary for favorably wrapping the workpiece W onto the forming surface Ds of the die D.

[0044] The jaw path calculating unit 54 will be described. First, as shown in Figs. 3A-3B, the respective positions and orientations of the jaws J_L, J_R are changed during the stretch forming while raising the die D. This is performed such that the workpiece W is prevented from wrinkling, that the thickness of the workpiece W is substantially uniformly changed across the entire part, and that no gap is generated between the workpiece W and the die D. The following method is conceivable as a method of calculating the paths of the jaws J_L, J_R achieving this stretch forming.

[0045] For example, while variously changing parameters such as the initial position, the initial orientation, and the rise speed of the die D and the initial positions, the initial orientations, the change speeds of positions, and the change speeds of orientations of the jaws J_L and J_R, the deformation behavior of the corresponding workpiece W is calculated by FEM (finite element method) analysis each time the parameters are changed. This is performed until the parameter values of the favorable deformation behavior of the workpiece W are found out.

[0046] However, such a trial-and-error method requires a considerable time for calculating the paths of the jaws J_L, J_R necessary for acquiring a favorable formed product.

[0047] Therefore, the inventors considered the following details.

[0048] First, the inventors thought that if the die D is in contact with the workpiece W held by the jaws J_L, J_R as shown in Fig. 5A and is moved in the contact direction (the Z direction), the workpiece W is favorably wrapped onto the forming surface Ds of the die D as shown in Fig. 5B, given that the movement of the jaws J_L, J_R is regulated only in the movement direction of the die D (the Z direction). In particular, the inventors thought that the workpiece W is naturally wrapped onto the forming surface Ds of the die D without wrinkling, with the thickness of the workpiece W uniformly changed across the entire part, and without a gap generated between the workpiece W and the die D.

[0049] Specifically, the inventors thought that if the jaws J_L, J_R are in a free state except the movement in the Z direction, since the positions and orientations of the jaws J_L, J_R are freely changed while the workpiece W is being wrapped onto the forming surface Ds due to the movement of the die D in the Z direction, the workpiece W is not significantly locally stretched (almost no local distortion is generated). Therefore, the inventors thought that the workpiece W is favorably wrapped onto the forming surface Ds of the die D such that a wrinkle is hardly generated, that the thickness of the workpiece W is substantially uniformly changed across the entire part, and that almost no gap is generated between the workpiece W and the die D.

[0050] Thus, the inventors thought that when the workpiece W is wrapped onto the die D by moving the die D while the jaws J_L, J_R are in a free state except the movement in the Z direction, generated paths P_{JL}, P_{JR} (dashed-two dotted lines) of the jaws J_L, J_R correspond to the paths of the jaws J_L, J_R necessary for acquiring a favorable formed product.

[0051] Moreover, the inventors thought that the paths

P_{JL}, P_{JR} of the jaws J_L, J_R necessary for acquiring a favorable formed product can be calculated based on this idea in a shorter time as compared to the trial-and-error method.

[0052] Based on such considerations by the inventors, the jaw path calculating unit 54 is configured to perform the simulation (wrapping simulation) in which, under the restricting condition that the positions and orientations of the jaws J_L, J_R can freely be changed except for the movement in the vertical direction (Z direction) being regulated, the workpiece W is wrapped onto the forming surface Ds of the die D by moving the die D in the vertical direction while the die D is in contact with the workpiece W held by the jaws J_L, J_R. The jaw path calculating unit 54 is configured to calculate the paths P_{JL}, P_{JR} of the jaws J_L, J_R based on a result of the wrapping simulation.

[0053] Specifically, the jaw path calculating unit 54 performs the wrapping simulation based on the forming conditions acquired by the forming condition acquiring unit 52 under the restricting condition regulating only the movement of the reference points R_{JL}, R_{JR} of the jaws J_L, J_R in the Z direction. For example, if the pre-stretch amount given as the forming condition is 2 %, the wrapping simulation is performed by using a model of the workpiece W stretched by 2 %.

[0054] The jaw path calculating unit 54 is configured to perform the wrapping simulation by using the workpiece W (model) having a thickness thinner than the thickness of the actual workpiece W. This is because when the thickness of the workpiece W is thinner, since the resistance during bending is less generated (the bending rigidity of the workpiece W is smaller), the workpiece W is more easily deformed with smaller distortion and, therefore, the workpiece W more easily comes into contact with the forming surface Ds of the die D (a gap is less generated) across the entire part. In other words, when the thickness of the workpiece W is thinner, the ideal paths P_{JL}, P_{JR} of the jaws J_L, J_R can be calculated such that the workpiece W comes into close contact with the forming surface Ds of the die D across the entire thereof.

[0055] The jaw path calculating unit 54 is configured to perform the wrapping simulation in which the die D is moved in the Z direction by a maximum movable amount to wrap the workpiece W onto the forming surface Ds of the die D. This is because the workpiece W is certainly wrapped onto the forming surface Ds of the die D across the entire thereof.

[0056] The jaw path calculating unit 54 may be configured to perform the wrapping simulation under the restricting condition that the friction coefficient is maximized between the workpiece W and the forming surface Ds of the die D. As a result, the workpiece W is restrained from slipping on the forming surface Ds of the die D in the wrapping simulation. Therefore, the wrapping simulation can be executed under the condition close to the actual apparatus. As a result, the paths P_{JL}, P_{JR} of the jaws J_L, J_R necessary for acquiring a favorable formed product can more accurately be calculated.

[0057] Additionally, the jaw path calculating unit 54 is configured to output a result of the wrapping simulation to an operator. This allows the operator to determine whether the result of the wrapping simulation is favorable.

[0058] For example, a display presents the positions and orientations of the jaws J_L, J_R, the position and orientation of the die D, the position, orientation, and shape of the workpiece W after the wrapping simulation as a result of the wrapping simulation. This enables the operator to confirm whether the favorable paths P_{JL}, P_{JR} of the jaws J_L, J_R are calculated by the control program creating apparatus 50 based on the result of the wrapping simulation. If the wrapping simulation result is not favorable because of, for example, an abnormality of the shape of the workpiece W or an absence of contact between the workpiece W and the end edge portions of the forming surface Ds of the die D, the operator can properly change the forming conditions such as the initial positions and the initial orientations of the jaws J_L, J_R and the die D.

[0059] If the operator determines that the wrapping simulation result is favorable, i.e., if the operator performs a corresponding operation to, for example, the input device such as a mouse and a keyboard, the paths P_{JL}, P_{JR} of the jaws J_L, J_R calculated by the jaw path calculating unit 54 are fixed.

[0060] Returning to Fig. 4, the die movement amount calculating unit 56 of the control program creating apparatus 50 is configured to calculate the Z-direction movement amount of the die D based on the paths P_{JL}, P_{JR} of the jaws J_L, J_R calculated by the jaw path calculating unit 54 (determined as being favorable by the operator).

[0061] As described above, the paths P_{JL}, P_{JR} of the jaws J_L, J_R calculated by the jaw path calculating unit 54 are the paths when the die D is moved in the Z direction by the maximum movable amount. This is because the paths P_{JL}, P_{JR} of the jaws J_L, J_R are obtained such that the workpiece W is certainly wrapped onto the entire forming surface Ds of the die D.

[0062] However, if the relative positions and orientations of the jaws J_L, J_R are changed with respect to the die D in accordance with the paths P_{JL}, P_{JR} of the jaws J_L, J_R as described above, the workpiece W may excessively be wound beyond the forming surface Ds of the die D as shown in Fig. 5B. From another viewpoint, the die D may move more than necessary in the Z direction. Actually, as depicted in Fig. 3(D), if the die D is at least moved in the Z direction such that the jaws J_L, J_R arrive on the tangent lines at the end edge portions of the forming surface Ds of the workpiece W, the workpiece W is wound onto the entire forming surface Ds. Therefore, the die movement amount calculating unit 56 is configured to calculate the Z-direction movement amount of the die D minimally required for winding the workpiece W onto the entire forming surface Ds of the die D.

[0063] Fig. 6 is a diagram for explaining a method of calculating a Z-direction movement amount of the die D. Fig. 6 shows a cross section of the die D parallel to the

Z-X plane. Points $P_{JL}(S)$ and $P_{JR}(S)$ indicate the starting points of the paths P_{JL}, P_{JR} of the jaws J_L, J_R. Therefore, the starting points $P_{JL}(S)$ and $P_{JR}(S)$ indicate the positions of the reference points R_{JL}, R_{JR} of the jaws J_L, J_R before starting the stretch forming. On the other hand, points $P_{JL}(F)$, $P_{JR}(F)$ indicate the ending points of the paths P_{JL}, P_{JR} of the jaws J_L, J_R. Therefore, the ending points $P_{JL}(F)$, $P_{JR}(F)$ indicate the positions of the reference points R_{JL}, R_{JR} of the jaws J_L, J_R after ending the stretch forming.

[0064] Dashed-dotted lines T_L, T_R indicate the tangent lines at the respective end edge portions of the forming surface Ds of the die D on the Z-X plane. Points C_L, C_R indicate intersections between the paths P_{JL}, P_{JR} of the jaws J_L, J_R and the tangent lines T_L, T_R (corresponding to "first and second intersections" of the claims).

[0065] A Z-direction distance (corresponding to a "first vertical direction distance" of the claims) H_L between the intersection C_L and an apex (a point at the maximum height position of the forming surface Ds) D_T of the die D corresponds to the Z-direction movement amount of the die D minimally required for a portion of the workpiece W closer to the jaw J_L to be wrapped onto the forming surface Ds of the die D. On the other hand, a Z-direction distance (corresponding to a "second vertical direction distance" of the claims) H_R between the intersection C_R and the apex D_T of the die D corresponds to the Z-direction movement amount of the die D minimally required for a portion of the workpiece W closer to the jaw J_R to be wrapped onto the forming surface Ds of the die D.

[0066] As shown in Fig. 6, the intersections C_L, C_R between the paths P_{JL}, P_{JR} of the jaws J_L, J_R and the tangent lines T_L, T_R at the both respective end edge portions of the forming surface Ds of the die D are not necessarily located at the same height position (Z-direction position). In other words, the Z-direction distances H_L, H_R may be different.

[0067] If the Z-direction distances H_L, H_R are different, the die D must be moved in the Z direction by the same movement amount as the larger Z-direction distance (H_R in Fig. 6) so as to wrap both the portion of the workpiece W closer to the jaw J_L and the portion of the workpiece W closer to the jaw J_R onto the forming surface Ds of the die D. If the die D is moved in the Z direction by the same movement amount as the smaller vertical direction distance H_L, the portion of the workpiece W closer to the jaw J_R cannot brought into contact with the end edge portion of the forming surface Ds of the die D.

[0068] Therefore, the die movement amount calculating unit 56 first calculates the intersections C_L, C_R between the paths P_{JL}, P_{JR} of the jaws J_L, J_R and the tangent lines T_L, T_R at the both respective end edge portions of the forming surface Ds of the die D based on the paths P_{JL}, P_{JR} of the jaws J_L, J_R calculated by the jaw path calculating unit 54 and the die shape acquired by the forming condition acquiring unit 52. The die movement amount calculating unit 56 then calculates the Z-direction distances H_L, H_R from the calculated intersections C_L, C_R to the apex D_T of the die D. The Z-direction distances H_L, H_R are compared to determine the greater one as the Z-direction movement amount of the die D.

[0069] The Z-direction movement amount of the die D may be calculated by using a straight line passing through two points on the end edge portions of the forming surface Ds of the die D as the tangent lines.

[0070] In the case of the die shape having a cross-sectional shape parallel to the Z-X plane differing depending on a Y-direction position, the Z-direction movement amount of the die D may be calculated by the following method. First, the intersections C_L, C_R are calculated between the paths P_{JL}, P_{JR} of the jaws J_L, J_R and the tangent lines T_L, T_R at the both respective end edge portions of the forming surface Ds of the die D in each of multiple Z-X planes at different Y-direction positions. A Z-direction distance is calculated between each of all the intersections C_L, C_R and the apex D_T of the die D. A maximum Z-direction distance is extracted from the multiple calculated Z-direction distances, and the extracted maximum Z-direction distance is defined as the Z-direction movement amount of the die D. As a result, even when the die shape has a cross-sectional shape parallel to the Z-X plane differing depending on a Y-direction position, the workpiece W can be wound onto the entire forming surface Ds of the die D.

[0071] The control axis operation pattern calculating unit 58 of the control program creating apparatus 50 is configured to calculate the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} based on the forming conditions acquired by the forming condition acquiring unit 52, the paths P_{JL}, P_{JR} of the jaws J_L, J_R calculated by the jaw path calculating unit 54, and the Z-direction movement amount of the die D calculated by the die movement amount calculating unit 58.

[0072] The control axis operation pattern calculating unit 58 calculates the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} for changing the respective positions and orientations of the jaws J_L, J_R and the die D, in accordance with the paths P_{JL}, P_{JR} of the jaws J_L, J_R from the respective initial positions and initial orientations of the jaws J_L, J_R and the die D acquired by the forming condition acquiring unit 52.

[0073] Specifically, the control axis operation pattern calculating unit 58 calculates the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} such that the Z-direction movement amount from the initial position of the die D becomes equal to the movement amount calculated by the die movement amount calculating unit 56 (e.g., the Z-direction distance H_R depicted in Fig. 6). Describing with reference to Fig. 6, the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} are calculated based on a portion of the path P_{JL} of the jaw J_L from the starting point $P_{JL}(S)$ to a point C_L' and a portion of the path P_{JR} of the jaw J_R from the starting point $P_{JR}(S)$ to the intersection C_R. The point C_L' is the point on the path P_{JL} at the same position as the Z-direction position of the intersection C_R as shown in Fig. 6.

[0074] If a post-stretch amount is given as the forming condition from the operator to the forming condition acquiring unit 52, the operation patterns of the control axes necessary for the post-stretch of the workpiece W by the post-stretch amount are added to the operation patterns of the control axes calculated based on the calculation results of the jaw path calculating unit 54 and the die movement amount calculating unit 56. The operation patterns of the tension axes J_{L5}, J_{R5} for stretching the workpiece W by the tension axes J_{L5}, J_{R5} are added such that the workpiece W is stretched by the post-stretch amount given from the operator after the workpiece W comes into contact with the entire forming surface Ds of the die D as shown in Fig. 3D.

[0075] If a wrapping-time stretch amount is given as the forming condition to the forming condition acquiring unit 52, the operation patterns of the control axes necessary for stretching the workpiece W by the wrapping-time stretch amount are added to the operation patterns of the control axes calculated based on the calculation results of the jaw path calculating unit 54 and the die movement amount calculating unit 56. The operation patterns of the tension axes J_{L5}, J_{R5} for stretching the workpiece W by the tension axes J_{L5}, J_{R5} are added such that the workpiece W is stretched by the wrapping-time stretch amount from the start to the end of wrapping of the workpiece W onto the forming surface Ds of the die D.

[0076] The FEM analyzing unit 60 of the control program creating apparatus 50 is configured to execute the FEM analysis of the workpiece W by using the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} calculated by the control axis operation pattern calculating unit 58.

[0077] Specifically, the FEM analyzing unit 60 is configured to use the FEM analysis to calculate the deformation behavior of the workpiece W generated by the stretch forming apparatus 10 performing the stretch forming in accordance with the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} calculated by the control axis operation pattern calculating unit 58. The FEM analyzing unit 60 is configured to output the result of the FEM analysis to an operator via a display, for example. This allows the operator to determine whether the result of the FEM analysis is favorable.

[0078] For example, the operator can know a partial thickness and a strain amount of the workpiece W after the stretch forming (a formed product). This enables the operator to confirm whether favorable operation patterns are calculated for the respective control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6}. If the result of the FEM analysis is not favorable because of, for example, a significant local difference in the thickness or the strain amount, the operator can properly change the forming conditions such as a pre-stretch amount.

[0079] If the operator determines that the result of the FEM analysis is favorable, i.e., if the operator performs a corresponding operation to, for example, the input device such as a mouse and a keyboard, the respective operation patterns of the control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} calculated by the control axis operation pattern calculating unit 58 are fixed.

[0080] The control program creating unit 62 of the control program creating apparatus 50 is configured to create a control program for automatically controlling the respective operations of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} of the actual stretch forming apparatus 10 based on the respective operation patterns of the control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} calculated by the control axis operation pattern calculating unit 58 (determined as being favorable by the operator). The control program creating unit 62 is configured to output the created control program as data.

[0081] When the respective operations of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} are automatically controlled by the control program created as described above, the stretch forming apparatus 10 favorably and automatically winds the workpiece W onto the forming surface Ds of the die D. As a result, a favorable formed product is fabricated.

[0082] This embodiment enables the calculation of the paths of the relative positions and orientations of the respective jaws J_L, J_R with respect to the die D necessary for acquiring a favorable formed product from the stretch forming, i.e., the respective operation patterns of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6}, in a short time. As a result, a burden of the operator can be reduced.

[0083] Although the present invention has been described with reference to the embodiment described above, the present invention is not limited thereto.

[0084] For example, in the case of the embodiment described above, as shown in Figs. 3A-3D, the orientations of the jaws J_L, J_R are changed such that the stroke directions (X_{JL} and X_{JR} directions) of the tension axes J_{L5}, J_{R5} match the extending directions of the workpiece W (the directions of the workpiece W extending from the die D toward jaws J_L, J_R) while the stretch forming is performed. However, the present invention is not limited thereto.

[0085] For example, as shown in Fig. 7A, the jaws J_L, J_R are in an orientation (horizontal orientation) with the stroke directions of the tension axes J_{L5}, J_{R5} (the X_{JL} and X_{JR} directions) matching the horizontal direction and hold the workpiece W in a horizontally extending orientation. While the jaws J_L, J_R are maintained in the horizontal orientation, the die D is moved in the vertical direction (Z direction) and the workpiece is wound onto the forming surface Ds of the die D as shown in Fig. 7B.

[0086] In this case, the jaw path calculating unit 54 of the control program creating apparatus 50 regulates the movement of the jaws J_L, J_R in the Z direction and additionally regulates the rotation around rotation center lines extending in the directions that are horizontal directions orthogonal to jaw facing directions (i.e., Y_{JL} and Y_{JR} directions) to calculate the paths P_{JL}, P_{JR} of the relative positions and orientations of the jaws J_L, J_R with respect to the die D. As a result, even when the jaws J_L, J_R are maintained in the horizontal orientation during the stretch forming, the control program can be created that automatically controls the respective operations of the multiple control axes J_{D1} to J_{D2}, J_{L1} to J_{L6}, J_{R1} to J_{R6} necessary for achieving a favorable formed product.

[0087] In the case of the embodiment described above, as shown in Fig. 2, the forming surface Ds of the die D is in a curved shape, the present invention is not limited thereto. For example, a flat surface such as a forming surface Ds' of a die D' as depicted in Fig. 8 may be available. The present invention is applicable to any dies including a forming surface allowing a workpiece to wrap thereon.

[0088] In the case of the embodiment described above, the plate-shaped workpiece W wrapped onto the die D is in a flat plate shape, the present invention is not limited thereto. For example, as in the case of a workpiece W' shown in Fig. 9, the workpiece may be in a curved shape curving in a direction A2 orthogonal to a jaw facing direction A1, instead of a flat plate shape. In this case, the jaws are so-called curved jaws capable of clamping the curved workpiece W' at the end edge portions opposite to each other.

[0089] Additionally, although the present invention has been described by taking as an example the stretch forming in which the die D is moved in the Z direction by the movement amount calculated by the die movement amount calculating unit 56 of the control program creating apparatus 50 without moving the jaws J_L, J_R in the vertical direction (Z direction), the present invention is not limited thereto. The Z-direction movement amount of the die D calculated by the die movement amount calculating unit 56 is, in other words, a relative Z-direction movement amount of the die D with respect to the jaws J_L, J_R, as depicted in Fig. 6. Therefore, it is only necessary that a total of the Z-direction movement amount of the die D and the Z-direction movement amount of the jaws J_L, J_R is equal to the movement amount calculated by the die movement amount calculating unit 56. Therefore, when the die D goes up in the Z direction while the jaws J_L, J_R go down in the Z direction, the workpiece W is wound onto the forming surface Ds of the die D.

[0090] Although the present invention has sufficiently been described in terms of preferable embodiments with reference to the accompanying drawings, various modifications and corrections are apparent for those skilled in the art. It should be understood that such modifications and corrections are included in the scope of the present invention unless the modifications and corrections depart from the scope of the present invention according to the accompanying claims.

[0091] The disclosure of the description, the drawings, and the claims of Japanese Patent Application No. 2012-229147 filed on October. 16, 2012 is incorporated by reference herein in its entirety.

Industrial Availability

[0092] The present invention is applicable to any stretch forming apparatuses having two jaws clamping a workpiece at respective end edge portions opposite to each other, a die disposed between the two jaws and coming into contact with the workpiece, and multiple control axes for changing the positions and orientations of the jaws and the die.

Claims

1. A stretch forming system comprising:

first and second jaws clamping a workpiece at respective end edge portions opposite to each other;
a die disposed between the first and second jaws and coming into contact with the workpiece; and
a plurality of control axes changing relative positions and orientations of the first and second jaws with respect to the die;
a jaw path calculating unit calculating respective paths of the relative positions and orientations of the first and second jaws with respect to the die when the workpiece is wrapped onto the die by moving the die in a vertical direction under a restricting condition that respective positions and orientations of the first and second jaws are freely changeable except for movement in a vertical direction being regulated; and
a control axis operation pattern calculating unit calculating respective operation patterns of the plurality of the control axes achieving the respective paths of the relative positions and orientations of the first and second jaws with respect to the die calculated by the jaw path calculating unit.

2. A stretch forming system comprising:

first and second jaws clamping a workpiece at respective end edge portions opposite to each other;
a die disposed between the first and second jaws and coming into contact with the workpiece; and
a plurality of control axes changing relative positions and orientations of the first and second jaws with respect to the die;
a jaw path calculating unit calculating respective paths of the relative positions and orientations of the first and second jaws with respect to the die when the workpiece is wrapped onto the die

by moving the die in a vertical direction under a restricting condition that respective positions and orientations of the first and second jaws are freely changeable except for movement in a vertical direction being regulated and rotation around a rotation center line being regulated, the rotation center line extending in a direction that is a horizontal direction orthogonal to a jaw facing direction; and
a control axis operation pattern calculating unit calculating respective operation patterns of the plurality of the control axes achieving the respective paths of the relative positions and orientations of the first and second jaws with respect to the die calculated by the jaw path calculating unit.

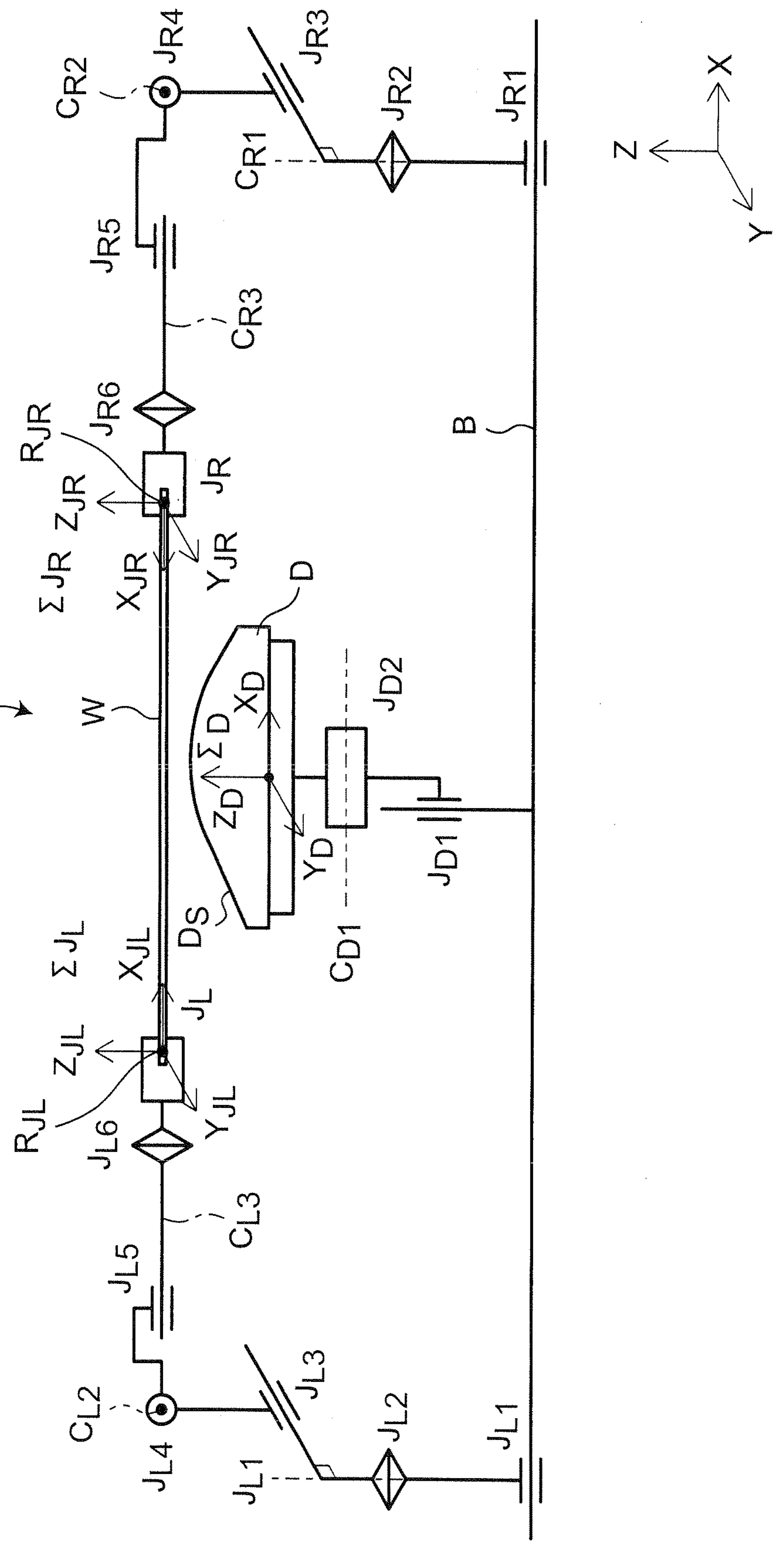
3. The stretch forming system according to claim 1 or 2, wherein the jaw path calculating unit calculates the respective paths of the relative positions and orientations of the first and second jaws with respect to the die by using a workpiece having a thickness thinner than the thickness of the actual workpiece.

4. The stretch forming system according to any one of claims 1 to 3, further comprising a die movement amount calculating unit calculating first and second intersections between the respective paths of the relative positions of the first and second jaws with respect to the die calculated by the jaw path calculating unit and respective tangent lines at the both end edge portions of a forming surface of the die,
the die movement amount calculating unit calculating first and second vertical direction distances from the calculated first and second respective intersections to an apex of the die,
the die movement amount calculating unit comparing the calculated first and second vertical direction distances with each other to determine the greater one as a relative vertical-direction movement amount of the die with respect to the first and second jaws.

5. A stretch forming method of using first and second jaws clamping a workpiece at respective end edge portions opposite to each other, a die disposed between the first and second jaws and coming into contact with the workpiece, and a plurality of control axes changing relative positions and orientations of the first and second jaws with respect to the die to wrap the workpiece onto the die by the first and second jaws for forming, the method including
calculating respective paths of the relative positions and orientations of the first and second jaws with respect to the die when the workpiece is wrapped onto the die by moving the die in a vertical direction under a restricting condition that the respective positions and orientations of the first and second jaws are freely changeable except for movement in a vertical direction being regulated, and
calculating respective operation patterns of the plurality of the control axes achieving the calculated respective paths of the relative positions and orientations of the first and second jaws with respect to the die.

6. A stretch forming method of using first and second jaws clamping a workpiece at respective end edge portions opposite to each other, a die disposed between the first and second jaws and coming into contact with the workpiece, and a plurality of control axes changing relative positions and orientations of the first and second jaws with respect to the die to wrap the workpiece onto the die by the first and second jaws for forming, the method including
calculating respective paths of the relative positions and orientations of the first and second jaws with respect to the die when the workpiece is wrapped onto the die by moving the die in a vertical direction under a restricting condition that the respective positions and orientations of the first and second jaws are freely changeable except for movement in a vertical direction being regulated and rotation around a rotation center line being regulated, the rotation center line extending in a direction that is a horizontal direction orthogonal to a jaw facing direction, and
calculating respective operation patterns of the plurality of the control axes achieving the calculated respective paths of the relative positions and orientations of the first and second jaws with respect to the die.

Fig. 1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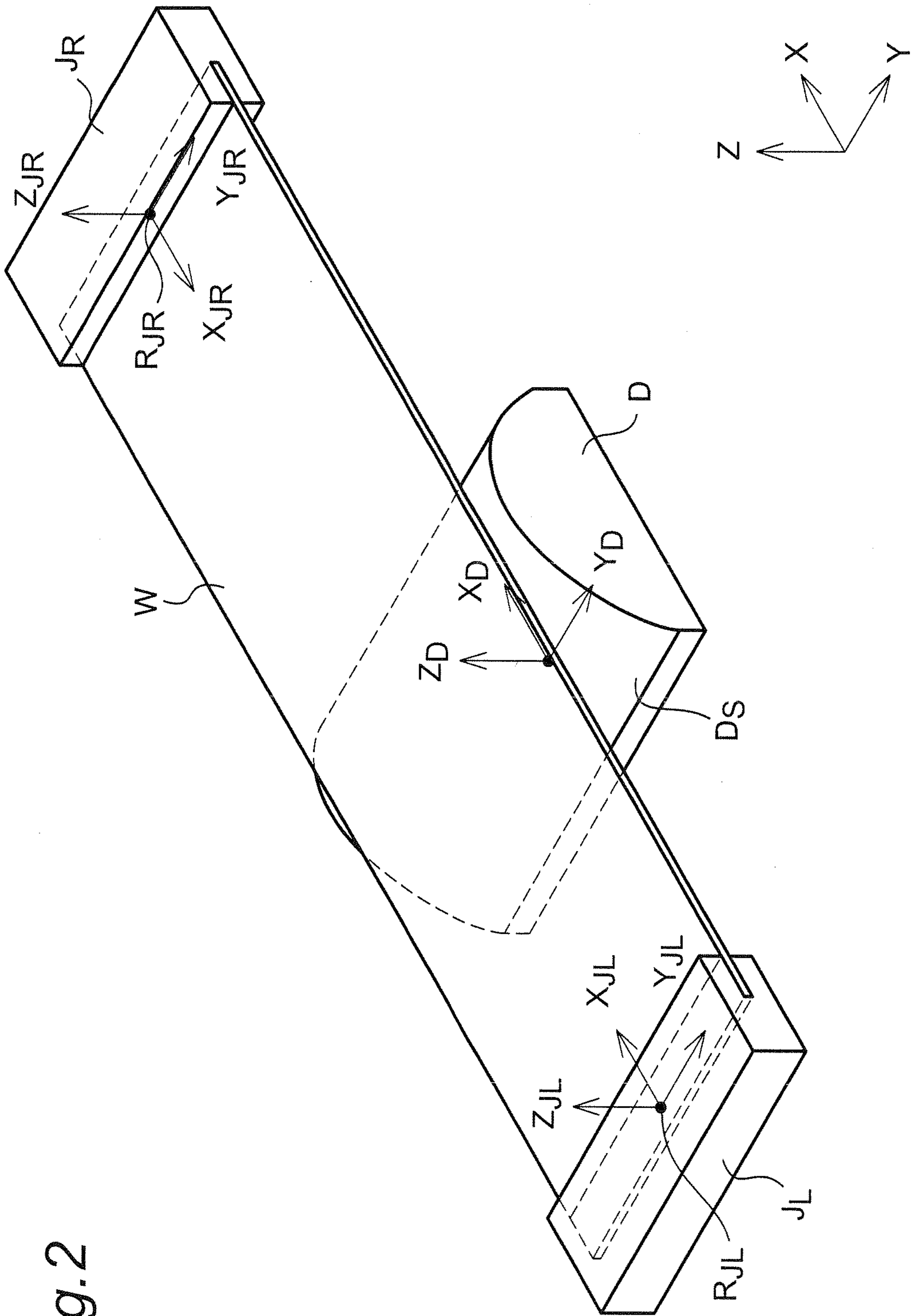


Fig.2

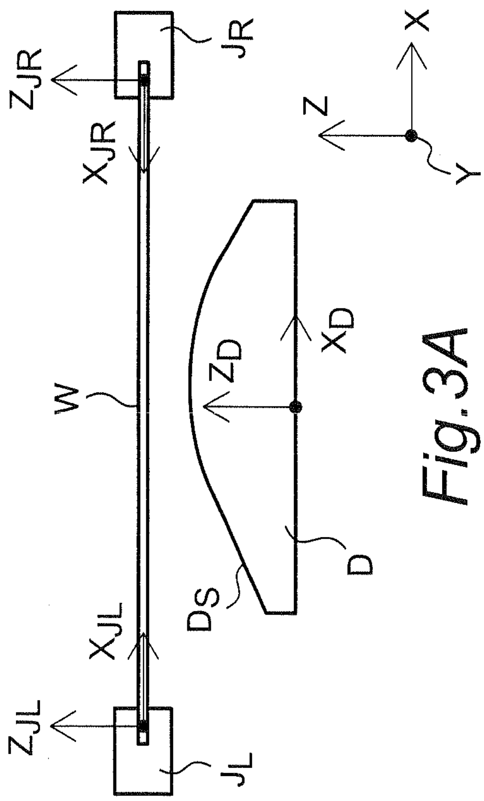


Fig.3A

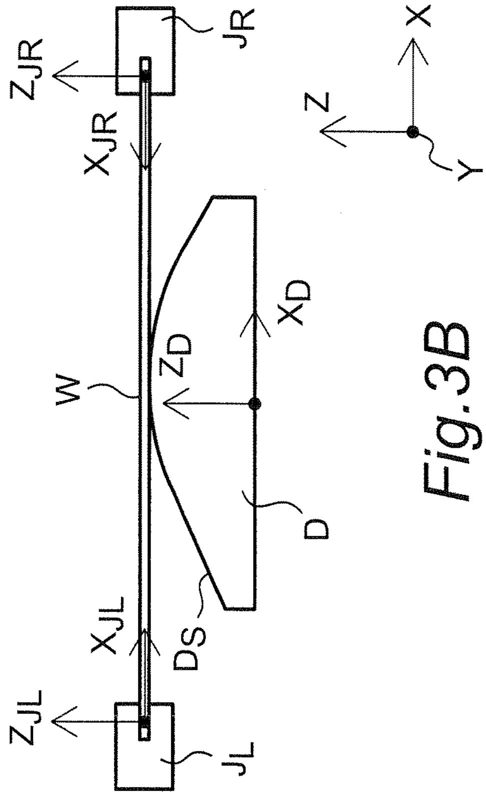


Fig.3B

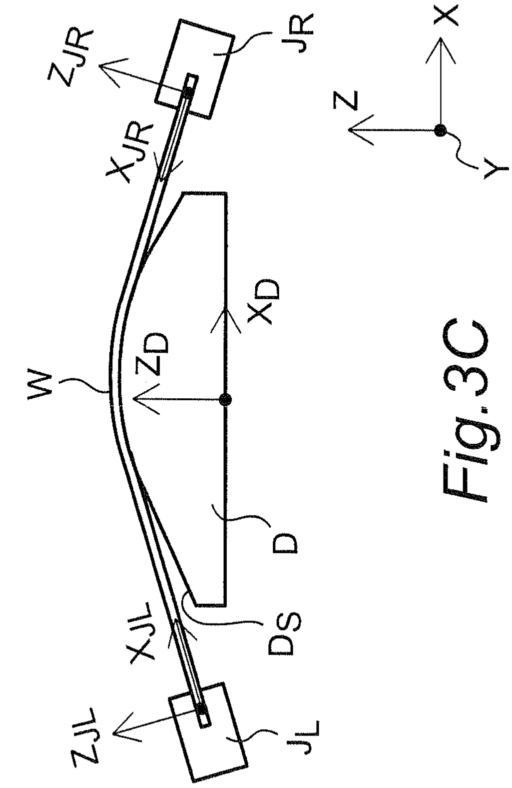


Fig.3C

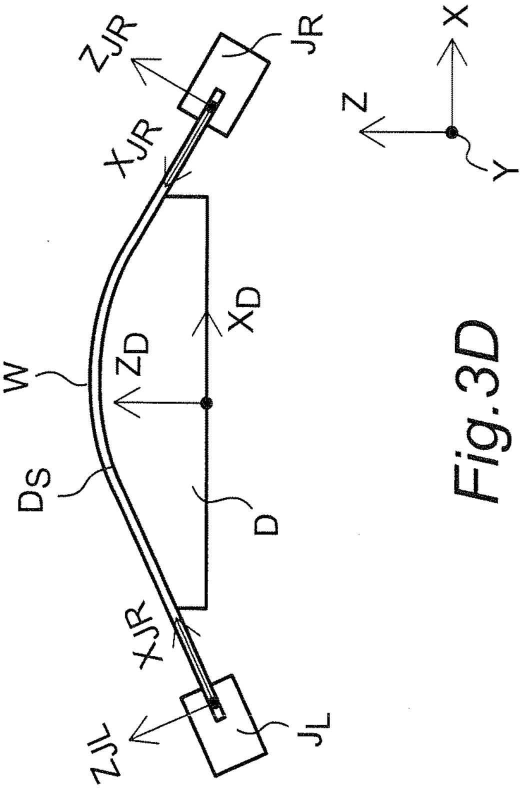
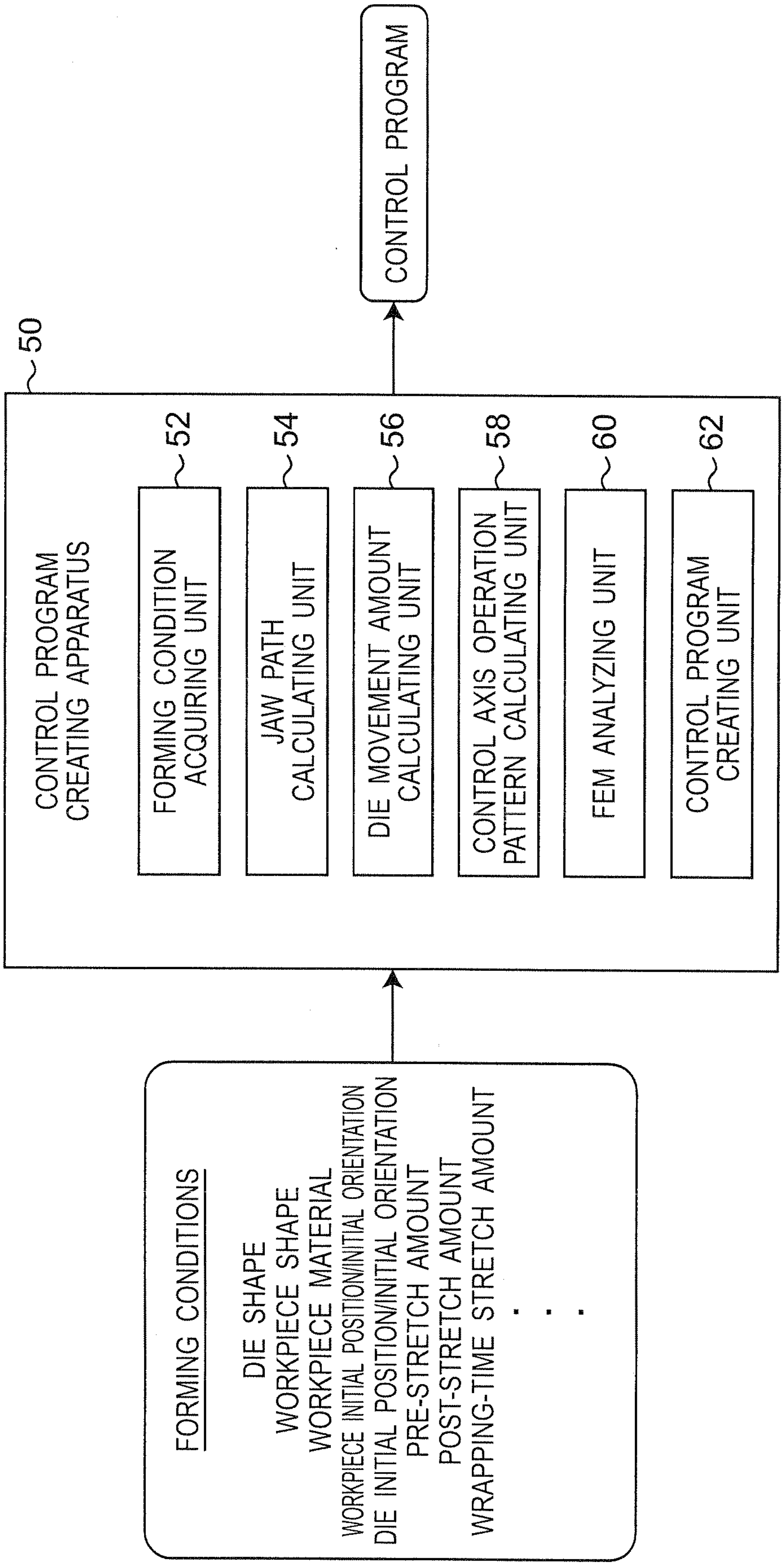


Fig.3D

Fig.4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WORKPIECE SHAPE
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PRE-STRETCH AMOUNT
POST-STRETCH AMOUNT
WRAPPING-TIME STRETCH AMOUNT
. . .
50
CONTROL PROGRAM CREATING APPARATUS
52
FORMING CONDITION ACQUIRING UNIT
54
JAW PATH CALCULATING UNIT
56
DIE MOVEMENT AMOUNT CALCULATING UNIT
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CONTROL PROGRAM

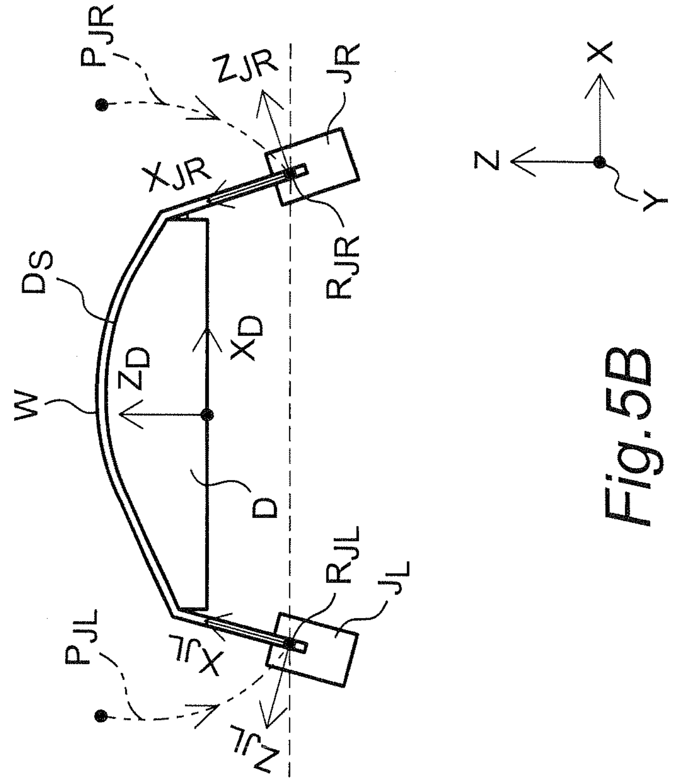
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Fig.5B

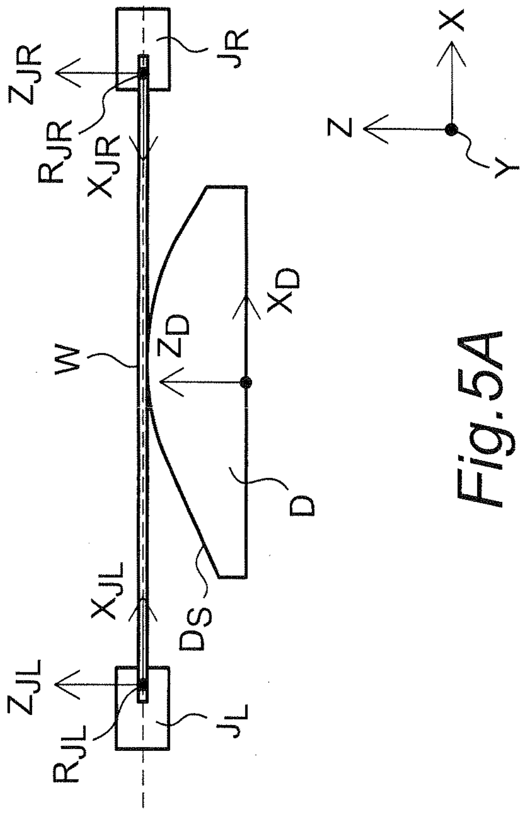
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Fig.5A

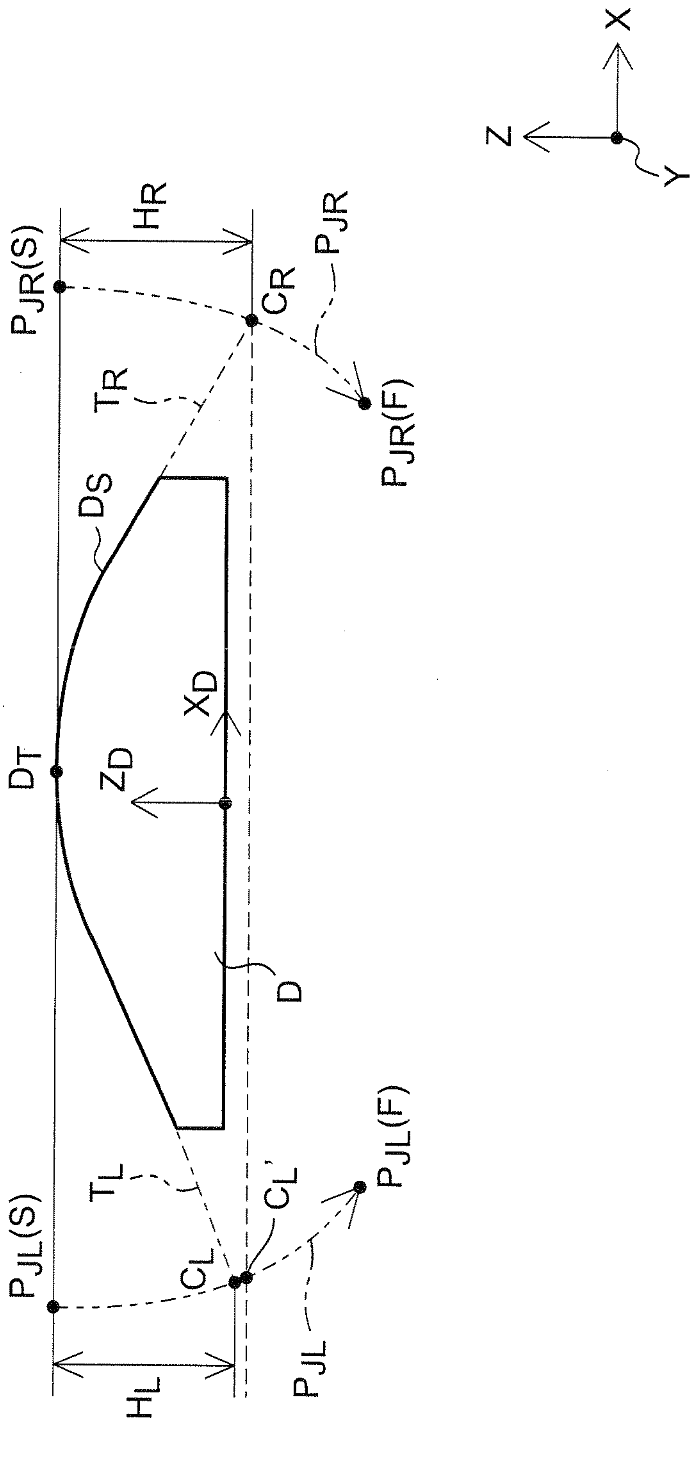

Fig.6

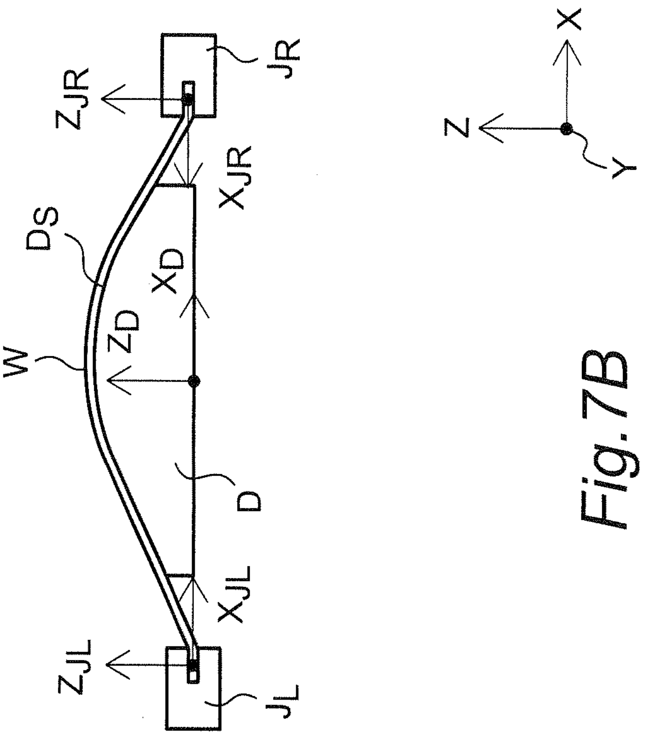
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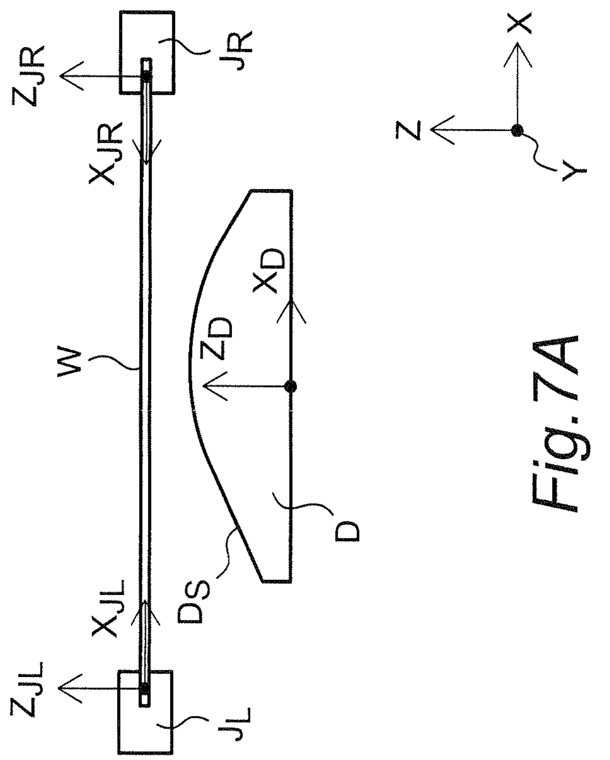
Fig.7B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X_JL
Z_JL
J_L
X
Z
Y

Fig.7A

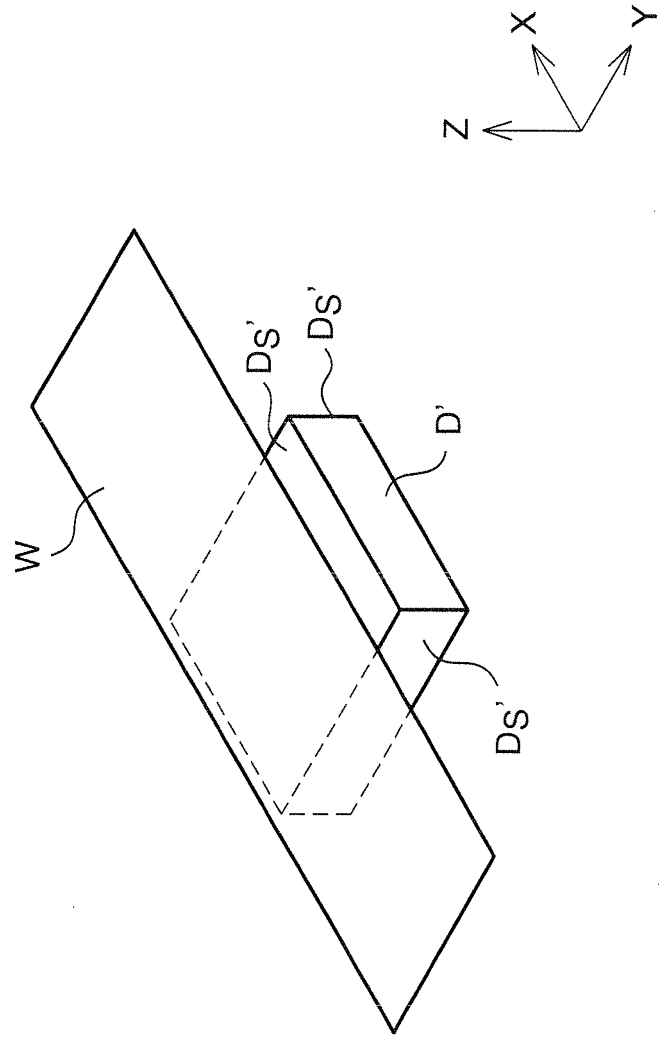
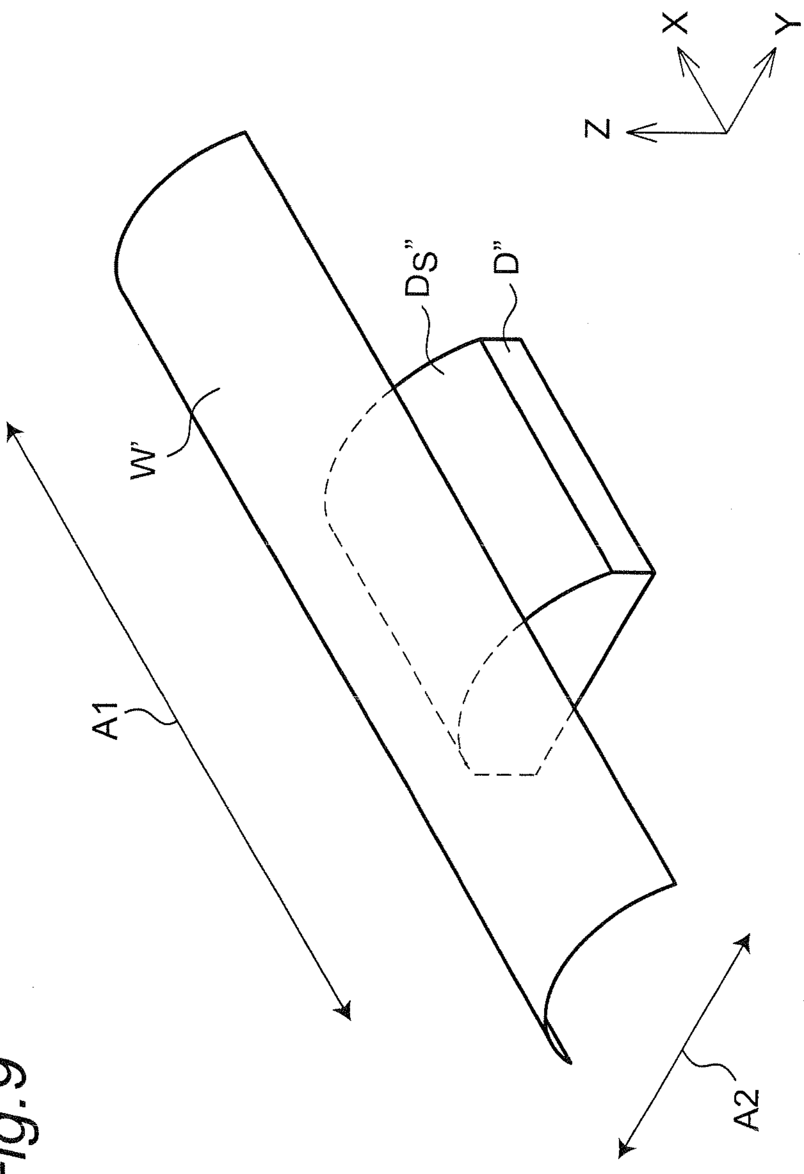


Fig.8

Fig.9



INTERNATIONAL SEARCH REPORT

International application No. PCT/JP2013/077517

A. CLASSIFICATION OF SUBJECT MATTER

B21D25/02(2006.01)i

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)
B21D25/02

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2013
Kokai Jitsuyo Shinan Koho	1971-2013	Toroku Jitsuyo Shinan Koho	1994-2013

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.
A	US 3948071 A (DeMott Electonics Co.), 06 April 1976 (06.04.1976), column 2, line 56 to column 5, line 44; fig. 1 to 3 (Family: none)	1-6
A	JP 2012-121044 A (Kawasaki Hydromechanics Corp.), 28 June 2012 (28.06.2012), paragraphs [0013] to [0027]; fig. 1 to 2 (Family: none)	1-6

☒ Further documents are listed in the continuation of Box C.

☐ See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be of particular relevance
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- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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- "&" document member of the same patent family

Date of the actual completion of the international search 13 December, 2013 (13.12.13)	Date of mailing of the international search report 24 December, 2013 (24.12.13)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2013/077517

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 2009-523613 A (Cyril Bath Co.), 25 June 2009 (25.06.2009), paragraphs [0023] to [0035]; fig. 1 to 9 & JP 5084747 B & US 2007/0163323 A1 & EP 1973678 A & WO 2007/084887 A2 & CA 2628302 A & CN 101360572 A & RU 2008133624 A & AU 2007205975 A & KR 10-2008-0085917 A	1-6
Y	JP 4-237526 A (ACB), 26 August 1992 (26.08.1992), paragraphs [0014] to [0037]; fig. 1 to 8 & US 5086636 A & EP 491071 A1 & DE 69006217 C & DE 69006217 D & FR 2650205 A & FR 2650205 A1 & ES 2048950 T & DK 491071 T & AT 100360 T	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2009523613 PCT **[0003]**
- JP 2012229147 A **[0091]**