(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 2 505 279 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
03.10.2012 Bulletin 2012/40

(51) Int Cl.:
B21D 31/00 *(2006.01)*

(21) Application number: **11462004.0**

(22) Date of filing: **29.03.2011**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

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(54) **Device for two sided incremental sheet forming**

(57) The invention relates to a device for two sided incremental sheet forming comprising a sheet plate clamp frame (2) for gripping a sheet (4) around its perimeter, supports (3) for holding said clamp frame (2) on a base plate (1), an upper forming tool (5) above the sheet (4), a lower forming tool (6) below the sheet (4) and means (7) for synchronised moving said tools facing each other. According to the invention the means (7) for synchronised moving the forming tools is a mechanical movement copying device and there are means for moving the lower forming tool (6) on the surface of the base plate (1) according to axes X and Y. The means for moving the lower forming tool (6) on the surface of the base plate (1) contains at least one ball transfer unit (8), which may be provided with an electric, mechanic, pneumatic or hydraulic drive.

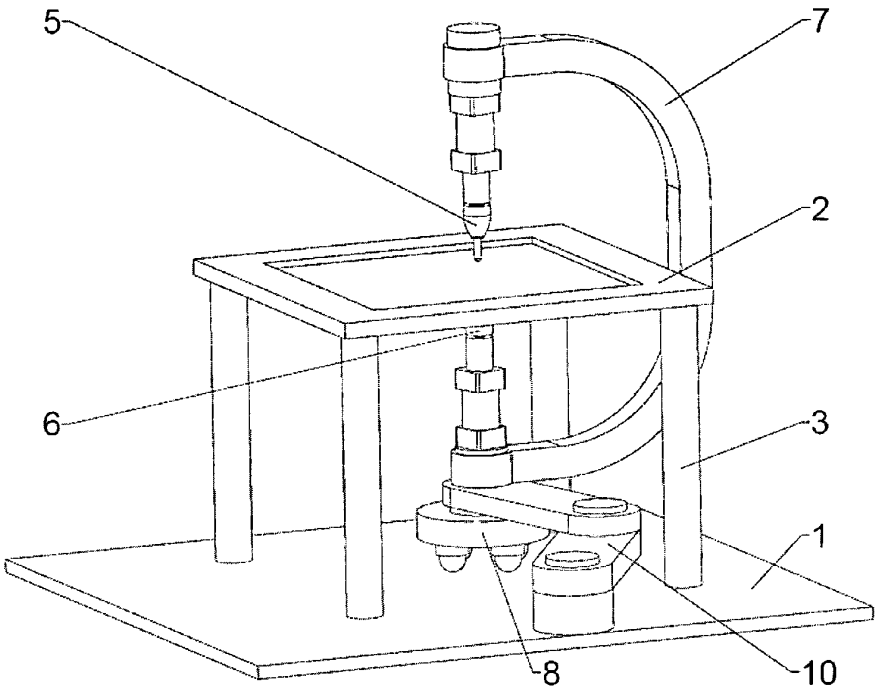

Fig. 3.

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Description

OBJECT OF THE INVENTION

[0001] The present invention relates to a device for two sided incremental sheet forming (TSISF), comprising a sheet plate clamp frame for gripping a sheet around its perimeter, supports for holding said clamp frame on a base plate, an upper forming tool above the sheet, a lower forming tool below the sheet and means for synchronised moving said tools facing each other, according to the preamble of claim 1.

BACKGROUND OF THE INVENTION

[0002] An early incremental sheet metal forming process used at large scale is spinning, used for the manufacturing of rotational parts in low to medium large series. Today the Incremental Sheet Forming (ISF) or Asymmetric Incremental Sheet Forming (AISF) process is similar to spinning (US 3342051, US 3316745, JP 10-180365).

[0003] Incremental Sheet Forming can be divided into two groups, depending on the number of contact points between sheet, tool and die. The term Single Point Incremental Forming (SPIF) is used when the bottom contour of the part is supported by a faceplate. In SPIF the forming tool is drawing contours from the outside inwards, moving the centre of the blank gradually downwards.

[0004] The term Two Point Incremental Forming (TPIF) is used when a full or partial die is present.

[0005] The forming tool in TPIF is drawing contours from the inside outwards, moving the perimeter of the blank gradually downwards or in the other case the die is moving upwards and the blank-holder is fixed. An alternative and more flexible variant with two synchronized forming tools can also be used to make the desired part. This process variant (JP 09-085355) is an obvious extension of TPIF. However, a synchronised control needs additional sensors and is expensive.

[0006] EP 1560668 discloses various configurations, including the use of two robots which needs synchronised control.

[0007] A process with one controller for two synchronized forming tools, with at least three degrees of freedom, corresponding to movements according to axes X, Y and Z, can be found in EP 1977842. This variant is also characterised in that it comprises the continuous detection of the stresses on the sheet due to the movement of the first and second tools and the actuation on the means of fastening to alter the gripping force thereof, according to the stresses detected.

[0008] A set-up so-called "Dyna(mic)-Die" has been suggested by Franzen et al. (Franzen, V., Kwiatkowski, L., Sebastiani, G., Shankar, R., Tekkaya, A.E., Kleiner, M., 2008. "Dyna-die: towards full kinematic incremental forming", Proceedings Esaform, Lyon, France, April 23-25 2008, paper #302.) but it is restricted to rotational symmetric motions and needs a synchronised control.

[0009] According to J. Cao at al. [Yongjun Wang, Ying Huang, Jian Cao: Experimental Study on a New Method of Double Side Incremental Forming, in the Proceedings of ASME 2008 Conference, October 7-10, 2008, Evanston, Illinois, USA, pp. 601-607] DSIF requires two forming tool heads opposing one another and moving simultaneously on both sides of a sheet metal. The device consists of a C frame mounted on the spindle saddle of a CNC machine and the tool heads are mounted on the top and bottom bases of the C frame. The drawback in this case is that a C frame mounted on the spindle saddle of a CNC machine is limiting the workspace and therefor the freedom of the forming.

[0010] The main problem with the prior art devices is that the movement of the lower tool may be influenced by the forces acting on the arm holding the tool and the desired accuracy of the forming may not always be achieved. The load on the mount frame or other means holding the forming tools may be more, than 100 kp, and it is rather difficult to keep the exact position of the tools.

[0011] Therefor, the object of the present invention is to eliminate the above drawback and to provide a device for two sided incremental sheet forming, which can ensure an accurate forming of sheet materials by stabilized and reliable guiding both of the forming tools.

SHORT DESCRIPTION OF THE INVENTION

[0012] Accordingly, the device suggested in the present invention comprises a mechanical movement copying device as means for synchronised moving the forming tools, and there are also means for moving the lower forming tool on the surface of a base plate, according to axes X and Y.

[0013] The upper forming tool is moved in X, Y and Z directions, according to the desired form. The lower forming tool is copying the X and Y motion of the upper forming tool, and this X and Y copying motion is realized with a mechanical copying device, but differently from the prior art, the lower forming tool has a motion in Z direction not together with the copying device but using some touching device (mechanic, pneumatic, hydraulic, electrical or the combination of those), it realizes the X and Y copying independently from the Z axis direction motion of the upper forming tool.

[0014] This lower touching device is fixed to said means for moving the lower forming tool on the surface of a base plate, with at least one ball transfer unit and with three degrees of freedom, corresponding to movements according to axes X and Y and a rotation around axis Z, on a base plate.

[0015] The reaction force in the Z direction acting on the lower forming tool and consequently on the pressing device from the pressing of the sheet is transferred to the base plate through the moving device.

[0016] The moving device is passive or active motion equipment and allows free motion in the X-Y plane, and

can stabilize the movement of it. A stabilizer may be constructed according to provide e.g. two rotational motions (see Fig. 3), one rotation and one translation motion (see Fig. 4) or translation motion in X and Y direction (see Fig. 5). In case of active motion, any kind of drive can be used.

[0017] The surface touching the lower forming tool mounting may be stiff, compliant, or regulated. The compliant version is preferred, because it provides the most effective self-adjusting position of the lower forming tool.

[0018] The sheet-forming device according to the invention contains at least one ball transfer unit as means for moving the lower forming tool on the surface of the base plate, and the ball transfer unit is provided with an electric, mechanic, pneumatic or hydraulic drive.

[0019] According to a preferred embodiment, there is a link mechanism or a lever transmission between the base plate or the drive and the ball transfer unit.

[0020] The mechanical movement copying device may be a mount frame, having a C, O or U shape, or may be a spindle-gear or a belt-pulley slide mechanism.

[0021] Preferably, the lower forming tool is movable against spring force according to axe Z in the means for moving the lower forming tool. Alternatively, the lower forming tool is moved by drive means according to axe Z in the means for moving the lower forming tool.

[0022] The drive means for moving the lower forming tool may be an electric, mechanic, pneumatic or hydraulic drive or a hammering device.

DESCRIPTION OF THE DRAWINGS

[0023] To complement this description and in order to aid a better understanding of the invention's characteristics, according to preferred practical embodiments thereof, there is a set of illustrative and non-limiting drawings integral to said descriptions, which are as follows:

Figure 1 shows a perspective view of the basic elements of the sheet-forming device wherein the forming tools mounted on cylinders (touching devices) are arranged on either side of the sheet and the mechanical movement copying device is a C-frame,

Figure 2 shows a perspective view of another variant of the sheet-forming device with double C-frame as a copying device,

Figure 3 shows a perspective view of a further variant of the sheet-forming device with a rotational stabilizer mechanism,

Figure 4 shows a perspective view of yet another variant of the sheet-forming device with a rotational and translational stabilizer mechanism,

Figure 5 shows a perspective view of another variant of the sheet-forming device with a translational stabilizer mechanism,

Figure 6 shows a perspective view of another variant of the sheet-forming device with a mechanical movement copying device consisting of two spindles, helical gears, corresponding slide rails, bearings and slides and

Figure 7 shows a perspective view of another variant of the sheet-forming device with a mechanical movement copying device consisting of cables, pulleys, corresponding slide rails, bearings and slides.

DETAILED DESCRIPTION OF THE INVENTION

[0024] The device for two sided incremental sheet forming according to the invention shown in Fig 1 contains a base plate 1 for holding a sheet plate clamp frame 2 for gripping a sheet 4 to be formed. The sheet is clamped by the frame all around its perimeter. The sheet plate clamp frame 2 is mounted on support rods 3 standing on the base plate. A first forming tool 5 is arranged above the sheet 4 and a second forming tool 6 is arranged below the sheet. Both tools are fixed on a mount frame 7. The mount frame has a C shape, and functions as a mechanical movement copying device ensuring synchronized movement of the upper tool and the lower tool, as known from Cao. However, further to that, there are means for moving the lower forming tool on the surface of the base plate 1 along X and Y direction. This means is here a ball transfer unit 8, which holds the lower forming tool at standard height with respect to the base plate, without having any impact to the movement in X or Y directions.

[0025] Further to that, the lower forming tool 6 is provided with means 9 for producing counter force in answer to the forming force of the upper forming tool. This means may be e.g. a spring or a pneumatic or hydraulic cylinder. The hydraulic or pneumatic unit may also provide an active force adjusted by a control unit.

[0026] The device in Fig. 2 is similar to that in Fig. 1, except that the mount frame 7 is not C shaped, but has a more rigid O shape.

[0027] In Fig. 3, an embodiment is shown, wherein the ball transfer unit is provided with a stabilizer mechanism 10, which can guide the movement of the lower forming unit and the ball transfer unit on the surface of the base plate 1, increasing the stability of the tool and accuracy of the movement. The stabilizer mechanism 10 in this case is a lever transmission, comprising two arms pivotably connected to each other and to the base plate.

[0028] Another stabilizer mechanism 10 is shown in Fig 4. The mechanism is here a link mechanism comprising an arm pivotably connected to the base plate and having a slot for receiving the lower forming tool.

[0029] A further variant of the stabilizer mechanism is shown in Fig. 5, wherein slides are guiding the ball transfer unit. A first slide 11 is mounted to the ball transfer unit and is moving on rails 12a and 12b, in X direction. Rails 12a and 12b are fixed to slides 13a and 13b, which in turn are moving on rails 14a and 14b, in Y direction.

[0030] The mechanisms in Figs 3, 4 and 5 are only stabilizing the movement of the lower forming tool 6 (and that of the upper tool as well), but - according to further preferred embodiments - may be provided with their own

drive means. The drive means may be any electric, mechanic, pneumatic or hydraulic drive, or even a CNC machine, which is programmed for the desired forming.

[0031] The means for synchronised moving said tools facing each other are mount frames according to Figs. 1 to 5, but any other mechanical copying device for synchronised moving said tools may be applied in the device according to the invention.

[0032] Figs. 6 and 7 show variants for mechanical copying devices. The device in Fig. 6 comprises slides controlled by spindle-gear connections, meanwhile Fig.7 shows a copying device wherein the slides are controlled by pulleys and cables. A rack mechanism with mating gears (follower gear and return gear) may also be a variant, similar to the device in Fig.6.

[0033] The device according to the invention enables safe and exact moving of the forming tools without applying sophisticated and expensive constructions. The means for moving the lower forming tool on the surface of the base plate, e.g. a ball transfer unit eliminates the non desired movement of the forming tools in the direction of the load, and in this way both the movements in X — Y directions and along axe Z can be controlled undisturbed. The whole device can be easily mounted and dismounted, and therefore it is especially applicable for producing complicated form pieces even in small series.

[0034] Although the present invention has fully been described by way of several embodiments and with reference to the accompanying drawings, it is not limited to the above mentioned embodiments. It is to be understood that various changes and modifications will be apparent to those skilled in the art without departing from the scope claimed in the attached claims.

Claims

1. A device for two sided incremental sheet forming comprising:

   - a sheet plate clamp frame (2) for gripping a sheet (1) around its perimeter,
   - supports (3) for holding said clamp frame (2) on a base plate (14),
   - an upper forming tool (4) above the sheet (1),
   - a lower forming tool (8) below the sheet (1) and
   - means (15) for synchronised moving said tools facing each other,

   characterised in that

   - said means (15) for synchronised moving the forming tools is a mechanical movement copying device and
   - there are means (12) for moving the lower forming tool (8) on the surface of the base plate (14) according to axes X and Y.

2. The sheet-forming device as claimed in Claim 1, **characterised in that** the means (12) for moving the lower forming tool (8) on the surface of the base plate (14) contains at least one ball transfer unit (13).

3. The sheet-forming device as claimed in Claim 2, **characterised in that** the ball transfer unit (13) is provided with an electric, mechanic, pneumatic or hydraulic drive.

4. The sheet-forming device as claimed in Claim 2, **characterised in that** the there is a link mechanism between the base plate (14) or the drive and the ball transfer unit (13).

5. The sheet-forming device as claimed in Claim 2, **characterised in that** the there is a lever transmission between the base plate (14) or the drive and the ball transfer unit (13).

6. The sheet-forming device as claimed in any of Claims 1 to 5, **characterised in that** the mechanical movement copying device (15) is a mount frame.

7. The sheet-forming device as claimed in Claims 6, **characterised in that** the mount frame (15) is a C, O or U frame.

8. The sheet-forming device as claimed in any of Claims 1 to 5, **characterised in that** the mechanical movement copying device is a spindle-gear slide mechanism.

9. The sheet-forming device as claimed in any of Claims 1 to 5, **characterised in that** the mechanical movement copying device is a belt-pulley slide mechanism.

10. The sheet-forming device as claimed in any of Claims 1 to 5, **characterised in that** the mechanical movement copying device is a rack mechanism with mating gears.

11. The sheet-forming device as claimed in any of Claims 1 to 10, **characterised in that** the lower forming tool is movable against spring force according to axe Z in the means (12) for moving the lower forming tool (8).

12. The sheet-forming device as claimed in any of Claims 1 to 11, **characterised in that** the lower forming tool is moved by drive means according to axe Z in the means (12) for moving the lower forming tool (8).

13. The sheet-forming device as claimed in Claim12, **characterised in that** the drive means for moving the lower forming tool (8) is an electric, mechanic, pneumatic or hydraulic drive.

14. The sheet-forming device as claimed in Claim12, **characterised in that** the drive means for moving the lower forming tool (8) is a hammering device.

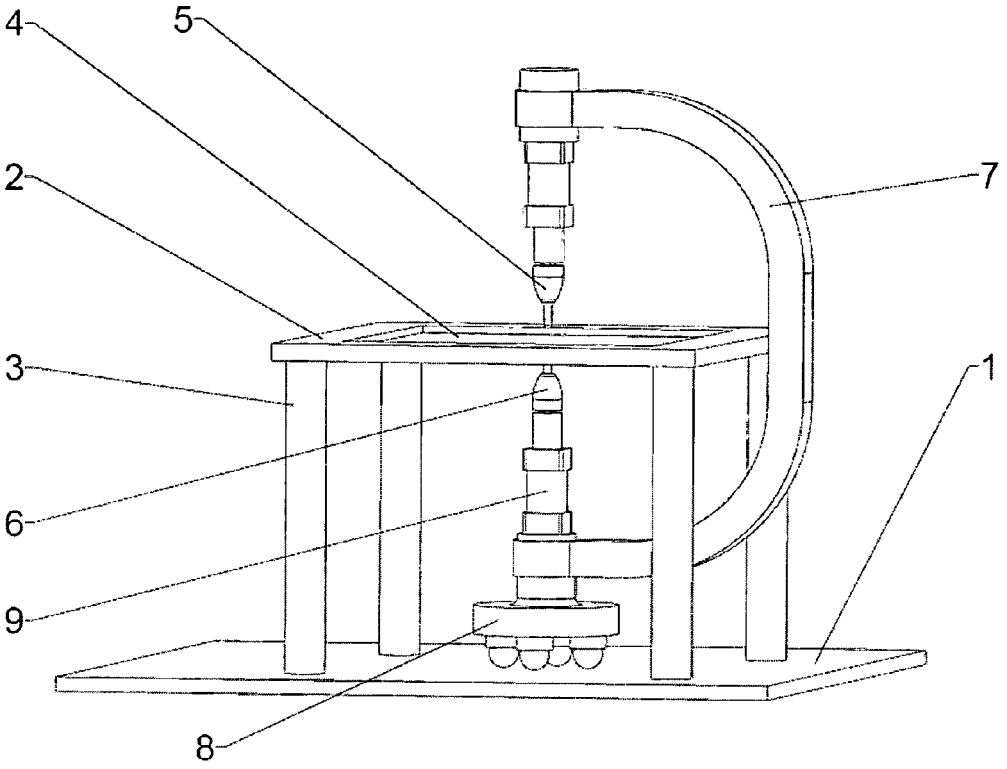

Fig. 1.

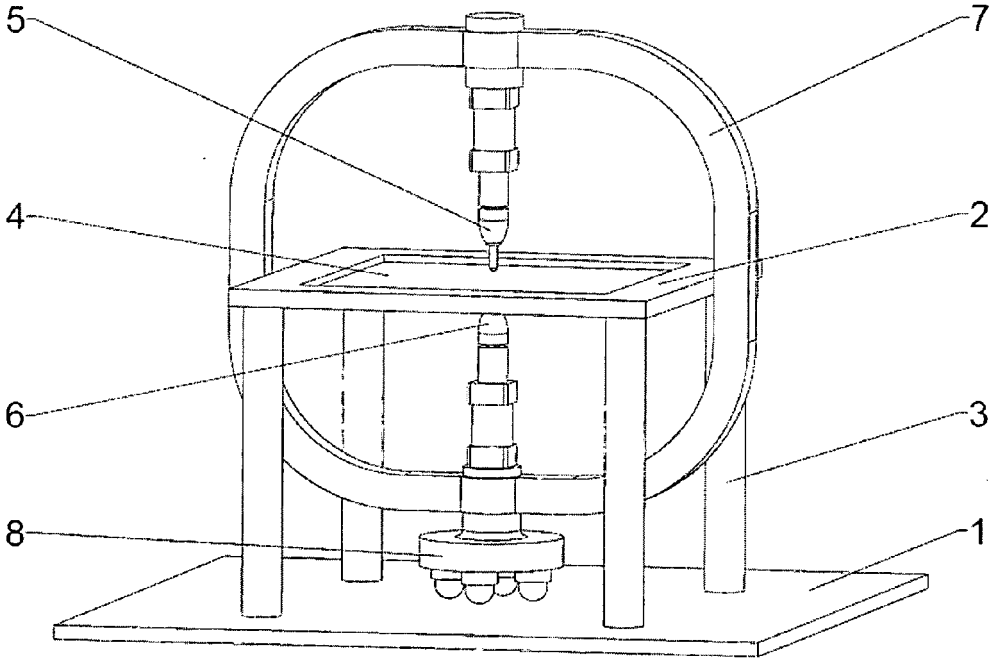

Fig. 2.

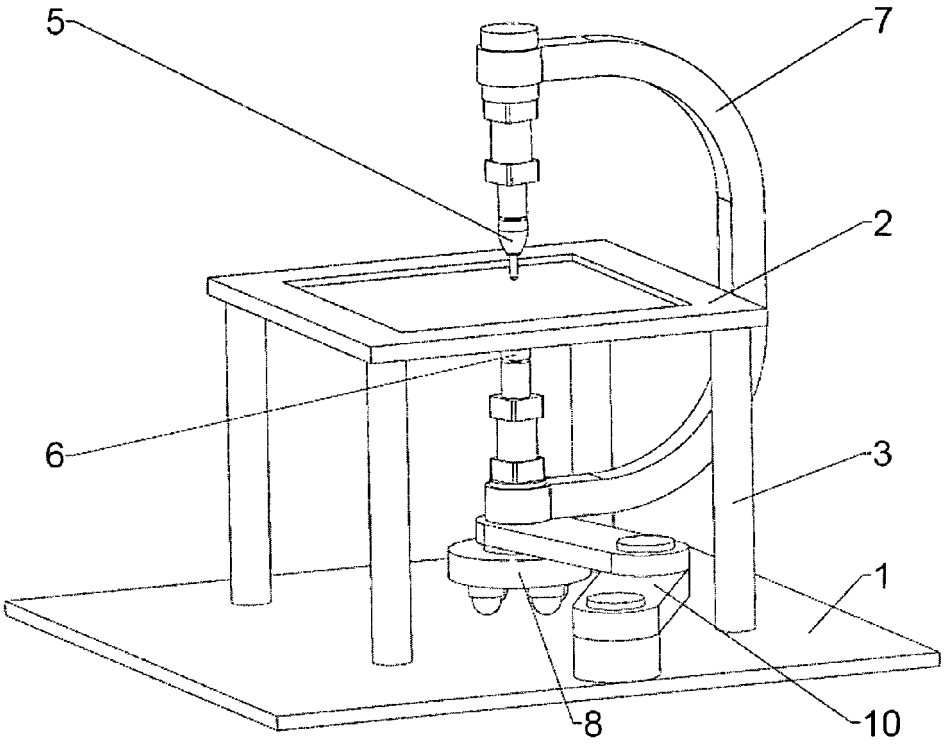

Fig. 3.

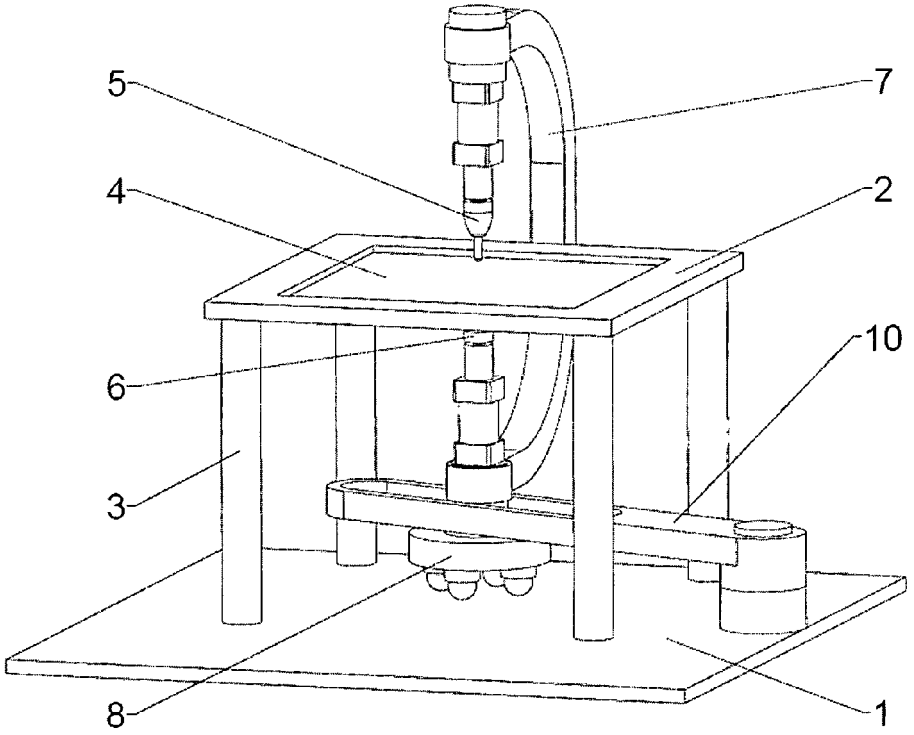

Fig. 4.

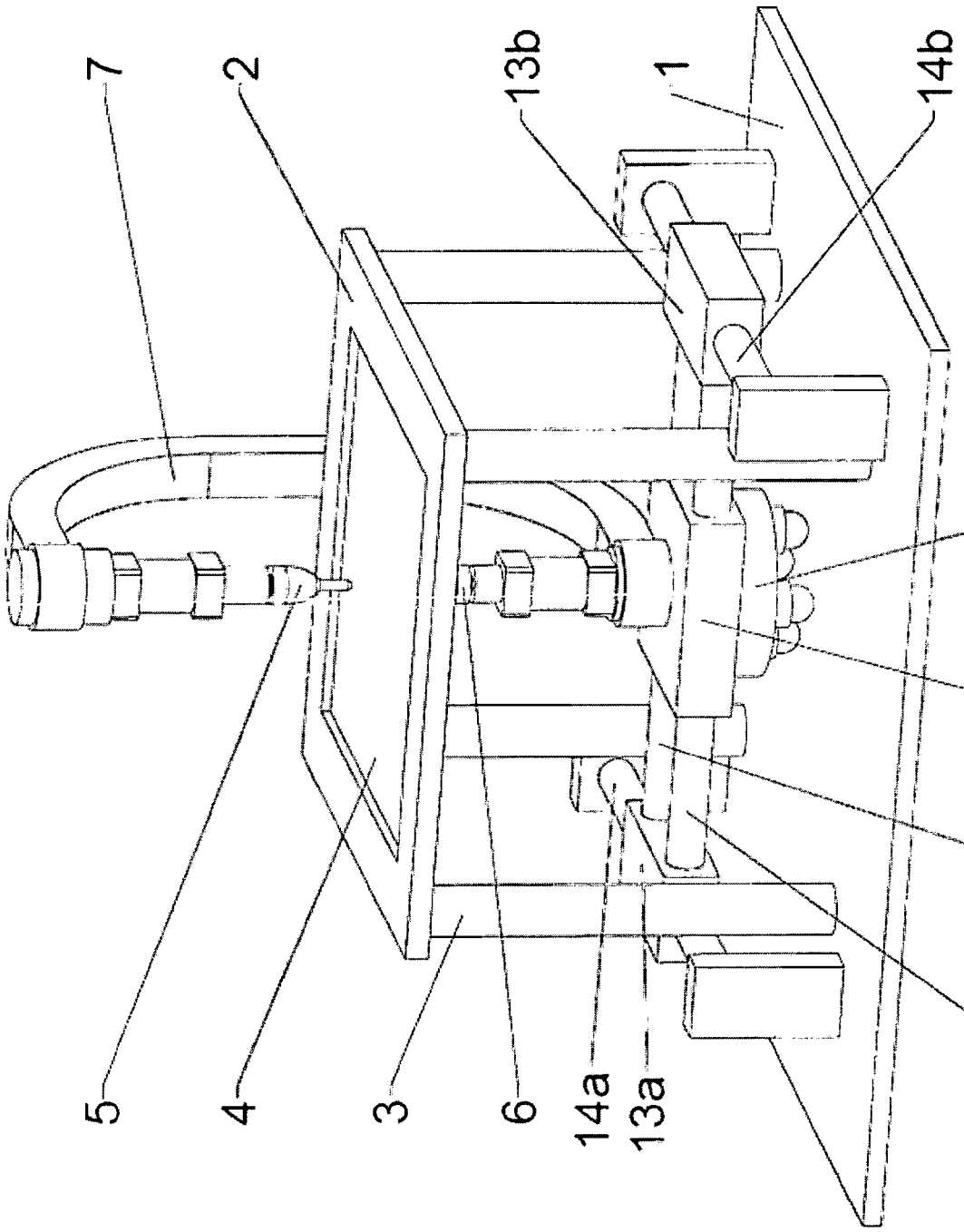

Fig. 5.

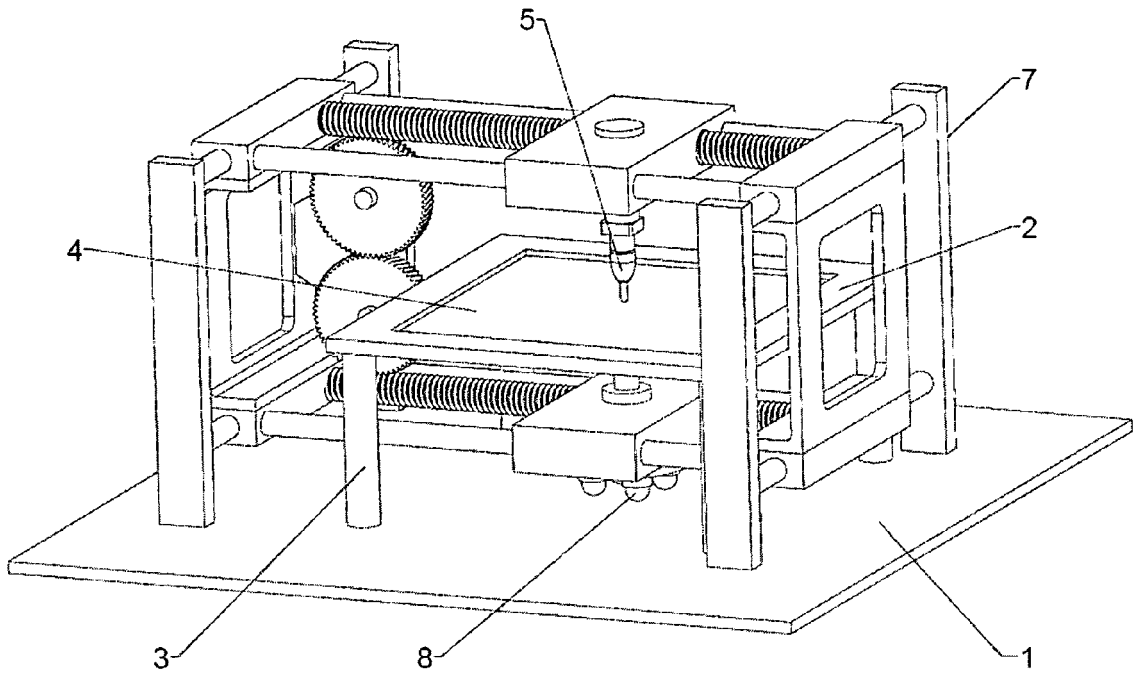

Fig. 6.

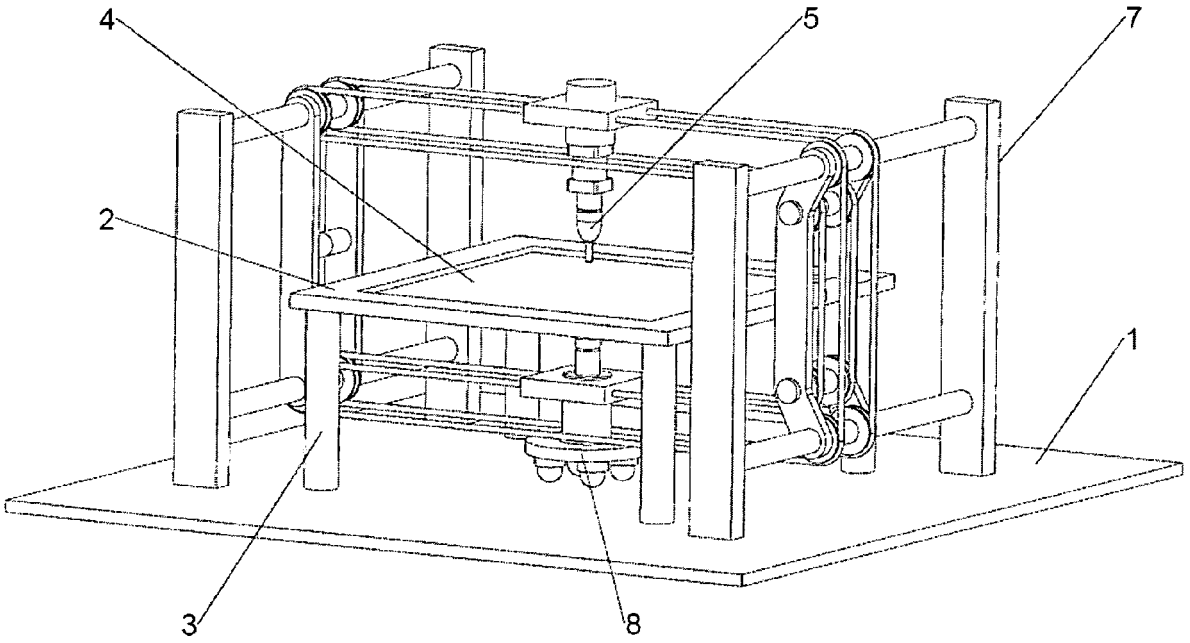

Fig. 7.

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EUROPEAN SEARCH REPORT

Application Number
EP 11 46 2004

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A	DE 10 2006 002146 A1 (DAIMLER CHRYSLER AG [DE] DAIMLER AG [DE]) 19 July 2007 (2007-07-19) * the whole document *	1-14	
A	DE 10 2007 056358 A1 (BAYERISCHE MOTOREN WERKE AG [DE]) 20 May 2009 (2009-05-20) * the whole document *	1-14	

TECHNICAL FIELDS SEARCHED (IPC)

B21D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	23 March 2012	Vinci, Vincenzo

CATEGORY OF CITED DOCUMENTS

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 11 46 2004

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23-03-2012

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- **YONGJUN WANG ; YING HUANG ; JIAN CAO.** Experimental Study on a New Method of Double Side Incremental Forming. *Proceedings of ASME 2008 Conference,* 07 October 2008, 601-607 **[0009]**