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(71) Applicant: **Quantix Digital S.r.l.**
**27029 Vigevano (Pavia) (IT)**

(72) Inventors:
- **VAILATI, Flavio**
  **24043 Caravaggio (Bergamo) (IT)**
- **VENTURELLI, Paolo**
  **20125 Milano (IT)**

(74) Representative: **Rapisardi, Mariacristina**
**Ufficio Brevetti Rapisardi S.r.l.**
**Via Serbelloni, 12**
**20122 Milano (IT)**

(54) **DIGITAL INKJET PRINTING MACHINE AND METHOD**

(57) An inkjet digital printing machine (1) comprising an inkjet printing unit (3) comprising a plurality of printing stations (4), a rotary table (2) supporting a plurality of support mandrels (6) of a plurality of containers (5) having a rotationally symmetrical outer surface to be printed, wherein the table (2) has a rotational axis (L), wherein the support mandrels (6) are distributed on the table (2) at a constant angular pitch and have their own axis (M) oriented radially with respect to the axis of rotation (L) of the table (2), wherein the table (2) is configured for sequentially transporting and stationing the mandrels (6) at the printing stations (4) wherein the mandrels (6) during printing, are driven in rotation on their own axes (M), wherein there is a programmable electronic controller with at least one programme for printing a graphism which sequentially provides for printing, at the same printing station, a first part (A, B, C, D, E, F, G) of the graphism during a first rotation of 360° of the mandrel (6) on its own axis (M) and at least a second part (A', B', C', D', E') of the graphism during a second rotation of further 360° of the mandrel (6) on its own axis (M), wherein the second part (A', B', C', D', E') of the graphism overlaps with the first part (A, B, C, D, E, F, G) of the graphism.

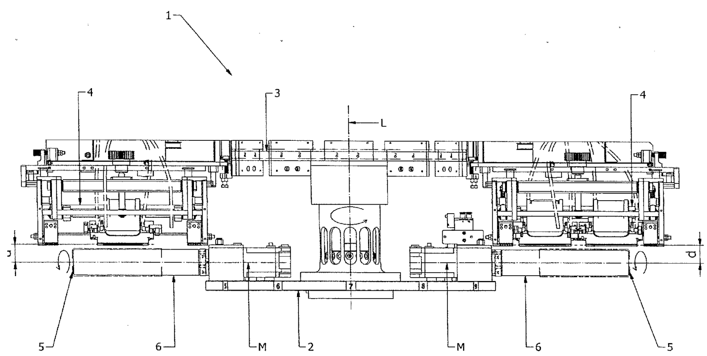



Fig.1

EP 4 420 885 A1

## Description

**[0001]** The present invention relates to a digital ink-jet printing machine and process.

**[0002]** Some solutions on the market for printing on cylindrical or other shaped containers include a turntable with radial mandrels to support the containers.

**[0003]** The turntable rotates to position the mandrels at successive printing stations, at each of which special printheads apply different coloured ink between printing stations.

**[0004]** When stationed at a printing station, the mandrel rotates on itself to expose the entire side surface of the containers to the printheads.

**[0005]** A recent market trend is to characterise printed graphics in such a way that they can provide multi-sensory stimulation.

**[0006]** In particular, there are now known applications, in a different sector, however, and related to offset printing presses, where the printed graphism is given not only an optical effect but also a tactile effect due to the increased thickness of the graphism, which creates surface discontinuities perceptible to the touch.

**[0007]** In practice, such offset presses achieve the desired tactile effect by using special expanding inks that expand during drying in an oven.

**[0008]** However, the results achievable with the use of such offset printing machines are rather limited in terms of the ability to diversify and customise the tactile effect.

**[0009]** This is mainly due to the fact that such offset printing machines do not make it possible to vary the thickness of the graphism locally.

**[0010]** The technical task of the present invention is, therefore, to provide an ink-jet digital printing machine and process that can eliminate the technical drawbacks of the known technique.

**[0011]** Within the scope of this technical task, one aim of the invention is to provide a digital ink-jet printing machine and process capable of printing graphics that provide multi-sensory stimulation.

**[0012]** Another purpose of the invention is to provide a digital ink-jet printing machine and process capable of realising a versatilely customisable tactile effect.

**[0013]** The technical task, as well as these and other purposes, according to the present invention are achieved by an ink-jet digital printing machine comprising a printing unit comprising a plurality of printing stations, a turntable supporting a plurality of support mandrels for supporting a plurality of containers having an outer surface with rotational symmetry on which to print a graphic pattern, wherein said turntable has a rotation axis, wherein said support mandrels are distributed on said turntable at a constant angular pitch and have their own axis which is radially oriented relative to said rotation axis of said turntable wherein said turntable is configured to convey and sequentially stop said mandrels at said printing stations, wherein said mandrels, during printing, are driven in rotation about their axis, characterised in that it has an electronic controller, a graphic pattern stored in said electronic controller, wherein said electronic controller is programmed with said program for printing said graphic pattern, which comprises the execution, in sequence, at a same printing station, of a first part of said graphic pattern during a first 360° rotation of the mandrel about its axis and at least a second part of said graphic pattern during a second further 360° rotation of the mandrel about its axis, wherein said second part of said graphic pattern is superimposed on said first part of said graphic pattern.

**[0014]** In an embodiment of the invention, the printing program locally varies the thickness of said graphism by superimposing said second part of the graphism selectively upon a portion of said first part of the graphism.

**[0015]** In an embodiment of the invention said portion of the first part of the graphism includes spatially separated areas.

**[0016]** In an embodiment of the invention, said second part of the graphism reproduces and matches said spatially separated areas.

**[0017]** In an embodiment of the invention, said graphism printing program provides for the printing of at least a third part of the graphism during a third rotation of a mandrel by a further 360° on its axis, wherein the third part of the graphism overlaps a portion of the second part of the graphism.

**[0018]** In an embodiment of the invention said third part of the graphism reproduces and matches said portion of the second part of the graphism.

**[0019]** The present invention further discloses a method of printing a graphic pattern on an outer surface, with rotational symmetry, of containers, by using an ink-jet digital printing machine comprising a plurality of printing stations, a turntable supporting a plurality of support mandrels for supporting said containers, wherein said turntable has a rotation axis, wherein said support mandrels are distributed on said turntable at a constant angular pitch and have their own axis which is radially oriented relative to said rotation axis of said turntable, wherein said turntable is configured to convey and sequentially stop said mandrels at said printing stations, wherein said mandrels, during printing, are driven in rotation about their axis, characterised in that a first part of said graphic pattern is printed during a first rotation of 360° of the mandrel about its axis, at a same printing station, and in sequence at least a second part of said graphic pattern is printed during a second further 360° rotation of the mandrel about its axis, wherein said second part of said graphic pattern is superimposed upon said first part of said graphic pattern.

**[0020]** Other features of the present invention are also defined in subsequent claims.

**[0021]** Further features and advantages of the invention will become more apparent from the description of a preferred but not exclusive form of the inkjet digital printing machine for printing a substrate with a longitudinal axis according to the invention, illustrated by way of illustration and not limitation in the accompanying drawings, in which

- Figure 1 shows a schematic side elevation view of the printing machine where only two printing stations are shown for clarity;
- Figure 2 shows a plan view of a printing station from below;
- Figure 3 shows a view of a printing station in radial direction with respect to the axis of rotation of the table;
- Figure 4 shows the same view as figure 3 but in vertical section, where the axial generatrices of the print substrate have been added schematically;
- Figure 5 shows an axonometric view of the printing station;
- Figure 6 shows a plan view of the printing machine from below;
- Figure 7 shows a side elevation view of the eccentricity profile detection station;
- Figure 8 shows an eccentricity profile of a container clamped on the mandrel;
- Figure 9 shows the hourly law of motion of the plasma emission modules of the pretreatment station and the printheads of the printing station;
- Figure 10 shows a side elevation view of the device in the pre-treatment station in a first configuration of the modular plasma emitter means;
- Figure 11 shows a side elevation view of the device in the pretreatment station in a second configuration of modular plasma emitter means;
- Figure 12 shows an axonometric view of the pretreatment station;
- Figure 13 shows a side elevation view of the device in the pretreatment station in a further configuration of modular plasma emitter means;
- Figure 14 shows a printing machine variant where a cooling station is provided immediately downstream of the plasma treatment station;
- Figure 15 shows a side elevation view of the cooling station of figure 14;
- Figure 16 is a vertical cross-sectional view of the cooling station of Figure 14;
- Figures 17a, 17b and 17c show in plan view the development of each of the three layers that form the multilayered graphic pattern printed on the outer cylindrical surface of the container;
- Figure 18 shows in lateral elevation the in-plane development of the multilayered graphic pattern printed on the outer cylindrical surface of the container.

**[0022]** The following detailed description refers to the attached drawings, which form part of it.

**[0023]** In drawings, similar reference numbers typically identify similar components, unless the context indicates otherwise.

**[0024]** The illustrative forms of realisation described in the detailed description and drawings are not intended in a limiting sense.

**[0025]** Other forms of realisation may be used, and other modifications may be made without departing from the spirit or scope of the subject matter depicted here.

**[0026]** The aspects of this description, as generally described in this context and illustrated in the figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and are part of this description.

**[0027]** With reference to the above mentioned figures, an ink-jet digital printing machine 1 is shown for printing the outer surface of containers 5 with a longitudinal axis C, particularly containers 5 with rotational symmetry around the longitudinal axis C.

**[0028]** Containers 5 particularly have a cylindrical outer surface where a graphic pattern is to be printed. Containers 5 can be for various purposes, e.g. food cans or cans for deodorants, detergents, etc.

**[0029]** The printing machine 1 comprises a printing unit 3 and a turntable 2 rotatable around an axis L and supporting a plurality of support mandrels 6 of the containers 5.

**[0030]** Mandrels 6 are distributed on turntable 2 at constant angular pitch.

**[0031]** Turntable 2 preferably has a vertical axis of rotation L.

**[0032]** Mandrels 6 are rotatable on their own axis M and rigidly support in rotation a corresponding container 5 each.

**[0033]** In the illustrated case where container 5 is perfectly symmetrical and centred on mandrel 6, the axes C and M coincide.

**[0034]** Mandrels 6 have the axis M oriented radially with respect to the rotational axis L of turntable 2.

**[0035]** Printing unit 3 comprises a plurality of printing stations 4 that run longitudinally and are each equipped with one or preferably several printheads 8.

**[0036]** Typically, the plurality of printing stations 4 includes printing stations with different coloured inks and at least one printing station with a transparent surface finishing material.

**[0037]** Printheads 8 have a main lying plane S which, in the case of a substantially parallelepiped shape, corresponds to the centre plane parallel to the two lateral longitudinal surfaces, and a longitudinal axis P.

**[0038]** In a printhead 8 of this shape, the lower longitudinal surface is equipped with one or more parallel longitudinal rows of firing nozzles.

**[0039]** Turnable 2 is configured to transport and station each mandrel 6 sequentially at printing station 4 where mandrel 6 can rotate on its axis M during printing.

**[0040]** The mandrel 6 stationed at a printing station 4 has its axis M parallel to and equidistant from the longitudinal axis P of the printheads 8.

**[0041]** Innovatively and advantageously, according to the present invention, the digital printing machine 1 has a programmable electronic controller, not shown in the figures, for controlling and commanding the printing mode of the graphic pattern(s) to be printed on the cylindrical outer surface of the containers 5.

**[0042]** Advantageously, the programmable electronic controller includes at least one programme for printing a graphic pattern that can also have a variable thickness.

**[0043]** Indicatively and not limitatively, and by way of example illustrated in Figures 17a, 17b, 17c, such a printing program envisages executing in sequence, at the same printing station 4, a first part A, B, C, D, E, F, G of the graphic pattern during a first rotation of 360° of the mandrel 6 on its axis M, and at least a second part A', B', C', D', E' of the graphic pattern during a second rotation of a further 360° of the mandrel 6 on its axis M.

**[0044]** Innovatively, the second part A', B', C', D', E' of the graphic pattern overlaps with the first part A, B, C, D, E, F, G of the graphic pattern.

**[0045]** Advantageously, it is possible to vary the thickness of the graphic pattern locally by selectively overlapping the second part A', B', C', D', E' of the graphic pattern with a single portion of the first part A, B, C, D, E, F, G of the graphic pattern.

**[0046]** Advantageously, even in the event that the portion of the first part A, B, C, D, E, F, G of the graphic pattern includes spatially separated areas, the second part A', B', C', D', E' of the graphic pattern reproduces and matches these spatially separated areas.

**[0047]** As a further novel advantage, in one embodiment of the present invention, the graphic pattern printing program provides for printing on the cylindrical outer surface of a container 5 of at least one third part A", B", E" of the graphic pattern during a third 360° rotation of the mandrel 6 on its axis M, wherein the third part A", B", E" of the graphic pattern selectively overlaps, reproduces and matches a portion A', B', E' of the second part A', B', C', D', E' of the graphic pattern.

**[0048]** The above mentioned graphic pattern printing program can be executed entirely by a single printing station 4.

**[0049]** Alternatively, it is possible to reduce the total number of full rotations of mandrel 6 on its own axis at the same printing station 4 by splitting the print programme between at least two printing stations 4 where mandrel 6 can be subjected to multiple full rotations on its own axis.

**[0050]** Printing machine 1 may comprise, as shown, a pretreatment device 102 positioned in a pretreatment station 103.

**[0051]** The pretreatment device 102 comprises a frame supporting plasma emission means for irradiating the outer surface of the container 5.

**[0052]** Turnable 2 is configured for transporting and stationing mandrel 6 at pretreatment station 103 before transporting and stationing mandrel 6 at the printing stations.

**[0053]** Turnable 2 is more precisely configured to transport and station mandrel 6 at an exposure position where the outer surface of container 5 is exposed to plasma.

**[0054]** In the exposure position, mandrel 6 can be rotated around its axis M for progressive plasma exposure of the outer surface of container 5.

**[0055]** Plasma emitters can be modular in design.

**[0056]** In particular, the emission means may comprise first plasma emission modules 105i, 105ii arranged at a first angular position about the axis of mandrel 6 stationed at the exposure position. The first 105i, 105ii modules are aligned to radiate an axial sector of the outer surface of container 5.

**[0057]** In practice, the first 105i, 105ii emission modules radiate adjacent and partially overlapping zones of the axial sector of the outer surface of container 5.

**[0058]** As a result of the rotation of mandrel 6 about its axis M, contiguous axial sectors of the outer surface of container 5 are exposed to the plasma, and upon completion of a rotation of mandrel 6 by 360° about its axis M, the entire outer surface of container 5 is exposed to the plasma irradiated by the first emission modules 105i, 105ii.

**[0059]** The frame individually supports the first 105i, 105ii modules, which can be removed and repositioned independently of each other as desired.

**[0060]** Device 102 provides means of varying the direction of emission of the first modules 105i, 105ii.

**[0061]** The means of varying the direction of emission include hinging pins 106 with which the first modules 105i, 105ii are hinged to the frame.

**[0062]** Hinging pins 106 are parallel to each other and orthogonal to the axis M of mandrel 6 when stationary in the exposure position.

**[0063]** The first modules 105i, 105ii can be locked, by means of special locking means not shown, in a range of angular positions around the respective hinging pins 106.

**[0064]** In practice, the orientation of each of the first emission modules 105i, 105ii can be set so that the angle of incidence $\theta$ of the plasma is substantially orthogonal to the corresponding radiated zone of the axial sector of the outer surface of the container 5.

**[0065]** If the axial sector of the outer surface of the container 5 exposed to the plasma is entirely cylindrical, then all the first modules 105i, 105ii will have emission surfaces with the same orientation; if, however, areas of the axial sector of the outer surface of the container 5 exposed to the plasma have different layouts, then correspondingly, the first modules 105i, 105ii will also have emission surfaces with different orientations in order to maintain the substantial orthogonality of the plasma incidence angle.

**[0066]** This concept is well exemplified in Figures 10 and 11.

**[0067]** In Figure 10, the radiated axial sector of the outer surface of container 5 comprises a first cylindrical sector zone 5a and a second truncated conical sector zone 5b converging towards the C axis of container 5.

**[0068]** The first 105i modules radiating the first cylindrical sector zone 5a have an emission surface with the same orientation, while the first 105ii module radiating the second truncated cone sector zone 5b has an emission surface with an orientation different from that of all the other first 105i modules.

**[0069]** In Figure 11, the axial sector of the external surface of the container 5 comprises a first cylindrical sector zone 5a, a second truncated conical sector zone 5b converging towards the C axis of the container 5, a third truncated conical sector zone 5c diverging from the C axis of the container 5, a fourth cylindrical sector zone 5d and a fifth truncated conical sector zone 5e converging towards the C axis of the container.

**[0070]** The first 105i modules radiating the first cylindrical sector zone 5a and the third cylindrical sector zone 5d present emission surfaces with the same orientation, while the first 105ii modules radiating the various truncated cone sector zones 5b, 5c, 5e present emission surfaces with a different orientation.

**[0071]** Preferably, the device 102 also provides means for varying the radial distance of the first emission modules 105i, 105ii from the axis of the mandrel 6 when stationary in the exposure position.

**[0072]** The means of varying the radial distance of the first emission modules 105i, 105ii serve to keep the distance of the first emission modules 105i, 105ii from the outer surface of the container 5 unchanged as the format of the container 5 itself changes.

**[0073]** Means of varying the radial distance of the first emission modules 105i, 105ii include, for example, a translatable bar 107 of collective support of the first emission modules 105i, 105ii.

**[0074]** The frame thus supports the moveable bar 107 from which the first modules 105i, 105ii can be removed and repositioned independently of each other at will.

**[0075]** To improve the flexibility of the radial adjustment, it can also be envisaged that the hinge pins 106 are individually supported by corresponding blocks, which in turn can be adjusted in position in sliding slots provided in the sliding bar 107.

**[0076]** Preferably, as illustrated, one or more second 105j, 105jj plasma emission modules are arranged at a second angular position around the axis of mandrel 6 in stationary at the exposure position.

**[0077]** Preferably the first emission modules 105i, 105ii are diametrically opposed to the second emission modules 105j, 105jj with respect to the axis M of the mandrel 6.

**[0078]** The second modules 105j, 105jj are aligned to irradiate an axial sector of the outer surface of container 5 diametrically opposite to that irradiated by the first emission modules 105i, 105ii.

**[0079]** The frame individually supports the second modules 105j, 105jj which can be removed and repositioned independently of each other as desired.

**[0080]** The device 102 also provides for the second modules 105j, 105jj means of varying the direction of emission similar to those provided for the first modules 105i, 105ii, in particular pins 106 with which the second modules 105j, 105jj are hinged to the frame.

**[0081]** The device 102 also provides for the second modules 105j, 105jj means of varying their radial distance from the axis of the mandrel 6 when stationary in the exposure position similar to those provided for the first modules 105i, 105ii, in particular a translatable bar 107 for collectively supporting the second emission modules 105j, 105jj.

**[0082]** As can be seen from the examples, in the case of a solid with non cylindrical rotational symmetry, in order to maintain the orthogonality of incidence of the plasma beam, it may be necessary to tilt one or more of the first emission modules or to adopt a shaped emission surface (as in the case of the modules 105ii of Figure 11). In some cases, in order to avoid a mechanical interference between two adjacent first emission modules with different inclination, it is possible to eliminate one of these two first emission modules and to provide in a diametrically opposite position with respect to the axis M of the mandrel 6 a second emission module intended to irradiate the same section of axial sector to which the first emission module removed would have been intended.

**[0083]** With the architecture of the first embodiment of figure 10, it is possible to irradiate entirely in one revolution of the mandrel 6 twice both the cylindrical part and the shoulder of the container 5 simply by varying the inclination of the head modules, while with the architecture of the second embodiment of figure 11, it is possible to irradiate entirely in one revolution of the mandrel 6 twice both the cylindrical parts and the truncated conical parts of the container 5 by providing special modules with a shaped emission surface, for example an emission surface with two sections inclined in a specular manner with respect to the axis of the modules.

**[0084]** In certain applications, if, for example, you wish to selectively intensify the pretreatment at a shoulder of a beverage can, compared to the architecture illustrated in figure 10, it is sufficient to deactivate (or remove) the second 105j modules orthogonal to the mandrel axis M and leave active only the modules with an emission surface inclined to the mandrel 6 axis M.

**[0085]** Figure 13 shows a variant in which the consecutive plasma emission modules 105i, 105j in the direction of the axis M of mandrel 6 have an overlapping section Ts in the direction of the axis M of mandrel 6.

**[0086]** In this way, no areas of container 5 are left without plasma treatment because the consecutive modules 105i, 105j in their Ts overlap radiate the same axial section of container 5: the surface of container 5, being uniformly plasma treated, therefore reacts uniformly to the subsequent deposition of the ink, which presents uniform colour and uniform adhesion on the uniformly plasma treated surface.

**[0087]** In the case illustrated the consecutive modules 105i, 105j in the direction of the axis M of mandrel 6 are on diametrically opposite sides of mandrel 6, but in solutions not shown they can be positioned on the same side of mandrel 6.

**[0088]** The pretreatment station 103 and the printing stations 4 are positioned along the circular trajectory of the mandrels 6 above the turntable 2 at a defined angular distance pitch around the rotary axis L of the turntable 2, in particular equal to or a multiple of the angular distance pitch of the mandrels 6.

**[0089]** The digital printing machine 1 provides servo drives for bidirectional linear movement of the plasma emitting means and respectively the printheads 8 of each printing station 4 in a direction parallel to the rotation axis L of the turntable 2.

**[0090]** The servo drive for the bidirectional linear movement of the plasma emitter means in particular can synchronously drive the bars 107.

**[0091]** Advantageously, the printing machine 1 also includes a station 100 for detecting the eccentricity profile of the containers 5 positioned upstream of the pretreatment station 102.

**[0092]** Detection station 100 includes distance sensor means of the containers locked on their mandrels 6 rotating on themselves.

**[0093]** Detection station 100 also includes an actuator controller for the servo drives in pretreatment station 102 and each printing station 4.

**[0094]** The controller is configured to drive the servo drives, while rotating the mandrel 6 on itself at the pretreatment station 102 and printing stations 4, with an hourly law s=s(t) uniquely determined by the detected eccentricity profile.

**[0095]** The time law s=s(t) is defined from the detected eccentricity profile so as to keep the distance of the plasma emission modules and printheads 8 from the container 5 in the pretreatment station 102 and in each printing station 4, respectively, constant.

**[0096]** Detection means 101 comprises one or more non-contact distance sensors, e.g. optical sensors.

**[0097]** The distance sensors 101 are mounted in a fixed position in the detecting station 100 and are oriented orthogonally to the axis M of the mandrel 6.

**[0098]** In a 360° turn of mandrel 6 on itself, sensors 101 acquire an eccentricity profile of container 5 clamped on mandrel 6.

**[0099]** The sensors means detect, during the rotation of container 5, its eccentricity by measuring the mutual distance, acquiring a series of points along the outer perimeter profile of container 5.

**[0100]** In practice, the electronic controller acquires the distance measurements and constructs a workpiece eccentricity curve with which it processes the hourly law s=s(t). This curve is sent to the driver of the drives that move the plasma emission modules and printheads 8.

**[0101]** The drives generate movement according to the hourly law s=s(t) so that the distance between the emission modules and the container 5, and between the printheads 8 and the container 5 respectively, is constant while the container 5 rotates on itself at the pretreatment station 102 and each printing station 4 respectively.

**[0102]** Plasma emitter modules and printheads 8 of successive printing stations are moved sequentially according to the same time law while stationed in the same container 5.

**[0103]** In fact, the container 5, once clamped by the mandrel 6, retains its eccentricity and angular position throughout its stay inside the press 1.

**[0104]** Machine 1 has an initial setup of the plasma emission means and printheads 8 of printing station 4.

**[0105]** In particular, the machine 1 provides for an initial setting of the initial distance of the emission modules from the axis M of the mandrel 6 and an initial setting of the initial distance d between the axis M of the mandrel 6 and the printheads 8 of the printing stations 4 and the orientation of the main laying planes S of the printheads 8.

**[0106]** The initial setting depends on the format of the containers 5 to be printed.

**[0107]** With the initial setting, the printheads 8 are tilted in such a way that the axis M of the mandrel 6 stationed at print station 4 belongs to the centre plane S of the printheads 8.

**[0108]** The longitudinal dimension of the printing station 4 must be such that it fits the axial length of the cylindrical printing substrates 5.

**[0109]** For this reason, although the solution shown as an example only envisages three printheads 8 per printing station 4 , the number of printheads 8 per printing station 4 may vary.

**[0110]** If printing stations 4 have several printheads 8, these must have an overlapping F section in the direction of their longitudinal axis P.

**[0111]** In order to ensure the partial overlap and at the same time the required inclination of their main plane of layering S, the adjacent printheads 8 have an offset angle $\alpha$ of their main plane of layering S with respect to the M axis of the mandrel 6.

**[0112]** Two orders of printheads 8 are thus delineated, where the printheads 8 of each order share the main lying plane S.

**[0113]** Printing station 4 features a 30, 36 frame supporting the two rows of printheads 8.

**[0114]** Each order of printheads 8 is supported by a corresponding support structure 13, 23, 31.

**[0115]** Each support structure 13, 23, 31 comprises a longitudinal plate 13 and, for each printhead 8, an angular support 31a, 31b in turn supporting a cradle 23 for printhead 8.

**[0116]** Each angular support 31a, 31b is independently supported by the longitudinal plate 13 in a linearly adjustable position along the longitudinal plate 13 itself.

**[0117]** Each angular support 31a, 31b in turn supports the cradle 23, and the printhead 8 attached to it, in an angularly adjustable position around a pin 32.

**[0118]** Each angular support 31a, 31b has a base 31a and a shoulder 31b.

**[0119]** The cradle 23 more precisely is fixed to a base 33 resting against the base 31a of the angular support 31a, 31b.

**[0120]** Means of setting printhead orientation 8 include a toggle system 9.

**[0121]** The toggle system 9 can be operated to force a coordinated rotation of the two rows of printheads 8 around a respective fulcrum 10.

**[0122]** For each order of printheads 8, the corresponding fulcrum 10 is positioned at the lower end 11 of the printheads 8 and defines a rotation axis Q parallel to the M axis of the mandrel 6.

**[0123]** On the fulcrums 10, consisting of pins with a half moon shaped cross-section, end blocks 36 of the longitudinal plates 13 are engaged.

**[0124]** In particular, the end blocks 36 have on their perimeter edge special engagement seats 36 conjugated to fulcrums 10.

**[0125]** The toggle system 9 has symmetrical connecting rods 12 each of which has its lower end hinged to the longitudinal plate 13 of a corresponding support structure 13, 23, 31a, 31b.

**[0126]** On the other hand, the upper end of each connecting rod 12 is operatively connected to a nut 15 engaged to slide along a screw 16 having a vertical axis V that intercepts the axis M of the mandrel 6.

**[0127]** More precisely, a longitudinal bar 37 is attached centrally to the nut 15, which has the connecting rods 12 hinged at the opposite ends.

**[0128]** The lower H and upper I hinge axes of connecting rods 12 are in turn parallel to the axis M of mandrel 6.

**[0129]** The screw 16 is supported in a special housing 19 fixed to a longitudinal bar 36 of the frame 30, 36.

**[0130]** In practice, the screw 16 can rotate on itself without translating to drag the mother screw 15 upwards to drive the toggle 9.

**[0131]** Elastic thrust means are provided to maintain the rotation of the two rows of printheads 8 around their respective fulcrums 10 when the toggle 9 is operated.

**[0132]** The elastic thrust means comprise symmetrical springs 17 configured and arranged to exert thrust in an oblique direction from top to bottom at the lower hinges of the connecting rods 12.

**[0133]** Each print station 4 also includes means of fine tuning the mutual position of the printheads 8. Fine tuning means include first fine tuning means of overlap F between printheads 8.

**[0134]** The first means of fine tuning comprise, for each printhead 8, a micrometer screw 20 counteracted by a spring 21 to reset the thread clearance of the micrometer screw 20.

**[0135]** The micrometer screw 20 is supported in a housing 22 fixed to the longitudinal plate 13 and engages a threaded hole 24 in a flange 25 fixed to the base 31a of the angular support 31a, 31b.

**[0136]** For adjustment, the angular support 31a, 31b and with it the cradle 23 housing the printhead 8 are moved along the longitudinal plate 13 by operating the micrometer screw 20.

**[0137]** Fine tuning means also include second fine tuning means of mutual alignment between the longitudinal P axes of the printheads 8.

**[0138]** Again, the second means of fine tuning comprise, for each printhead 8, a micrometer screw 26 counteracted by a spring 40 resetting the thread clearance of the micrometer screw 26.

**[0139]** The micrometer screw 26 is supported in a housing 38 fixed to the base 31a of the angular support 31a, 31b and engages a threaded hole 39 in the base 33 of the cradle 23.

**[0140]** The micrometer screw 26 rotates the cradle 23 around the pin 32 and the rotation of the cradle 23 is counteracted by a spring 41 supported by the shoulder 31b of the angular support 31a, 31b and resting against the cradle 23.

**[0141]** The spring 41 slides over the cradle 23 allowing the latter to rotate but remains under tension so as to block the angle of rotation achieved by the cradle 23 following the operation of the micrometer screw 26.

**[0142]** Each printing station 4 is set up to dispense ink of only one colour.

**[0143]** The printing process takes place as follows.

**[0144]** Prior to the start of the printing process, initial settings related to the format of the containers 5 to be printed are made.

**[0145]** In particular, depending on the format of the containers 5, a certain distribution of first and second plasma emission modules is selected at the pretreatment station 103, their initial linear position is set, for example by adjusting the initial position of the bars 107, and the angle of the emission modules around the pins 106 is set.

**[0146]** The linear and angular position of printheads 8 is also set at print station 4.

**[0147]** In particular, at each printing station 4, the toggle 9 is operated to reorient the positioning planes S of the printheads 8 in such a way that the printing can substantially take place with the condition that the container axis 5 belongs to the main positioning plane S of the printheads 8.

**[0148]** Prior to the start of the printing process, the printheads 8 of each printing station 4 are also set in register by means of the micrometer screws 20, 26, which adjust the overlapping section F between the printheads 8 and respectively the alignment of their longitudinal axis P in the direction parallel to the axis M of the mandrel 6.

**[0149]** In particular, the overlapping section F must be such that it overlaps one or more of the intended firing nozzles in adjacent printheads 8.

**[0150]** Once the preliminary adjustments have been completed, turntable 2 is operated, whose mandrels 6 are supplied with containers 5 from a loader not shown.

**[0151]** The turntable 2 is rotary driven in steps, and at each step it sequentially positions each container 5 first below the detecting station 100, then below the pretreatment station 103, and finally below the subsequent printing stations 4.

**[0152]** At each stop of table 2, mandrels 6 are rotated in their axis M.

**[0153]** As the container 5 rotates underneath detecting station 100, its eccentricity profile is acquired, which will be processed by the electronic controller to establish the hourly law of motion s=s(t) that the plasma emission modules and printheads 8 will have to execute in order to maintain a constant distance from container 5.

**[0154]** In each printing station 4, an ink is dispensed in a single pass with the printheads 8 moving according to the hourly law of motion s=s(t) in a manner synchronised with the rotation on itself of the container 5.

**[0155]** Each printing station 4 is dedicated to the application of a single ink of a different colour from that used in the other print stations 4.

**[0156]** Figures 14 to 16 show a container cooling station 5 positioned immediately downstream of the plasma station.

**[0157]** The cooling station comprises at least one cooling module 120 including a cooling compressed air emission tube 121 and a heated air suction tube 122.

**[0158]** Mandrel 6 is stationed at the cooling station with the axis M parallel to the axis of the emission tube 121 and the axis of the suction tube 122.

**[0159]** Tubes 121, 122 and are configured one for radial air emission and the other for radial air intake.

**[0160]** The emission tube 121 has emission holes 123 distributed at least along most of the length of the emission tube 121, while the suction tube 122 has a suction slot 124 extending at least along most of the length of the suction tube 122.

**[0161]** Compressed air is delivered by the emission tube 121 in the direction towards the container 5 and the air stream heated by contact with the surface of the container 5 is sucked in by the suction tube 122.

**[0162]** The direction of rotation on itself of the mandrel 6, and consequently of the container 5 at the cooling station, favours the transfer of the cooling air layer to the suction slot 124.

**[0163]** Preferably a cooling module 120 above and a cooling module 120 below the mandrel 6.

**[0164]** Of course, the emission tube 121 and the suction tube 122 are connected with appropriate air distribution and smoke suction respectively.

**[0165]** The cooling station is able to reduce the container surface temperature 5 to an optimum value for inkjet printing.

**[0166]** The digital inkjet printing machine thus conceived is susceptible to numerous modifications and variations, all of which are within the scope of the inventive concept; moreover, all details are replaceable by technically equivalent elements.

**[0167]** In practice, the materials used, as well as the dimensions, can be any according to requirements and the state of the art.

## Claims

1. An ink-jet digital printing machine (1) comprising a printing unit (3) comprising a plurality of printing stations (4), a turntable (2) supporting a plurality of support mandrels (6) for supporting a plurality of containers (5) having an outer surface with rotational symmetry on which to print a graphic pattern, wherein said turntable (2) has a rotation axis (L), wherein said support mandrels (6) are distributed on said turntable (2) at a constant angular pitch and have their own axis (M) which is radially oriented relative to said rotation axis (L) of said turntable (2), wherein said turntable (2) is configured to convey and sequentially stop said mandrels (6) at said printing stations (4), wherein said mandrels (6), during printing, are driven in rotation about their axis (M), **characterised in that** it has an electronic controller, a graphic pattern stored in said electronic controller, wherein said electronic controller is programmed with said program for printing said graphic pattern, which comprises the execution, in sequence, at a same printing station, of a first part (A, B, C, D, E, F, G) of said graphic pattern during a first 360° rotation of the mandrel (6) about its axis (M) and at least a second part (A', B', C', D', E') of said graphic pattern during a second further 360° rotation of the mandrel (6) about its axis (M), wherein said second part (A', B', C', D', E') of said graphic pattern is superimposed on said first part (A, B, C, D, E, F, G) of said graphic pattern.

2. The ink-jet digital printing machine (1) according to the preceding claim, **characterised in that** said printing program locally varies the thickness of said graphic pattern, providing for a superimposition of said second part (A', B', C', D', E') of said graphic pattern selectively upon a portion of said first part (A, B, C, D, E, F, G) of said graphic pattern.

3. The ink-jet digital printing machine (1) according to the preceding claim, **characterised in that** said portion of said first part (A, B, C, D, E, F, G) of said graphic pattern includes spatially separated areas.

4. The ink-jet digital printing machine (1) according to the preceding claim, **characterised in that** said second part (A', B', C', D', E') of said graphic pattern reproduces and corresponds with said spatially separated areas.

5. The ink-jet digital printing machine (1) according to any preceding claim, **characterised in that** said printing program of said graphic pattern envisages, at said same printing station, the printing of at least a third part (A", B", E") of said graphic pattern during a third further 360° rotation of said mandrel (6) about its axis (M), wherein the third part (A", B", E") of said graphic pattern is superimposed upon a portion (A', B', E') of said second part (A', B', C', D', E') of said graphic pattern.

6. The ink-jet digital printing machine (1) according to the preceding claim, **characterised in that** said third part (A", B", E") of said graphic pattern reproduces

and corresponds with said portion (A', B', E') of said second part (A', B', C', D', E') of said graphic pattern.

**7.** The ink-jet digital printing machine (1) according to any preceding claim, **characterised in that** said rotation axis (L) of said turntable (2) is vertical.

**8.** A method of printing a graphic pattern on an outer surface, with rotational symmetry, of containers (5), by using an ink-jet digital printing machine (1) comprising a plurality of printing stations (4), a turntable (2) supporting a plurality of support mandrels (6) for supporting said containers (5), wherein said turntable (2) has a rotation axis (L), wherein said support mandrels (6) are distributed on said turntable (2) at a constant angular pitch and have their own axis (M) which is radially oriented relative to said rotation axis (L) of said turntable (2), wherein said turntable (2) is configured to convey and sequentially stop said mandrels (6) at said printing stations (4), wherein said mandrels (6), during printing, are driven in rotation about their axis (M), **characterised in that** a first part (A, B, C, D, E, F, G) of said graphic pattern is printed during a first rotation of 360° of the mandrel (6) about its axis (M), at a same printing station, and in sequence at least a second part (A', B', C', D', E') of said graphic pattern is printed during a second further 360° rotation of the mandrel (6) about its axis (M), wherein said second part (A', B', C', D', E') of said graphic pattern is superimposed upon said first part (A, B, C, D, E, F, G) of said graphic pattern.

**9.** The printing method according to the preceding claim, **characterised in that** the thickness of said graphic pattern is varied locally by providing for a superimposition of said second part (A', B', C', D', E') of said graphic pattern selectively upon a portion of said first part (A, B, C, D, E, F, G) of said graphic pattern.

**10.** A container obtained with a printing process in accordance with either of claims 8 and 9.

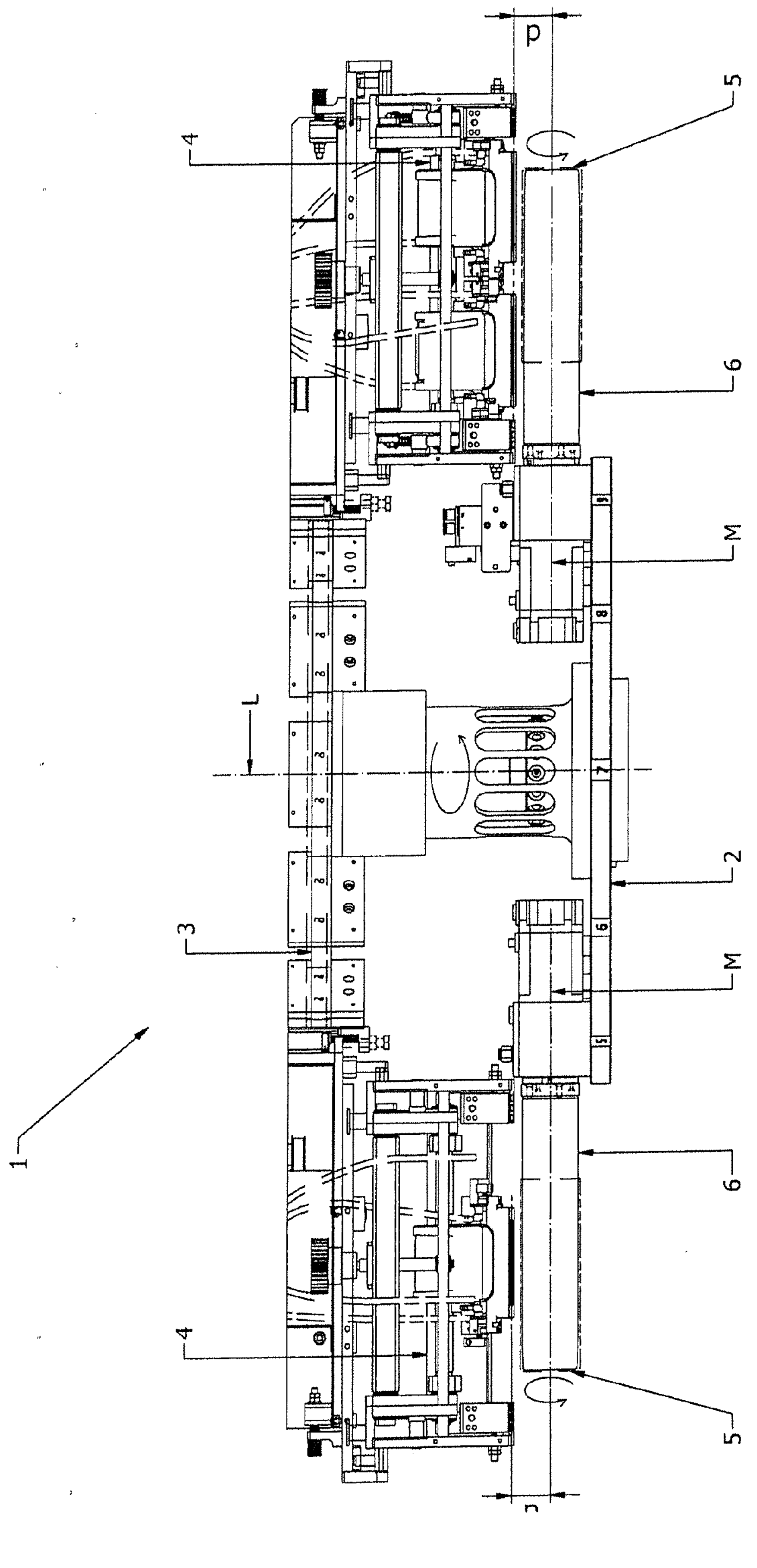
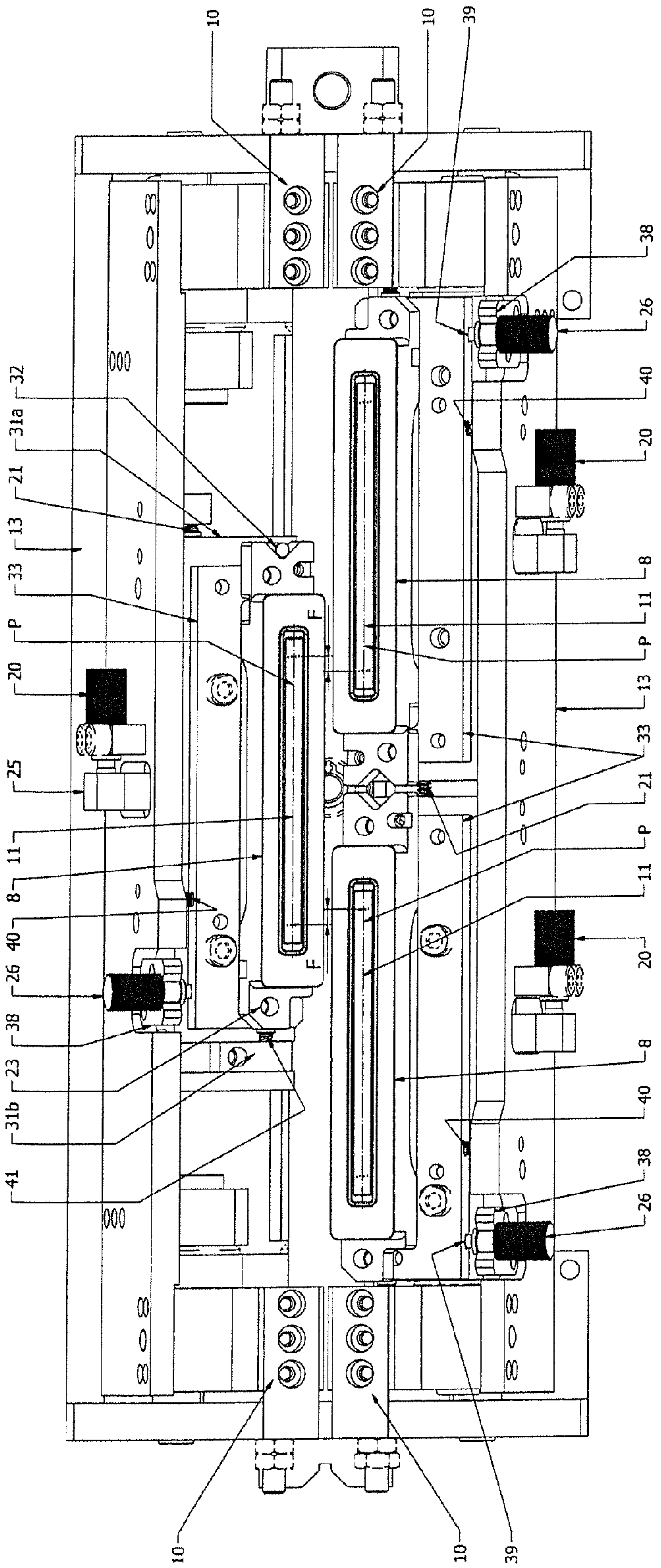



Fig.1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31a
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P
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11
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38
23
31b
41
F
F

Fig.2

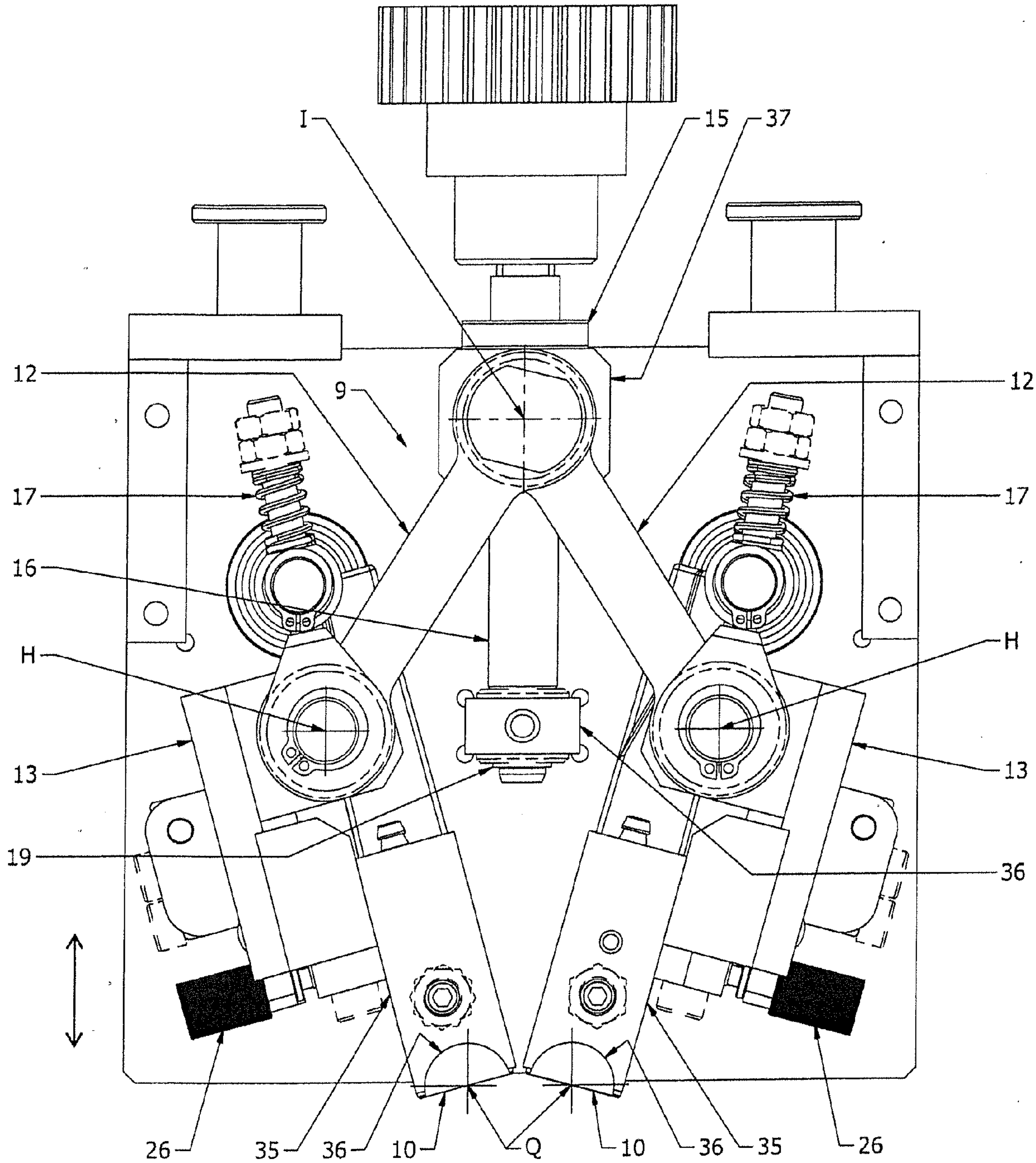



Fig.3

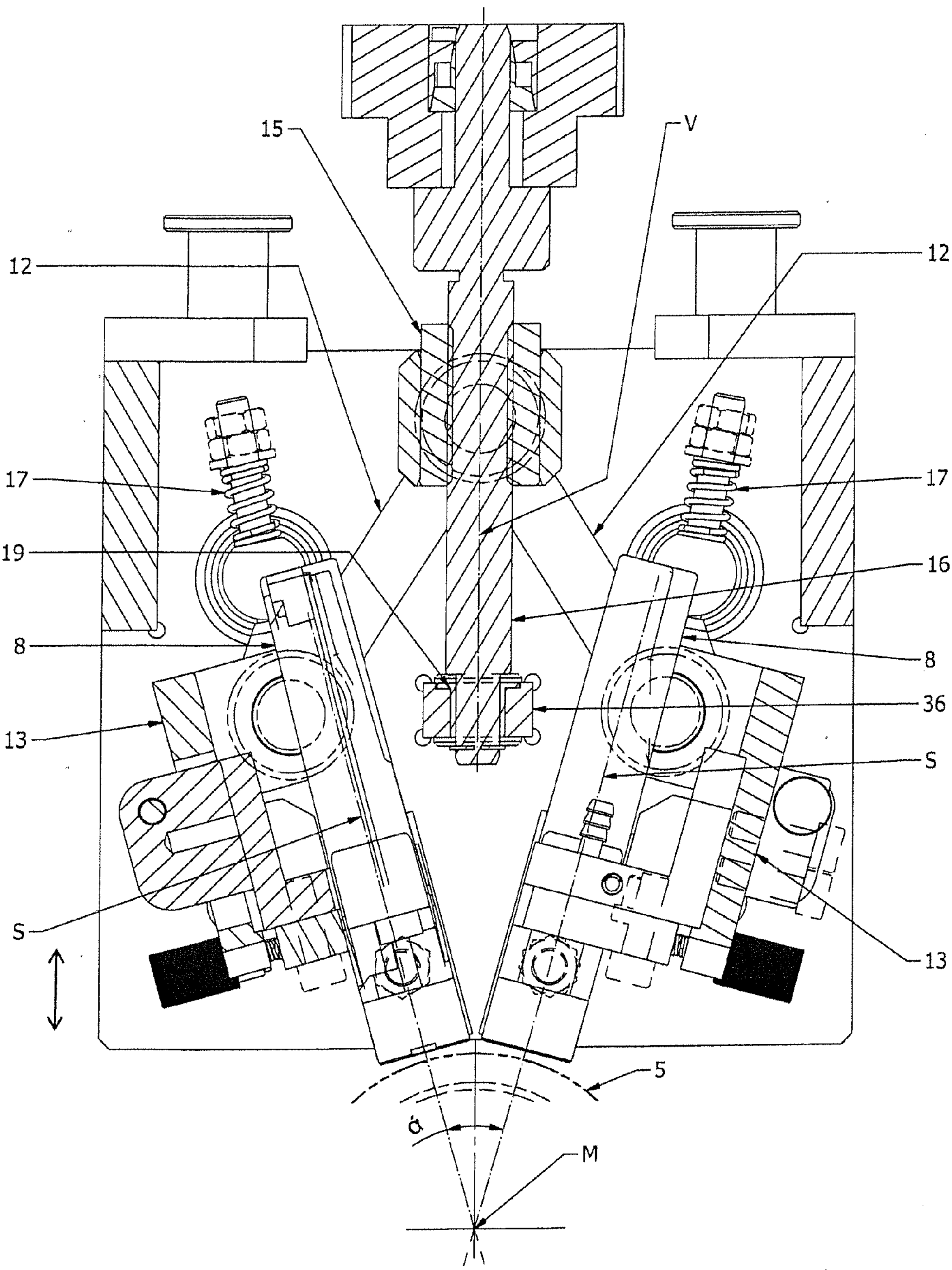



Fig.4

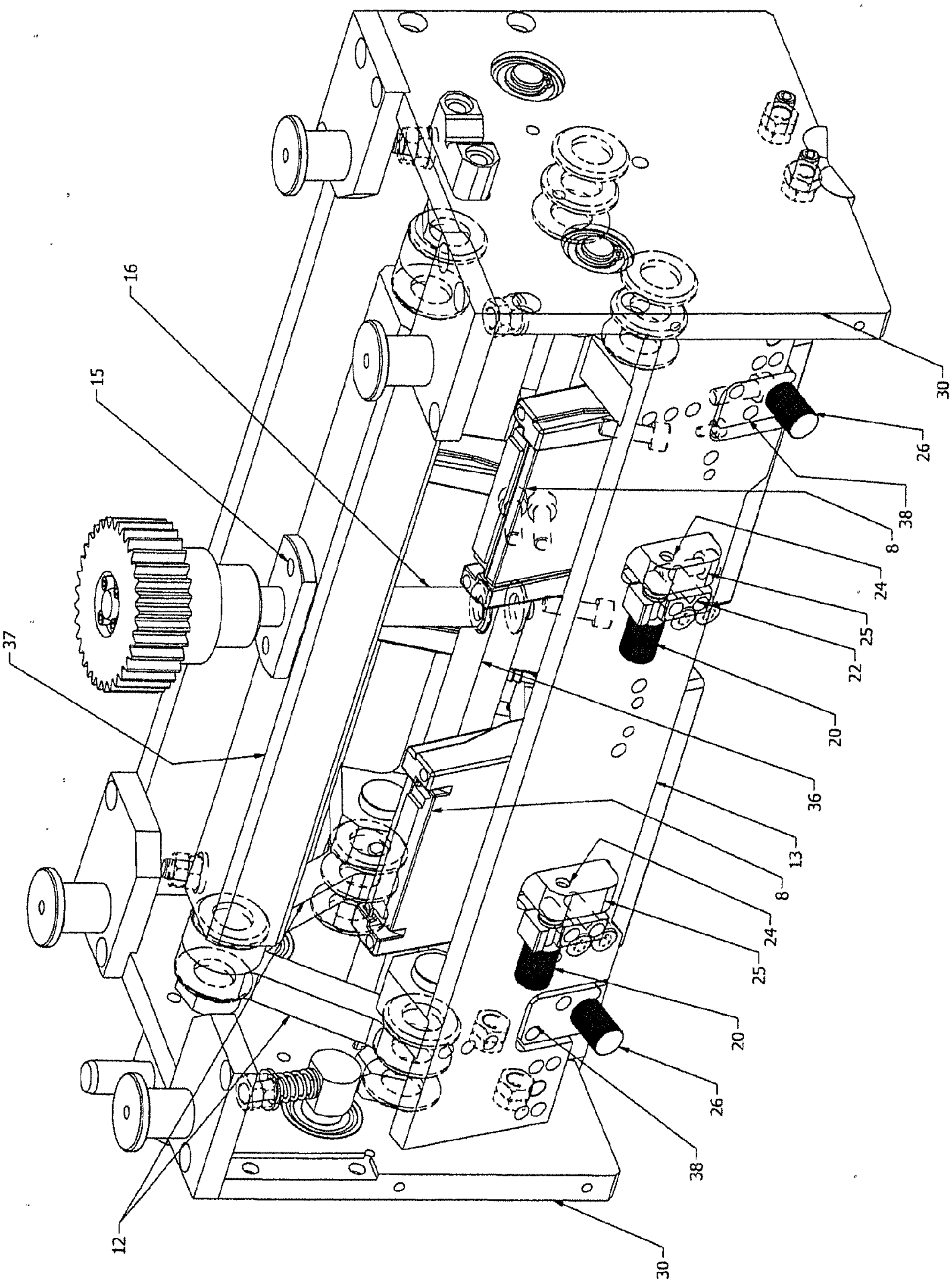



Fig.5

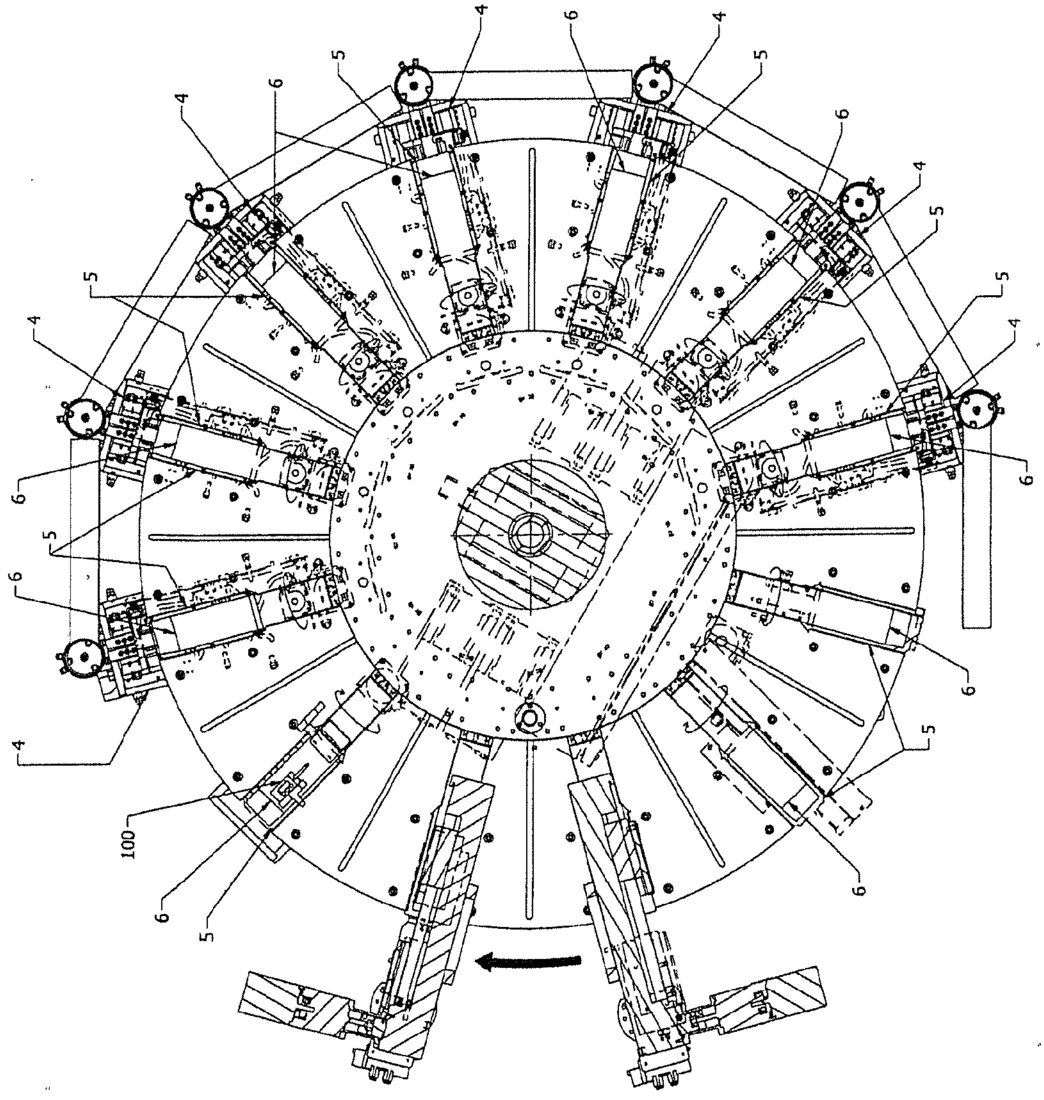



Fig.6

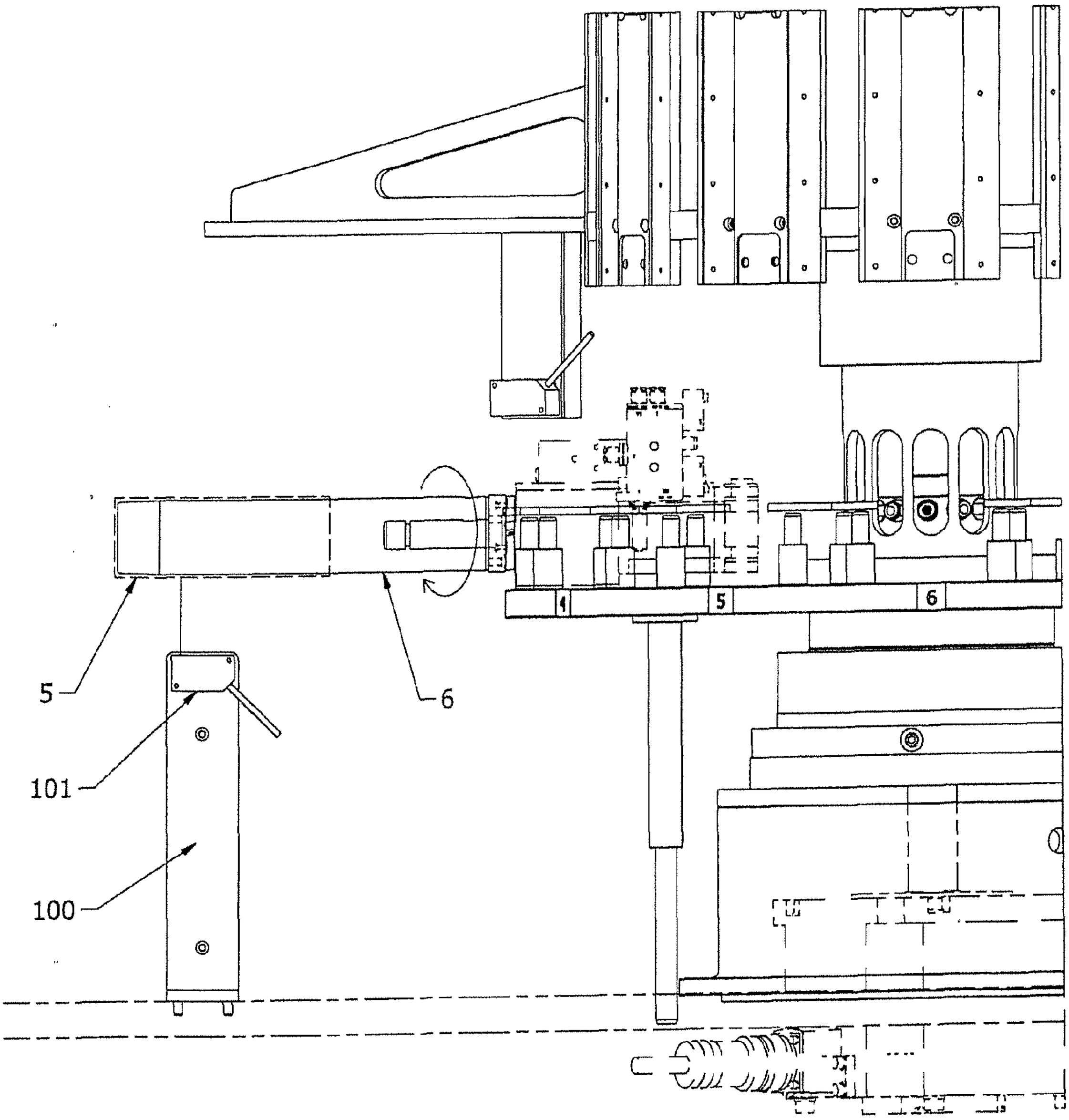



Fig.7

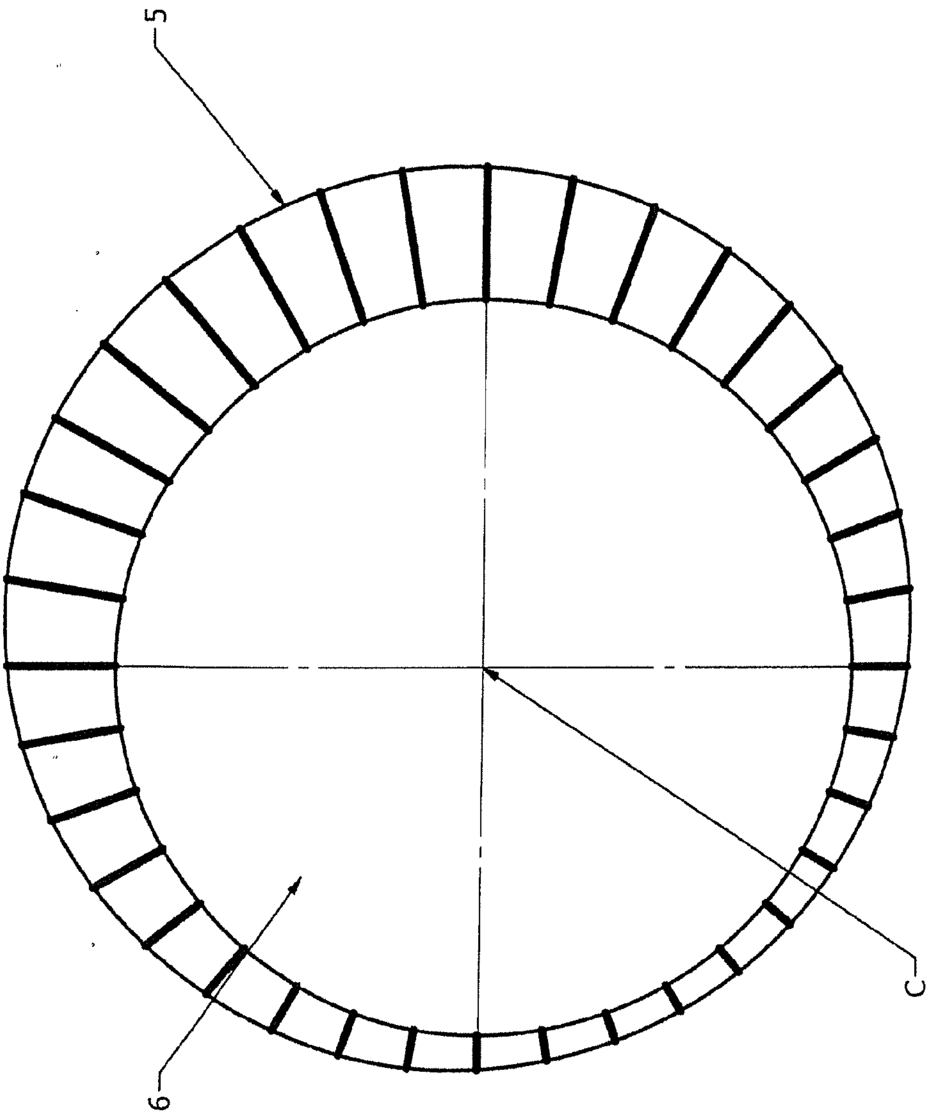



Fig.8

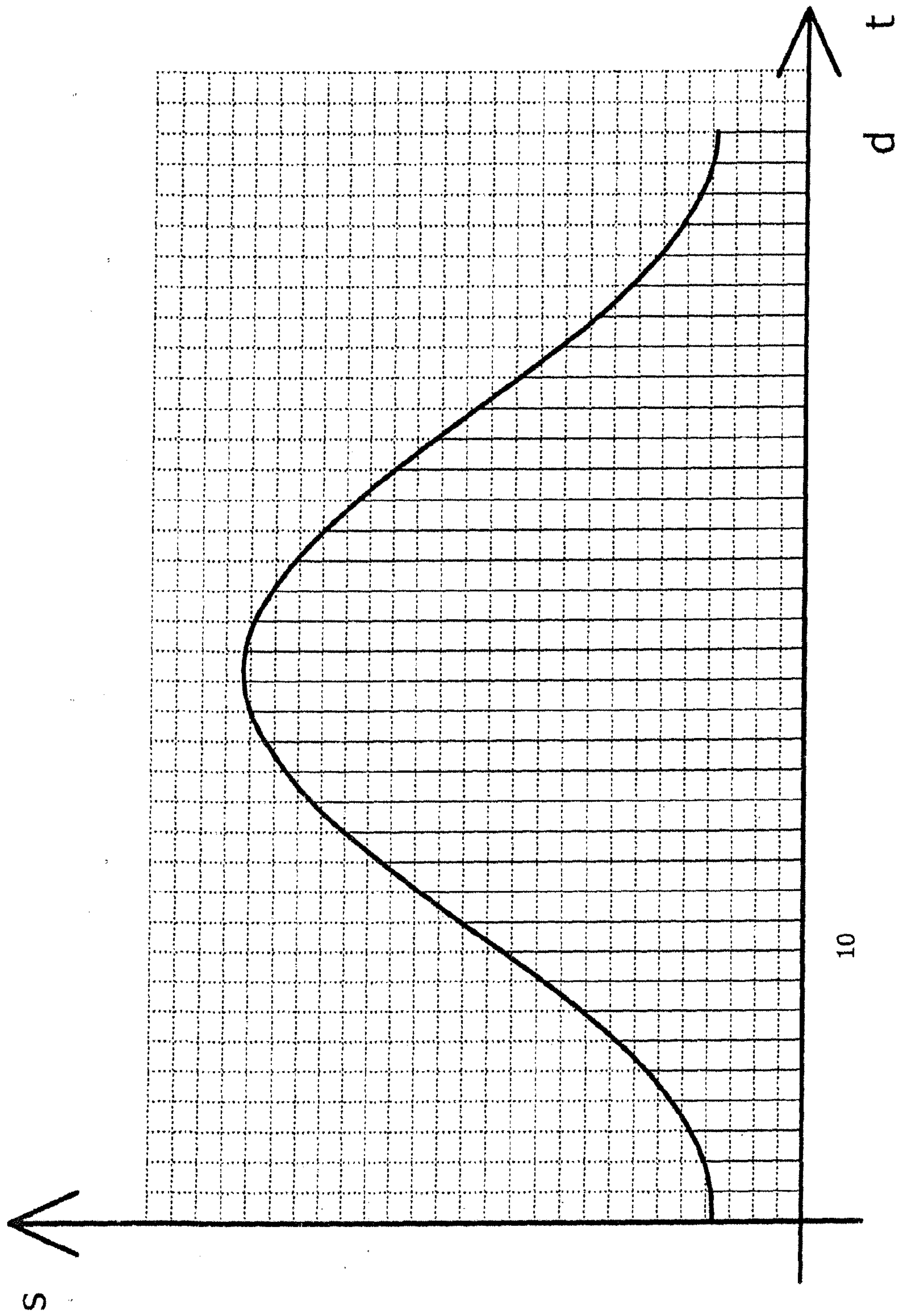



Fig.9

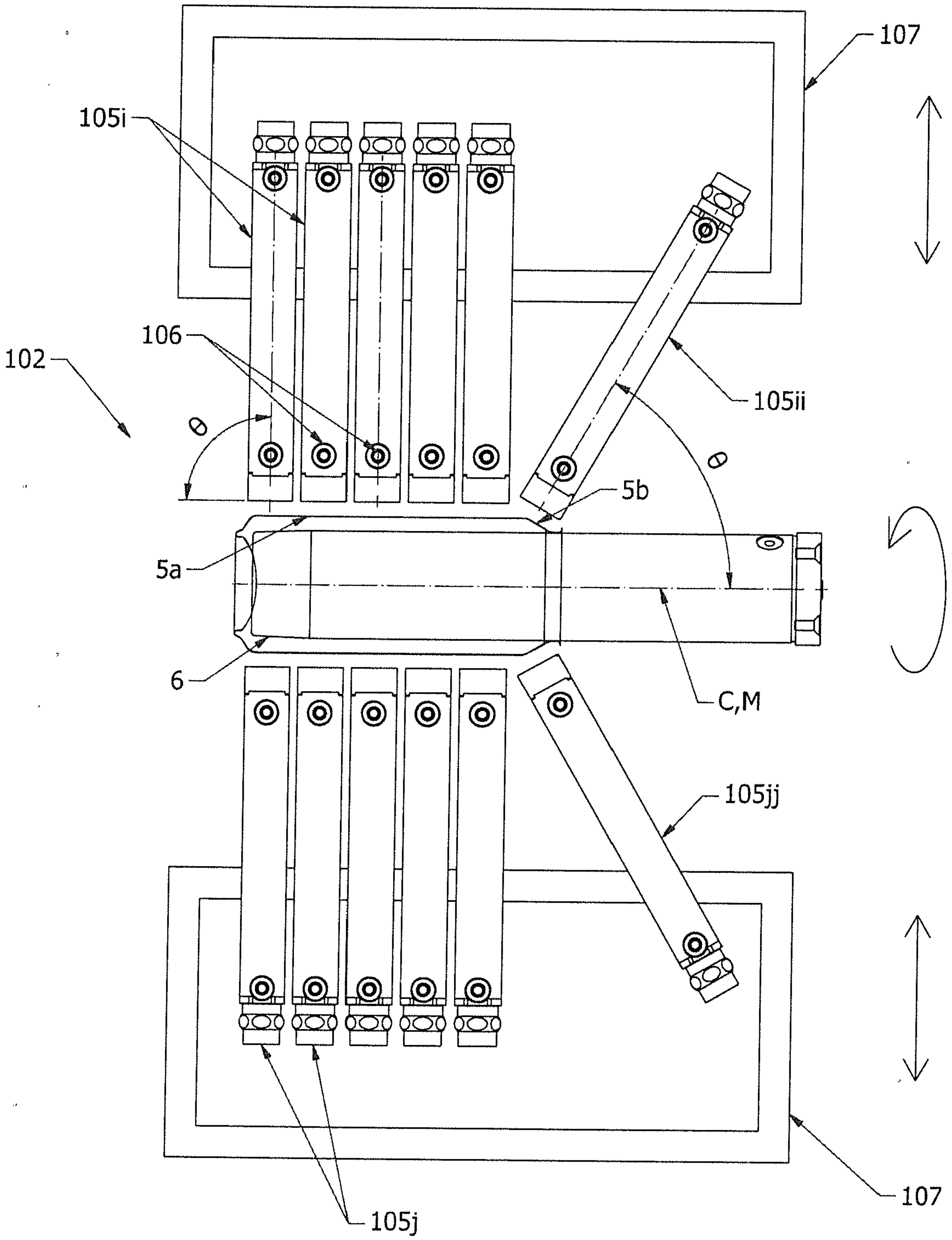
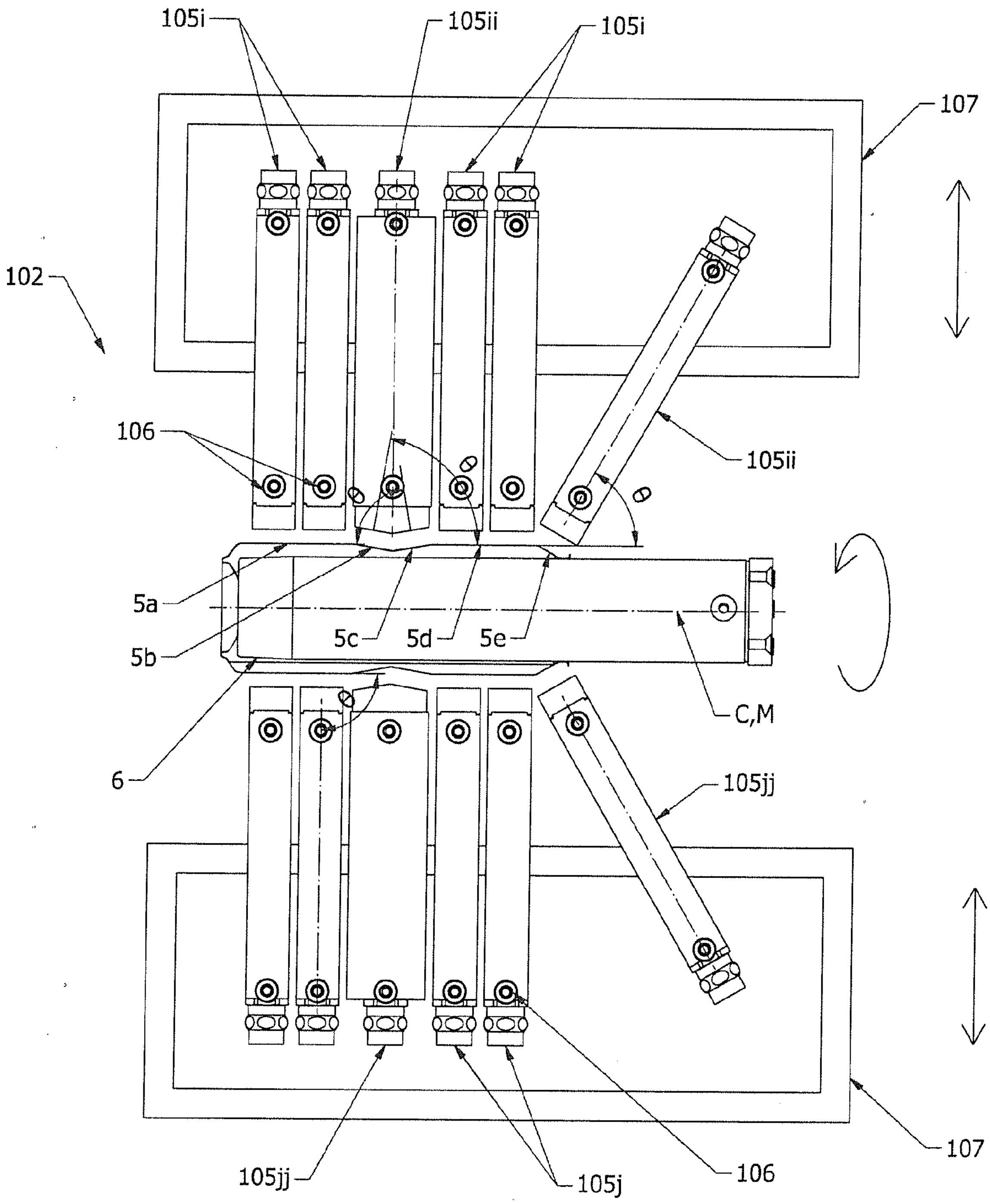



Fig.10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105ii
105i
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105ii
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105j
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107

Fig.11

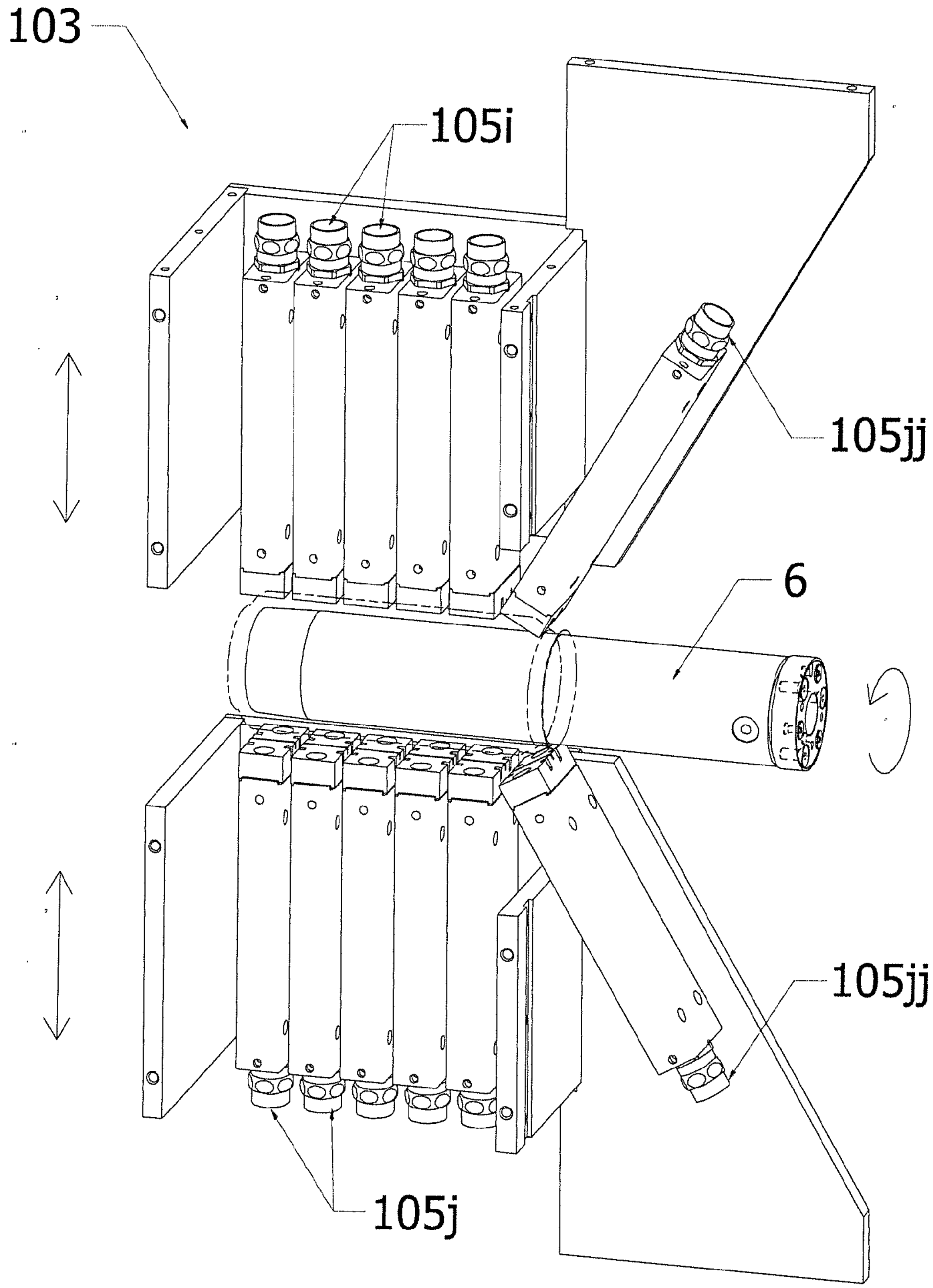


Fig.12

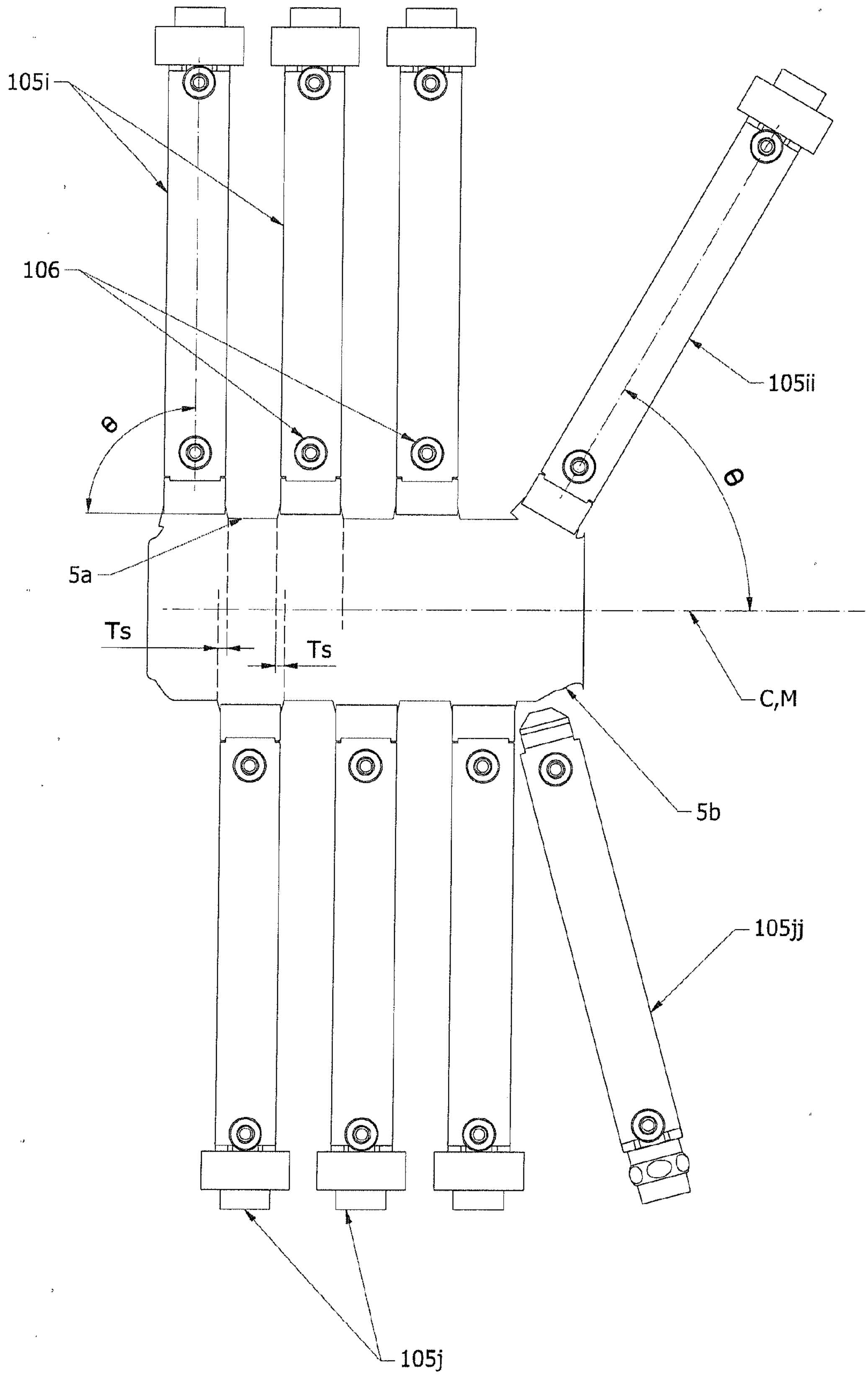


Fig.13

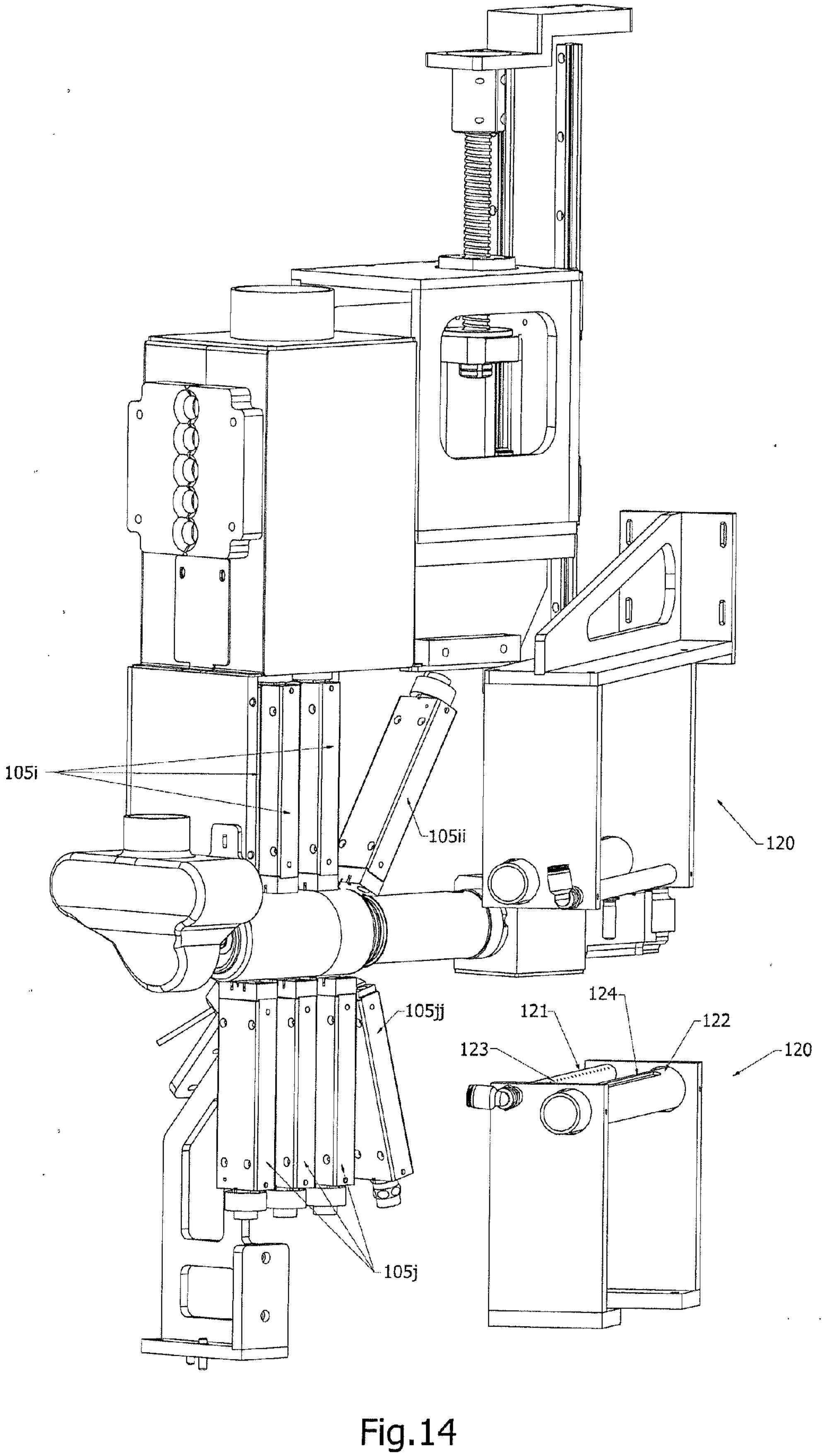


Fig.14

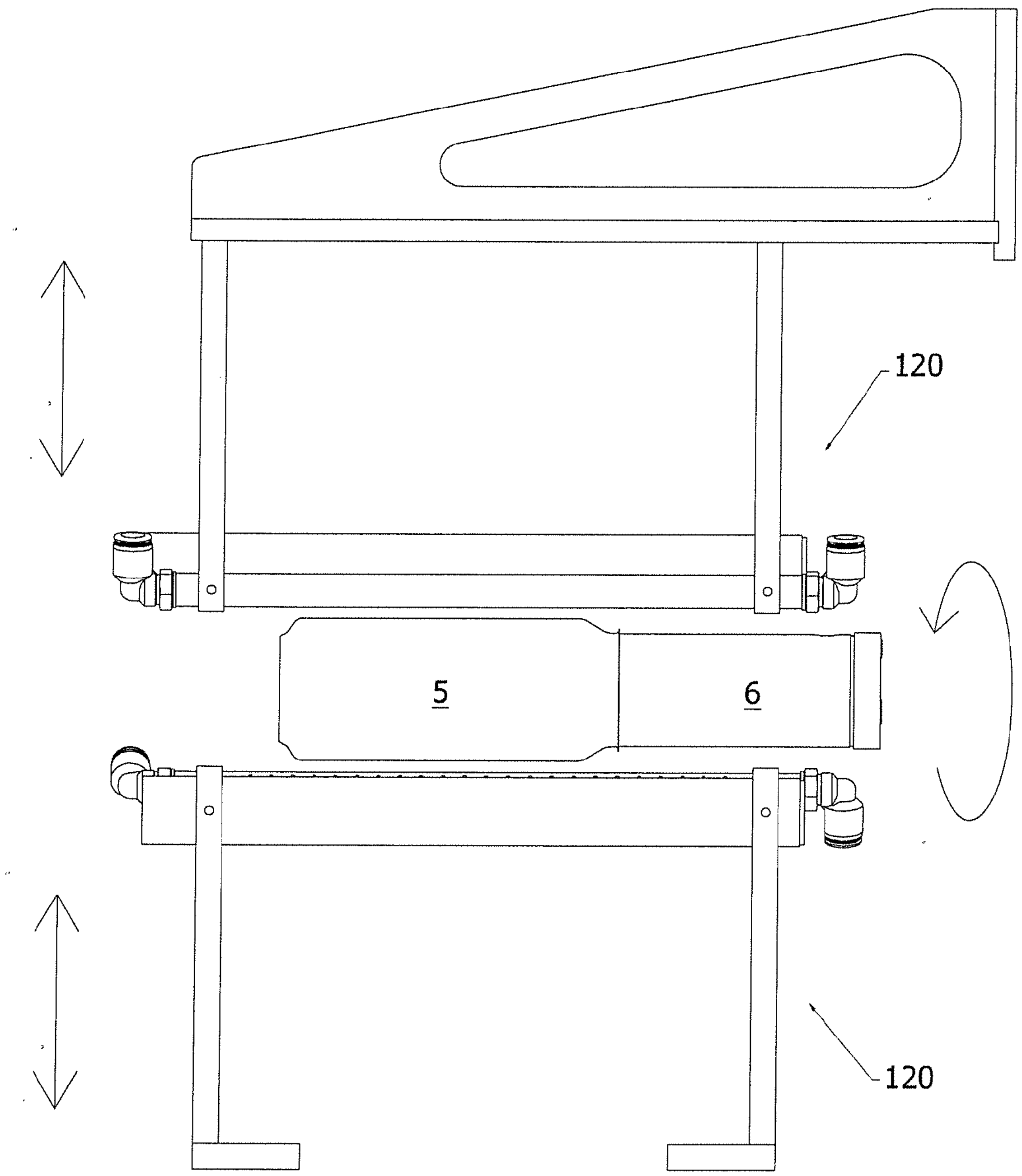


Fig.15

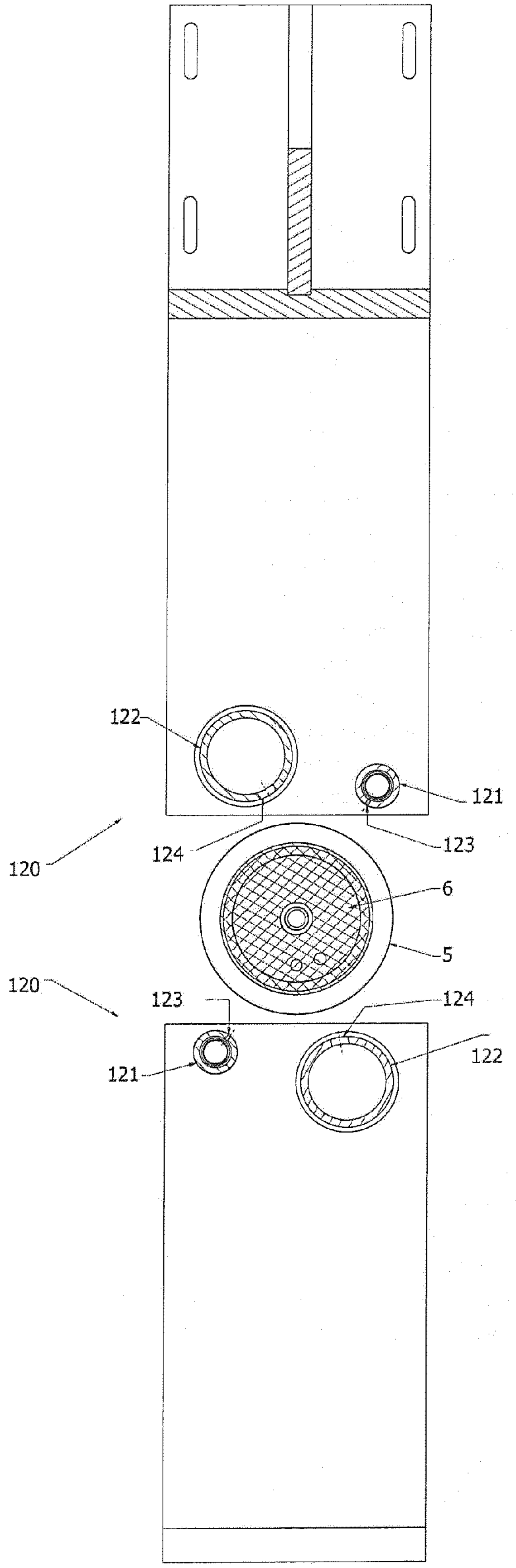


Fig.16

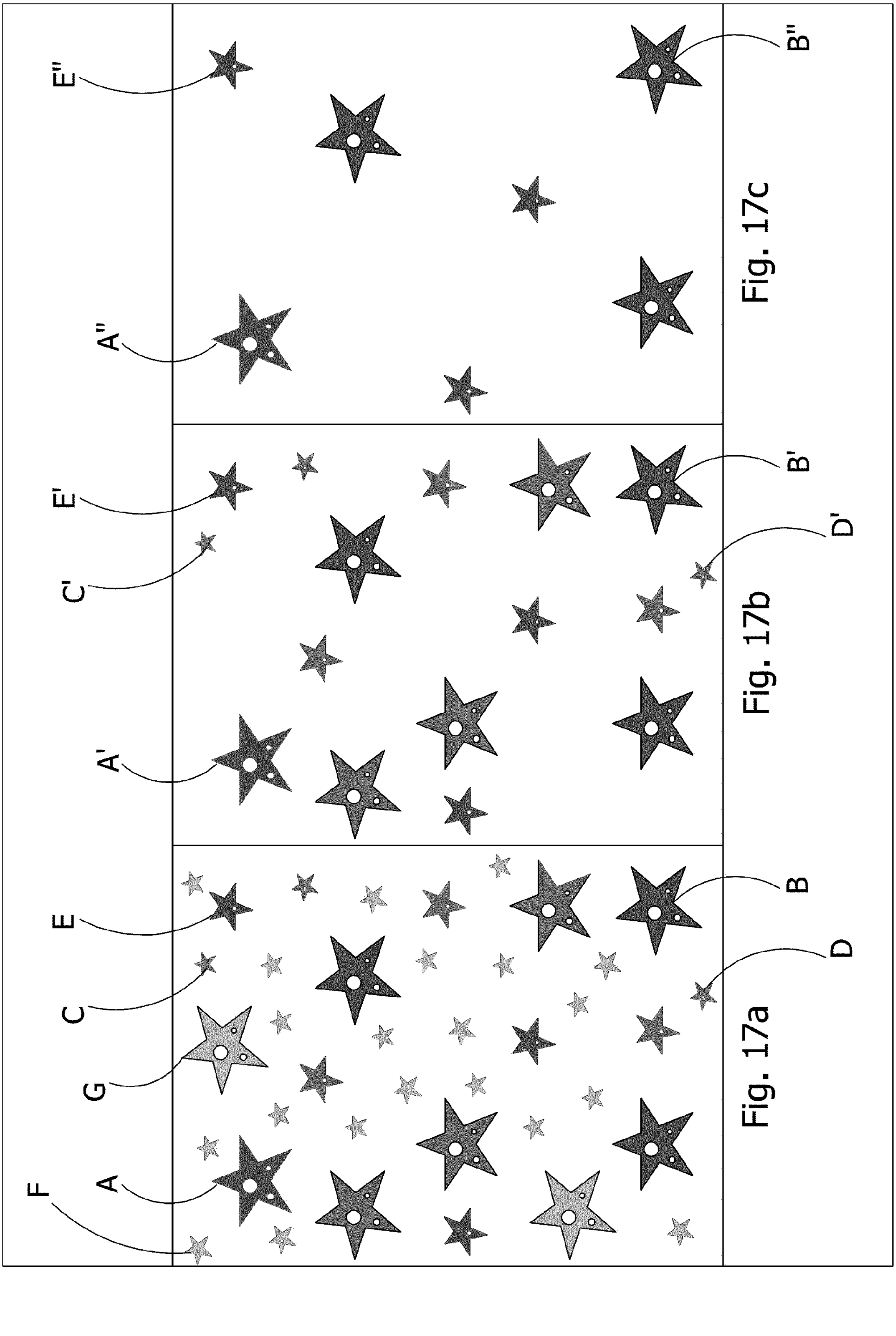


Fig. 17a

Fig. 17b

Fig. 17c

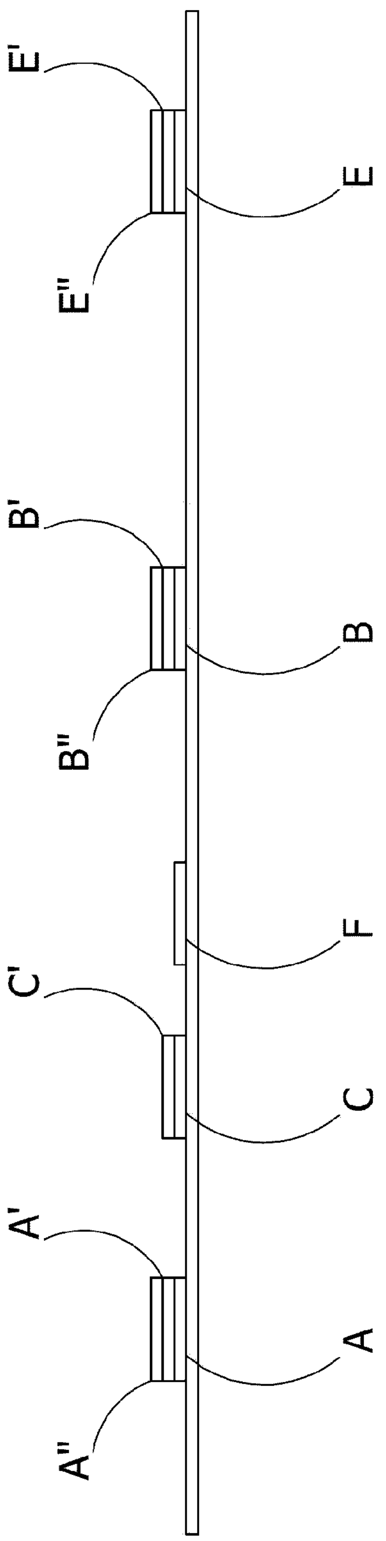


Fig. 18

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# EUROPEAN SEARCH REPORT

Application Number
EP 24 15 6275

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| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
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B65G
B41J

The present search report has been drawn up for all claims

1

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| The Hague | 25 June 2024 | Dewaele, Karl |

CATEGORY OF CITED DOCUMENTS

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