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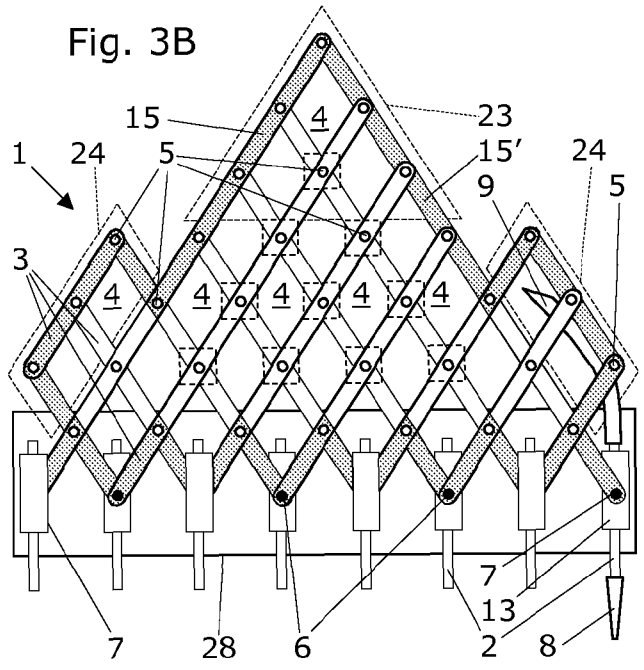
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(54) **Title**: SPREAD SHEARE



(57) **Abstract**: A spread sheare (1), preferably of a robot arm (28) of a liquid handling workstation or robotic sample processor, is accomplished for the variable but equidistant allocation of at least three liquid handling tools (2) in a Cartesian coordinate system of a liquid handling apparatus with an X-, Y-, and Z-axis. The liquid handling tools (2) are orientated substantially parallel to the vertical Z-axis and are aligned in direction of the horizontal Y-axis. The spread sheare (1) comprises pantograph members (3,15,15') that form a plurality of parallelograms (4) and that are pivotally connected to each other at nodal points (5,5',5",6), preferably located in all four corners of the parallelograms (4). Each liquid handling tool (2) is attached to a nodal anchor point (6,6') or to a single end point (7) of the spread sheare (1). According to a first aspect of the present invention, each nodal anchor point (6,6'), to which a liquid handling tool (2) is attached, is rigidly connected via two pantograph members (3) that join at this nodal anchor point (6,6') to at least five nodal points (5,5',5") located on said two pantograph members (3). Preferably, each single end point (7), to which a liquid handling tool (2) is attached, is rigidly connected via the pantograph member (3,15,15'), the single end point (7) is located on, to at least four nodal points (5) located on the respective pantograph member (3). According to a second aspect of the present invention, the pantograph members (15,15') at a first and second extreme position form a triangle structure, at least the nodal points (5) on these extreme positioned pantograph members (15,15') and the nodal points (5) that are located next to each nodal anchor point (6,6'), to which a liquid handling tool (2) is attached, are each equipped with a bearing (22) for rigidly but pivotably connecting the two pantograph members (3,15,15') meeting at the respective nodal points.

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Spread Sheare

Technical area of the invention

The invention relates to a spread sheare for variable but equidistant allocation of at least three liquid handling tools that are aligned in a single row and that are selected from a group comprising pipette tips, dispenser tips, sensors and probes. Such liquid handling tools are known from e.g. automated pipetters or dispensers that are accomplished to take up and/or deposit liquid samples and that are a preferred part of liquid handling workstations or robotic sample processors such as the GENESIS Freedom® workstation or the Freedom EVO® platform (both of Tecan Trading AG, 8708 Männedorf, Switzerland).

Related prior art

US 2004/0076550 A1 of the present applicant discloses a pipetting device that is accomplished as a multi-channel pipetter on which eight pipettes are mounted to elongated supports so they can be horizontally displaced, lifted and lowered. The elongated supports are attached to a carriage that provides horizontal movement to the supports as well as expanding or compressing the intervals between neighboring supports or pipettes respectively. The intervals are always essentially equally large, because a so-called "Luxembourg Grid" connects the neighboring supports. Direct driving of the supports seated at the positions 3 and/or 7 and the use of a return spring has proven itself in order to routinely provide intervals that match with the pitch of a 96 well microplate. This pipetting device obviously is intended to be incorporated into one of the liquid handling workstations or robotic sample processors as mentioned above. This "Luxembourg Grid" has proven itself for the reproducible positioning of the pipettes with respect to the wells of a 24-well or 96-well microplate according to the ANSI/SBS 1-2004 Standard.

From US 6,235,244 B1, another multi-channel pipetting system is known. The handheld system has eight fittings whose spacing can be simultaneously, quickly and accurately adjusted so that the spacing between each adjacent pipette tip fitting is substantially identical. The tip fittings are attached one to another by linkage such as a pantograph linkage. The spacing of the pipette tips can be adapted to the well pitch of a multi-well microplate and is limited by adjustable sliding stops. Uniformly increasing and decreasing the spacing is accomplished by pulling and pushing a rod attached to the one fitting tip. A schematic drawing of the respective pantograph linkage is depicted in Fig. 1A.

A variable-pitch pick and place device with a pantograph linkage is known from US 6,439,631 B1. This device with another pantograph linkage is designed for a chip handling system in the production of electronic chips. The linkage itself is connected to a plurality of device-gripping mechanisms arranged in a row so as to keep uniform, though variable, spacing between the device-gripping mechanisms. The number of such mechanisms is increased relative to the number of parts in the linkage for reduced tolerance stack-up and improved positioning accuracy. Preferably, the device-gripping mechanisms are alternately arranged in two rows on both sides of the pantograph lattice. A schematic drawing of the respective pantograph linkage for twelve device-gripping mechanisms is depicted in Fig. 1B.

Objects and summary of the invention

As already indicated with respect to the "Luxemburg Grid" of US 2004/0076550 A1, and as revealed when testing the pantograph linkage according to US 6,235,244 B1, it turned out that when the pipette tips have to be routinely and precisely positioned to microplates with 384 wells or even to microplates with 1536 wells, precision of positioning is not sufficient. It is therefore an object of the present invention to propose an alternative linkage for variable but equidistant allocation of at least three liquid handling tools that are aligned in one row and that preferably are selected from a group comprising pipette tips, dispenser tips, sensors and probes.

With reference to a first aspect, this object is achieved by the spread sheare according to the independent claim 1, which defines a spread sheare for the variable but equidistant allocation of at least three liquid handling tools in a Cartesian coor-

dinate system liquid handling apparatus with an X-, Y-, and Z-axis. The liquid handling tools are orientated substantially parallel to the vertical Z-axis and are aligned in direction of the horizontal Y-axis. The spread sheare comprises pantograph members that form a plurality of parallelograms and that are pivotally connected to each other at nodal points located in corners of the parallelograms. A liquid handling tool is attached to each nodal anchor point or single end point . The spread sheare of the present invention according to a first alternative is characterized in that the spread sheare further comprises added wings arranged on both sides of the spread sheare

Additional and inventive features derive from the attached claims.

The spread sheare according to the present invention includes the following advantages:

- Every pantograph member is inter-linked with other pantograph members by a multitude of joint points or nodal points respectively. This results in multiple over-determination of the flexible lattice structure of the spread sheare and thus, in considerably reduced play and tolerances. In consequence, the pipetting or dispenser heads that are attached to an extreme joint or nodal point or to a single end point at one end of the spread sheare are more precisely hold in place.
- Attaching the pipetting or dispenser heads in an intermediate joint or nodal position within the spread sheare provides additional reduction of play and tolerances and thus, additional precision.
- Forming a triangle structure with the pantograph members at a first and second extreme position and selecting only certain nodal points equipped with bearings provides maximal stability to a spread sheare that is equipped with a minimum of bearings.

Brief introduction to the drawings

Attached to this specification are drawing sheets that schematically depict prior art pantographs and preferred embodiments of the spread sheare according to the present invention. There are shown in

Fig. 1 Pantograph linkages known from the prior art, wherein:
Fig. 1A shows the pantograph linkage comprising 13 upper nodal points from US 6,235,244 B1, with 8 pipetting heads attached to 6 extreme nodal anchor points that interlink pantograph members and to 2 single end points; and
Fig. 1B shows the pantograph linkage comprising 11 upper and 5 lower nodal points from US 6,439,631 B1, with 12 pick and place heads attached to 10 intermediate points that are located in-between two nodal points 5,5' which interlink pantograph members and to 2 single end points;

Figs. 2-3 A spread sheare with 8 pipetting heads attached to 6 extreme nodal points that interlink pantograph members and to 2 single end points, wherein:
Fig. 2A shows a spread sheare with 15 parallelograms and 22 upper nodal points, according to a first embodiment of the present invention;
Fig. 2B shows a first alternative variant of a spread sheare with 21 parallelograms and 28 upper nodal points, according to a second embodiment of the present invention;
Fig. 2B in addition shows a second alternative variant of a spread sheare based on a triangle structure with the pantograph members at a first and second extreme position and a minimum of nodal points equipped with bearings;
Fig. 3A shows a spread sheare with 19 parallelograms and 28 upper nodal points, according to a third embodiment of the present invention; and
Fig. 3B shows a first alternative variant of a spread sheare with 25 parallelograms and 34 upper nodal points, according to a fourth embodiment of the present invention;
Fig. 3B in addition shows a second alternative variant of a spread sheare based on a triangle structure with the pantograph members at a first and second extreme position and a minimum of nodal points equipped with bearings;

Figs. 4-5 A spread sheare with 8 pipetting heads attached to 8 intermediate nodal points that interlink pantograph members, wherein:
Fig. 4A shows a spread sheare with 22 parallelograms, 22 upper and 7 lower nodal points, according to a fifth embodiment of the present invention;
Fig. 4B shows a first alternative variant of a spread sheare with 30 parallelograms, 28 upper and 9 lower nodal points, according to a sixth embodiment of the present invention;
Fig. 4B in addition shows a second alternative variant of a spread sheare based on a triangle structure with the pantograph members at a first and second extreme position and a minimum of nodal points equipped with bearings;
Fig. 5A shows a spread sheare with 25 parallelograms, 28 upper and 6 lower nodal points, according to a seventh embodiment of the present invention; and
Fig. 5B shows a first alternative variant of a spread sheare with 34 parallelograms, 34 upper and 9 lower nodal points, according to an eighth embodiment of the present invention.
Fig. 5B in addition shows a second alternative variant of a spread sheare based on a triangle structure with the pantograph members at a first and second extreme position and a minimum of nodal points equipped with bearings;

Fig. 6 Cross section views of a housing for a Z-drive of a liquid handling tool and the spread sheare of the present invention; wherein:
Fig. 6A shows a 3D-view with a gear rack that is movable in the Z-direction by the Z-drive; and
Fig. 6B shows a vertical cross section through the gear rack and the spread sheare;

Fig. 7 Perspective views of a spread sheare with 25 parallelograms and 34 upper nodal points with added wings arranged on both sides of the spread sheare, according to a further embodiment of the present invention; and

Fig. 7A shows a first alternative variant of the spread sheare, wherein on at least a first side of each parallelogram, a further pantograph member is pivotably mounted parallel to the pantograph member forming said first side, such that the pantograph members forming the two adjacent sides of the parallelogram with respect to said first side are situated between the further pantograph member and the pantograph member forming said first side;

Fig. 7B shows a first alternative variant of the spread sheare, wherein on a first side and on a second side of each parallelogram, , two further pantograph members are pivotably mounted parallel to the pantograph members forming said first side respectively second side, such that the pantograph members forming the two adjacent sides of the parallelogram with respect to said first side are situated between the further pantograph member and the pantograph member forming said first side.

Detailed description of the prior art embodiments

Figure 1A shows the pantograph linkage comprising thirteen upper nodal points as known from US 6,235,244 B1. Eight liquid handling heads 13 with liquid handling tools 2 in the form of pipettes are attached to a total of six extreme nodal anchor points 6 that interlink pantograph members 3 and to two single end points 7 at the end of the first and last pantograph member 3 of the spread sheare 1. For manipulating these eight liquid handling tools 2, a minimal number of only six parallelograms 4 are utilized. Each one of the extreme nodal anchor points 6 is rigidly connected to three or four nodal points 5 located on the two pantograph members 3 that join at one of these extreme nodal anchor points 6. In addition, each single end point 7 is rigidly connected to 2 nodal points located on one of the respective pantograph members 3. For pipetting, a disposable pipette tip 8 is connected to one side of the liquid handling tool 2 and a tubing 9 for providing under-pressure or over-pressure in the pipette tips 8 is attached to an opposite side of the liquid handling head 13 (only one tip 8 and one tubing 9 is shown for better overview). The average mean deviation of the position of the liquid handling tools 2 was measured to be +/- 0.4 mm in a number of about 10^6 positioning movements.

Figure 1B shows the pantograph linkage comprising eleven upper and five lower nodal points as known from US 6,439,631 B1. Twelve pick and place heads 10 (each equipped with one pick and place tool 10') are attached to ten intermediate points 14 that are located in-between two nodal points 5,5' which interlink pantograph members and to 2 single end points at the end of the first and last pantograph member 3 of the spread sheare 1. These pick and place heads 10 are arranged in two rows with six pick and place heads 10, one in front and one behind the spread sheare 1 (not all pick and place heads 10 of the front row are drawn for better overview). For manipulating these twelve pick and place tools 10', a minimal number of only five parallelograms 4 are utilized. Each one of the ten intermediate points 14 is rigidly connected to two or three nodal points 5,5' located on the pantograph member 3 the intermediate point 14 is located on. In addition, each single end point 7 is rigidly connected to 2 nodal points located on one of the respective first and last pantograph members 3 of the spread sheare 1. For picking up or placing work pieces, a pick and place tool 10' is connected to one side of the pick and place head 10 and a wiring 11 for providing electric power to the pick and place tool 10' is attached to the other side of the pick and place head 10 (only one wiring 11 is shown for better overview). A roller 12 that moves in a guide (not shown) provides additional stability to the spread sheare 1.

Detailed description of the preferred embodiments

The Figures 2 and 3 show a spread sheare 1 with eight liquid handling heads 13 with liquid handling tools 2 in the form of pipettes that are attached to a total of six extreme nodal anchor points 6 that interlink pantograph members 3 and to two single end points 7 at the end of the first and last pantograph member 3 of the spread sheare 1. For pipetting, a disposable pipette tip 8 is connected to one side of the liquid handling tool 2 or pipette and a tubing 9 for providing under-pressure or over-pressure in the pipette tips 8 is attached to the other side of the liquid handling head 13 (only one tip 8 and one tubing 9 is shown for better overview). Every pantograph member 3 is inter-linked with other pantograph members 3 by a multitude of joint points or nodal points 5,6 respectively. This results in multiple overdetermination of the flexible lattice structure of the spread sheare 1 and thus, in considerably reduced play and tolerances with respect to repeated, accurate and precise locating the liquid handling tools 2.

In each case, a spread sheare 1 for the variable but equidistant allocation of at least three liquid handling tools 2 is shown. The spread sheare 1 preferably is incorporated in a Cartesian coordinate system liquid handling apparatus (not shown) with an X-, Y-, and Z-axis. Most preferably, a robot arm 28 of a liquid handling workstation or robotic sample processor is accomplished to move in such a Cartesian coordinate system with an X-, Y-, and Z-axis; such a robot arm preferably comprises at least one spread sheare 1. The liquid handling tools 2 preferably are orientated substantially parallel to the vertical Z-axis and are aligned in direction of the horizontal Y-axis. The spread sheare 1 comprises pantograph members 3 that form a plurality of parallelograms 4. The pantograph members 3 are pivotally connected to each other at nodal points 5,5',6. The nodal points 5,5',6 most preferably are located in all four corners of the parallelograms 4. In order to comply with the minimal requirement as defined in claim 1, however, the optional nodal points 18 (two dotted rhombi) and the preferred nodal point 19 (dotted circle) do not absolutely need to be accomplished as a connection of the respective pantograph members.
In consequence, the pipetting or dispenser heads that are attached to an extreme nodal anchor point 6 or to a single end point 7 at one end of the spread sheare 1 are more reproducibly hold in place with respect to the Y-axis if compared with the known prior art. Precision measurements confirm this finding: With respect to the preferred embodiment of Figure 2B, the average mean deviation of the position of the liquid handling tools 2 was measured to be +/- 0.3 mm in a number of 6×10^6 positioning movements. With respect to the preferred embodiment of Figure 3B, the average mean deviation of the position of the liquid handling tools 2 was measured to be +/- 0.15 mm in a number of 6×10^6 positioning movements.

Each liquid handling tool 2 is attached to a nodal anchor point 6,6' or to a single end point 7 of the spread sheare 1. In the context of the present invention, the liquid handling tools 2 are selected from the group comprising pipette tips, dispenser tips, sensors and probes. Examples of pipette or dispenser tips include disposable tips and permanent tips (e.g. from stainless steel). Examples of sensors include temperature sensors. Examples of probes include liquid level detection tips, surface sensing devices and pH probes. All these liquid handling tools are provided with the necessary tubing 9 and/or wiring 11.

According to the first four embodiments of the present invention, each nodal anchor point 6,6', to which a liquid handling tool 2 is attached, is rigidly connected, via two pantograph members 3 that join at this nodal anchor point 6,6', to at least five nodal points 5,5' located on said two pantograph members 3. Preferably, these embodiments are defined by the fact that each single end point 7, to which a liquid handling tool 2 is attached, is rigidly connected via the pantograph member 3, the single end point 7 is located on, to at least four nodal points 5 located on the respective pantograph member 3.

Figure 2A shows the first preferred embodiment of a spread sheare 1 according to the present invention. For manipulating these eight liquid handling tools 2, a total number of fifteen parallelograms 4 are utilized. As a result, each one of the extreme nodal anchor points 6 is rigidly connected to five to seven nodal points 5 located on the two pantograph members 3 that join at one of these extreme nodal anchor points 6. In addition, each single end point 7 is rigidly connected to four nodal points 5 located on one of the respective pantograph members 3. The total number of nodal points 5,6 is 28.

Figure 2B shows a first alternative variant of the second preferred embodiment of a spread sheare 1 according to the present invention. For manipulating these eight liquid handling tools 2, a total number of twenty-one parallelograms 4 are utilized. As a result, each one of the extreme nodal anchor points 6 is rigidly connected to seven nodal points 5 located on the two pantograph members 3 that join at one of these extreme nodal anchor points 6. In addition, each single end point 7 is rigidly connected to seven nodal points 5 located on one of the respective pantograph members 15,15'. The total number of nodal points 5,6 is 34. It is expressly noted here that (if compared with the first embodiment of Fig. 2A) the added triangle 23 (see dashed lines) on top of the spread sheare 1 considerably increases the degree of multiple over-determination and thus adds to the stability of the flexible lattice structure of the spread sheare 1.

Figure 2B also shows a second alternative variant of the second preferred embodiment of a spread sheare 1 according to the present invention. Again, for manipulat-

ing these eight liquid handling tools 2, a total number of twenty-one parallelograms 4 are utilized. In contrast to the first variant, however, at all nodal points that are not located on one of the extreme positioned pantograph members 15,15' (which form a triangle structure together with the extreme nodal anchor points 6 and single end points 7) and that are not located next to each nodal anchor point 6, to which a liquid handling tool 2 is attached, the bearing 22 can be omitted (indicated as dashed squares). It is observed that the stability of this second alternative variant with 24 fitted and 10 omitted bearings 22 lays between the stability of the first preferred embodiment as depicted in Fig. 2A (with twenty-two bearings at all nodal points) and the first alternative variant of the second preferred embodiment (with 34 bearings at all nodal points; see Fig. 2B). It thus surprisingly turned out that the addition of only 2 more bearings 22 but forming the triangle structure provided a considerable improvement with respect to the first preferred embodiment as depicted in Fig. 2A.

Figure 3A shows the third preferred embodiment of a spread sheare 1 according to the present invention. For manipulating these eight liquid handling tools 2, a total number of nineteen parallelograms 4 are utilized. As a result, each one of the extreme nodal anchor points 6 is rigidly connected to six to eighth nodal points 5 located on the two pantograph members 3 that join at one of these extreme nodal anchor points 6. In addition, each single end point 7 is rigidly connected to four nodal points 5 located on one of the respective pantograph members 3. The total number of nodal points 5,6 is 34. It is expressly noted here that (if compared with the first embodiment of Fig. 2A) the added wings 24 on both sides of the spread sheare 1 considerably increase the degree of multiple over-determination and thus add to the stability of the flexible lattice structure of the spread sheare 1.

Figure 3B shows a first alternative variant of the fourth preferred embodiment of a spread sheare 1 according to the present invention. For manipulating these eight liquid handling tools 2, a total number of twenty-five parallelograms 4 are utilized. As a result, each one of the extreme nodal anchor points 6 is rigidly connected to eighth nodal points 5 located on the two pantograph members 3 that join at one of these extreme nodal anchor points 6. In addition, each single end point 7 is rigidly connected to seven nodal points 5 located on one of the respective pantograph

members 15,15'. The total number of nodal points 5,6 is 40. It is expressly noted here that (if compared with the first three embodiments of Figs. 2A, 2B, and 3A) the combination of added triangle 23 on top of the spread sheare 1 and added wings 24 (see dashed lines) on both sides of the spread sheare 1 considerably increase the degree of multiple over-determination and thus add to the stability of the flexible lattice structure of the spread sheare 1.

Figure 3B also shows a second alternative variant of the fourth preferred embodiment of a spread sheare 1 according to the present invention. Again, for manipulating these eight liquid handling tools 2, a total number of twenty-one parallelograms 4 are utilized. In contrast to the first variant, however, at all nodal points that are not located on one of the extreme positioned pantograph members 15,15' (which form a triangle structure together with the extreme nodal anchor points 6 and single end points 7) and that are not located next to each nodal anchor point 6, to which a liquid handling tool 2 is attached, the bearing 22 can be omitted (indicated as dashed squares).

For at least the four embodiments discussed so far, it is preferred that the largest extension of the spread sheare 1 in direction of the Y-axis is defined by two single end points 7, or by two single end points 7 and two upper nodal points 5 (see Figs. 3A and 3B).

The Figures 4 and 5 show a spread sheare 1 with eight liquid handling heads 13 with liquid handling tools 2 in the form of pipettes that are attached to a total of eight nodal anchor points 6,6' that all interlink pantograph members 3,15,15'. For pipetting, a disposable pipette tip 8 is connected to one side of the liquid handling tool 2 or pipette and a tubing 9 for providing under-pressure or over-pressure in the pipette tips 8 is attached to the other side of the liquid handling head 13 (only one tip 8 and one tubing 9 is shown for better overview). Every pantograph member 3,15,15' is inter-linked with other pantograph members 3,15,15' by a multitude of joint points or nodal points 5,5',5'',6,6' respectively. This results in multiple over-determination of the flexible lattice structure of the spread sheare 1 and thus, in considerably reduced play and tolerances with respect to repeated, accurate and precise locating the liquid handling tools 2. For easier viewing, the most preferred

robot arm 28 of a liquid handling workstation or robotic sample processor that comprises at least one spread sheare 1 according to the present invention is not shown here.

In each case, a spread sheare 1 for the variable but equidistant allocation of at least three liquid handling tools 2 is shown. The spread sheare 1 preferably is incorporated in a Cartesian coordinate system liquid handling apparatus (not shown) with an X-, Y-, and Z-axis. The liquid handling tools 2 preferably are orientated substantially parallel to the vertical Z-axis and are aligned in direction of the horizontal Y-axis. The spread sheare 1 comprises pantograph members 3,15,15′ that form a plurality of parallelograms 4. The pantograph members 3,15,15′ are pivotally connected to each other at nodal points 5,5′,5″,6,6′. The nodal points 5,5′,5″,6,6′ are most preferably located in all four corners of the parallelograms 4.

In consequence, the pipetting or dispenser heads that are attached to an intermediate nodal anchor point 6′ or to an extreme nodal anchor point 6 are more reproducibly hold in place with respect to the Y-axis if compared with the known prior art.

According to the second four embodiments of the present invention (see Figs. 4-5), each nodal anchor point 6,6′, to which a liquid handling tool 2 is attached, is rigidly connected, via two pantograph members 3,15,15′ that join at this nodal anchor point 6,6′, to at least five nodal points 5,5′,5″ located on said two pantograph members 3,15,15′.

Figure 4A shows the fifth preferred embodiment of a spread sheare 1 according to the present invention. For manipulating these eight liquid handling tools 2, a total number of twenty-two parallelograms 4 are utilized. As a result, each one of the intermediate nodal anchor points 6′ is rigidly connected to five to nine nodal points 5,5′ located on the two pantograph members 3 that join at one of these intermediate nodal anchor points 6′. The total number of nodal points 5,5′,6′ is 37. It is expressly noted here that (if compared with the first embodiment of Fig. 2A) the added segment 25 (with the lower nodal points 5′) on the base of the spread sheare 1

considerably increases the degree of multiple over-determination and thus adds to the stability of the flexible lattice structure of the spread sheare 1.

Figure 4B shows a first alternative variant of the sixth preferred embodiment of a spread sheare 1 according to the present invention. For manipulating these eight liquid handling tools 2, a total number of thirty parallelograms 4 are utilized. As a result, each one of the intermediate nodal anchor points 6' is rigidly connected to nine to ten nodal points 5,5',5'' located on the two pantograph members 3,15,15' that join at one of these intermediate nodal anchor points 6'. The total number of nodal points is 45. It is expressly noted here that (if compared with the fifth embodiment of Fig. 4A) the added triangle 23 (with the upper nodal points 5) on the top of the spread sheare 1 and the added peaks 26 (with the lower extreme nodal points 5'') at the base of the added segment 25 considerably increase the degree of multiple over-determination and thus add to the stability of the flexible lattice structure of the spread sheare 1.

Figure 4B also shows a second alternative variant of the sixth preferred embodiment of a spread sheare 1 according to the present invention. Again, for manipulating these eight liquid handling tools 2, a total number of thirty parallelograms 4 are utilized. In contrast to the first variant, however, at all nodal points that are not located on one of the extreme positioned pantograph members 15,15' (which form a triangle structure together with the intermediate nodal anchor points 6') and that are not located next to each intermediate nodal anchor point 6', to which a liquid handling tool 2 is attached, the bearing 22 can be omitted (indicated as dashed squares). This does not necessarily apply to the lower extreme nodal points 5''.

Figure 5A shows the seventh preferred embodiment of a spread sheare 1 according to the present invention. For manipulating these eight liquid handling tools 2, a total number of twenty-five parallelograms 4 are utilized. As a result, each one of the extreme nodal anchor points 6 is rigidly connected to eighth nodal points 5 located on the two pantograph members 3 that join at one of these extreme nodal anchor points 6. In addition, each intermediate nodal anchor point 6' is rigidly connected to six to nine nodal points 5,5',5'' located on one of the respective pantograph members 3. The total number of nodal points is 42. It is expressly noted here that (if

compared with the third embodiment of Fig. 3A) the added peaks 26 (with the lower nodal points 5′ and the lower extreme nodal points 5″) on the base of the spread sheare 1 considerably increase the degree of multiple over-determination and thus add to the stability of the flexible lattice structure of the spread sheare 1.

Figure 5B shows a first alternative variant of the eighth preferred embodiment of a spread sheare 1 according to the present invention. For manipulating these eight liquid handling tools 2, a total number of thirty-four parallelograms 4 are utilized. As a result, each one of the intermediate nodal anchor points 6′ is rigidly connected to nine to eleven nodal points 5,5′,5″ located on the two pantograph members 3,15,15′ that join at one of these intermediate nodal anchor points 6′. The total number of nodal points is 51. It is expressly noted here that (if compared with the sixth embodiment of Fig. 4B) the added wings 24 (with the upper nodal points 5) on both sides of the spread sheare 1 again increase the degree of multiple over-determination and thus add to the stability of the flexible lattice structure of the spread sheare 1.

Figure 5B also shows a second alternative variant of the eighth preferred embodiment of a spread sheare 1 according to the present invention. Again, for manipulating these eight liquid handling tools 2, a total number of thirty-four parallelograms 4 are utilized. In contrast to the first variant, however, at all nodal points that are not located on one of the extreme positioned pantograph members 15,15′ (which form a triangle structure together with the intermediate nodal anchor points 6′) and that are not located next to each intermediate nodal anchor point 6′, to which a liquid handling tool 2 is attached, the bearing 22 can be omitted (indicated as dashed squares). This does not necessarily apply to the lower extreme nodal points 5″.

It has been shown that more nodal points 5,5′,5″ fitted with bearings 22 contribute to higher stability of the spread sheare. Therefore, it can be stated for the second alternative embodiments shown in the Figs. 2B, 3B, 4B, and 5B that omitting 10 bearings results in a spread sheare with maximal stability but with a minimum of bearings; omitting less than 10 bearings would add to over-determination of the system and thus lead to enhanced stability of the spread sheare 1. Moreover and in general, for achieving the densest package of liquid handling tools 2 in order to mi-

nimize the pitch between the individual pipette or dispenser tips (whether they are disposable or not), alternate attachment of the liquid handling tools 2 to the spread sheare 1 is preferred (see e.g. Figs. 2A, 2B, 3B, 4B, and 5B).

The Figure 6 shows cross section views of a housing 16 for a Z-drive (not shown) of a liquid handling tool 2 and the spread sheare of the present invention. To this housing 16 is attached a gear rack 20. To each gear rack 20 is attached a liquid handling head 13 (not shown). To each liquid handling head 13 can be attached a liquid handling tool 2 that preferably is selected from the group comprising pipette tips, dispenser tips, sensors and probes. The gear rack also takes up tubing 9 and/or wiring 11 for providing the liquid handling head 13 and its liquid handling tool 2 with under-pressure and/or over-pressure as well as with electric power or bias voltage as required.

Fig. 6A shows a 3D-view with the gear rack 20 that is movable in the Z-direction (see vertical double arrow) by the non-shown Z-drive. The liquid handling apparatus preferably is accomplished to position (with the help of a spread sheare 1) a series of liquid handling tools 2 in a Cartesian coordinate system with an X-, Y-, and Z-axis. Three extreme nodal anchor points 6 and three upper nodal points 5 can be seen on the Fig. 6A, while the pantograph members 3 of the spread sheare 1 are situated in a very compact position. Each nodal anchor point 6 and upper nodal point 5 comprises a washer 21 and a bolt 17 that preferably is equipped with a pressure plate (as shown). Each bolt 17 preferably is bedded in a bushing or bearing 22 that penetrates the respective pantograph member 3. Preferred bushings are e.g. precision ball bearings or friction bearings such as produced, for example, by The Timken Company (Canton, Ohio, US).

Fig. 6B shows a plane view of the cross section of Fig. 6A through the gear rack 20 and the spread sheare 1. The liquid handling apparatus preferably is accomplished to position (with the help of a spread sheare 1) a series of liquid handling tools 2 in a Cartesian coordinate system with an X-, Y-, and Z-axis. One extreme nodal anchor point 6 can be seen on the Fig. 6B. This extreme nodal anchor point 6 comprises a washer 21 and a bolt 17 that preferably is equipped with a pressure plate 27

(as shown). The bushing or bearing 22 that penetrates the pantograph member 3 is clearly seen.

Fig. 7A shows a perspective view of a further embodiment of the present invention, wherein in order to increase the stability of the spread shear 1 - in addition to the two layers of pantograph members 3 forming parallelograms 4 - a third layer of pantograph members 3′ are provided on at least one side of each parallelogram 4. These further pantograph members 3′ are pivotably mounted at nodal points 5,5′,5″,6 located in corners of the parallelograms 4. Furthermore these further pantograph members 3′ are arranged parallel to the pantograph members 3 forming said first side of the parallelogram. Thus a three-layer sandwich structure is formed on these sides of the parallelograms 4 as seen on Fig. 7A. The further pantograph members 3′ are arranged such that the pantograph members 3 forming the two adjacent sides of the parallelogram 4 with respect to said first side are situated between the further pantograph member 3′ and the pantograph member 3 forming said first side.

Fig. 7B shows a perspective view of an alternative embodiment of the present invention with a third layer of pantograph members 3′ and 3″. As opposed to Fig. 7A, where the third layer of pantograph members 3′ is provided only on one side of each parallelogram 4 – thereby resulting in only every second parallel pantograph member 3 being complemented with a further pantograph member 3′ – in the embodiment of Fig. 7B, two further pantograph members 3′, 3″ are provided on a first side and on a second side of each parallelogram 4. These further pantograph members 3′, 3″ are also pivotably mounted at nodal points 5,5′,5″,6 located in corners of the parallelograms 4. Furthermore these further pantograph members 3′, 3″ are arranged parallel to the pantograph members 3 forming said first side respectively second side of the parallelograms 4. The further pantograph members 3′, 3″ are arranged such that the pantograph members 3 forming the two other facing sides of the parallelograms 4 are situated between the further pantograph members 3′, 3″ and the pantograph members 3 forming said first and second facing sides of the parallelograms 4.

It shall be noted, that the addition of this third layer of further pantograph members 3' significantly improves the stability of the spread sheare and thus greatly reduces the average mean deviation of the position of the liquid handling tools 2.

It will be appreciated that inverse arrangements of the spread sheare 1 as shown in the Figs. 2-5 belongs to the scope of the present invention. In consequence, e.g. the upper nodal points 5 of the spread sheare 1 become lower nodal points 5' and *vice versa*. The axes X, Y, Z have been designated arbitrarily; these designations may be randomly changed without departing from the spirit of the present invention.

It is noted that – according to an alternative definition of the present invention – the preferred minimal number of upper nodal points 5, lower nodal points 5', and lower extreme nodal points 5'' that preferably are equipped with a bearings 22 results from the circumference or periphery of the selected spread sheare 1 as it is indicated in the Figures 2A, 2B, 3A, 3B, 4A, 4B, 5A, and 5B by grey color underlying the respective pantograph members 3, 15, and 15' or the selected parts thereof. One possible exception of this definition is indicated in the Fig. 2A, where the preferred nodal point 19 not necessarily needs to be equipped with a bearing 22. In agreement with this alternative definition and with the foregoing definitions are the embodiments shown in the Figs. 2B and 3A. In the embodiment of Fig. 3B, this alternative definition of the preferred minimal number of nodal points 5,5' results in 12 omitted bearings 22. In the Figs. 4 and 5, additionally omitted bearings (not marked by dashed squares) may be recognized as well.

The same reference numerals refer to the same features, even when not in all cases the reference numeral is indicated in a drawing or individually addressed in the specification. Any combination of the herein disclosed embodiments of the spread sheare 1 according to the present invention that is reasonable for a person skilled in the art is included by the present invention.

Reference numbers

1	spread sheare	13	liquid handling head
2	liquid handling tool	14	intermediate point
3	pantograph member	15	first extreme position of 3
3′	further pantograph member	15′	second extreme position of 3
3″	further pantograph member	16	housing
4	parallelogram	17	bolt
5	upper nodal point	18	optional nodal points
5′	lower nodal point	19	preferred nodal point
5″	lower extreme nodal point	20	gear rack
6	extreme nodal anchor point	21	washer
6′	intermediate nodal anchor point	22	bushing, bearing
7	single end point	23	added triangle
8	disposable tip	24	added wing
9	tubing	25	added segment
10	pick and place head	26	added peak
10′	pick and place tool	27	pressure plate
11	wiring	28	robot arm
12	roller		

What is claimed is:

1. A spread sheare (1) for the variable but equidistant allocation of at least four liquid handling tools (2) in a Cartesian coordinate system of a liquid handling apparatus with an X-, Y-, and Z-axis;
the liquid handling tools (2) being orientated substantially parallel to the vertical Z-axis and being aligned in direction of the horizontal Y-axis;
the spread sheare (1) comprising pantograph members (3,15,15') that form a plurality of parallelograms (4) and that are pivotally connected to each other at nodal points (5,5',5'',6) located in corners of the parallelograms (4);
a liquid handling tool (2) being attached to each nodal anchor point (6) or single end point (7);
wherein the spread sheare (1) further comprises added wings (24) arranged on both sides of the spread sheare (1).

2. The spread sheare (1) of claim 1,
wherein at least the nodal points (5) on these extremely positioned pantograph members (15,15') and the nodal points (5) that are located next to each nodal anchor point (6), to which a liquid handling tool (2) is attached, being each equipped with a bearing (22) for rigidly but pivotably connecting the two pantograph members (3,15,15') meeting at the respective nodal points.

3. The spread sheare (1) of one of the claims 1 or 2,
wherein the parallelograms (4) are pivotally connected to each other at nodal points (5,5',5'',6) located in all four corners of the parallelograms (4).

4. The spread sheare (1) of one of the claims 1 to 3,
wherein the spread sheare (1) comprises only upper or lower nodal points (5,5').

5. The spread sheare (1) of one of the claims 1 to 4,

wherein each nodal anchor point (6) is rigidly connected to at least 6 nodal points (5,5') located on the two pantograph members (3) that join at one of these nodal anchor points (6),
and wherein each single end point (7) is rigidly connected to at least 4 nodal points located on one of the respective pantograph members (3), the spread sheare (1) having 19 parallelograms (4).

6. The spread sheare (1) of one of the claims 1 to 4,
wherein each nodal anchor point (6) is rigidly connected to at least 8 nodal points (5,5') located on the two pantograph members (3) that join at one of these nodal anchor points (6),
and wherein each single end point (7) is rigidly connected to at least 7 nodal points located on one of the respective pantograph members (15,15'), the spread sheare (1) having 25 parallelograms (4).

7. The spread sheare (1) of one of the claims 1 to 3,
wherein the spread sheare (1) has extreme nodal anchor points (6) and/or intermediate nodal anchor points (6'), to each of which a liquid handling tool (2) is attached.

8. The spread sheare (1) of claim 7,
wherein the spread sheare (1) comprises at least 2 extreme nodal anchor points (6), at least 6 intermediate nodal anchor points (6'), upper nodal points (5), lower nodal points (5') and lower extreme nodal points (5'').

9. The spread sheare (1) of claim 8,
wherein each extreme nodal anchor point (6) is rigidly connected to at least 8 nodal points (5,5',5'') located on the two pantograph members (3) that join at one of these extreme nodal anchor points (6),
and wherein each intermediate nodal anchor point (6') is rigidly connected to at least 6 upper and lower nodal points (5,5',5'') located on the two pantograph members (3) that join at one of these intermediate nodal anchor points (6'), the spread sheare (1) having 25 parallelograms (4).

10. The spread sheare (1) of claim 8,
wherein each intermediate nodal anchor point (6') is rigidly connected to at least 9 nodal points (5,5',5'') located on the two pantograph members (15,15') that join at one of these extreme nodal anchor points (6)the spread sheare (1) having 34 parallelograms (4).

11. The spread sheare (1) of one of the claims 1 to 4, 6 to 8 or 10
wherein pantograph members (15,15') at a first and second extreme position form a triangle structure.

12. The spread sheare (1) of one of the preceding claims,
wherein on at least a first side of each parallelogram (4) a further pantograph member (3') is pivotably mounted at nodal points (5,5',5'',6) located in corners of the parallelograms (4); said further pantograph member (3') being arranged parallel to the pantograph member (3) forming said first side,
and wherein said further pantograph member (3') is arranged such that the pantograph members (3) forming the two adjacent sides of the parallelogram (4) with respect to said first side are situated between the further pantograph member (3') and the pantograph member (3) forming said first side.

13. The spread sheare (1) of one of the preceding claims 1 to 11,
wherein on a first side and on a second side of each parallelogram (4), the first side facing the second side, two further pantograph members (3', 3'') are pivotably mounted at nodal points (5,5',5'',6) located in corners of the parallelograms (4); said further pantograph members (3', 3'') being arranged parallel to the pantograph members (3) forming said first side respectively second side,
and wherein said further pantograph members (3', 3'') are arranged such that the pantograph members (3) forming the two other facing sides of the parallelograms (4) are situated between the further pantograph members (3', 3'') and the pantograph members (3) forming said first and second facing sides of the parallelograms (4).

14. The spread sheare (1) of one of the preceding claims,

wherein the largest extension of the spread sheare (1) in direction of the Y-axis is defined by two single end points (7), or by two single end points (7) and two upper nodal points (5).

15. The spread sheare (1) of one of the preceding claims,
wherein the liquid handling tools (2) are attached to liquid handling heads (13), which in turn are attached to extreme nodal anchor points (6) or to intermediate nodal anchor points (6') of the spread sheare (1).

16. The spread sheare (1) of one of the preceding claims,
wherein the liquid handling tools (2) are selected from the group comprising pipette tips, dispenser tips, sensors and probes.

17. A robot arm (28) of a liquid handling workstation or robotic sample processor that is accomplished to move in a Cartesian coordinate system with an X-, Y-, and Z-axis,
wherein the robot arm (28) comprises at least one spread sheare (1) of one of the preceding claims.

18. A liquid handling workstation or robotic sample processor that comprises at least one robot arm (2) of claim 17.

AMENDED CLAIMS

received by the International Bureau on 29 September 2011 (29.09.2011)

1. A spread sheare (1) for the variable but equidistant allocation of at least four liquid handling tools (2) in a Cartesian coordinate system of a liquid handling apparatus with an X-, Y-, and Z-axis;
the liquid handling tools (2) being orientated substantially parallel to the vertical Z-axis and being aligned in direction of the horizontal Y-axis;
the spread sheare (1) comprising pantograph members (3,15,15') that form a plurality of parallelograms (4) and that are pivotally connected to each other at nodal points (5,5',5",6) located in corners of the parallelograms (4);
a liquid handling tool (2) being attached to each nodal anchor point (6) or single end point (7);
wherein the spread sheare (1) further comprises added wings (24), the added wings (24) being configured as additional pantograph members (3), that:
   a) are arranged on both sides of the spread sheare (1);
   b) are arranged outside of extremely positioned pantograph members (15,15'); and
   c) add additional nodal points (5) and thereby increase the degree of multiple over-determination of the flexible lattice structure of the spread sheare (1).

2. The spread sheare (1) of claim 1,
wherein at least the nodal points (5) on these extremely positioned pantograph members (15,15') and the nodal points (5) that are located next to each nodal anchor point (6), to which a liquid handling tool (2) is attached, being each equipped with a bearing (22) for rigidly but pivotably connecting the two pantograph members (3,15,15') meeting at the respective nodal points.

3. The spread sheare (1) of one of the claims 1 or 2,
wherein the parallelograms (4) are pivotally connected to each other at nodal points (5,5',5",6) located in all four corners of the parallelograms (4).

4. The spread sheare (1) of one of the claims 1 to 3,
wherein the spread sheare (1) comprises only upper or lower nodal points (5,5').

5. The spread sheare (1) of one of the claims 1 to 4,
wherein each nodal anchor point (6) is rigidly connected to at least 6 nodal points (5,5') located on the two pantograph members (3) that join at one of these nodal anchor points (6),
and wherein each single end point (7) is rigidly connected to at least 4 nodal points located on one of the respective pantograph members (3), the spread sheare (1) having 19 parallelograms (4).

6. The spread sheare (1) of one of the claims 1 to 4,
wherein each nodal anchor point (6) is rigidly connected to at least 8 nodal points (5,5') located on the two pantograph members (3) that join at one of these nodal anchor points (6),
and wherein each single end point (7) is rigidly connected to at least 7 nodal points located on one of the respective pantograph members (15,15'), the spread sheare (1) having 25 parallelograms (4).

7. The spread sheare (1) of one of the claims 1 to 3,
wherein the spread sheare (1) has extreme nodal anchor points (6) and/or intermediate nodal anchor points (6'), to each of which a liquid handling tool (2) is attached.

8. The spread sheare (1) of claim 7,
wherein the spread sheare (1) comprises at least 2 extreme nodal anchor points (6), at least 6 intermediate nodal anchor points (6'), upper nodal points (5), lower nodal points (5') and lower extreme nodal points (5'').

9. The spread sheare (1) of claim 8,
wherein each extreme nodal anchor point (6) is rigidly connected to at least 8 nodal points (5,5',5'') located on the two pantograph members (3) that join at one of these extreme nodal anchor points (6),

and wherein each intermediate nodal anchor point (6') is rigidly connected to at least 6 upper and lower nodal points (5,5',5'') located on the two pantograph members (3) that join at one of these intermediate nodal anchor points (6'), the spread sheare (1) having 25 parallelograms (4).

10. The spread sheare (1) of claim 8,
wherein each intermediate nodal anchor point (6') is rigidly connected to at least 9 nodal points (5,5',5'') located on the two pantograph members (15,15') that join at one of these extreme nodal anchor points (6)the spread sheare (1) having 34 parallelograms (4).

11. The spread sheare (1) of one of the claims 1 to 4, 6 to 8, or 10,
wherein pantograph members (15,15') at a first and second extreme position form a triangle structure.

12. The spread sheare (1) of one of the preceding claims,
wherein on at least a first side of each parallelogram (4) a further pantograph member (3') is pivotably mounted at nodal points (5,5',5'',6) located in corners of the parallelograms (4); said further pantograph member (3') being arranged parallel to the pantograph member (3) forming said first side,
and wherein said further pantograph member (3') is arranged such that the pantograph members (3) forming the two adjacent sides of the parallelogram (4) with respect to said first side are situated between the further pantograph member (3') and the pantograph member (3) forming said first side.

13. The spread sheare (1) of one of the preceding claims 1 to 11,
wherein on a first side and on a second side of each parallelogram (4), the first side facing the second side, two further pantograph members (3', 3'') are pivotably mounted at nodal points (5,5',5'',6) located in corners of the parallelograms (4); said further pantograph members (3', 3'') being arranged parallel to the pantograph members (3) forming said first side respectively second side,
and wherein said further pantograph members (3', 3'') are arranged such that the pantograph members (3) forming the two other facing sides of the

parallelograms (4) are situated between the further pantograph members (3', 3") and the pantograph members (3) forming said first and second facing sides of the parallelograms (4).

14. The spread sheare (1) of one of the preceding claims,
wherein the largest extension of the spread sheare (1) in direction of the Y-axis is defined by two single end points (7), or by two single end points (7) and two upper nodal points (5).

15. The spread sheare (1) of one of the preceding claims,
wherein the liquid handling tools (2) are attached to liquid handling heads (13), which in turn are attached to extreme nodal anchor points (6) or to intermediate nodal anchor points (6') of the spread sheare (1).

16. The spread sheare (1) of one of the preceding claims,
wherein the liquid handling tools (2) are selected from the group comprising pipette tips, dispenser tips, sensors and probes.

17. A robot arm (28) of a liquid handling workstation or robotic sample processor that is accomplished to move in a Cartesian coordinate system with an X-, Y-, and Z-axis,
wherein the robot arm (28) comprises at least one spread sheare (1) of one of the preceding claims.

18. A liquid handling workstation or robotic sample processor that comprises at least one robot arm (2) of claim 17.

STATEMENT UNDER ARTICLE 19 (1)

Only the independent claim 1 is amended, the dependent claims 2-18 remain unchanged. In the also enclosed orientation page 19, all inserts entered into the amended claim 1 are marked by underlining. The respective sources of disclosure as found in the originally filed application are pointed out in upper brackets in each case.

The marked wording is inserted to more clearly point out the individual features of the added wings that are characterizing the spread sheare according to the current invention. These features unambiguously unfold to the person of skill from the Figures 3A, 3B, 5A, 5B, 7A, and 7B in combination with the disclosure of the specification on pages 11 (lines 1-6) and 14 (lines 12-16) as originally filed. This amendment makes clear that the added wings are flexible parts of the flexible lattice structure of the spread sheare. In consequence and contrary to the assessment of the ISR, the added wings are not comparable e.g. to the draw plates 13,14 in document D1 (NL 6 504 453 A), which draw plates are not flexible and are arranged outside of the spread sheare.

For all amendments, the sources of disclosure in the originally filed application have been pointed out in the accompanying letter, proving that no new matter is introduced by these amendments and that the provisions of Art. 19 PCT are met.

Fig. 1A Prior Art

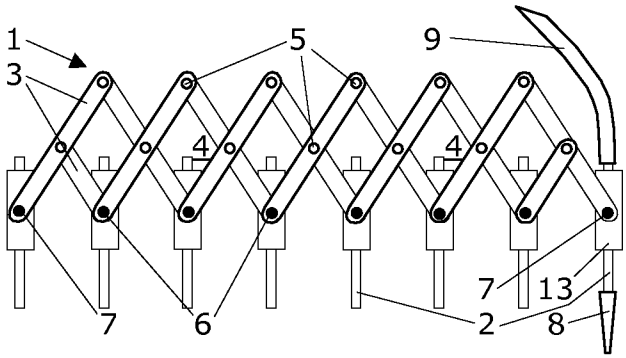


Fig. 1B Prior Art

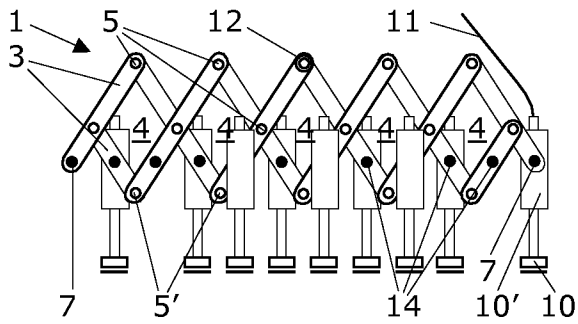


Fig. 2A

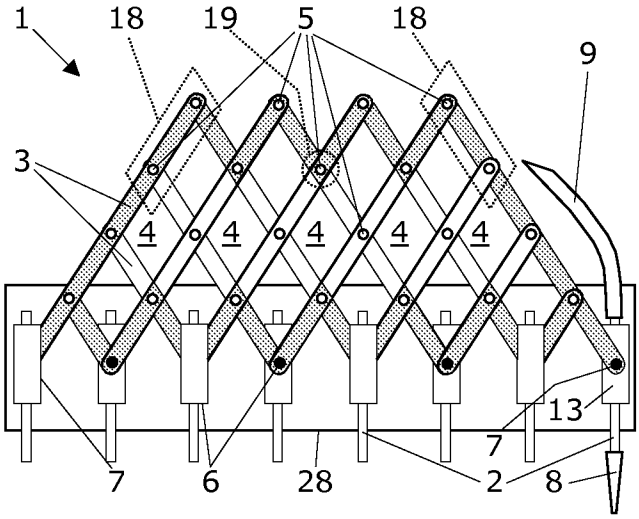


Fig. 2B

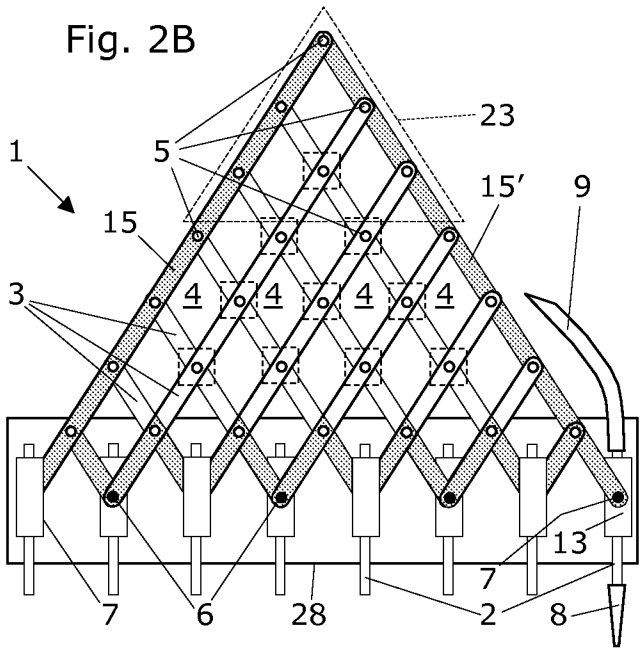


Fig. 3A

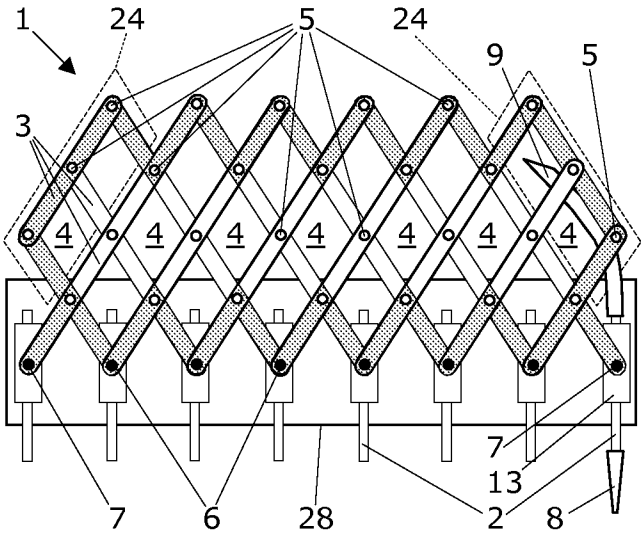


Fig. 3B

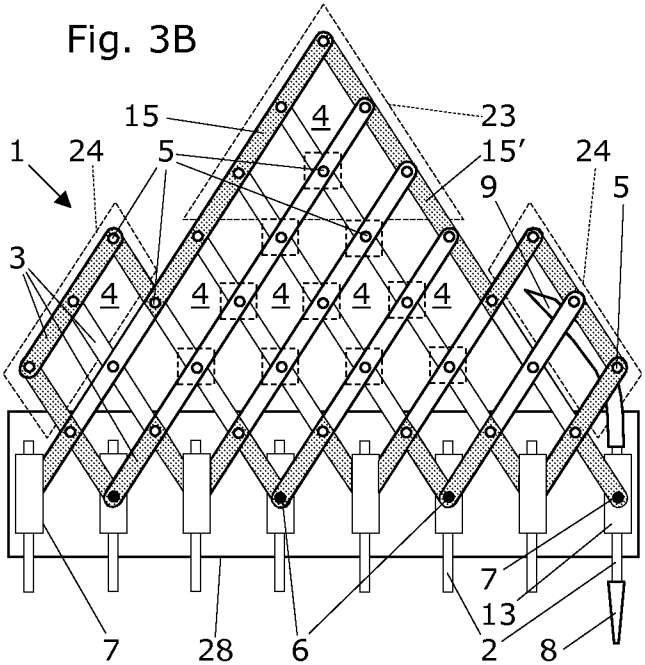


Fig. 4A

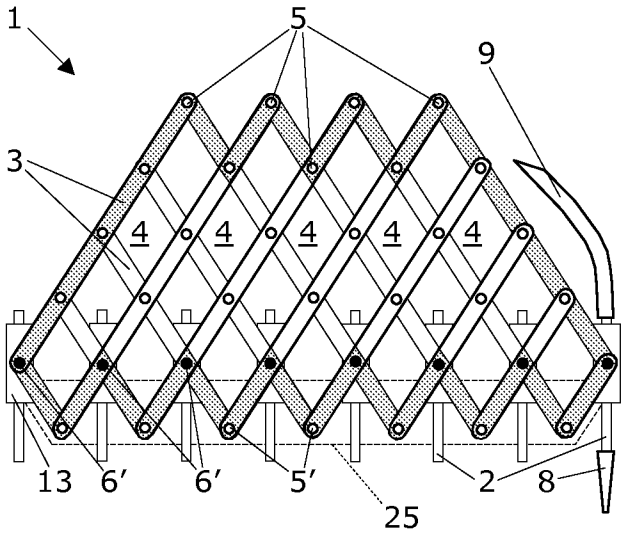


Fig. 4B

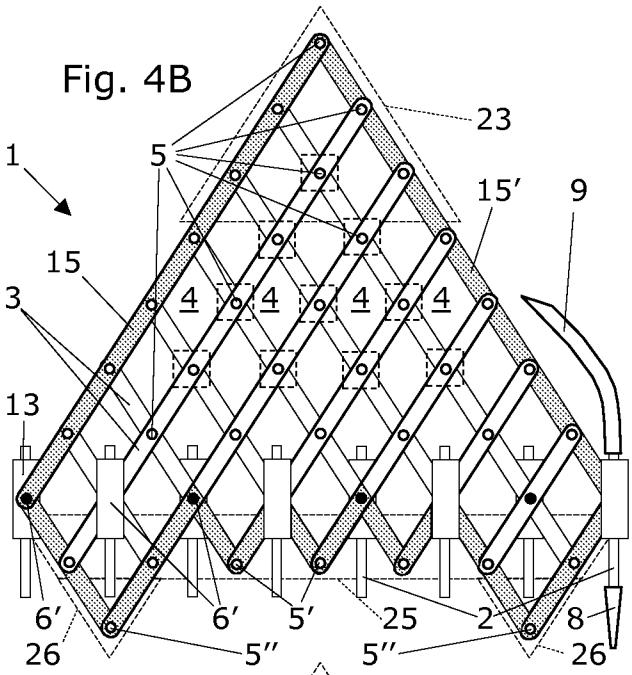


Fig. 5A

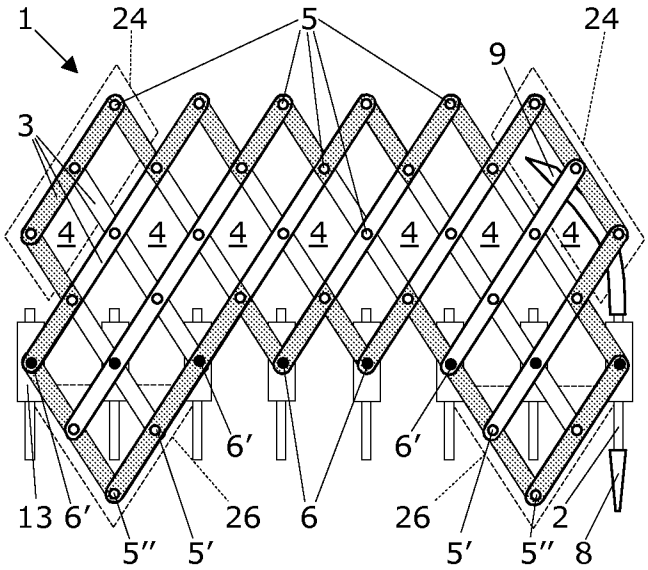


Fig. 5B

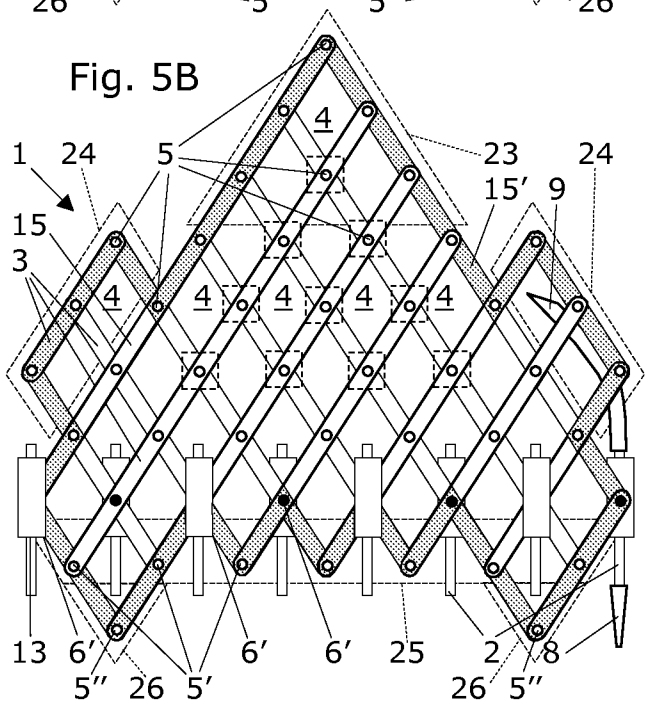


Fig. 6A

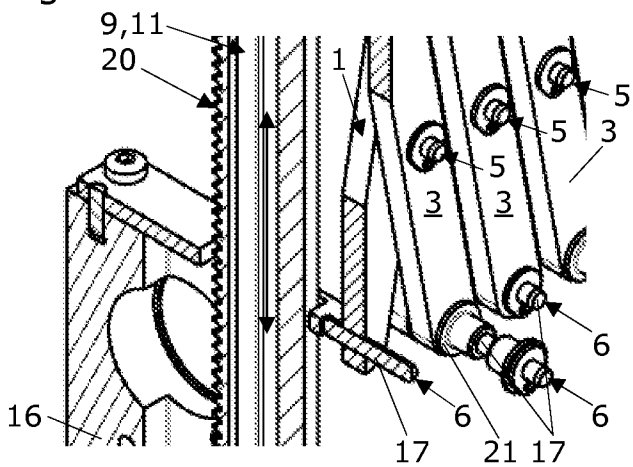


Fig. 6B

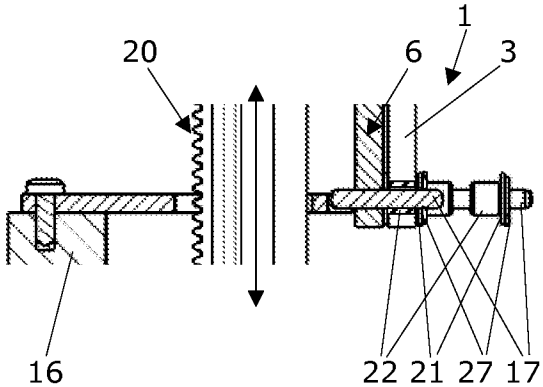


Fig. 7A

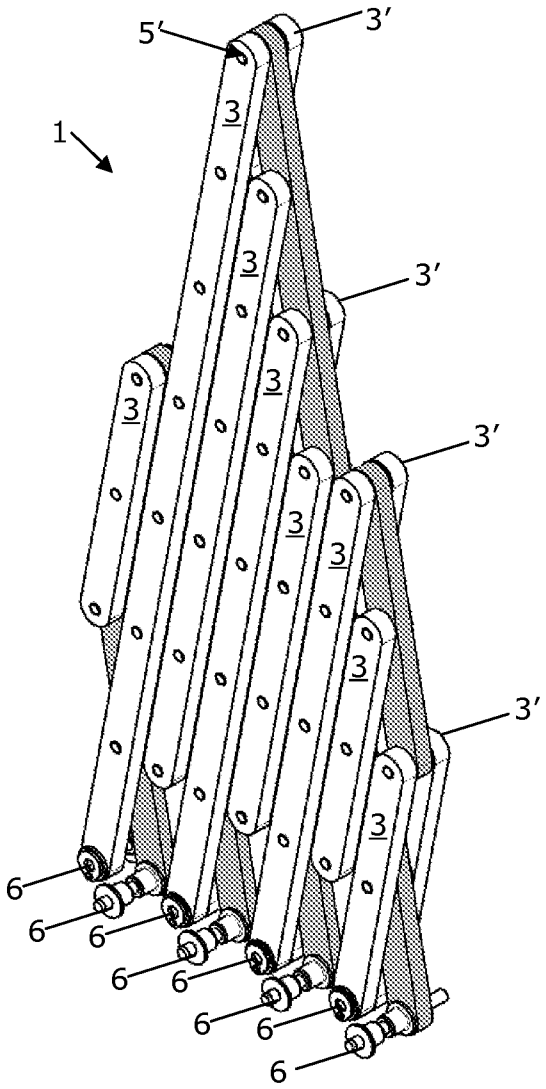
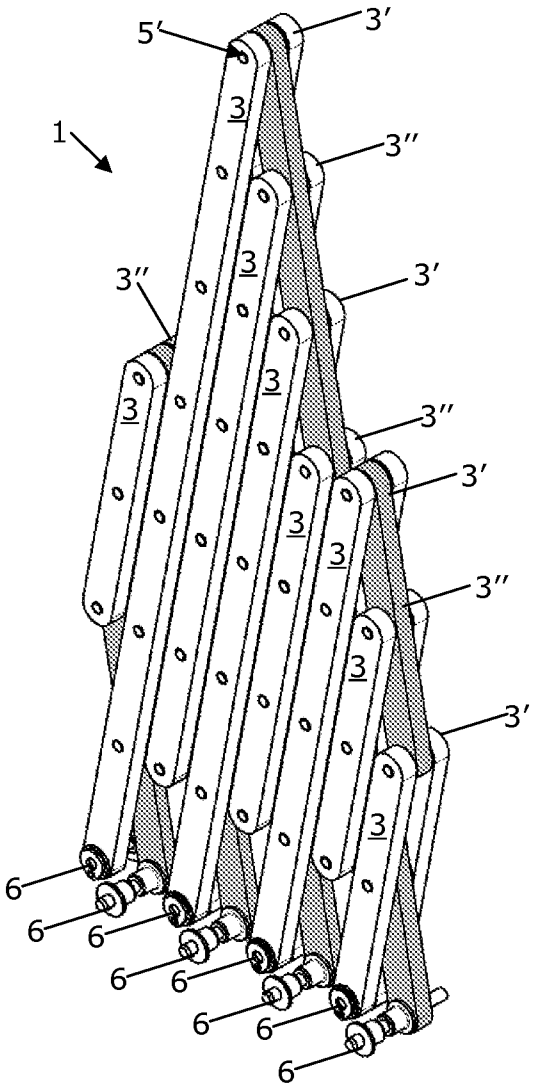


Fig. 7B



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2011/060034

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N35/10
ADD.

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)
G01N B01L

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

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	NL 6 504 453 A (JOHANNES HENRICUS KRUIP) 10 October 1966 (1966-10-10) figure 1	1-18
X	WO 00/35584 A1 (MATRIX TECHNOLOGIES CORP [US]) 22 June 2000 (2000-06-22) pages 4-6; figures 2-5	1-18
X	US 2004/076550 A1 (RUEDISSER MARTIN [CH] ET AL) 22 April 2004 (2004-04-22) cited in the application the whole document	1-18
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