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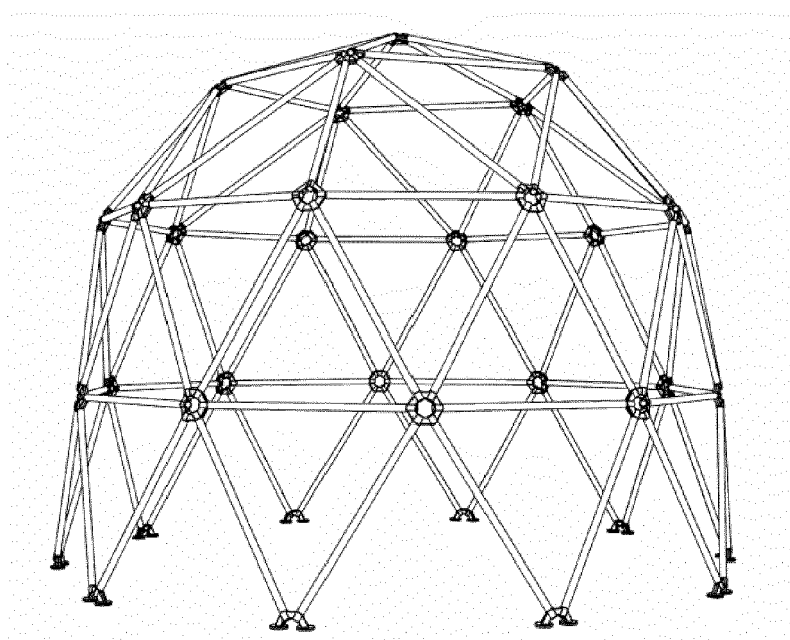
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(54) **METHODS FOR ASSEMBLING A LATTICE STRUCTURE**

(57) Methods for assembling a lattice structure are provided. The method comprises providing at least three node elements and two or more elongated bars. The method includes displacing a first elongated bar of the elongated bars, in a first direction, such that the proximal end of the first elongated bar is inserted into a hollow insertion channel of a first node element and displacing a second elongated bar of the elongated bars, in a second

direction, such that the proximal end of the second elongated bar is inserted into a hollow insertion channel of a second node element. The method further comprises: displacing the first elongated bar in a third direction, opposite to the first direction, such that the distal end of the first bar is inserted into a corresponding hollow insertion channel of a third node element. Methods for disassembling a lattice structure are also provided.



**Fig. 7**

## Description

### BACKGROUND

**[0001]** Lattice structures may generally be defined by a plurality of interconnected struts normally joined or attached to one another at appropriate connecting components, and collectively arranged to produce the intended structure. The use of these structures has been generally known and used in the construction of a variety of architectural and engineering structures. Certain recognized advantages of such structures include a substantially balanced distribution of loads and stresses throughout the formed structure, as well as the ability to take advantage of the light-weight and high strength of the materials from which such assemblies are formed.

**[0002]** However, the problems exhibited by these known types of lattice structures are well known. More specifically, the connecting gusset plate components or other connector parts utilized in assembling the known types of lattice structures may require e.g., the use of a large number of bolts or fasteners. This structural arrangement generally increases the manufacturing and maintenance cost.

**[0003]** It is further known to incorporate threaded connections to assemble the struts to the connecting components. However, the threading procedure is time consuming, and therefore, expensive considering the number of components involved in the formation of a given lattice structure.

**[0004]** Connecting components have also been developed which include the plurality of interconnected struts having modified ends, e.g., flattened or bent. However, such mechanical deformation is costly and may weaken the structural integrity of the entire structure.

**[0005]** Additionally, in order to assemble the struts forming part of the lattice structure, manual aid is generally required. Particularly, large lattice structures involve intricate assembly steps that require significant human interaction and skill. The unexperienced manipulation of the struts directly increases the risk for the operator especially if the operator may be standing directly under or near the struts to be assembled. In some cases, the lattice structures may also require highly skilled technicians to appropriately configure and join the struts.

**[0006]** In summary, the assembly of the lattice structures may be cumbersome and time consuming. Complex connecting components are generally used. Moreover, the known methods to assemble a lattice structure require multiple builders to assist in assembly of the structure and the struts must be manipulated to form the correct angle. Tools are required to assemble and disassemble the structure. These problems may result in increased costs, increased assembly and disassembly time, inferior structural characteristics, limited structure size, and more risk for the operators.

**[0007]** Examples of the present disclosure seek to at least partially reduce one or more of the aforementioned

problems.

### SUMMARY

**[0008]** According to a first aspect, a method for assembling a lattice structure is provided. The method comprises providing at least three node elements comprising: a main body including two or more hollow insertion channels, wherein the hollow insertion channels are configured to receive an elongated bar, wherein the hollow insertion channels extend from an outer end to an inner end, wherein a predetermined position for receiving the bars is defined, along the length of the hollow insertion channels, between the outer end and the inner end of the hollow insertion channels, or the predetermined position for receiving the bars is defined beyond the inner end of the channels, wherein the predetermined position is defined at a distance  $x$  from the outer end of the channels. The method further comprising: providing two or more elongated bars, wherein each of the bars comprises a proximal end and a distal end, displacing a first elongated bar of the elongated bars, in a first direction, such that the proximal end of the first elongated bar is inserted into a hollow insertion channel of a first node element of the node elements, from the outer end of the hollow insertion channel to the inner end of the hollow insertion channel, until the proximal end of the first elongated bar is situated at a position beyond the defined predetermined position, displacing a second elongated bar of the elongated bars, in second direction, such that the proximal end of the second elongated bar is inserted into a hollow insertion channel of a second node element, from the outer end of the hollow insertion channel to the inner end of the channel, until the proximal end of the second elongated bar is situated at a second position between the outer end of the channel and the defined predetermined position. The method further comprises: displacing the first elongated bar, in a third direction, opposite to the first direction, such that the distal end of the first bar is inserted into a corresponding hollow insertion channel of a third node element of the node elements.

**[0009]** According to this first aspect, three or more node elements and two or more elongated bars that are configured to the function of forming a lattice structure are provided. To this end, the node elements are provided with a main body including two or more hollow insertion channels configured to receive the elongated bars. A predetermined position for receiving the distal end of the bars may be defined, along the length of the hollow insertion channels, between the outer end of the hollow insertion channels and the inner end of the hollow insertion channels. The predetermined position for receiving the distal end of the bars may also be defined at a position beyond the inner end of the hollow insertion channels. As a result, the predetermined position for receiving the bars may be defined at any position along the length of the hollow insertion channels or at any position beyond the inner end of the channels, at a distance  $x$  from the

outer end of the channels.

**[0010]** With the provision of such nodes and bars, the proximal end of the first bar is displaced and inserted, in a first direction, into the corresponding hollow insertion channel of the first node element until such proximal end of the bar is situated, at a first position, beyond the defined predetermined position. As a result, since the proximal end of the first bar is inserted into the hollow insertion channel up to a relatively deep position (i.e. a position beyond the predetermined position for receiving the bars), the distal end of the first bar may not interfere with the installation of the third node, as will be described later on.

**[0011]** A proximal end of a second bar is displaced and inserted, in a second direction, into the corresponding hollow insertion channel of the second node element, from the outer end of the channel to the inner end of the channel, such that the proximal end of the second elongated bar is situated, at a second position, between the outer end of the channel and the defined predetermined position. As a result, since the proximal end of the second bar is inserted, into the hollow insertion channel, to a relatively shallow position (as compared with the position at which the first bar is inserted), the distal end of the second bar is situated at a suitable position for receiving the third node.

**[0012]** At this point, the first bar is displaced in a third direction, opposite to the first direction, such that the distal end of the bar is inserted into the corresponding hollow insertion channel of the third node element.

**[0013]** The lattice structure can thus be assembled in a simple and fast manner. The assembly of the lattice structure may also be performed without complex tools or heavy cranes and using a relatively low number of operations. Moreover, the same assembly procedure may be employed regardless of the cross-sectional shapes of the bar. In fact, standard bars or tubes can be used without any substantial modification at their distal and proximal ends. Additionally, all node parts can be fabricated repetitively by standard and inexpensive techniques, e.g., metal casting or plastic injection molding.

**[0014]** The lattice structure may also be easily repaired, and maintenance can be performed in an easy way. Any damaged bar or node may be easily replaced following a simple disassembly / assembly sequence.

**[0015]** In some examples, the method further comprises, after displacing a second elongated bar of the elongated bars in second direction: displacing the third node element of the node elements towards the second bar such that the distal end of the second bar is inserted into the corresponding hollow insertion channel of the third node element.

**[0016]** The third node element may be displaced towards the second bar such that the distal end of the second bar is inserted into a corresponding hollow insertion channel of the third node element. With such an arrangement, the assembly of the third node with respect to the second bar is not interfered by the distal end of the first

elongated bar since, as commented above, such first bar has been inserted into the corresponding hollow insertion channel of the first node to a relatively deep position into the hollow insertion channel (i.e. a position beyond the defined predetermined position for receiving a bar) such that the distal end of the first bar does not interfere with the installation of the third node to the second bar. It is noted that, once the third node element has been assembled to the second elongated bar, the distal end of the first bar is not inserted into the corresponding elongated channel of the third node element. In some examples, the method comprises:

- securing the proximal end of the second bar to the second node element and / or securing the distal end of the second bar to the third node element, and
- securing the proximal end of the first bar to the first node element and / or securing the distal end of the first bar to the third node element.

**[0017]** With such an arrangement, and upon the appropriate joining of the bar ends to the corresponding node channels (e.g. bolted or glued), the translational and the rotational movements of the bars become effectively restrained, thus the buckling resistance of the bars under compressive loads is optimized. Additionally, a strong and stiff attachment between the bars and the node elements is achieved.

## BRIEF DESCRIPTION OF THE DRAWINGS

### **[0018]**

Figures 1a - 1d schematically illustrate an example of a node element;

Figure 2 schematically illustrates another example of a node element;

Figure 3 schematically illustrates a further example of a node element;

Figure 4 schematically illustrates another example of a node element;

Figure 5a - 5c schematically illustrate a further example of a node element;

Fig 6a - 6g schematically illustrate a sequence of situations that may occur during the performance of a method for assembling a lattice structure;

Figure 7 shows an example of a lattice structure assembled using the method for assembling a lattice structure described with reference to figures 6a - 6g;

Figures 8a - 8b schematically illustrate a sequence of situations that may occur during the performance

of a method for disassembling a lattice structure.

## DETAILED DESCRIPTION OF EXAMPLES

**[0019]** Figures 1a - 1d schematically illustrate an example of a node element. The node element 10 shown in the figures 1a — 1d may be part of a lattice structure as will be described later on. Examples of the lattice structure may be a lattice tower, a dome, a scaffold or a deck. For example, the node element may be used in the lattice structure described with reference to figure 7. The node element may also be part of space frames e.g., single or multilayered space frames.

**[0020]** Figure 1a shows the node element 10. The node element 10 may be made e.g. of metal, fiber reinforced plastic, concrete, or any other suitable material. The node element 10 may comprise a main body 11. In this example, the main body 11 is a hexagonal ring including six sides 18a - 18f and six vertexes 19a - 19f.

**[0021]** The main body 11 may comprise an outer side 11a and an inner side 11b. The main body 11 may further comprise six hollow insertion channels 12a - 12f extending between the outer side 11a and the inner side 11b forming a corresponding through-hole. The hollow insertion channels 12a - 12f may be situated at corresponding vertexes 19a - 19f of the main body.

**[0022]** Each hollow insertion channel 12a - 12f may comprise an inner end 13a - 13f and an outer end 14a - 14f. The inner end 13a - 13f of the hollow insertion channels 12a - 12f may extend beyond the inner side 11b of the main body 11. Similarly, the outer end 14a - 14f of the hollow insertion channels 12a - 12f may extend beyond the outer side 11a of the main body 11.

**[0023]** The hollow insertion channels 12a - 12f may be specifically shaped to provide the insertion of an elongated bar (not shown in figure 1a but shown in figure 1b) of a certain kind or shape. The elongated bar in question can thus be inserted from the outer end 14a - 14f of the hollow insertion channels to the inner end 13a - 13f of the hollow insertion channels by traversing the corresponding through-hole.

**[0024]** As shown in figure 1b, a predetermined position 17 for receiving bars may be defined, in this example, beyond the distal end 13a of one of the channels. The predetermined position 17 may be defined, at least, at a distance x (e.g., 8 centimeters) from the outer end 14a of the channel (in a direction towards the inner end 13a). The distance x may correspond to at least the double of the predefined distance d (which may be predefined between the outer end of the channel 14a and either a final position along the length of the hollow insertion channel or a final position beyond the inner end 13a of the channel) (e.g., 4 centimeters). The final position may correspond to the position of the proximal end of the bar, once the lattice structure has been assembled. The bar in such final position is not shown in this figure.

**[0025]** It is noted that if the proximal end of the bar is situated beyond the predefined position 17 (as the bar is

inserted from the outer end 14a to the inner end 13a of the channel), the distal end (not shown) of the bar will not interfere with the installation of a further node to the lattice structure to be formed, as will be explained later on.

**[0026]** However, as shown in figure 1c, if the proximal end of the bar is situated in a position between the outer end 14a and the predefined position 17 for receiving the bar, the distal end (not visible) of the bar will be at a suitable position for receiving a further node element (i.e. at its final position), as will also be explained later on. It is thus clear that the predetermined position 17, for inserting the bars, is a position which delimits first insertion positions (i.e. relatively deep insertion positions) of the proximal end of the bar (at which a distal end of the bar will not interfere with the installation of a further node) and second insertion positions (i.e. relatively shallow insertion positions) of the proximal end of the bar (at which the distal end of the bar will be at a suitable position for receiving a node i.e. at its final position). It is noted that the predetermined position 17 for inserting the bars may be defined in a substantially similar way with respect to the remaining channels of the node. In some examples, the predetermined position for inserting the bars may be defined at the same distance x with respect to the outer end of the corresponding channel, for all the channels of the node element (and for all the node elements forming part of the lattice structure to be formed).

**[0027]** As commented above, the distance x corresponds to the double of the distance d. The distance d corresponds a distance between the outer end of the channel and either a final position along the length of the hollow insertion channel or a final position beyond the inner end 13a of the channel. The term "*final position*" refers to the final position of the proximal end of the bar once the lattice structure has been assembled. It is noted that the proximal end of the bar, in this figure, is situated in such final position. However, the proximal end of the bar is not visible in this figure. It is further noted that the distance d may be the same for all the channels of a node element and, in some other examples, for all the node elements forming part of a lattice structure. Alternatively, the distance d may be different for some or all the channels of a node element.

**[0028]** Again in figure 1a, the hollow insertion channels 12a — 12f may have the same diameter along the length of the hollow insertion channel. In some other examples, each hollow insertion channel may have a greater diameter at or near the outer end 14a - 14f of the hollow insertion channel than the diameter at or near the inner end 13a - 13f of the hollow insertion channel such that the diameter of the hollow insertion channel decreases along the longitudinal length of the hollow insertion channel. This way, each hollow insertion channel may be tapered, thus the insertion of a bar into the hollow insertion channel may be facilitated. The hollow insertion channels 12a - 12f may have the same or different diameters in order to properly allocate the corresponding elongated member.

**[0029]** The hollow insertion channels 12a - 12f may be integrally formed with the main body 11 of the first node element 10. Alternatively, the hollow insertion channels 12a - 12f may be coupled to the main body 11 of the first node element 10.

**[0030]** The hollow insertion channels 12a - 12f may be tilted at an angle with respect to one of the adjacent corresponding hollow insertion channels 12a - 12f. Particularly, the angle may be defined between a longitudinal axis of the hollow insertion channels and a longitudinal axis of one of the adjacent hollow insertion channels 12a — 12f. The angle may be any suitable angle that provides the insertion of a bar in the required position. For example, the angle between the longitudinal axis of the hollow insertion channels 12a and the longitudinal axis of the adjacent hollow insertion channel 12b may be between 55 and 70 degrees. Similar angles may be defined between the remaining channels.

**[0031]** The angle between the longitudinal axis of the hollow insertion channels 12a — 12f may be the same for each or some of the hollow insertion channels. Alternatively, the angle between the longitudinal axis of the hollow insertion channels 12a - 12f may be different for each or some of the hollow insertion channels.

**[0032]** As can be seen in figure 1d, the main body 11 may further comprise an opening 11c. The opening 11c may be configured to receive a retention element 11d, once the lattice structure is assembled. The retention element 11d may be made of metal, concrete, or plastic material. The material of the retention element 11d may be the same as the material of the node element. Alternatively, the first node element and the retention element 11d may be made of different materials. The retention element 11d may comprise an appropriate form such that the retention element may be inserted into the opening, and it may remain inserted into such opening.

**[0033]** The retention element 11d can be placed into the opening 11c to better withstand compressive forces either once the lattice structure is assembled or once all bars of the corresponding node are installed. Furthermore, the retention element 11d provides a suitable transmission of the compressive forces from the bars to the corresponding node elements. The retention element may be secured to the node by any suitable element e.g., using bolts, screws, adhesives, or welding.

**[0034]** Figure 2 schematically illustrates an example of another node element. The node element shown in figure 2 differs from the node element shown in figures 1a — 1d only in that the main body takes the form of a half hexagon and two supports are included. The structure and operation of the remaining components of the node may substantially be the same as hereinbefore described.

**[0035]** As commented above, the node element 20 may comprise a main body 21. The main body 21 may be a half hexagon including three sides 28a - 28c and two vertexes 29a - 29b. Similarly as before, the main body 21 may comprise an outer side 21a and an inner

side 21b. The main body 21 may further comprise two hollow insertion channels 22a - 22b extending between the outer side 21a and the inner side 21b forming a corresponding through-hole. The two hollow insertion channels 22a - 22b may be situated at the corresponding vertexes 29a - 29b.

**[0036]** Each hollow insertion channel 22a - 22b may comprise an inner end 23a - 23b and an outer end 24a - 24b. The inner end 23a - 23b of the hollow insertion channels 22a - 22b may extend beyond the inner side 21b of the main body 21. Similarly, the outer end 24a - 24b of the hollow insertion channels 22a - 22b may extend beyond the outer side 21a of the main body 21.

**[0037]** Additionally, the main body 21 may comprise two supports 25a - 25b configured to be (permanently or temporarily) situated on a first plane or level e.g. on the floor.

**[0038]** Figure 3 schematically illustrates an example of another node element. The node element 30 shown in figure 1c differs from the node element shown in figures 1a — 1d only in that the main body is a ring 31. The structure and operation of the remaining components of the node may substantially be the same as hereinbefore described.

**[0039]** Figure 4 schematically illustrates a further example of a node element. The node element 40 shown in figure 1d differs from the node element shown in figure 1a only in that the main body is a hollow sphere 41. The structure and operation of the remaining components of the node may substantially be the same as hereinbefore described.

**[0040]** Figure 5a - 5c schematically illustrate a further example of a node element. Particularly, figure 5a illustrates an isometric view of a cross-section of the node element 50. Figure 5b and 5c illustrate a top view of a cross-section of the node element. Similarly as before, the node element 50 shown in this figure may be part of a lattice structure.

**[0041]** As shown in figure 5a, the node element 50 may comprise a main body 51. In this example, the main body 51 is a solid sphere. However, in some other examples, further suitable forms of the main body may be possible e.g. a hollow polyhedron.

**[0042]** The main body 51 may comprise an outer side 50a. The main body 51 may further comprise six hollow insertion channels. Each hollow insertion channel may extend between an outer end of the hollow insertion channel and an inner end of the hollow insertion channel. However, this figure only shows four hollow insertion channels 52a - 52d. It is noted that the remaining two hollow insertion channels, forming part of this node, are not shown in this figure. Moreover, the figure only shows that the hollow insertion channel 52a extends between an inner end 53a of the hollow insertion channel and an outer end 54a and that the hollow insertion channel 52b extends between an inner end 53b of the hollow insertion channel and an outer end 54b. The outer end 54a - 54b of the hollow insertion channels may extend beyond the outer

side 50a of the main body 51. In any case, the remaining hollow insertion channels forming part of the node may have a similar structure.

**[0043]** The hollow insertion channels 52a - 52d may be specifically shaped to provide the insertion of an elongated bar 60 - 61 of a certain kind or shape. The elongated bar 60 - 61 in question can thus be inserted from the outer end 54a - 54b of the hollow insertion channels to the inner end 53a - 53b. Then, the elongated bar may be advanced until an end of the bar is situated at a (predetermined) desired position of the end of the bar with respect to the hollow insertion channel, as will be explained later on.

**[0044]** Moreover, as shown in figure 5b, a predetermined position 70, for receiving the distal end of the bars, may be defined, along the length of the hollow insertion channels, between the outer end of the hollow insertion channels and the inner end of the channels. In this example, only a predetermined position 70 of a hollow insertion channel is shown. However, the predetermined position 70 may be defined in the remaining hollow insertion channels in a substantially similar way.

**[0045]** As can be seen in this figure, the predetermined position 70 may be situated, at least at a distance x from the outer end 54a of the hollow insertion channel. The distance x may correspond to the double of the distance d. The distance d may be a predefined distance between the outer end of the channel 14a and a final position along the length of the hollow insertion channel. The final position refers the position of the proximal end of the bar with respect to the corresponding channel once the lattice structure has been assembled. It is noted that the proximal end of the bar shown in this figure is not in such final position.

**[0046]** Particularly, as shown in this figure, the proximal end of the bar may be situated beyond the predetermined position 70 (for receiving a bar) (i.e. a relatively deep position within the channel) defined along the length of the hollow insertion channel. However, as shown in figure 5c, the proximal end of the bar may also be situated between the outer end 54a of the channel and the predetermined position 70 for inserting the bar (i.e. a relatively shallow position within the channel).

**[0047]** The position reached by the proximal end of the bar, during its insertion into the hollow insertion channel, may define the position of the other end of the bar such that either the other end of the bar does not interfere with the installation of a further node (figure 5b) or the other end of the bar is in a position suitable for the installation of such further node (figure 5c), as again will be explained later on.

**[0048]** It is noted that figure 5c shows the final position of the proximal end of the bar once the lattice structure is assembled. As can be seen in the figure, the distance d corresponds to a distance defined from the outer end 54a of the channel to such final position of the proximal end of the bar. The distance x may thus be, at least, the double of such distance d.

**[0049]** Figures 6a - 6g schematically illustrate a sequence of situations that may occur during the performance of a method for assembling a lattice structure. Same reference numbers denote the same elements as those in the previous figures. The method is described below with reference to the sequences of situations illustrated by figures 6a — 6g.

**[0050]** The figure 6a illustrates an example of an initial situation. In this figure, a first node element 100 is provided. The node element may be substantially similar to the node element shown with reference to figures 1a - 1d. The first node element 100 may be situated at a position in a first plane or level, e.g. on the floor using the corresponding supports 125a - 125b.

**[0051]** In this figure, a first elongated bar 101 may be provided. The first bar 101 may extend from a proximal end 101a to a distal end 101b.

**[0052]** The bars forming part of the lattice structure may be made of any suitable material. Typical materials may include steel, aluminum, carbon or glass fiber reinforced plastics among others. In examples of lattice structures wherein a relatively high performance of such structures is required, the bars may be made e.g., of carbon fiber reinforced plastics. Graphite materials and titanium are materials which also may be used for bars in space applications wherein dimensional stability is often a requirement.

**[0053]** The bars may comprise e.g. a substantially circular cross-section although other cross-sectional shapes are possible e.g. a substantially square cross-section having four connected sidewalls.

**[0054]** Following the example, the proximal end 101a of the bar 100 may be brought near a hollow insertion channel 122a of the node element 100. This way, the bar 101 is ready to be inserted into the hollow insertion channel 122a until the end 101a of the bar reaches a desired position with respect to the hollow insertion channel 122a.

**[0055]** The bar 101 may have a suitable diameter in order to be inserted into a lumen of the hollow insertion channel in the direction of the arrow (arrow A). The bar 101 may further have a very low coefficient of friction, thus the insertion and the removal of the bar may be improved.

**[0056]** Once the bar 101 is situated at a suitable position to be inserted, the bar may be introduced into the hollow insertion channel 122a, in a first direction (in the direction of the arrow A), until the end 101a of the bar reaches the desired position with respect to the hollow insertion channel 122a, thus indicating that the bar has been properly inserted into the passage of the node element. Particularly, a position for receiving the bar may be defined as hereinbefore described, specifically beyond the inner end 123a of the channel. The proximal end 101a of the bar 101 may be inserted into the hollow insertion channel until the proximal end 101a of the bar is situated beyond the defined predetermined position for receiving the bar 101.

**[0057]** Particularly, the defined predetermined position for inserting the bar 101 may be situated at a distance  $x$  from the outer end. As commented above, this distance may correspond to at least the double of the distance  $d$ , wherein the distance  $d$  corresponds to the distance between the outer end of the channel and the "final" position of the proximal end of the bar, with respect to the corresponding channel, once the lattice structure is assembled.

**[0058]** In figure 6b, the proximal end 101a of the bar has already been introduced into the hollow insertion channel 122a, in the first direction (in the direction of the arrow A), from the outer side 121a of the main body to the inner side 121b of the main body, until the desired position of the end 101a of the bar with respect to the hollow insertion channel 122a is reached. Particularly, as commented above, the proximal end 101a of the bar has been introduced into the hollow insertion channel 122a until the end 101a of the bar extends beyond the defined predetermined position for receiving the bar (defined beyond the inner end 123a of the channel). As shown in the figure, the predetermined position for inserting the bar 101 may be situated, at least, at a distance  $x$  from the outer end 122a of the channel. This distance  $x$  may correspond to at least the double of the distance  $d$  which is a predefined distance between the outer end of the channel and the predefined final position of the distal end of the bar, once the lattice structure is assembled.

**[0059]** With such an arrangement, the distal end 101b of the bar will not interfere with the installation of a third node, in the lattice structure to be assembled, as will be explained later on.

**[0060]** In figure 6c, a second node element 200 may be provided. The second node element 200 may be similar to the node element described with reference to figure 2. The above-commented third node element 300 may also be provided. This node element 300 may be similar to the node element described with reference to figures 1a - 1d.

**[0061]** The second node element 200 may be situated at a position in a first plane or level, e.g. on the floor using the corresponding supports.

**[0062]** A second bar 150 may be provided. The bar may extend from a proximal end (not visible) to a distal end (not visible). At this point, the third node element may still not be part of the lattice structure i.e. the third node may be situated further away from the lattice structure to be formed.

**[0063]** Similarly as before, the proximal end (not visible) of the bar may be brought near the outer end 224b of the hollow insertion channel 222b of the node element 200. Once the bar 150 is situated at a position which is suitable for the bar to be inserted into the hollow insertion channel, the proximal end of the bar may be introduced into the hollow insertion channel 222b, in a second direction (see the arrow B).

**[0064]** Particularly, a predetermined position for re-

ceiving the bar 150 may be defined as hereinbefore described, specifically beyond the inner end 223b of the channel. The proximal end of the bar may be inserted into the hollow insertion channel 222b at a position situated between the outer end of the channel and the predetermined position for inserting the bars (i.e. it may be inserted to a relatively shallow position into the hollow insertion channel as compared with the first elongated bar).

**[0065]** The figure shows that the proximal end (not visible) of the bar 150 has already been introduced into the hollow insertion channel 222b, in a second direction (arrow B), from the outer side of the main body (and thus from the outer end of the hollow insertion channel), until a position at or near the inner end of the channel is reached i.e. a position situated between the outer end of the channel and the defined predetermined position for inserting the bar 150. It is noted that this position of the proximal end of the bar corresponds to the above-commented final position of the proximal end of the bar which may further define the distance  $d$  (and thus the distance  $x$ ). At this point, the proximal end of the bar 150 may be secured to the node using suitable coupling means e.g. bolting, riveting, welding techniques and so forth.

**[0066]** Following the example, once the distal end of the bar has been properly inserted and coupled to the node 200, a first hollow insertion channel 312e of the third node 300 may be brought near the distal end (not visible) of the bar 150, at a position suitable for the insertion of the distal end of the bar into the channel 312e. The channel 312e may be aligned with respect to the distal end of the bar. At this point, the node element 300 may be displaced in the direction of the arrow (arrow C) such that the distal end of the bar may be inserted into the passage 312e. Similarly as before, the distal end of the bar 150 may be secured to the node.

**[0067]** As can be seen in the figure, the bar 101 does not interfere with the installation of the node 300 with respect to the bar 150. Particularly, the distal end of the bar is not inserted into the corresponding hollow insertion channel of the node 300 and thus does not interfere with the installation of the node. This is due to the fact that the bar 101 has been displaced, in the first direction, such that the proximal end of the bar is brought to a position situated beyond the predefined position, for receiving the bar, of the hollow insertion channel, as hereinbefore described. Particularly, the proximal end of the first bar has been inserted to a relatively deep position into the hollow insertion channel (as compared with the second bar) such that the other end of the first bar does not interfere with the installation of the node.

**[0068]** In this respect, by inserting the first bar 101 beyond the predetermined position, for inserting the bar 101, a portion of the bar 101 is situated beyond such predetermined position. Thus, the remaining portion of the bar 101 between the outer end of the hollow insertion channel of the first node and the distal end of the bar 101 comprises a length that allows the installation of the node

300.

**[0069]** Alternatively, the third node element 300 may be pre-attached and pre-installed to the distal end of the bar 150.

**[0070]** In figure 6d, the node 300 has already been installed at the desired position, in the lattice structure, as hereinbefore described.

**[0071]** Additionally, the figure shows that the bar 101 has been displaced in a third direction (see arrow D), opposite to the first direction (see arrow A in figure 6b) such that the distal end (not visible) of the bar 101 has been introduced into the through-hole formed by the hollow insertion channel 312f of the third node 300, from the outer side 314f of the hollow insertion channel (and thus from the outer side of the node) to the inner side 313f of the hollow insertion channel (and thus to the inner side of the node) until the desired final position of the distal end (not visible) of the bar with respect to the hollow insertion channel has been reached. The proximal end of the bar may also be situated in the defined final position for receiving the bar. This final position may be situated along the length of the corresponding hollow insertion channel. In some examples, this final position may also be situated a bit beyond the inner end of the channel or a bit before the outer end of the channel.

**[0072]** It is noted that the proximal end of the bar, after the displacement of the bar, may be situated at or near the inner end of the corresponding hollow insertion channel of the node 100. It is further noted that the distal end of the bar may be inserted into the second hollow insertion channel 312f of the node 300 without traversing the corresponding through-hole and it may be inserted into the second hollow insertion channel, at a position, at or near the inner end of the hollow insertion channel. In any case, it is noted that this position of the proximal end of the bar corresponds to the above-commented final position of the proximal end of the bar which may further define the distance d (and thus the predefined position x for receiving bars).

**[0073]** At this stage, the ends of the bar 101 may be secured to the corresponding node using e.g., bolts, studs and / or any suitable welding technique.

**[0074]** In figure 6e, a third bar 160 may be provided. The bar 160 may extend from a proximal end 160a to a distal end 160b.

**[0075]** The figure shows that the distal end 160b of the bar has already been introduced into the hollow insertion channel 312d of the node 300, in a fourth direction (arrow D), from the outer end 314d of the passage to the inner end 313d of the passage, by traversing the corresponding through-hole, until a desired position of the distal end 160b of the bar with respect to the hollow insertion channel 312d is reached. Particularly, a predefined position for receiving the bar may be defined, as hereinbefore described. The predefined position for inserting the bars may correspond to the double of the distance d, wherein the distance d corresponds to the distance between the outer end of the channel and the final position of the distal

end of the bar 160 once the lattice structure is assembled.

**[0076]** The distal end 160b of the bar has been introduced into the hollow insertion channel 312d until the end 160b of the bar is situated beyond the predetermined position for receiving the bar i.e. the bar has been introduced to a relatively deep position into the hollow insertion channel. The proximal end 160a of the bar thus will not interfere with the installation of a fifth node element in the lattice structure to be formed, as will be explained later on.

**[0077]** In figure 6f, a fourth hollow bar 170 may be provided. The bar 170 may extend from a proximal end 170a to a distal end 170b. Additionally, a fifth bar 180 may also be provided. The bar 180 may extend from a proximal end (not visible) to a distal end 180b.

**[0078]** The figure shows that the proximal end 170a of the bar has already been introduced into the hollow insertion channel 312c of the second node element 200, in a fifth direction (arrow E), from the outer side 314c of the hollow insertion channel to the inner side 313c of the hollow insertion channel, until the desired position of the end 170a of the bar with respect to the hollow insertion channel 312c has been reached. Particularly, a predefined position for receiving the bar may be defined, beyond the inner end of the channel, as hereinbefore described. The proximal end 170a of the bar has been introduced, into the hollow insertion channel, until the end 170a of the bar is situated beyond the defined predetermined position for inserting the bar. Similarly as before, the predefined position for inserting the bars may correspond to the double of the distance d, wherein the distance d corresponds to the distance between the outer end of the channel and the final position of the proximal end of the bar 170, with respect to the channel, once the lattice structure is assembled. The bar 170 thus will also not interfere with the installation of the fifth node, as will be explained later on.

**[0079]** Additionally, a fourth node element 400 may be provided. The fourth node element may be the same or similar to the node element 200 described with reference to figure 2. The fourth node element 400 may be situated at a position in a first plane or level, e.g. on the floor using the corresponding supports. Again, a predetermined position for receiving the bar may be defined, specifically beyond the inner end of the channel. The predetermined position may be at a distance x from the outer end of the channel. The distance x may be the double of a distance d, wherein the distance d corresponds to the distance between the outer end of the channel and the final position of the proximal end of the bar 180 once the lattice structure is assembled. It is noted that the proximal end of the bar 180, in this figure, is situated in such final position although the distal end is not visible.

**[0080]** As shown in the figure, the bar 180 has been displaced in a sixth direction (arrow F) such that the proximal end of the bar is inserted into the corresponding hollow insertion channel of the node 400, from the outer side of the channel, and the proximal end of the bar is

situated between the outer side of the channel and the predetermined position for inserting the bar. The bar may thus be brought to a relatively shallow position as compared with the bars 160, 170. The proximal end of the bar 180 may be secured to the node as hereinbefore described. As a result, the distal end 180b of the bar is situated at a suitable position for the reception of a fifth node, as will be described later on.

**[0081]** In figure 6g, the fifth node 500 may be provided. The node may be the same or similar to the node 300 or the nodes described with reference to figures 1a - d.

**[0082]** A first hollow insertion channel of the node 500 may be brought near the distal end (not visible) of the bar 180, at a position suitable for the insertion of the distal end of the bar into the corresponding passage. The passage may be aligned with respect to the distal end of the bar 180. At this point, the node element 500 may be displaced, in an appropriate direction, such that the distal end of the bar 180 may be inserted into the corresponding passage of the node 500. Similarly as before, the distal end of the bar 180 may be secured to the node 500. In alternative examples, the node element 500 may be pre-attached (and thus pre-installed) to the distal end of the bar 180.

**[0083]** The figure shows that the bar 160 has been displaced in a direction (see arrow G), opposite to the fourth direction (see arrow D in figure 2e), such that the proximal end (not visible) of the bar 160 has been introduced into the corresponding through-hole formed by a hollow insertion channel of the fifth node 500, from the outer side of the hollow insertion channel (and thus from the outer side of the node) to the inner side of the hollow insertion channel (and thus to the inner side of the node) until a desired position of the end (not visible) of the bar with respect to the hollow insertion channel is reached and, all this, while the distal end (not visible) of the bar 160 may remain inserted into the corresponding hollow insertion channel of the node 300, at a position at or near the inner end of the hollow insertion channel. It is noted that the proximal end of the bar 160 may be inserted into the corresponding hollow insertion channel of the node 500 without traversing the corresponding through-hole. It is further noted that the proximal end of the bar 160 may be situated at or near the inner end of the corresponding hollow insertion channel of the node 500.

**[0084]** Similarly, the bar 170 has been displaced in a direction (see arrow H), opposite to the fifth direction (see arrow E in figure 2f), such that the distal end (not visible) of the bar 170 has been introduced into the through-hole formed by a corresponding hollow insertion channel of the fifth node 500, from the outer side of the hollow insertion channel (and thus from the outer side of the node) to the inner side of the hollow insertion channel (and thus to the inner side of the node) until a desired position of the end (not visible) of the bar with respect to the hollow insertion channel is reached (e.g., at position at or near the inner end of the hollow insertion channel) and, all this, while the proximal end (not visible) of the bar may

remain inserted into the corresponding hollow insertion channel of the node 200 (e.g., at position at or near the inner end of the hollow insertion channel). It is noted that the distal end of the bar may be inserted into the corresponding hollow insertion channel of the node 500 without traversing the corresponding through-hole.

**[0085]** It is noted that, once the bars 160, 170 have been displaced in their corresponding direction, the proximal end of the bars is situated in the above-commented final position which will further define the distance d (and thus the predefined final position for receiving a bar).

**[0086]** At this stage, the bars 160, 170, 180 may be secured between their corresponding nodes using e.g., bolts, studs and / or any suitable welding technique.

**[0087]** Evidently, the remaining parts of the lattice structure to be formed may be assembled in a substantially similar way. As a result, a lattice structure, as shown in figure 7, may be obtained.

**[0088]** It is noted that a method for assembling a lattice structure, as hereinbefore described may be performed using any of the node elements described with reference to figures 1 - 5 and any combination thereof.

**[0089]** Figures 8a - 8b schematically illustrate a sequence of situations that may occur during the performance of a method for disassembling a lattice structure which has been previously assembled using the method described with reference to figures 2a - 2g. Same reference numbers denote the same elements as those in the previous figures. The method is described below with reference to the sequences of situations illustrated by figures 8a - 8b.

**[0090]** The figure 8a illustrates an example of an initial situation. The distal end 150b and the proximal end 150a of a bar 150, which has been previously assembled and secured to the lattice structure as hereinbefore described, may be released with respect to the corresponding nodes 300, 200.

**[0091]** The bar 150 may be displaced in the second direction (see arrow B) until the proximal end 150a of the bar reaches a desired position with respect to the hollow insertion channel, beyond the predetermined position for receiving a bar, defined as hereinbefore described. As a result, the distal end 150b of the bar may be extracted from the corresponding hollow insertion channel of the third node 300.

**[0092]** Similarly, the distal end 101b and the proximal end 101a of a bar 101, which has been previously assembled and secured to the lattice structure as hereinbefore described, may be released (unsecured) with respect to the corresponding nodes 300, 100.

**[0093]** The bar 101 may be displaced in the first direction (see arrow A) until the proximal end 101a of the bar is situated beyond the predetermined position for receiving the bar, defined as hereinbefore described. As a result, the distal end 101b of the bar 101 may be extracted from the corresponding hollow insertion channel of the third node 300.

**[0094]** At this stage, the third node 300 may easily be

removed from the lattice structure.

**[0095]** In figure 8b, the third node element has already been removed from the lattice structure, as hereinbefore described. The first bar 101 may be displaced in a direction (see arrow D) opposite to the first direction (see arrow A in figure 6a) until the proximal end 101a of the bar 101 is extracted from the corresponding hollow insertion channel of the first node 100.

**[0096]** Similarly, the second bar 150 may be displaced in a direction (see arrow I) opposite to the second direction (see arrow B in figure 6c) until the proximal end 150a of the bar 150 is extracted from the corresponding hollow insertion channel of the second node 200.

**[0097]** As a result, the bars 101, 150 can be easily removed from the lattice structure.

**[0098]** Evidently, further nodes and bars forming part of the lattice structure may be disassembled in a similar way.

**[0099]** The lattice structure may thus be easily repaired, and maintenance can be performed in an easy way. Any damaged bar or node may be easily replaced following a simple disassembly sequence.

**[0100]** It is noted that the methods for assembly and disassembly a lattice structure, as hereinbefore described, may be used in one or more of the following lattice structures:

- Grid structures for the aerospace industry, e.g. payload adaptors, rocket inter-stages, satellite central cylinders, etc,
- Lattice towers for electricity transmission, wind power turbines or telecommunications,
- Lattice bridges, trusses, grids, girders, domes (e.g. geodesic domes), barrel vaults, and hyperbolic paraboloids,
- Space frames, grids, decks, and scaffolds,
- Airplane, helicopter, or airship fuselages,

**[0101]** Although only a number of examples have been disclosed herein, other alternatives, modifications, uses, and/or equivalents thereof are possible. Furthermore, all possible combinations of the described examples are also covered. Thus, the scope of the present disclosure should not be limited by particular examples, but should be determined only by a fair reading of the claims that follow. If reference signs related to drawings are placed in parentheses in a claim, they are solely for attempting to increase the intelligibility of the claim, and shall not be construed as limiting the scope of the claims.

## Claims

1. A method for assembling a lattice structure comprising:
  - providing at least three node elements comprising:

• a main body including two or more hollow insertion channels, wherein the hollow insertion channels are configured to receive an elongated bar, wherein the hollow insertion channels extend from an outer end to an inner end, wherein a predetermined position for receiving the bars is defined, along the length of the hollow insertion channels, between the outer end and the inner end of the hollow insertion channels, or the predetermined position for receiving the bars is defined beyond the inner end of the channels, wherein the predetermined position is defined at a distance x from the outer end of the channels,

- providing two or more elongated bars, wherein each of the bars comprises a proximal end and a distal end,

- displacing a first elongated bar of the elongated bars, in a first direction, such that the proximal end of the first elongated bar is inserted into a hollow insertion channel of a first node element of the node elements, from the outer end of the hollow insertion channel to the inner end of the hollow insertion channel, until the proximal end of the first elongated bar is situated at a position beyond the defined predetermined position,

- displacing a second elongated bar of the elongated bars, in second direction, such that the proximal end of the second elongated bar is inserted into a hollow insertion channel of a second node element, from the outer end of the hollow insertion channel to the inner end of the hollow insertion channel, until the proximal end of the second elongated bar is situated at a position between the outer end of the channel and the defined predetermined position,

- displacing the first elongated bar, in a third direction, opposite to the first direction, such that the distal end of the first bar is inserted into a corresponding hollow insertion channel of a third node element of the node elements.

2. A method according to claim 1, wherein a distance d is predefined between the outer end of the hollow insertion channels and either a final position for receiving the bars predefined along the length of the hollow insertion channels or a final position for receiving the bars predefined beyond the inner end of the channels, wherein the distance x corresponds to at least the double of the predefined distance d.
3. A method according to claim 2, wherein, for the corresponding hollow insertion channel of the first node element, the final position corresponds to the position at which the proximal end of the first elongated bar is situated with respect to the corresponding hollow insertion channel of the first node element after displacing the first elongated bar in the third direc-

tion.

4. A method according to any of claims 2 - 3, wherein, for the corresponding hollow insertion channel of the second node element, the final position corresponds to the position at which the proximal end of the second elongated bar is situated with respect to the corresponding hollow insertion channel of the second node element after displacing a second elongated bar in the second direction.

5. A method according to any of claims 1 - 4, further comprising:

- displacing the first elongated bar, in a third direction, opposite to the first direction, such that the distal end of the first bar is inserted into a first hollow insertion channel of a third node element while the proximal end of the first elongated bar remains inserted into the hollow insertion channel of the first node element.

6. A method according to any of claims 1 - 5, further comprising after displacing a second elongated bar of the elongated bars, in the second direction:

- displacing the third node element of the node elements towards the second bar such that the distal end of the second bar is inserted into a corresponding hollow insertion channel of the third node element.

7. A method according to any of claims 1 — 5, wherein a distal end of the second elongated bar is pre-inserted and pre-attached to second hollow insertion of the third node element.

8. A method according to any of claims 6 - 7, further comprising:

- securing the proximal end of the second bar to the second node element and / or securing the distal end of the second bar to the third node element, and
- securing the proximal end of the first bar to the first node element and / or securing the distal end of the first bar to the third node element.

9. A method according to any of claims 1 — 8, further comprising:

- displacing the second elongated bar of the elongated bars, in second direction, such that the proximal end of the second elongated bar is inserted into a hollow insertion channel of a second node element, from the outer end of the hollow insertion channel to the inner end of the hollow insertion channel, until the proximal end of

the second elongated bar is situated at a position between the outer end of the channel and the inner end of the channel of the second node element.

10. A method according to any of claims claim 1 - 9, wherein the predetermined position for receiving the bars is defined at the same distance  $x$  for all the hollow insertion channels.

11. A method according to any of claims 1 - 10, wherein the main body comprises an outer side and an inner side, wherein the hollow insertion channels extend between the outer side of the body and the inner side of the body forming a corresponding through-hole.

12. A method according to any of claims 1 - 11, further comprising:

- inserting a retention element into an opening of the main body of the node elements

13. A method for disassembling a lattice structure according to any of claims 1 - 12, further comprising:

- displacing the first elongated bar, in the first direction, until the proximal end of the first bar is situated beyond the defined predetermined position and the distal end of the bar is extracted from the corresponding hollow insertion channel of the third node element,
- displacing the second elongated bar, in the second direction, until the proximal end of the second bar is situated beyond the defined predetermined position and the distal end of the second bar is extracted from the corresponding hollow insertion channel of the third node element, and
- removing the third node element from the lattice structure.

14. A method according to claim 13, further comprising:

- displacing the first elongated bar, in the third direction, opposite to the first direction, until the proximal end of the first elongated bar is extracted from the corresponding hollow insertion channel of the first node element,
- displacing the second elongated bar, in a fourth direction, opposite to the second direction, until the proximal end of the second elongated bar is extracted from the corresponding hollow insertion channel of the second node element.

15. A method according to any of claims 13 - 14, further comprising:

- before displacing the first elongated bar, in the

first direction, releasing the proximal end of the first elongated bar with respect to the first node element and releasing the distal end of the first elongated bar with respect to the third node element.

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- before displacing the second elongated bar, in the second direction, releasing the proximal end of the second elongated bar with respect to the second node element and releasing the distal end of the second elongated bar with respect to the third node element.

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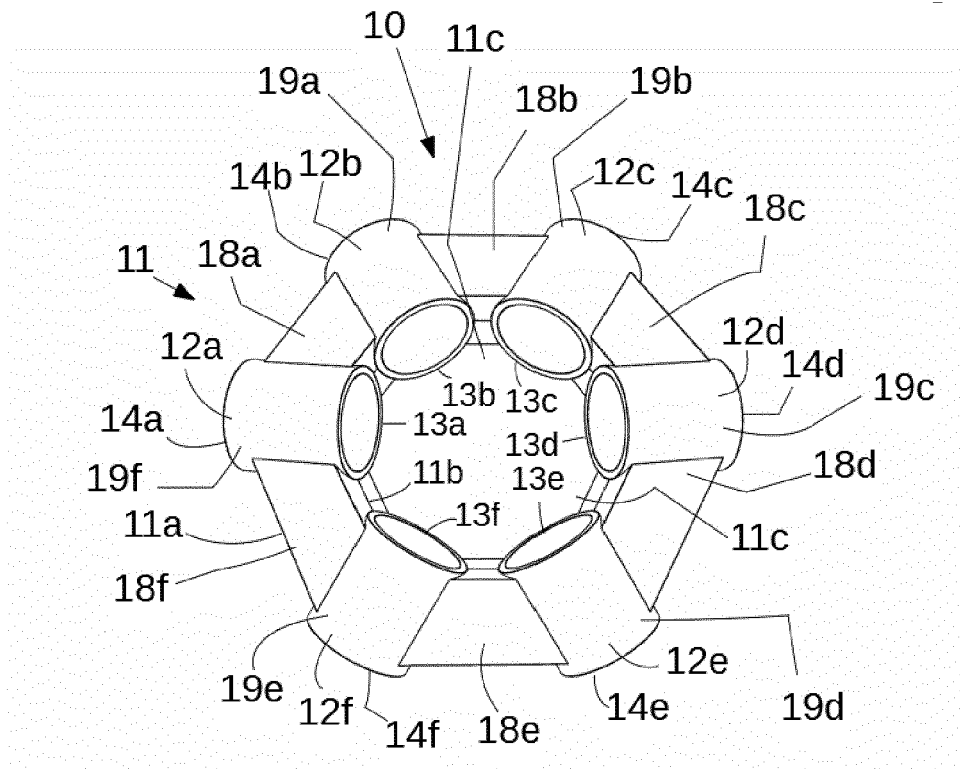


Fig. 1a

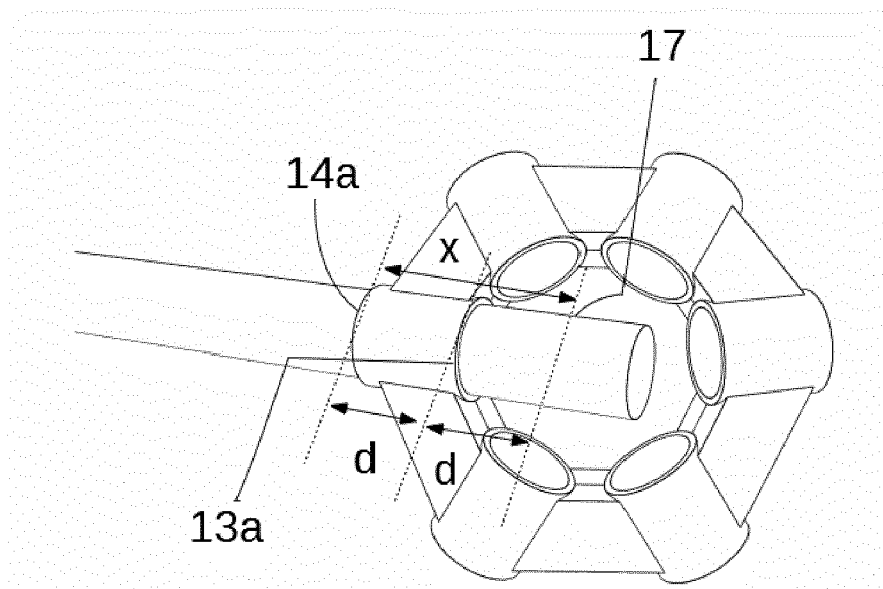


Fig. 1b

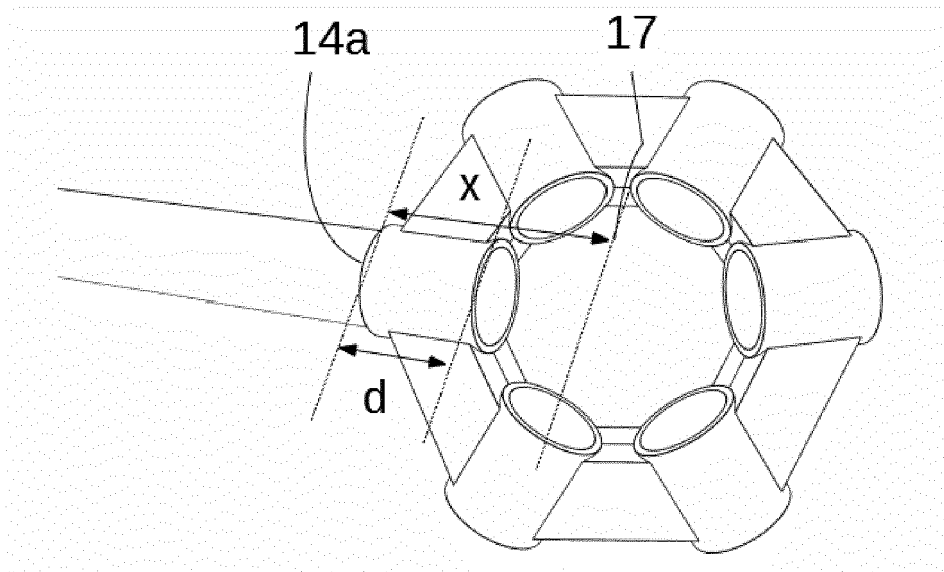


Fig. 1c

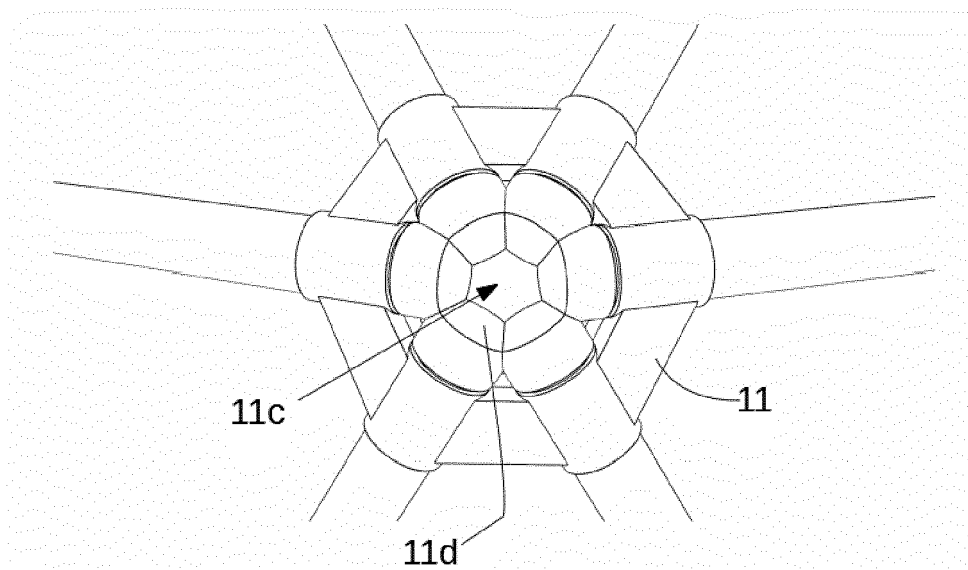


Fig. 1d

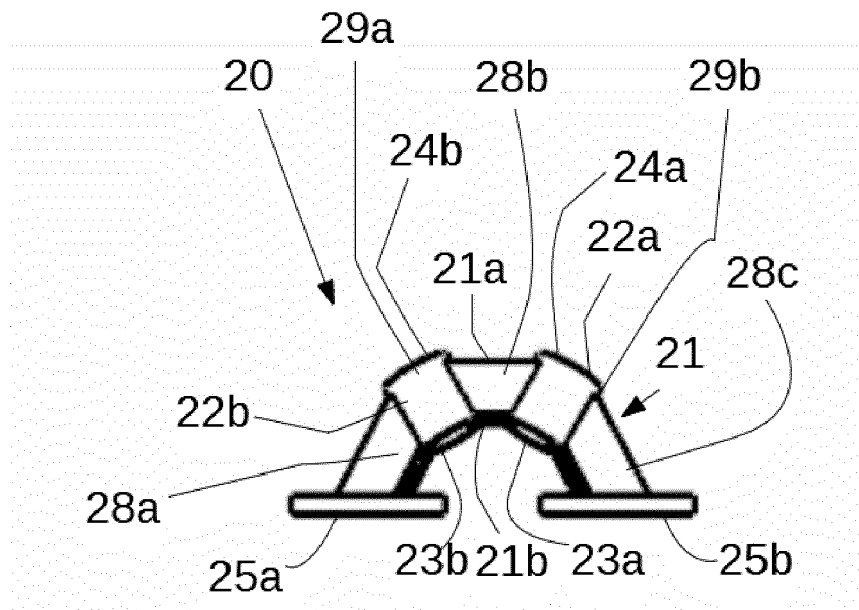


Fig. 2

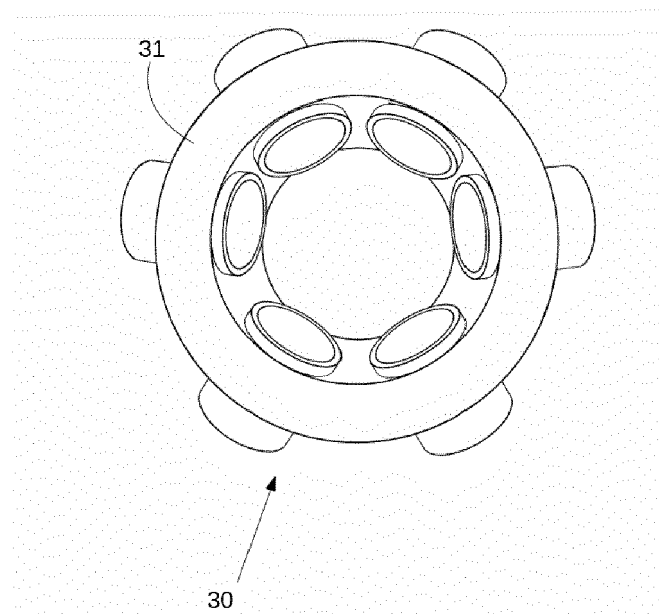


Fig. 3

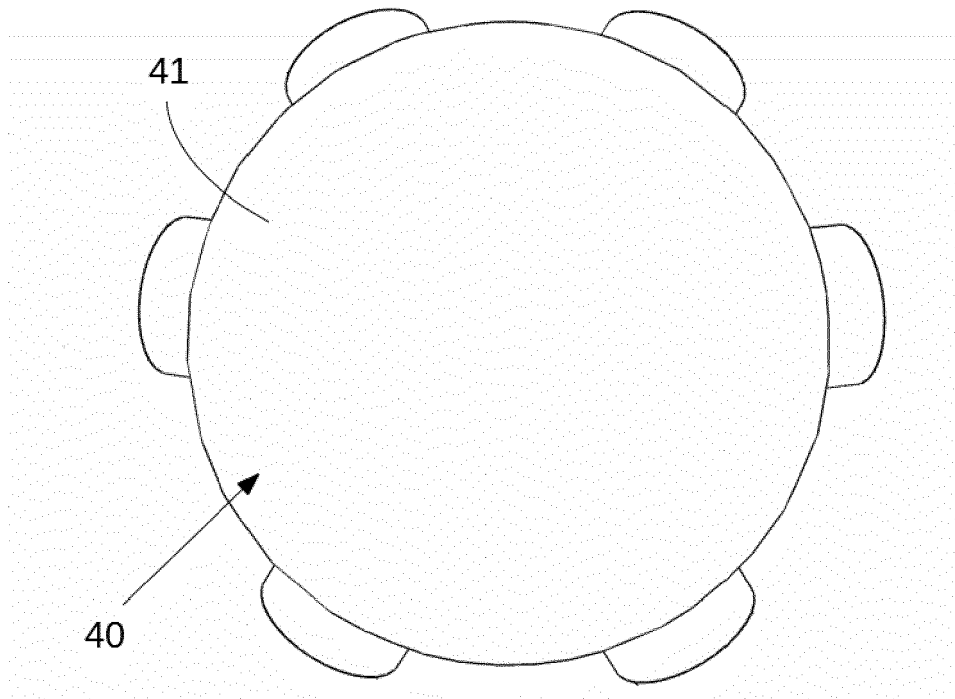


Fig. 4

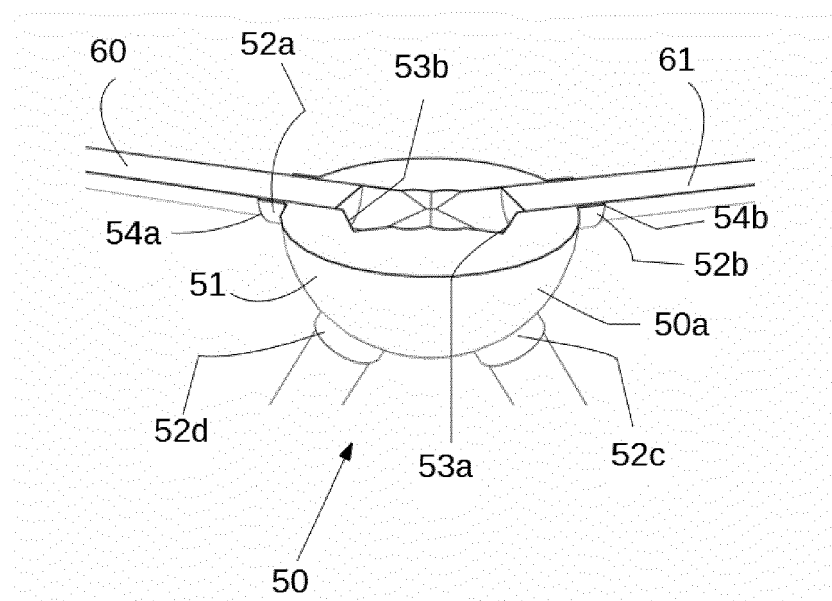


Fig. 5a

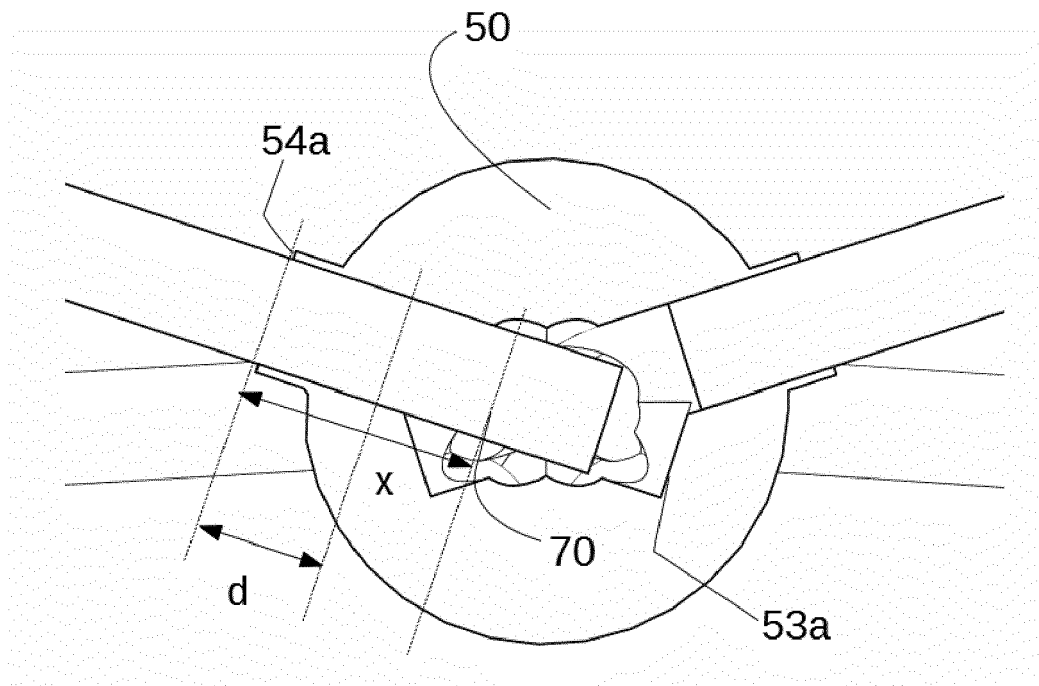


Fig. 5b

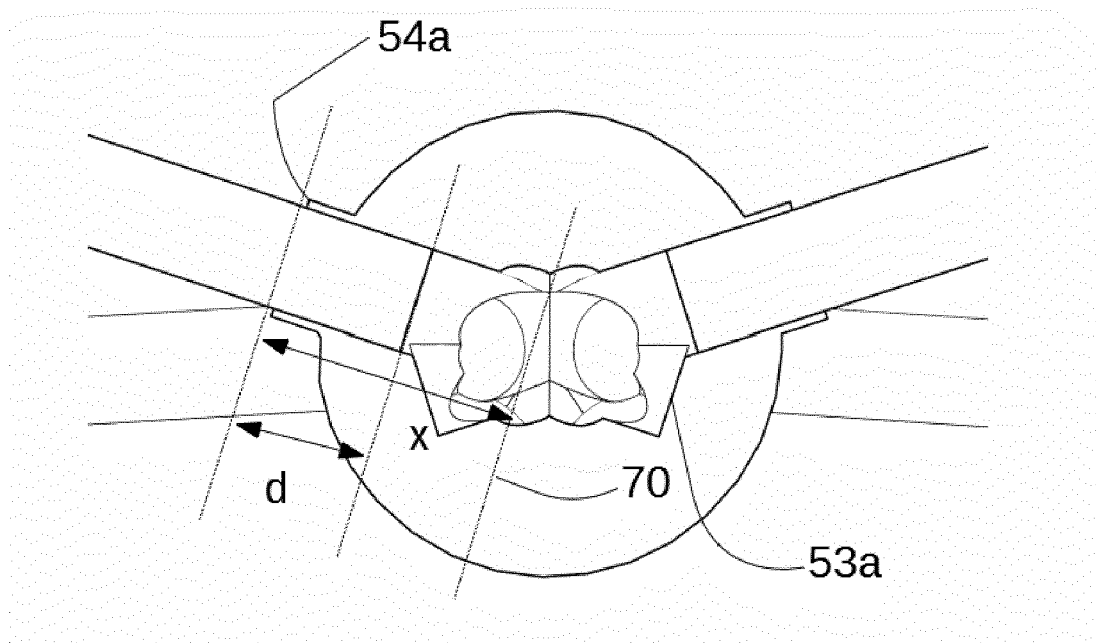


Fig. 5c

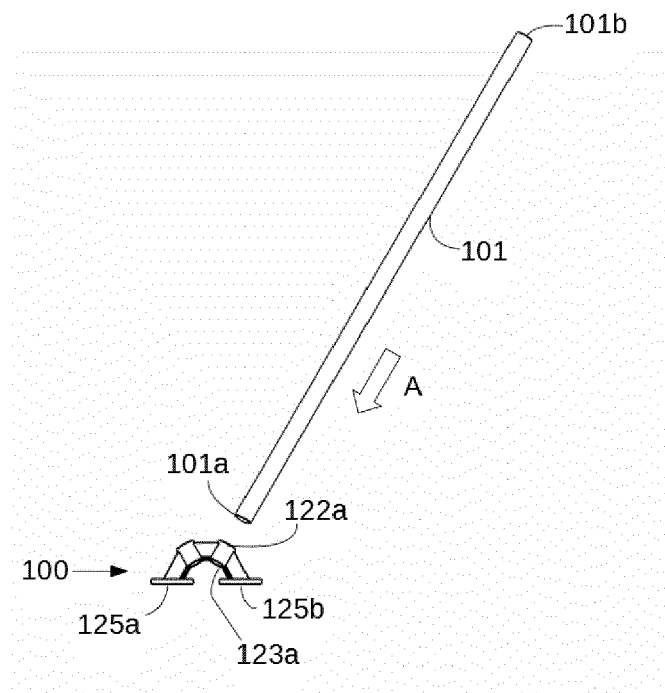


Fig. 6a

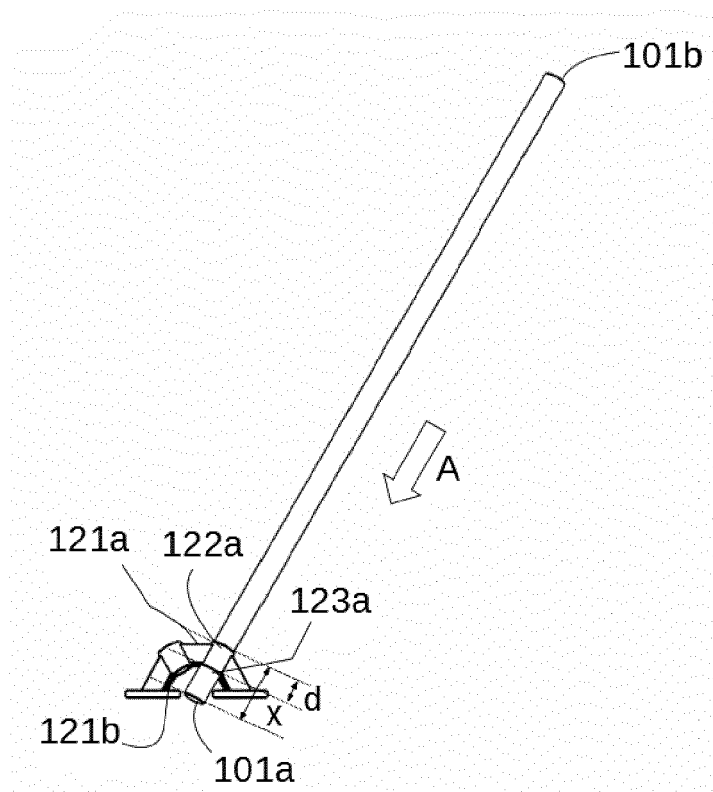


Fig. 6b

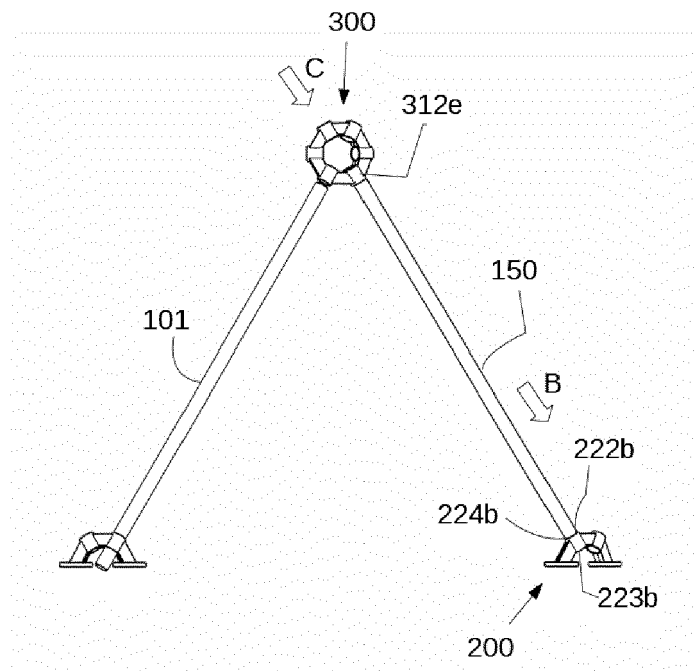


Fig. 6c

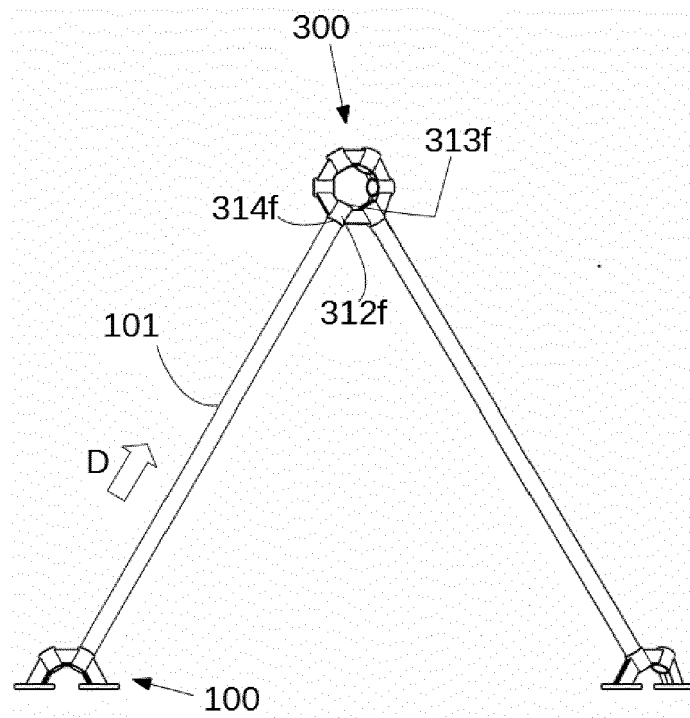


Fig. 6d

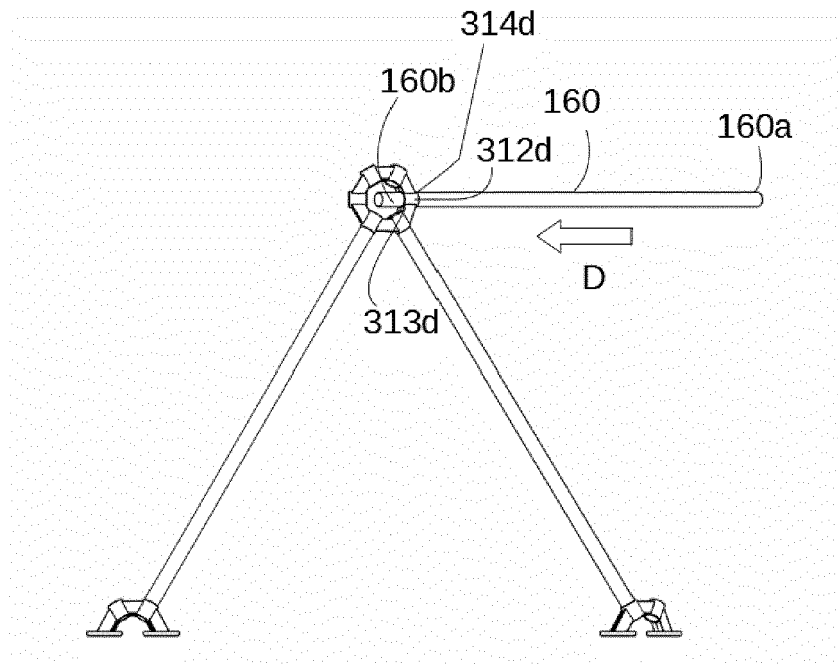


Fig. 6e

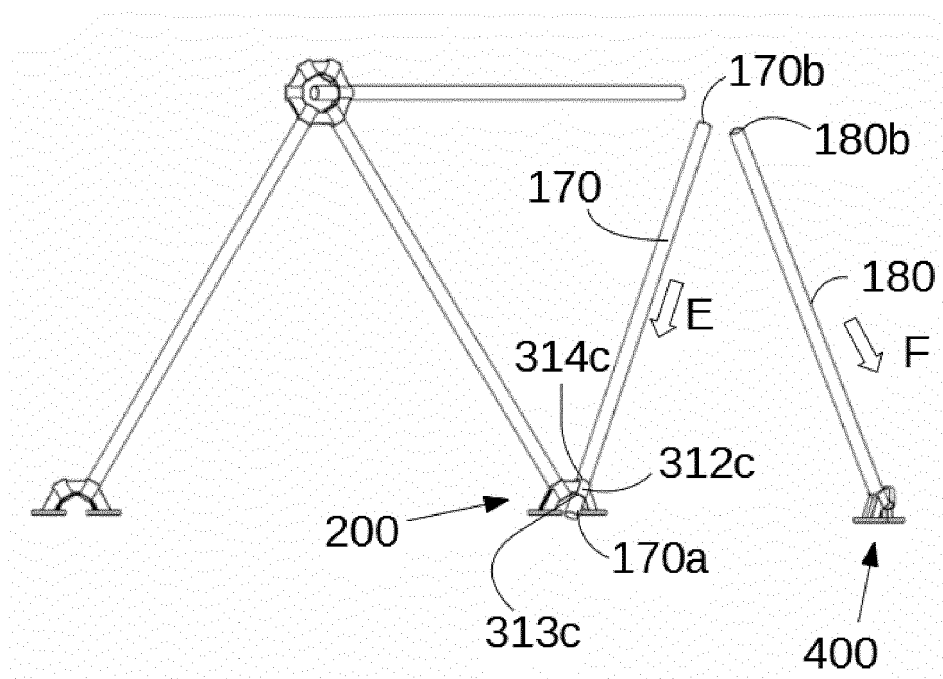


Fig. 6f

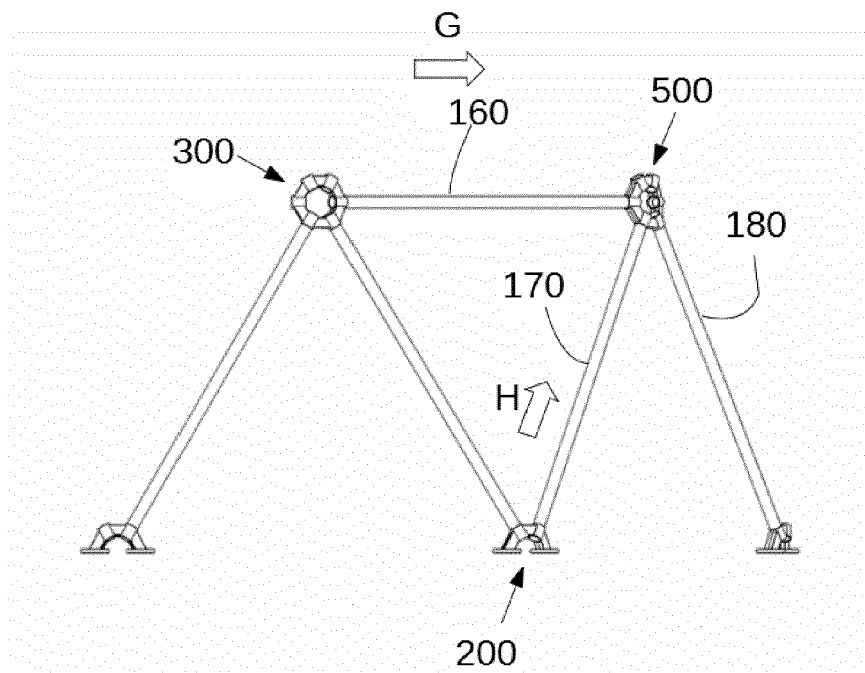


Fig. 6g

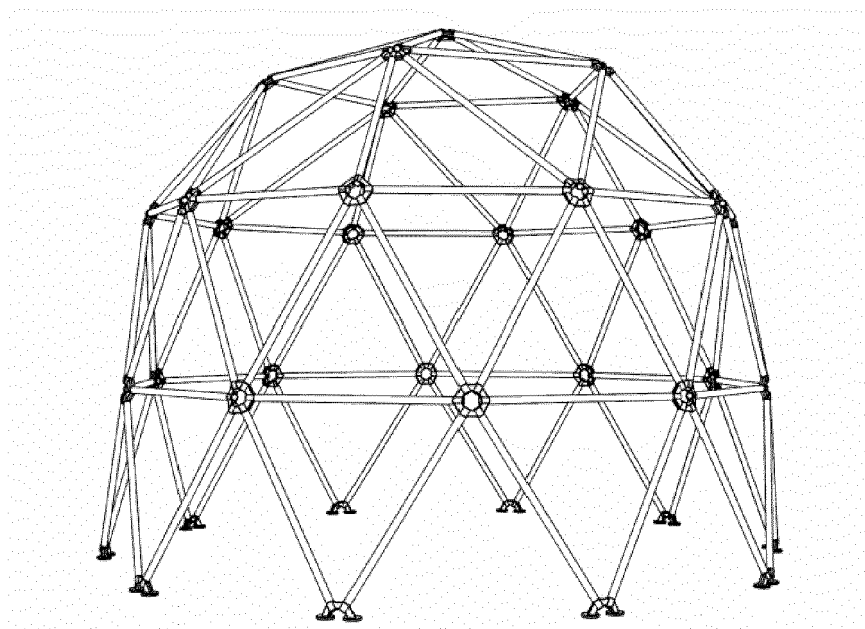


Fig. 7

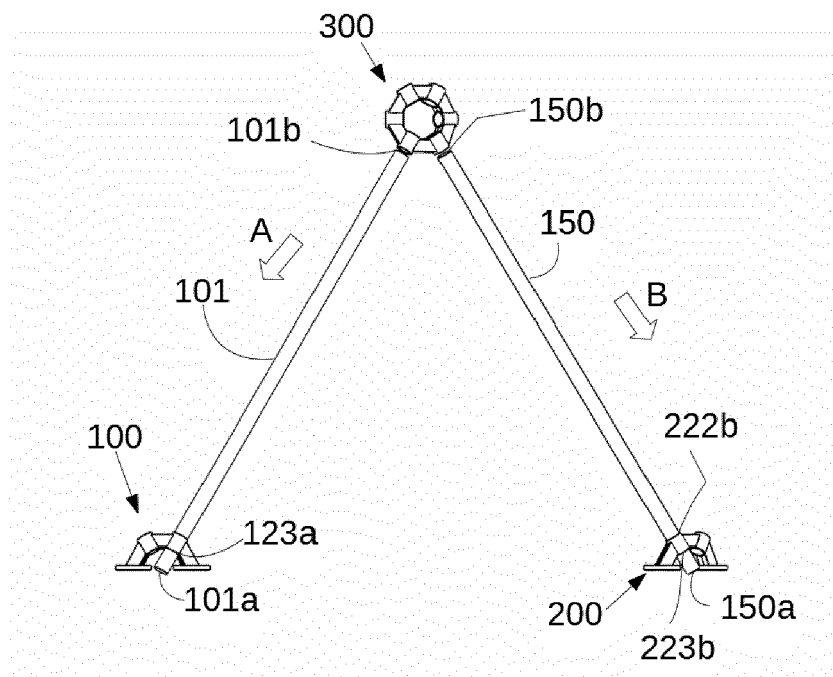


Fig. 8a

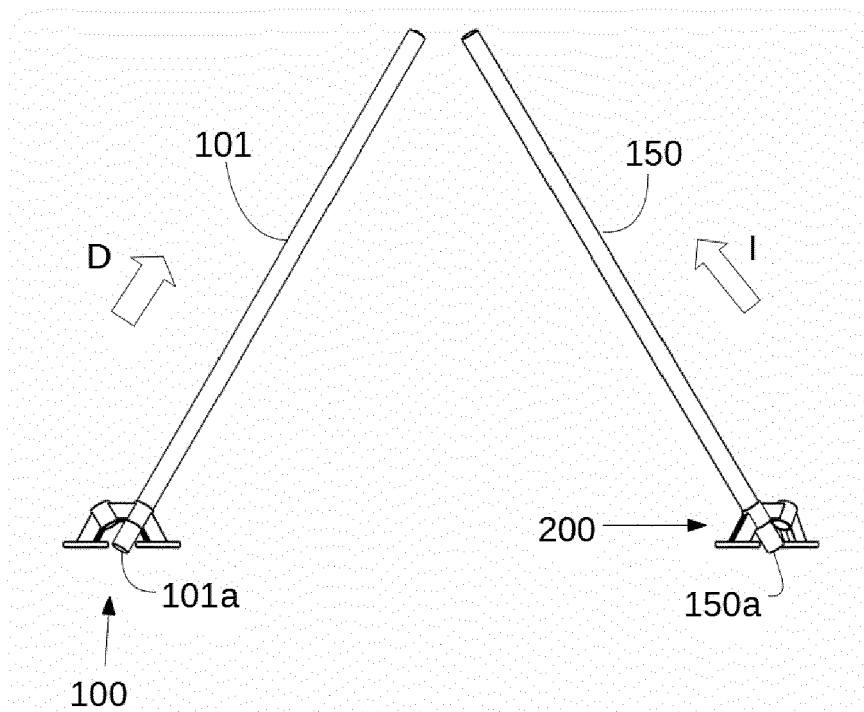


Fig. 8b



## EUROPEAN SEARCH REPORT

Application Number

EP 21 38 2836

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages                                                   | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
|----------|---------------------------------------------------------------------------------------------------------------------------------|-------------------|-----------------------------------------|
| X        | BE 804 514 A (KETELAERE RUDOLF DE)<br>2 January 1974 (1974-01-02)<br>* page 3, line 24 - page 5, line 8;<br>figures 1-6 *       | 1-15              | INV.<br>E04B1/19                        |
| X        | US 1 113 371 A (PAJEAU CHARLES H [US])<br>13 October 1914 (1914-10-13)<br>* page 1, line 36 - page 3, line 25;<br>figures 1-9 * | 1-15              |                                         |

TECHNICAL FIELDS  
SEARCHED (IPC)

E04B

The present search report has been drawn up for all claims

Place of search

The Hague

Date of completion of the search

24 March 2022

Examiner

Melhem, Charbel

## CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone  
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**ANNEX TO THE EUROPEAN SEARCH REPORT  
ON EUROPEAN PATENT APPLICATION NO.**

EP 21 38 2836

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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24-03-2022

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| 10 | Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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| 15 | <b>US 1113371</b>                         | <b>A</b>            | <b>13-10-1914</b>          | <b>NONE</b>         |
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