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(54) **THREE-DIMENSIONAL STRUCTURAL SYSTEM MADE FROM SPHERICAL JOINTS AND BEAMS**

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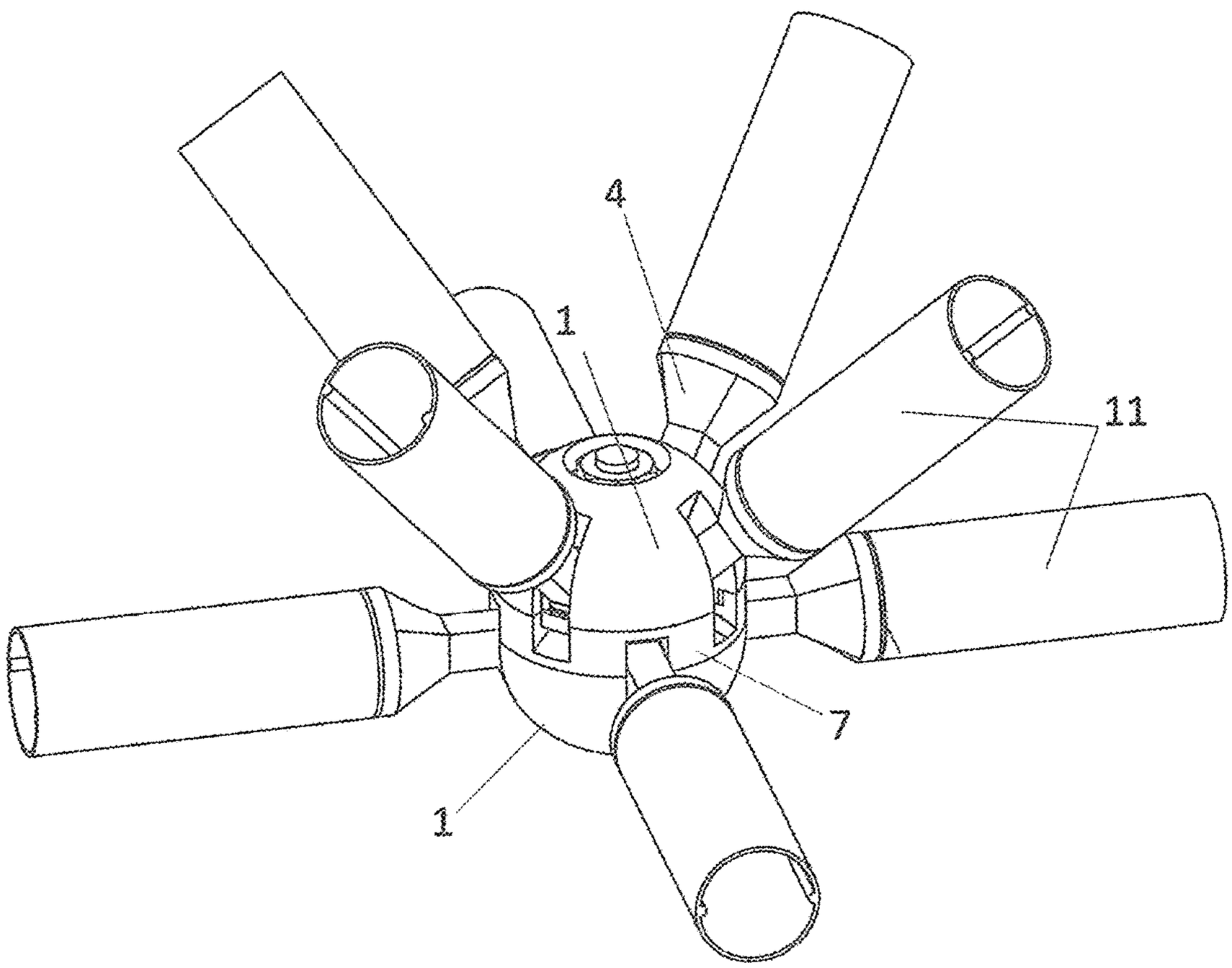
(57) **ABSTRACT**

Disclosed is a system of spherical joints and tubular beams that interconnect to make a spatial reticulate construction based on geometries composed of basic tetrahedral and semi-tetrahedral modules. The joint includes two equal semispherical caps symmetrically organized around a central plate with four or more square fissure sections, joined by a single central screw allowing simultaneous clamping of eight or more hammer terminals at the beam ends. These extremities have a prismatic hammer shape with hexadecagonal base and a multifaceted hemisphere. The frames have a prismatic square section, allowing rotation only in the plane of the board of the joint. The design has a prismatic shape with a square section of multifaceted pole hammer terminals present both on the hammer head and within the caps which eliminates the structural instability that arises in the reticular structure due to the rotation of the beams around the several crux after clamping.



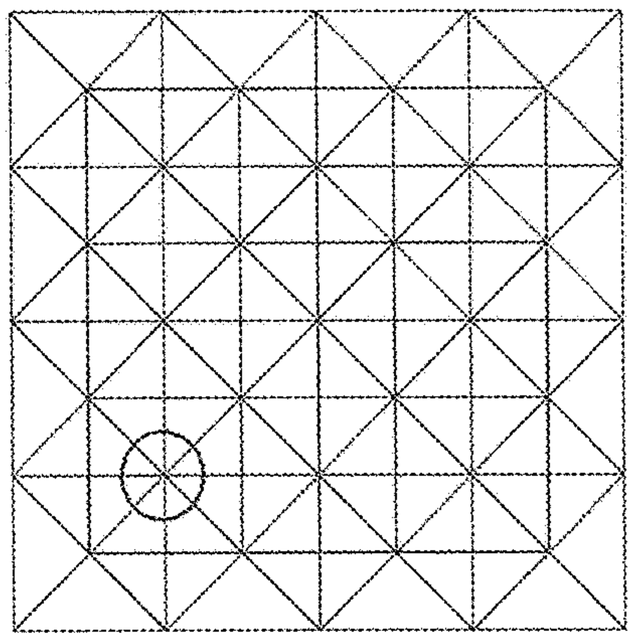


fig. 1

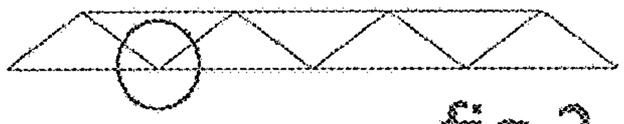


fig.2

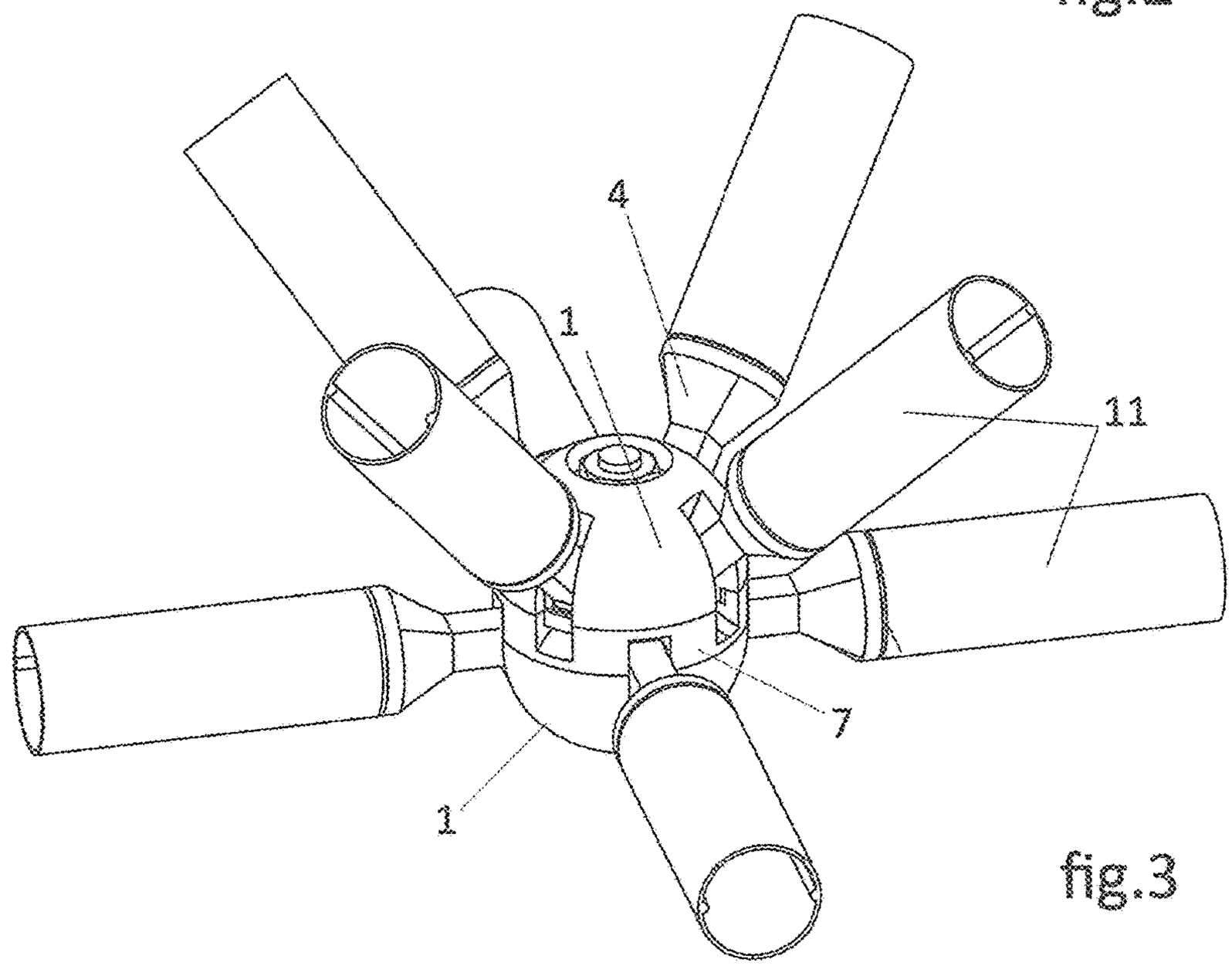


fig.3

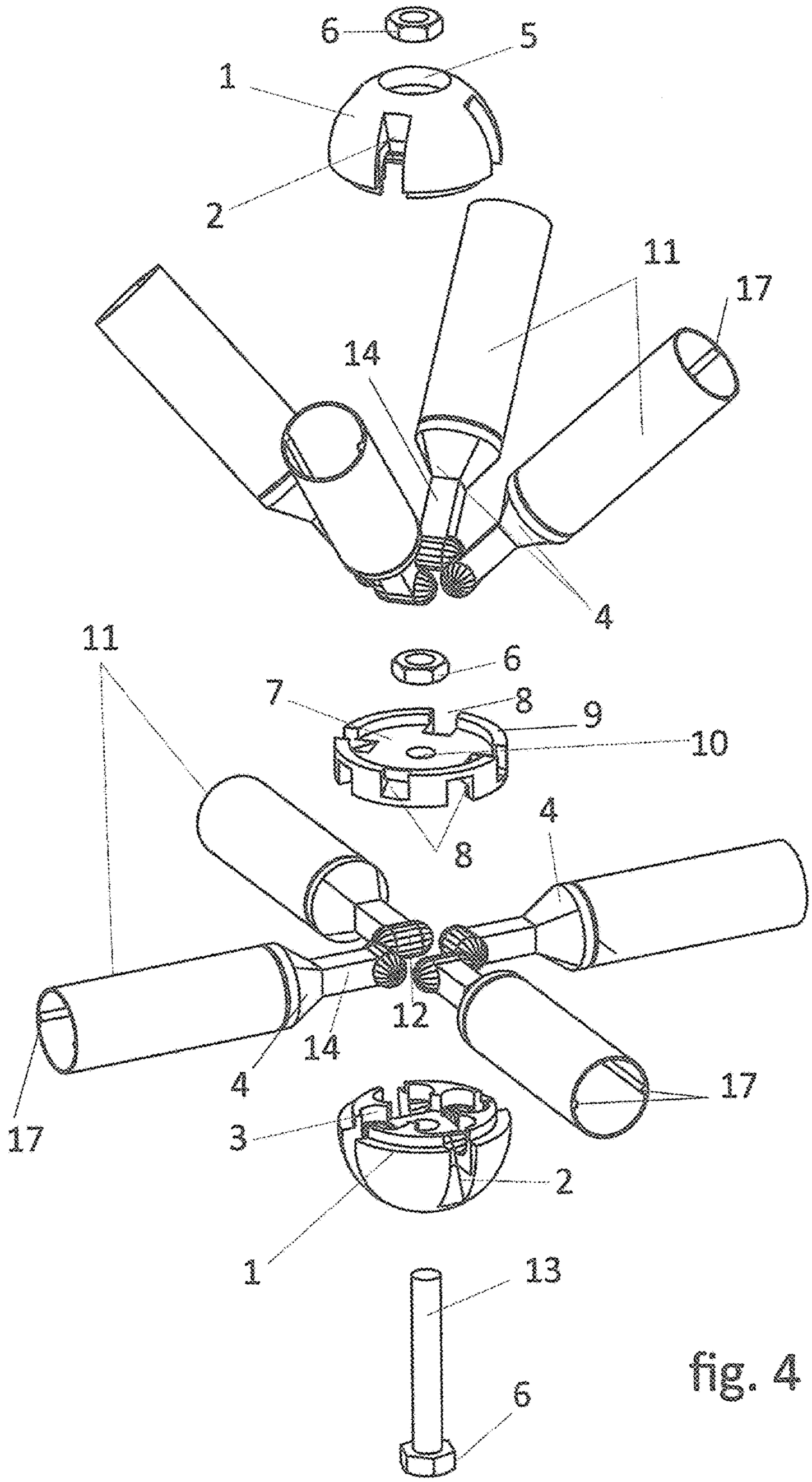


fig. 4

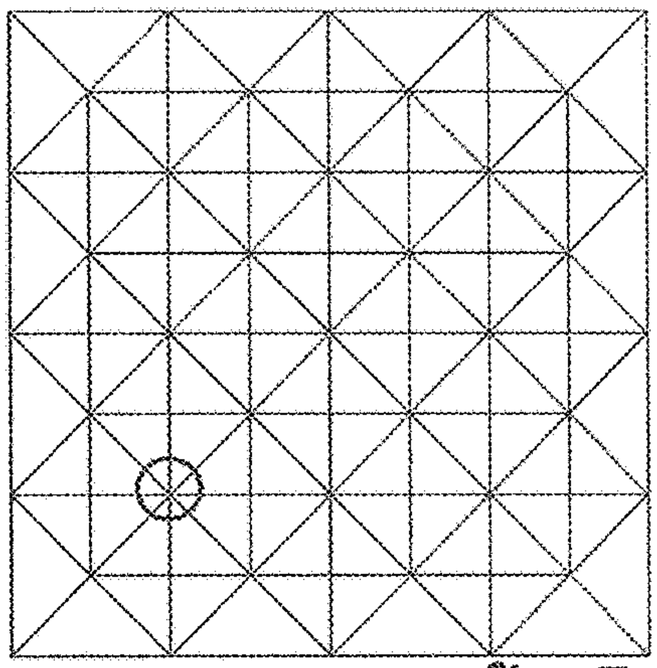


fig.5

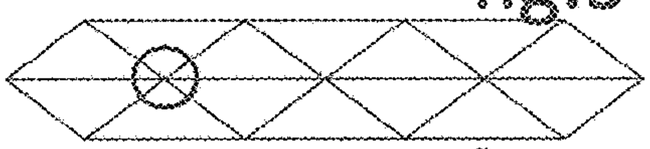


fig.6

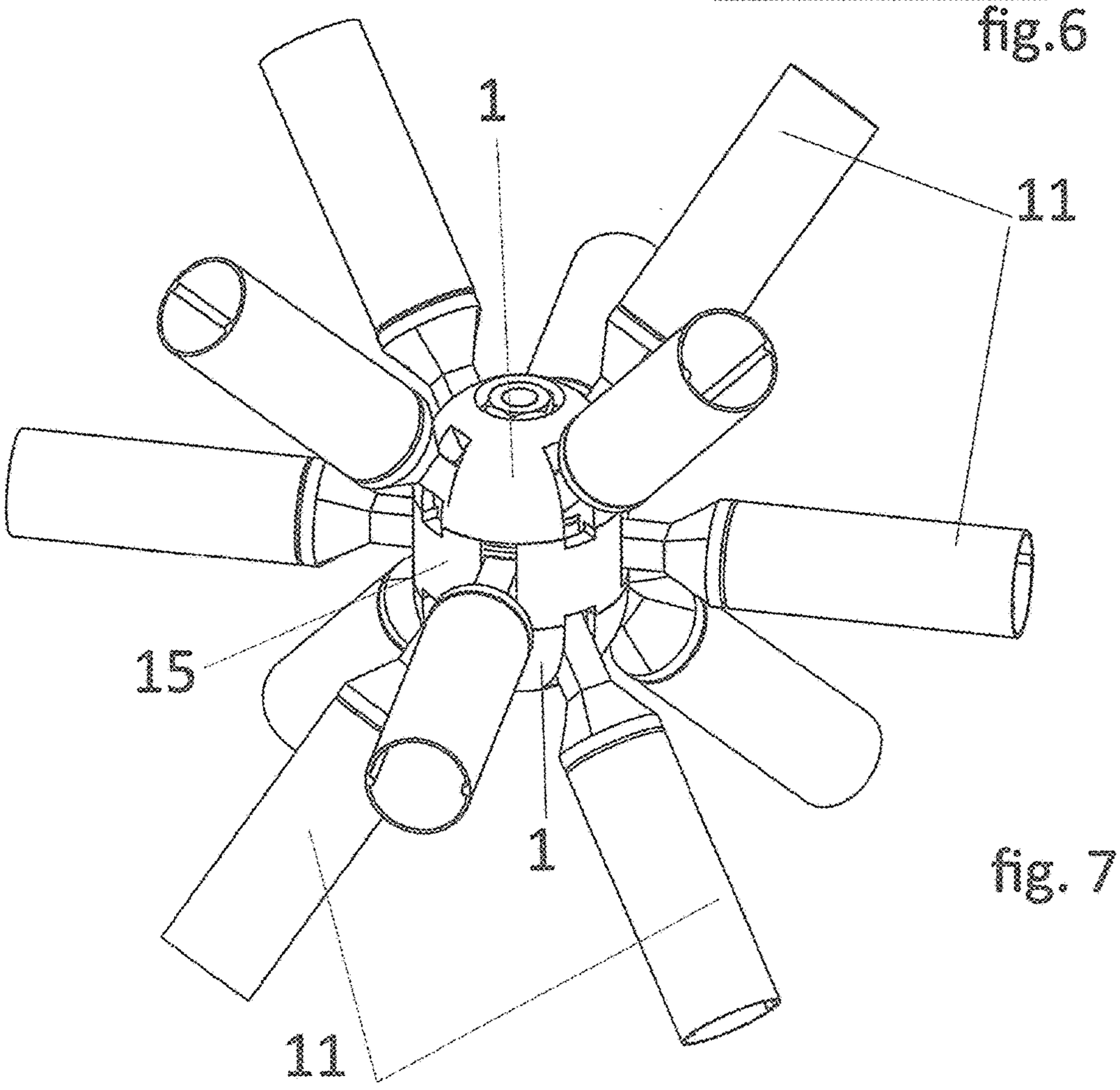


fig. 7

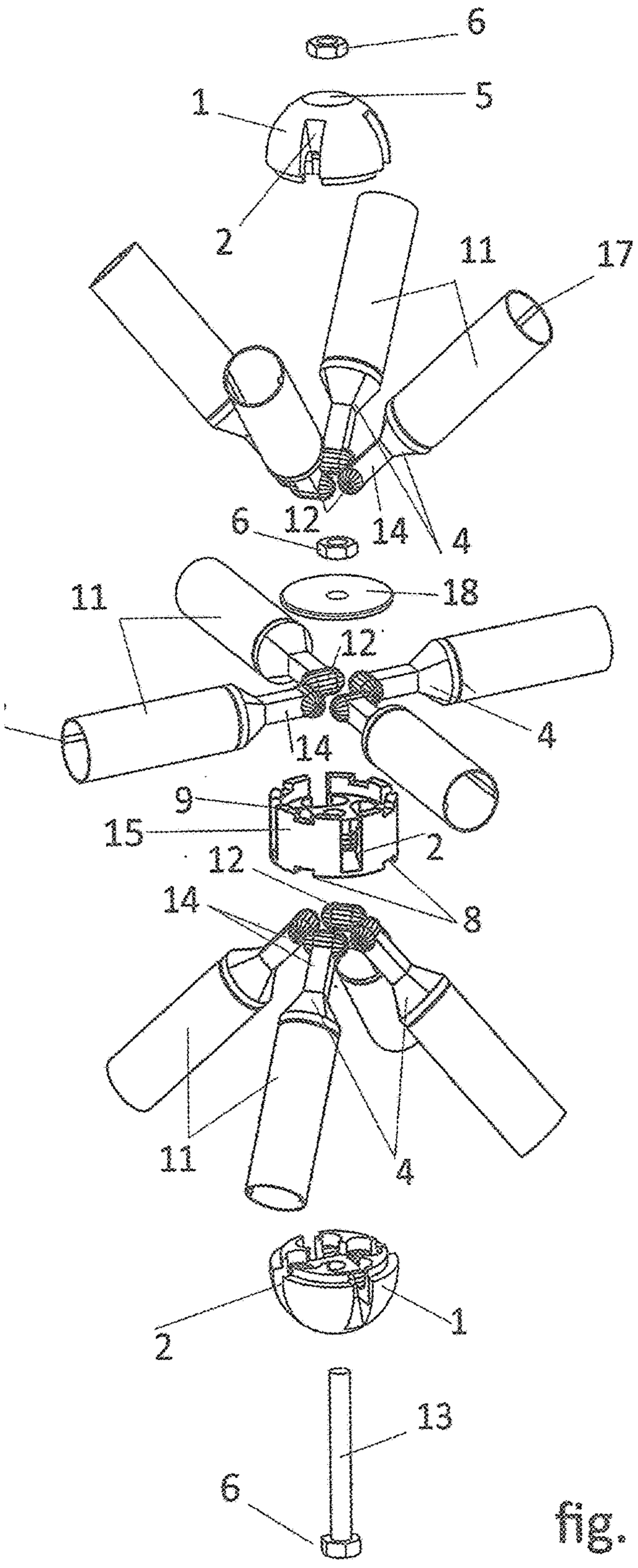


fig. 8

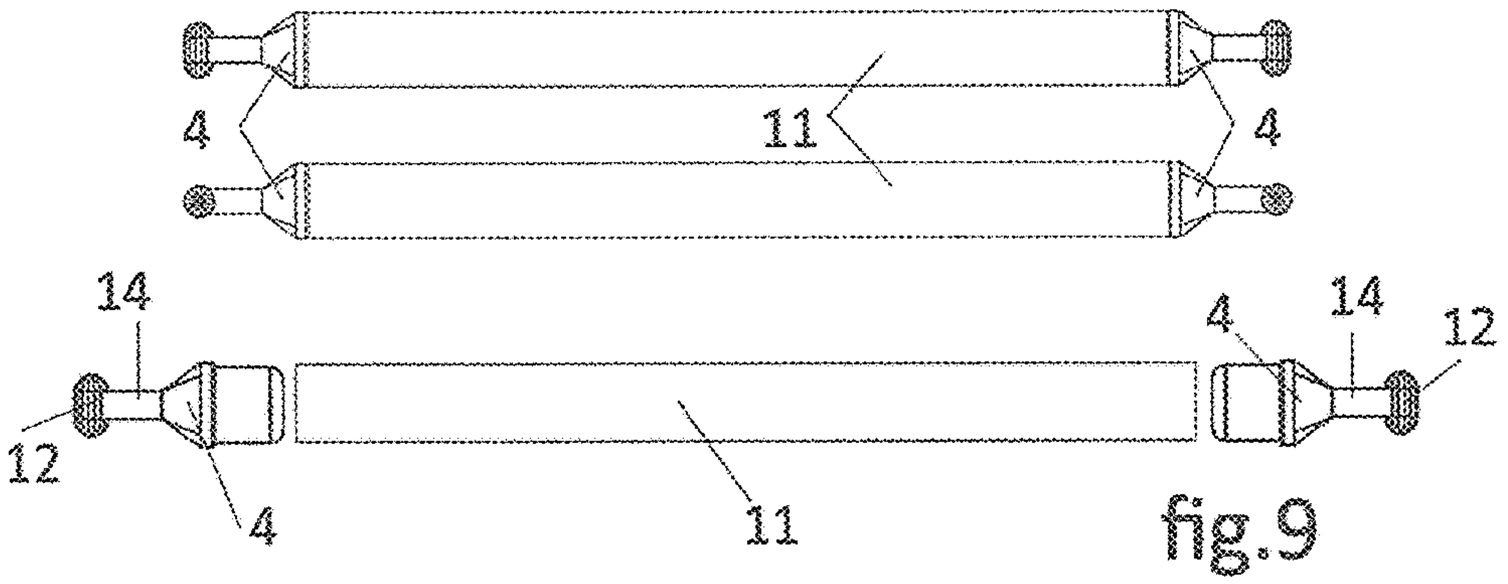


fig.9

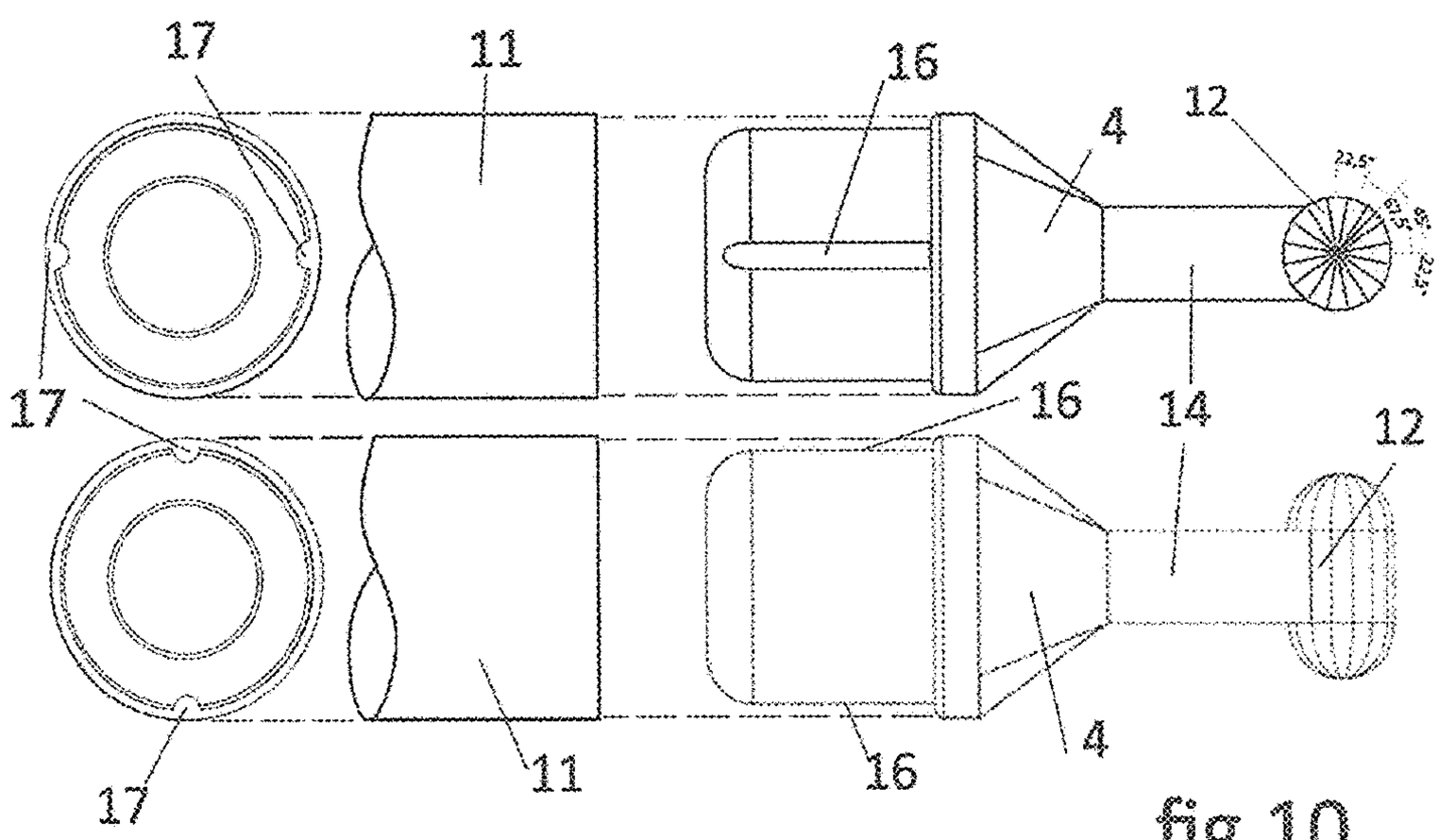


fig.10

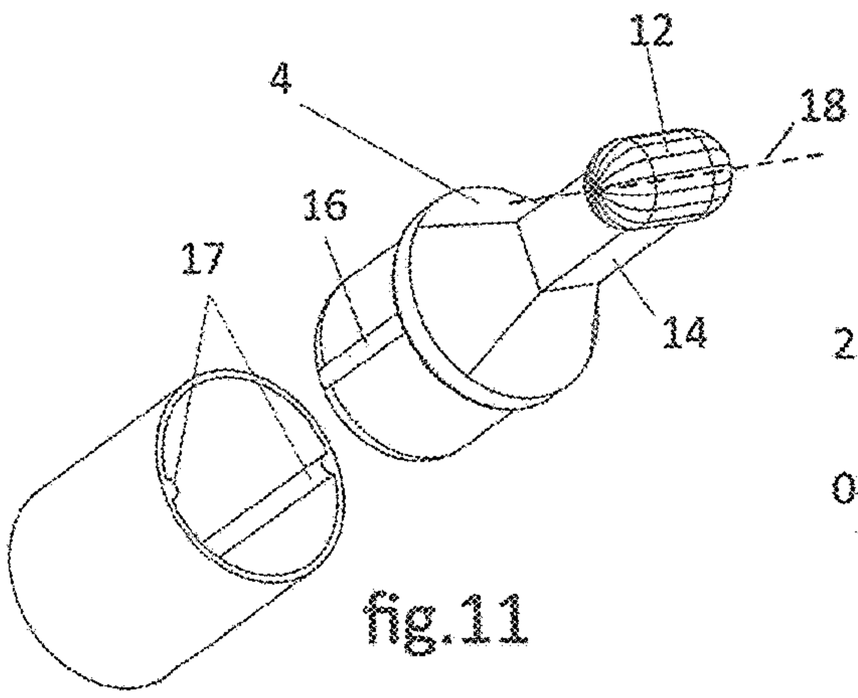


fig.11

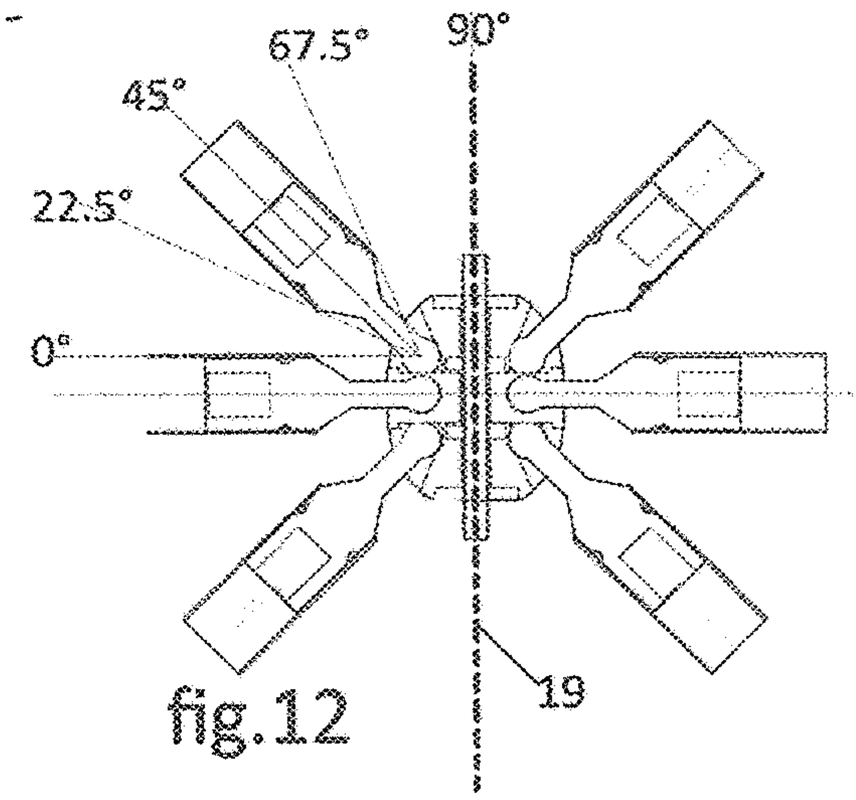


fig.12

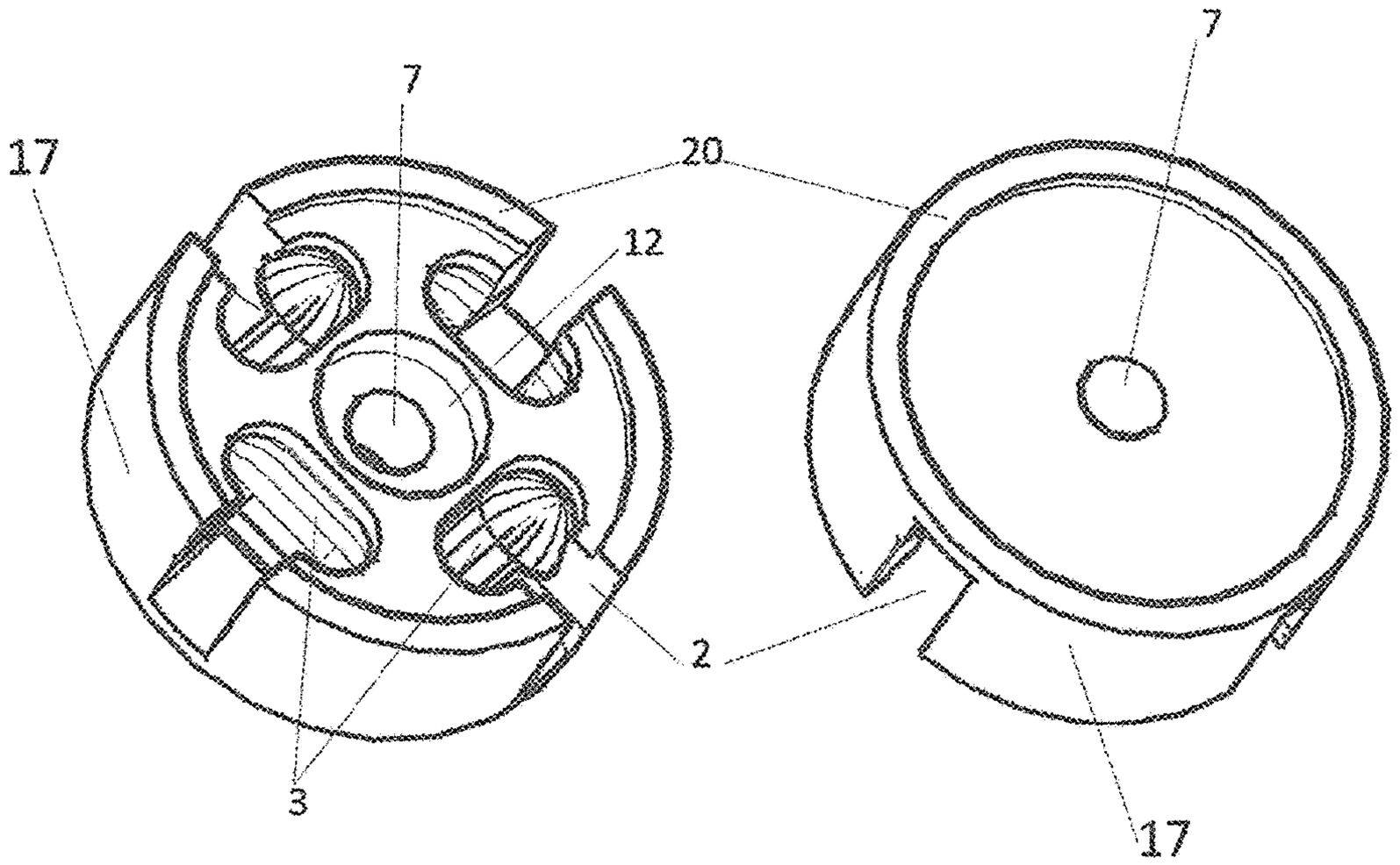


fig.13

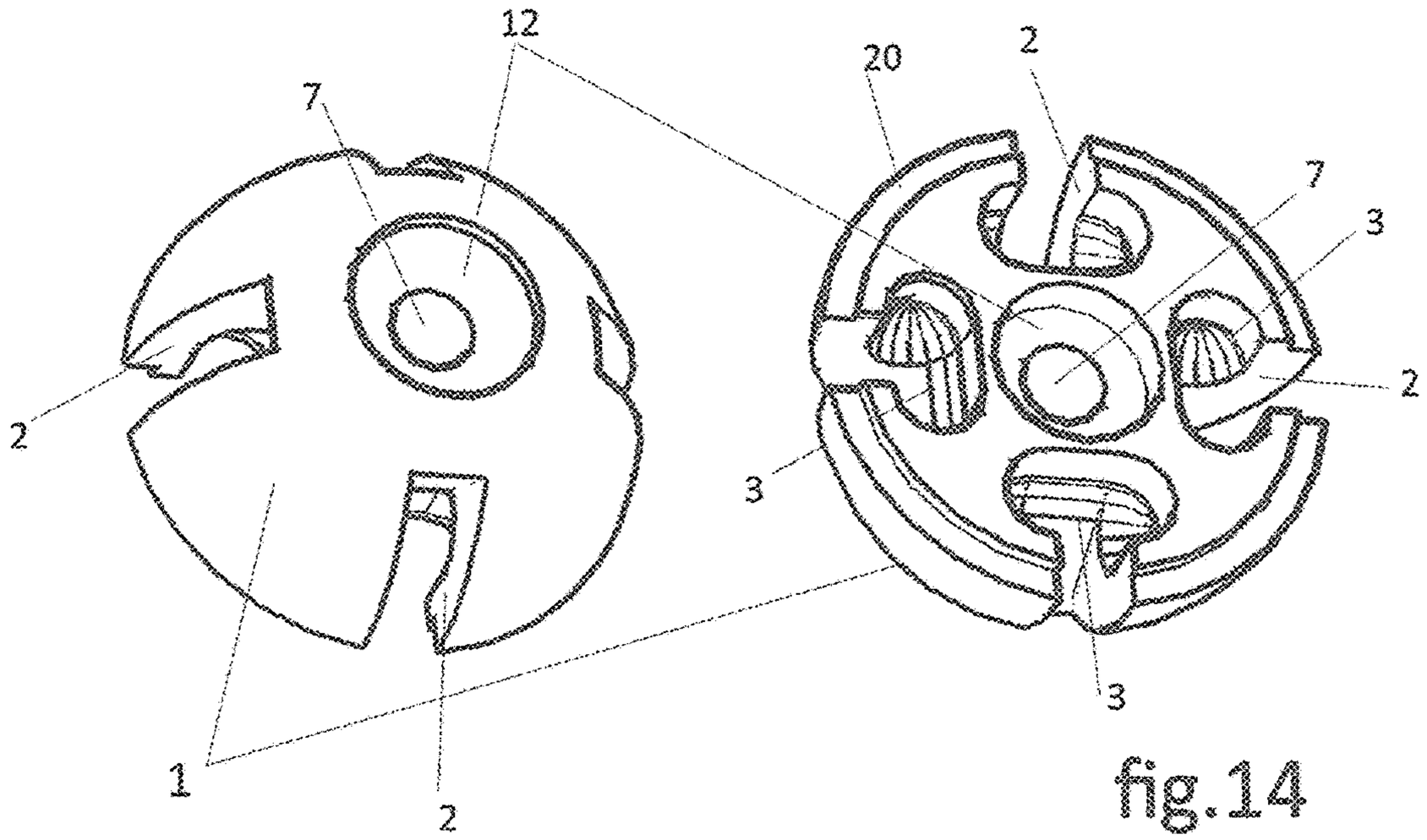


fig.14

THREE-DIMENSIONAL STRUCTURAL SYSTEM MADE FROM SPHERICAL JOINTS AND BEAMS

[0001] The invention (images 1-14) consists of a system for spatial reticular structures composed of joints and beams. The joints are composed of two semispherical caps (**1**) equipped with square fissure sections (**2**) and internal cables housing hexadecagonal prismatic shapes in the central part and multifaceted semispherical shapes in the lateral parts (**3**) equal in size to each other and symmetrically organized round a central plate (**7**) this is then joined together by a single central screw (**13**) with nuts (**6**) through the central hole (**10**). In these caps converge the ends of the tubular beams (**4**) composed of hammer heads (**12**), they also have a prismatic hexadecagonal shape in the central part and a multifaceted semispherical shape in the lateral part (**12**) and they are supported by a prismatic square stem section (**14**).

[0002] These elements are assembled through the addition of terminals (**4**) fixed at the extremity of beams (**11**), in the housing (**13**) and in the fissures (**2**), (**8**) on the caps (**3**) and the central plate (**7**), which achieves a definitive fixing of position due to the central fulcrum (**13**) which prevents the beams from moving or rotating.

[0003] The external diameter of the joints and the length of beams are variable depending on the reticular structure required and are based geometrically on tetrahedral and semi-octahedron modules. The assembly of these modules produces a double (Image 1) and triple layer (Image 3), whose diagonal beams take on the name of 'diagonal beams' while the horizontal beams take the name of 'higher horizontal beams' if they are above the plate, and lower horizontal beams if they are below.

[0004] There are already two similar patents for spatial reticular structures systems, issued to the same inventors and depositors of this patent, that use joints composed by two semispherical caps equipped with fissures and housing which flow into the terminals of the hammer heads beams, joined by a single central fulcrum: the patent numbers for these systems are no 01260770, owner Ventrella Ettore and no 0001389994 owner Ventrella Roberta.

[0005] The disadvantages of this system, identified in the innumerable structures made by the same owners of the patent, essentially are that the beams can turn around the crux also after their clamping, causing unexpected inclines of the joint axes, consequently creating abnormal position and consecutive fleeting within the spatial reticular structure, especially when in order to achieve particular shapes not all eight or twelve of the beams specified in the patent are attached. This happened especially in the perimeter crux above the double layer plates where only three lower horizontal beams and two diagonals attach.

[0006] These disadvantages are caused by two main factors: 1) the hammer terminals of the beams are of a cylindrical shape with a smooth outside and they are situated in a similar smooth housing situated in the hemispherical cap of the joint; 2) the stem that supports the terminal is also cylindrical in shape. Consequently after the screwing of the central pivot, preventing rotation in the above invention is entrusted only to the low friction between the cylindrical smooth heads of the beams and their housing in the existent hemispherical cap. This friction is insufficient to stop the rotation of the beams after the assembly and prevent the instability problems of the spatial reticular structure.

[0007] Instead with this invention the rotation of the beams around the crux after the screwing of the central bolt (**13**) is stopped thanks to the particular shape at the head of the beams. The head of the beams are hexadecagonal-prismatic section in the centre and a multifaceted hemisphere in the lateral parts (**12**) and in the cavity of their housing in the hemispherical cap (**3**). Another (element) characteristic of this invention that prevents the rotations of joints after their clamping is caused by the frame (**14**) which supports the hammer heads (**4**) of the beams. They also have a prismatic square shape and they are inserted into the fissures of the cap and the central plate which also has a prismatic square structure (**2**).

[0008] The hexadecagonal section form (polygon with 16 sides) of the pole's terminals allows one to fix the beams at +45°, +67.5°, +90° and ±22.5° diagonals, whereas for the lower horizontal beams the allowed positions, in addition to 0°, are ±22.5°. These beam angles are adequate for realizing any type of reticular spatial structure with semi-tetrahedral and/or tetrahedral module.

[0009] In each joint up to eight or twelve beams can meet together.

[0010] The joint with eight beams (FIGS. **1** and **2**) is composed of two equal spherical caps and they are symmetrical (**1**) each one provided with four fissures of 67.5° (**2**) square section and hexadecagonal prismatic cavities in the central part and a multifaceted hemispherical in the lateral parts (**3**), a central hole (**10**), a recess (**5**)for the housing of nut (**6**) and a central plate (**7**) it also equipped with parallel-piped square section incisions (**8**) organized at 90°, a superior side (**9**) and a central hole (**10**).

[0011] The locking of the eight beams (**11**) is done by inserting the terminals (**4**) with a prismatic square section stem (**14**) and multifaceted hammer heads (**12**) into the equivalent fissures of the same stem's form, clamping in the same time with the screw (**13**) before four horizontal beams with the intern nut (**6**) and later those diagonal with the external nut (**6**).

[0012] The connection of the terminal (**4**) into the beams (**11**) is done by inserting the grooves (**16**) into the guide (**17**) in the tubular beams (**11**) (FIG. **5**).

[0013] After the clamping the beams are unable to do further rotations and therefore the aforementioned instability problems for the spatial reticular structure are avoided.

[0014] The joint with twelve beams (FIGS. **3** and **4**) is made up of the same elements, pole and hemispherical caps of joints with eight beams (**1**), whereas the central plate (**7**) is made up with the plate (**15**) equipped with a parallel-piped square section and vertical fissures (**16**), to which correspond the prismatic hexadecagonal section cavities (**17**) in the central part and a multifaceted hemisphere in the lateral parts and a central hole (**10**), in order to contain the hexadecagonal hammer heads terminals of the other four horizontal beams an extra central disc is also included (**16**).

[0015] The clamping of twelve beams happens through the insert of a central pivot (**13**) that fix at the same time to the terminals of eight beams by nuts (**6**) and later the other four diagonals through another external nuts (**6**).

[0016] The connection between the pole (**11**) and the terminals with hammer heads (**4**) can be achieved through soldering, screwing, pasting, scraping or deep-drawing the tube.

[0017] The invention is shown with diagrams which demonstrate assembly.

[0018] FIGS. **1** and **2** represent the diagram of a double layer reticular spatial structure , in plan and elevation

[0019] FIG. **3** represent closed joint axonometry, made up of two spherical caps (**1**) and a central plate (**7**), in which eight beams converge and the plan of a spatial reticular structure with semi-tetrahedron double layer (FIGS. **1**, **2**) with an interposed tetrahedron.

[0020] FIG. **4** represents the exploded diagram of the eight pole joints (**11**) hidden by two hemispherical caps (**1**) and a central plate (**7**) through one single crew (**13**). The median nut (**6**) and the external nut (**6**).

[0021] FIGS. **5** and **6** represents the diagram of a triple layer reticular spatial structure with a semi-tetrahedron base module and an interposed tetrahedron, in plan and elevation

[0022] FIG. **7** represents the twelve convergent beams (**11**) joint axonometry

[0023] FIG. **8** represents the exploded diagram the twelve beams joint hidden by two hemispherical caps (**1**), the central plate (**15**), and the disk (**16**) through a single screw (**13**) and the external nuts (**6**).

[0024] FIG. **9** represents the pole (**11**) with variable length, diameter and thickness to the extremities of which are fixed, through soldering, screwing, pasting or scraping to the terminals (**4**) from the hexadecagonal section hammer head in the central part and multifaceted hemispherical in the lateral parts (**12**) supported by a square section stem (**14**).

[0025] FIGS. **10**, **11** represent the particularity of the pole's terminal (**4**) fitted with a hammer head with a prismatic hexadecagonal section in the central part and a multifaceted hemisphere in the lateral parts (**12**) and a support stem with a square parallel-piped shape (**14**).

[0026] FIG. **12** represents the angular positions of the terminals of the beams after the clamping: 0°, ±22.5°, 45°, 67.5°, 90°.

[0027] FIG. **13** represents the higher and lower view of the central plate (**15**) within the hexadecagonal form cavities in the central part and a multifaceted hemisphere in the lateral parts (**3**), arranged orthogonally and at the external part square section fissures with 22.5° angulations (**8**) and tooth coupling (**9**);

[0028] FIG. **14** represent the internal and external view of the pole (**1**) within the hexadecagonal form cavities in the central part and a multifaceted hemisphere in the lateral parts (**3**), arranged orthogonally and at the external part square section fissures with 67.5° (**2**) and external recess that lock off the joint (**6**).

1. Construction system for reticular spatial structures composed of tubular rods and three-dimensional spherical joints formed by two equal semi-spherical caps (**1**) between them and arranged symmetrically around a central plate (**7** or **15**) comprising four internal prismatically shaped cavities with a hexadecagonal base in the central part and sixteen-sided semi-sphere in the lateral parts (**3**) in correspondence with the four slots mutually orthogonal in the squared section (**2**) for the insertion and locking of the terminals (**4**) of the eight or twelve diagonals tubular hammer rods of prismatic shape (**12**) with a basis hexadecagonal in the central part and sixteen-sided semi-sphere in the lateral parts (**12**), supported by a square section shank (**14**) and locked into the positions of 0°, ±22.5, 45°, 67.5°, 90° after tightening with a 'single central screw (**13**) along the 'axis of the node (**19**). Said rods (**11**) before tightening rotate freely about the transverse axis (**18**) of the heads of the hammers (**12**) and are then locked into place by tightening the central pin into the predetermined angles so as to transform and stabilize the joint hinge into a interlocking joint.

2. Construction system for reticular spatial structures according to claim **1**, further comprising a cylindrical central plate (**7**) for the coupling, an 8-rod of the same diameter as the caps (**1**) which corresponds with each side and on the tooth coupling to four slots, orthogonal to each other, of square section (**8**) with an angle of 12.5 degrees, for the 'insertion and subsequent locking of the terminals (**4**) and of the four horizontal beams (**11**).

3. Construction system for reticular spatial structures according to claim **1**, further comprising a cylindrical central plate (**15**) for the coupling rods (**12**), of the same diameter as the caps (**1**), which has, in correspondence to the lower side, four slots with a square section (**8**) with an angle of 12.5 degrees, and eight slits in correspondence to the upper side, four with angles at 0 degrees (**9**), and four with angles of 12.5 degrees (**2**) corresponding to the prismatic cavity with a hexadecagonal base in the central part and sixteen-sided semispherical form on the lateral parts (**3**) for the insertion of the terminals (**4**) and the subsequent locking of the four rods stream (**11**).

4. Construction system for reticular spatial structures according to claim **1**, wherein the terminal is (**4**) inserted to the two ends of the rods, consisting of a joining element for joining the tubular rod, by a groove (**16**) for the coplanar positioning of the two terminals, a central cone for connection to the square section, a prismatic shank with a square base (**14**), the hammer head with prismatic shape and the hexadecagonal base in the central part and the sixteen-sided semisphere in the lateral parts (**12**).

5. Construction system for reticular spatial structures according to claim **1**, further comprising 'tubular rods of any geometric section (**11**) provided by guide in its interior and for its entire length (**17**) to allow the correct matching with the groove (**16**) present on the terminal (**4**) and coplanar alignment of the two terminals.

6. Construction system for reticular spatial structures according to claim **1**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

7. Construction system for reticular spatial structures according to claim **2**, wherein the terminal is (**4**) inserted to the two ends of the rods, consisting of a joining element for joining the tubular rod, by a groove (**16**) for the coplanar positioning of the two terminals, a central cone for connection to the square section, a prismatic shank with a square base (**14**), the hammer head with prismatic shape and the hexadecagonal base in the central part and the sixteen-sided semisphere in the lateral parts (**12**).

8. Construction system for reticular spatial structures according to claim **3**, wherein the terminal is (**4**) inserted to the two ends of the rods, consisting of a joining element for joining the tubular rod, by a groove (**16**) for the coplanar positioning of the two terminals, a central cone for connection to the square section, a prismatic shank with a square base (**14**), the hammer head with prismatic shape and the hexadecagonal base in the central part and the sixteen-sided semisphere in the lateral parts (**12**).

9. Construction system for reticular spatial structures according to claim **2**, further comprising 'tubular rods of any geometric section (**11**) provided by guide in its interior and for its entire length (**17**) to allow the correct matching with the groove (**16**) present on the terminal (**4**) and coplanar alignment of the two terminals.

10. Construction system for reticular spatial structures according to claim **3**, further comprising 'tubular rods of any geometric section (**11**) provided by guide in its interior and for its entire length (**17**) to allow the correct matching with the groove (**16**) present on the terminal (**4**) and coplanar alignment of the two terminals.

11. Construction system for reticular spatial structures according to claim **4**, further comprising 'tubular rods of any geometric section (**11**) provided by guide in its interior and for its entire length (**17**) to allow the correct matching with the groove (**16**) present on the terminal (**4**) and coplanar alignment of the two terminals.

12. Construction system for reticular spatial structures according to claim **2**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

13. Construction system for reticular spatial structures according to claim **3**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

14. Construction system for reticular spatial structures according to claim **4**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

15. Construction system for reticular spatial structures according to claim **5**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

16. Construction system for reticular spatial structures according to claim **7**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

17. Construction system for reticular spatial structures according to claim **8**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

18. Construction system for reticular spatial structures according to claim **9**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

19. Construction system for reticular spatial structures according to claim **10**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

20. Construction system for reticular spatial structures according to claim **11**, wherein the shape of the hammer head (**12**) of the terminal (**4**) and its housing (**3**) into the caps (**1**) and (**15**), are of any polygonal geometrical shape in section (hexagon, octagon, dodecagon, etc.) to increase the friction between the components heads (**12**) and cavity (**3**) and allow the rods take multiple positions about the transverse axis (**18**) of the hammer (**12**).

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