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

(11) **EP 4 321 710 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
14.02.2024 Bulletin 2024/07

(21) Application number: **22189769.7**

(22) Date of filing: **10.08.2022**

(51) International Patent Classification (IPC):
E04H 15/38 *(2006.01)*

(52) Cooperative Patent Classification (CPC):
E04H 15/38

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

(71) Applicant: **Barari Reshtehroudi, Mohammadmahdi**
Greater Manchester M3 3AE (GB)

(72) Inventor: **Barari Reshtehroudi, Mohammadmahdi**
Greater Manchester M3 3AE (GB)

(74) Representative: **Gislon, Gabriele et al**
Marietti, Gislon e Trupiano S.r.l.
Via Larga, 16
20122 Milano (IT)

(54) **SELF-SUPPORTING ACTIVE BENDING STRUCTURE**

(57) A lightweight self-supporting structure (1), comprising a plurality of elongated elements (11, 12, 13, 14, 15, 16, 17), and at least two connection elements (10',10"), said elongated elements being connected to each other substantially at their two end portions (111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172) by means of said two connection elements (10',10"), wherein said structure (1) is movable, between a non-active configuration (P1), wherein said elongated elements (11, 12, 13, 14, 15, 16, 17) are positioned at a minimum distance between each other, and an active bending configuration (P2), wherein the elongated elements (11, 12, 13, 14, 15, 16, 17) are bent, and are positioned at a greater distance between each other with respect to the minimum distance and the structure (1) is stable due to active bending forces generated within said plurality of bent elongated elements.

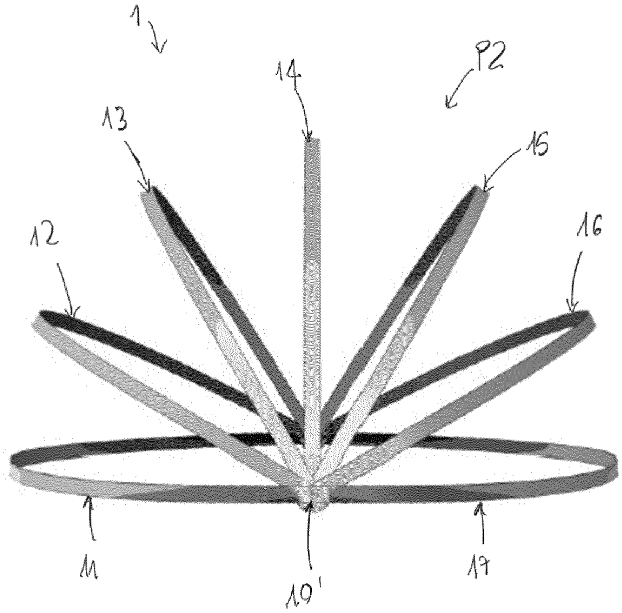

Fig. 7

EP 4 321 710 A1

Description

FIELD OF THE INVENTION

[0001] The invention relates to the field of lightweight supporting structures. In particular, the invention relates to the field of lightweight self-supporting structures employing active bending theory.

STATE OF THE ART

[0002] Lightweight supporting structures have been in use for centuries across a wide range of building sectors for load-bearing, both for housing or infrastructure. In recent times, they are preferred when easiness of transport and installation is needed, as, for example, in case of emergency, leisure or sport.

[0003] The field of lightweight supporting structures can be subdivided into categories based on the approach used for their creation, both in terms of the properties of the materials composing their building elements and in terms of the architectures of the entire structure.

[0004] One of the categories is represented by surface-active structures, which by definition refers to systems of flexible or rigid plates. Such structures are able to resist compression, shear or tension, in which the mobilization of sectional forces causes force redirection. These structures are formed with shells and plates and use a mixture of shear stress, compression stresses and surface tension in order to carry external loads. Typical examples of surface-active structures are folded plates, shells and plates which carry in-plane loads, wherein the plate bends in its own plane such as a shear wall with horizontal and vertical forces which are applied to its plane and thus produce in-plane bending moments. In-plane bending moments do not cause the plate to bend out of its own plane.

[0005] A subcategory of section-active structures is represented by active bending structures. Generally speaking, active bending is comprehended as an approach rather than a distinct category of structure. Active bending describes curved beam and surface structures that use the elastic deformation of initially straight or planar elements as a basis for their geometry. The common denominator of such structures is the formation process that elastically bends the building elements, as opposed to geometrical definition or the circumscribed load-bearing behaviour. It is fundamental to work within the elastic range of the material composing the planar or straight building elements, that are bent to create curved geometries. The elastic energy stored in the bent building elements could be used to self-stabilize a structure or be used as part of an ordinary structure with surcharging a number of active bent members to optimize and increase the productivity and efficiency of the structure.

[0006] The load-bearing behaviour of active bending structures is the result of the capacity of such structures to develop real shell or arch properties in their final state of deformation. Thus, active bending structures may be defined as structural systems that include curved beam or shell elements that base their geometry on the elastic deformation from an initially straight or planar configuration. In such structures, great importance is placed on the principle that the elastic limit of used materials is never reached by bending stress, which thus informs element stiffness.

[0007] The elastic behaviour of building materials has been utilised in a plethora of vernacular architecture construction methods. This has led to a widely renowned type of construction that is dominant in specific applications or certain cultures. Even in opposing cultures and countries which may be on the completely opposite side of the world, examples of similar shell and arch structures that are elastically formed can be seen. In particular, Middle-Eastern nomadic tribes used active bending structures composed of partially bent wooden rib skeletons combined with animal or vegetable fibres to build mobile or temporary shelters. These constructions are based on an empirical approach, also known as behavioural-based approach.

[0008] New materials such as high strength aluminium and Glass Fibre Reinforced Plastic (GFRP) became increasingly prevalent and widely used in the 1970s. This allowed for the first expedition and mountaineering tents, which used supporting arches which are elastically bent, to be introduced. The poles of the tent could be bent by hand into a grid shell/dome or series of arches/tunnel configurations without much effort at all. The secure industrial production of these products was enabled because of an in-depth empirical analysis.

[0009] It is clear that such tent structures have helped to reach a more analytical understanding of active bending self-supporting structures. This analytical approach, also known as Geometry Based Approach, has guaranteed the creation of more complex structures involving double curved surface shells and grid-shells. Even if precise and reliable, the Geometry Based Approach turned to be extremely complicated in view of the complex equations that describe the elastic behaviour of the building elements of the active bending structures.

[0010] Recently, simulation techniques have advanced to such an extent that they facilitate the analysis and form-finding of structures that form their curved, complex geometry singularly via the process of erection, during which their elastic deformation takes place. This has therefore been used as a basis for a number of investigations which include fresh types of grid-shells and surface-shells, as well as structural bent components which use membranes as a system of restraint, membranes possessing elastically bent battens, and numerous different types of elastic/adaptive kinetic structures. Although the attempts done may be different in terms of their approach to design and the construction type, they all share one common factor: the use of building elements that are straight or planar for the creation of curved geometries. Hence, the common denominator between these structures is the process of formation, in which the elements are elastically bent, leading to questions that are similar in their addressing of form-finding, materiality and the planning processes. The continuous developments in simulation tools and new materials provide the suggestion that the offered solutions are far from reaching the point of exhaustion in their respective application fields.

[0011] In view of the above, during the last decade, the active bending theory has gained significant attention, largely due to the advancement in technologies relating to the use, design and construction of lightweight structures. The great potential of such structures lies in their proven ability to expand the structural morphology of lightweight structures, thus producing low technology structures with relatively easy manufacturing requirements.

[0012] This is mainly due to the introduction of fibre reinforced polymers (FRP). Such materials show a low modulus of elasticity and high yield stress, features that make them suitable materials in active bending structures applications. Fibre reinforced polymers have been known since the 1950s, but it was only in recent times that the manufacturing industrial processes have made them economical and, therefore, convenient for the construction field.

[0013] However, the majority of projects undertaken in the field of active bending structures are architectural projects for the creation of large, fixed buildings having an exclusively artistic rather than functional design. Such buildings are characterized by their particularly complex structures, which make them hard to erect and therefore inconvenient to be disassembled and transported in a different location.

[0014] With this in mind, in the field of active bending structures, the need for a lightweight self-supporting structure that is easy to assemble and disassemble is particularly felt. There is also a need for an active bending lightweight self-supporting structure that is particularly easy to manufacture and transport.

SUMMARY OF THE INVENTION

[0015] It is an aim of the present invention to provide a solution to the above-mentioned drawbacks.

[0016] These and other objects are achieved by means of a lightweight self-supporting structure according to claim 1.

[0017] Further aspects and/or features are set forth in the dependent claims.

[0018] The lightweight self-supporting structure according to the present invention is particularly adapted to support a load such as a cover, and comprises a plurality of elongated elements, and at least two connection elements, said elongated elements of said plurality of elongated elements being connected to each other substantially at their two extremities end portions by means of the two connection elements; wherein the structure is movable, preferably by a rotation substantially at the two end portions between a non-active configuration, wherein the elongated elements are positioned at a minimum distance between each other, and an active bending configuration, wherein the elongated elements are bent, and are positioned at a greater distance between each other with respect to the minimum distance in the non-active configuration and the structure is stable due to active bending forces generated within the plurality of bent elongated elements. Advantageously, the configuration of the structure is simple and comprises few components, resulting in a self-supporting structure which is easy to transport and mount.

[0019] Furthermore, the elastic energy stored in the bent elongated elements is used to self-stabilize the structure, with no need of further support elements. A further advantage is that the curved or bent elongated elements base their geometry on the elastic deformation from an initially straight or planar non-active configuration: the transition from the non-active configuration to the active bending configuration requires very little effort from users, for whom it is therefore very easy to switch from non-active configuration to active bending structure configuration, where the non-active configuration is convenient for transport.

[0020] According to an aspect, the structure in the active bending configuration, is stable only due to active bending forces generated within said plurality of elongated elements.

[0021] Advantageously, the stability of the structure is given by the bending forces between the bent elongated elements, and further support elements are not necessary.

[0022] According to an aspect, the elongated elements are equally spaced apart from each other when the structure is in the active bending configuration, and preferably, according to this aspect, the elongated elements of the plurality of elongated elements are at a maximum distance between each other in said active bending configuration.

[0023] Advantageously, in this configuration the elongated elements are placed in their final position, they will be in symmetrical positions. The interactions created in the strips neutralize the forces created, and, as a result, the structure become completely stable. In other words, this configuration allows a great stability, given by the weight distribution on the elongated elements, which are equally spaced from each other.

[0024] According to an aspect, at least two of the elongated elements, preferably all the elongated elements overlap when the structure is in the non-active configuration.

[0025] Advantageously, this compact configuration allows an easy transport of the structure.

[0026] According to an aspect, the elongated elements are made of fibre reinforced polymers (FRP).

[0027] Advantageously, such materials show a low modulus of elasticity and high yield stress, making the elongated elements suitable to be bent and to form a stable self-supporting structure.

[0028] Furthermore, such material is economical and, therefore, convenient for the construction of the self-supporting structure.

[0029] According to an aspect, the two connection elements comprise pivotable connection means, preferably a hinge, to allow a rotation between the plurality of elongated elements at the two end portions.

[0030] According to a further aspect, each of the two connection elements comprises pins and each elongated element of the plurality of elongated elements comprises two holes, each disposed substantially at one respective end portion and configured for housing the pins to rotatably connect the plurality of elongated elements, wherein the holes of each elongated element match, in use, the holes of the other elongated elements of the plurality of elongated elements.

[0031] According to this aspect, each pin has a diameter comprised between 1 mm and 10 mm, preferably between 2 mm and 8 mm, more preferably equal to 2 mm.

[0032] Furthermore, according to these aspects, each hole is placed at a distance from a corresponding extremity of each elongated element that is less than 5% of a total length of said elongated element, preferably less than 3% of said total length, more preferably less than 1% of said total length. Advantageously, this positioning of the holes, and consequently of the connection elements, allows an easy rotation of the elongated elements with respect to each other.

[0033] According to an aspect, the elongated elements comprise at least a couple of elongated elements connected to form a substantially circular shape when the structure is in the active bending configuration. Advantageously, the two elongated element connected to form a substantially circular shape, form a very stable base for the self-supporting structure.

[0034] According to an aspect, the plurality of elongated elements has a substantially rectangular shape, and preferably comprises a plurality of strips, which are bent at least in said active bending configuration. According to an aspect each elongated element has a length of at least 5 m, and preferably no longer than 7 m.

[0035] It has to be noted that, with the increase in length of the elongated elements, stiffness decreases, and as a result, the amount of stress and horizontal reactions created was reduced. Also, the amount of deformation is directly related to the length of the elongated elements, so that deformation was greater in models with a length longer than 7m.

[0036] According to a further aspect, each elongated element has a width comprised between 5 cm and 20 cm, preferably between 6 cm and 16 cm, more preferably equal to 8 cm.

[0037] According to an aspect each elongated element has a thickness comprised between 5 mm and 20 mm, preferably equal to 8 mm.

[0038] According to an aspect, each elongated element has a module of elasticity comprised between 15 MPa and 30 MPa, preferably equal to 17 MPa. Advantageously, materials with such modulus of elasticity (and high yield stress) avoid reaching yield stress point of the elongated elements during initial bending and external loading, and prevents permanent deformation. In fact, it has to be noted that higher modulus of elasticity increased rigidity in the materials. This increase in stiffens results in both, the amount of force required for initial bending and the displacement under loading. On the other hand, with increasing stiffness in elongated elements, the amount of stress increases and brings the tension closer to the elongated elements' materials yield stress point.

[0039] Overcoming materials yield stress point causes permanent (plastic) deformation.

[0040] According to an aspect, the plurality of elongated elements are placed in the same order, from the innermost to the outermost, at the two end portions.

[0041] It should be noted that the expression "same order" means that the elongated elements will be connected to each other at both the first connection element and second connection element with respective end portions being located from the innermost to the outermost. Advantageously, elongated elements exert forces on other members during installations and arrangement.

BRIEF DESCRIPTION OF THE DRAWINGS

[0042] These and other aspects of the present invention will be clearer by the following detailed description provided herein by way of example only and without limitations, with reference to the accompanying figures, in which:

- Figure 1 is a perspective view of a possible embodiment of two elongated elements of the structure according to an embodiment of the present invention, in which the two elongated elements are connected to form a substantially circular shape;
- Figure 2 is a sequence schematically showing two elongated elements of the structure 1 according to an embodiment of the invention moving from the non-active configuration P1 and the active bending configuration P2;
- Figures 3 and 4 are detail views of the elongated elements with connection elements according to an embodiment of the invention;
- Figure 5 is a sequence schematically showing the structure 1 according to an embodiment of the invention moving from the non-active configuration P1 and the active bending configuration P2;
- Figures 6, 7 and 8 are two perspective views of the structure 1 according to an embodiment of the invention in said active bending configuration P2;
- Figure 9 is a perspective view of the structure 1 according to an embodiment of the invention, supporting a cover 2 in said active bending configuration P2;

- Figures 10 - 11 are perspective views of the structure 1 according to an embodiment of the invention.

DISCLOSURE OF PREFERRED EMBODIMENTS.

[0043] In the following, a possible embodiment of the lightweight self-supporting structure 1 according to the invention will be described with non-limitative reference to the attached figures.

[0044] The lightweight self-supporting structure 1 according to the invention is particularly adapted to support a load such as a cover 2, and comprises a plurality of elongated elements 11, 12, 13, 14, 15, 16, 17, and at least two connection elements 10', 10".

[0045] According to a possible embodiment, the elongated elements 11, 12, 13, 14, 15, 16, 17 have a length of at least 5 m, and a width comprised between 5 cm and 20 cm, preferably between 6 cm and 16 cm, more preferably equal to 8 cm.

[0046] Furthermore, the elongated elements 11, 12, 13, 14, 15, 16, 17 can have a thickness comprised between 5 mm and 20 mm, preferably equal to 8 mm.

[0047] The elongated elements 11, 12, 13, 14, 15, 16, 17 according to the invention are connected to each other substantially at their two end portions 111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172 by means of the at least two connection elements 10',10", wherein the connection elements 10', 10" preferably allow a rotation between the plurality of elongated elements 11, 12, 13, 14, 15, 16, 17 at the respective two end portions 111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172.

[0048] For example, according to a possible embodiment shown in figures 3, 4, and 6, 7, the connection elements 10', 10" comprise pivotable connection means 10', 10", preferably an hinge, to allow a rotation between the plurality of elongated elements 11, 12, 13, 14, 15, 16, 17 at said end portions.

[0049] It has to be noted that the expressions "pivotable connection element" and "hinge" are used herein to indicate a mechanical element that connects the plurality of elongated elements 11, 12, 13, 14, 15, 16, 17, allowing an angle of rotation between them.

[0050] The plurality of elongated elements 11, 12, 13, 14, 15, 16, 17 connected by the pivotable connection elements 10', 10" rotate relative to each other about fixed axis of rotation A1', A1", and preferably all other translations or rotations are prevented, such that each pivotable connection element 10', 10", or hinge, has one degree of freedom.

[0051] According to a possible embodiment, shown in figures 3 and 4, each connection element 10', 10" comprises pins 13', 13" and each elongated element 11, 12, 13, 14, 15, 16, 17 comprises two holes 11', 11", 12', 12", each disposed substantially at a respective end portion 111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172 and configured for housing the pins 13', 13" to rotatably connect the plurality of elongated elements.

[0052] It should be noted that the holes 11', 11", 12', 12" of each elongated element matches, in use, the holes 12', 12", 11', 11" of the other elongated elements of the plurality of elongated elements Preferably, each pin 12', 12" has a diameter comprised between 1 mm and 10 mm, preferably between 2 mm and 8 mm, more preferably equal to 2 mm.

[0053] According to a possible embodiment, each hole 11', 11"; 12', 12" is placed at a distance from a corresponding extremity 111', 112'; 121', 122'; 131', 132'; 141', 142'; 151', 152'; 161', 162'; 171', 172' of each elongated element 11, 12, 13, 14, 15, 16, 17 that is less than 5% of a total length of said elongated element, preferably less than 3% of said total length, more preferably less than 1% of said total length.

[0054] It has to be noted that the expressions "extremity" is used herein to indicate furthest end or end edge of an elongated element 11, 12, 13, 14, 15, 16, 17.

[0055] The structure 1 according to the invention is movable, preferably by a rotation substantially at said end portions, between a non-active configuration P1, wherein said elongated elements 11, 12, 13, 14, 15, 16, 17 are positioned at a minimum distance between each other, and an active bending configuration P2, wherein the elongated elements 11, 12, 13, 14, 15, 16, 17 are bent, and are positioned at a greater distance between each other with respect to the minimum distance in the non-active configuration P1 and the structure 1 is stable due to active bending forces generated within said plurality of bent elongated elements.

[0056] According to a possible embodiment, the elongated elements 11, 12, 13, 14, 15, 16, 17 are made of a flexible material, preferably fibre reinforced polymers (FRP).

[0057] In fact, the elongated elements are flexible in order to be bent in the active bending configuration P2, and each elongated element 11, 12, 13, 14, 15, 16, 17 has a module of elasticity comprised between 15 MPa and 30 MPa, preferably equal to 17 MPa.

[0058] Preferably, according to a possible embodiment, the structure 1, in the active bending configuration P2, is stable due only to active bending forces generated within said plurality of elongated elements.

[0059] According to a possible embodiment, the plurality of elongated elements 11, 12, 13, 14, 15, 16, 17 have a substantially rectangular shape, and preferably comprise a plurality of strips, which are bent at least in the active bending configuration P2.

[0060] With reference to figures 5 - 9, in a possible configuration the elongated elements 11, 12, 13, 14, 15, 16, 17 are equally spaced apart from each other when the structure 1 is in the active bending configuration P2, and preferably the elongated elements 11, 12, 13, 14, 15, 16, 17 are at a maximum distance between each other in said active bending configuration P2.

[0061] For example, with reference to figure 5, seven elongated elements 11, 12, 13, 14, 15, 16, 17 equal in size and geometry are perfectly aligned and joined at each end portion 111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172 in the non-active configuration P1.

[0062] Then, by applying an initial bend, and sliding elongated elements 11, 12, 13, 14, 15, 16, 17 on top of each other, the elongated elements 11, 12, 13, 14, 15, 16, 17 begin to bent, and both end portions 111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172 of each elongated element will start to move towards each other.

[0063] In the final active bending configuration P2 the seven elongated elements 11, 12, 13, 14, 15, 16, 17 are located on angles of 0°, 30°, 60°, 90°, 120°, 150° and 180°.

[0064] When the elongated elements 11, 12, 13, 14, 15, 16, 17 are placed in their final position in the active bending configuration P2, they will be in symmetrical positions, except the elongated element located at a 90° angle. The interactions created in the elongated elements neutralize the forces created, and, as a result, the structure 1 become completely stable.

[0065] In any case, embodiments in which the elongated elements 11, 12, 13, 14, 15, 16, 17 are spaced apart at different distances are not excluded.

[0066] For example, with reference to figures 10 and 11, a structure 1 with the asymmetric angles between the elongated elements 11, 12, 13, 14, 15, 16, 17 is shown.

[0067] According to this configuration, four elongated elements can be located near the 0° angle and three elongated elements around the 90° angle.

[0068] This configuration also provides stability without external support.

[0069] It should be noted that in said active bending configuration P2 of the structure 1, the plurality of elongated elements 11, 12, 13, 14, 15, 16, 17 comprise at least a couple of elongated elements 11, 17 connected to form a substantially circular shape.

[0070] The couple of elongated elements 11, 17, connected to form a substantially circular shape, substantially form a circular support base 11, 17 for the structure 1, suitable for laying on the ground, or on a horizontal surface.

[0071] According to a possible embodiment shown in figure 2, the elongated elements 11, 12, 13, 14, 15, 16, 17 are unbent in the non-active configuration P1, and the elongated elements 11, 12, 13, 14, 15, 16, 17 are subsequently bent, to reach the active bending configuration P2 of the structure 1.

[0072] According to a further possible configuration shown in figure 5, the elongated elements 11, 12, 13, 14, 15, 16, 17 are already bent in the non-active configuration P1.

[0073] With reference to figures 5, 10 and 11, at least two of the elongated elements, preferably all the elongated elements 11, 12, 13, 14, 15, 16, 17 overlap when the structure is in the non-active configuration P1.

[0074] In a possible configuration, the plurality of elongated elements 11, 12, 13, 14, 15, 16, 17 can be placed in the same order, from the innermost to the outermost, at the two end portions 111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172.

Claims

1. A lightweight self-supporting structure (1), particularly adapted to support a load such as a cover (2), comprising a plurality of elongated elements (11, 12, 13, 14, 15, 16, 17), and at least two connection elements (10', 10"), said elongated elements of said plurality of elongated elements (11, 12, 13, 14, 15, 16, 17) being connected to each other substantially at their two end portions (111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172) by means of said two connection elements (10', 10"), wherein said structure (1) is movable, preferably by a rotation substantially at said two end portions (111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172), between a non-active configuration (P1), wherein said elongated elements (11, 12, 13, 14, 15, 16, 17) are positioned at a minimum distance between each other, and an active bending configuration (P2), wherein the elongated elements (11, 12, 13, 14, 15, 16, 17) are bent, and are positioned at a greater distance between each other with respect to the minimum distance in said non-active configuration (P1) and the structure (1) is stable due to active bending forces generated within said plurality of bent elongated elements.

2. The lightweight self-supporting structure (1) according to claim 1, wherein said structure (1), in the active bending configuration (P2), is stable due only to active bending forces generated within said plurality of elongated elements.

3. The lightweight self-supporting structure (1) according to claim 1 or 2, wherein the said elongated elements (11, 12, 13, 14, 15, 16, 17) are equally spaced apart from each other when said structure is in said active bending configuration (P2).

4. The lightweight self-supporting structure (1) according to any of the preceding claims, wherein the elongated elements of the plurality of elongated elements (11, 12, 13, 14, 15, 16, 17) are at a maximum distance between each other in said active bending configuration (P2).

5. The lightweight self-supporting structure (1) according to any of the preceding claims, wherein at least two of said elongated elements, preferably all the elongated elements (11, 12, 13, 14, 15, 16, 17) overlap when said structure is in said non-active config-

uration (P1).

6. The lightweight self-supporting structure (1) according to any of the preceding claims, wherein said plurality of elongated elements (11, 12, 13, 14, 15, 16, 17) is made of fibre reinforced polymers (FRP).

7. The lightweight self-supporting structure (1) according to any of the preceding claims, wherein said two connection elements (10', 10") comprise pivotable connection means (10', 10"), preferably an hinge, to allow a rotation between the plurality of elongated elements (11, 12, 13, 14, 15, 16, 17) at said two end portions.

8. The lightweight self-supporting structure (1) according to any of the preceding claim, wherein each of said two connection elements (10', 10") comprises pins (13', 13") and each elongated element of the plurality of elongated elements (11, 12, 13, 14, 15, 16, 17) comprises two holes (11', 11", 12', 12"), each disposed substantially at one of said two end portions (111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172) and configured for housing said pins (13', 13") to rotatably connect the plurality of elongated elements, said holes (11', 11", 12', 12") of each elongated element matching, in use, the holes (12', 12", 11', 11") of the other elongated elements of the plurality of elongated elements.

9. The lightweight self-supporting structure (1) according to claim 8, wherein each pin (12', 12") has a diameter comprised between 1 mm and 10 mm, preferably between 2 mm and 8 mm, more preferably equal to 2 mm.

10. The lightweight self-supporting structure (1) according to any claim 7 - 9, wherein each pivotable connection elements (10', 10"), preferably each hole (11', 11"; 12', 12"), is placed at a distance from a corresponding extremity (111', 112'; 121', 122'; 131', 132'; 141', 142'; 151', 152'; 161', 162'; 171', 172') of each elongated element (11, 12, 13, 14, 15, 16, 17) that is less than 5% of a total length of said elongated element, preferably less than 3% of said total length, more preferably less than 1% of said total length.

11. The lightweight self-supporting structure (1) according to any of the preceding claims, wherein said plurality of elongated elements (11, 12, 13, 14, 15, 16, 17) comprise at least a couple of elongated elements connected to form a substantially circular shape when said structure (1) is in said active bending configuration (P2).

12. The lightweight self-supporting structure (1) according to any one of the preceding claims, wherein said elongated elements (11, 12, 13, 14, 15, 16, 17) have a substantially rectangular shape, and preferably comprise a plurality of strips.

13. The lightweight self-supporting structure (1) according to any of the preceding claim, wherein each elongated element (11, 12, 13, 14, 15, 16, 17) has a length of at least 5 m.

14. The lightweight self-supporting structure (1) according to any of the preceding claim, wherein each elongated element (11, 12, 13, 14, 15, 16, 17) has a module of elasticity comprised between 15 MPa and 30 MPa, preferably equal to 17 MPa.

15. The lightweight self-supporting structure (1) according to any one of the preceding claims, wherein the plurality of elongated elements (11, 12, 13, 14, 15, 16, 17) are placed in the same order, from the innermost to the outermost, at the two end portions (111, 112, 121, 122, 131, 132, 141, 142, 151, 152, 161, 162, 171, 172).

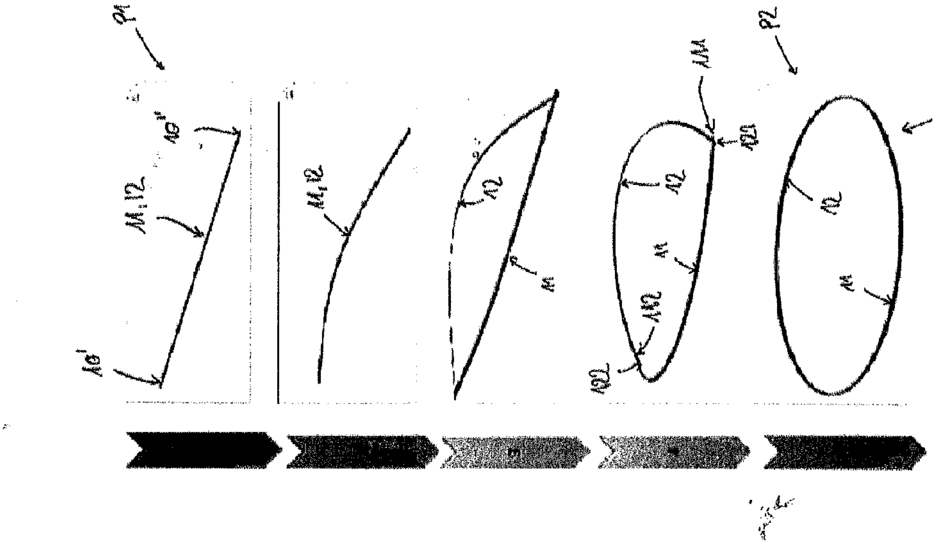

Fig. 2

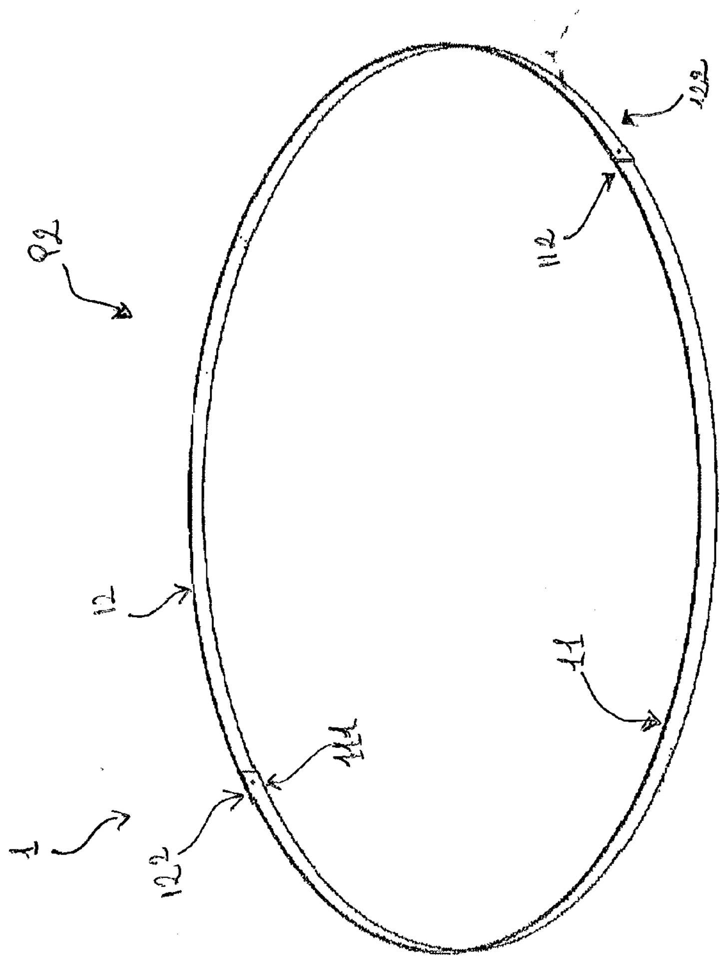

Fig. 1

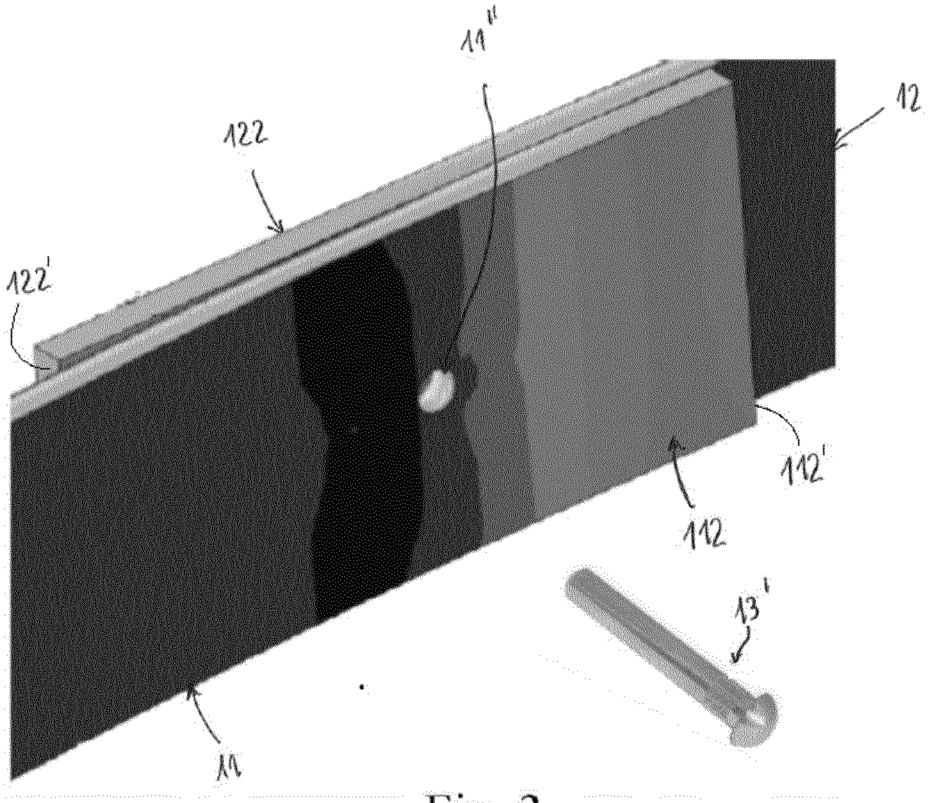

Fig. 3

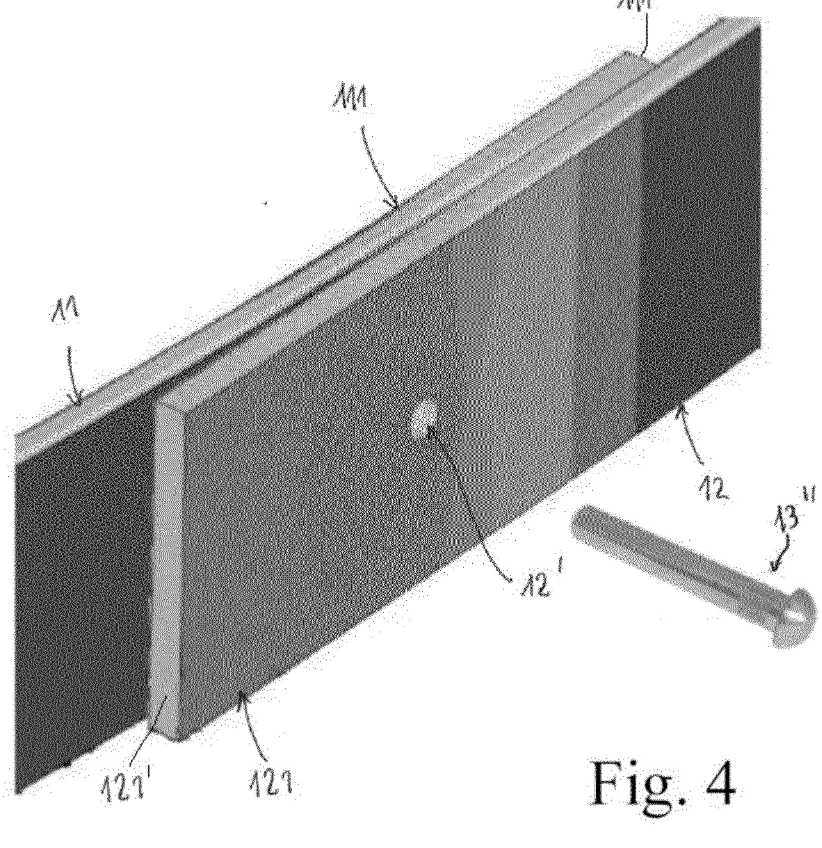

Fig. 4

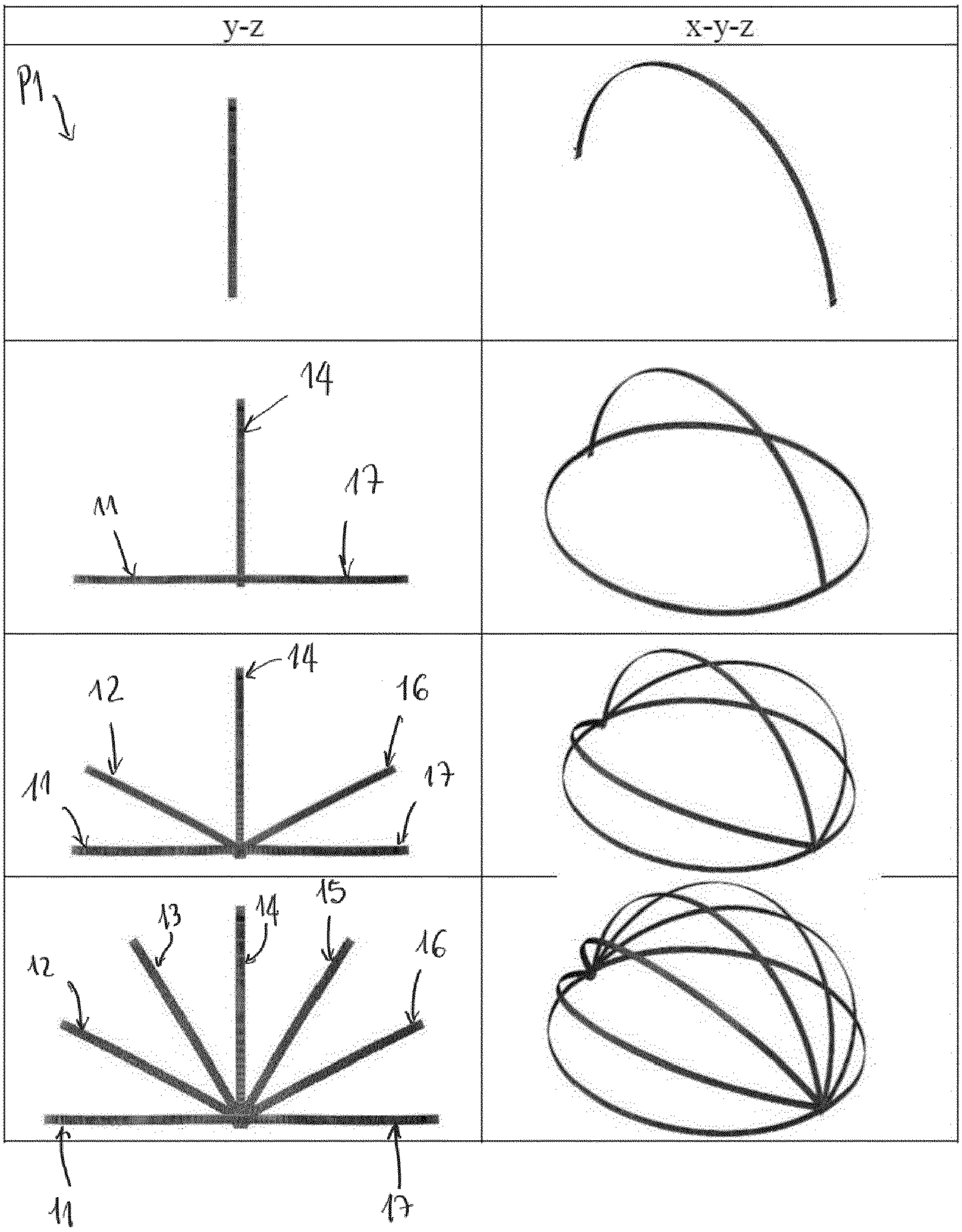

Fig. 5

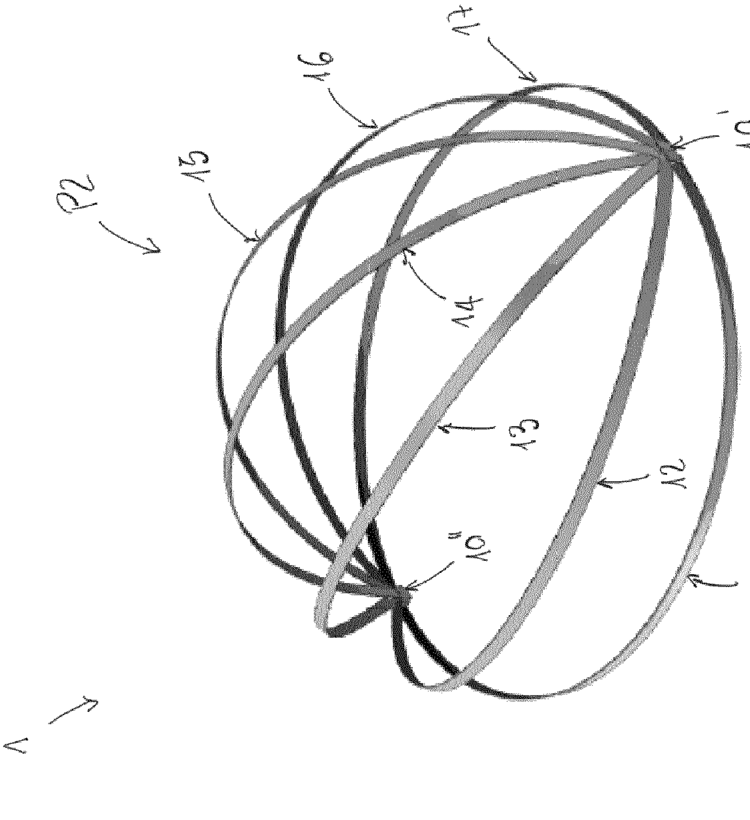

Fig. 6

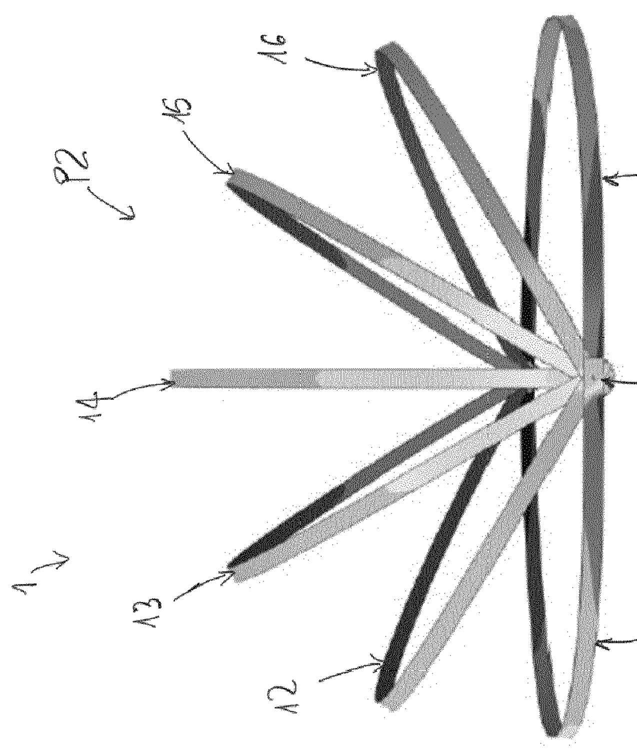

Fig. 7

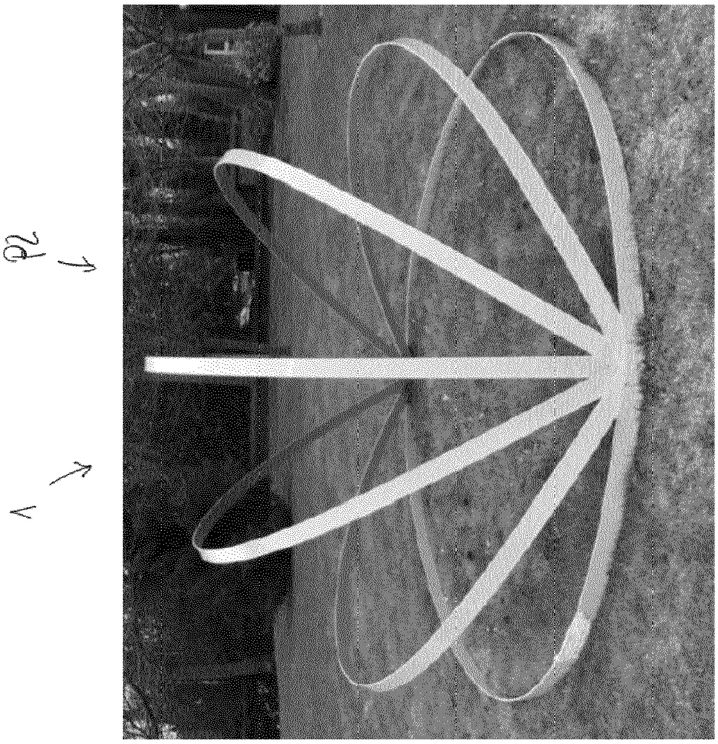

Fig. 8

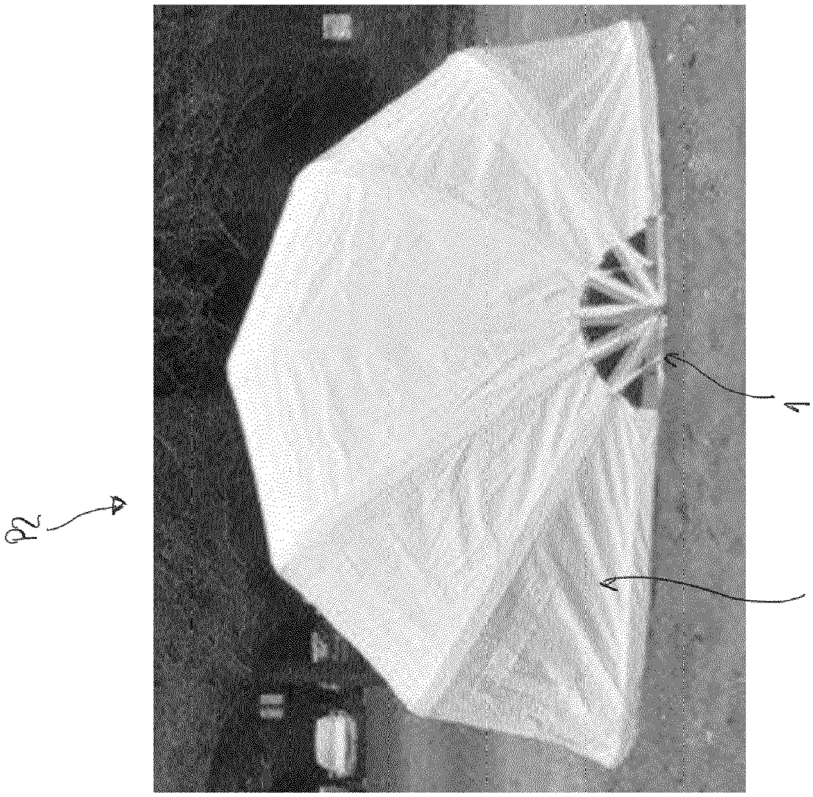

Fig. 9

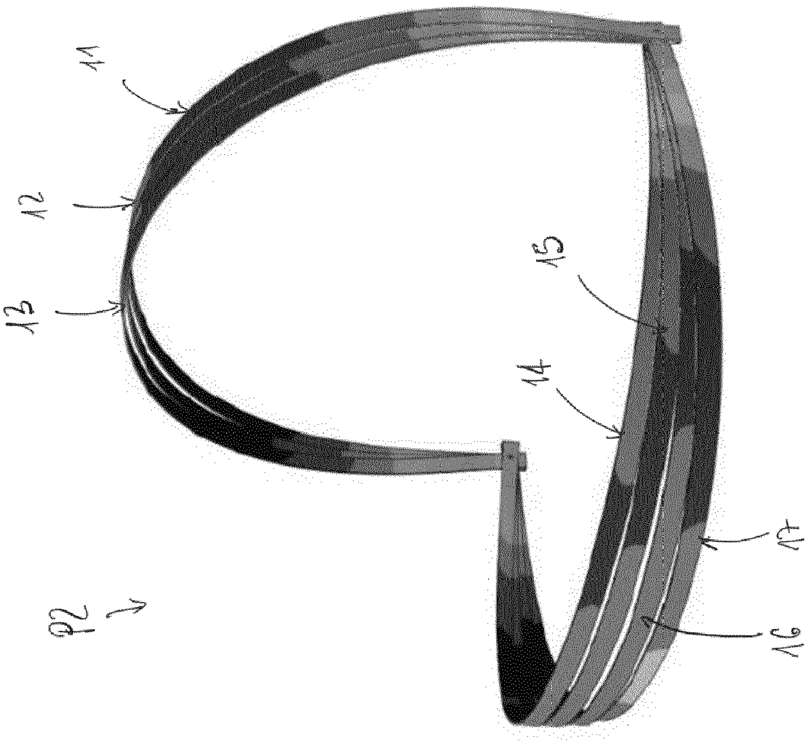

Fig. 11

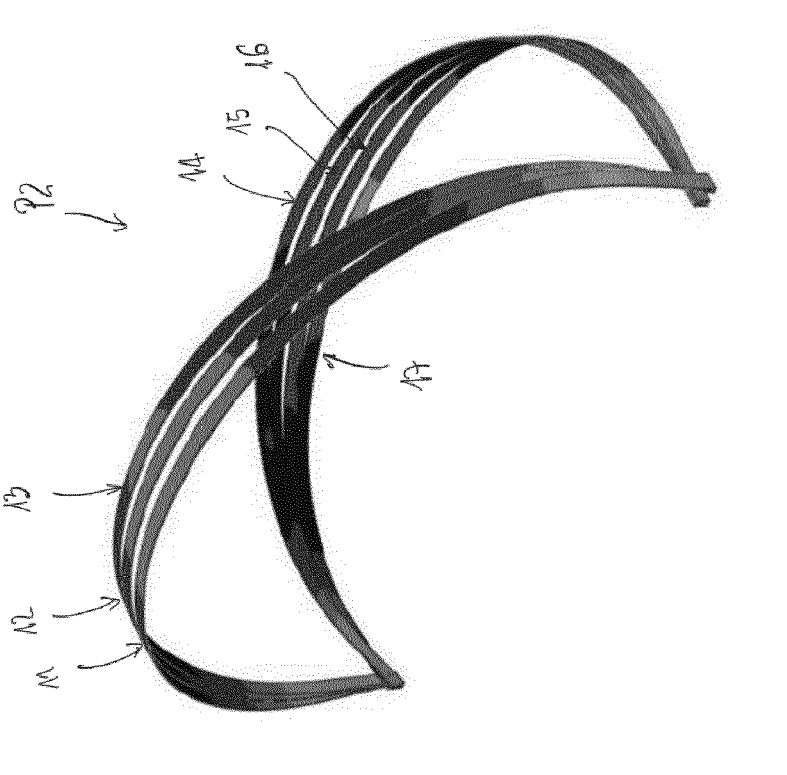

Fig. 10

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 22 18 9769

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	GB 2 167 462 A (LEWIS GILBERT EDWARD) 29 May 1986 (1986-05-29) * page 1, lines 40-55,74-82; claim 1; figures 1-4 *	1-11, 13-15	INV. E04H15/38
X	US 3 190 300 A (WEAR N JACK S) 22 June 1965 (1965-06-22) * column 3, lines 56-75; figures 1,2 *	1,3-7, 9-11, 13-15	
X	US 2012/067387 A1 (WHYBREW LARRY O [US] ET AL) 22 March 2012 (2012-03-22) * paragraphs [0063] - [0066], [0071], [0072]; figures 1-9 *	1-15	
X	DE 23 15 143 A1 (PIEST JAN) 15 August 1974 (1974-08-15) * page 2, paragraph 3; figures 1,2,5 * * page 4, paragraph 3 *	1-11, 13-15	
			TECHNICAL FIELDS SEARCHED (IPC)
A	DE 20 2021 102722 U1 (BERLINER SEILFABRIK GMBH & CO [DE]) 15 September 2021 (2021-09-15) * paragraph [0046] *	6	E04H

The present search report has been drawn up for all claims

2

Place of search	Date of completion of the search	Examiner
Munich	24 January 2023	Rosborough, John

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 22 18 9769

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-01-2023

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
GB 2167462	A	29-05-1986	NONE		
US 3190300	A	22-06-1965	NONE		
US 2012067387	A1	22-03-2012	NONE		
DE 2315143	A1	15-08-1974	BE 799228	A	31-08-1973
			DE 2315143	A1	15-08-1974
			DE 7311445	U	02-08-1973
			IT 983381	B	31-10-1974
DE 202021102722	U1	15-09-2021	DE 202021102722	U1	15-09-2021
			WO 2022243121	A1	24-11-2022

EPO FORM P0459

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