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(54) CELLULAR ENERGY-ABSORBING STRUCTURE FASTENING DEVICE

(57) Helmet (1) comprising: a shell (2); a head receiving system (3); at least one cellular energy-absorbing structure (4) comprising a plurality of interconnected open-cells (9) configured to absorb energy by deforming during an impact on the shell (2); at least one clamping device (5) comprising a base (6) and a counter-base (7) connected to each other via a collapsible body (8) configured to pass-through the cellular energy-absorbing structure (4); wherein the collapsible body (8) is sized so as to pass through one or more open-cells (9) of the cellular energy-absorbing structure (4) and the clamping device (5) is connected to the shell (2) and/or to the head receiving system (3) for clamping the cellular energy-absorbing structure (4) to the shell (2) and/or to the head receiving system (3).

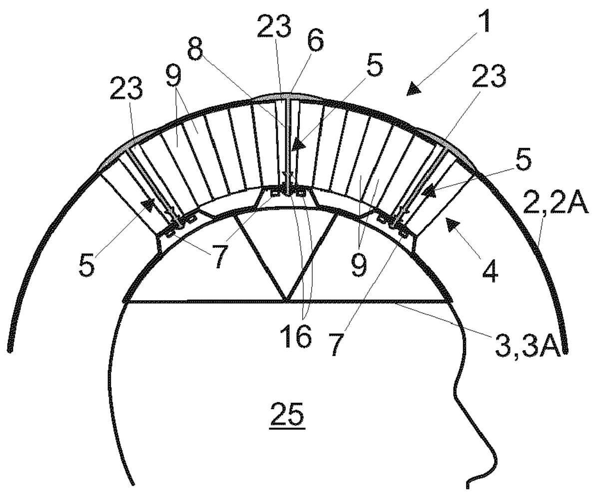


Fig.1B

EP 4 082 372 A1

Description

TECHNICAL FIELD

[0001] The present invention relates to the field of helmets with cellular energy-absorbing structures. In particular, the present invention relates to the helmets using layered structures with relative movement between layers for reducing translational acceleration and angular acceleration of the brain.

BACKGROUND ART

[0002] In the state of the art several types of helmets are known: motorcycle helmets, automotive race helmets, industrial safety helmets, bike helmets, ski helmets, water-sports helmets, equestrian helmets, American football helmets, etc.

[0003] Traditional sport, car and motorcycle helmets comprise:

- an outer shell, preferably a hard shell;
- a protective liner matching with the shell and arranged into the shell;
- a comfort liner for making the helmet much more comfortable when it’s worn by the user;
- a retention system, generally comprising a strap and a quick-release locking system.

[0004] Industrial safety helmets normally comprise:

- a outer hard shell;
- a harness connected to the hard shell.

[0005] The outer shell gives to the helmet a specific appearance and provides a first protection against impacts. In the helmets having a protecting liner, the shell also contains the protective liner. The material of the shell can be a polymer such as PC (polycarbonate), PE (polyethylene), ABS (acrylonitrile butadiene styrene) or a composite material such as glassfibre or carbon fibre. Depending on the material, the shell is generally thermomoulded or thermo-formed, for example in bike helmets, or injection-moulded, for example in ski helmets.

[0006] Generally, the protective liner is made of a polymeric foam, like EPS (Expanded Polystyrene) or EPP (Expanded Polypropylene), and is used for absorbing the energy generated during a collision. The EPS liner or layer absorbs the energy of an impact through compression. Currently EPS is the most used material for absorbing the energy of an impact and employed in most of helmets. Alternatively, high-performance energy-absorbing material are known, such as the energy-absorbing material distributed with brand Koroyd®. This kind of cellular energy-absorbing material absorbs much more energy than traditional EPS/EPP liners when an impact load substantially orthogonal to the shell occurs. This kind of cellular material absorbs energy through a progressive buckling of its cells.

[0007] The comfort liner can comprise pillows made of synthetic or natural material, which adheres or is connected to the internal side of the protective liner. In this way, the head of the user is not in direct contact with the protective liner but with the comfort liner that is much more comfortable. Alternatively to the comfort liner, industrial helmets have a harness, consisting of a system of straps made of woven bands or polyethylene. A harness is a cheap solution for combining a system for maintaining the helmet over the head of the wearer and a system for absorbing part of the energy of an impact. The harness absorbs less impact energy than polymeric foam liners.

[0008] The retention system is used for maintaining the helmet in position on the head of the user and can comprise a regulation device for regulating the tightening of the helmet on the head.

[0009] During an impact, for example due to a fall of a biker, the outer shell can impact against an object, like the ground, in any direction and the impact load has a normal component and/or a tangential component. The tangential component can create a rotation of the skull with respect to the brain, while the normal component can cause the skull fracture leading to death. Both kind of injuries are important and needs to be reduced as much as possible by the helmet.

[0010] In order to absorb both normal and tangential components of an impact load, the solutions available in the state of the art employ a device for absorbing the tangential component and a device for absorbing the normal component. In particular, all known solutions do not connect them together.

[0011] For example, certain helmets manufactured by the company Smith™ comprise a cellular energy-absorbing pad of the company Koroyd® and a brain protection system developed by the company MIPS®. The cellular energy-absorbing pad efficiently absorbs the normal component of impact load, while the brain protection system efficiently absorbs the tangential component. The cellular energy-absorbing pad fits in an EPS liner and the brain protection system is connected to the same EPS liner, as described by the document EP2440082B1. Said cellular energy-absorbing pad is not connected to said brain protection system and consequently they work like independent devices and not synergically.

[0012] Other solutions that solve only one of the problems of absorbing the normal component or absorbing the tangential component of an impact load are available. For example, the helmet described in the document WO2016209740A1 comprises a protective liner split in two parts, an outer liner and an inner liner. The outer liner is connected to the inner liner through an elastic band, which allows relative movements between the inner and outer liners. This feature allows to reduce rotational or translational brain injuries. This document provides a solution for dividing a protective liner in two parts for efficiently absorbing rotational acceleration due to the tangential component of an impact load, but neglects how to efficiently mitigate linear acceleration imparted by the normal impact component.

[0013] Since the device for absorbing normal impact component does not cooperate with the device for absorbing the tangential impact component, the impact loads are not efficiently absorbed. Moreover, the deformation of the device for absorbing normal impact components can compromise the functionality of the other one, or vice versa. In this way, the devices theoretically work efficiently, but in practice each one affects the functioning of the other.

[0014] Furthermore, all the available solutions for sport, motorcycle and car helmets use polymeric foam liners, e.g. EPS or EPP liners, when the international rules are evolving in favour of more environment-friendly solutions, which avoid or reduce these kinds of materials.

[0015] None of the available solutions provides helmets able to efficiently absorb all kind of impacts through an integrated solution that results in a cheaper, simpler and more environmentally friendly product.

SUMMARY

[0016] Said and other inconvenients of the state of the art are now solved by a helmet comprising: a shell, at least one cellular energy-absorbing structure, at least one clamping device and a head receiving system. Said at least one cellular energy-absorbing structure comprises a plurality of interconnected open-cells configured to absorb energy by deforming during an impact on the shell; said at least one clamping device comprises a base and a counter-base connected to each other via a collapsible body. The collapsible body is configured to pass-through the cellular energy-absorbing structure. Wherein the collapsible body is sized so as to pass through one or more open-cells of the cellular energy-absorbing structure and the clamping device is connected to the shell and/or to the head receiving system for connecting the cellular energy-absorbing structure to the shell and/or to the head receiving system. This arrangement allows to directly connect the cellular energy-absorbing structure with the clamping device/s and in turn to connect the clamping device to the shell and/or to the head receiving system. This chain of connections allows to coordinate the relative movements of the cellular energy-absorbing structure/s, the clamping device/s, the shell and the head receiving system. In particular, being the body of the clamping device collapsible, the clamping device follows the movements of the cellular energy-absorbing structure when it crumples, also compensating lateral movements due to the tangential component of the impact load.

[0017] Preferably, the cellular energy-absorbing structure can be an array of energy-absorbing open-cells interconnected via their sidewalls. This architecture of the cellular energy-absorbing structure is particularly efficient in absorbing axial loads, thus loads substantially parallel to the open-cells longitudinal axis. In particular, each open-cell can have an open base facing the shell and an opposite open base facing the head receiving system. This arrangement of the open-cells allows to absorb more efficiently the axial impact load through the progressive crumpling of the cells.

[0018] Alternatively, the cellular energy-absorbing structure can be a lattice structure comprising solid portions and open portions configured to form a network of interconnected open-cells. This architecture of the cellular energy-absorbing structure is particularly efficient in absorbing loads coming from any direction. In particular, the cellular energy-absorbing structure can be arranged so that one side of the structure faces towards the shell and an opposite side faces towards the head receiving system. In this way, the cellular energy-absorbing structure is arranged between the shell and the head receiving system.

[0019] Advantageously, the compressive force required to collapse the clamping device along a direction can be lower than or equal to that required to deform the open-cells of the cellular energy-absorbing structure along the same direction. This means that the clamping device does not resist when the cellular energy-absorbing structure is compressed due to an impact load and the cellular energy-absorbing structure can be compressed as if there were no clamping devices.

[0020] Preferably, the shell can comprise only a hard shell or, alternatively, a rigid or semi-rigid outer shell and an inner shock absorbing liner connected to each other. In the former case, the shell is constituted by a hard shell, as in the case of industrial helmets. In the latter case, the shell comprises an outer shell and an inner shock absorbing liner, as in the case of sport helmets. The inner shock absorbing liner is preferably made of a polymeric foam and can comprise a pocket wherein the cellular energy-absorbing structure is arranged. This pocket is configured to retain the cellular energy-absorbing structure without using additional retaining devices. In this way, the cellular energy-absorbing structure and the shell remain connected despite of the clamping devices/s.

[0021] Preferably, the base or counter-base can be connected to the shell or to the head receiving system through connecting means. In this way, the clamping devices are attached to the shell and the cellular energy-absorbing structure is attached to the shell via the clamping devices. This arrangement applies both in the case of a shell comprising only a hard shell, and in the case of an outer shell with an inner shock absorbing liner.

[0022] Preferably, the connecting means can comprise a Velcro layer, an adhesive layer or snap-fit connector/s for simplifying the interconnection between the clamping device and the shell or the head receiving system.

[0023] Advantageously, the base or counter-base can be embedded with the shell. In this way, the base or counter-base is firmly attached to the shell. This arrangement applies both in the case of a shell comprising only a hard shell, and in the case of an outer shell with an inner shock absorbing liner.

[0024] Alternatively, the collapsible body of the clamping device/s can be inserted in a hole of the shell and the base or counter-base can abut against the external face of the shell. In this way, the base or counter-base leans on the external surface of the shell and the rest of the clamping device clamps the cellular energy-absorbing structure to the shell.

[0025] Advantageously, the collapsible body of the clamping device can comprise a stretchable elongated body comprising a retaining portion, acting as counter-base and a base connected to the elongated body. This kind of single piece clamping device is elastic and can collapse and stretch so as to follow any kind of deformation of the cellular energy-absorbing structure. Preferably, said base can be rigid or semi-rigid so as to not flex when it lies over one side of the cellular energy-absorbing structure. More preferably, said rigid or semi-rigid base is co-molded with the elastic elongated body so to form a single piece despite of the elastic and rigid parts of the clamping device.

[0026] Preferably, the stretchable elongated body is configured to elongate under tension between 30% and 500% of its original length.

[0027] Moreover, the stretchable elongated body can be at least in part made of a viscoelastic material. In this way, the elongation/shortening of the stretchable elongated body contributes to absorb the impact energy, in particular that of tangential component.

[0028] Alternatively, the collapsible body of the clamping device can comprise a flexible elongated body connected to the base and having an outer surface comprising a plurality of spaced teeth and spaced recesses. Said counter-base can comprise at least one flexible pawl shaped so as to fit in one of said recesses. By means of this second kind of clamping device, the cellular energy-absorbing structure can be easily and quickly connected to the shell or head receiving system. The flexible body of the clamping device allows to follow the deformations of the cellular energy-absorbing structure, in particular when it crumples.

[0029] Advantageously, this kind of clamping device can comprise a flexible elongated body that is at least partially pleated or coiled, or comprises geometric perturbations to facilitate the collapse of the collapsible body.

[0030] Alternatively, the base can comprise a protuberance having a plurality of teeth configured to cooperate with a mouth of a hollow body connected to the counter-base, said protuberance and said hollow body forming the collapsible body of the clamping device. This third kind of clamping device allows a facilitated axial collapsing of the collapsible body, since the protuberance enters in the hollow body in an easy way. Furthermore, the teeth prevent any rebounding of the cellular energy-absorbing structure and maintain it crumpled.

[0031] Preferably, the head receiving system can be a harness system or a comfort system. Preferably said harness system or a comfort system can be connected to the counter-base or base of the at least one clamping device. In this way, a correct positioning of the head of the wearer with respect to the helmet is guaranteed.

[0032] Advantageously, the base can comprise a low friction layer arranged on the outer surface of the base. In this way, the clamping device can slide over the outer shell or the inner shock absorbing liner when the cellular energy-absorbing structure compresses along an in-plane direction.

[0033] These and other advantages will be better understood thanks to the following description of different embodiments of said invention given as non-limitative examples thereof, making reference to the annexed drawings.

DRAWINGS DESCRIPTION

[0034] In the drawings:

Fig. 1A shows a schematic view of a cross-sectioned helmet according to a first embodiment of the present invention;

Fig. 1B shows a schematic view of a cross-sectioned helmet according to a second embodiment of the present invention;

Fig. 1C shows a schematic view of a cross-sectioned helmet according to a third embodiment of the present invention;

Fig. 1D shows a schematic view of a cross-sectioned helmet according to a fourth embodiment of the present invention;

Fig. 1E shows a schematic view of a cross-sectioned helmet according to a fifth embodiment of the present invention;

Fig. 1F shows a schematic view of a cross-sectioned helmet according to a sixth embodiment of the present invention;

Fig. 2A shows a schematic view of a cellular energy-absorbing structure and a clamping device of a first type before being compressed;

Fig. 2B shows a schematic view of a cellular energy-absorbing structure and a clamping device of a first type after a compression due to a normal load;

Fig. 2C shows a schematic view of a cellular energy-absorbing structure and a clamping device of a first type after a compression due to an inclined load;

Fig. 3A shows a schematic view of a cellular energy-absorbing structure and a clamping device of a second type during the assembling phase;

Fig. 3B shows a schematic view of a cellular energy-absorbing structure and a clamping device of a second type before being compressed;

Fig. 3C shows a schematic view of a cellular energy-absorbing structure and a clamping device of a second type after a compression due to a normal load;

Fig. 3D shows a schematic view of a cellular energy-absorbing structure and a clamping device of a second type after a compression due to an inclined load;

Fig. 4A shows a schematic view of a cellular energy-absorbing structure and a clamping device of a third type during the assembling phase;
Fig. 4B shows a schematic view of a cellular energy-absorbing structure and a clamping device of a third type before being compressed;
Fig. 4C shows a schematic view of a cellular energy-absorbing structure and a clamping device of a third type after a compression due to a normal load;
Fig. 4D shows a schematic view of a cellular energy-absorbing structure and a clamping device of a third type after a compression due to an inclined load;
Fig. 5A shows a schematic view of a cellular energy-absorbing structure and a clamping device of a fourth type during the assembling phase;
Fig. 5B shows a schematic view of a cellular energy-absorbing structure and a clamping device of a fourth type before being compressed;
Fig. 5C shows a schematic view of a cellular energy-absorbing structure and a clamping device of a fourth type after a compression due to a normal load;
Fig. 5D shows a schematic view of a cellular energy-absorbing structure and a clamping device of a fourth type after a compression due to an inclined load;
Fig. 6A shows the helmet of Fig. 1A when an inclined impact load hits the shell of the helmet;
Fig. 6B shows the helmet of Fig. 1B when an inclined impact load hits the shell of the helmet;
Fig. 6C shows the helmet of Fig. 1C when an inclined impact load hits the shell of the helmet;
Fig. 6D shows the helmet of Fig. 1D when an inclined impact load hits the shell of the helmet;
Fig. 6E shows the helmet of Fig. 1E when an inclined impact load hits the shell of the helmet;
Fig. 6F shows the helmet of Fig. 1F when an inclined impact load hits the shell of the helmet;
Fig. 7A shows an axonometric view of said second type of clamping device;
Fig. 7B shows an axonometric view of the clamping device of Fig. 7A connected to an outer shell;
Fig. 7C shows an axonometric view of the clamping device and the outer shell of Fig. 7B wherein the clamping device is inserted in a cell of the cellular energy-absorbing structure;
Fig. 7D shows an axonometric view of the clamping device, the outer shell and the cellular energy-absorbing structure of Fig. 7C wherein the clamping device clamps the cellular energy-absorbing structure to the outer shell;
Fig. 8A shows an axonometric view of said fourth type of clamping device;
Fig. 8B shows an axonometric view of the clamping device of Fig. 8A connected to an outer shell;
Fig. 8C shows an axonometric view of the clamping device and the outer shell of Fig. 8B wherein the clamping device is inserted in a cell of the cellular energy-absorbing structure;
Fig. 8D shows an axonometric view of the clamping device, the outer shell and the cellular energy-absorbing structure of Fig. 8C wherein the clamping device clamps the cellular energy-absorbing structure to the outer shell;
Fig. 9A shows an axonometric view of a clamping device passing through an outer shell and clamping a cellular energy-absorbing structure to the outer shell;
Fig. 9B shows a cross section of the clamping device, the outer shell and the cellular energy-absorbing structure of Fig. 9A;
Fig. 10 shows an axonometric view of an alternative connection between the outer shell and the clamping device;
Fig. 11A shows a side view of a clamping device of the second type;
Fig. 11B shows a cross-section of the clamping device of Fig. 11A;
Fig. 11C shows a top view of the clamping device of Fig. 11A;
Fig. 12A shows a side view of a clamping device of the fourth type;
Fig. 12B shows a cross-section of the clamping device of Fig. 12A;
Fig. 12C shows a top view of the clamping device of Fig. 12A;
Fig. 13A shows a side view of a clamping device of the fourth type;
Fig. 13B shows a cross-section of the clamping device of Fig. 13A;
Fig. 13C shows a top view of the clamping device of Fig. 13A.

DETAILED DESCRIPTION

[0035] The following description of one or more embodiments of the invention is referred to the annexed drawings. The same reference numbers indicate equal or similar parts. The object of the protection is defined by the annexed claims. Technical details, structures or characteristics of the solutions here-below described can be combined with each other in any suitable way.

[0036] In the present description, for the sake of conciseness, the term "cellular energy-absorbing structure 4" is sometime abbreviated as "cellular structure 4", as well as the term "inner shock absorbing liner 2B" is abbreviated as "inner liner 2B". Other similar abbreviations can be present in the following description.

[0037] Figs. 1 represent some embodiments of the helmet 1 according to the present invention. This helmet 1 comprises a shell 2, at least one cellular energy-absorbing structure 4, a head receiving system 3 and one or more clamping devices 5.

[0038] As described in detail in the following, the clamping devices 5 are employed to allow a relative movement between two parts of the helmet 1 and to absorb the energy related to this movement.

[0039] In particular, in the embodiment of Fig. 1A the clamping devices 5 connect the cellular structure 4 to the shell 2. In the embodiment of Figs. 1C and 1D the clamping devices 5 connect the cellular structure 4 to the head receiving system 3, while in the embodiments of Figs. 1B, 1E and 1F, the clamping devices 5 connect the cellular structure 4 both to the shell 2 and to the head receiving system 3.

[0040] The clamping device 5 is configured to pass-through the thickness of the cellular structure 4, from side to side. The clamping device 5 comprises a base 6, a counter-base 7 and a collapsible body 8 connecting them to each other. The base 6 and the counter-base 7 are opposite to each other with respect to the cellular structure 4. The collapsible body 8 is sized so as to pass through one open-cell 9 of the cellular structure 4, as shown in Figs.1A,1B,1C,1E,1F, or through a plurality of open-cells 9, as shown in Fig. 1D. The collapsible body 8 cross-section is thus smaller than the open-cell 9 cross-section.

[0041] The collapsible body 8 of the clamping device can be made, at least in part, of a polymeric material. When a mechanical interaction with the counter-base 7 is required, the material of the collapsible body 8 is a plastic material, like polyethylene or nylon, as described for the clamping devices 5 of Figs.2,4,5. Vice versa, if a mechanical interaction with the counter-base 7 is not required, as described for the clamping device 5 of Figs. 3, the collapsible body 8 is made of an elastic material, for example rubber, thermoplastic polyurethane (TPU), thermoplastic elastomer (TPE), silicone or another elastomeric material.

[0042] As shown in the embodiments of Figs. 1A,1B,1C,1E and 1F, the cellular structure 4 comprises an array of energy-absorbing open-cells 9. These open-cells 9 are connected to each other via their sidewalls 10.

[0043] The open-cells 9 are open at their ends so that each open-cell 9 realizes a tube through which the air can flow. The open-cell 9 has a circular cross-section as represented in Figs. 7-9. Alternatively, the cross-section of the open-cells 9 can be a square, a hexagon, a non-uniform hexagon, a reentrant hexagon, a chiral truss, a diamond, a triangle or an arrowhead.

[0044] The open-cells 9 of said array can be welded to each other via their sidewalls 10. Alternatively, the tubes can be bonded by means of adhesive layers interposed between adjacent sidewalls 10. This kind of adhesive can be a thermo-adhesive material, thus an adhesive that at room temperature is solid and becomes liquid above 80-100°C. Otherwise, the adhesive could also be a reactive adhesive or pressure sensitive adhesive.

[0045] When the open-cells 9 have a circular cross-section, the outer diameter of the circular cross-section can range between 2,5 and 8 mm, and the wall thickness of said open-cells 9 can range between 0,05 and 0,2 mm.

[0046] The array of energy-absorbing open-cells 9 can be configured to absorb the energy through a plastic deformation of the sidewalls 10 of the open-cells 9, wherein "plastic deformation" means that the sidewalls 10 crumple irreversibly, or through an elastic deformation of the sidewalls 10 of the open-cells 9. In the latter case, the deformation is almost completely reversible and the sidewalls 10 come back a shape similar or equal to the original one.

[0047] Alternatively, the open-cells 9 can be the cells of a lattice structure, as schematically shown in Fig. 1D. In this case, the open-cells 9 are constituted by hollow portions defined by the solid portions 12 of the lattice structure. Substantially, the three-dimensional grid of solid portions 12 of the lattice structure defines a network of interconnected open-cells 9 (i.e. the hollow portions of the lattice structure), through which the air can flow. These open portions 13 of the lattice structure realize said open-cells 9. The lattice structure 4 can be configured to absorb the energy through a plastic or elastic deformation of the solid portions 12.

[0048] It's useful to clarify that a cellular structure 4 cannot have wide cells, otherwise the energy-absorption is compromised and the cellular structure 4 becomes too soft for absorbing compressive loads. Consequently, the clamping devices 5 comprise slender collapsible bodies 8 for allowing the insertion into said openings 11 and the passage through the open-cell/s 9. If the energy-absorbing structure would be made of an expandable foam, like in the prior art solution, the hole for receiving the plug could be sized at will. Vice versa, in the present solutions, the cellular structure 4 imposes the dimension of the connecting device 5 and not conversely.

[0049] The cellular structure 4, both in the version having an array of energy-absorbing open-cells 9 and in the lattice structure, comprises a surface facing towards the shell 2 and a surface facing towards the head receiving system 3, as shown in Figs. 1. These surfaces comprise a plurality of openings 11 of said open-cells 9. In any one of these openings 11, the connecting devices 5 can be inserted.

[0050] With reference to Fig. 1A, it's represented an industrial safety helmet 1 comprising only an outer shell 2A. This outer shell 2A is a hard shell, thus a shell made of a rigid plastic so to resist impacts. To the outer shell 2A a plurality of clamping devices 5 are connected through connecting means 15. These connecting means 15 can be an adhesive layer attached to the outer surface of the base 6 of the clamping device 5 and to the inner surface of the outer shell 2A. Each clamping device 5 crosses the cellular structure 4 with its collapsible body 8. The collapsible body 8 passes through one open-cell 9 of the cellular structure 4. The bases 6 of the clamping devices 5 lie on the outer face of the cellular structure 4, while the counter-bases 7 of the clamping devices 5 lie on the inner face of the cellular structure 4. In this way, the cellular structure 4 is connected to the outer shell 2A, but relative lateral movements between them are allowed, as shown in Fig. 6A. The helmet 1 also comprises a head receiving system 3, that in this case is a harness system 3A. This harness system 3A is connected directly to the outer shell 2A, as in the traditional industrial safety helmets, and guarantees a space between the head 25 of the wearer and the cellular structure 4. Despite of this embodiment refers to an industrial safety helmet, the same features can be used for realizing a different type of helmet.

[0051] With reference to Fig. 1B, it is represented a helmet 1 comprising an outer shell 2A and head receiving system 3 connected to each other through clamping devices 5. The cellular structure 4 is clamped between the outer shell 2A and the head receiving system 3, through clamping devices 5. The clamping devices 5 are configured to pass with their collapsible bodies 8 through respective holes 23 in the outer shell 2A and penetrate respective open-cells 9 of the cellular structure 4. The clamping devices 5 are also configured to pass through the head receiving system 3 and to mechanically connect with the counter-bases 7. The collapsible body 8 comprises teeth 16 configured to enter in the counter-base 7 and expand outwardly once they are on the other side of the counter-base 7. The counter-bases 7 are arranged over the head receiving system 3, so that the head receiving system 3 remains clamped between the counter-bases 7 and the cellular structure 4. In this way, the collapsible body 8 cannot easily pulled out from these slots and the cellular structure 4 remains clamped between the outer shell 2A and the head receiving system 3. In this case, the head receiving system 3 is another type of harness system 3A, which allows a fine positioning of the head 25. This kind of helmet 1 allows a relative movement of the head receiving system 3 with respect to the outer shell 2A and with respect to the cellular structure 4.

[0052] With reference to Fig. 1C, it's represented a helmet 1 comprising a shell 2 composed by an outer shell 2A and an inner shock absorbing liner 2B. The outer shell 2A of the embodiments of Figs. 1A,1B is substantially equal to that of the embodiments of Figs.1D-1F. From a structural point of view, since the embodiments of Figs. 1A,1B are better for industrial safety helmets, the outer shell 2A is thicker than that of the other embodiments. On the contrary, since the helmets of the embodiments of Figs. 1C-1F are suitable for sport helmets, the outer shell 2A can be rigid, like in the motorcycle or automotive helmets, or semi-rigid, like in the bike or ski helmets.

[0053] The inner shock absorbing liner 2B is preferably made of an expanded foam polymer, like EPS or EPP.

[0054] In the embodiment of Fig. 1C, the inner liner 2B comprises a pocket 14 in which the cellular structure 4 is arranged. The pocket 14 is a recess of the inner surface of the inner liner 2B. This pocket 14 is shaped so as to be substantially complementary to the cellular structure 4. In this way, the cellular structure 4 is retained in the pocket 14 without additional connecting means. The pocket 14 has inner mouth that is smaller than its bottom surface, consequently once the cellular structure 4 is arranged in this pocket 14, it cannot come out. The outer shell 2A and the inner liner 2B comprise a plurality of vents 28. A vent 28 is an opening that allows an air transit from the external environment to the head 25 of the wearer. The vent 28 crosses the outer shell 2A and inner liner 2B up to the bottom of the pocket 14. From here, the air can reach the head 25 thanks to the open-cells 9 of the cellular structure 4. The helmet 1 is thus permeable. The clamping devices 5 are configured to cross the cellular structure 4 from one side to the other, and their collapsible bodies 8 are configured to penetrate in respective open-cells 9 of the cellular structure 4. The clamping devices 5 are inserted in the cellular structure 4 so that the bases 6 face towards the head receiving system 3 and the counter-bases 7 faces towards the bottom of the pocket 14. The counter-bases 7 are preferably disks made of nylon, polycarbonate or PTFE (polytetrafluoroethylene). The collapsible bodies 8 can be connected to the counter-bases 7 once they come over the cellular structure 4. The connection between this kind of counter-base 7 and the collapsible body 8 is described in the following with reference to the clamping devices 5 of Figs. 4 and 5. Thanks to the counter-bases 7, the cellular structure 4 is spaced with respect to the bottom of the pocket 14 and do not enter in contact with it. The bases 6 are connected to the head receiving system 3 through connecting means 15. In this embodiment, the connecting means 15 are a Velcro connection and the head receiving system 3 a comfort liner 3B. The Velcro connection comprises a hooking part and a hook part structured in a known manner. The hook part is preferably arranged on the base 6, and the comfort liner 3B comprises an outer woven cover that acts a hooking part. In this type of helmet 1, the head receiving system 3 can move with respect to the cellular structure 4 and the cellular structure 4 can slide over the bottom of the pocket 14 as explained later on in the description.

[0055] With reference to Fig. 1D, it's represented a helmet 1 comprising a shell 2 composed by an outer shell 2A and an inner liner 2B as explained for the helmet 1 of the embodiment shown in Fig. 1C. In this case the vents 28 are arranged not in correspondence of the cellular structure 4, but in a further embodiment (not shown) they can be arranged in correspondence of the cellular structure 4 so that an airflow cross all the elements of the helmet 1. In this embodiment, the cellular structure 4 is a lattice structure, as described above. The collapsible bodies 8 of the clamping devices 5 pass-through a plurality of open-cells 9 in order to come over from the opposite side of the cellular structure 4. The bases 6 of these clamping devices 5 stay on the outer side of the cellular structure 4 and lie on it, while the counter-bases 7 are arranged over the head receiving system 3. Substantially, the collapsible bodies 8 cross the open-cells 9 and the head receiving system 3. In this way, the counter-bases 7 lie on the inner surface of the head receiving system 3, as shown in Fig. 1D. In this version of the helmet 1, the clamping devices 5 clamp the head receiving system 3 and the cellular structure 4 together. Furthermore, the clamping devices 5 comprise respective low friction layers 26 arranged on the outer surfaces of the bases 6. This low friction layer 26 can be made of nylon, polycarbonate or PTFE for reducing the friction between the bases 6 and the bottom of the pocket 14. In this way, the cellular structure 4 can slide over the inner liner 2B. The head receiving system 3 of this embodiment is a comfort system 3B of a different type with respect to that of Fig.1C.

[0056] With reference to Fig. 1E, it's represented a helmet 1 comprising a shell 2 having an outer shell 2A and an inner liner 2B, as described above. Some vents 28 cross the outer shell 2A and the inner liner 2B. To the inner liner 2B are connected some counter-bases 7 that are partially embedded in the inner liner material. The head of said counter-bases 7 comes out of the inner liner 2B so that a mechanical connection between the collapsible body 8 and the counter-base 7 can be achieved. The mechanical connection at issue can be configured like that shown in Figs. 2, 4 or 5. The bases 6 of the clamping devices 5 face towards the head receiving system 3 and they comprise connecting means 15 for connecting the head receiving system 3 to these bases 6. The connecting means 15 can be snap-fit connectors that engage the bases 6. The head receiving system 3 can be a comfort system 3B. In particular, in this embodiment, the cellular structures 4 are more than one and a first group of clamping devices 5 is used for connecting the first cellular structure 4 to the inner liner 2B, and a second group of clamping devices 5 is used for connecting the second cellular structure 4 to the inner liner 2B. The clamping devices 5 of this embodiment allows a relative movement of the comfort system 3B with respect to the inner liner 2B and also with respect to the cellular structure 4. In this embodiment, the inner liner 2B can comprise a low friction coating facing the cellular structure/s 4 so to reduce the friction between these two elements of the helmet 1.

[0057] With reference to Fig. 1F, it's represented a helmet 1 comprising a shell 2 having an outer shell 2A and an inner liner 2B, as described above. Some vents 28 cross the outer shell 2A and the inner liner 2B. The bases 6 of the clamping devices 5 are embedded in the inner liner 2B, while the collapsible bodies 8 protrude outside the inner surface of the inner liner 2B towards the inner of the helmet 1. The collapsible bodies 8 comprise a plurality of teeth 16 shaped so as to cross slots of the head receiving system 3 and expand once on the other side. The connection of the clamping devices 5 with the head receiving system 3 of this embodiment is similar to that of Fig. 1B, with the difference that the head receiving system 3 directly acts as counter-base 7 for a plurality of clamping devices 5.

[0058] The embodiment of Fig. 1F also comprises a spacer 27 for each clamping device 5. The spacer 27 is a ring of nylon or PTFE. The collapsible body 8 of the clamping device 5 passes through the central hole of the spacer 27. The spacers 27 are arranged so as to stay between the inner surface of the inner liner 2B and the outer face of the cellular structure 4. In this way, the spacers 27 act as cushions between the inner liner 2B and the cellular structure 4, allowing a relative sliding. In this embodiment, the head receiving system 3 can move with respect to the cellular structure 4 and, together, they can move relative to the inner liner 2B. Alternatively, instead of the spacers 27, the inner liner 2B of the embodiment of Fig. 1F can comprise a low friction coating facing the cellular structure 4 so to reduce the friction between these two elements of the helmet 1.

[0059] In the Figs.2-5 are shown some types of clamping devices and how they interact with the cellular structure 4.

[0060] The clamping device of Figs. 2 comprises a base 6 having a protuberance 8C and counter-base 7 comprising a hollow body 8D. The protuberance 8C and the hollow-body 8C constitute the collapsible body 8. The protuberance 8C is shaped so as to enter in the hollow body 8D through the mouth 21. The protuberance 8C comprises a dentition 20 that is configured to cooperate with the mouth 21 of the hollow body 8D, so to make the extraction of the protuberance 8C from the hollow body 8D not possible or difficult. The counter-base 7 is shaped so to lie on one side of the cellular structure 4, while the base 6 is shaped so to lie on the opposite side of the cellular structure 4. The hollow body 8D and the protuberance 8C are dimensioned so as to enter in one single open-cell 9, without the need of creating a wider pass-through hole or enlarging the existing ones. As shown in Fig. 2B, when a normal and out-of-plane force F is applied to the cellular structure 4 and to the clamping device 5, the open-cells 9 progressive buckle and their sidewalls 10 crumple. The clamping device 5 is configured so that the collapsible body 8 of the clamping device 5 follows this collapse without opposing a resistance. When an angled force F is applied to the cellular structure 4, as shown in Fig. 2C, the cellular structure 4 also slightly laterally buckles and the counter-base 7 translates with respect to the base 6. Even in this case, the clamping device 5 follows this movement through a deformation. This deformation of the clamping device 5 allows to absorb the tangential component of the impact force F.

[0061] The clamping device 5 of Figs. 3 comprises a stretchable elongated body 8A that is attached to the base 6. Said stretchable elongated body 8A comprise a retaining portion 7A which acts as counter-base 7. The stretchable elongated body 8A is made of an elastic material so that the stretchable elongated body 8A can get longer. The retaining portion 7A is spaced from the base 6 at a predetermined distance. The stretchable elongated body 8A also comprises an exceeding portion 22 which extends beyond the retaining portion 7A. In order to let pass the stretchable elongated body 8A through one open-cell 9, the exceeding portion 22 is inserted in the open base 11 of said one open-cell 9 and once, it comes over the opposite side of the cellular structure 4, the exceeding portion 22 is pulled until the retaining portion 7A, passing through the open-cell 9, comes out from said opposite side. The flexibility of retaining portion 7A allows the passage through one open-cell 9. At this point, the exceeding portion 22 is released and the elasticity of the stretchable elongated body 8A spreads the retaining portion 7A over said opposite side of the cellular structure 4. In this way, the clamping device 5 exerts a force that attracts the retaining portion 7A and the base 6 towards each other. After the positioning phase described above and schematically represented in Fig. 3A, the exceeding portion 22 is cut, e.g. with scissors, and the clamping device 5 looks as in Fig 3B. This kind of clamping device 5 can change its shape and follow the deformations of the cellular structure 4. For example, in Fig. 3C a force F applies orthogonally to the cellular structure 4 and the open-cells 9 axially crumple. In this case, the stretchable elongated body 8A relaxes, getting shorter. If the impact force F is angled, as shown in Fig. 3D, the cellular structure 4 also translates and slightly bends laterally. In this case, the clamping device 5 deforms, allowing this translation/deformation of the cellular structure 4.

[0062] Alternatively, the stretchable elongated body 8A of the clamping device 5 is made at least in part of a viscoelastic polymer. In particular, the stretchable elongated body 8A can be entirely made of a viscoelastic polymer or can comprise an outer elastic portion inside which is arranged a viscoelastic material, for example a viscoelastic foam.

[0063] The clamping device 5 of Figs. 4 and 5 are substantially equal, except for the presence of geometric perturbations 19 on the collapsible body 8 of the embodiments of Figs.4. For this reason, these embodiments of the clamping device 5 of Figs. 4 and 5 are described together. The collapsible body 8 of these embodiments comprises a flexible elongated body 8B that is connected to the base 6. This flexible elongated body 8B is made of a plastic material and is configured to be flexible but not stretchable. Only a portion of the elongated body 8B can be configured to elongate in case of a pulling force greater than a certain threshold. This elongation of the flexible body 8B of these clamping devices 5 corresponds to a permanent deformation. The outer surface of the flexible elongated body 8B comprises a plurality of spaced teeth 16 alternated by recesses 17. The flexible elongated body 8B looks similar to a cable-tie. Said teeth 16 are configured to mechanical cooperate with at least one flexible pawl 18 belonging to the counter-base 7. The flexible pawl 18 is shaped so as to fit in one of said recesses 17 making the extraction of the flexible elongated body 8B from the counter-base 7 unfeasible or really difficult. Consequently, the flexible elongated body 8B enters in the counter-base 7 but cannot be extracted. Once one of the teeth 16 has engaged the flexible pawl 18 of the counter-base 7 and reached the right portion, the portion of the flexible elongated body 8B coming out from the counter-base 7 is removed, for example with scissors, as shown in Figs. 4A and 5A. The clamping devices 5 so look as Figs. 4B and 5B show. As shown in Figs. 4C and 5C, when a normal and out-of-plane force F is applied to the cellular structure 4, the open-cells 9 progressively buckle and their sidewalls 10 crumple. The flexible elongated body 8B of the clamping device 5 is configured to flex, following the collapse of the cellular structure 4 without opposing a resistance. When an angled force F is applied to the cellular structure 4, as shown in Figs. 4D and 5D, the cellular structure 4 also slightly lateral buckles and the counter-base 7 translates with respect to the base 6. Even in this case, the clamping device 5 follows this movement through a deformation. This deformation of the clamping device 5 allows to absorb the tangential component of the impact force F. In particular, the embodiment of Figs. 4 has a flexible elongated body 8B at least partially pleated. These geometric perturbations 19 facilitate the collapse of the collapsible body 8. Alternatively, in an embodiment not shown, the flexible elongated body 8B can be coiled instead of pleated.

[0064] Advantageously, in one or all the embodiments of the above-described clamping device 5, the collapsible body 8 of the clamping device 5 is configured to not impede the collapsing of the cellular structure 4. In particular, the compressive force required to collapse the clamping device 5 along a direction X, as shown in Figs. 2B, 3C, 4C, 5C, is lower than or equal to the compressive force required to deform the open-cells 9 of the cellular energy-absorbing structure 4 along the same direction X.

[0065] In the Figs. 6, the helmets 1 of the embodiments of Figs. 1 are represented during an impact with an inclined force F hitting the outer shell 2A.

[0066] In particular, in Fig. 6A is represented the helmet 1 of the embodiment of Fig. 1A during an impact. The impact is represented through an inclined force F which causes a rotation R of the outer shell 2A with respect to the head 25 of the wearer. A first portion of the impact force F is absorbed by the harness system 3A which deforms prior that the head 25 reaches the cellular structure 4. Once the head 25 enters in contact with the cellular structure 4, the open-cells 9 crumple absorbing the normal component Fn of the force F. In the Figs. 6 the crumpling of the open cells 9 is represented through a reduction of the thickness of the cellular structure 4. Concurrently, the clamping devices 5 laterally stretch allowing a relative movement of the cellular structure 4 with respect to the outer shell 2A. The deformation of the clamping devices 5 allows to absorb the tangential component Ft of the impact force F.

[0067] Fig. 6B shows the helmet 1 of the embodiment of Fig. 1B during an angled impact with a force F which causes a rotation R of the outer shell 2A with respect to the head 25 of the wearer. The deformation of the cellular structure 4 and of the clamping devices 5 is similar to that described for Fig. 6A. The open-cells 9 of the cellular structure 4 axially progressive buckle absorbing the normal component Fn of the force F and, in the same time, the clamping devices 5 bend and stretch absorbing the tangential component Ft of the force F.

[0068] Fig. 6C shows the helmet 1 of the embodiment of Fig. 1C during an angled impact with a force F which causes a rotation R of the shell 2 with respect to the head 25 of the wearer. In this case, the cellular structure 4 slides by means of the counter-bases 7 over the bottom of the pocket 14. Consequently, the cellular structure 4 deforms along both in-plane and out-of-plane directions. The cellular structure 4 hits against the sidewall of the pocket 14 and it compresses. The consequently deformation of the cellular structure 4 occurring parallel to the bottom of the pocket 14 absorbs a great part of the tangential component Ft of the force F. While the axial crumpling of the open-cells 9 absorbs the normal component Fn of the force F. Moreover, the clamping devices 5 bend contributing to absorb the tangential component Ft of the force F during the cellular structure 4 deformation.

[0069] Fig. 6D shows the helmet 1 of the embodiment of Fig. 1D during an angled impact with a force F, which causes a rotation R of the shell 2 with respect to the head 25 of the wearer. In this case, the lattice structure 4 slides over the bottom of the pocket 14 by means of low friction layers 26 arranged over the outer surfaces of the bases 6. Therefore, the cellular structure 4 deforms along both in-plane and out-of-plane directions. The cellular structure 4 hits against the sidewall of the pocket 14 and it compresses. The lattice structure slides in the pocket 14 deforming the solid portions 12 and absorbing a great part of the tangential component Ft of the force F. Concurrently, the top-down crumpling of the open-cells 9 absorbs the normal component Fn of the force F. Moreover, the clamping devices 5 bend contributing to absorb the tangential component Ft of the force F during the lattice structure deformation.

[0070] Fig. 6E shows the helmet 1 of the embodiment of Fig. 1E during an angled impact with a force F which causes a rotation R of the shell 2 with respect to the head 25 of the wearer. In this case, the deformation of the clamping devices 5 absorbs the tangential component Ft of the impact force F, together with the bending of the cellular structure 4, while the normal component Fn of the impact force F simultaneously crumples the open-cells 9 of the cellular structure 4.

[0071] Fig. 6F shows the helmet 1 of the embodiment of Fig. 1F during an angled impact with a force F which causes a rotation R of the shell 2 with respect to the head 25 of the wearer. Similarly to the case of Fig. 6E, the deformation of the clamping devices 5 together with the bending of the cellular structure 4 absorb the tangential component Ft of the impact force F, while the normal component Fn of the impact force F is absorbed by the axial progressive buckling of the open-cells 9 of the cellular structure 4.

[0072] In particular, in Figs. 7 is represented an exemplary embodiment of the clamping device 5 of Figs. 3. The clamping device 5 comprises a base 6 monolithically connected to the stretchable elongated body 8A, which in turn is a single piece with the retaining portion 7A. This version of the clamping device 5 is represented in detail in the Figs. 11. In particular, from Fig. 11C appears immediately clear that the base 6 is wider than the retaining portion 7A. Indeed, the base 6 is often used as interface with other elements of the helmet 1, as shown in Figs. 1A and 1D. In Fig. 11A, it's perceivable that the base 6 is slightly curved both on the inner and outer faces. This shape allows a better fitting with the cellular structure 4 and with the shell 2. Moreover, the base 6 can be made of a different material with respect to the elastic material of the stretchable elongated body 8A, as shown in Fig. 11B. In particular, the base 6 can be made of a rigid plastic, like nylon, polycarbonate or ABS that is co-molded with the elastic material of the stretchable elongated body 8A. For example, the clamping devices 5 of the embodiment of Figs. 1D, 6D are realized in this way.

[0073] The clamping device 5 of Fig. 7A is firstly attached to the shell 2, for example with an adhesive layer that acts as connecting means 15, as shown in Fig. 7B. Secondly, the cellular structure 4 is arranged over the outer shell 2A so that the stretchable elongated body 8A passes-through an open-cell 9 and the exceeding portion 22 comes over the cellular structure 4, as shown in Fig. 7C. Thirdly, the exceeding portion 22 is pulled so that the retaining portion 7A comes out the cellular structure 4 and pushes the cellular structure 4 towards the outer shell 2A, as shown in Fig. 7D. Finally, the exceeding portion 2 is cut and the connection between the outer shell 2A and the cellular structure 4 is realized in a quick and cheap manner. The arrangement of Figs. 7 corresponds to that of the embodiment shown in Figs. 1A and 6A.

[0074] The clamping device 5 of Figs. 8 comprises a base 6 monolithically connected to the flexible elongated body 8B. A separated counter-base 7, comprising a plurality of pawls 18, can be inserted over the flexible elongated body 8B, as shown in Fig.8A. The shape of the clamping device 5 of Figs. 8 is shown in detail in Figs. 12. The counter-base 7 comprises three flexible pawls 18 and a central hole dimensioned for receiving the flexible elongated body 8B with its teeth 16. The teeth 16 are interspersed with recesses 17. The teeth 16 interact with the flexible pawls 18 so that the latter can fit in one of said recesses 17. Once that the flexible pawls 18 enter in one recess 17, the counter-base 7 keeps its position along the flexible elongated body 8B, as shown in the zoomed portion of Fig. 12B. The base 6 is wider than the counter-base 7 and it's slightly curved for the reasons explained for the embodiment of Figs. 11. The base 6 and the flexible elongated body 8B are a single piece made of the same material, while the counter-base 7 is independent from them and can be made, or not, of the same material.

[0075] As shown in Fig. 8B, the clamping device 5 of Fig. 8A is firstly attached to the outer shell 2A, for example with glue or an adhesive layer. Once the clamping device 5 is connected to the shell 2, the cellular structure 4 is arranged over the shell 2, so that the flexible elongated body 8B passes-through and comes over one of the open-cells 9 of the cellular structure 4, as shown in Fig. 8C. Thirdly, the cellular structure 4 is secured to the shell 2 through the counter-base 7. The flexible elongated body 8B is inserted in the counter-base 7 to lock the cellular structure 4 to the shell 2. Finally, the exceeding part of the flexible elongated body 8B is cut. This kind of clamping device 5 substantially corresponds to that used in the embodiment of Fig.1B and is similar to those of Figs. 1E and 1F.

[0076] In Figs. 9, the clamping devices 5 pass-through holes 23 in the shell 2. The outer shell 2A comprises recesses 29 for accommodating the bases 6 of corresponding clamping device 5. In this way, the base 6 is almost not perceivable from outside. The collapsible body 8 passes through the open-cell 9, as shown in Fig. 9B and exits from the opposite side of the cellular structure 4. A counter-base 7 is fitted on the flexible elongate body 8B of the clamping device 5. The clamping device 5 of Figs. 9 substantially corresponds to the clamping device 5 of Figs. 13. This clamping device 5 is operatively equal to that of Figs. 12, with the only difference that flexible elongate body 8B comprises the teeth 16 and the recesses 17 only on one side, while on the other side elongate body 8B is smooth, as shown in Fig. 13B. The teeth 16 are not perceivable in Figs. 13, but they are visible in the Fig. 9B. The arrangement of clamping device 5 over the outer shell 2A of Figs. 15 corresponds to that represented in Figs. 1B,6B.

[0077] In the embodiments of Figs. 7, 8 and 9, the cellular structure 4 is an array of energy-absorbing open-cells 9, but the same applies in case of a lattice structure.

[0078] In Fig. 10 is also represented an alternative way to permanently connect the clamping device 5 to the outer shell 2A. In this embodiment, the base 6 comprises two holes and the outer shell 2A comprises two anchoring portions 24 shaped to pass through said two holes. Once the base 6 is in contact with the inner surface of the outer shell 2A, the anchoring portions 24, that in Fig. 10 are shown still intact, are fused and the connection between the base 6 and the outer shell 2A becomes permanent.

[0079] All the features described for the embodiments of Figs. 1, can be mixed to obtain further embodiments not represented but included in the present invention. For example the bases 6 of clamping devices 5 of the embodiment of Fig. 1F can be embedded in the outer shell 2A of the embodiment of Fig. 1A.

[0080] Furthermore, even if the embodiments of Figs. 1A, 1D employ the clamping devices 5 of the Figs. 3 and the embodiments of Figs. 1B, 1C, 1E, 1F employ clamping devices of the types represented in Figs. 4 or 5, other clamping device 5 according to the present invention can be used instead of those.

[0081] Concluding, the invention so conceived is susceptible to many modifications and variations all of which fall within the scope of the inventive concept, furthermore all features can be substituted to technically equivalent alternatives. Practically, the quantities can be varied depending on the specific technical requirements. Finally, all features of previously described embodiments can be combined in any way, so to obtain other embodiments that are not herein described for reasons of practicality and clarity.

Legend of reference signs:

[0082]

1 helmet
2 shell
2A outer shell
2B inner shock absorbing liner
3 head receiving system
4 cellular energy-absorbing structure
5 clamping device
6 base
7 counter-base
7A retaining portion
8 collapsible body
8A stretchable elongated body
8B flexible elongated body
8C protuberance
8D hollow body
9 open-cell
10 sidewalls
11 open base of the open-cell
12 solid portion of the lattice structure
13 open portion of the lattice structure
14 pocket
15 connecting means
16 tooth of the collapsible body
17 recess of the collapsible body
18 flexible pawl
19 geometric perturbation
20 dentition
21 mouth
22 exceeding portion
23 hole in the shell
24 anchoring portion on the shell
25 head of the wearer
26 low friction layer
27 spacer
28 vent
29 recess of the shell
F force
Fn normal component of the force
Ft tangential component of the force
R relative rotation

Claims

1. Helmet (1) comprising:

- a shell (2);
- a head receiving system (3);
- at least one cellular energy-absorbing structure (4) comprising a plurality of interconnected open-cells (9) configured to absorb energy by deforming during an impact on the shell (2);
- at least one clamping device (5) comprising a base (6) and a counter-base (7) connected to

each other via a collapsible body (8) configured to pass-through the cellular energy-absorbing structure (4);

wherein the collapsible body (8) is sized so as to pass through one or more open-cells (9) of the cellular energy-absorbing structure (4) and the clamping device (5) is connected to the shell (2) and/or to the head receiving system (3) for clamping the cellular energy-absorbing structure (4) to the shell (2) and/or to the head receiving system (3).

2. Helmet (1) according to claim 1, wherein the cellular energy-absorbing structure (4) comprises an array of energy-absorbing open-cells (9) interconnected via their sidewalls (10), preferably each open-cell (9) has an open base (11) facing towards the shell (2) and an opposite open base (11) facing towards the head receiving system.

3. Helmet (1) according to claim 1, wherein the cellular energy-absorbing structure (4) is a lattice structure comprising solid portions (12) and open portions (13) configured to form a network of interconnected open-cells (9), preferably the cellular energy-absorbing structure (4) is arranged so that one side of the structure (4) faces towards the shell (2) and an opposite side faces towards the head receiving system (3).

4. Helmet (1) according to any one of preceding claims, the clamping device (5) is configured so that the compressive force required to collapse the clamping device (5) along a direction (X) is lower than or equal to that required to deform the open-cells (9) of the cellular energy-absorbing structure (4) along the same direction (X).

5. Helmet (1) according to any one of preceding claims, wherein the shell (2) comprises only an outer hard shell (2A).

6. Helmet (1) according to any one of claims 1 to 4, wherein the shell (2) comprises a rigid or semi-rigid outer shell (2A) and an inner shock absorbing liner (2B) connected to each other, preferably the inner shock absorbing liner (2B) comprises a pocket (14) configured to retain the cellular energy-absorbing structure (4).

7. Helmet (1) according to any one of preceding claims, wherein the base (6) or counter-base (7) is connected to the shell (2) or to the head receiving system (3) through connecting means (15).

8. Helmet (1) according to claim 7, wherein the connecting means (15) comprise a Velcro connection, an adhesive layer or snap-fit connector/s.

9. Helmet (1) according to any one of claims 1 to 6, wherein the base (6) or counter-base (7) is embedded with the shell (2).

10. Helmet (1) according to any one of claims 1 to 6, wherein the collapsible body (8) is inserted in a hole (23) of the shell (2) and the base (6) or counter-base (7) abuts against the shell (2).

11. Helmet (1) according to any one of preceding claims, wherein the collapsible body (8) of the clamping device (5) comprises a stretchable elongated body (8A) comprising a retaining portion (7A) acting as counter-base (7), said stretchable elongated body (8A) being connected to said base (6), preferably said stretchable elongated body (8A) is configured to elongate between 30% and 500% of its original length, more preferably the stretchable elongated body (8A) is at least in part made of a viscoelastic material.

12. Helmet (1) according to any one of claims 1 to 10, wherein the collapsible body (8) of the clamping device (5) comprises a flexible elongated body (8B) connected to the base (6) and having an outer surface comprising a plurality of spaced teeth (16) and spaced recesses (17), said counter-base (7) comprises at least one flexible pawl (18) shaped so to fit in one of said recesses (17), preferably the flexible elongated body (8B) is at least partially pleated or coiled, or comprises geometric perturbations (19) to facilitate the collapse of the collapsible body (8).

13. Helmet (1) according to any one of claims 1 to 10, wherein the base (6) comprises a protuberance (8C) having a dentition (20) configured to cooperate with a mouth (21) of a hollow body (8D) connected to the counter-base (7), said protuberance (8C) and said hollow body (8D) forming the collapsible body (8) of the clamping device (5).

14. Helmet (1) according to any one of preceding claims, wherein the head receiving system (3) comprises a harness system (3A) or a comfort system (3B), preferably said harness system (3A) or a comfort system (3B) being connected to the counter-base (7) or base (6) of the at least one clamping device (5).

15. Helmet (1) according to any one of preceding claims, comprising a low friction layer arranged on the at least one clamping device (5).

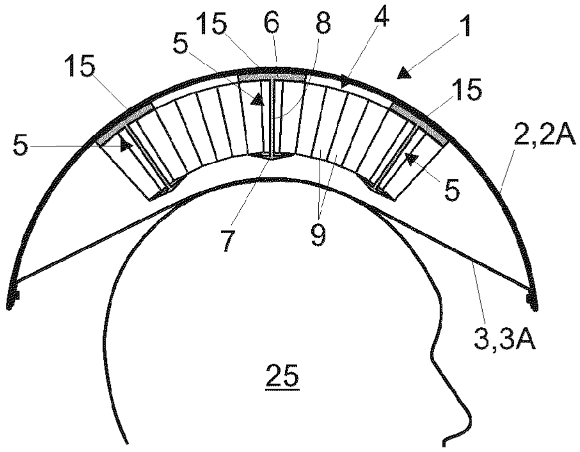


Fig.1A

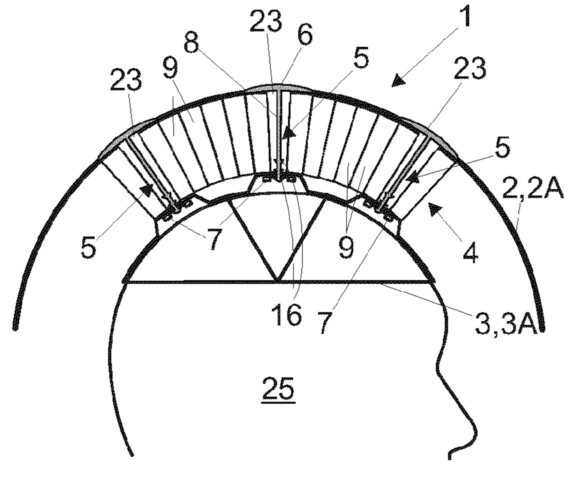


Fig.1B

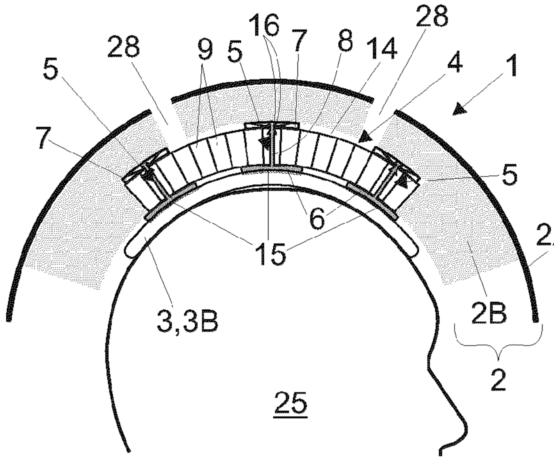


Fig.1C

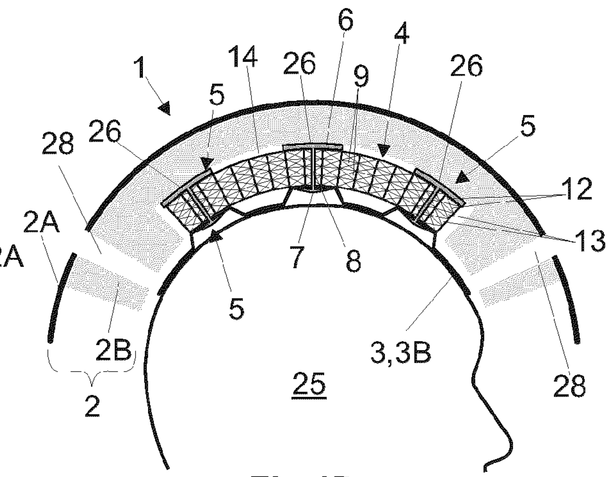


Fig.1D

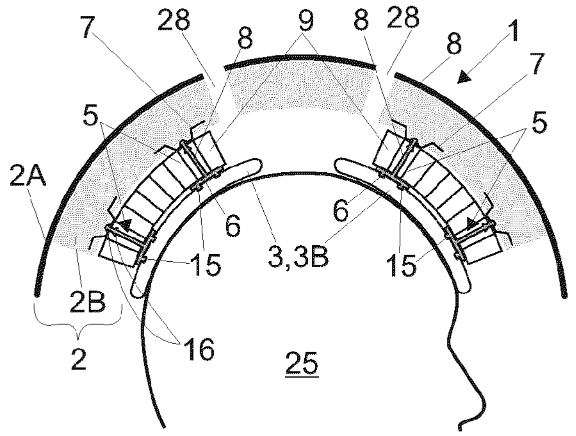


Fig.1E

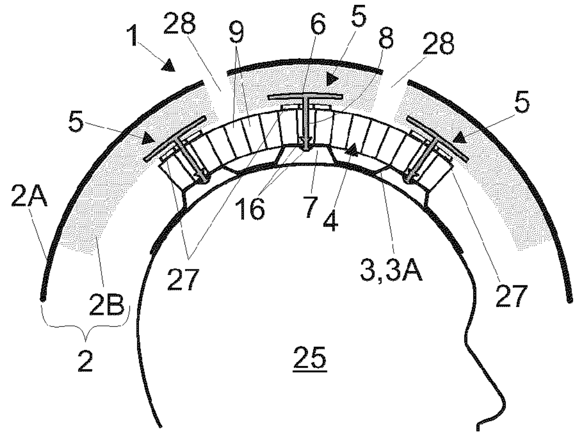


Fig.1F

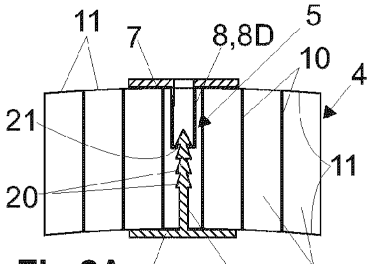
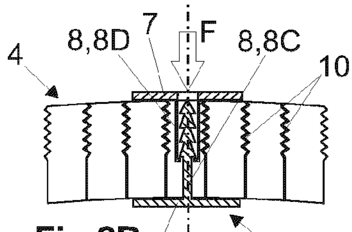


Fig.2A



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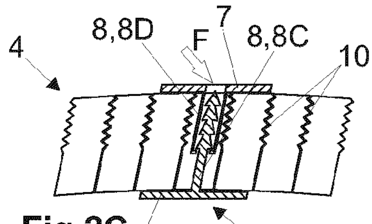


Fig.2C

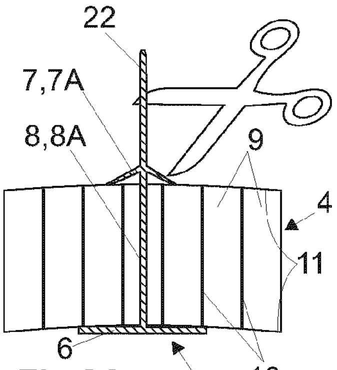


Fig.3A

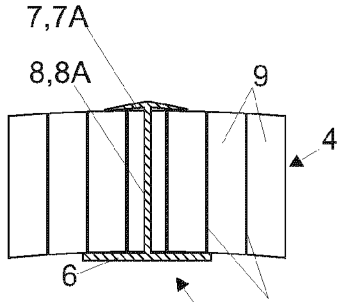
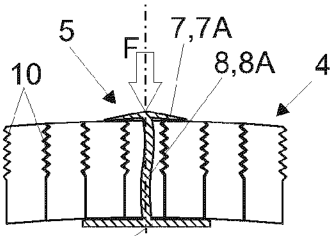


Fig.3B



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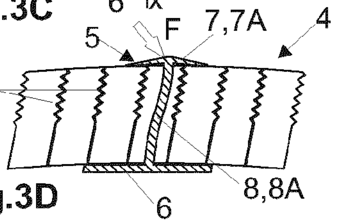
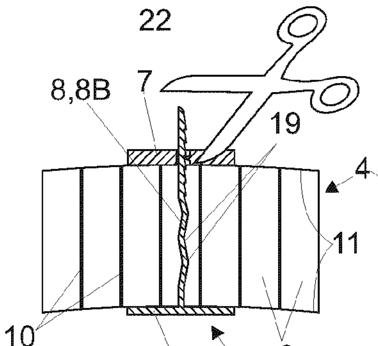


Fig.3D



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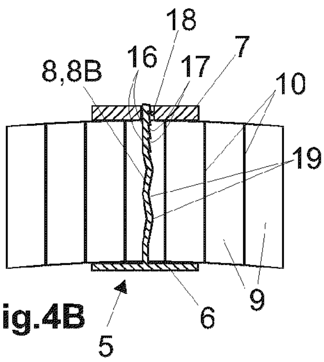


Fig.4B

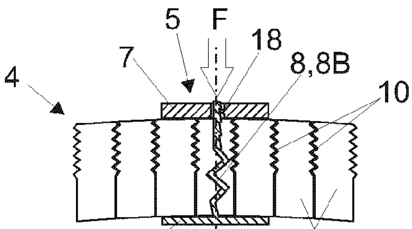
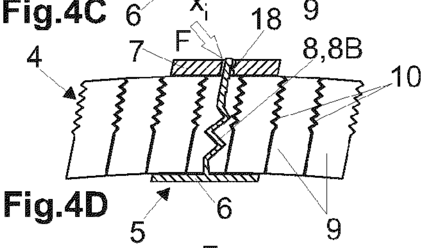


Fig.4C



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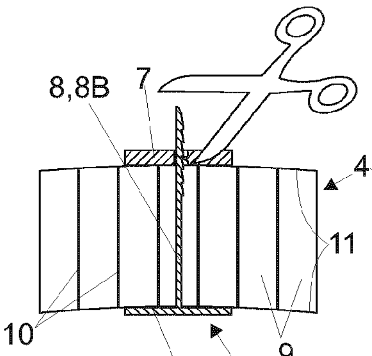


Fig.5A

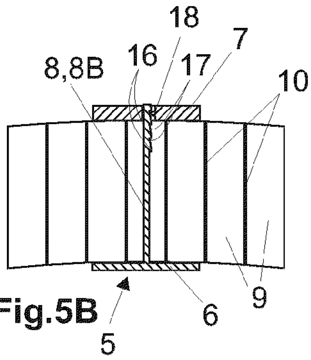


Fig.5B

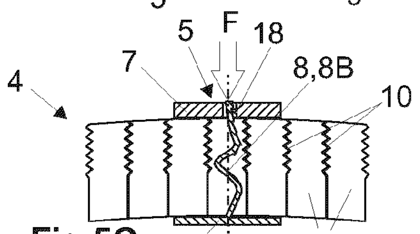


Fig.5C

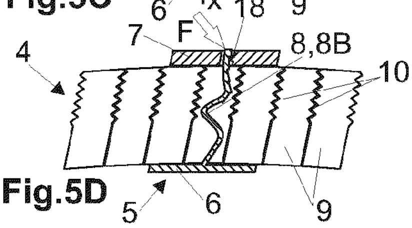
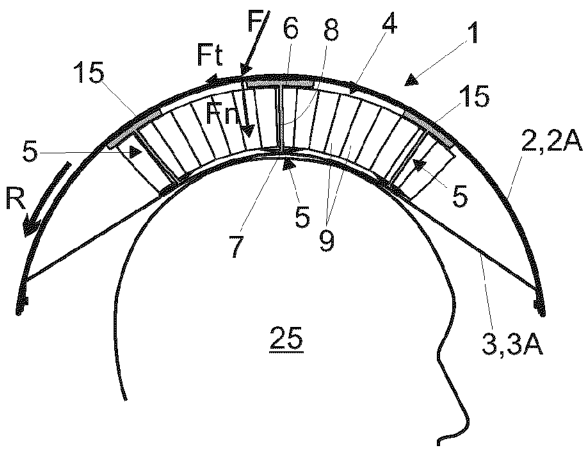


Fig.5D



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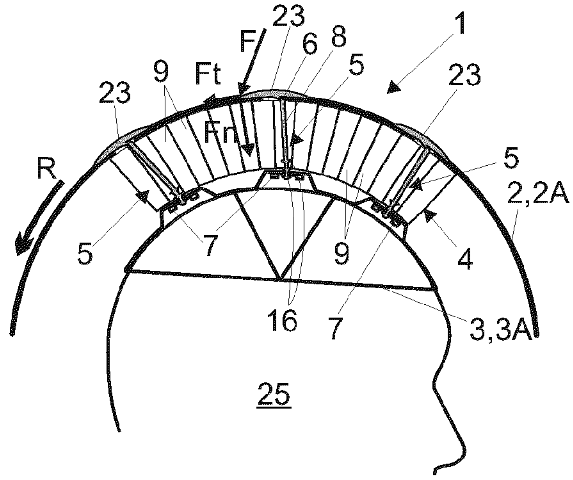


Fig.6B

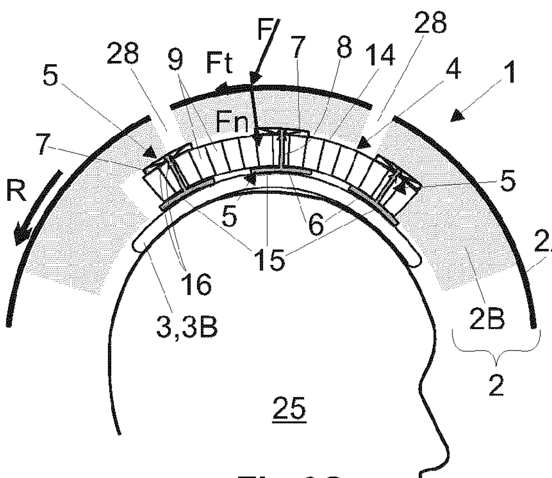


Fig.6C

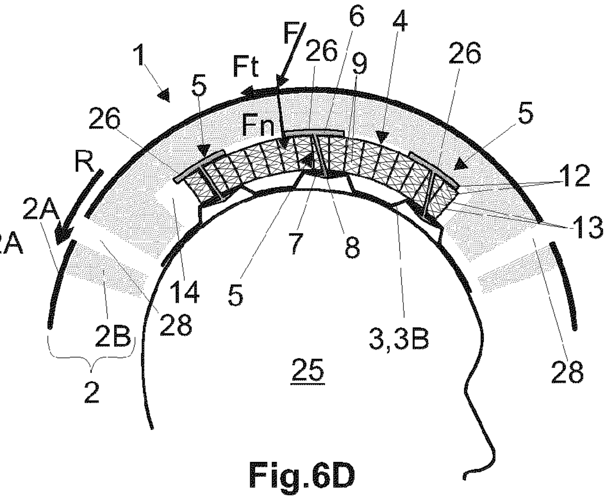


Fig.6D

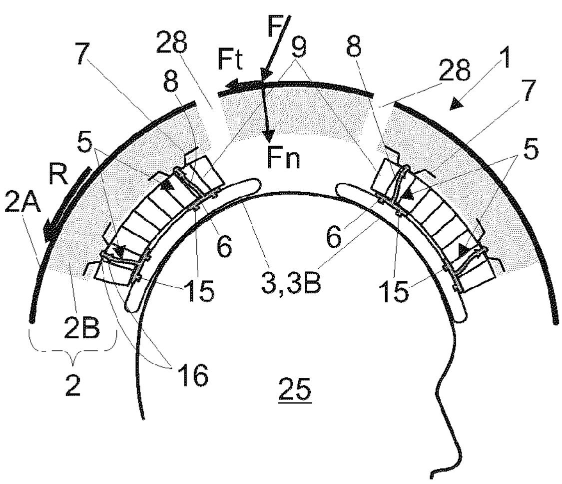


Fig.6E

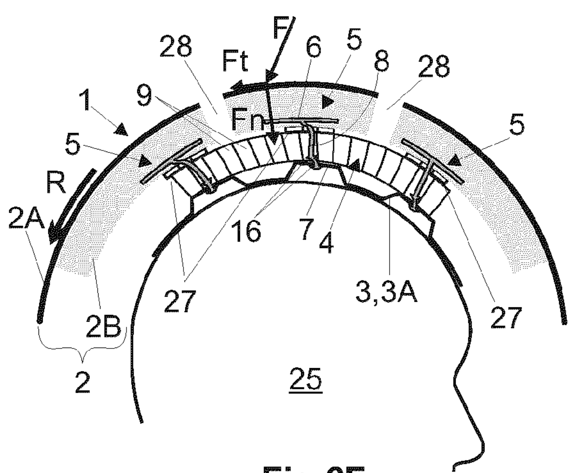


Fig.6F

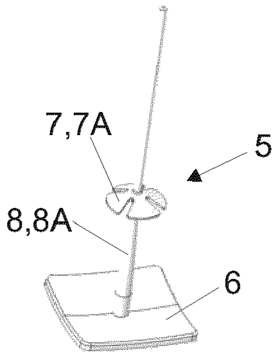
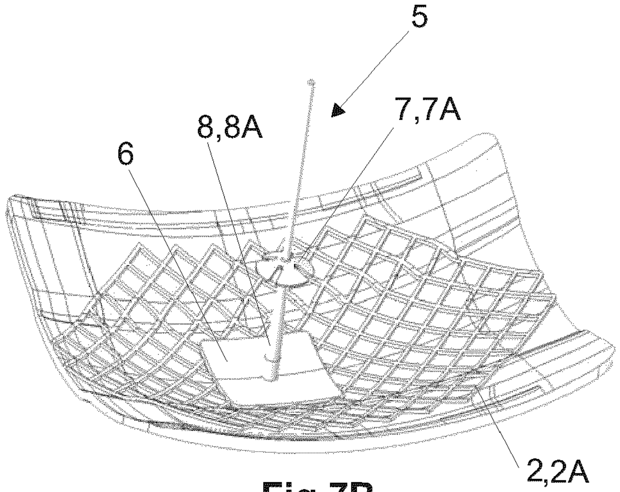


Fig.7A



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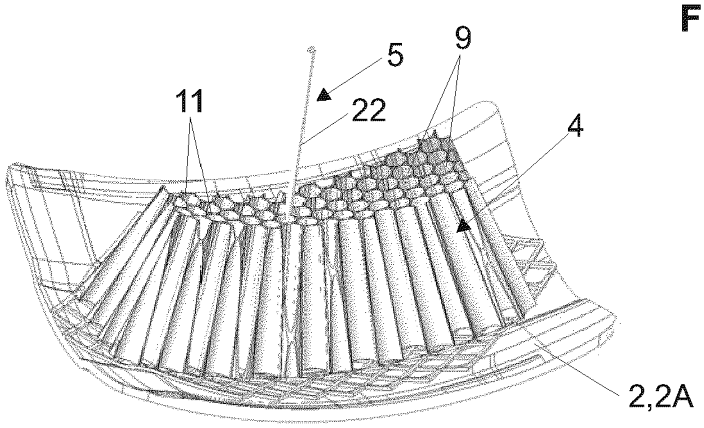

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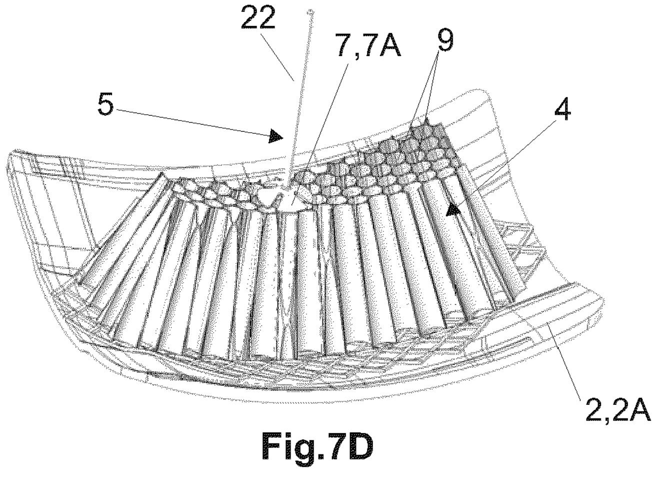

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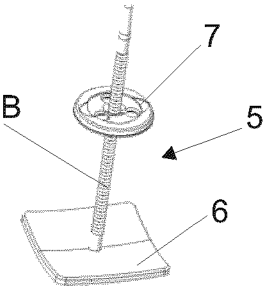

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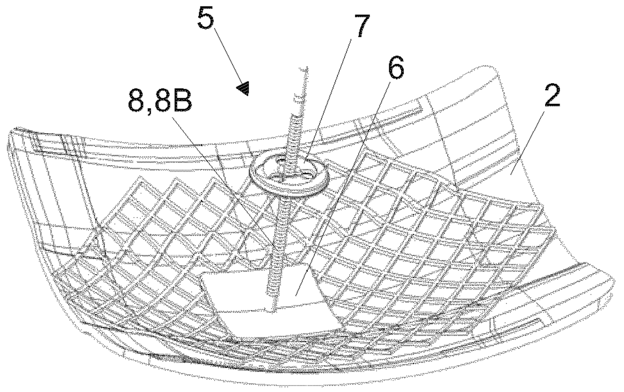

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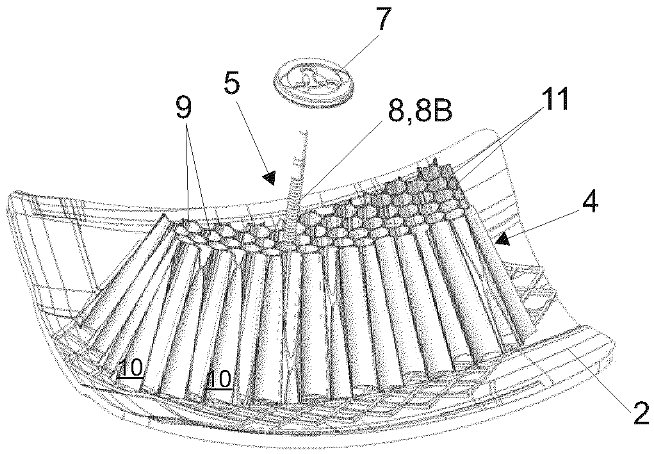

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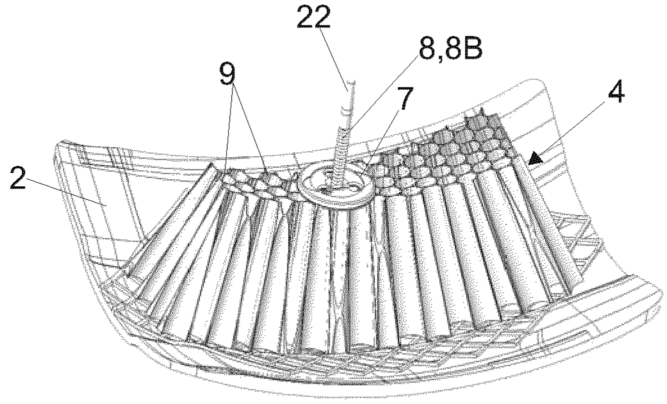

Fig.8D

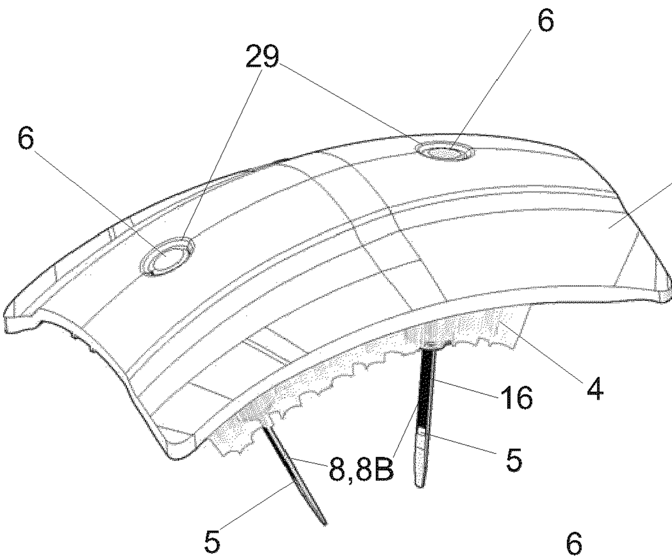

Fig.9A

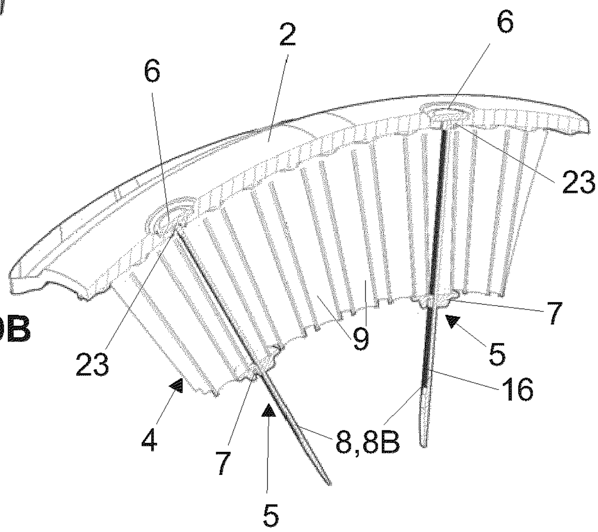

Fig.9B

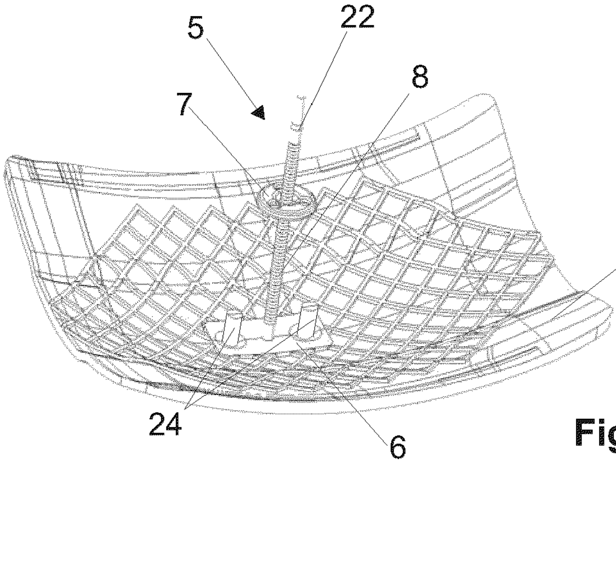

Fig.10

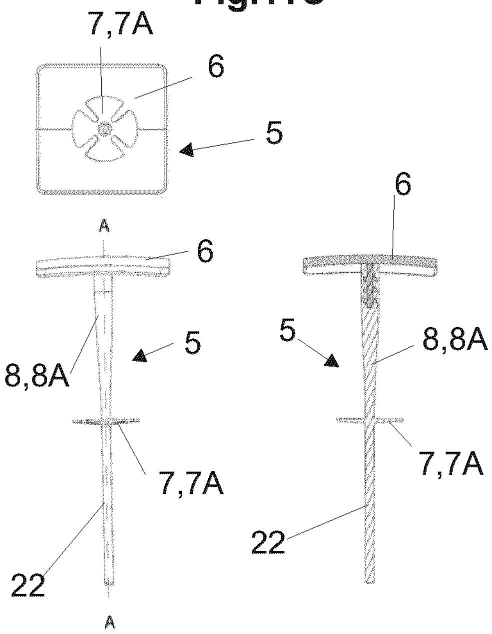

Fig.11C

Fig.11A

Fig.11B

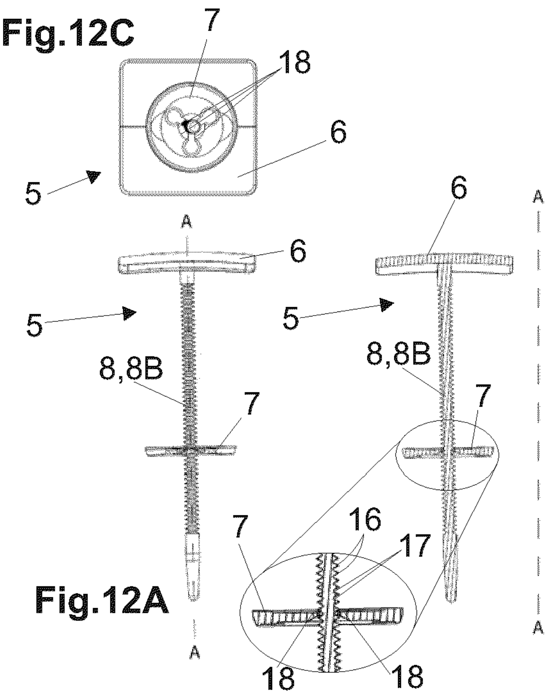

Fig.12C

Fig.12A

Fig.12B

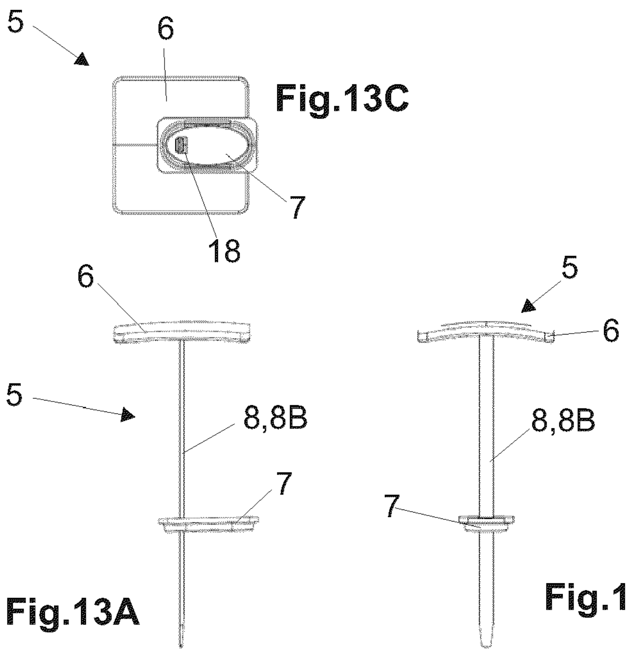

Fig.13C

Fig.13A

Fig.13B

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EUROPEAN SEARCH REPORT

Application Number
EP 21 02 0236

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y	WO 2018/231632 A1 (BELL SPORTS INC) 20 December 2018 (2018-12-20) * paragraphs [0038] - [0046]; figures 1c,2a *	1-15	INV. A42B3/06 A42B3/12
Y	WO 2020/245609 A1 (HEXR LTD [GB]) 10 December 2020 (2020-12-10) * page 13, lines 28-33; figure 1 *	1-15	
A	US 2010/115686 A1 (HALLDIN PETER [SE]) 13 May 2010 (2010-05-13) * paragraphs [0019] - [0022]; figures 1a,1b *	1-15	
A	WO 2006/022680 A1 (FULL90 SPORTS INC [US]; CLEVELAND WILLIAM K [US] ET AL.) 2 March 2006 (2006-03-02) * paragraphs [0065] - [0068]; figures 4,5 *	1-15	
A	EP 3 422 887 A1 (APEX BIOMEDICAL COMPANY LLC [US]) 9 January 2019 (2019-01-09) * paragraph [0030]; figure 2a *	1-6	TECHNICAL FIELDS SEARCHED (IPC) A42B

1 The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	12 October 2021	D'Souza, Jennifer

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- WO 2016209740 A1 **[0012]**