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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 connecting

plug (5) comprising an expandable elongated body (8) configured to penetrate and frictionally engage one or more cells (9) of the cellular energy-absorbing structure (4) and a head portion (6) that remains outside the cellular energy-absorbing structure (4).

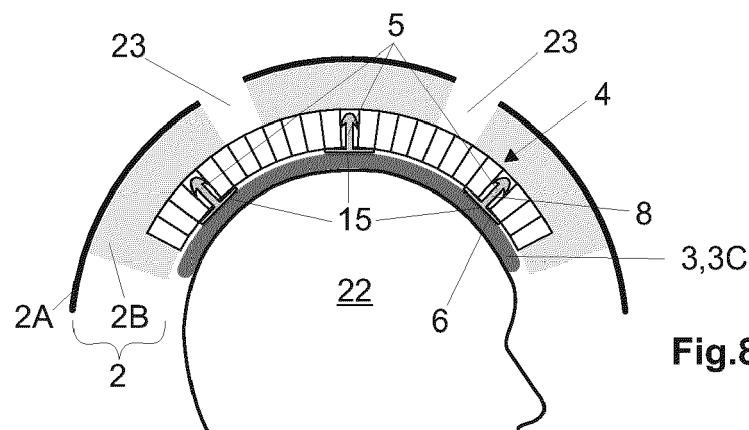


Fig.8C

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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, 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 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 strips 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 dampers, 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 this kind of materials.

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

SUMMARY

[0016] Said and other inconvenients of the state of the art are now solved by a helmet comprising: a shell, a head receiving system, at least one cellular energy-absorbing structure and at least one connecting plug. 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 connecting plug comprises an expandable elongated body configured to penetrate and frictionally engage one or more cells of the cellular energy-absorbing structure and a head portion that remains outside the cellular energy-absorbing structure. This architecture allows to directly connect the cellular energy-absorbing structure with the connecting plug/s and in turn to connect the connecting plug/s 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 and connecting plug/s. 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] Advantageously, the cellular energy-absorbing structure can comprise 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 towards the shell and an opposite open base facing towards the head receiving system. This arrangement of the open-cells allows to absorb more efficiently the axial impact load through a 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] 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 consists of 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 the connecting plug/s.

[0020] Preferably, the head portion can comprise an outer surface facing outward with respect to the cellular energy-absorbing structure. This surface can be used for connecting the connecting plug to the shell or to the head receiving system. In particular, said outer surface can comprise a low friction layer arranged over said outer surface. This low friction layer allows relative movements between the cellular energy-absorbing structure and the shell for absorbing the tangential component of the impact load.

[0021] Advantageously, the connecting plug can comprise connecting means for connecting the cellular energy-absorbing structure to the shell or to the head receiving system. In this way, the connection to the shell or to the head receiving system is simplified and no connections to other intermediate elements are required. 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. Preferably, said connecting means can comprise a Velcro connection, an adhesive layer or snap-fit connector/s. In this way, the connection of the cellular energy-absorbing structure is facilitated and requires only few seconds. Assembling costs are thus saved.

[0022] Preferably, the head portion can be co-molded with the shell. In this way, the head portion 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.

[0023] Alternatively, the connecting plug can be inserted in a hole of the shell so that the expandable elongated body protrudes inwardly with respect to the shell and the head portion abuts against the shell. In this way, the head

portion leans on the external surface of the shell and the rest of the connecting plug anchors the cellular energy-absorbing structure to the shell.

[0024] Advantageously, the expandable elongated body of the connecting plug can comprise a plurality of spaced flexible gripper elements protruding from the elongated body. These gripper elements allow to engage the inner of the open-cell/s and to guarantee an excellent connection with the cellular energy-absorbing structure.

[0025] In particular, the elongated body of the connecting plug can comprise an axial bore for permitting a radial inwards deflection of the elongated body or an introduction of an insert element.

[0026] Preferably, the connecting plug can also comprise an insert element configured to be introduced in the axial bore of the elongated body. In this way, the elongated body can radially expand, fitting to the inner side of the open cells. Preferably, the insert element or the axial bore can comprise a taper portion for progressively expanding the elongated body radially outward. The taper portion facilitates the radial expansion of the elongated body.

[0027] Advantageously, the height of the elongated body can be shorter than the thickness of the cellular energy-absorbing structure. In this way, when the cellular energy-absorbing structure crumples, the elongated body of the connecting plug does not arrive to touch the head of the wearer.

[0028] Preferably, the expandable elongated body can be made, at least in part, of an elastic and flexible material which allows a lateral bending and an elongation of the connecting plug that facilitates the relative movements of the cellular energy-absorbing structure with respect to the shell or to the head receiving system.

[0029] Advantageously, the head portion can comprise one or more positioners configured to be inserted in respective cells of the cellular energy-absorbing structure. These positioners facilitate the orientation of the connecting plugs with respect to the cellular energy-absorbing structure.

[0030] 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

[0031] In the drawings:

Fig. 1A shows an axonometric view of a connecting plug according to the present invention;
 Fig. 1B shows a side view of the connecting plug of Fig. 1A and a cellular energy-absorbing structure;
 Fig. 1C shows an axonometric view of the connecting plug of Fig. 1A and of a cellular energy-absorbing structure wherein the plug is not yet inserted in the cellular energy-absorbing structure;

Fig. 1D shows an axonometric view of the connecting plug of Fig. 1A and of a cellular energy-absorbing structure wherein the plug is inserted in the cellular energy-absorbing structure;

Fig. 2A shows a schematic view of a cellular energy-absorbing structure and a first type of connecting plug during its insertion in the cellular energy-absorbing structure;

Fig. 2B shows a schematic view of a first type of connecting plug inserted in a cellular energy-absorbing structure before being compressed;

Fig. 2C shows a schematic view of a cellular energy-absorbing structure and a first type of connecting plug after a compression due to a normal load;

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

Fig. 3A shows a schematic view of a cellular energy-absorbing structure and a second type of connecting plug during its insertion in the cellular energy-absorbing structure;

Fig. 3B shows a schematic view of a second type of connecting plug inserted in a cellular energy-absorbing structure before being compressed;

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

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

Fig. 4A shows a schematic view of a cellular energy-absorbing structure and a third type of connecting plug during its insertion in the cellular energy-absorbing structure;

Fig. 4B shows a schematic view of a third type of connecting plug inserted in a cellular energy-absorbing structure before being compressed;

Fig. 4C shows a schematic view of a cellular energy-absorbing structure and a third type of connecting plug after a compression due to a normal load;

Fig. 4D shows a schematic view of a cellular energy-absorbing structure and a third type of connecting plug after a compression due to an inclined load;

Fig. 5A shows a schematic view of a cellular energy-absorbing structure and a fourth type of connecting plug during its insertion in the cellular energy-absorbing structure;

Fig. 5B shows a schematic view of a fourth type of connecting plug inserted in a cellular energy-absorbing structure before being compressed;

Fig. 5C shows a schematic view of a cellular energy-absorbing structure and a fourth type of connecting plug after a compression due to a normal load;

Fig. 5D shows a schematic view of a cellular energy-absorbing structure and a fourth type of connecting plug after a compression due to an inclined load;

Fig. 6A shows a schematic view of a cellular energy-absorbing structure and a fifth type of connecting

plug during its insertion in the cellular energy-absorbing structure;

Fig. 6B shows a schematic view of a fifth type of connecting plug inserted in a cellular energy-absorbing structure before being compressed;

Fig. 6C shows a schematic view of a cellular energy-absorbing structure and a fifth type of connecting plug after a compression due to a normal load;

Fig. 6D shows a schematic view of a cellular energy-absorbing structure and a fifth type of connecting plug after a compression due to an inclined load;

Fig. 7A shows a schematic view of a cross-sectioned helmet according to a first embodiment of the present invention;

Fig. 7B shows a schematic view of a cross-sectioned helmet according to a second embodiment of the present invention;

Fig. 7C shows a schematic view of a cross-sectioned helmet according to a third embodiment of the present invention;

Fig. 8A shows a schematic view of a cross-sectioned helmet according to a fourth embodiment of the present invention;

Fig. 8B shows a schematic view of a cross-sectioned helmet according to a fifth embodiment of the present invention;

Fig. 8C shows a schematic view of a cross-sectioned helmet according to a sixth embodiment of the present invention;

Fig. 8D shows a schematic view of a cross-sectioned helmet according to a seventh embodiment of the present invention;

Fig. 9A shows the helmet of Fig. 7A when an inclined load hits the outer shell of the helmet;

Fig. 9B shows the helmet of Fig. 7B when an inclined load hits the outer shell of the helmet;

Fig. 9C shows the helmet of Fig. 7C when an inclined load hits the outer shell of the helmet;

Fig. 10A shows the helmet of Fig. 8A when an inclined load hits the outer shell of the helmet;

Fig. 10B shows the helmet of Fig. 8B when an inclined load hits the outer shell of the helmet;

Fig. 10C shows the helmet of Fig. 8C when an inclined load hits the outer shell of the helmet;

Fig. 10D shows the helmet of Fig. 8D when an inclined load hits the outer shell of the helmet.

DETAILED DESCRIPTION

[0032] 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.

[0033] 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 "connecting plug 5" is abbreviated as "plug 5". Other similar abbreviations can be present in the following description.

[0034] With reference to Fig. 1 is shown a first embodiment of the connecting plug 5 according to the present invention. This plug 5 comprises a head portion 6 and an expandable elongated body 8 protruding from said head portion 6, like a mushroom.

[0035] The expandable elongated body 8 can comprises a plurality of gripper elements 17 that extend radially outward from the cylindrical body of the expandable elongated body 8. The gripper elements 17 can be annular fins having various forms. Alternatively, each fin can be composed by several petals (not shown) instead of being annular.

[0036] The plug 5 so conformed is shaped so to enter into one cell of the cellular energy-absorbing structure 4, as shown in Figs. 1B, 1C and 1D. Substantially, the elongated body 8 is dimensioned so to enter in one single open-cell 9 of the cellular structure 4, without needing to enlarge the hole or performing other holes in the cellular structure 4. In this way, the integrity of the cellular structure 4 is guaranteed and its energy-absorbing performances assured at every point.

[0037] As shown in Figs. 1B, 1C and 1D, 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.

[0038] The open-cells 9 are opened at their ends so that each open-cell 9 realizes a tube through which the air can flow.

[0039] The open-cell 9 has a circular cross-section as represented in Figs. 1C, 1D. Alternatively, the cross-section of the open-cells 9 can be a square, a hexagon, a non-uniform hexagon, a re-entrant hexagon, a chiral truss, a diamond, a triangle or an arrowhead.

[0040] 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.

[0041] 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.

[0042] 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 the term "plastic deformation" means that the sidewalls 10 irreversibly crumple, 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 to a shape similar or equal to the original one.

[0043] Alternatively, the open-cells 9 can be the cells

of a lattice structure, as schematically shown in Fig. 7A. 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.

[0044] 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, even the plugs 5 comprise slender elongated bodies 8 in order to enter into the openings 11 of the cells 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 solution, the cellular structure 4 imposes the dimension of the plug 5 and not conversely.

[0045] The cellular structure 4, both in the version having an array of energy-absorbing open-cells 9 and in the lattice structure version, comprises a surface facing towards the shell 2 and a surface facing towards the head receiving system 3, as shown in Figs. 7-10. These surfaces comprise a plurality of openings 11 of said open-cells 9. In any one of these openings 11, the plug 5 can be inserted.

[0046] As shown in Figs. 1C and 1D, the elongated body 8 penetrates the open-cell 9 entering via the opening 11. The plug 5 is shaped so that the entire elongated body 8 enters in the cellular structure 4, as shown in Fig. 1D.

[0047] Once that the plug 5 is inserted in the open-cell 9 of the cellular structure 4, only the head portion 6 emerges from the cellular structure 4.

[0048] The head portion 6 is preferably a flat and wide portion of the plug 5. The head portion 6 is wider more than three times the elongated body 8 width. The head portion 6 comprises a flat or slightly curved surface. Once the plug 5 is inserted in the cellular structure 4, the head portion 6 abuts against the cellular structure 4.

[0049] The gripper elements 17 of the plug 5 of Figs. 1 are configured to frictionally engage the inner side of the open-cell 9 in which the elongated body 8 penetrates. The gripper elements 17 anchor the elongated body 8 to the open-cell 9 and consequently the plug 5 can be pulled out of the open-cell 9 only applying to the head portion 6 a pulling force.

[0050] The plug 5 is preferably made, at least in part, of a flexible and elastic material, like silicone, rubber, TPE, TPU or another elastomeric material. The plug 5 does not require to be entirely made of said material. For example, the head portion 6 can be made of plastic and more rigid material, that is co-molded with the more flexible and elastic material of the elongated body 8. Alter-

natively, even the elongated body can be made of a plastic material and only the gripper elements are flexible. In the latter case, the elongated body 8 can bend due to its slender ratio, thus the ratio between the height and width of the elongated body.

[0051] In a further alternative, the head portion 6 can comprise a viscoelastic part that allows a relative sliding of the opposite faces of the head portion. For example, the head portion 6 can comprise a viscoelastic foam sandwiched between the upper and lower surfaces of the head portion 6.

[0052] The plug 5 can be shaped and structured in different ways, as Figs. 2-6 show. In particular, the plug 5 can have gripper elements 17 having an arrow-shaped cross-section, as shown in Figs. 2. The arrow-shaped gripper elements 17 are oriented so to facilitate the entrance in the open-cell 9 and to grab on to the inner surface of the open-cell 9 when pulled out. The cellular structure 4 can deform, as shown in Figs. 2C, 2D, and nevertheless the plug 5 follows its deformation.

[0053] In Figs. 3, it's shown a second embodiment of the plug 5. In this case, the plug 5 is composed by two elements, an insert element 19 and a holed body 26. The holed body 26 comprises an axial bore 18 into which the insert element 19 can be inserted. The distal end of the insert element 19 is sharpened so to facilitate the entry in said axial bore 18. This end is also wider than the trunk of the insert element 19, so to push radially outside the sidewall of the holed body 26. The axial bore 18 is stricter than the sharpened end of the insert element 19. The insert element 19 is inserted in the holed body 26 only once the holed body has been inserted in the open-cell 9 of the cellular body 4. In this way, the holed body expands outwardly, squashing it against the inner surface of the open-cell 9. In this embodiment, both the insert element 19 and the holed body 26 are preferably made of a flexible material like an elastomer. The head portion 6 of this kind of plug 5 is constituted by the base portion of the holed body 26 and the base portion of the insert element 19. Together, they form the head portion 6. In particular, the face of the head portion 6 facing outwardly with respect to the cellular structure 4 is that of the insert element 19. Similarly, the trunks of the holed body 26 and of the insert element 19 constitute the expandable elongated body 8 of the connecting plug 5. Even this type of plug 5 is configured to follow the deformation of the cellular structure 4 without interfering, as shown in Figs. 3C, 3D.

[0054] The plug 5 type of Figs. 4 is similar to that of the first embodiment shown in Figs. 2, but several layers of gripper elements 17 are present. These gripper elements 17 are thinner than those of Figs. 2, and consequently more flexible. Vice versa, they are more and consequently, they exert more grip on the inner surface of the open-cell 9.

[0055] The fourth type of the plug 5, shown in Figs. 5, comprises an axial bore 18 and gripper elements 17 larger than the open-cell 9 width. In this way, the axial bore 18 allows an inward deformation of the elongated body

8 in correspondence of said gripper elements 17. Vice versa, the elasticity of the elongated body 8 material, exerts a radial outwardly push on the inner surface of the open-cell 9. The plug 5 of Figs. 5 also comprise positioners 21 configured to be inserted in respective open-cells 9 of the cellular structure 4. These positioners 21 are pins protruding from the head portion 6 and shaped so to enter in respective open-cells 9. These positioners 21 allow to avoid rotations of the plug 5 about its axis of symmetry. The plug 5 can comprise only one positioner 21. Also all the other types of plugs 5 can comprise one or more positioners 21.

[0056] The fifth type of the plug 5 of Figs. 6 is similar to that of Figs. 3. In this embodiment, the insert element 19 has a tapered portion 20. In this way, when the insert element 19 penetrates the axial bore 18 of the holed body 26, the holed body 16 expands outwardly, compressing the inner surface of the open-cell 9. Alternatively, the tapered portion 20 can be arranged in the holed body 26. In this case, the axial bore 18 is tapered and the trunk of the insert element 19 is cylindrical. In this embodiment of the plug 5, the head portion 6 is constituted by the base portion of the holed body 26. The elongated body 8 of the plug 5 of this embodiment is composed by the trunk of the holed body 26 and by the insert element 19. Some small gripper elements can be arranged on the outer surface of the holed body 26. In this version of the plug 5, at least the holed body 26 is made of an elastic material. As for the other types of plugs 5, the deformation of the cellular structure 4 is followed by the plug 5, which deforms accordingly.

[0057] As shown in all Figs. 2-5 having suffix "C" or "D", the plug 5 always follow the axial crumpling of the cellular body 4, see Figs. 2C,3C,4C,5C,6C, and the lateral bending of the cellular structure 4, see Figs. 2D,3D,4D,5D,6D.

[0058] As shown in Figs. 2-5, the plug 5 is always shorter than the cellular structure 4. That means that the height of the elongated body 8 is smaller than the cellular structure 4 thickness. In this way, even if the energy-absorbing structure 4 is axially compressed, the distal end of the plug 5 does not come out from the cellular structure 4. Consequently, any interference of the plug 5 with the wearer's head is avoided. Alternatively, the elongated body 8 of the plug 5 can be made of a flexible material, so that, even if its end comes into contact with the wearer's head, it does not become risky.

[0059] Even if it's not represented, the same architectures of the plug 5 can be used with a lattice structure. In this case, the cellular structure 4 has more open portions and the plug 5 can be inserted in one or more of these open-cells and can expand, as described above, for frictionally engaging the lattice structure.

[0060] As shown in Figs. 7 and 8, the helmet 1 comprises a cellular energy-absorbing structure 4 and a plurality of connecting plug 5 as previously described. The helmet 1 also comprises a shell 2. All Figs. 7 and 8, except that of Fig. 8B, show helmets 1 having only one cellular

structure 4. On the contrary, Fig. 8B shows a helmet 1 have a plurality of cellular structures 4. Despite this, the present invention relates to helmets 1 having one or more cellular structures 4, consequently, even if they're not represented, the arrangements of Fig. 7A,7B,7C,8A,8C,8D can comprise more cellular structures 4, and the arrangement of Fig. 8B can comprise only one cellular structure 4.

[0061] Figs. 7 show a helmet 1 having a shell 2 constituted only by an outer hard shell 2A. Vice versa, Figs. 8 show a helmet 1 having a shell 2 comprising an outer shell 2A and an inner shock absorbing liner 2B. The outer shell 2A of the embodiments of Figs. 8 is substantially equal to that of the embodiments of Figs. 7. From a structural point of view, since the embodiments of Figs. 7 are better for industrial safety helmets, the outer shell 2A is thicker than that of the embodiments of Figs. 8. On the contrary, since the helmets of the embodiments of Fig. 7 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.

[0062] The inner shock absorbing liner 2B, also called inner liner 2B, is preferably made of an expanded foam polymer, like EPS or EPP. The combination of the inner liner 2B and the outer shell 2B constitutes the shell 2 of Figs. 8.

[0063] The inner liner 2B can be connected to the outer shell 2A through an adhesive layer (not shown) or through other types of connections.

[0064] The connecting plugs 5 are provided for connecting the cellular structure 4 to something else. Specifically, to connect the cellular structure 4 to the outer shell 2A, to the inner liner 2B or to the head receiving system 3.

[0065] Several types of head receiving systems 3 can be employed in the helmet 1 of the present invention. For example, the head receiving system 3A of Fig. 7A and 7C is a harness system, traditionally used in the safety industrial helmets. Vice versa, in the embodiments of Figs. 7B and 8D the head receiving system 3 comprises a headband or a cradle 3B thus a system configured to fit with the upper part of the wearer's head 22. Alternatively, the head receiving system 3 of Figs. 8C comprises a comfort liner 3C, that could be a permeable padded cushion.

[0066] With reference to Fig. 7A, the helmet 1 comprises an outer shell 2,2A that is connected through the connecting plugs 5 to the cellular energy-absorbing structure 4. The head portion 6 of the plugs 5 is connected to the outer shell 2,2A through connecting means 15 and the cellular structure 4 is fixed to the elongated bodies 8 of the plugs 5. The gripper elements 17 of the plugs 5 are anchored to the cellular structure 4 and consequently it remains in place. In particular, the cellular structure 4 of this embodiment is a lattice structure, consequently the elongated bodies 8 of the plugs 5 penetrate more open-cells 9 of the lattice structure 4. The head 22 of the wearer does not directly touch the cellular structure 4, because

the harness 3A suspends the cellular structure 4 above the head 22. The connecting means 15 of this embodiment can be an adhesive layer. In this way, as described in detail in the following, the cellular structure 4 can translate with respect to the outer shell 2,2A. Even if this embodiment employs a lattice structure, the same type of helmet 1 can be realized with an array of interconnected open-cells 9 as previously described.

[0067] With reference to Fig. 7B, the helmet 1 comprises an outer shell 2,2A connected to a cellular structure 4 through an adhesive layer (not shown) or through other types of connections. The cellular structure 4 is in turn connected to the headband/cradle 3B via the connecting plugs 5. The elongated bodies 8 of the plugs 5 are inserted in respective open-cells 9, while the head receiving system 3 is connected to the rest of the helmet 1 by means of connecting means 15 arranged over the outer surface of the head portions 6. In this embodiment, the outer shell 2A is firmly attached to the cellular structure 4, while the head receiving system 3,3B can move with respect to the cellular structure 4 thanks to the connecting plug 5.

[0068] With reference to Fig. 7C, the helmet 1 comprises an outer shell 2,2A connected to the cellular structure 4. The connection of the cellular structure 4 with the outer shell 2,2A is made through connecting plugs 5. In particular, the connecting plugs 5 pass through holes 16 in the shell 2A and enter into respective open-cells 9 of the cellular structure 4. The head portions 6 of the plugs 5 can be partially encased in respective recesses of the outer shell 2,2A. The head 22 is spaced from the cellular structure 4 by means of a harness 3A, similarly to helmet 1 of Fig. 7A. In this embodiment of the helmet 1, the cellular structure 4 can move relative to the outer shell 2A because of the flexibility of the connecting plugs 5. In particular, despite it's not represented in the figures, the cellular structure 4 can slide over the inner surface of the outer shell 2A and the connecting plugs 5 bend to follow the cellular structure 4 movements. Despite this, the cellular structure 4 remains connected to the shell 2A and relative movement between them is allowed. This kind of movement in particular occurs when the impact against the outer shell 2A is not normal to the outer surface of the shell 2A, but inclined. In this way, the tangential component of the impact force is absorbed by the deformation of the connecting plugs 5, while the normal component of the impact force is absorbed by the axial crumpling of the open-cells 9 of the cellular structure 4.

[0069] With reference to Fig. 8A, the helmet 1 comprises a shell 2 having an outer shell 2A and inner shock absorbing liner 2B. In particular, the outer shell 2A is connected to the inner liner 2B through an adhesive (not shown) or another type of connection mean. The inner liner 2B is thus firmly connected to the outer shell 2A. 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 an 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 23. A vent 23 is an opening that allows the air to flow from the external environment to the head 22 of the wearer. The vent 23 crosses the outer shell 2A and inner liner 2B up to the bottom of the pocket 14. From here, the air reaches the head 22 thanks to the open-cells 9 of the cellular structure 4. The helmet 1 is thus permeable. A plurality of connecting plugs 5 are coupled to the cellular structure 4 so that their head portions 6 face towards the inner liner 2B. Over the outer surface of the head portions 6 is arranged a low friction layer 24. This low friction layer 24 can be a thin layer of nylon, polycarbonate or PTFE (polytetrafluoroethylene). In this way, the head portion 6 can slide over the bottom of the pocket 14 without difficulties. Moreover, due to the thickness of the head portions 6, the cellular liner 4 is kept spaced from the bottom of the pocket 14. The head portions 6 having said low friction layers 24 act as skates and allow a relative movement between the cellular structure 4 and the inner liner 2B. In this way, the cellular structure 4 is slidingly connected to the inner liner 2B. Even if it's not represented in Fig. 8A, this helmet 1 comprises a head receiving system 3 arranged between the head 22 and the cellular structure 4, for making the helmet 1 more comfortable.

[0070] With reference to Fig. 8B, the helmet 1 comprises an outer shell 2A and inner liner 2B connected to the outer shell 2A. The outer shell 2A and the inner liner 2B comprises more vents 23 for allowing an air circulation from outside to inside, as described for the helmet of Fig. 8A. The cellular structure 4 is connected to the inner liner 2B through a particular version of connecting plugs 5. These connecting plugs 5 comprise respective connecting plug support 25 that are permanently connected to the inner liner 2B. The connecting plug support 25 is a base co-moulded with the inner liner 2B so that a part of this support 25 cantilevers with respect to the inner liner 2B. This portion of the support 25 coming out from the inner liner 2B is configured to be connectable to the plug 5, for example through a snap-fit connection. In turn, the plug 5 is insertable in an open-cell 9 of the cellular structure 4 for connecting the latter to the inner liner 2B. In the helmet of Fig. 8B, the cellular structures 4 are more than one. In particular, a front cellular structure 4 is arranged in the front of the helmet 1, while a rear cellular structure 4 is arranged in the rear of the helmet 1. More cellular structures 4 allows to protect, in a different manner, different portions of the head 22. Moreover, more cellular structures 4 facilitate the arrangement of them in the helmet 1. This arrangement is applicable to all types of helmet of Figs. 7 and 8. In this kind of helmet 1, the cellular structures 4 can move with respect to the inner liner 2B, while the latter remains firmly connected to the

outer shell 2A. Even if it's not represented in Fig. 8B, this helmet 1 can comprise a head receiving system 3 arranged between the head 22 and the cellular structure 4, for making the helmet 1 more comfortable.

[0071] Alternatively to the connecting plug support/s 25, the head portion 6 of the connecting plug 5 can be directly co-moulded in the inner liner 2B, so that the elongated body 8 comes out from the inner liner 2B. In this embodiment (not shown), the inner liner 2B can comprise a low friction coating. This coating of the inner liner 2B can face the cellular energy-absorbing structure 4 so to reduce the friction between them.

[0072] With reference to Fig. 8C, the helmet 1 comprises an outer shell 2A and an inner liner 2B with a plurality of vents 23, similar to those of the helmet 1 of Fig. 8A. In the same way, the inner liner 2B comprises a pocket 14 into which the vents 23 flow. The pocket 14 is shaped so to fit with the cellular structure 4 and consequently the cellular structure 4 remains in place. A head receiving system 3, that is a comfort liner 3C, is connected to the cellular structure 4 through connecting plugs 5. The elongated bodies 8 of the plugs 5 are inserted in the open-cells 9 of the cellular structure 4 so that the head portions face towards the comfort liner 3C. Over the outer surface of head portions 6, that in the Fig. 8C is the surface facing the head 22, are arranged connecting means 15. In particular, in this helmet 1, the connecting means 5 comprise a Velcro connection having a hooking part and a hook part structured in a known manner. The hook part is preferably arranged on the head portion 6, and the comfort liner 3C 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, as explained later on in the text.

[0073] With reference to Fig. 8D, the helmet 1 comprises an outer shell 2A and an inner liner 2B connected to each other. The outer shell 2A and inner liner 2B comprise vents 23 for ventilating the head 22 of the wearer, as described for the previous types of helmets 1. The helmet 1 also comprises a cellular structure 4 connected to the inner liner 2B. In turn the cellular structure 4 is connected to the head receiving system 3 through connecting plugs 5. The head receiving system 3 of this embodiment can be a headband/cradle 3B. The headband/cradle 3B is connected to the head portions 6 of the plugs 5 through connecting means 15. As in the previous version of helmet of Fig. 8C, the head receiving system 3B can float over the cellular structure 4 and a relative movement between them is allowed.

[0074] In the Figs. 9 and 10, some types of relative movements of the parts of the helmet 1 according to the present invention are represented. Connecting plugs 5 are used to allow and absorb the movement occurring between at least two parts of the helmet 1. Since the connecting plug 5 can deform its shape, this deformation contributes to absorb shear forces caused by an impact on the outer shell 2A.

[0075] The connecting plugs 5 according to the present

invention are used to connect two or more elements of the helmet 1. As described above, in the helmets 1 of Figs. 7A and 7C the connecting plugs 5 connect the outer shell 2A to the cellular structure 4, in the helmets 1 of Figs. 7B, 8C and 8D, the connecting plugs 5 connect the cellular structure 4 to the head receiving system 3, while in the helmets 1 of Figs. 8A and 8B the connecting plugs 5 connect the inner liner 2B to the cellular structure 4.

[0076] In Figs. 9 and 10, the crumpling of the open cells 9 is represented through a reduction of the thickness of the cellular structure 4.

[0077] Fig. 9A shows the helmet 1 of the embodiment of Fig. 7A during an angled 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 22 of the wearer. A first portion of the impact force F is absorbed by the harness 3A which deforms prior that the head 22 reaches the cellular structure 4. Once the head 22 enters in contact with the cellular structure 4, the solid portions 12 of the lattice structure deform absorbing the normal component F_n of the force F . Concurrently, the connecting plugs 5 laterally stretch allowing a relative movement of the cellular structure 4 with respect to the outer shell 2A. The deformation of the connecting plugs 5 allows to absorb the tangential component F_t of the impact force F .

[0078] Fig. 9B shows the helmet 1 of the embodiment of Fig. 7B during an angled impact with a force F which causes a rotation R of the outer shell 2A with respect to the head 22 of the wearer. During the impact with the force F , the head receiving system 3 rotates with respect to the cellular structure 4 and, simultaneously, the open-cells 9 of the cellular structure 4 progressive buckle along their longitudinal axes. The rotation of the head receiving system 3 is allowed by the deformation of the plugs 5, which absorb the tangential component F_t of the impact force F , while the normal component F_n of the force F is absorbed by the deformation of the open-cells 9.

[0079] Fig. 9C shows the helmet 1 of the embodiment of Fig. 7C during an angled impact with a force F which causes a rotation R of the outer shell 2A with respect to the head 22 of the wearer. The deformation of the cellular structure 4 and of the plugs 5 is similar to that described for Fig. 9A. The open-cells 9 of the cellular structure 4 axially progressive buckle absorbing the normal component F_n of the force F , and in the same time the plugs 5 bend and stretch absorbing the tangential component F_t of the force F .

[0080] Fig. 10A shows the helmet 1 of the embodiment of Fig. 8A during an angled impact with a force F which causes a rotation R of the shell 2 with respect to the head 22 of the wearer. In this case, the cellular structure 4 slides through the head portions 6 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, contrasted by the sidewall of the pocket 14, collapse along a curved direction that is parallel to the bottom of the pocket 14. This deformation absorbs a

large part of the tangential component F_t of the force F , while the axial crumpling of the open-cells 9 absorbs the normal component F_n of the force F . Moreover, the plugs 5 bend contributing to absorb the tangential component F_t of the force F during the cellular structure 4 deformation.

[0081] Fig. 10B shows the helmet 1 of the embodiment of Fig. 8B during an angled impact with a force F which causes a rotation R of the shell 2 with respect to the head 22 of the wearer. In this case, the deformation of the connecting plugs 5 absorbs the tangential component F_t of the impact force F , while the normal component F_n of the impact force F simultaneously crumple the open-cells 9.

[0082] Fig. 10C and Fig. 10D respectively show the deformation of the helmets 1 belonging to the embodiments of Fig. 8C and 8D. Both these helmets allow a relative movement of the head receiving system 3 with respect to the cellular structure 4. The bending and stretching of the plugs 5 allow said relative movement and absorb the tangential component F_t of the impact force F , while the simultaneous progressive buckling of the open-cells 9 absorb the normal component F_n of the force F .

[0083] All the features described for the embodiments of Figs. 7 and 8, can be mixed to obtain further embodiments not represented but included in the present invention. For example the connecting plug supports 25 of the embodiment of Fig. 8B can be co-moulded with the outer shell 2A of the embodiment of Fig. 7A, obtaining the same results.

[0084] Furthermore, even if the embodiments of Figs. 7 and 8 employ the connecting plug 5 of the Figs. 2, any other plug 5 according to the present invention can be used instead of that.

[0085] 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.

[0086] Legend of reference signs:

- 1 helmet
- 2 shell
- 2A outer shell
- 2B inner shock absorbing liner
- 3 head receiving system
- 3A harness system
- 3B headband/cradle
- 3C comfort liner
- 4 cellular energy-absorbing structure
- 5 connecting plug
- 6 head portion

- 7 outer surface
- 8 expandable elongated 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 hole of the shell
- 17 gripper element
- 18 axial bore
- 19 insert element
- 20 taper portion
- 21 positioner
- 22 head of the user
- 23 vents
- 24 low friction layer
- 25 connecting plug support
- 26 holed body
- F force
- F_n normal component of force F
- F_t tangential component of force F
- 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 connecting plug (5) comprising an expandable elongated body (8) configured to penetrate and frictionally engage one or more cells (9) of the cellular energy-absorbing structure (4) and a head portion (6) that remains outside the cellular energy-absorbing structure (4).

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).

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, wherein the shell (2) comprises only an outer hard shell (2A). 5
5. Helmet according to any one of claims 1 to 4, wherein the shell 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). 10
6. Helmet (1) according to any one of preceding claims, wherein the head portion (6) comprises an outer surface (7) facing outward with respect to the cellular energy-absorbing structure (4), preferably said outer surface (7) comprising a low friction layer (24). 15
7. Helmet (1) according to any one of preceding claims, wherein the connecting plug (5) comprises connecting means (15) for connecting the cellular energy-absorbing structure (4) to the shell (2) or to the head receiving system (3), preferably said connecting means (15) comprise a Velcro connection, an adhesive layer or snap-fit connector/s. 20 25
8. Helmet (1) according to any one of claims 1 to 6, wherein the head portion (6) is co-molded with the shell (2). 30
9. Helmet (1) according to any one of claims 1 to 6, wherein the connecting plug (5) is inserted in a hole (16) of the shell (2) so that the expandable elongated body (8) protrudes inwardly with respect to the shell (2) and the head portion (6) abuts against the shell (2). 35
10. Helmet (1) according to any one of preceding claims, wherein the expandable elongated body (8) of the connecting plug (5) comprises a plurality of spaced flexible gripper elements (17) protruding from the elongated body (8). 40
11. Helmet (1) according to any one of preceding claims, wherein the expandable elongated body (8) of the connecting plug (5) comprises an axial bore (18). 45
12. Helmet (1) according to claim 11, the connecting plug (5) further comprises an insert element (19) configured to be inserted in the axial bore (18) of the expandable elongated body (8), preferably the insert element (19) or the axial bore (18) comprises a taper portion (20) for expanding the elongated body (8) radially outward. 50 55
13. Helmet (1) according to any one of preceding claims, wherein the height of the expandable elongated body

(8) is shorter than the thickness of the cellular energy-absorbing structure (4).

14. Helmet (1) according to any one of preceding claims, wherein the expandable elongated body (8) is made at least in part of an elastic and flexible material.
15. Helmet (1) according to any one of preceding claims, wherein the head portion (6) comprises one or more positioners (21) configured to be inserted in respective open-cells (9) of the cellular energy-absorbing structure (4).

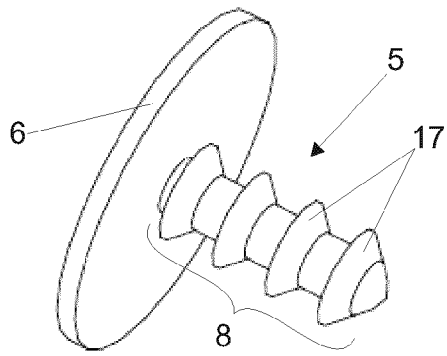


Fig.1A

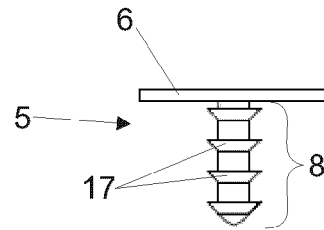


Fig.1B

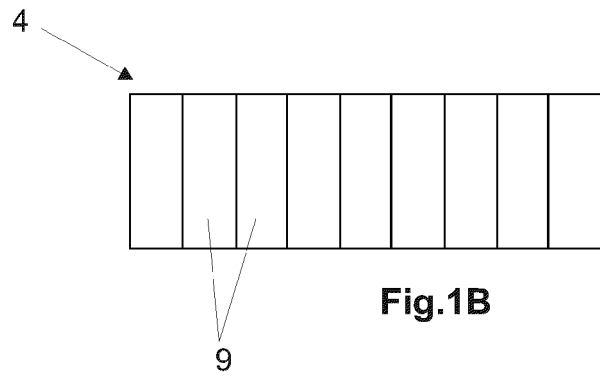


Fig.1C

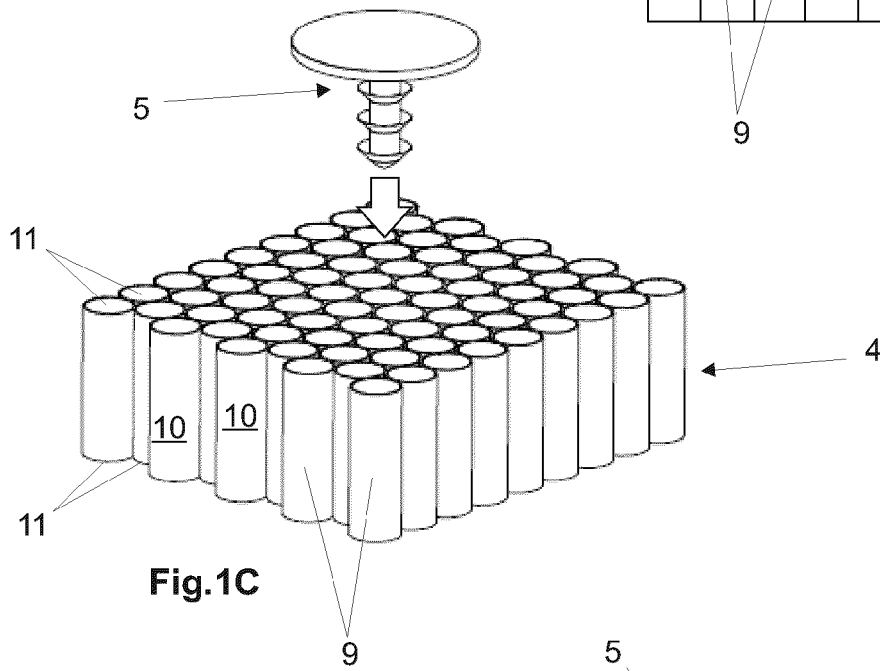
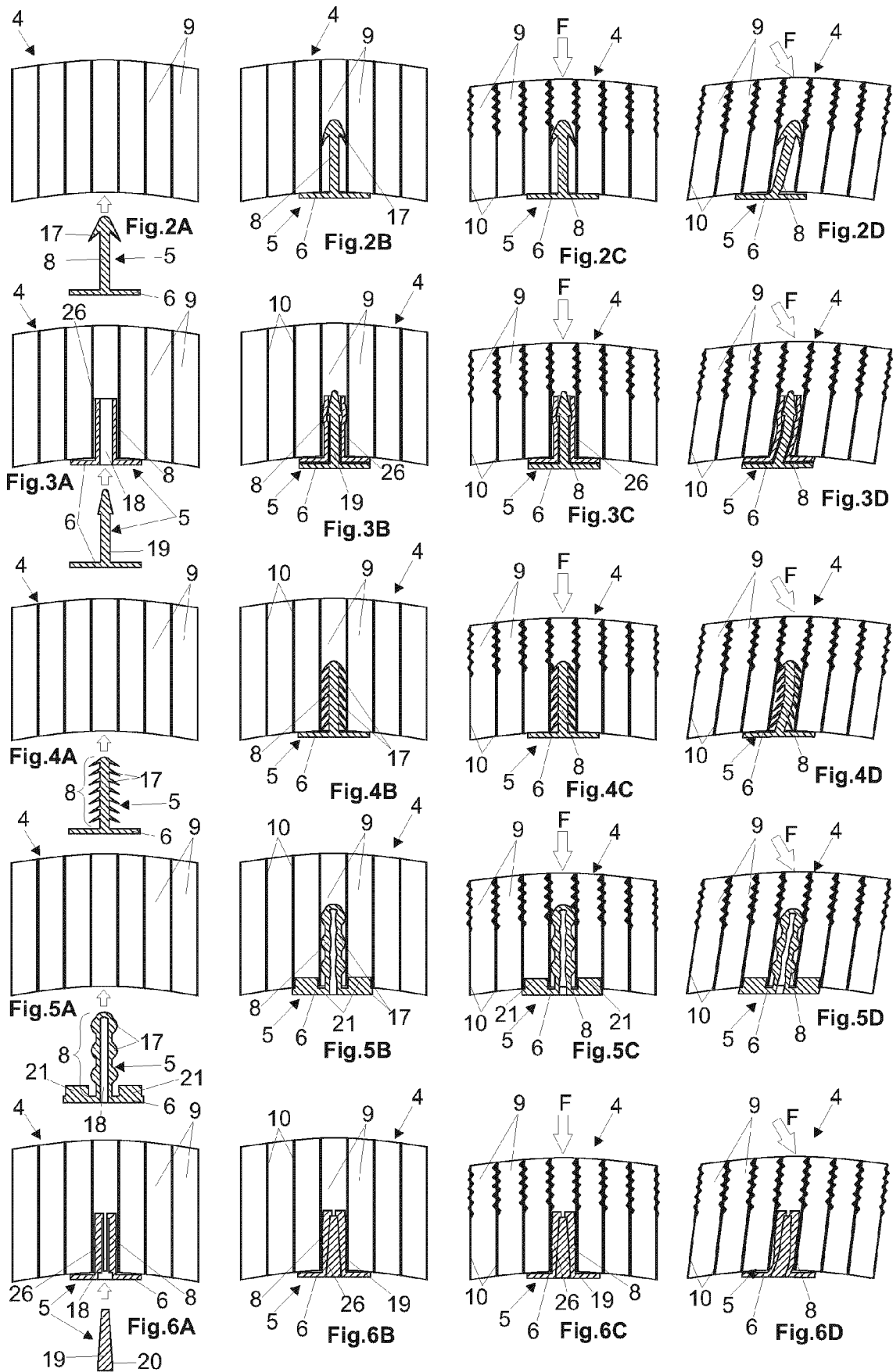
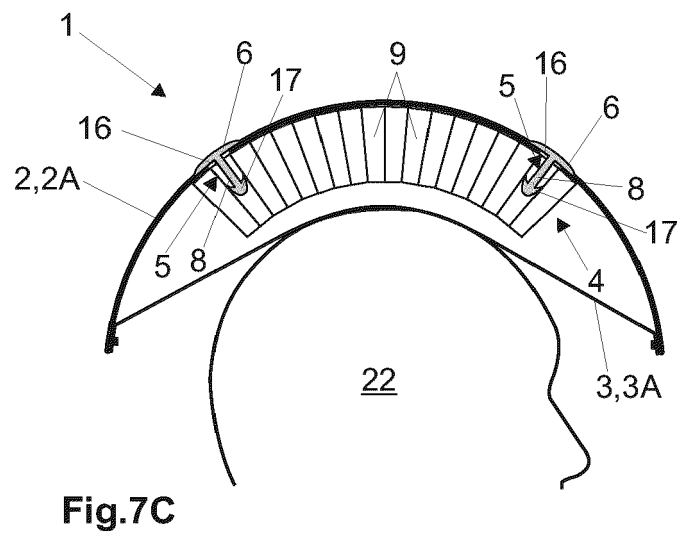
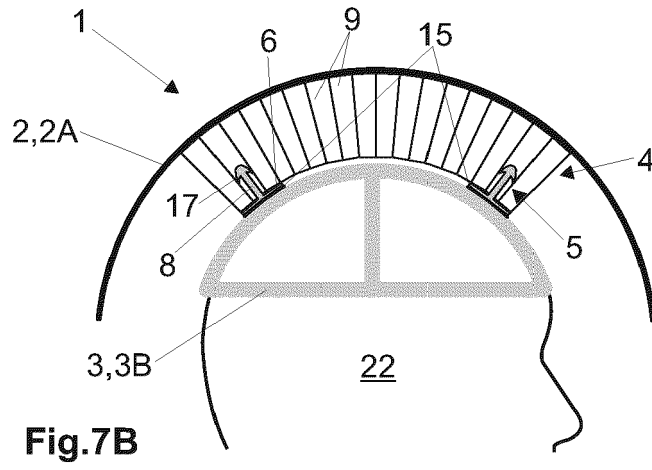
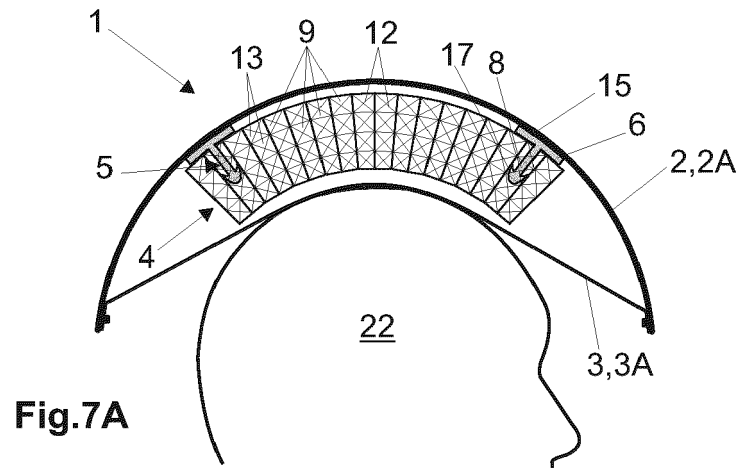
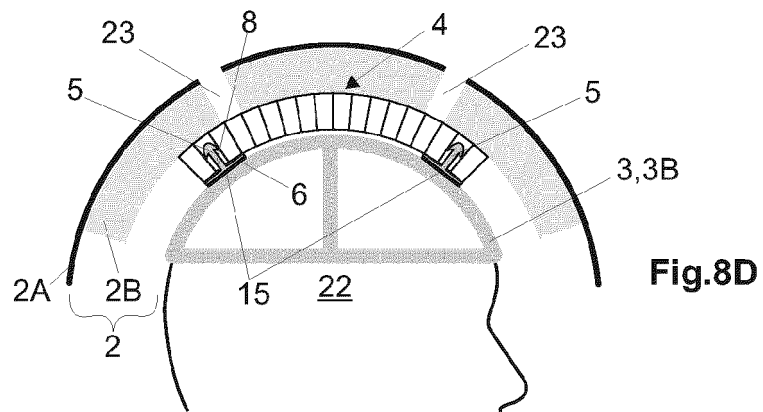
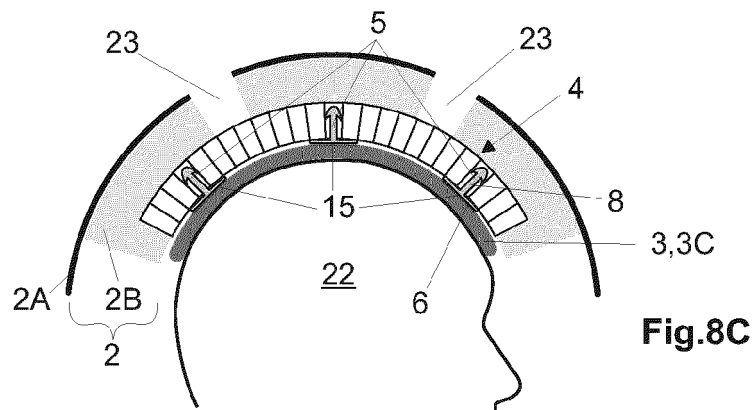
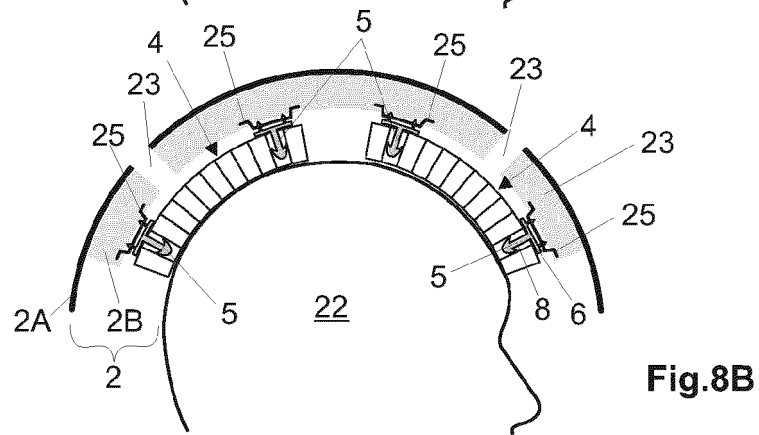
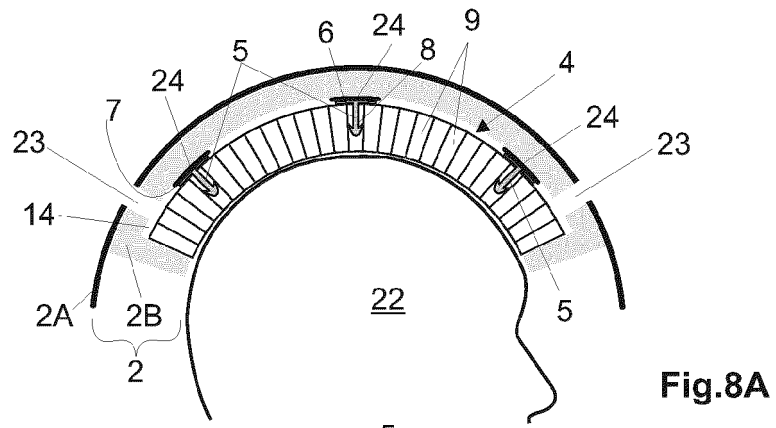
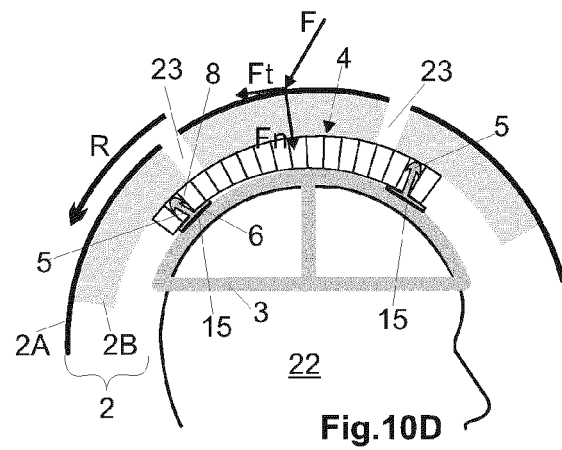
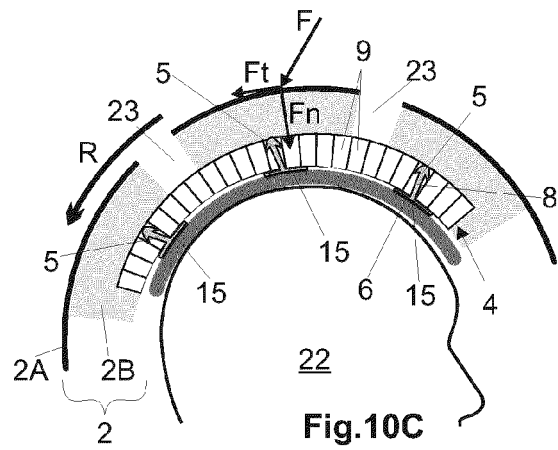
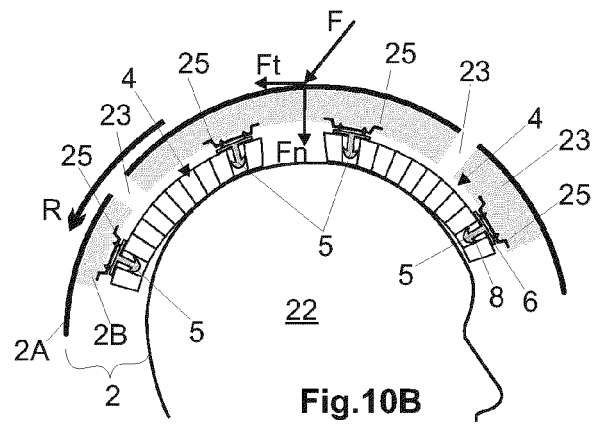
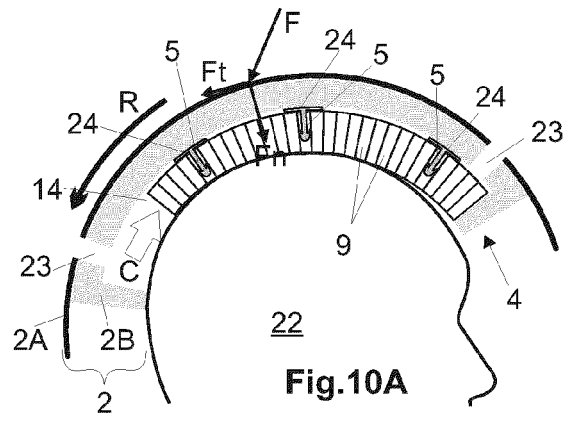
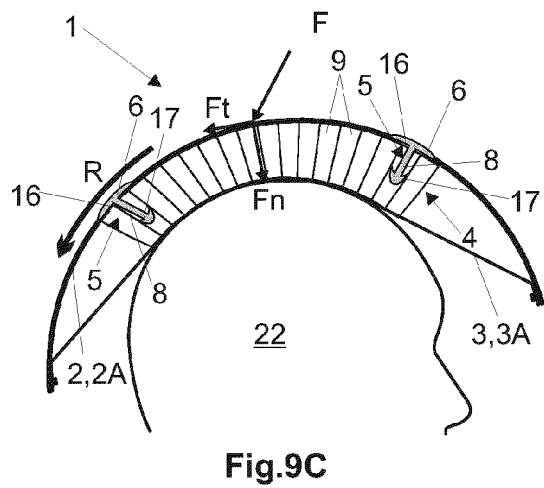
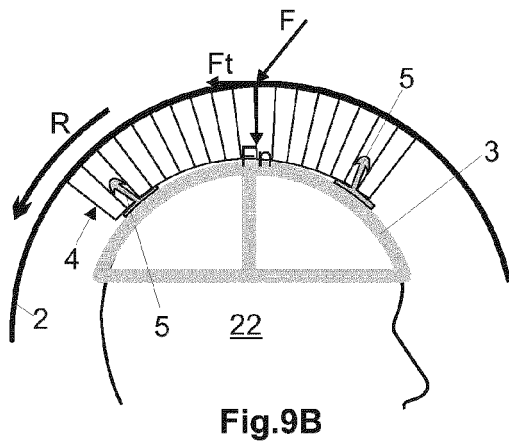
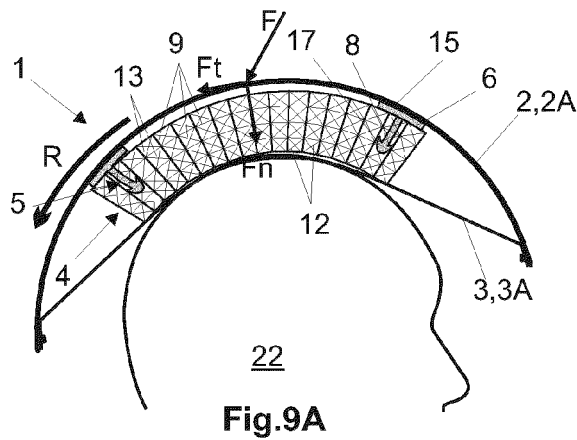


Fig.1D











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The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 13 October 2021	Examiner D'Souza, Jennifer
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